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ZOOLOGY- GENERAL ELECTIVE-I

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CONTENTS

Course: Zoology-General elective
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UNIT 1: CELL TYPE

CONTENTS

1.1 OBJECTIVES

Study of this unit will let the students to:

- Define Prokaryotic cell.
- Explain the structure of prokaryotic cell.
- Write about Eukaryotic cell.
- Elucidate the structure of Eukaryotic cell.
- Differentiate between prokaryotic and eukaryotic cell.

1.2 INTRODUCTION

A structure containing a mass of cytoplasm surrounded by semi-permeable membrane called plasma membrane is called a cell. It encloses cytoplasm, many cell organelles along with nucleus or nuclear material. On the basis of organization of membranes, variety and structure of cytoplasmic organelles and complexity of nuclear region, the cells are classified into two types: Prokaryotic cell and Eukaryotic cell. These terms were suggested by **Hans Ris** in **1960s**.

1.3 HISTORY AND ORIGIN

A cell was defined as **"**unit of biological activity delimited by a semi permeable membrane and capable of self-reproduction in a medium free of other living systems" by **Loewy and Siekevitz (1963)**.

The study of cell has been made possible with the help of light microscope. **Robert Hooke (1665)** with the help of light microscope discovered that a section of cork is made up of small cavities surrounded by firm walls. He used the term **"cell"** for the first time to describe his investigations on the "texture of a piece of cork". Later on **A. Van Leeuwenhoek (1632-1723)** observed various unicellular organisms and cells like bacteria, protozoan's, red blood cells and sperm etc. He observed nucleus in some erythrocytes and all this was made possible with the improved microscopes. In **1809, Mirble M.** stated that all plant tissues are composed of cells. In the same year, importance of cells in living organisms was described by **J.B. Lamarck**. **Robert Brown** in **1831** observed nucleus in certain plant cells. *Mimosa* cells were boiled in nitric acid by **Dutrochet (1837)** to separate the cells to conclude that all

organic tissues are composed of globular cells, united by simple adhesive forces. “All living organism are composed of cells” was stated by **Schwann, T. (1839)** after examining a variety of animals and plant tissues.

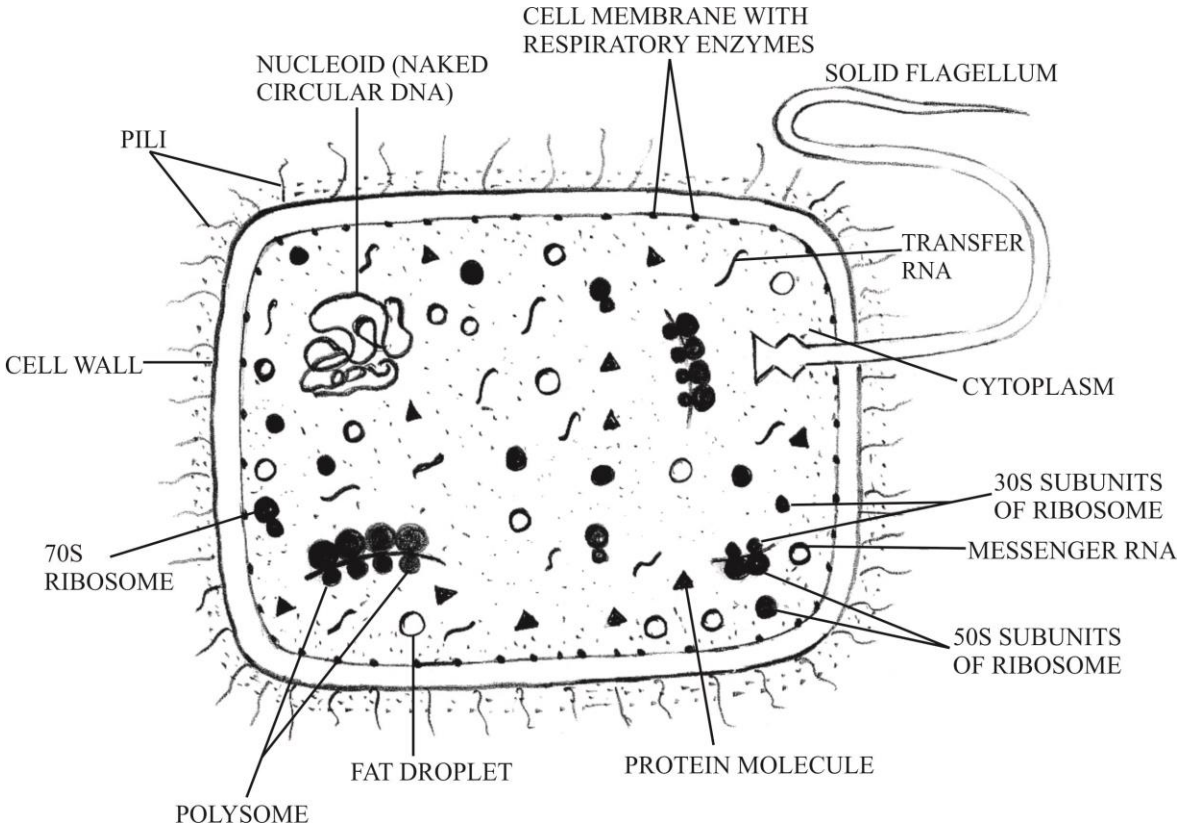

Fig. 1.1: A Bacterial Cell

1.4 BASIC COMPONENTS OF PROKARYOTIC AND EUKARYOTIC CELL

1.4.1 PROKARYOTIC CELLS

Prokaryotic cells are the most primitive cells and have simple structural organization. It has a single membrane system. They include bacteria, viruses, blue-green algae, mycoplasmas, rickettsias, spirochetes etc. Cyanobacteria or blue green algae are the largest and most complex prokaryote, in which photosynthesis of higher plants type have evolved. **Prokaryotes** are included in the kingdom **Monera** and the super kingdom **Prokaryota**. The Prokaryotes have the following characters:

1. The size of prokaryotic cells ranges between 1 to 10 µm. They occur in a variety of forms.

2. Prokaryotic cell consists of three main components:

(I) **Outer covering:** It is composed of inner cell or plasma membrane, middle cell wall and outer slimy capsule.

a. **Cell membrane:** Cell membrane made up of lipids and proteins, is thin and flexible and controls the movement of molecules across the cell. Respiratory enzymes are carried by it for energy releasing reactions. **Mesosomes**, the in-folds of plasma membrane bears respiratory enzymes and these are considered analogous to mitochondria of eukaryotic cells. Similarly, the pigments and enzymes molecules that absorb and convert the light into chemical energy in photosynthetic cells are also associated with the plasma membrane's in-folds called **photosynthetic lamella**. These lamellae are analogous to the chloroplast of eukaryotic cells. Plasma membrane plays role in replication and division of nuclear material. Since the in-folds remain continuous with the cell membrane, they are not considered as separate compartments. Thus, prokaryotic cell is non-compartmentalized.

b. **Cell wall :** It is a rigid or semi-rigid non-living structure that surrounds the cell membrane and its thickness ranges between 1.5 to 100 µm. Chemically it is composed of **peptidoglycans**. . Some bacteria such as mycoplasmas lack cell wall.

c. Slimy capsule: A gelatinous coat outside the cell wall is the slimy capsule. It is composed of largely of polysaccharides and sometimes it may have polypeptides and other compounds also. It protects the cell against desiccation, virus attacks, phagocytosis and antibiotics

(II) **Cytoplasm:** Prokaryotic cytoplasm contains proteins, lipids, glycogen and inorganic ions along with enzymes for biosynthetic reactions and ribosomes, tRNA and mRNA for protein synthesis. Prokaryotic cytoplasm has some special features as follows:

a. It lacks cell organelles like endoplasmic reticulum, mitochondria, Golgi apparatus, Centrosomes, vacuoles, Lysosomes, microfilaments, intermediate filaments and microtubules.

b. The only cytoplasmic organelle found in prokaryotic cells is the **ribosomes**. They are smaller than eukaryotic ribosomes i.e., 70S and lie free in the cytoplasm. They form poly-ribosomes at the time of protein synthesis. They are the sites of protein synthesis.

c. Like eukaryotic cells, the cytoplasm of prokaryotic cell does not show streaming movement or cyclosis.

d. Gas vacuoles are also formed in some prokaryotic cells.

e. The cell does not show phagocytosis, pinocytosis and exocytose, substances enter and leave the cell through the cell membrane.

f. They may contain deposits of polysaccharides or inorganic phosphates.

(III) **Nucleoid:** Nuclear envelope is absent in prokaryotic cell and the genetic material lies directly into the cytoplasm. Such nuclear material is known as **nucleoid**. **Nucleoid** consists of greatly coiled single pro-chromosome. It shows the following special features:

a. A short and simple pro-chromosome is present which is attached at least at one point on cell membrane.

b. Mostly there is single copy of chromosome, the prokaryotic cell is haploid.

c. The DNA is naked as it is not associated with basic histone proteins. It is double stranded, helical and circular.

d. The amount of DNA is lesser than eukaryotic cell and it codes fewer proteins. Replication of DNA is continuous throughout the cell cycle. Transcription and translation occurs in cytoplasm and processing of mRNA is not required.

e. The processes like meiosis, gamete formation or fertilization are absent. Conjugation is seen in some bacteria.

f. Mitotic apparatus absent.

g. There is no nucleolus.

h. Cell membrane folds or mesosomes help to segregate the replicated products of chromosomes into daughter cells.

3. Plasmids: In some prokaryotic cells, in addition to nucleoid, a small circular double stranded DNA molecule is present. It is called **plasmid**. Plasmids have 1000 to 30,000 base pairs and they generally encode proteins required by the organism to resist antibiotic and other toxic material.

4. **Flagellum:** It is a whip like locomotory structure found in many bacteria. It is 150Å thick and 10 to 15µm long. As the flagellum does not have any surrounding membrane, it grows at the tip.

It has two main parts: Filament and basal body.

i) Filament- Filament extends out of cell into the medium and it is composed of many intertwined spiral chains of the subunits of a protein called **flagellin**. Flagellin differs from actins or tubulin.

(ii) **Basal Body-** The basal body attaches the flagellum to the cell and generates the force to rotate it. It is composed of many components and numerous proteins. It has two parts: shaft and hook.

5. Pili: These are short, rod like non-motile processes or fimbriae present on many bacteria. These are formed of pilin protein. They are usually less than 10 nm thick. They help in attachment of bacteria to surfaces or food or to one another. Tubular sex Pili are present in some bacteria.

Prokaryotic cells have all the biochemical mechanisms required to synthesize complex organic materials from simple organic precursors necessary for life. Thus, inspite of being simple in structure prokaryotes are more versatile in their synthetic activities than eukaryotes.

1.4.2 EUKARYOTIC CELLS

The internal organization of eukaryotic cell is more developed than prokaryotic cells from which they are believed to have been evolved. They are evolved to have double membrane system. Primary membranes are the one that surrounds the cell, celled cell or plasma membrane and the secondary membrane surround the nucleus and other cellular organelles. Eukaryotic cells occur in protists, fungi, plants and animals. Eukaryotic cells have the following characteristics:

1. **Number-** In multicellular organisms the numbers of cells are correlated with the body size. The human blood contains about 30 quadrillion (3×10^{15}) corpuscles and a 60 kg human being has about 60×10^{15} cells. All multicellular organisms begin their life with a single cell "Zygote" and then become multicellular by its mitotic division during development.

2. Shape- A cell may be spherical, cuboidal, oval, disc-like, polygonal, columnar, spindle like or irregular. Thus, cells acquire a variety of shapes not only in various organisms but also

in different tissues of the same organism. The shape of cell is correlated with its functions like the shape of muscles and nerve cells are well adapted to their functions. Many factors such as cell functions, age of cell, presence or absence of cell wall, viscosity of cytoplasm etc. are responsible for various shapes of cells.

3. Size- Most of the eukaryotic cells is microscopic and their size ranges between 10 to 100µm. Sporozoits of malaria parasite (*Plasmodium vivax)* is among the smallest cells having the size equal to 2µm long. While the Ostrich egg measures 175 × 120mm. Nerve cells are the longest having the size of its fiber to be of few meters long. Human cells generally range from 20 to 30µm.

4. Components of a cell- Three main components of the eukaryotic cells are cell membrane, cytoplasm and nucleus. The cytoplasm and the nucleus further have several components. Various cell components are discussed below:

(i) **Cell membrane-** Cell membrane, plasma membrane or plasmalemma is a thin elastic living covering that surrounds the cell keeping the cell contents in place, provides shape to the cell and controls the transfer of materials across it. It is composed of lipid-protein complex. It lacks respiratory enzymes. In many protists and animal cells it allows endocytosis and exocytosis.

In certain protists, many fungi and all plant cells, the cell membrane is covered by a thick, rigid non-living cell wall that protects and supports the cell. In prokaryotes the cell wall surrounding the plasma membrane has a different structure in comparison to eukaryotes.

(ii) **Cytoplasm**- The cytoplasm or the cytosome is a semi-fluid, homogeneous, translucent ground substance known as cytoplasmic matrix or cytosol which is present between the cell membrane and the nucleus. In the protozoan cell the outer firm layer of cytoplasm is called ectoplasm and the inner layer around the central fluid mass is called the endoplasm. The cytosol shows "cyclosis" or the streaming movement. The eukaryotic cytoplasm has the following features:

a. Organelles*:* The organized structures having the specific functions and capacity of growth and multiplication in some cases are known as organelles. Mitochondria, centrosomes, Golgi bodies, plastids and vacuoles are the organelles that can be observed under light microscope, while endoplasmic reticulum, ribosome, microfilaments, microtubules, intermediate filaments and micro bodies can only be seen under electron microscope. These organelles are often

described as protoplasmic structures. The cells having cilia or flagella have their basal bodies at the bases are in the cytoplasm while rest of its part extends out of cytoplasm. These organelles are described as follows:

I. Mitochondria: The rod like or globule shaped structures scattered in the cytoplasm are found singly or in groups. They are bounded by **double membrane** of lipoproteins. The inner membrane gives out finger like structure known as **cristae** which partially subdivide the inner chamber of mitochondrion. On the inner surface of cristae are present mushroom like structures, **oxysomes that** are related to phosphorylation. The space between the membranes and its lumen is filled with mitochondrial **matrix**. Both the membranes and the matrix contain many oxidative enzymes and coenzymes. Since mitochondria contain DNA molecules and ribosomes, they synthesize certain proteins. They produce the energy and reserve it in the form of **adenosine triphosphate (ATP).** Due to the presence of its own DNA and ability of protein synthesis along with its duplication, the mitochondria are called **semi autonomous organelle**. The DNA of mitochondria resembles that of bacterial cell; hence it is also called as **endo-symbiotic organelle**.

II. Centrosomes: (9+0) there is a clear zone around centrioles, near the nucleus, that includes a specialized portion of cytoplasm, called **centrospheres**. Its matrix is called kinoplasm that bears two rounded bodies the "centrioles". Each centriole consists of **nine fibrillar** units and each of them is found to contain **three microtubules** arranged in a circle. Both the centrioles are arranged at right angle to each other. Centrioles form the spindles of microtubules at the time of cell division. Centrioles are absent in plant cell and the spindle is formed without their help.

III. Golgi bodies: These are the stack of flattened parallel-arranged **sacs** and **vesicles** found in association of endoplasmic reticulum. They are composed of many **lamellae, tubules, vesicles and vacuoles**. Their membranes are supposed to be originated from ER and are composed of lipoproteins. In plant cells the Golgi complex is called **dictyosome** that secretes required materials for the formation of cell wall at the time of cell division. It helps in the formation of acrosome of sperms, release of hormones, enzymes and other synthetic materials.

IV. Plastids: These organelles are found in plant cells and are absent in animal cells. They may be colored like chloroplast or chromoplasts or colorless like leucoplast. Since the leucoplast store and metabolise the starch and lipids, they are called amyloplast and lipoplast

respectively. Chloroplast contains the green pigment the chlorophyll that helps in photosynthesis and protein storage. Chloroplast has a **double outer membrane**, the **stroma**, that bears many soluble enzymes, and a complex system of membrane bound compartments called **thalakoids** constituting **granna**. Like mitochondria, chloroplast also has their own DNA, ribosomes and complete protein synthetic machinery. Hence these are also called endo-symbiotic and semi-autonomous organelle.

V. Metaplasm: The particles like vacuoles, granules and other cytoplasmic bodies such as ribonucleoprotein molecules are represented by it.

VI. Cilia, basal bodies and flagella: Cilia are the minute structures covering the surface in some cells. Both cilia and flagella originate from the **basal bodies or blepharoplast** lying in cytoplasm. They consist of nine outer fibrils with the two larger fibrils in the centre. Each fibril consists of two microtubules, or has **9+2** arrangement. Cilia and Flagella are the structure born by certain cells. They are composed of microtubules made of the protein **tubulin**. They have 9 + 2 plan of microtubule. Both grow at the base. They act as locomotory organelles, moves by their beats or undulations for they get the energy by breakdown of ATP molecule.

VII. Microtubules: The ultra fine tubules of protein (**tubulin**) traversing the cytoplasm of plant and animal cells providing the structural framework to the cell, determine the cell shape and general organization of the cytoplasm are known as microtubules. Tubules are made up of **13 individual filaments**. Microtubules help in transport of water and ions, cytoplasmic streaming (cyclosis) and the formation of spindles during cell division.

VIII. Basal granules: The spherical bodies found at the base of cilia and flagella are called the basal bodies. Each of them is composed of **nine fibrils** and each fibril consists of the three microtubules, out of which two enter the cilia or flagella.

IX. Ribosome's: Ribosome is the minute spherical structures that originate in nucleolus and are found attached with the membrane of endoplasmic reticulum and in the cytoplasm. They are mainly composed of **ribonucleic acids (RNA) and protein**. They are mainly responsible for **protein synthesis**.

b. Inclusions: These are the **non-living or deutoplasmic structures** which are incapable of growth and multiplication. Common cell inclusions are stored organic materials such as starch grains, glycogen granules, aleuron grains, fat droplets, pigment granules and inorganic

crystals. Cytoplasm is stores raw materials needed for the metabolism in both the cytoplasm and the nucleus. Many metabolic processes like biosynthesis of fatty acids, nucleotides, proteins and oxidation take place in cytoplasm. It distributes the nutrients, metabolites and enzymes in a cell and brings about exchange of materials between the organelles as well as with the environment or extracellular fluid also.

c. Nucleus: In a eukaryotic cell the genetic material is enclosed by a distinct **nuclear envelope** that forms a prominent spherical organelle the "Nucleus". The nuclear envelope bears **pores** for the exchange of materials between the cytoplasm and the nucleoplasm.

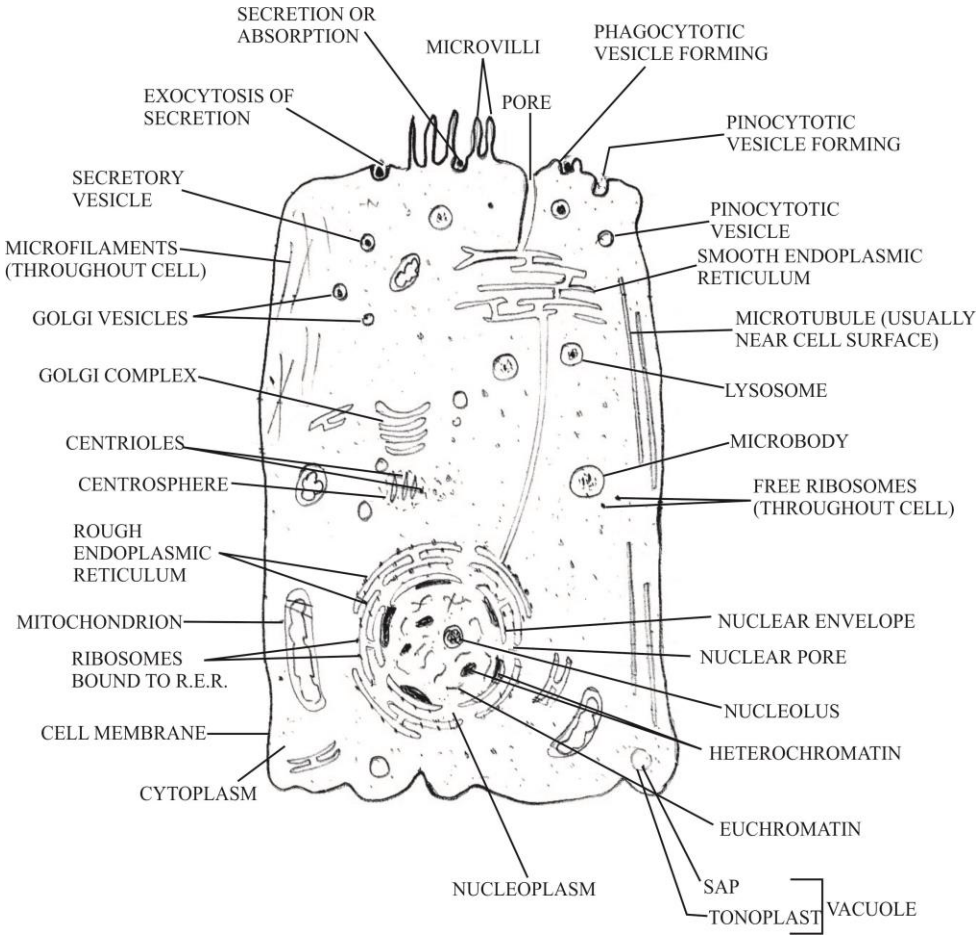

Fig. 1.2: An animal cell as shown by electron microscope

1.4.3 DIFFERENCES BETWEEN PROKARYOTIC CELLS AND EUKARYOTIC CELLS

The internal organization of eukaryotic cell is more developed than prokaryotic cells from which they are believed to have been evolved.

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
1.	A prokaryotic cell is surrounded by a single membrane layer.	1.	A eukaryotic cell is surrounded by a double membrane layer.
2.	In most cases the cell wall surrounds the plasma membrane and it is composed of carbohydrates, lipids proteins and certain amino acids.	2.	Cell wall is present in protists, most fungi and plants and is composed of chitin in most fungi and or cellulose in others.
3.	Respiratory enzymes are present on cell membranes.	3.	Absent on the cell membrane
4.	Thalakoids occurs free in cytoplasm.	4.	They occur within the chloroplast.
5.	Cytoplasm lacks organelles like centrosomes, endoplasmic reticulum, mitochondria, Golgi apparatus, microfilaments, intermediate filaments, microtubules and micro bodies. While ribosomes are present	5.	All the cell organelles are present in the cell along with ribosomes.
6.	Gas vacuoles may occur while sap vacuoles are	6.	Sap vacuoles are commonly present.

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
	absent.		
7.	70S ribosomes are present that lie free in cytoplasm or attached to mRNA.	7.	80S ribosome's are present, either free or bound to ER and nuclear envelope or mRNA.
8.	Endocytosis and exocytose do not occur.	8.	These processes take place in many protists and in animals.
9.	Process of meiosis or gamete formation or true fertilization does not occur.	9.	In these cells the process of meiosis, gamete formation and true fertilization occur in most cases of sexual reproduction.
10.	Cells are haploid.	10.	Cells are diploid, while haploid cells also occur.
11.	Nuclear envelope is absent and nuclear material lie in cytoplasm and is called nucleoid. Nucleoid contains a single chromosome.	11.	Nuclear envelope surrounds the nuclear material. The structure is called nucleus. It contains two to many chromosomes.
12.	Nucleolus absent.	12.	One or more nucleoli are present within the nucleus.
13.	Circular DNA is present	13.	Nuclear DNA is linear

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
	without associated proteins.		and is associated with proteins, while extra nuclear DNA is present without proteins.
14.	Flagella if present are simple, consist of a single fibril and are formed of a protein flagellin.	14.	Flagella, if present are complex, have 9+2 pattern of microtubules formed of a protein tubulin.
15.	Plasmids and pili occur in many prokaryotic cells.	15.	These structures are absent.
16.	Most prokaryotes are asexual organisms.	16.	Most of them are sexual organisms.

1.5 SUMMARY

Robert Hook (1665) for the first time described the texture of a piece of cork as “cell”. Similar structures were observed by many scientists while studying many living organisms. It was Schwann T. (1839) who stated that all living organisms are composed of cells after examining a variety of plant and animal tissues. Basically two types of cells are there, “Prokaryotic” and “Eukaryotic”. Prokaryotic cells are the primitive cells that include bacteria, blue-green algae, viruses and photosynthetic cells cyanobacteria etc. Their size varies from 1 to 10 um and they consist of mainly three components: the outer covering that includes all cell membrane, cell wall and a slimy capsule. Another component is cytoplasm which lacks cell organelles except ribosomes. The processes like phagocytosis and endocytosis are absent. The third component is nucleoid that lacks nuclear membrane. Additional small circular DNA the plasmid may also be present. Flagella and pili like structure are also seen in some prokaryotic cells. Eukaryotic cells are more developed and are surrounded by double

membranes. Shape and size of these cells and their number in multicellular organisms varies. It is also composed of three main components. Cell membrane or plasma membrane is a thin elastic living covering. The cytoplasm is a semi fluid, homogenous, translucent consisting of many cell organelles, inclusions, cilia, flagella, basal bodies and microtubules.

1.6 GLOSSARY

Cytoplasm: Gel like substance enclosed within the cell membrane excluding nucleus.

Plasma membrane: It is the biological membrane that separates the interior of the cell from the outside environment.

Prokaryote: The cell that lacks a distinct nucleus and other specialized membrane bound organelles.

Eukaryote: an organism whose cell contains a membrane bound distinct nucleus along with other specialized organelles enclosed in membranes.

Mesosome: The in-folding of plasma membrane in some bacterial cells that carry respiratory enzymes.

Poly-ribosome: It is a group of ribosomes associated with a single messenger RNA during the translation process.

Phagocytosis: The process by which a cell engulfs a solid particle to form an internal vesicle known as phagosome is called phagocytosis, also called eating of cell.

Pinocytosis: The process of intake of liquid into a cell by the budding of small vesicles from the cell membrane is called pinocytosis, also called drinking of cell.

Exocytosis: In the process of exocytosis materials are exported outside the cell by using energy from ATP molecules.

Conjugation: When the genetic material is transferred from one bacterial cell to other either by direct contact or by a bridge like connection between two cells is called conjugation.

1.7 SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

1.7.1 MULTIPLE CHOICE QUESTIONS:

1. There is no organized nucleus in:

(a) Bacterial cell (b) Green algae cell

(c) Animal cell (d) Plant cell

2. The prokaryotic cells are characterized by:

(a) A distinct nuclear membrane (b) Absence of chromatin material

(c) Distinct chromosome (d) Absence of nuclear membrane

3. In a prokaryotic cell, DNA is:

(a) Enclosed by nuclear envelop (b) Lacking

(c) Not a genetic material (d) Without a membrane

4. Cell wall is found around the:

(a) Prokaryotic cells (b) Algal cells

(c) Plant cells (d) All the above

5. Chemical energy of food stuffs is converted into biologically useful forms by:

(a) Ribosomes (b) Golgi complex

(c) Mitochondria (d) Plastids

6. Sun radiant energy is converted into chemical energy of organic compound by:

(a) Mitochondria (b) Chloroplast

(c) Ribosomes (d) Centrosomes

7. Which structure is present only in animal cell?

(a) Cell membrane (b) Lysosomes

(c) Centrioles (d) Ribosomes

8. Single envelope system is characteristic of:

(a) Prokaryotic cell (b) Eukaryotic cell

(c) None (d) Both

9. Prokaryote and eukaryotes have the common:

(a) Mitotic apparatus (b) Histone

(c) Genetic code (d) Mitochondria

10. Unicellular microscopic organisms were first studied by:

(a) Robert Hooke (b) Priestley

(c) Pasteur (d) Leeuwenhoek

ANSWERS:

1. (a) 5.(c) 9. (c)

2. (d) 6.(b) 10.(d)

3. (d) 7.(c)

4. (d) 8.(a)

1.7.2 VERY SHORT QUESTIONS

1. What are prokaryotes? Give an example.

2. What are eukaryotes? Give few examples.

3. Cell is an open dynamic system. Is it correct?

4. Prokaryotic cells are haploid. Is it so?

5. What are cyanobacteria?

6. Give three essential characteristics of cell?

7. Where is nucleolus found?

8. What are the power houses of the cell?

9. Name the protein factories of prokaryotic and eukaryotic cells?

10. What is the control centre of a cell?

ANSWERS:

1. Organisms without an organized nucleus e.g., Bacteria

2. Organisms with an organized nucleus. Plants, yeast

3. Yes

4. Yes

5. Blue green algae

6. Cell membrane, cytoplasm, nuclear material

7. Nucleus

8. Mitochondria

9. Ribosome

10. Nucleus

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1.9 TERMINAL AND MODEL QUESTIONS

1. What is a cell? Draw a neat and labeled diagram of prokaryotic and eukaryotic cells.

2. Describe the structure of prokaryotic cells.

3. Give the salient features of eukaryotic cell.

4. Tabulate the differences between prokaryotic and eukaryotic cells.

5. What are cytoplasmic inclusions? Describe them in brief.

UNIT 2: STRUCTURE AND TYPES OF DNA

CONTENTS

2.1 OBJECTIVE

Study of this unit will let the students to:

- Structure, functions and type of DNA
- Watson and Crick's structural model of DNA
- Chemical composition of DNA
- Replication of DNA
- Recombinant DNA

2.2 INTRODUCTION

Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) the principal **genetic materials** of living organisms are chemically called **nucleic acids**. Nucleic acid especially the DNA, a universal genetic material of most of the organisms, is having all the features required to be a good genetic materials. DNA is a macromolecule and is a helically twisted double chain of poly deoxyribonucleotides.

In **prokaryotes** it occurs in **nucleoid** and also as **plasmids**, both are **double stranded circular DNA**. In **Eukaryotes** most of the DNA is found in **chromatin of nucleus**. It is **linear**. Some small quantitative of DNA are found in **mitochondria and plastids** which is generally double stranded and circular RNA also acts as genetic material in majority of plant viruses.

Features of DNA to act as genetic material:

- Genetic material is able to **store information** used to control both the development and metabolic activities of cell
- It should be **chemically stable** so that it can be replicated accurately during cell division
- It should be **transmitted for generations**
- It should be able to undergo **mutations providing genetic variability** required for the evolution.

2.3 STRUCTURE OF DNA

Nucleic acid (DNA or RNA) first called **nuclein** by a Swiss chemist **Friedreich Miescher** (1869) as he removed nuclei from pus cells and isolated DNA i.e., "nuclein" from it. Nucleic acid (DNA or RNA) are macromolecules composed of repeating sub unit called **nucleotides.**

Constitution of a nucleotide:

- A phosphate group
- A five carbon sugar (ribose in RNA and deoxyribose in DNA)
- A cyclic nitrogen containing compound called a base (purines and pyrimidines)

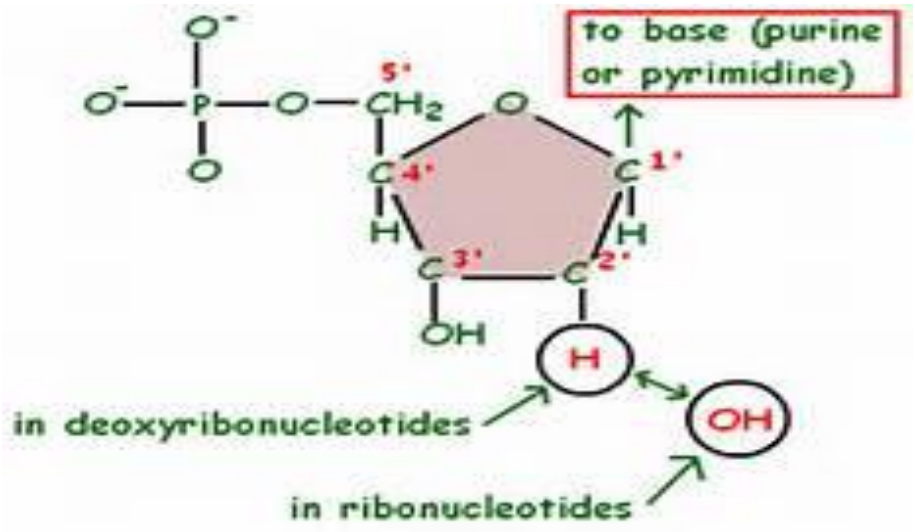

Fig.2.1 Structure of a nucleotide (in general)

Most commonly DNA occurs as a **double helix.** The two spiral strands of DNA are collectively called DNA duplex. Two separate and anti parallel chains of DNA are wound around each other in a **right handed helical manner**. The DNA double helix comes to have two types of alternate **grooves major** and **minor** with the sugar phosphate backbone on the outer sides. The bases paired by hydrogen bonding are stocked on each other.

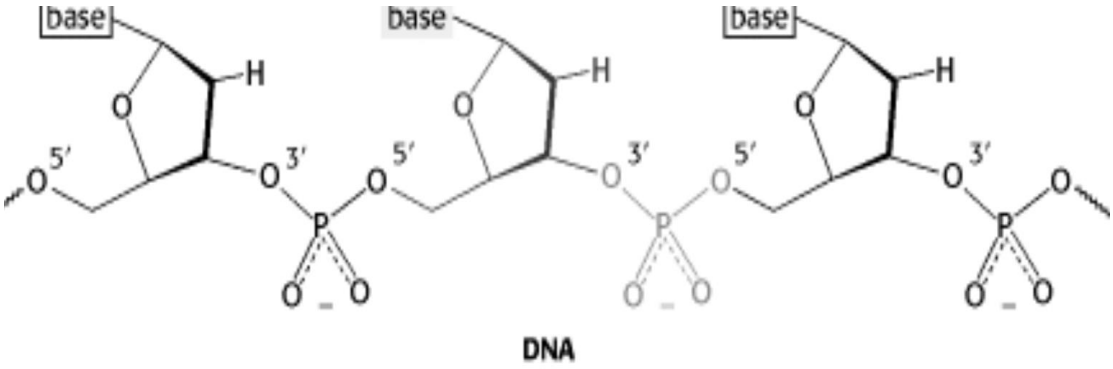

Fig. 2.2 Backbone of DNA. [The backbones are formed by 3 -to-5 phosphodiester linkages

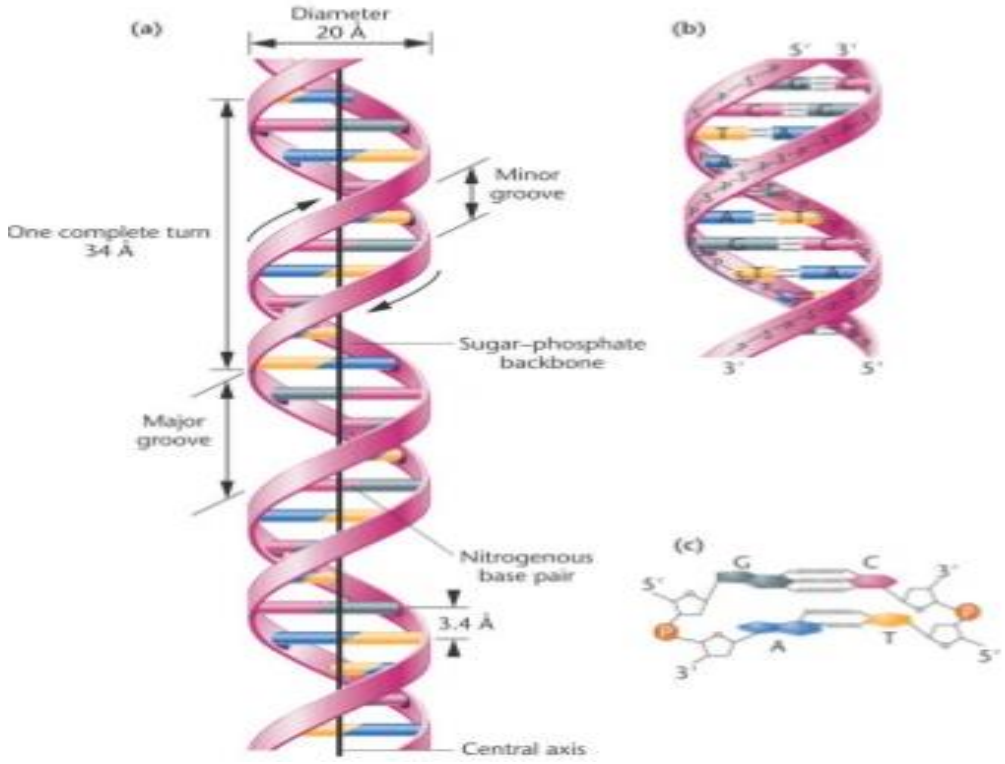

Fig. 2.3 DNA Double Helix Right Handed Helix Mode

2.4 CHEMICAL COMPOSITION OF DNA

Deoxyribonucleotides (monomer) of DNA are composed by three different types of chemicals.

(1) Phosphoric acid (H_3PO_4) has three reactive (-OH) groups of which two are involved in forming sugar phosphate back bone of DNA.

(2) Pentose sugar ($C_5H_{10}O_4$) - DNA contains 2'-deoxy-D-ribose, hence the name deoxyribose.

(3) Nitrogen bases- DNA contained four different nitrogen bases (**A, G, C & T).** These four bases are grouped in to two classes on the basis their chemical structure.

(a) Purine base – Adenine and Guanine

(b) Pyrimidine bases- Cytocine and uracil

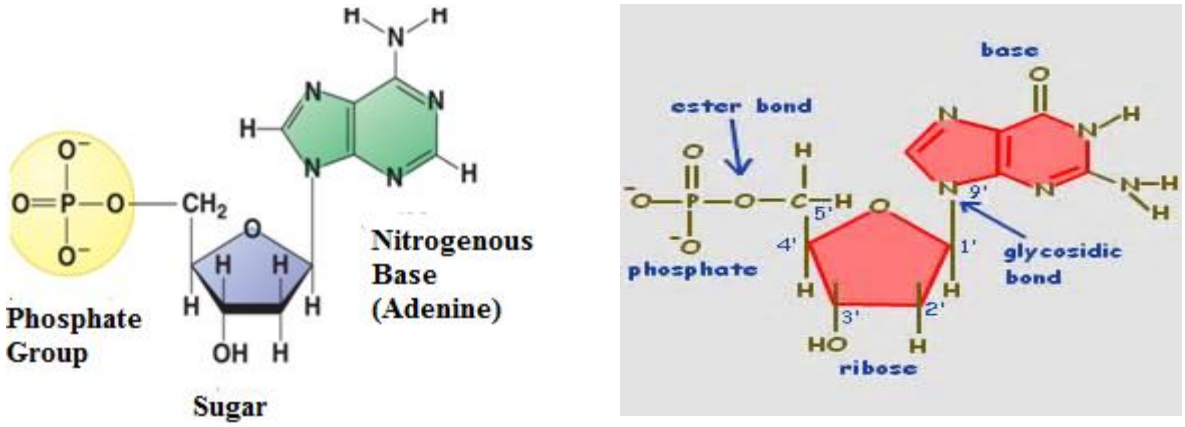

Fig. 2.4 Chemical constituents of a nucleotide

(a) Purine bases - DNA has two types of purines (**adenine and guanine**). Each purine is a type of nitrogen base having a **double ring structure** (i.e. 9 member double rings with nitrogen at 1, 3, 7 and 9 positions).

Some of the common names of these bases reflect the circumstances of their discovery. Guanine, for example, was first isolated from guano (bird manure), and thymine was first isolated from thymus tissue.

(b) Pyrimidine bases- DNA has two types of pyrimidine bases (**cytosine and thymine**). Each pyrimidine is a type of nitrogen containing base having a **single ring structure** (i.e. 6 member rings with nitrogen at 1 and 3 positions).

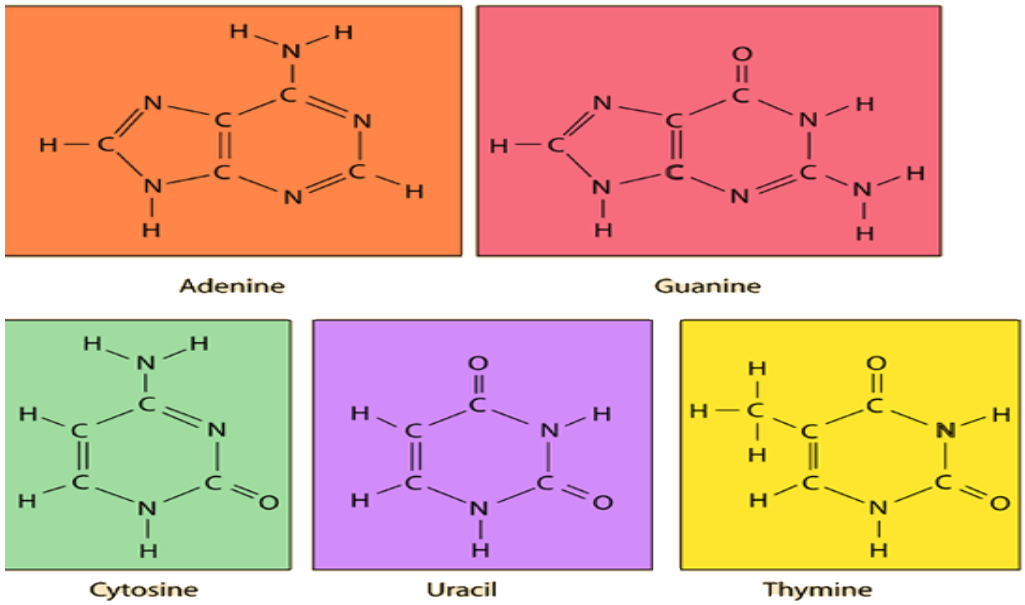

Fig. 2.5 Nitrogen bases of nucleic acids

(**A, G and C** is common to DNA and RNA, **U** is present in RNA and **T** in DNA)

Nucleosides- A nitrogenous base with a molecule of deoxyribose sugar (without phosphate group) is known as nucleosides. In nucleic acids, the nitrogen bases are covalently attached to the 1'-position of a pentose sugar ring with the help of glycosidic bond.

Nitrogen base + sugar = nucleoside.

- Adenine + deoxyribose = deoxyadenosine
- Guanine + deoxyribose = deoxyguanosine
- Cytosine + deoxyribose = deoxycytidine
- Thymine + deoxyribose = deoxythymidine

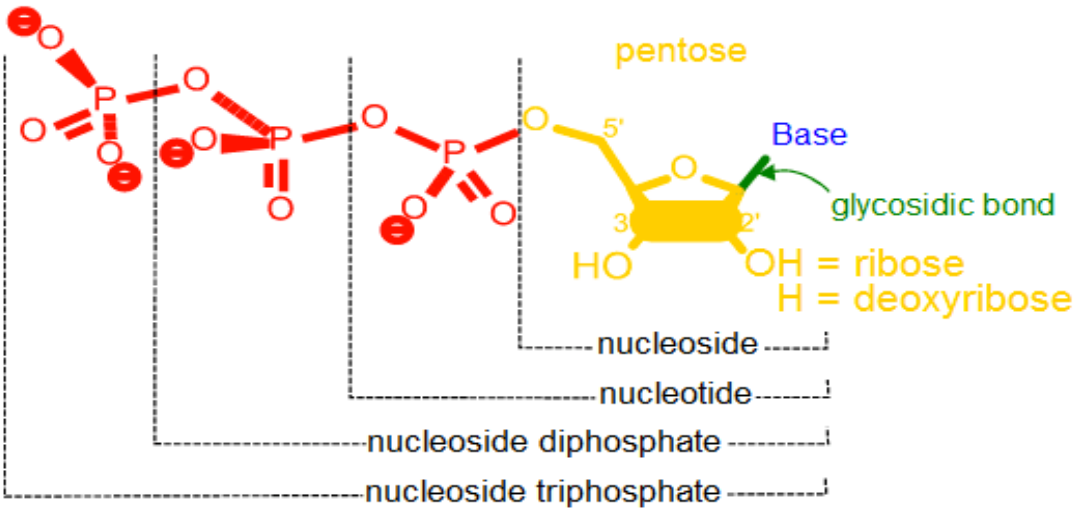

Fig.2.6 Progressive formation of nucleoside to nucleotide (from lower to higher energy compounds)

Nucleotides- A nucleotide is formed of one molecule of deoxyribose sugar, one molecule of phosphoric acid and anyone of the nitrogen base. Phosphoric molecule is attached to the 5^{th} – carbon atom of deoxyribose ring with the help of phosphoesterbond.

Nucleosides + phosphoric acid = nucleotides

Different nucleotides of DNA are as follows:

(1)Adenine + deoxyribose + phosphoric acid = deoxyadenylic acid or deoxyadenylate / dAMP

(2) Guanine + deoxyribose + phosphoric acid = deoxyguanylic acid or deoxyguanylate / dGMP

(3)Cytosine + deoxyribose + phosphoric acid = deoxycytidylic acid or deoxycytidylate / dCMP

(4)Thymine+deoxyribose+phosphoric acid = deoxythymidylic acid or deoxythymidylate / dTMP

Nitrogen base	**Nucleoside (nitrogen base + sugar)**	**Nucleotide (nucleocide +phosphate gp.)**
Adenine (A)	A+S= Adenosine	Adenylic acid adenosine monophosphate (AMP)
Guanine (G)	G+S= Guanosine	Guanylic acid

		Guanosine monophosphate (GMP)
Thyamine (T)	T+S = Thyamidine	Thyamidylic acid
		Thyadine monophosphate (TMP)
Cytosine (C)	C+S = Cytidine	Cytidylic acid
		Cytidine monophosphate (CMP)

Table- 1 Nitrogen bases, their respective nucleosides and nucleotides of DNA

2.5 WATSON AND CRICK DOUBLE HELIX MODEL OF DNA

The structure of DNA was deduced by American **J. D. Watson and F.H.C. Crick in** 1953 for which they received the Nobel Prize in 1962. Their double- helix model of DNA structure model is widely accepted. Their double helix model of DNA was based on the data and information given by so many workers like **E. Chargaff, M.H.F. Wilkins, R. Franklin and their coworkers.** Main contributions in deducing this model was of:

Chargaff's rule, Franklin's X-ray diffraction patterns and Kornberg's results

James Watson

Francis Crick

Rosalind Franklin

Maurice Wilkins

Chargaff's rule- In 1940's **Erwin Chargaff** analyzed base content of DNA using new chemical techniques and their observations and generalizations were called as Chargaff's rule. Chargaff's rule strongly suggested that thymine and adenine as well as cytosine and

guanine were present in DNA, always bonded to each other by H-bonds and shows some fixed inter relationship

- The proportion of A always equals that of T, and the proportion of G always equals that of C or **A = T and G = C.**
- The amount of A, T, G, and C in DNA vary from species to species but **A+T/G+C = constant for a particular species.**

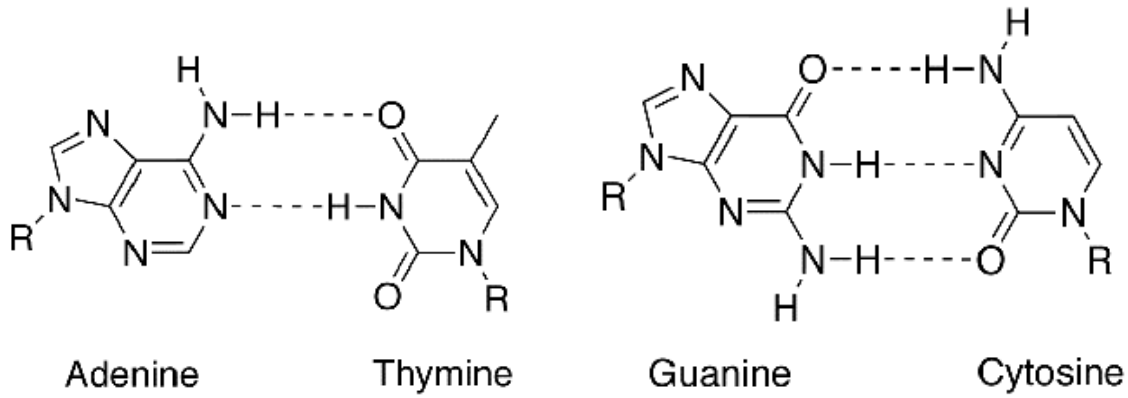

Fig. 2.7 Structures of the Base Pairs (Proposed by Watson and Crick)

Franklin's X-ray diffraction patterns- Watson and Crick made use of the data of x-ray crystallographic of DNA structure from the studies of **M.H.F. Wilkins, R. Franklin** and their coworkers. According to their data, DNA was a highly ordered, multiple stranded structure with repeating sub structure spaced every 3.4A^{o} along the axis of the molecule.

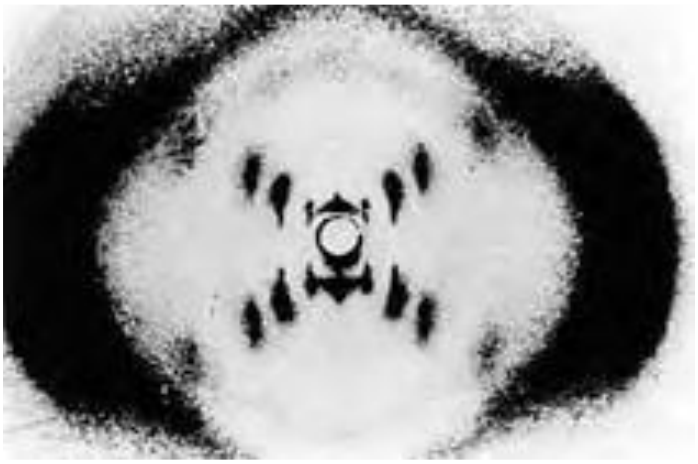

Fig. 2.8 X-Ray Diffraction Photograph of a Hydrated DNA Fiber
The central cross is diagnostic of a helical structure

Korenberg's results- Korenberg and his associates tried to synthesize DNA in a medium free of DNA but in the presence of enzyme **DNA polymerase** and nucleotides-the building blocks of DNA. They found that in a DNA free medium with all necessary compounds DNA synthesis does not occur but the same happens i.e., DNA synthesis starts only when some DNA was added as a primer to the same medium.

The important features of their model of DNA are-

(a) Two helical polynucleotide chains are coiled around common axis, where the backbone is constituted by sugar phosphate and the bases project inside.

(b) The polynucleotide chains run in opposite directions. It means, if one chain has the polarity 5'P → 3'OH, the other has 3'OH→5'P.

(c) The two chains are held together by hydrogen bonds between their bases. Three hydrogen bonds occur between cytosine and guanine (C≡G) and two hydrogen bonds between adenine and thymine (A=T).

(d) The diameter of the helix is $20A^0$ and bases are separated by 3.4 A^0 along the helix axis and related by a rotation of 36^0.

(e) The helical structure repeated after 10 residues on each chain, and intervals of 34 A^0 .

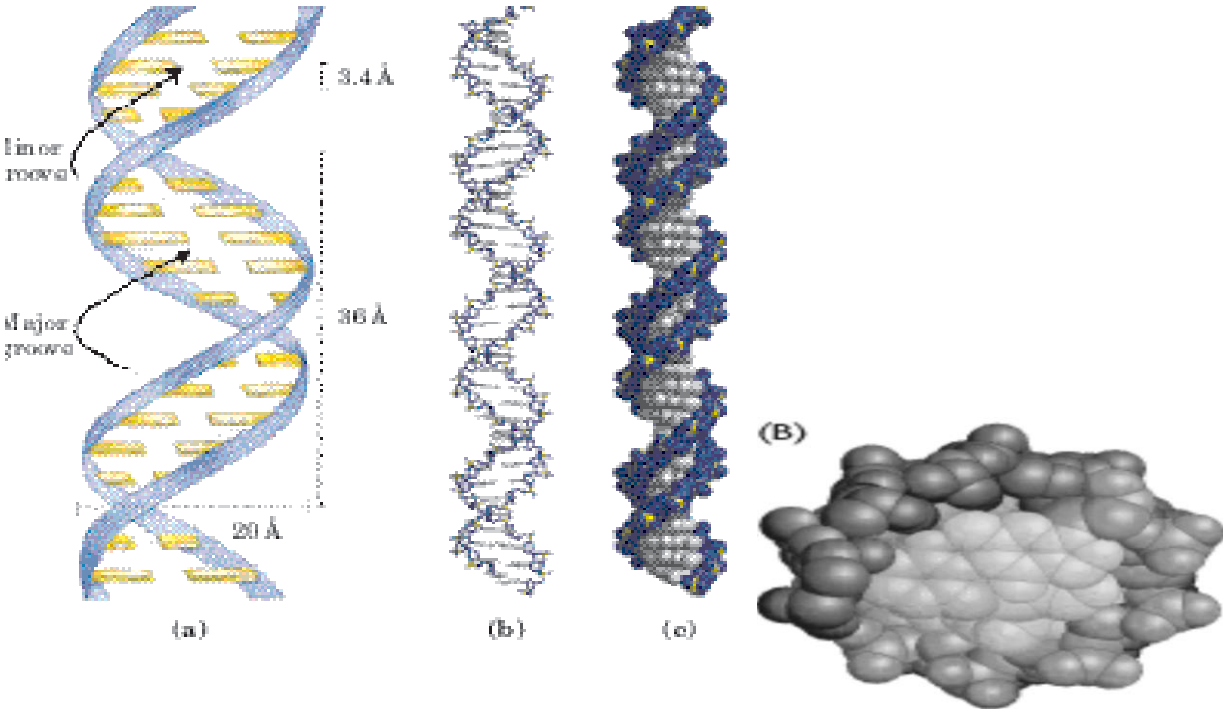

Fig. 2.9 Watson-Crick Model for the structure of DNA. The original model proposed by Watson and Crick had 10 base pairs, or 34 Å (3.4 nm), per turn of the helix; subsequent measurements revealed 10.5 base pairs, or 36 Å (3.6 nm), per turn. ***(a)*** *Schematic representation, showing dimensions of the helix.* ***(b)*** *Stick representation showing the backbone and stacking of the bases.* ***(c)*** *Space-filling model* ***(B)*** *Radial view, looking down the helix axis*

2.6 TYPES OF DNA

The vast majority of the DNA molecules present in the aqueous protoplasm of living cells almost certainly exist in the Watson – Crick double helix form is the B-form of DNA. B-DNA shows right handed coiling. Intracellular B-DNA appears to have an average of 10.4 nucleotide pairs per turn. In high concentration of salt or in a dehydrated state, DNA exits in the A-form. A- DNA is also a right handed helix and contains 11 base pairs per turn. Recently DNA sequences have been shown to exist in a unique left handed structure also called double helical Z-DNA. It contains 12 base pairs per turn. In Z-DNA, the sugar-phosphate backbone follows a zigzagged path giving it the name Z-DNA or Z-form. The helices of A and B form DNA are wound in a right handed manner. Specific segments of DNA molecules can undergo conformational shift from the B-form to the Z-form and vice-versa. These changes may be brought about by some specific regulatory proteins. The Z-form DNA is postulated to play a role in gene regulation.

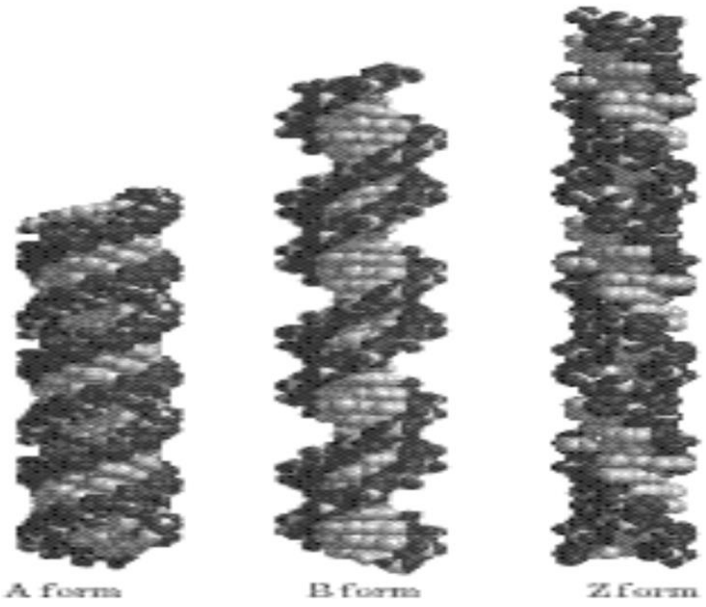

Figure 2.10 Comparison of A, B, and Z forms of DNA, each structure shown here has 36 base pairs.

Features	A-DNA	B-DNA	C-DNA	Z-DNA
Helical sense	Right handed	Right handed	Right handed	Left handed

Diameter (nm)	-2.6nm	-2.0nm	-	-1.8nm
Base-pairs per helical turn (n)	11	10	10	12 (6 dimers)
Helical twist per bp (360/n)	33^0	36^0	39^0	60^0 (per dimer)
Helix rise per bp (nm)	0.26nm	0.34nm	-	0.37nm
Base tilt to helix axis	20^0	6^0	-	7^0
Major groove	Narrow/deep	Wide/deep	-	Flat
Minor groove	Wide/shallow	Narrow/deep	-	Narrow/deep
Helix pitch (nm)	2.8nm	3.4nm	-	4.5nm
Condition	75% relative humidity, Na^+ K^+, Cs^+ ions.	92% relative humidity, low ionic strength	66% relative humidity, Li^+ ions	Very light salt concentrations

Table- 2 Comparison of different type of DNA

There are certain other forms of DNA such as D-form and E-form, both of which are found as rare extreme variants and contain only 8 and 7.5 base pairs per turn respectively.

2.7 FUNCTION OF DNA

1. DNA is genetic material which able to store information used to control both the development and metabolic activities of cells.
2. DNA can be replicated accurately during cell division and transmitted for generations.
3. Crossing over during meiosis produces natural recombination of DNA which is passed on to next generation to produce variants in all sexually reproducing organisms.
4. DNA able to undergo mutations providing genetic variability required for evolution.
5. Differentiation of various body parts is due to differential functioning of specific parts of DNA.
6. Developmental stages occur in the life cycle of an organism by an internal clock of DNA functioning.

2.7.1 EVIDENCE FOR DNA IS GENETIC MATERIAL

2.7.1 (A) Griffith's experiment on bacteria:

The **transformation** was first studied by a British doctor S. F. Griffith (1928). Griffith observed that ***Diplococcus pneumonia*** known as ***Pneumococcus*** has two strains

(a) Virulent or S-III- or smooth or capsulated type-in which mucous coat produce shiny colonies and cause pneumonia

(b) Non Virulent or R-II- or rough or non-capsulated – in which mucous coat is absent and do not cause pneumonia.

Summary of Griffith's experiments on transformation

a) Smooth type bacteria were injected into mice. The mice died as a result of pneumonia caused by virulent.
b) Rough type bacteria were injected in to mice. The mice lived and pneumonia was not produced.
c) Smooth type bacteria which cause disease were heat killed and then injected in to the mice. The mice lived and pneumonia was not caused.
d) Rough type bacteria and smooth type heat killed bacteria were injected together in to mice. The mice died due to pneumonia and virulent smooth type living bacteria could also be recovered from their bodies.

The occurrence of living S-type virulent bacteria is possible only by their transformation from R-type or non virulent bacteria which pick up the trait of virulent from dead or heat killed S-type bacteria. The phenomenon is called **Griffith effect or transformation**.

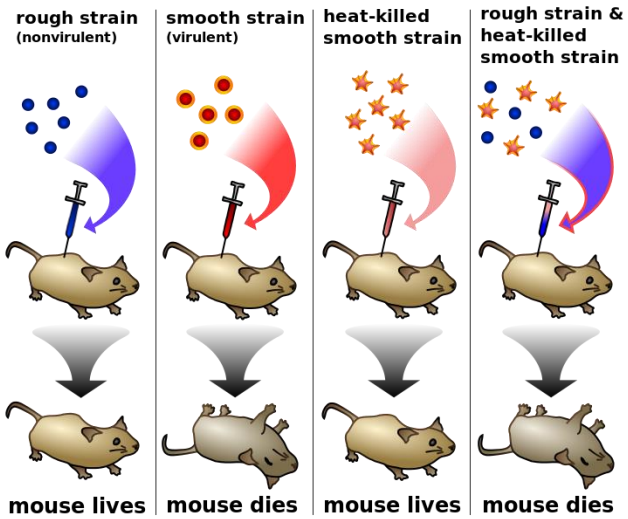

Fig.2.11 Diagrammatic representation of Griffith's effect of transformation

But Griffith effect or experiment can't prove the following points:

- ✓ Whether or not mice were essential for transformation of R-type into S-type
- ✓ Whether the character of virulence belong to polysaccharide of mucilage, protein or DNA of S-type bacteria that resulted in the transformation

2.7.1 (B) Avery, Macleod and Mc Carty Experiment

In 1940, **Avery, Macleod and Mc Carty** did various experiments to show and prove DNA to be transforming agents in Griffith's observations. They showed that if highly purified DNA from type III S Pneumococci was present with type II R Pneumococci, some of the types 11 R Pneumococci were transferred to type III S. This is known **as transforming principle**. Finally the results obtained by Avery and coworkers clearly established that the genetic information in pneumococcus was present in DNA.

Summary of Avery, Macleod, and Mc Carty's experiment-

1. Type II R → II R colonies.
   &
   DNA extract type III S heat killed →no colonies.
2. Type II + DNA extract type III S heat killed + serum that precipitates II R cells from mixture → III S colonies.
3. Type II + DNA extract type III S heat killed + serum that precipitate II R cells from mixture +RNase→ III S colonies.

4. Type II + DNA extract type III S heat killed + serum that precipitates II R cells from mixture + protease→ III S colonies.
5. Type II + DNA extract type III S heat killed + serum that precipitates II R cells from mixture + DNAase → no colonies

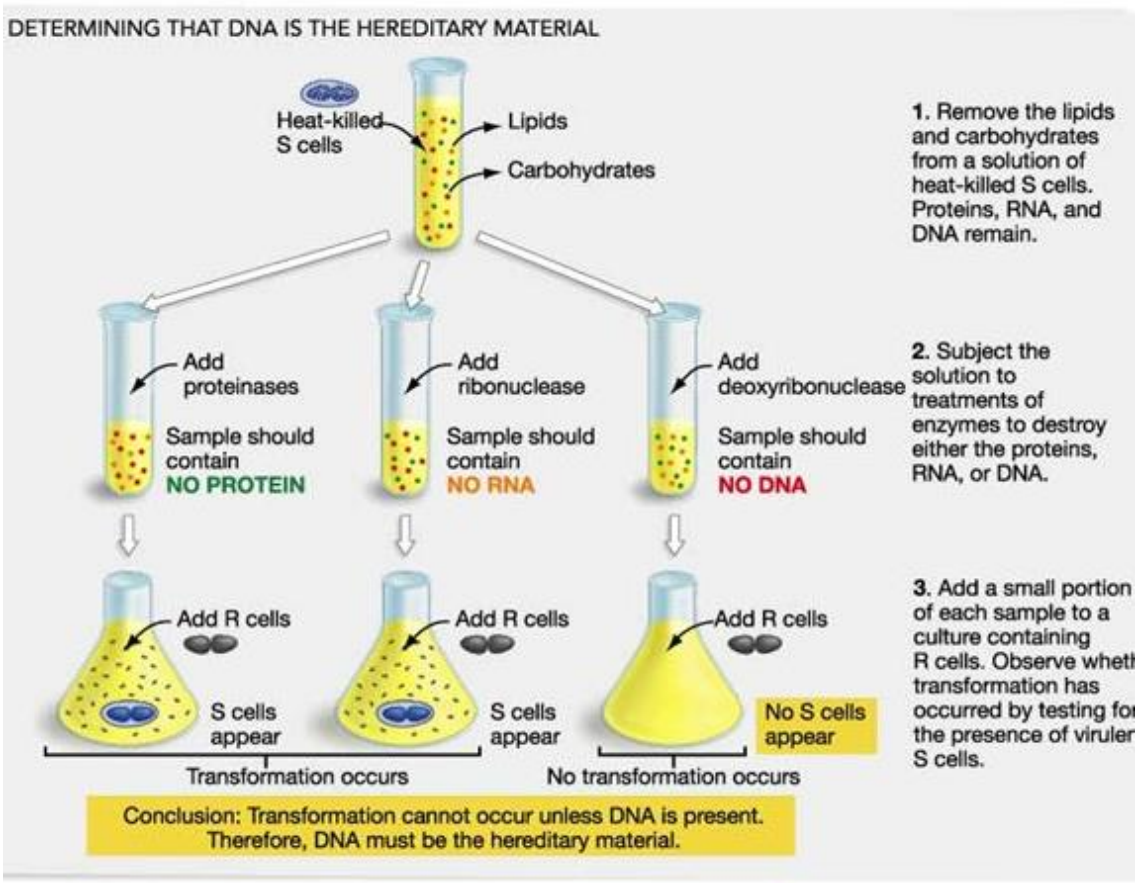

Figure 2.12 The Avery-MacLeod-McCarty experiments

2.7.1 (C) Hershey and Chase Experiment:

Hershey and Chase in 1950 conducted an experiment with phage T_2 inside the common bacterium ***Escherichia coli*** and proved that the DNA is the genetic material in bacteriophage T_2. His experiment goes as follows:

- Escherichia coli cells were infected with P^{32} labeled phage (DNA labeled) and after being allowed time for infection, they were agitated in a blender which sheared off the phage coats.
- The phage coats and the infected cells were then separated by centrifugation. Radioactivity was measured in the cell pellet and in the phage coat suspension.
- Most of the radioactivity was found in the cells.

- The same experiment was repeated using phage with S^{35} (labeled proteins) and found that the results were very different.
- The bacterial cells showed the presence of radioactive DNA labeled with P^{32} while radioactive protein labeled with S^{35} appeared on the outside of bacteria cells.
- Labeled DNA was also found in the next generation of phage. This experiment showed that only DNA enters the bacterial host and not the protein which helps in phage multiplication.
- This provided the unequivocal proof that DNA is the genetic material.

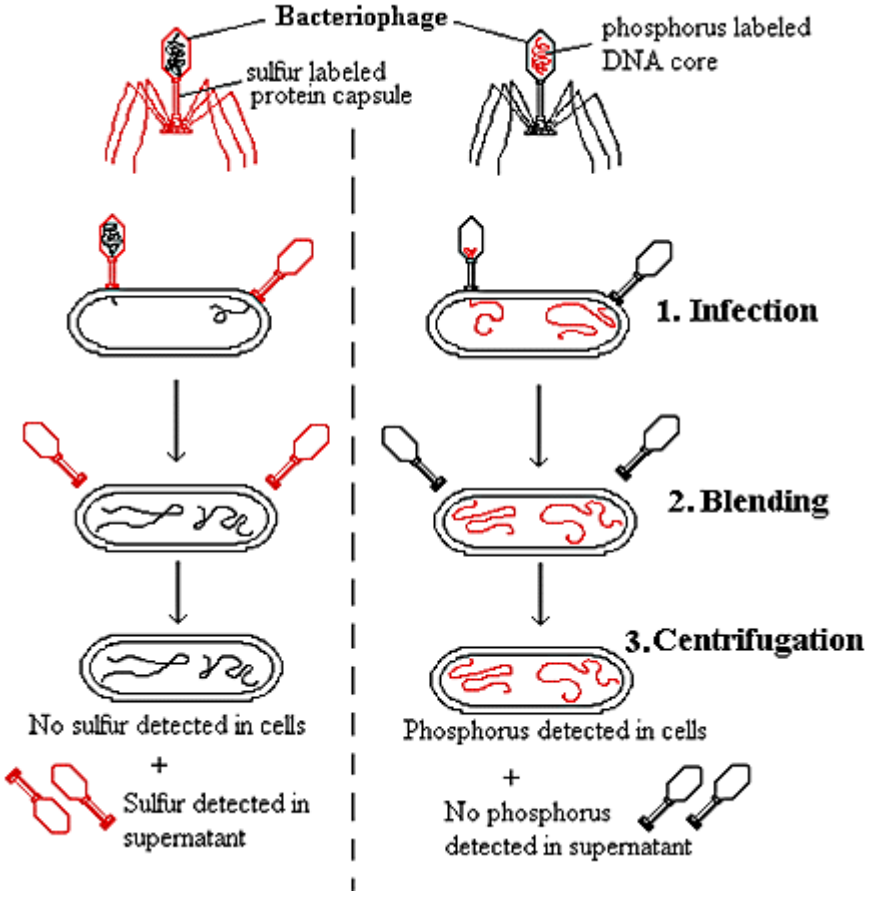

Fig. 2.13 Hershey and Chase Experiment

2.8 REPLICATION OF DNA

Replication is the process of formation of carbon copies on DNA. DNA functions as its own template. DNA replication is an autocatalytic function of DNA. During DNA replication the weak hydrogen bonds between nitrogen bases of the nucleotides separate so that the two

polynucleotide chains of DNA separate and uncoil. The chains thus separated are complementary to one another. Each stand acts as a **template** and makes its own complimentary copy over it so that the new formed DNA duplex has **one parental stand and one newly formed strand.** This method of formation of new daughter DNA molecules is called **semi-conservative method of replication.**

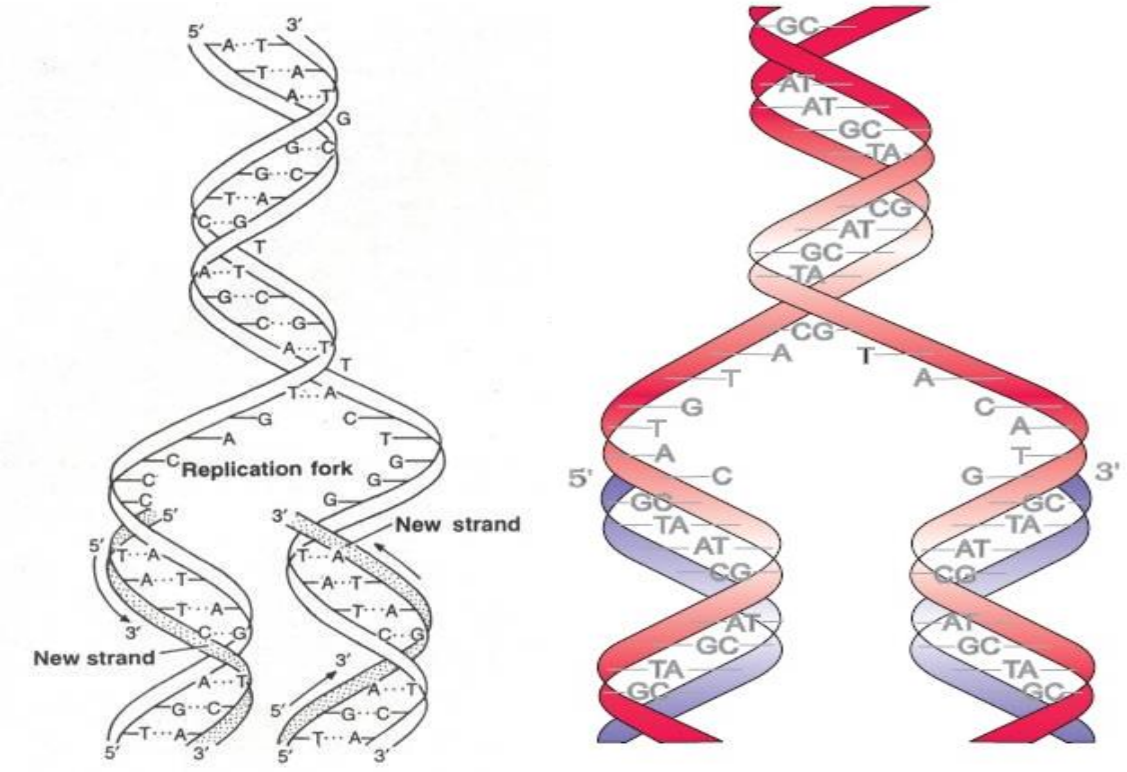

Fig. 2.14 Replication of DNA as suggested by Watson and Crick.
[The parent strands become separated; each is the template for biosynthesis of a complementary "daughter" strand]

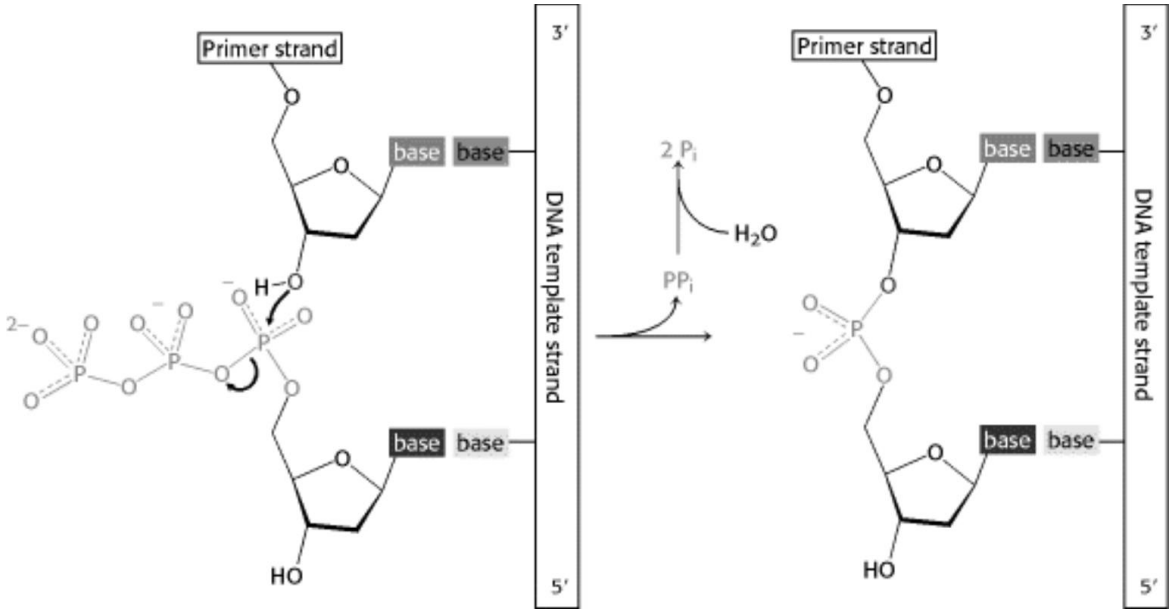

Fig.2.15 DNA Replication (phosphodiester bridge is catalyzed by DNA polymerases]

2.8.1 EXPERIMENT TO PROVE SEMI-CONSERVATIVE MODE OF DNA DUPLICATION

The Meselson- Stahl Experiment- The result of the first critical test of Watson and Crick's proposal that DNA replicates semi conservatively were published in 1958 by M.S. Meselson and F.W. Stahl. Their experiment was as follows:

- They grew Escherichia coli for many generations in a medium having heavy isotopes of nitrogen, N^{15} till the bacterial DNA becomes completely labeled with heavy isotope.
- The labeled bacteria were then shifted to fresh medium having normal or N^{14}.
- After each cell division DNA was separated from a sample of the cells and analyzed on a CsCl (cesium chloride) gradient using the technique of equilibrium density gradient centrifugation, which separates molecules according to differences in buoyant density.
- Meselson and Stahl found that DNA of the first generation was hybrid or intermediate between N^{15} and N^{14}.
- The second generation of bacteria contained two types of DNA, 50% light and 50% hybrid.

- There were exactly the results to be expected if DNA replication is semi conservative

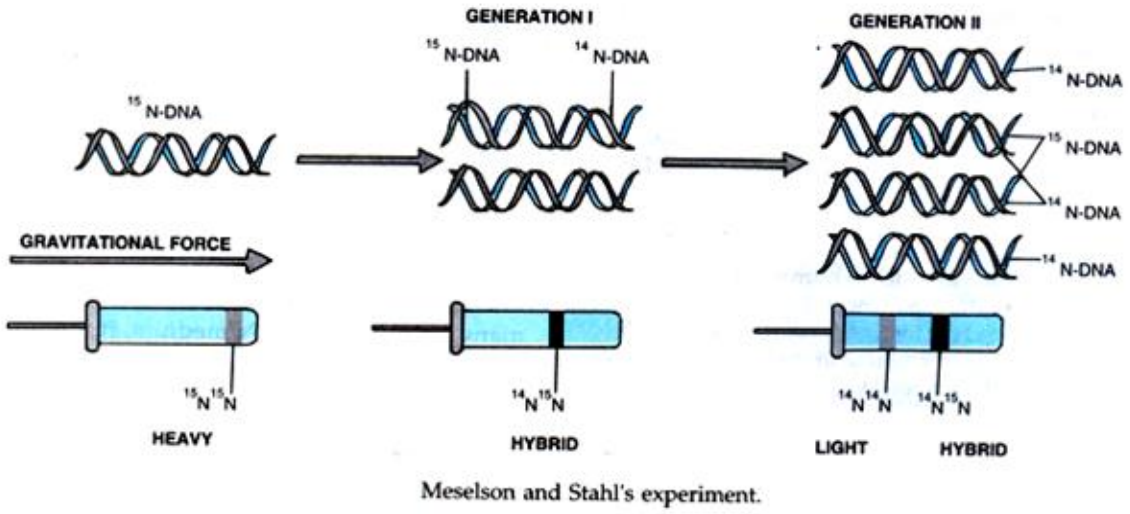

Fig. 2.16 Diagram of Semi-conservative Replication.[After M. Meselson and F. W. Stahl. Proc. Natl. Acad. Sci. U.S.A. 44(1958):671.]

2.8.2 MECHANISM OF DNA REPLICATION

DNA replication is the process of copying a DNA molecule and involves following four major steps-

1. Initiation of DNA replication
2. Unwinding of helix
3. Formation of primer strand
4. Elongation of new strand.

1. Initiation of DNA replication- Replication is regulated by the rate of initiation. Replication of DNA in E. coli always begins at a definite site called **origin of replication**. The ***E. coli,*** origin of replication lies within the genetic locus **'ori'** and is bond to the cell membrane. 'Ori' contains four 9bp binding sites for the initiator protein (DnaA-ATP). The helicase DnaB (or mobile promoter) binds and extends the single-stranded region for copying.

2. Unwinding of helix- Unwinding of DNA molecule into two strands results in the formation of Y shaped structure called **replication fork.** Due to unwinding positive super coiling has to be relieved by the **enzyme topoisomerase or DNA Gyrase**.

3. Formation of Primer strand- As the newly formed replication fork displaces the parental lagging strand, a mobile complex called a **primosome**, which includes the DnaB, Helicase and DNA primase help in the synthesizes **of RNA primers**. Both leading and lagging strand primers are elongated by **DNA polymerase III.** Need of primer is there to facilitate the action of DNA polymerase III as this enzyme cannot initiate the process but can add activated deoxyribonucleotides to the 3' OH end of primer.

4. Elongation of new strand – after the formation of primer strand, DNA replication occurs in 5'→3'direction and complementary deoxyribonucleotides are added only to the free 3'OH end of the primer. A dimer of DNA polymerase III elongates both leading (3'→5') and lagging strands. The leading strand shows continuous replication while the lagging strand shows discontinuous replication. These short pieces of DNA replicated against lagging strand are known as **Okazaki fragments.** Okazaki fragments are 1000-2000 nucleotides long in prokaryotes. A separate RNA primer is used for the synthesis of each Okazaki fragments which, after replacing the RNA primers from deoxyribonucleotides, are later joined together with the help of **DNA ligase** or **DNA synthetase** forming a continuous lagging strand. Hence DNA replication is semi-discontinuous as the leading strand is synthesized continuously and the lagging strand is formed discontinuously in short pieces that join later.

Important features of Prokaryotic replication→

i. Bacteria have a single loop of DNA that must replicate before the cell divides.
ii. Replication proceeds in one direction from 5'→3'.
iii. Replication may be bidirectional or directional.
iv. One cycle of DNA replication gets completed in 40 minutes.
v. Prokaryotes are able to replicate their DNA at a rate of about 106 base pairs/min

Important features of Eukaryotic replication→

i. Replication starts at many points of origin and spreads with many replication bubbles. These bubbles are the places where the DNA strands are separating and replication is occurring.
ii. Replication forks are the V shaped ends of the replication bubbles.
iii. Eukaryotes replicate their DNA at slower 500-5000 base pairs per minutes.
iv. These cells can complete **DNA replication in one hour.**

2.9 RECOMBINANT DNA

The tools and technologies of molecular biology **for breaking and rejoining DNA sequences** from two or more different organisms are known as DNA recombinant technologies. These modified DNA fragments are called recombinant DNA. A recombinant DNA molecule is a vector in which the desired DNA fragment has been inserted to enable its cloning in an appropriate host. This is achieved by using specific enzymes (**restriction enzymes**) for cutting the DNA into suitable fragments and then for joining together the appropriate fragments by ligation.

2.9.1 STEPS OF RECOMBINANT DNA TECHNOLOGY

i. **Identification and isolation of the desired gene** or DNA fragment to be recombined with other DNA or cloned.
ii. **Insertion of the isolated gene in a suitable vector** (a vector is a plasmid- a small accessory ring of DNA in the cytoplasm of bacteria or virus which is used to transfer foreign genetic material in to a cell)
iii. **Introduction of recombinant DNA in to host**- ***E. Coli, Bacillus subtitles*** and **yeast** are used as hosts for the recombinant DNA. Three methods are used for introduction or recombinant DNA into the host.
    a. **Transformation**- it is the process by which a cell takes up naked DNA segment from the environment and incorporate it into its own chromosomal DNA.
    b. **Transduction**- it is the transfer of DNA from one organism to another through a bacteriophage.
    c. **Vector less gene transfer**- gene transfer can be affected by certain means that do not use vectors. It may be done by microinjection needles or gene gun or biolistic.
iv. **Multiplication /expression/integration** followed by expression of the introduced gene in the host.

2.9.2 BIOLOGICAL TOOLS FOR RDT (RECOMBINANT DNA TECHNOLOGY)

Three biological tools are used for RDT

A. Enzymes

i. Lysing enzymes- lysozyme.

ii. Cleaving enzymes-
    a. exonucleases - ƛ exonucleases, exonuclease III
    b. Endonucleases
    c. Restriction endonucleases- EcoB, EcoK, EcoRI
iii. Synthesizing enzymes- reverse transcriptase
iv. Joining enzymes- ligases
v. Alkaline phosphateses

B. Vehicle DNA

a. plasmids – pBR322, pBR324
b. Bacteriophage DNA- SV40, phase ƛ

C. Passenger DNA

a. complementary DNA
b. synthetic DNA
c. Random DNA.

2.10 SUMMARY

Many lines of evidence show that DNA bears genetic information. In particular, the Avery-MacLeod-McCarty experiment showed that DNA isolated from one bacterial strain can enter and transforms the cells of another strain, endowing it with some of the inheritable characteristic of the donor. The Hershey-Chase experiment showed that the DNA and not its protein coat of a bacterial virus carries the genetic message for replication of the virus in a host cell.

Putting together much published data, Watson and Crick postulated that native DNA consists of two antiparallel chains in a right-handed double-helical arrangement. Complementary base pairs, A-T or A-U and G-C are formed by hydrogen bonding within the helix. Pairs are stacked perpendicular to the long axis of the double helix, 3.4 Å apart, with 10.5 base pairs per turn. DNA can exist in several structural forms. Two variations of the Watson-Crick form or B-DNA are A and Z-DNA. Some sequence dependent structural variations cause bends in the DNA molecule. DNA strands with appropriate sequences can form hairpin/cruciform structures or triplex or tetraplex DNA.

Replication is the process of formation of carbon copies. DNA functions as its own template. DNA replication is an autocatalytic function of DNA. This method of formation of new daughter DNA molecules is called semi-conservative method of replication.

The tools and technologies of molecular biology for breaking and rejoining DNA sequences from two or more different organisms are known as recombinant DNA technology. These modified DNA fragments are called recombinant DNA. This is achieved by using specific enzymes (restriction enzymes) for cutting the DNA into suitable fragments and then for joining together the appropriate fragments by ligation.

2.11 GLOSSARY

DNA- Deoxyribonucleic acid, the information carrying genetic material that comprises the genes

Genetics- the science of heredity and variation

Gene- a hereditary determinant of a specific biological function, a unit of inheritance located in a fixed place on the chromosome.

Nucleic acid- a macromolecule composed of phosphoric acid, pentose sugar, and organic bases, DNA and RNA.

Nucleotide- a unit of DNA and RNA molecules containing a phosphate, a sugar, and an organic base

Replication- a duplication process that is accomplished by copying from a template

2.12 SELF ASSESSMENT QUESTION

1. DNA is acidic due to the presence of:

(a) Nitrogen bases (b) Sugar

(c) Phosphate group (d) double helix structure

2. DNA double helix model was proposed by

(a) Watson (b) Watson and Franklin

(c) Franklin and Crick (d) Watson and crick

3. Double Helix model of DNA was based on the observations of:

(a) Watson (b) Wilkins and Franklin

(c) Franklin and Crick (d) Watson and crick

4. DNA replication is:

(a) Dispersive (b) Conservative

(c) Non conservative (d) Semi conservative

5. DNA replication enzyme is:

(a) DNA Gyrase (b) DNA polymerase

(c) Restriction Endonuclease (d) all of these

6. Who proposed the concept of transformation?

(a) Hershey and Chase (b) Griffith

(c) Avery, Macleod, and Mc Carty's (d) none of these

7. Who proved chemical basis of transformation?

(a) Harshey and Chase (b) Griffith

(c) Avery, Macleod and Mc Carty's (d) Watson and Crick

8. Recombinant DNA technology is primarily based of the discovery of which enzyme?

(a) DNA Polymerase (b) DNA Ligase

(c) DNA Endonuclease (d)) DNA Restriction Endonuclease

9. Vector in RNA recombinant Technology helps in:

(a) Infecting host cell with bacteria (b) Transferring target DNA in host cell

(c) Transferring desired gene for recombination (d) transferring any type of DNA in host cell

10. When E.coli is cultured in N^{15}, for two cell cycles, how many DNA molecules of DNA after two cycles will have heavy N:

(a) All but 2 molecules will be pure heavy (b) All but no molecules will be pure heavy

(c)All DNA molecules will have N^{15} (d) 50% heavy and 50% light

ANSWERS: 2.12

1- c, 2- d, 3-d, 4- d, 5- b, 6- b, 7- c, 8- d, 9- b, 10-a

2.12.1 Fill in the Blanks

1. Two types of nucleic acids differ from each other in ----- as well as ------.
2. DNA and RNA has similar --- but different ----.
3. Any types of DNA molecules will always follow---- rule, which states that total amount of --- are always equal to the total amount of ---- .
4. While proving the chemical responsible for transformation of bacteria, ---- enzyme was used to prove it as it could digest --- which was found responsible for causing transformation while other enzymes like ---, ---- and --- were found ineffective.
5. Endonuclease can cut DNA from ----- site but restriction Endonuclease at some ----- sites also called as ---- sequences.

Answers: 2.12.1

1. Sugar, nitrogen base
2. Purines, pyrimidines
3. Chargaff's , purines, pyrimidines
4. DNase, DNA, RNase, Lipase, protease
5. Any non specific, specific, Palindromic

2.14 TERMINAL QUESTIONS

A- Long answerer questions-

i) What is DNA? Explain their types and function.

ii) Write an essay on Watson and Crick structural model of DNA.

iii) Discuss the chemical composition of DNA.

B- Short answerer questions-

i) Differentiate between B-DNA & Z-DNA.

ii) What is recombinant DNA?

iii) What do you mean by replication of DNA?

C- Fill in the blanks-

i) Prokaryotic replication proceeds in…..direction from…….

ii) Most commonly DNA occurs as a ……helix.

iii) Replication is the process of formation of ……

ANSWERS: 2.14(C)

(i) One, 5'→3'

(ii) Double

(iii) Carbon copies.

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UNIT 3: CELL DIVISION

CONTENTS

3.1 OBJECTIVES

After reading this unit the readers will be able to:

- Define mitosis and meiosis.
- Elucidate stages of cell cycle.
- Explain cytokinesis.
- Describe reproductive cycle stages and synaptonemal complex.
- Discuss recombination nodules.
- Compare between mitosis and meiosis.

3.2 INTRODUCTION

A multicellular organism starts its life as a single cell and it undergoes repeated division, thus, the growth and development of every living organism depends on the growth and multiplication of its cells. The cell increase in size due to growth and it is the characteristic feature of all the living organisms. After the cell attains maximum growth, it begins to divide. The vegetative growth of an organism takes place by an increase in the number of cells through cell divisions which follows the geometrical progression. The cell division is a continuous and dynamic process and it involves the following three stages:

1. DNA or genome replication
2. Nuclear division or karyokinesis
3. Cytoplasmic division or cytokinesis

The cell division is of two types on the basis of number of genomes present in the daughter cells in comparison to the dividing parent cell — **mitosis** and **meiosis**.

1. Mitosis- The term mitosis was coined by **W. Flemming** in 1882. The multiplication of a body cell into two daughter cells of equal size and containing the same number of chromosomes as in the parent cell is called mitosis or **somatic division**.

2. Meiosis- The term meiosis was first coined by **J. B. Farmer (1905) with J. E. Moore.** Meiosis occurs only in gonads (in germ mother cells) during the formation of gametes like sperm and ovum. Meiosis is a process by means of which double number or 2N or diploid

chromosomes is reduced to its half number or N or haploid. It is also called **reduction process.**

3.3 CELL CYCLE STAGES, MITOSIS & CYTOKINESIS

3.3.1 CELL CYCLE

Every cell having the capacity to divide passes through a regular cycle of changes known as cell cycle. A cell starts its cycle in diploid condition.

3.3.1.1 PHASES OF CELL CYCLE

Cell cycle consists of two stages: A long un-dividing stage called **interphase or I-phase** and a short dividing stage called **mitotic or M-phase** (Fig. 8.1).

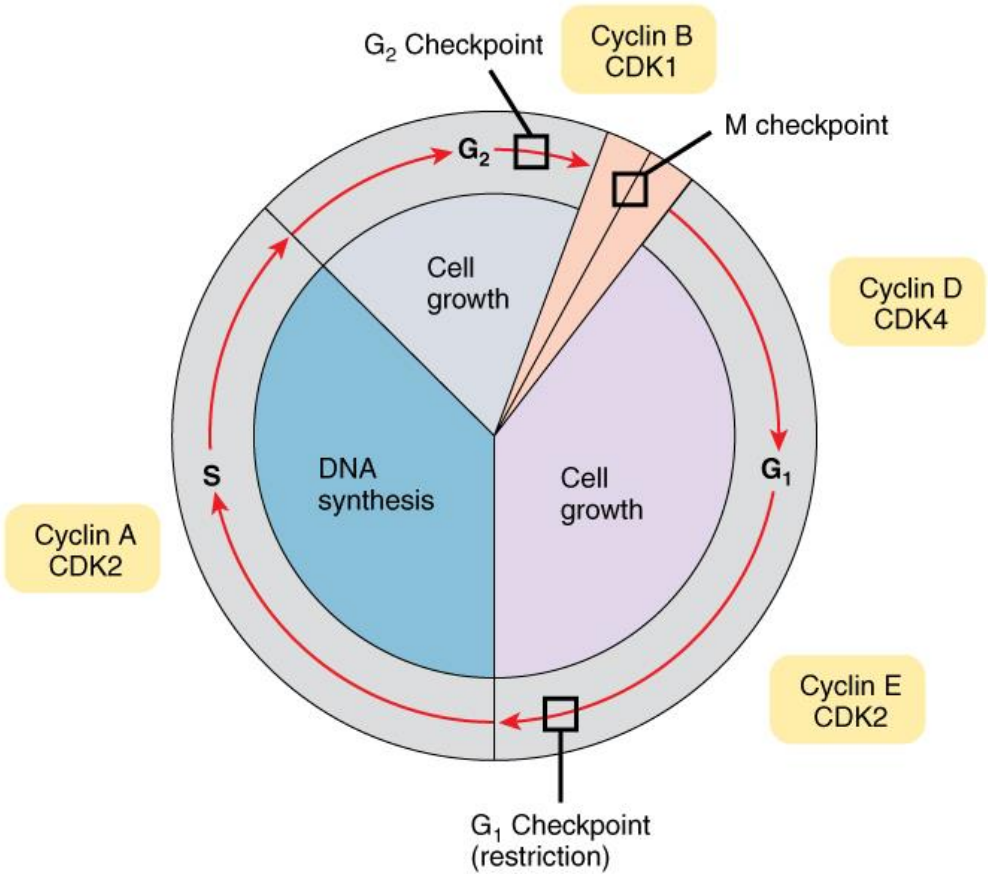


Fig. 3.1: Cell Cycle checkpoints

1. ***Interphase-*** The time between the end of telophase and the beginning of the next M-phase is called the interphase. It is a long stage that lasts for 10 to 30 hours. During this phase the

cell grows by synthesizing biological molecules such as lipids, proteins, carbohydrates, nucleic acids.

Interphase is further divided into three sub phases or periods: first gap or G1 phase, synthetic or S phase and second gap or G2 phase.

(i) **G_1 phase-** The **gap between previous mitosis and beginning of DNA synthesis** is represented by G_1 phase. In this stage initial growth of a newly formed cell takes place. Various biological molecules (carbohydrates, proteins, lipids, including some non-histones, RNAs) are synthesized in this phase. Normal metabolism is carried out for the preparation for DNA replication that is to take place next to it. DNA synthesis does not occur in this phase.

(ii) **S Phase-** During this **phase duplication of each chromosome** take place by replication of new DNA molecule on the template of the existing DNA. Synthesis of histone proteins and their mRNA, some non-histone proteins and formation of new nucleosome also occur in S-phase only. In most of the eukaryotes the S-phase lasts for 6 to 8 hours.

(iii) **G_2 Phase-** G_2 phase is the gap between DNA synthesis and nuclear division. RNA transcription and protein synthesis continues during this phase. Further growth of the cell and preparation for its division also takes place in this stage. During this stage the cytoplasmic organelles such as centrioles, mitochondria and Golgi apparatus are doubled, proteins for spindle and asters are synthesized and active metabolism stores energy for the next mitosis. The G_2 phase in most cells lasts for 2 to 5 hours.

2. ***Mitotic Phase-*** Interphase is followed by mitotic phase. During mitotic phase the already **duplicated chromosomes are equally distributed to the daughter cells** which contain exactly the same hereditary information as the parent cell. Though, the other cell components (organelles and molecules) are also divided approximately equally between the daughter cells, but not as precisely as the DNA. After the mitosis is over, the daughter cells enter the G_1 phase of the next cell cycle.

During mitosis many structural and physiological changes take place in the cell, as the chromatin of the nucleus is packed into visible chromosomes, which are set free by breakdown of nuclear envelope. An extensive reorganization of the membranous components and cytoskeletal elements takes place. Endoplasmic reticulum and Golgi apparatus break down into small vesicles and stops the protein movement. Microtubules dissociate into tubulin dimers and are assembled into the spindle which occupies most of the cell and helps

in the distribution of chromosomes into the daughter cells. Actin filaments get reorganized and form a contractile ring for the cytoplasmic division.

3.3.1.2 CONTROL OF CELL CYCLE

1. ***Nucleo-cytoplasmic Ratio-*** In 1910**, Hertwig** proposed that the **cell division starts when the ratio between the volume of the nucleus and the volume of the cytoplasm is upset.** As the cell grows, the synthesis of proteins, nucleic acids, lipids and other cellular components takes place. During synthesis of these molecules, the back and forth movements of materials through the nuclear and the cell membranes occurs. With the growth of the cell, its volume increases more than the surface of the nucleus and the cell, and at a critical point, the surface of the nucleus become inadequate for the exchange of materials between the nucleus and the cytoplasm required for further growth. The cell divides at this stage and regains the optimum and efficient nucleo-cytoplasmic ratio that allows the growth. Although the cell division usually occurs after a cell has grown to a certain size, there are important exceptions to this pattern.

2. ***Surface-Volume Ratio-*** With the growth of the cell size, its volume increases more than its surface area. All the materials of the cell required for its maintenance and growth are drawn through its surface. A stage will reach when the surface area is insufficient to supply the large volume of the cell. It is thought that there is a critical point at which the cell division starts and the division of the cell greatly increases the surface without increasing the volume. This theory fails in case of starved cells, which may divide without doubling their size and form smaller daughter cells.

3. ***Nucleolus-*** Damage to nucleolus at a certain critical time (telophase or mid prophase) stops cell division.

4. ***Cyclic Nucleotides-*** Concentration of cAMP and cGMP vary regularly during the cell division. Concentration of cAMP is high during G_1 phase, but it falls as the cell enters the S phase and mitosis. However the concentration of cGMP often varies in the reverse pattern. Thus, addition or removal of any of these nucleotides can start or stop entry of many cells into S phase and the subsequent M phase. The concentration of these cyclic nucleotides remains constant throughout the cell cycle in many cells.

Also, plant cells do not have cyclic nucleotides. On the basis of these facts, cyclic AMP and GMP are no longer thought to regulate the cell cycle.

5. ***Phosphorylation-*** During cell cycle the phosphate groups are added to the histone groups particularly to H_1 as the cell enters S phase, increases during M phase, and are removed on the completion of mitosis before G_1 starts. Phosphate groups are also added and removed to non-histone proteins during cell cycle. Thus, it is believed that the changes in the histones and non-histones may have a role in the control of cell cycle because these proteins have been found to regulate the activity of genes in RNA transcription during interphase.

6. ***Cyclin****:* The concentration of the protein called cyclin appears to control mitosis as it builds up during interphase and is degraded during mitosis.

3.3.2 MITOSIS

A German biologist **Eduard Strasburger** described mitosis for the first time in 1875. Same was described later in 1879 by **Walther Flemming** who also termed it "mitosis" in 1882.

It is the most common method of cell division in eukaryotes that takes place in somatic cells of the body and hence it is also known as somatic division. However in gonads it occurs in undifferentiated germ cells. In plants it takes place in the cells of meristematic tissues. The duration of mitosis on an average is from 30 minutes to 3 hours.

Mitosis is defined as the division of a parent cell into two identical daughter cells each with a nucleus having the same amount of DNA, the same number and kind of chromosomes and the same hereditary instructions as the parent cell. Therefore, it is also known as the equational division. There are two main events involved in mitosis: **Karyokinesis or division of the nucleus and cytokinesis or division of cytoplasm.**

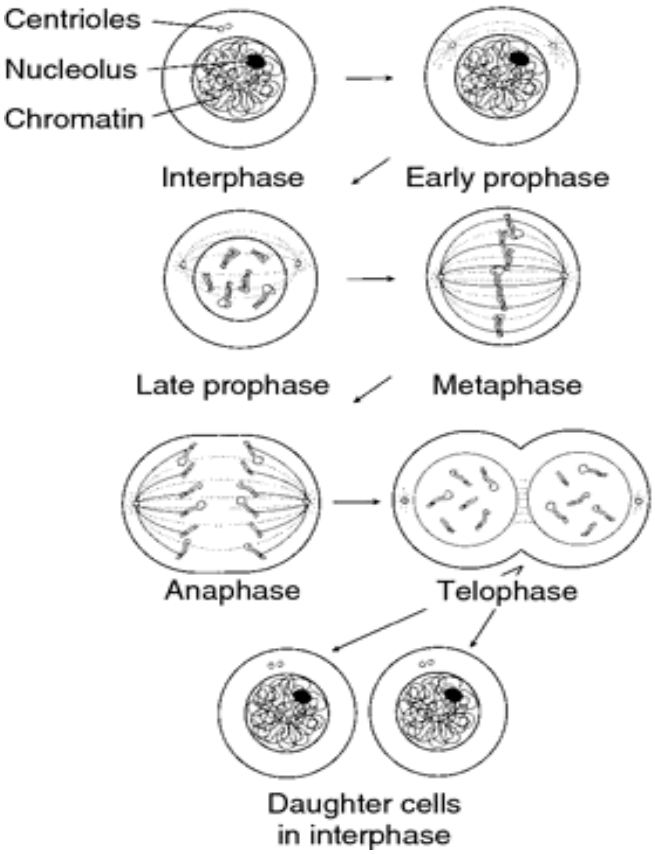


Fig. 3.2: Stages of mitosis in animal cells

3.3.2.1 KARYOKINESIS

In eukaryotes, karyokinesis is a complex process due to the presence of many chromosomes. It is a continuous process which may be divided into four stages: prophase, metaphase, anaphase and telophase.

1. ***Prophase-*** In an interphase cell the chromosomes are greatly extended and spread throughout the space in the nuclear compartment. Approximately 4 meters of DNA is organized into 46 duplicated chromosomes is present in the nucleus of a human G_2 cell. The prophase is long and complex that lasts for about 50 minutes. It may be divided into 3 sub stages: early prophase, middle prophase and late prophase.

A) Early prophase- During the early prophase of mitosis the following events take place:

(i) The shape of cell becomes almost rounded and the cytoplasm becomes viscous.

(ii) The centrioles lie close to the nucleus and around them assembles the short radiating microtubules by polymerization of the tubulin dimers. Both pairs of centrioles also called **diplosomes**, start moving to the opposite ends of the cell. The microtubules surrounding each pair of centrioles appear like a star body, and are called the **aster**. The microtubules which

are also termed as **astral rays**, are not in contact with the centrioles, but are separated from them by an amorphous zone of cytoplasm known as **pericentriolar cloud**. The microtubules stretching between the diplosomes moving apart increase in number and length by incorporating more tubulin dimers. Thus, asters shift the duplicated centrioles to the opposite ends of the cell from where the centriole pair will pass into separate daughter cells when cytokinesis occurs. Though the centrioles have no role in the formation of the spindle but they may be concerned with orienting the spindle.

(iii) Long microtubules assemble on one side of the nucleus to form mitotic spindle. **Microtubules are arranged in bundles called spindle fibers** and at each pole of the spindle lies the mother-daughter centriole pair.

(iv) The chromosomes that appear like threads in the nucleus gradually change into short, thick rods by loss of water and progressive coiling and become visible. Due to the duplication of DNA and chromosomal proteins during the interphase, each chromosome appears longitudinally double, consisting of two identical sister chromatids which are held together at the narrow region called **primary constriction or centromere**. Each chromatid has a disc like structure at centromere, where the spindle microtubules join it. This disc is called as **kinetochore**.

B) Middle prophase- It includes the following events:

(i) The chromosomes further get shorter, thicker and their chromatids become uncoiled and finally they assume their characteristics sizes and become distinguishable individually.

(ii) **Nucleoli** progressively become smaller and **finally disappear.** Nuclear envelope begins to breakdown into small vesicles which disperse into the cytoplasm. The lamina dissociates into its protein subunits.

C) Late Prophase- This phase involves the following events:

(i) The nuclear envelope breaks completely thus, releasing the chromosomes and other nuclear contents into the cytoplasm.

(ii) The spindle gains their proper shape and size.

(iii) The growing spindles push the centriole pairs to the opposite ends of the cell.

2. ***Metaphase-*** The metaphase being short and simple lasts for 2 to 10 minutes and it involves the following events:

A. The spindle occupies the region of the nucleus.

B. The chromosomes move to the **equatorial plane** of the spindle.

C. Some spindle microtubules extend to and join the chromosomes. These are called chromosomal or kinetochore microtubules.

D. The chromosomes get aligned at the middle of the spindle in the form of a plate called **equatorial or metaphase plate**. This plate is formed by the kinetochores, the arms of the chromatids trailing away on the sides. It is at the right angles of the long axis of the spindle. During metaphase the chromosomes have fully aligned into a plate and await the separation of their chromatids.

3. ***Anaphase-*** Anaphase lasts only 2 to 3 minutes and it comprises the following events:

A. The **sister chromatids of each chromosome slightly separate** at the primary constriction so that their kinetochores stretch towards the opposite poles of the spindle. In all the chromosomes separation of chromatids occurs almost simultaneously. The **chromatids are now referred to as chromosomes** because they are no longer held to their duplicates.

B. After a short time, the chromatids separate completely from their former mates, and start moving to opposite poles of the spindle. As each chromosome is being pulled by its attached microtubules, its kinetochore leads and arms trail behind. As a result the chromosomes are pulled into V, J and I shapes, depending upon the position of the kinetochore. (Metacentric, sub metacentric or telocentric respectively)

C. As the chromosomes move toward their respective poles, the two poles move farther apart by elongation of spindle.

The anaphase ends when all the chromatids reach the opposite poles. Each pole of the spindle receive one chromatid from every metaphase chromosome, the two groups of chromatids have exactly the same hereditary information.

4. ***Telophase-*** The telophase is long and complex and lasts for an hour or so. In this phase nucleus is reconstructed from each group of chromosomes. It involves the following events:

A. The **chromosomes** at each pole **unfold, and become long and slender**. Finally, they become indistinguishable as were in an interphase cell.

B. **Nuclear envelope** is **reconstructed** around each group of chromosomes gradually. First, the membrane vesicles associate with the individual unfolding chromosomes, partially

enclosing each chromosome. Then they fuse to form an envelope surrounding the entire set of chromosomes at each pole. The lamina proteins re-associate simultaneously with the reconstruction of nuclear envelope and form a complete lamina within the nuclear envelope

C. Nucleolar material, composed of partially processed ribosomal subunits and processing enzymes, dispersed into the cytoplasm in the prophase return to the nucleolar organizer site and forms a small nucleolus. Processing of this preexisting material then continues. Transcription of new rRNA also begins at this time; it gradually speeds up until it attains the high level of characteristic of interphase cell. Along with this, the nucleolus grows and attains its normal size. The nucleolus reformed at telophase, thus contains both old and new rRNA and ribosomal proteins.

With the transformation of chromosomes into chromatin and reconstruction of nucleoli, transcription of all the three RNA types gradually becomes normal.

The spindle begins to disappear and the asters become small by depolymerization of microtubules and the centrioles take up their characteristic interphase position close to the one side of the nucleus. Short spindle microtubules persist for sometime at the spindle equator to mark the region where the cytoplasm will later divide.

3.3.2.2 CYTOKINESIS

Cytokinesis is the division of cytoplasm. It encloses the daughter nuclei formed by the karyokinesis in separate cells, thus completing the process of cell division. Cytokinesis is signaled at the metaphase by cytoplasmic movements that bring about equal distribution of mitochondria and other cell organelles in the two halves of the cell. Division occurs differently in animal cells and the plant cells.

3.3.2.3 SIGNIFICANCE OF MITOSIS

Mitosis has manifold significance-

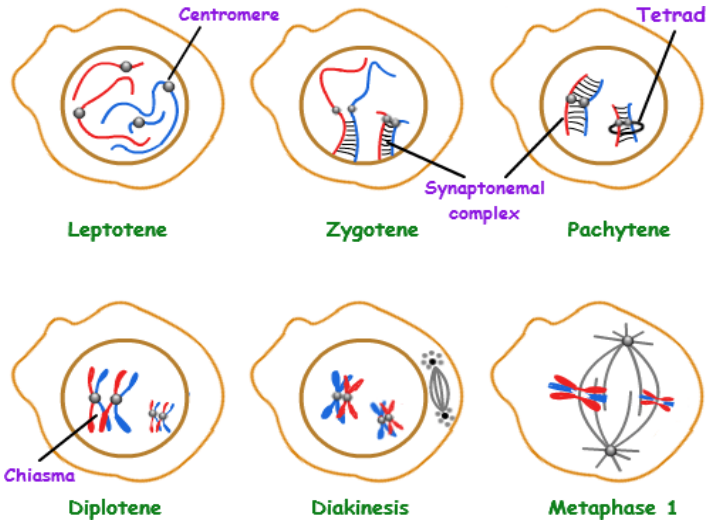
- **Maintenance of Size**- Mitosis helps maintaining the size of the cell. A cell, when full grown, divides by mitosis instead of growing further.
- **Growth**- A fertilized egg develops into an embryo and finally into an adult by repeated mitotic cell division.
- **Maintenance of Chromosome Number**- Mitosis keeps the number of chromosomes equal in all the cells of an individual. Thus mitosis provides a complete set of genetic information to each cell, since DNA is duplicated in S phase prior to mitosis.

- **Repair**- Mitosis provides new cells to replace the old worn out and dying cells.
- **Healing and Regeneration**- Mitosis produces new cells for the healing of wounds and regeneration.
- **Reproduction-** Mitosis brings about multiplication in the acellular organisms. In multicellular organisms also, it plays an important role in reproduction, asexual as well as sexual.
- **Evidence of Basic Relationship of Organisms-** Mitosis, being essentially similar in many kinds of organisms, supports the basic relationship of all living things.

3.4 MEIOSIS

In 1887, August Weismann predicted on theoretical grounds that the number of chromosomes must be reduced by one-half during gamete formation. **Edouard Van Beneden** demonstrated reduction division in1887. **J.B. Farmer and Moore** introduced the term "meiosis" in 1905.

Mitosis occurs in all kinds of eukaryotic cells, while meiosis is confined to certain cells and takes place at a particular time. Only the cells of sexually reproducing organisms undergo meiosis, and only special cells in the multicellular organisms switch over from mitosis to meiosis at the specific time in the life cycle. Meiosis produces gametes or gametic nuclei in animals, some lower plants, and various protists and fungus groups. Meiosis forms spore in higher plants. The spores give rise to gamete producing structure called gametophytes, which produces gametes by mitosis.



Meiosis consists of two divisions that take place in rapid succession, with the chromosomes replicating only once. Thus, a parent cell produces four daughter cells, each having half the number of chromosomes and half of the nuclear DNA amount present in the parent cell. Meiosis is therefore also known as **reduction division**. The two divisions of meiosis are known as the first and the second meiotic divisions or **meiosis-I and meiosis-II.**

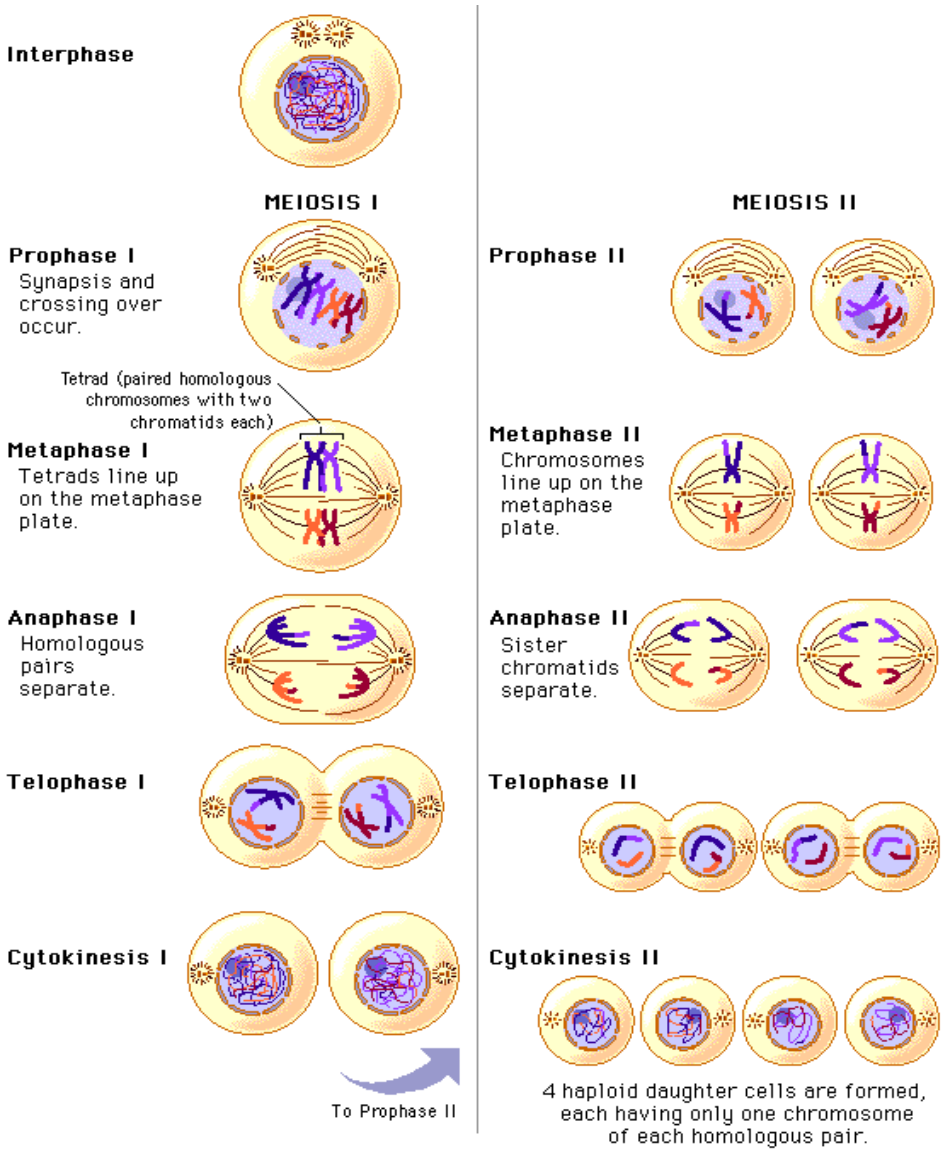


Fig.3.3: Stages of meiosis in animal cells

3.4.1 DIVISIONS OF MEIOSIS

3.4.1.1 FIRST MEIOTIC DIVISION OR MEIOSIS-I

During the first meiotic division, the two homologous chromosomes of each pair separate

from each other and go to separate daughter cells. This reduces the number of chromosomes from diploid to haploid condition**. Meiosis-I** is therefore known as **heterotypic division**. The four phase of this division are called Prophase-1, metaphase-1, anaphase-1 and telophase-1.

1. ***Prophase--***. The meiotic prophase-1 is **more complex** than the mitotic prophase because of the process of recombination that occurs in it. It also lasts **much longer** than the mitotic prophase in the same organism. It may extend over weeks, months or even years. Although it is more or less a continuous process, it is divided into 5 sub-stages: leptotene, zygotene, pachytene, diplotene and diakinesis.

(a) ***Leptotene-*** Leptotene begins when chromosomes appear as thin threads by condensation. The chromosomes become thicker as condensation proceeds. They lie jumbled up so that it is not possible to trace individual chromosomes. Each chromosome is double, consisting of two chromatids due to DNA replication during premeiotic interphase. However, the chromatids are closely adhered together and are not distinguishable.

(b) ***Zygotene-*** The homologous chromosomes come to lie side by side in pairs. The pairing of homologous chromosomes is called **Synapsis or conjugation**. A pair of homologous chromosome lying together is termed as a **bivalent**. Pairing is so through that the corresponding ends and all the corresponding genes of the two homologous chromosomes lie exactly opposite to each other. The centrosome of the chromosomes also lies adjacent to one another. The chromatids are still not visible. A regular space of about 0.15 to 0.2 μm wide exists between the synapsed homologous chromosomes, bearing a highly specialized fibrillar organelle, **the synaptonemal complex**. The synaptonemal complex consists of three parallel and equally spaced longitudinal filaments flanked by chromatin and interconnected by short transverse filaments. The complex contains DNA and some specific proteinaceous material. It was discovered by Montrose J. Moses in 1955 in crayfish.

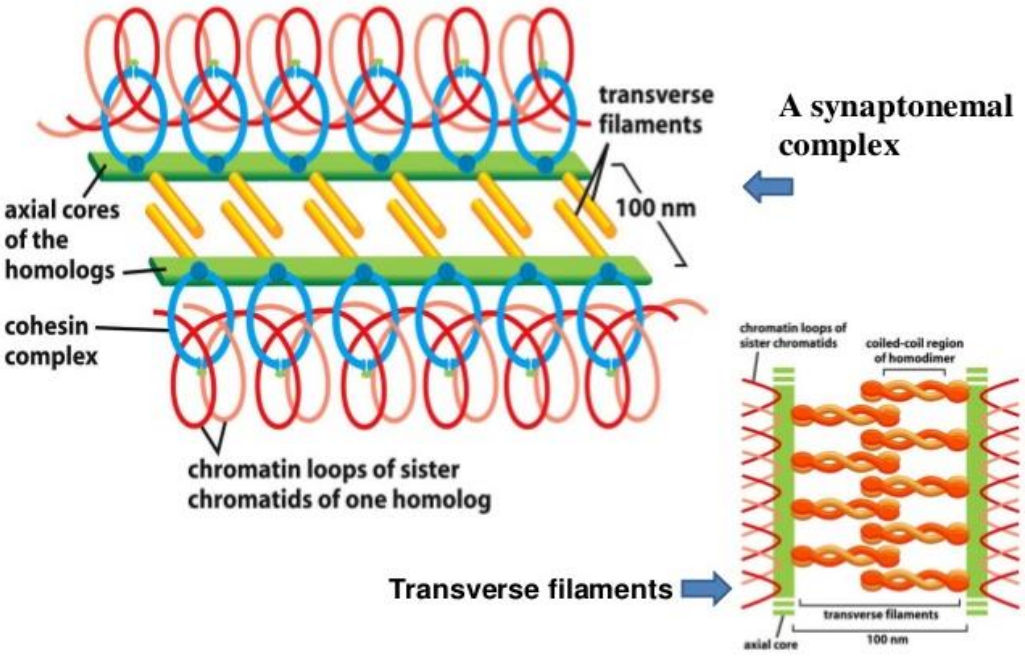


Fig. 3.4: Synaptonemal complex

(c) ***Pachytene-*** The synapsed chromosomes continue to become short and thick. The chromatids of each synapsed chromosome slightly separate and become visible. A chromosome with two visible chromatids is known as **dyad**. A group of four homologous chromatids (two dyads) is called a **tetrad**. The number of tetrads equals the haploid number of chromosomes. The two chromatids of the same chromosomes are called are called sister chromatids and those of the two homologous chromosomes are called non-sister chromatids. The leptotene and the zygotene stages last for a few hours, the pachytene may take weeks, months or even years. It is prolonged because recombination or crossing over occurs in it.

Recombination involves mutual exchange of the corresponding segments of non-sister chromatids of homologous chromosomes. It occurs by breakage and reunion of non sister chromatid segments. Certain structures mediate the meiotic recombination by marking the sites of crossing over. These are known as **recombination nodules** (RNs). They are multicomponent proteinaceous ellipsoids found in association with the synaptonemal complex during prophase-I of meiosis (Carpenter, 1975b). The **synaptonemal complex**, a protein structure, helps in recombination by keeping the homologous chromosomes in paired state for the required period and also by containing and aligning the enzymes needed for breakage and union.

(d) ***Diplotene-*** At this stage the **homologous chromosomes separate** at many places. This is called **disjunction**. It occurs because the synaptic forces and the synaptonemal complex

disappear. The chromatids become more distinct and tetrads seem very clear. The homologous chromosomes do not separate at certain points. These points are called **chiasmata**. The chiasmata mark the sites where the exchange of chromatids occurred during pachytene. The number of chiasmata is related to the length of the chromosomes. Longer chromosomes have more chiasmata than the shorter ones. In case of single chiasmata, the bivalent looks like a cross; in case of two chiasmata, it looks like a ring; and in case of many it shows series of loops.

(e) ***Diakinesis***- In this stage the chromosomes condense again into short, thick rods. The chiasmata disappear by sliding towards the tips of chromosomes due to tight condensation. This process is called **terminalization**. The centrioles already duplicated in premeiotic interphase, move apart in pairs to the opposite ends of the cell. Asters form around each centriole pair. Spindle develops between the centriole pairs. The nucleolus disintegrates. The nuclear envelope breaks down into vesicles. The tetrads are released into the cytoplasm.

2. ***Metaphase-*** The spindle shifts to the position that is earlier occupied by the nucleus. The tetrads scattered in the cytoplasm move to the equator of the spindle. Here, they **align in two parallel metaphase plates**, one formed by chromosomes and other by their homologous. The attachment of the tetrads to the spindle microtubules in metaphase-I is different from that of mitotic metaphase chromosomes. Each homologous chromosome has two kinetochores, one for each of its two chromatids. Both the kinetochores of a homologous chromosome connect to the same spindle pole. The two kinetochores of its homologue join the opposite spindle pole.

3. ***Anaphase-I-*** From each tetrad, two chromatids of a chromosome move as a unit (dyad) to one pole of the spindle, and the other two chromatids of its homologue migrate to the opposite pole. Thus, the two homologous chromosomes of each pair are separated in the anaphase-I of meiosis. The process is also called as **disjunction.** As a result half of the chromosomes, which appear in early prophase, go to each pole. Thus, it is during anaphase-I that the real reduction in the chromosome number occurs. Each chromosome at the pole is still double and consists of two chromatids. Thus, the group of chromosomes at each pole though has only one member of each homologous pair still contains twice the haploid amount of DNA.

4. ***Telophase***-During telophase-I, the chromosome at each pole of the spindle partly unfold and elongate, and form a nucleus with nucleolus and nuclear envelope. The spindle and asters disappear.

The cytoplasm divides at its middle by constriction in an animal cell and by cell plate formation in a plant cell. This produces, two daughter cells, each with one nucleus. The nucleus of each daughter cell has received only one chromosome from each homologous pair. Thus, it has **half the number of chromosome, but double the amount of nuclear DNA as each chromosome is double.**

3.4.1.2 FIRST MEIOTIC DIVISION OR MEIOSIS-II

The meiosis-II is similar to mitosis as in this division, the two chromatids of each chromosome separate from each other and go to separate daughter cells. With the result, the number of chromosomes remains the same as produced by meiosis-I. Meiosis-II is, therefore, known as **homotypic division.** The four stages of this division are called prophase-II, metaphase-II, anaphase-II and telophase-II.

1. ***Prophase-I-*** When there is no interkinesis, the telophase-I spindle is replaced by two new spindles; and the centrioles and asters, if present, duplicate and one copy of each comes to lie at each pole of the new spindles. The telophase-I chromosomes move from the poles of the old spindle to the equators of the new spindles. If decondensation has occurred during telophase-I, the chromosome recondense to short rod lets as they migrate to the metaphase-II spindles.

If interkinesis is present, centrioles move apart and asters are formed around them. A spindle is formed between the centrioles. Chromosomes each consisting of two chromatids, appear in the nucleus. They are set free in the cytoplasm by breakdown of the nuclear envelope. Nucleus disappears.

2. ***Metaphase-II***- The chromosomes get arranged at the equator of the spindle as a metaphase plate. The chromatids of each chromosome are joined at their kinetochores by chromosomal microtubules extending from the opposite poles of the spindle as in mitosis.

3. ***Anaphase-II***- The two chromatids of each chromosome separate and move to the opposite poles of the spindles. Here they are called chromosomes. Each pole has **haploid number of chromosomes and haploid amount of DNA**. This amount is one-fourth of the DNA present in the original cell which entered meiosis.

4. ***Telophase-I-:*** The chromosome at each pole decondenses, and nuclear envelope develops around them. This produces two nuclei. Nucleolus is formed in each nucleus. Spindle and asters disappear. In cases that lack interkinesis, four nuclei are formed in telophase-II.

3.4.2 CYTOKINESIS

Cytoplasm divides at its middle by constriction in an animal cell and by cell plate formation in a plant cell. This produces two daughter cells. The later have half the number of chromosomes, and half the amount of nuclear DNA, i.e., in Reduction division is complete when this point is reached. The cells formed by meiosis-II in animals are mature gametes. They do not divide further. A gamete must fuse with another suitable gamete before a new individual can develop. The cells formed by meiosis-II in plants are the spores. The spores can develop into new individuals without fusing in pairs. In fact the main difference between a spore and a gamete is the ability of the spore to develop directly into a new individual.

3.5 COMPARISON BETWEEN MITOSIS AND MEIOSIS

Mitosis and meiosis can be differentiated through following points:-

S. No.	Mitosis	S. No.	Meiosis
1.	It occurs in all kinds of cells and may continue throughout life.	1.	It occurs only in special cells(gamete mother cells or spore mother cells) and at specific times
2.	It involves a single division, resulting in two daughter cells only.	2.	It involves two successive divisions, resulting in four daughter cells.
3.	A cell can repeat mitosis almost indefinitely.	3.	Meiosis takes place only once in a cell.
4.	All mitotic divisions are alike.	4.	Two meiotic divisions are dissimilar, first is reductional and second equational.
5.	Each mitotic division is preceded by an interphase	5.	The second meiotic division is generally not preceded by an interphase.

6.	Chromosomes replicate before each mitotic division.	6.	Chromosome do not replicate before second meiotic division.
7.	Prophase is relatively short and simple.	7.	Prophase-1 is very long and elaborate, comprising 5 sub phases.
8.	Prophase chromosomes appear double from the very start.	8.	Prophase-1 chromosomes do not look double in the beginning.
9.	There is no pairing of homologous chromosomes, hence no chance of crossing over.	9.	Homologous chromosomes pair and often undergo crossing over in prophase-1.
10.	No chiasmata are formed.	10.	Chiasmata form temporarily where crossing over occurs.
11.	Chromatids are genetically similar to chromosomes they arise from	11.	Chromatids may differ genetically from the chromosomes they arise from due to crossing over.
12.	No synaptonemal complex forms between chromosomes.	12.	Synaptonemal complex forms between synapsed homologous chromosomes
13.	Chromosomes do not unfold, and no transcription and protein synthesis occur in prophase.	13.	Chromosomes unfold and, transcription and protein synthesis may occur in diplotene of prophase-I.
14.	All chromosomes form a single plate in metaphase.	14.	Chromosomes form two parallel plates in metaphase-I and one plate in metaphase-II.
15.	The two kinetochores of a chromosome connect to both the poles of the spindle.	15.	The kinetochores of a chromosome connect to the same spindle pole in metaphase-I and to both the poles in metaphase-II.
16.	Anaphase involves separation of chromatids of each	16.	Anaphase-I involves separation of homologous chromosomes. The

	chromosome.		chromatids move apart in anaphase-II.
17.	Telophase occurs in all cases.	17.	Telophase-I is eliminated in some cases.
18.	Daughter cells have diploid number of chromosomes like the parent cell.	18.	Daughter cells have haploid number of chromosomes unlike the parent cell.
19.	Daughter cells have 2n amount of DNA unlike 4n amount in the parent cell.	19.	Daughter cells have 1n amount of DNA unlike the 4n amount in the parent cell.
20.	Daughter cells divide again after interphase.	20.	Daughter cells, if gametes, do not divide further.
21.	Mitosis brings about growth, repair and healing.	21.	Meiosis forms gametes or spores, helps maintain the number of chromosomes constant from generation to generation, and introduces variation.
22.	Mitosis is much shorter than meiosis in the same animal.	22.	Meiosis is much longer than mitosis in the same animal.
23.	Cytokinesis usually follows karyokinesis.	23.	Cytokinesis often doesn't occur after meiosis-I, but always occur after meiosis-II, forming four cells simultaneously.
24.	Mitosis may occur in haploid or diploid cells	24.	Meiosis always occurs in diploid cells.
25.	Chromosomes do not show chromomeres.	25.	Chromosomes may show chromomeres.

3.6 SUMMARY

Cell division is a continuous and dynamic process that involves replication of DNA, karyokinesis and cytokinesis. Mitosis and meiosis are the two types of cell division. In mitosis somatic cells are divided in two daughter cells of equal size and containing equal number of chromosomes, while meiosis is a reductional cell division that takes place in germ cells. Cell cycle undergoes various phases like long interphase (time between the end of telophase and beginning of next phase); G_1-Phase (time between previous mitosis and beginning of DNA synthesis; S-Phase during which duplication of each chromosomes takes place; G_2-Phase, the gap between DNA synthesis and nuclear division and a short mitotic phase during which the already duplicated chromosomes are equally distributed to the diploid daughter cells. The cell cycle is controlled by various parameters like nucleo-cytoplasmic ratio; cyclic nucleotides; phosphorylation and the protein cyclin. Mitosis or the equational cell division involves various stages like prophase, metaphase, anaphase and telophase followed by cytokinesis. It is a vital process as it maintains the size, growth, chromosome number of the cell along with carrying out repairs, healing and regeneration and reproduction of cell. Meiosis involves two stages, meiosis-I and meiosis-II that takes place in rapid succession, with the chromosomes replicating only once. During meiosis-I two homologous chromosomes of each pair separate from each other and go to separate daughter cells, reducing the number of chromosomes from diploid to haploid condition. Its first stage is prophase-I that is further divided into 5 sub stages: i) Leptotene (during leptotene condensation of chromosomes takes place), ii) zygotene (during zygotene homologous chromosomes pair and synaptonemal complex is formed. iii) pachytene is the third sub-stage in which two chromatids of synapsed chromosomes becomes visible and is known as dyad. Recombination also takes place during this stage. iv) At the stage of diplotene disjunction at many points takes place on homologous chromosomes. v) Diakinesis: During diakinesis terminalization takes place. Meiosis-II is similar to mitotic division in which two chromatids of each chromosome separate from each other and go to separate daughter cells. Various stages involved are prophase-II, metaphase-II, anaphase-II and telophase-II. At the end of the cell division cytoplasm divides at its middle by constriction in an animal cell and by cell plate formation in a plant cell. This process is called cytokinesis.

3.7 GLOSSARY

Karyokinesis: It is the division of nucleus during cell cycle.

Cytokinesis: Division of cytoplasm that separates the daughter cells following division of parent cells.

Genome: Genome is defined as complete set of gene or genetic material present in a cell.

Spindles: A protein structure that divides the genetic material in a cell. The spindle is necessary to equally divide the chromosomes in a parental cell into two daughter cells during both types of nuclear division: mitosis and meiosis.

Asters: Asters are star like cellular structures, formed around each centrosome during mitosis in an animal cell. Astral rays, composed of microtubules, radiate from the centrospheres.

Meristematic tissues: A meristematic tissue in most plants contains undifferentiated cells and is found in zones of the plant where growth can take place.

Gonads: The organs that produces gametes (sperms and ovum); i.e. testis or ovary.

Nucleosomes: In eukaryotic cells the chromosomes consisting of a length of DNA are coiled around a core of histones. This structural unit is called nucleosome.

Cytoskeleton: It is a microscopic network of protein filaments and tubules in the cytoplasm of many living cells.

Somatic cell: The cells of a living organism other than the reproductive cells are known as somatic cells.

Germ cell: These are haploid cells that have the capacity to unite with the germ cell of the opposite sex and reproduce new individual. These are also called gametes.

Kinetochore: It is a protein structure present on chromosomes and is a by which they are attached to spindle fibers.

Spores: It is a minute, one-celled, reproductive unit that is capable of giving rise to a new individual without sexual fusion and is the characteristic of protozoans, fungi and lower plants.

Bivalent: A pair of homologous chromosomes.

Chiasmata: During the first metaphase of meiosis, chromosomes remain in contact at certain points at which crossing over and exchange of genetic material occur between the strands. These points are called chiasmata.

3.8 SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

3.8.1 MULTIPLE CHOICE QUESTIONS

1. The proper sequence of cell cycle is:

(a) S, M, G1, G2 (b) M, G1, G2, S

(c) S, G1, G2, M (d) G1, S, G2, M

2. Karyokinesis refers to the division of:

(a) Cytoplasm into two (b) Nucleus into two

(c) Protoplasm into two (d) None of them

3. The spindle fibers attach chromosomes with:

(a) Chromo center (b) Centriole

(c) Kinetochore (d) Telocentric

4. Who proposed the term mitosis?

(a) Farmer and Moore (b) Flemming

(c) Nigeli (d) Brown

5. Chromosomes reach equator during cell division at:

(a) Prophase (b) Metaphase

(c) Anaphase (d) Telophase

6. Mitosis occurs in:

(a) Roots (b) Shoots

(c) Germ cells (d) Somatic cells

7. Nuclear membrane disappears at which stage:

(a) Metaphase (b) Anaphase

(c) Early prophase (d) Late prophase

8. Chromosomes move towards different poles, during cell division, due to:

(a) Centrioles (b) Vacuoles

(c) Cytokinesis (d) Microtubules

9. In cell cycle DNA replication takes place in:

(a) M-phase (b) S-phase

(c) G1 -phase (d) G2-phase

10. Anaphase of mitosis differs from metaphase in:

(a) Half the number of chromosomes

(b) Half the number of chromatids in each chromosome

(c) Half the number of chromosomes but doubles the number of chromatids in each chromosome

(d) Half the number of chromosomes and half the number of chromatids in each chromosome.

11. Synaptonemal complex is associated with:

(a) Mitotic chromosomes (b) Paired meiotic chromosomes

(c) Lampbrush chromosomes (d) Polytene chromosomes

12. The term meiosis was coined by:

(a) Leeuwenhoek (b) Beadle and Tatum

(c) Hooke and Brown (d) Farmer and Moore

13. During meiosis exchange of paternal and maternal chromosomes is called:

(a) Recombination (b) Linkage

(c) Segregation (d) Crossing over

14. Crossing over and unzipping of homologous chromosomes in meiosis occurs at:

(a) Diplotene (b) Pachytene

(c) Zygotene (d) Leptotene

15. Synapsis occurs during:

(a) Leptotene (b) Zygotene

(c) Pachytene (d) Diplotene

16. Crossing over occurs at:

(a) One stranded stage (b) Two stranded stage

(c) Three stranded stage (d) Four stranded stage

17. Advantage of crossing over is that it causes:

(a) Linkage (b) Stability

(c) Inbreeding (d) Variation

18. At the end of first meiotic division, number of chromosomes is:

(a) Halved (b) Doubled

(c) Remains same (d) Tripled

19. Second meiotic division results:

(a) Separation of homologous chromosomes (b) Separation of chromatids and centromeres

(c) Synthesis of fresh DNA (d) Separation of sex chromosomes

20. Anaphase in second meiotic division is characterized by:

(a) Separation of non-homologous chromosomes(b) Separation of homologous chromosomes

(c) Separation of chromatids (d) All of them

3.8.2 VERY SHORT QUESTIONS

1. In which period of interphase DNA duplicates?

2. What is G1 period?

3. In which cell mitosis occurs?

4. Who proposed the term mitosis?

5. What are different stages of mitosis?

6. Which stage of mitosis is of longest duration?

7. What is cytokinesis?

8. At which stage centrioles replicate?

9. In which cell meiotic divisions occur?

10. What are the various sub stages of meiotic prophase?

11. Who gave the term meiosis?

12. In which stage of meiosis, homologous chromosomes form pair?

ANSWERS:

3.8.1- 1. (d), 2.(b), 3.(b), 4.(b), 5.(b), 6.(d), 7.(c), 8.(d), 9.(b), 10.(b), 11.(b), 12.(d), 13.(d), 14.(a), 15.(b), 16.(d), 17.(d),18.(a), 19.(b), 20.(c)

3.8.2- 1. S-phase (synthetic phase).

2. Period between end of mitosis and start of DNA synthesis.

3. Somatic cells.

4. W. Flemming in 1882.

5. Prophase, metaphase, anaphase, telophase.

6. Prophase.

7. Division of cytoplasm.

8. Interphase.

9. Gonadian cells (spermatozoa and ovum).

10. Leptonema, Zygonema, Pachynema, Diploma and diakinesis.

11. J. B. Farmer and J. E. Moore in 1905.

12. Zygotene or zygonema.

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3.10 TERMINAL AND MODEL QUESTIONS

1. Explain in details cell cycle.

2. Describe the various phases involved in the mitotic division of an animal cell.

3. Elucidate the process of mitosis with neat and labeled diagram.

4. What is the significance of mitosis?

5. Give an account of meiotic type of cell division.

6. Describe the changes that occur in nucleus during meiosis.

7. Write about synaptonemal complex and chiasma formation.

8. Differentiate between the mitotic and meiotic division.

UNIT 4: TAXONOMY AND SYSTEMATICS

CONTENTS

4.1 OBJECTIVES

As more and more data regarding life forms come to light, **taxonomy** becomes more and more refined. To understand diversity a system of taxonomy is required. Taxonomy allows understanding diversity better. This chapter will deal with how living beings are named, grouped and classified and some important features of these groups.

About **2.0 million** types of animals and about **1.0 million** types of plants have already been described and named and many new forms are discovered every year. Animals and plants vary greatly in their forms, structures and mode of life. To identify an organism of known characters from the vast number of organisms is simply impossible. The number and **diversity** of living organisms are so enormous that it is very difficult to study without classifying them into certain groups or categories. Thus taxonomy allows us to identify and recognize organisms. Hence, in this chapter, you would learn about the role of taxonomy in the classifying the **organisms** and its relationship with **systematics.**

4.2 INTRODUCTION

Initially, an attempt was made to classify plants and animals on their habitat, distribution (air, land, and water), beneficial and harmful basis. **Aristotle (384-332 B.C.)** who is known as **"Father of Zoology"** classified animals on the basis of their morphology and categorized into three groups namely as:

I. Verms

II. Insecta

III. Vertebrata

He classified a total of **520 species** of animals in his book **"Histiria Animalium".** Due to his unique tremendous contribution in **Zoology,** he is also known as: **"Father of Biological Classification".**

John Ray (1627-1705) was first coined the term **"species"** and described **18000 plants** in his book **entitled "Historia Generalis Plantarum"** which was published in three volumes between **1686 to 1704**. He was the first person who made a differentiation between **genus and species.**

In this series, **Theophrastus (370-385 B. C.),** who was the student of **Plato** and **Aristotle** known as **"Father of Botany"** classified **480 plants** into four groups into his famous book **"Historia Plantarum".** These four groups as follows:

I. Trees

II. Shrubs

III. Under shrubs

IV. Herbs

However, it was followed by a Swedish Naturalist **Carolus Linnaeus (1707-1778),** who used **"Binomial Nomenclature"** system of classification instead of using common name of plants and animals both in his famous book entitled **"Systema Naturae".** He listed **9378** species of plants and animals in his book which had published in **1735**. Because of using a scientific system of classification firstly, Carolus Linnaeus has been crowned with the title of **"Father of Modern Taxonomy".**

4.3INTRODUCTION TO TAXONOMY AND ITS RELATIONSHIP WITH SYSTEMATIC

TAXONOMY: (Gk., Taxis -arrangement, nomos - law). The term taxonomy was first coined by **A. P. de Candolle in 1813**. Taxonomy may be defined as the branch of science which deals with the **identification, nomenclature** and **classification** of any plant or animal all over the world is called taxonomy.

There are about **2.0 million** of species and many are being discovered by taxonomists in all over the world. All of these species may be classified according to the norms of taxonomy and each species may be identified separately by its peculiar characteristics. In the absence of taxonomy, it would be very difficult to recognize, identify and classify plants and animals without committing any mistakes. It means without **systematics** there is no significance of taxonomy and without taxonomy, there is no existence of systematics. **Systematics and taxonomy both are complementary to each other.**

However, the study of taxonomy can be done under the following headings:

1. CLASSIFICATION: Classification may be defined as a system of arrangement of individuals into various categories which exhibit a relationship with each other.

2. IDENTIFICATION: To determine the exact place or position of any plant or animal according to the system of classification (systematics) is called identification.

3. NOMENCLATURE: Nomenclature may be defined as a process of giving a name to plants and animals according to the systematics.

4. KEY: Those distinguishing or diagnostic characters which help in the identification of any plant or animal in the systematics are called key.

Taxonomy is the science of defining groups of biological organisms on the basis of shared characteristics and giving names to those groups. Organisms are grouped together into **taxa** (singular: taxon) and these groups are given a **taxonomic rank**. Groups of a given rank can be aggregated to form a super group of lower rank, thus creating a **taxonomic hierarchy**. The Swedish botanist **Carl Carolus Linnaeus** is regarded as the "**Father of Taxonomy"**, as he developed a system known as **Linnean classification** for categorization of organisms and Binomial Nomenclature for naming organisms.

With the advent of such fields of study as **phylogenetics, cladistics**, and **systematics,** the Linnaean system has progressed to a system of modern biological classification based on the **evolutionary relationships** between organisms, both living and extinct. An example of a modern classification is the one published in **2015** for all extant taxa (to the level of Order) by **M. Ruggiero and co-workers.**

In the branch of biology, that deals with the framing of laws and principles of classifying the organisms on the basis of their evolutionary relationship. The main aim of the taxonomic study is to assign an appropriate place to an organism in a systematic framework of classification. This framework is called **taxonomic hierarchy.**

In this, the taxonomic groups are arranged in a definite order, from higher to lower categories. Each category is considered a **taxonomic unit** which represents a **taxon**. A natural taxon refers to a group of similar, genetically related individuals having certain characters distinct from those of other groups. For example, all the insects form a taxon.

In classification, the organisms that closely resemble one another are placed in a group, the groups which have similarities are combined together into larger groups and these into still larger ones. These various grouping levels or ranks in classification are known as **categories.** The **taxonomic hierarchy** or hierarchy of categories was first established by **Linnaeus (1758)** in the animal kingdom. The **seven** major categories, in descending order, are:

Kingdom

Phylum

Class

Order

Family

Genus

Species

CATEGORY *Vs* TAXON

Category	**Taxon**
1. It is only an abstract term.	1. It is a group of concrete biological objects and is assigned to a category.
2. It represents a rank or level in classification.	2. It represents a group of real organisms.

Examples

1. The taxon of birds is **Aves** and their category is **Class.**

2. The sponges from the taxon **Porifera** and their category is **Phylum.**

3. *Rosa Indica* is a **taxon** and Species is a **category.**

INTERMEDIATE CATEGORIES

With the discovery of more and more organisms, it becomes difficult to place an organism in the **traditional categories**. Hence, to make the taxonomic position of a species more precise, the categories have been split by prefixing **"super"** or **"sub"** to the existing categories. As they are introduced later on in the hierarchical system, they are called intermediate categories. Thus we have:

Sub-kingdom

Super-division

Super-phylum

Sub-division

Super-class

Sub-class

Sub-order

Sub-family

Genus

Species

SPECIES

It occupies a **key position** in taxonomy. It is the **basic unit** for understanding **taxonomy** and **evolution.** A species is defined as "a dynamic, genetically distinct group of organisms, which resemble one another in all essential characters (morphological and reproductive) and interbreed freely in nature to produce fertile offsprings".

For example, mango (*Mangifera indica*), potato (*Solanum tuberosum*) and lion (*Panthera leo*). In this case, indica, tuberosum, and leo are the species of genera Mangifera, Solanum and Panthera respectively.

(The individual of species also represents population of species and they do not breed with individuals of other species).

G ENUS

It is a group of an assemblage of related species which resemble one another in certain characters. Species, in a genus, usually have many features in common. Such groups of common features are called correlated characters. All the species of a genus are presumed to have evolved from a **common ancestor.**

The genus has a **significant position** in classification. By the rule of binomial nomenclature, a species cannot be named unless it is assigned to a genus. Sometimes a genus may consist of only one existing species.

For example, modern man to the genus *Homo*, such a genus is called monotypic. The other consisting of many species are called polytypic. For example, the genus *Panthera* has a large number of closely related species such as *Panthera leo* (lion), *P. pardus* (leopard) and *P. onca* (jaguar).

FAMILY

It is the taxonomic category which contains one or **more related genera**. All the genera of a family have some common features. They are separable from the genera of a related family by some important and characteristics differences. The genera of cats (*Felis*) and leopard (*Panthera*) are included in the family Felidae.

ORDER

It is the next higher taxonomic category which includes related families. For example, the families, Canidae, Hyaenidae (hyenas) and Ursidae (bears) are included under the order Carnivora.

CLASS

This category includes one or more **related orders**. For example, class Mammalia of animals includes orders of all mammals like Chiroptera (bats), Marsupialia (kangaroos), Rodentia (rodents), Cetacea (whales), Carnivora (carnivores), Primates (apes and man).

DIVISION OR PHYLUM

It is formed of one or more related classes. The term **phylum** (Pl. - phyla) is commonly employed for animals while **division** is used for plants. For example, Phylum Chordata of animals includes several classes like Cyclostomata (Lamprey), Chondrichthyes (Cartilaginous fish), Osteichthyes (Bony fish), Amphibia, Reptilia, Aves (Birds) and Mammalia.

KINGDOM

It is the **highest taxonomic category.** It includes one or more related divisions or phyla. In the Linnaeus system of classification, all plants are included under kingdom **Plantae** and all animals under the kingdom **Animalia.**

TYPES OF TAXONOMY

1. α (ALPHA) TAXONOMY: If taxonomy is concerned with characterization and naming of any species is called alpha-taxonomy.

2. β (BETA) TAXONOMY: If taxonomy is concerned with the arrangement of species according to the law of systematics is called beta taxonomy.

3. γ (GAMA) TAXONOMY: Ultimately when taxonomy is concerned with some biological aspects like texa, evolutionary rate and trends then it is called gamma taxonomy.

SYSTEMATICS

Systematics (Gk., Systema - a system of classification). Term systematics was first described by **Carolus Linnaeus** in his book **"Systema Naturae".** Systematics may be defined as the scientific study of taxonomy which deals identification, nomenclature, and classification of all living individuals and relationships among them are called systematics. **Biological systematics** is the study of the diversification of living forms, both past and present, and the relationships among living things through time. It is a modified form of classical systematics (old systematics) which was first used by **Plato and Aristotle.**

The term **New Systematics** (neosystematics or biosystematics) was proposed by **J. Huxley in 1940** to consider some new branches of taxonomy like Morphotaxonomy, Karyotaxonomy, Cytotaxonomy, Experimental Taxonomy, Biochemical Taxonomy, Chemotaxonomy and Numerical Taxonomy etc. Besides this "New Systematics" also deals many aspects of morphology, ecology, biochemistry, physiology, cytology and genetics etc.

Hence, systematic biology is the field that:-

A. Provides scientific names for organisms

B. Describes them,

C. Preserves collections of them,

D. Provides classifications for the organisms, keys for their identification and data on their distributions,

E. Investigates their evolutionary histories, and

F. Considers their environmental adaptations.

This is a field with a long history that in recent years has experienced a notable renaissance, principally with respect to theoretical content. Part of the theoretical material has to do with **evolutionary areas** (topics e and f above), the rest relates especially to the problem of classification. Taxonomy is that part of Systematics concerned with topics **(a) to (d)** above.

Taxonomy, systematic biology, systematics, biosystematics, scientific classification, biological classification, phylogenetics: At various times in history, all these words have had **overlapping meanings** — sometimes the same, sometimes slightly different, but always overlapping and related. However, in modern usage, they can all be **considered synonyms** of

each other. For example, Webster's 9th New Collegiate Dictionary of 1987 treats **"classification",** "taxonomy", and "systematics" as synonymous.

Europeans tend to use the terms **"systematics"** and **"biosystematics"** for the field of the study of **biodiversity** as a whole, whereas **North Americans** tend to use "taxonomy" more frequently. However, taxonomy, and in particular alpha taxonomy, is more specifically the identification, description, and naming (i.e. nomenclature) of organisms, while **"classification"** focuses on placing organisms within hierarchical groups that show their relationships to other organisms. All of these biological disciplines can deal both with extinct and with extant organisms.

Systematics uses taxonomy as a primary tool in understanding, as nothing about an organism's relationships with other living things can be understood without it first being properly studied and described in sufficient detail to identify and classify it correctly. Scientific classifications are aids in recording and reporting information to other scientists and to laymen. The **systematist**, a scientist who specializes in systematics, must, therefore, be able to use existing classification systems or at least know them well enough to skillfully justify not using them.

PRINCIPALS OF SYSTEMATICS

Systematics is the scientific study that attempts to recognize, describe, name and arrange the diverse organisms according to an organized plan based on the unique features of species and groups. It is also called the science of diversity of organisms because it involves a shift from **diversity** to unity through comparison among individuals.

FIELDS OF SYSTEMATICS

The basic **requirements in systematics are** as following:

I. The arrangement of organisms into groups.

II. A system for naming the organisms.

III. Framing the rules for Classification, Nomenclature, and Taxonomy.

UTILITY OF SYSTEMATICS

It provides useful information about the **evolution**, **adaptations** and **diversity** of organisms.

1. It is essential for the study of other branches of life sciences like ecology, cytology and genetics etc.

2. It helps in the identification of crop pests and thus planning in their eradication.

3. It helps in solving the problems of various epidemic diseases throughout the world.

4. It helps in the identification of plants and animals with superior genomes for breeding programs.

5. It helps in the identification of indicator organisms, which provide information about pollution, availability of ground water and minerals etc. in a particular area.

6. It enables us to identify the fossils which give us full clues about the phylogeny of organisms.

However, these terms are often used interchangeably as they are complementary. Biosystematics deals with the variation within a species and its general evolution.

RELATIONSHIP BETWEEN TAXONOMY AND SYSTEMATICS

Taxonomy is concerned with the classification and naming of organisms. Since Darwin's proposal that all organisms on earth share a common ancestor, taxonomists have made sure that organism that do not share a recent common ancestor are not classified in the same group formally. Taxonomists call groups that have 2 or more separate recent common ancestors "polyphyletic." No taxonomists will knowingly recognize polyphyletic groups.

However, mistakes are sometimes made, even with the best intentions, and sometimes taxonomists do group organisms that are only superficially similar to the same group, resulting in a polyphyletic group. A prime example is Pachydermata, a taxon (group with a name) that is no longer recognized because it is polyphyletic. Pachydermata consisted of thick-skinned, large land mammals like elephants, hippos and rhinos. However, it has been shown that they are only superficially similar because elephants are more closely related to elephant shrews and hippos are most closely related to pigs, cows and whales. The rhinos are in turn more closely related to horses than to the elephants and hippos. Therefore, Pachydermata is no longer recognized as a validtaxon.

Sadly, many practicing taxonomists no longer concern themselves with a number of evolutionary changes that have occurred within or between lineages. Some of them, called cladists, are misguided in their classificatory practiceand they recognize such groups as the birds + living reptiles as "Reptilia." Darwinians recognize that birds are distinct from reptiles and classify birds in Aves and living reptiles in Reptilia. Because of these differences in classification philosophy, there is no consensus on the classification of many groups. The result is taxonomic chaos that is going to be around for decades to come.

Systematics is concerned with the evolutionary relationships of organisms. Systematists are concerned with ascertaining which organisms share a recent ancestry with which other organisms. Systematists are also concerned about a number of evolutionary changes that may have occurred within and between lineages. **Systematics** is the study of the **units of biodiversity**. Systematics differs from ecology in that the later is concerned with the interactions of individuals (and therefore species) in a particular time, while the former is concerned with the diversification of **lineages through time.**

Systematics includes the discovery of the basic units of **biodiversity** (species), reconstructing the patterns of relationships of species at successively higher levels, building classifications based on these patterns and naming appropriate **taxa** (taxonomy) and the application of this pattern knowledge to study changes in organisms' features through time. It also includes the building and maintenance of **biodiversity** collections, upon which all the products of systematic studies are based.

Ultimately it may be concluded that taxonomy is the classification and naming of all living things, while, systematics refers to the study of the relationships between these living things as they evolve. **The taxonomic hierarchy was devised and published by Swedish scientist Carl Linne in 1735. All branches of systematics, such as Botany, Zoology, Microbiology and Mycology, are covered under taxonomy. Taxonomy as the science of biological classification is a subdivision of systematics.**

4.4 IMPORTANCE AND APPLICATION OF BIOSYSTEMATICS

Systematics is concerned with the evolutionary relationships of organisms. Systematists are concerned with ascertaining which organisms share a recent ancestry with which other organisms. Systematists are also concerned about a number of evolutionary changes that may have occurred within and between lineages. As the **sub-discipline** of biology that investigates relationships of taxa, systematics is the foundation for **comparative biology**. Comparative biology is that type of study that attempts to relate features of one organism, or type of organism, to features in another type of organism. This always is a question of **homology** or sameness due to the common **evolutionary origin.**

In **systematic studies,** we hypothesize homology of features among taxa and then gather data to test these **hypotheses.** This is important because appearance alone is often not a good

indicator that features in different taxa are homologous -- many times similar structures will evolve independently in different lineages. If they are **homologous**, we expect that they will share many things because of their common **ancestry**, while if they are not, it is impossible to predict just how similar they will be. Hence, any study that asks why or how about a feature in more than one taxon, and draws comparative conclusions about them, rests on a **systematic foundation.**

APPLICATIONS

Biosystematics is playing a very crucial role in this living being world. There are more than **two million species of animals** and about **one million species** of plants, while several more to be discovered yet. These species may be identified and classified with the help of taxonomy according to the rules and regulations of systematics. Otherwise, in the absence of systematics (taxonomy), it would have been very difficult to isolate these species with a particular name.

In addition without knowledge of systematics it would be very difficult to discover new species and also there should not be made any differentiation between them. No **scientific survey** can be made without prior knowledge of systematics. Besides this, there is no being left importance of **civilization** because, civilization and systematics are complementary to each other in the sense that if a man maintains his life (daily routine work) or home systematically, means he is civilized otherwise like animals.

In the same sense or way, there is a vast variety amongst plants and animal species which all are systematically or in the civilization manner are well being arranged only by systematics can be summarized as follows:

1. ROLE OF SYSTEMATICS IN DIVERSITY: It has been already stated that there is a vast variety of plants and animals on the planet. They belong to different **habits** and **habitats.** Several species of plants and animals are to be discovered yet. Systematics or taxonomy provides us different kinds of information about the **ecology** of all these species**. Phylogeny** and evolutionary processes of species could be understood only through systematics.

2. ROLE OF SYSTEMATICS IN APPLIED BIOLOGY: Systematics has been playing a very important role in applied biology. Crops and trees of economic importance are being destroyed at large scale by various types of **pests.** Without knowing the name of such pests, it will be very difficult to eradicate them. Harmful and beneficial plants can be checked with the knowledge of systematics. Several **diseases** of plants and animals can be checked only through the knowledge of systematics.

3. ROLE OF SYSTEMATICS IN PUBLIC HEALTH: Use of many **insecticides** to control the pests is the cause of many health problems in men and their pet animals. Several **disease**s like malaria, filaria, dysentery, dengue fever, Kala - Azar and sleeping sickness are due to cause of **mosquitoes a**nd **protozoans.** Many water borne, air borne and noise borne diseases are also rapidly spreading. To control these diseases and other health problems, it is essential to correctly identify their sources, vector and control strategy should be planned in such a way that the target source of diseases is being attacked only. It is possible only with the help of systematics.

4. ROLE OF SYSTEMATICS IN PRESERVATION OF WILDLIFE: India is well known for the variety of **wildlife** found here. There are about two million species of animals and one million species of plants. But during the past 50-60 years, wildlife has depleted rapidly due to **indiscriminate killing** of animals and illegal falling of tree and deforestation. Now India faces a crisis of ecological imbalance on a massive scale. During the last three decades alone **95 species** of birds and **37 species** of mammals have been extinct. Today, about a total sum of **200 species** of birds and **100 species** of mammals are facing severe threat of extinction. Systematics identifies such animals and plants and help in the protection of the environment.

5. ROLE OF SYSTEMATICS IN ENVIRONMENT PROTECTION: All living organisms depend upon a balanced environment for their growth and development. All components of the balanced environment are present in a definite ratio but sometime this ratio became disturbed and affects the organism's life. Several undesirable **xenobiotics** and pollutants are entering in our environment continuously by manmade activities.

These activities are the major cause of depletion of our environment. Noise pollution, water pollution, land pollution, air pollution and various chemicals, heavy metals, pesticides, biocides, insecticides, asbestos, fertilizers, antibiotics and detergents are the major cause of environment depletion. Systematics can play a very important role in the identification of these various kinds of **xenobiotics** properly and could save the depleted environment.

6. ROLE OF SYSTEMATICS IN COMMERCE: Various useful products like honey, silk, and dye are obtained from insects. Many useful verities can be used for commercial production by **manipulating species**. The production yields can be increased by replacing harmful or neutral germplasm by better quality of germplasm.

The introduction of useful germplasm is possible only through the correct identification of species. Exact identification of harmful pests and their control help in the protection of many medicinal, economic plants and various animals. Many plants of economic importance can be identified for breeding to increase their yields and production of **disease resistant** verities is possible only through the knowledge of systematics.

7. ROLE OF SYSTEMATICS IN FINDING NEW SPECIES: A long-standing role for systematists is that of going into the field and collecting samples of organisms, then comparing them with known specimens in order to determine whether something significantly different has been found- a new species.

8. ROLE OF SYSTEMATICS IN BIODIVERSITY CONSERVATION: With increasing pressures from a growing world **population** and resulting pressure on **biotic resources,** we now and in the future have to make difficult decisions about what parts of the Earth will be maintained in a **"natural"** state in order to conserve the biodiversity present there. How do we decide, given limited resources, which to protect? If we decide that we want to maximize **biodiversity,** then the phylogenetic patterns produced by systematists give us a way to prioritize areas based upon the diversity they contain.

9. ROLE OF SYSTEMATICS IN DOCUMENTATION: Another crucial role for systematists is that of identification specialists. They are in a unique position to provide this service, with experience and the **necessary tools**. The importance of correct identification cannot be overstated -- when a life, for instance, hangs in the balance depending on whether the plant or mushroom that has been ingested is poisonous or not, this service is critical.

Other types of biological research are essentially valueless if their subjects are misidentified since closely related **taxa** can have very different properties and generalizations must be made carefully. Hence, **documentation** is important so that subsequent investigators can confirm identifications. The only lasting way to document identity is to deposit a **voucher specimen** in an appropriate collection. Studies that do not utilize this service will have less value in the long term because of the impossibility of verifying identification.

10. ROLE OF SYSTEMATICS IN HORTICULTURE AND FLORICULTURE: Knowledge of systematics is essential for horticulture and floriculture also. Several ornamentals have been introduced due to proper identification and nomenclature. Its knowledge is also required to study the natural resources of areas to know the land potential.

Systematics has its relevance in fisheries and for the study of economically and medicinally important plants. All pharmaceutical studies are based on the work of taxonomists. Taxonomists are being employed at various positions in the museum, colleges, institutions, research institutions and in various public and private organizations. So, it has wide scope and applications as a profession also.

4.5 SUMMARY

1. The term taxonomy was first coined by A. P. de Candolle in 1813.
2. Taxonomy is a branch of science which deals identification, nomenclature, and classification.
3. Taxonomy may be categories as alpha, beta and gamma taxonomy.
4. Term systematics was first described by Carolus Linnaeus.
5. Systema Naturae is a famous book of Carolus Linnaeus.
6. Systematics is a scientific study of taxonomy.
7. New systematics or biosystematics or neosystematics was proposed by J. Huxley in 1940.
8. Systematics and taxonomy both are complementary to each other.
9. Aristotle is known as the father of Zoology and father of biological taxonomy due to his tremendous contribution in Zoology.
10. Binomial nomenclature, a system of classification is given by Carolus Linnaeus.
11. Systematics is a modified form of classical systematics or old systematics.
12. Species is the basic unit of taxonomy as well as evolution in both plants and animals.
13. All the organisms should be classified i.e. divided into groups and subgroups.
14. Classification is as old as the power of speech.
15. The method of rearranging and regrouping of organism into various divisions is called classification.
16. Identification means the determination of the correct place of an organism in a previously established plan of classification.
17. Homology establishment helps much in finding the exact position of an organism.
18. The kingdom is the highest category of taxonomic studies.
19. Systematics provides useful information about the evolution, adaptations, and diversity of organisms.
20. Systematics is concerned with the evolutionary relationships of organisms.

4.6 SELF ASSESSMENT QUESTIONS

1. The term taxonomy was first coined by

a- A. P. de Candolle
b- Carolus Linnaeus
c- John Ray
d- Aristotle

2. Taxonomy that is concerned with the arrangement of species according to the law of systematics is called

a- α (ALPHA) TAXONOMY
b- β (BETA) TAXONOMY
c- γ (GAMA) TAXONOMY
d- All of the above

3**……**refers to the study of the relationships between these living things as they evolve

a- Systematic
b- Taxonomy
c- Classification
d- Nomenclature

4. The taxon of birds is **Class** and their category is **Aves.** (True or False)

ANSWERS: 1.a, 2.b, 3.a, 4.False

4.7 TERMINAL QUESTIONS

1. Write the definition of taxonomy?
2. Define species?
3. What is the meaning of Taxa?
4. Describe Taxonomy and its relationship with Systematic in detail?
5. Define Systematic. What are the importance and applications of Systematics?
6. Write a detail account on taxonomic hierarchy?

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UNIT 5: ZOOLOGICAL NOMENCLATURE

CONTENTS

5.1 *OBJECTIVES*

In the lastchapter, you have learned about the **taxonomy** and **systematics** and its relationships between them. About **2 million** types of animals and about **1 million** types of plants have already been described and named and many new forms are discovered every year. Animals and plants vary greatly in their forms, structure and mode of life. To identify an organism of known characters from the vast number of organisms is simply **impossible**. The number and diversity of living organisms are so enormous that it is difficult to study without classifying them into certain **groups** or **categories.** This classification allows us to identify and recognize organisms.

In this chapter, you would learn about the **rules** and **regulation** of nomenclature of animals as well as plants. You will have also learned the **common name** or **vernacular names** and **scientific names** and difference between them. It would also emphasize the importance of scientific names.

5.2 INTRODUCTION

Nomenclature of any individual either that is animal or plant play a very significant role in the **taxonomy.** There are more than **two million species** of animals and about **one million** species of plant, while several more to be discovered. These species may be identified and classified with the help of nomenclature either it is **zoological** or **botanical nomenclature**. Without nomenclature, it would be very difficult to differentiate them. In this chapter, you will read about the **law of nomenclature, binomial and trinomial system of classification.** This chapter will deal with how living beings are named, grouped and classified.

TYPES OF BIOLOGICAL CLASSIFICATION

As more and more data regarding life forms have come to light, classification becomes more and more refined. To understand the **diversity of living beings**, a system of classification is required. Classification allows understanding diversity better.The art of identifying distinction among organisms and placing them into groups that reflect their most significant feature and relationship, morphological and evolutionary and others is called **biological classification**. Organisms have been classified from a different point of view at different times. Three main schemes of classification emerged one after one.

PRACTICAL CLASSIFICATION

BASIS: Organism were originally classified on the basis of their **utility** to man. They were grouped as the **useful** and **harmful** forms and as **edible** and **inedible** ones. This grouping, though rough, was of immediate and practical use to man. The criteria used in practical classification are arbitrary. For example, animals were recognized as food animals, fur animals, pets, beasts and burden etc., while, plants as crop yielding timber yielding, fiber plants etc. This system of classification based on their value to man, irrespective of their structural similarities is called **practical classification**.

DRAWBACK: It gave **heterogeneous** groups of unrelated organisms. For example, edible animals included shrimps, fishes; chickens and goat through these animals radically differ from one another.

ARTIFICIAL CLASSIFICATION:-

BASIS: The system of classification based on one or few **randomly** selected characters for grouping the organisms is known as **artificial classification**. Such system of classification was in use during the early periods. It is based on few a few **superficial resemblance** rather than **natural** or **evolutionary relationships**. It, therefore, gives only a little information about the groups.

The **Greek naturalists** classified animals according to similarities in their **habitat** and **habit**. The animals were grouped as **aquatic, terrestrial and aerial dwellers (**according to habitat), as **carnivorous** and **herbivorous.** (According to mode of feeding) and as **oviparous** (egg-laying) and **viviparous** (giving birth to young ones) according to the mode of breeding. The plants were classified as**herbs, shrubs and trees.** Aristotle (384 – 322 B. C.) was the first one to adopt this system of classification.

DRAWBACKS: The artificial system of classification is, no doubt easier, but has serious drawbacks:

1. As the characters are randomly picked up, they do not reflect any **phylogenetic relationship.**
2. Unrelated organisms are put together, forming **heterogeneous** groups. For example, birds, bats, and insects are combined together as flying animals. Cacti, Euphorbias, and halophytes are clubbed together as **succulent plants.**
3. Related organisms are placed in different groups. For example, Whales an aquatic and rats a **terrestrial animal.**

4. The characters may change with the change in environment. For example, change of habit in radish (annual and biennial habits).
5. It does not show any **evolutionary relationships.**

NATURAL CLASSIFICATION:-

BASIS: In this system of classification all the important characteristics of the organism that provide information regarding their**natural relationship** are taken into consideration. It, therefore, gives more or detailed information about the groups. The system employs those characters which are relatively constant. The English naturalist, **John Ray (1627-1705)** was the first **systematist** to form the structural similarities as the basis of classification. He used constant andwell-defined characters in his classification, thus making systematic a scientific discipline. He published an accurate description of over **18000 plants** in his book ***HistoriaGeneralisPlantarium*.**

ADVANTAGES: Natural classification is the most logical system of classification and has been **adopted** by all the **biologists**. It is better than artificial classification in many respects:

1. It avoids the **heterogeneous** grouping of unrelated organisms.
2. It indicates **natural relationships** among organisms.
3. It shows **evolutionary or phylogenetic relationships.**

Difference between artificial and natural classification

Artificial Classification	**Natural Classification**
1. It is based on **one** or a **few characters.**	It is based on a **number of characters.**
2. It gives meager information about the groups.	
3. It uses **superficial characters** such as habitat and habits.	It gives detailed information about the groups.
	It uses characters pertaining to **morphology, anatomy, cytology, ontology, phylogeny, physiology and biochemistry.**
4. It gives heterogeneous groups of unrelated organisms.	

5. It does not reflect **phylogenetic relation slip of organisms.**	It gives homogenous groups of related organisms. It depicts the **phylogenetic relationship of organisms.**

Natural classification considers more evidence than **artificial classification**, including internal as well as external features, similarities of embryo, morphology, anatomy, physiology, biochemistry, cell structure and behavior. Classification is used today are natural and phylogenetic.

PHYLOGENETIC SYSTEM OF CLASSIFICATION:-

Classification based on **evolutionary relationships** of an organism is called **phylogenetic system of classification.** It reflects the true relationships among the organisms. The phylogenetic system was first proposed by **Engler and Prant (1887-1899).** The concept of fixity of species, prevalent before **Darwin**, changes to a dynamic or over changing one i.e. Species are never **static** and **undergo changes**. Its major source is **fossil record**. This is never complete due to difficulty in formation, discovery, and study of fossils. As and when new fossils are discovered, newer relationships are observed and consequently the**phylogenetic system** is updated.

Thus, like the species, classification is also **dynamic.** In addition to morphological characters, the evolutionary development of groups of organisms, from its origin to the present state, forms the **basis** of classification. From the evolutionary point of view, the presence of fundamental structural similarities in different species is explained on the basis that all the species were derived from a **common ancestor** were related to one another. Thus, the establishment of the theory of evolution puts systematic on new lines.

CLASSIFICATION GUIDELINE:-

Todetermine the position of an organism in a natural or phylogenetic system of classification, a modern taxonomist uses many principles and criteria. He studies the **similarities** and **differences** in organisms by examining many characteristics. These includes

the knowledge of morphology (external features), anatomy (internal structure), cytology (cell structure), physiology (life processes), ontogeny (development of an individual organism), phylogeny (evolutionary history), ethology (behavior), reproductive behavior and biochemistry etc. The main difficulty in the classification is that of sorting the cases of **analogy** or **convergent evolution***i.e.*the development of similar adaptations by organisms of different ancestries.

Analogous organs have the same function and are superficially alike but are quite different in fundamental structure and embryonic origin. For example, **insect** and **bird wings.** Both these organs are used for flying in the air, but they are very **different in their structure.** An insect wing is an extension of the integument, whereas, a bird wing is formed of limb bones covered with flesh, skin, and feathers. Another example of analogous organs is pectoral fin of shark and flipper of dolphin.

5.3 *INTERNATIONAL CODE OF ZOOLOGICAL NOMENCLATURE*

One of the primary responsibilities of **systematic biology** is the development of our biological **nomenclature** and **classifications.** Nomenclature is not an end to systematics and taxonomy but is a necessity in organizing information about **biodiversity.** Nomenclature functions to provide labels (names) for all **taxa** at all levels in the **hierarchy** of life.

Zoological nomenclature is a language that we use to communicate ideas and information about the **diversity of life**. It is an information retrieval system conveying information about diversity and relationships. In **1898 International Congress of Zoology** organized an **International Commission of Zoological Nomenclature** and suggests some rules and regulations for nomenclature.

These rules were revised in **1948** and **1950** in **International Congress of Zoology** and **International Congress of Botany** respectively. **12th International Congress on Nomenclature in 1975** laid down some general principals in the form of **International Code of Botanical Nomenclature (ICBN)** and **International Code of Zoological Nomenclature (ICZN**) which are as following:

1. **Binomial and trinomial system of nomenclature** should be adopted.

2. Name of the **genus** should start with **capital letter** followed by **species** with **small**

letters.

3. The name of the genus should be a **single word** and**difficult**, **long** should be avoided.

4. Genus name should be read as a **generic name** followed species as a **specific name**.

5. The scientific name must be derived from **Latin language** only.

6. The scientific name must be always written in **italics or underlined only.**

7. The plants and animals should have **independent** and **different** names.

8. In scientific name first word will be represented by **genus** and second and third (if present) will be represented as **species** and **subspecies** respectively.

9. Within animal kingdom no two genera should have the same name and within the genus, no two species should have the same name.

10. A scientific name must have its **original spellings** and errors must be corrected.

11. The name of author should be written in **Roman script** after the species without comma between them.

12. The scientific name should be too**easy to pronounce**.

13. The scientific name should not have less than **three** and not more than **twelve letters.**

14. The scientific name of plant or animal should be **self-explanatory** in its characters.

15. Every species should have a **generic name.**

16. Other components of taxonomy like phylum, class, order should also start with a**capital letter**.

17. Species should not be identified with its **size.**

18. The name of family should start with capital letter and should be suffix –**IDEA** and subfamily by **INAE.**

19. The generic or specific name first published is the only one recognized. All duplicate names are **synonyms.**

20. The formations of family and subfamily names follow rules which are different in the **Zoological and Botanical Codes.**

21. A name may be based on any part of an animal or a plant, or on any stage of an **organism's life history**.

22. In case of discovery of different name of same genus and species by different scientists, the name **first published should be accepted.**

Thus, presently there are four different codes of nomenclature used today.

1. International Code of Zoological Nomenclature (ICZN). 1999.
2. International Code of Botanical Nomenclature (ICBN) 1994.
3. International Code of Nomenclature of Bacteria (ICNB). 1976.
4. International Code of Nomenclature for Cultivated Plants (ICNCP). 1980.

Some General Objectives of Scientific Nomenclature:-

UNIQUENESS: The name of a particular organism gives one immediate access to all of the known information about the particular **taxon**. Every name must be unique because it is the key to the entire literature relating to the species or higher taxon in question. If several names have been given to the same taxon, there must be a clear-cut method whereby it can be determined which of the names has validity.

UNIVERSALITY: Scientific communication would be made very difficult if we had only **vernacular names** for taxa in innumerable languages in order to communicate with each other. To avoid this we have adopted an international agreement for a single language (**Latin**) and a single set of names for biological diversity to be used on a worldwide basis.

STABILITY: As recognition symbols of diversity, names of organisms would lose much of their usefulness if they were changed frequently and arbitrarily.

5.4 *BINOMIAL AND TRINOMIAL COMPONENTS OF CLASSIFICATION*

In the system of classification, every individual has identification**,** for which **nomenclature** is a must. Without nomenclature, it will be very difficult to differentiate it with other individuals. Generally, individuals are classified into **two categories** as **Common or Vernacular Name** and **Scientific Name.**

1. COMMON OR VERNACULAR NAME: A **common name** of a taxon or organism also known as a **vernacular name in** English, is a **name** that is based on the normal or local language in different regions as well as the country. In other words, the locally used name are called **vernacular names**. This kind of **name** is often contrasted with the scientific **name**. Such names are based on the same peculiarity of the organism, e.g. Kanteli (a plant having spines).

For Example, thesimple domestic bird is commonly known as **Gauraiya** in India and Pakistan, while in England **House sparrow**, In German **Hausperling**, in Holand**Musch,** and in Japan it is known as **Suzune.**

ADVANTAGES

1. Easy for the local people to follow

2. Easy to learn, speak and write

3. Usually short.

DRAWBACKS

1. The same animal or plant is known by a different common name in **different countries** where different languages are used.

2. A singular vernacular name is often used for **several species**.

3. The common names may be **misleading**. For example, Jellyfish, Silverfish, Starfish are the names of some animals, none of which is a really a fish (except dogfish).

4. The common names lack a **scientific basis** as they do not convey any taxonomic relationship with other organisms.

5. Only those organisms which are **beneficial** or **harmful** to man have been provided these names. Insignificant ones were left out.

6. New common names cannot be introduced nor can the old ones be **changed at will.**

2. SCIENTIFIC NAMES: In view of the shortcomings of common names, another system was called **scientific** or **technical system** has been devised to name the organisms. According to this system, scientific names of organisms are based on agreed **principals** and **criteria** which are acceptable all over the world. The scientific names ensure that only one name is given to an organism and description of the organism should help the other people to arrive at the same name in any part of the world.

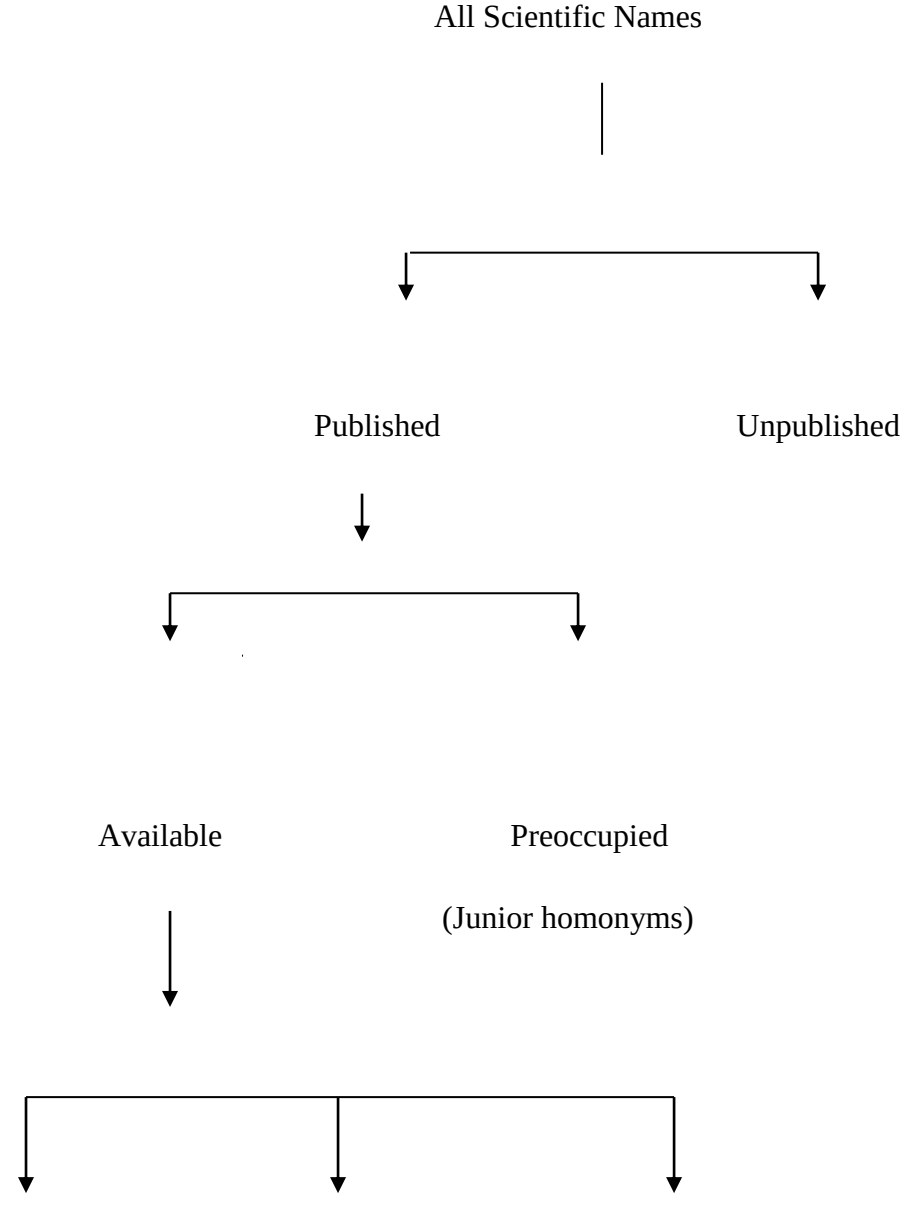
ADVANTAGES

1. They help in **classification.**
2. A newly discovered organism can be **easily described** and **named.**
3. Each kind of organism is given a **single scientific name**.
4. This scientific name eliminates the confusion of **multiple naming.**
5. An incorrect name can be easily set right.
6. They are **universally accepted.**
7. They indicate the relationship of a species with others placed in the **same genus.**
8. They indicate some important **characteristics of the organisms.**
9. The scientific names are often derived from**Latin/ Greek** which are **dead languages.**
10. Hence, there is less possibility of change in the meaning of their words.

RULES FOR SCIENTIFIC NAMES

1. Each organism to be given a **single scientific name**. However, species having subspecies, varieties or races are given a **trinomial name.**
2. The scientific name should be printed in **italics**. (If handwritten or typed, the name is **underlined**).
3. The first (generic) name should always begin with **capital letter**. It is often abbreviated by using only its first initial. For example; *C. familiaris* for *Canisfamiliaris* (dog).
4. The first letter in a species should always begin with a **small letter.**

5. The names of the division above the genus are not printed in italics. However, they are started with a **capital letter**. For example: The order and the class of humans are written as **Primates** and**Mammalia** respectively.
6. The generic name appears**only once**whereas the specific name may appear **many times,** but each time with a separate genus. For example:*Mangiferaindica* and *Tamarindusindicus* are the names of mango and tamarind respectively.
7. Two species belonging to the same genus cannot have the **same specific name.**



Categories of Scientific Names (Modified from Blackwelder, 1967).

SYSTEM OF SCIENTIFIC NAMES:-

Following have been practices of providing scientific names to organisms:

POLYNOMIAL NOMENCLATURE

Polynomial names were in use much before **1750**. In this system, the scientists used to add a series of **descriptive words**. Names become **very lengthy** and **difficult** to remember. For example, the plant **Caryophyllum** has been given the name **Caryophyllumsexatilisfolisgramineusumbellatiscorymbis,** meaning caryophyllum growing on rocks having grasslike leaves and **umbellate – corymb** arrangement of flowers. This type of naming was called **polynomial nomenclature.**

5.4.1 BINOMIAL NOMENCLATURE

The **polynomial system** was quite a trouble or difficult. It also changed from scientist to scientist. Consequently, in **1758,** the system of writing scientific name of plants and animals adopted by **C. Linnaeus** (a Swedish naturalist) is called **Binomial Nomenclature**. This system proved better and ultimately became a common and established.

According to this system, the **scientific name** comprises of two words **genus** (generic name) and **species** (specific name). The generic name is **common** for all the species in a genus, while the specific name is commonly based on some **special** or **definite characters**. Generic names are used to written in **Latin** or **Greek** words usually begin with a **capital letter,** while specific names are always being written in **small letters**. Both generic, as well as specific names, should be written in **italics** or **underlined**.

Sometimes, the scientific name is also written in the **honor** of scientist is followed by a specific name. If the person honored is a man the specific name ends in **"i".** For example, the earthworm, *Lumbricusfriendi* is named after Rev. **H. Friend**. If the person honored is a woman, the specific name ends **"ae".** Sometimes, the specific name indicates **a locality** as **indica** for India or color as **niger** for black.

All generic and specific epithets have authors, the name(s) of the person(s) who first officially described them in a publication. You will often see scientific names with an

author's name following it. This is **often confusing** to non-taxonomists but is really important because it is very useful in tracing the history of applications of names through time. Scientific names with very similar spellings can usually be distinguished from one another when an author's names are included.

For Example: Indian bird **Gauraiya**, scientific name is *Passer domesticus* and **Dog** is *Canisfamiliaris*and **Human beings** as *Homo sapiens* Linnaeus.

5.4.2 TRINOMIAL NOMENCLATURE

Whenever the system of nomenclature is usually adopted by **three words** called **trinomial nomenclature**. There are some species which contain **subspecies.** Subspecies is generally followed by species and also written in **Latin** word always. These subspecies usually found in the **different region** of the world containing different characteristics.

Thus, For example, the common specific name of **crow** is *Corvus splendens*, but its three species are generally found in India, Burma, and Sri Lanka. **In India,** it is named as *Corvussplendenssplendens*, in **Burma***Corvus splendensinsolens,*and in **SriLanka,** it is the trinomial nomenclature indicates the**generic, specific and subspecific name** called *Corvus splendensprotegatus*.

Sometimes, the **name of a scientist** is followed by trinomial nomenclature as *Columba livia intermedia* Strickland (Prof. Strickland), *Pantheraleopersica* Linn. etc. The scientific names provided are often descriptive and also indicate some important characteristics of the organisms. **For animals**,scientific names are governed by the International Code of Zoological Nomenclature. Only one rank is allowed below the rank of species: subspecies. However, Advantages of using scientific names for an organism are as follows:

1.0 The scientific name remains the **same worldwide**, hence is easily recognizable.
2.0 The possibility of confusion due to multiple names were given to the same organism in different parts of the world is **eliminated by scientifically** naming the organism.
3.0 A relationship between different species of organisms in a particular genus can be **deduced** by scientific names.
4.0 It also helps in recognizing or identifying any **new organisms** discovered.
5.0 Any incorrect name to a particular organism can be **corrected.**

5.5 *SUMMARY*

- To study understand **diversity of living beings**, a system of classification is required.
- In ancient time organisms were originally classified on the basis of their utilty of man.
- Artificial classification is based on the some randomly selected characters.
- Practical classification is based on their value to man, irrespective of

their structural similarities is called **practical classification**.

- John Ray published accurate description of over **18000 plants** in his

book***HistoriaGeneralisPlantarium.***

- Natural classification shows **evolutionary or phylogenetic relationships among organisms.**
- Phylogenetic system was first proposed by **Engler and Prant (1887-1899).**
- **Zoological nomenclature** is a language that we use to communicate ideas and information about the **diversity of life**.
- In **1898 International Congress of Zoology** organized an **International**

Commission of Zoological Nomenclature and suggests some rules and

regulations for nomenclature.

- **12th International Congress on Nomenclature in 1975** laid down some

general principals in the form of **International Code of Botanical**

Nomenclature (ICBN) and International **Code of Zoological Nomenclature**

(ICZN).

- **Binomial and trinomial system of nomenclature** should be adopted.
- International Code of Zoological Nomenclature (ICZN). 1999.
- International Code of Botanical Nomenclature (ICBN) 1994.

- International Code of Nomenclature of Bacteria (ICNB). 1976.
- International Code of Nomenclature for Cultivated Plants (ICNCP). 1980.
- A **common name** of a taxon or organism also known as a **vernacular name in** English, is a **name** that is based on the normal or local language in different regions as well as country.
- Each organism to be given a **single scientific name**.
- Consequently in **1758,** the system of writing scientific name of plants and animals adopted by **C. Linnaeus** (a Swedish naturalist) is called **Binomial Nomenclature**.
- The system of nomenclature is usually adopted by **three words** called **trinomial nomenclature**.
- The trinomial nomenclature indicate **generic, specific and subspecific name**.

5.5 *SELF ASSESSMENT QUESTIONS*

1- The phylogenetic system was first proposed by

a- C. Linnaeus

b- Engler and Prant

c- Darwin

d- Strickland

Ans- b

2. The main difficulty in the classification is that of sorting the cases of

a-Analogy

b- Homology

c- Physiology

d- Ontogeny

Ans- a

2- Which of following is not a principle of International Code of Zoological Nomenclature (ICZN):

a- Binomial and trinomial system of nomenclature should be adopted

b- Name of the genus should start with capital letter followed by species with small letters

c- The scientific name must be always written in italics or underlined only.

d- The scientific name must be derived from Italian language only

Ans- d

3- Classification based on ……..of an organism is called phylogenetic system of classification

Ans- evolutionary relationships

4- The trinomial nomenclature indicates the generic, specific and ……name

Ans- sub specific

5.7 *TERMINAL QUESTIONS*

1- What is the meaning of phylogenetic system of classification?

2- What is the difference between artificial and natural classification?

3- Why it is necessary to provide a scientific name to an animal?

4- How living beings are named, grouped and classified scientifically?

5- Describe various types of Biological classifications?

6- Write a detail account on Binomial and Trinomial components of nomenclature?

7- Write a essay on ICZN?

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UNIT 6: ORIGIN OF LIFE

CONTENTS

6.1 OBJECTIVES

If there were other life out there in the universe, how similar do you think it would it be to life on Earth? Would it use DNA as its genetic material, like you and me? Would it even be made up of cells? We can only speculate about these questions, since we haven't yet found any life forms that hail from off of Earth. But we can think in a more informed way about whether life might exist on other planets (and under what conditions) by considering how life may have arisen right here on our own planet.

In this chapter, we'll examine scientific ideas about the origin of life on Earth. The when of life's origins (3.5 billion years ago or more) is well-supported by fossils and radiometric dating. But the how is much less understood. In comparison to the central dogma or the theory of evolution, hypotheses about life's origins are much more...hypothetical. No one is sure which hypothesis is correct – or if the correct hypothesis is still out there, waiting to be discovered.

6.2 INTRODUCTION

The term ‘evolution’ can be defined as “the changes in the genetic composition of a population with the passage of each generation.” The outcome of the evolutionary process is an adaptation of an organism to its environment. The evolution is the property of population and not of individuals. Natural selection is the evolutionary force. In our solar system, there are seven major planets besides Earth. Neptune, Uranus, Saturn and Jupiter are said to be having clouds like surface bur Mercury and Venus lack water and atmosphere. The Mars which distance from earth is about 35,000,000 miles possibly has oxygen, CO2 and water but with temperature ranging between 10oC to freezing point. Some life has been reported to be present on Mars but still, it is a matter of debate. The life cannot exist all the time on earth because the high temperature and dry climate of the early time of earth would have made life impossible to exist. The world has its own account of the origin of life.

The earth was cast off from some molten and hot gaseous material. This mass later condensed and gradually cooled and decreased in volume. The earth acquired in the course of time a gaseous atmosphere with sufficient pressure to retain water on the surface. The water filled the deep area, which made sea and oceans. The life could appear only after the water and lands had cooled.

6.3 ANCIENT THEORIES RELATED TO ORIGIN OF LIFE

6.3.1 SPECIAL CREATION THEORY

The biblical story of the creation of world within six days was put forward by Spanish monk father Suarez. He described that the earth and heaven were created on the first day and sky on the second day. The third day the earth surface was dried and ancestors of plant and animalsoriginated. The sun, the moon, and the stars were created on the fourth day. The birds and fishesare created on the fifth day and finally, man and beast were created on the sixth day of creation.

In the end of the seventh day, a woman was constructed from the 12th ribbed of the man.

6.3.2 THEORIES OF SPONTANEOUS GENERATION

This theory is also known as the theory of a-biogenesis. According to this theory, life has originated from the non-living organic material. Anaximander and Anaxagoras believed that life appeared in the small seed which came to earth along with rain water. Aristotle suggested that a number of animals originated in the way discussed above. A number of worms, larvae of bees, larvae of wasps, ticks, flies and many other insects develop from the morning dew or from decaying slime manure, from dry wood, hair, sweat and meat while tapeworms are born in the rotting portion of the body and excreta. Mosquitoes, flies, moths, beetles, fleas, bed-bugs and bees are generated in the slime of well, rivers or sea, in the humus of the fields, in manure, in decaying trees or fruits etc. crab and mollusks were brought to come from the moist soil and decaying slime. Some higher animals have similar origin though in the case of latter his first appearance is in the form of a worm. In fifteen century, it was thought that leaves falling from trees turned into fish if they fell in the water and turned into a bird if they fell on land.

Experimental studies

Redi's experiments

Francesco Redi (1626-1698) was the first to put forth the experimental evidence of the concept of spontaneous generation. He placed the meat or fish in three large jars. One jar was left open, one was covered with gauze and one was covered with a muslin cloth. The meat or fish decayed in all jars and flies were attracted to all. He showed that the white maggots in the meat of the first jar were the larvae of flies and nothing else. He notices that in the second

jar, worms did not appear in the meat. However, he noticed the eggs and some developing stages on the wire gauze. He, therefore, concluded that the decaying substance or soil or mud was only a place or nest for the development of the insects and that the necessary prerequisite for the appearance of the worms was laying of eggs.

LazzaroSpallanzani disproved the theory of spontaneous generation in 1765. He boiled the meat in the sealed long-necked flask. The broth remained clear for months. No sign of life was recorded. Needham claimed that by boiling, the vital forces necessary for a spontaneous generation had driven out. Then the seal was broken and the broth was exposed to fresh air. On testing the broth, the presence of microbes proved the origin of life from preexisting life.

Louis Pasteur disproved the theory of spontaneous generation in the nineteenth century. He boiled a solution of sugar and yeast for several hours in a swan neck flask and the flask wasleft unsealed. The solution remained free of microbes because the swan neck flask was shaped so to trap viable microbial particles and to allow only air to enter the flask. After breaking the neck of the flask, he reported the micro-organism in the solution, thus he disproved the concept of spontaneous generation.

6.3.3 COSMOZOIC THEORY

The cosmozoic theory is also known as Panspermia theory. According to this theory, the life is distributed throughout the cosmos in the form of the resistant spores of living forms, the cosmozoa. These reached the earth accidentally from some other planet, and on getting favorable conditions for life these developed into organisms. The cosmozoic theory was proposed by Richter. According to this theory, life came from another planet in the form of celestial bodies and small particles carrying viable germs or spores, which upon reaching on earth accidently, could develop and initiate panoply of living organisms. Life only changes its form but is never created from dead substances. It has no origin and has always existed. Preyer assumed that life must have existed even at that time when the earth was a mass of molten liquid. According to him, life comes from life and never from dead material.

6.4 MODERN CONCEPT OF ORIGIN OF LIFE

A.I Oparin, published a book named “The Origin of Life” in 1939. In addition, several realistic theories have also been offered to explain the origin of the earth and life, but the most widely accepted theory today is known as the Big Bong theory, proposed in 1951. Before twenty billion years the universe was one big ball of neutrons or neutral particles. The

movement of these particles becomes greater until the big ball generated the nearly unbelievable amount of heat. The increase in temperature caused a parallel increase in pressure. Finally, the big ball exploded and created the biggest bang ever known. Neutrons were flung everywhere. As the neutrons moved farther from their point of origin, they began to cool and produce negative charges or electron. The production of electron left behind protons and the attraction of electron to proton created hydrogen. This process continued until the newly formed particles began to aggregate into small balls. Each ball becomes a galaxy; our galaxy is the Milky Way. Within each galaxy, the process continued to form smaller balls, creating the solar system. This ball can be best thought of as clouds of gases, which astronomers call dust clouds. As time passes each dust cloud became cooler. Many dust clouds developed extremely cold temperature that hovered near absolute zero. However, as the particle of the dust cloud showed down and moved closer, heat once again was generated. The heat becomes too intense so as to cause the fusion of hydrogen, forming helium and releasing energy in the form of light and heat. The acceleration of this process caused dust clouds to throw off groups of particles, creating eddies of smaller clouds. The hot and illuminated central masses became the stars of the universe, the less hot eddies of dust radiating around them became a planet. Today these processes continued. Stars and planets are constantly being born throughout the universe while other explode and disappear into oblivion.

Our earth came into existence in five billion years ago. Earth was like other planets. Itwas at first a very hot molten mass of materials. However, as the mass cooled, hydrogen became the basic building block from which all other elements were made. The core of earth today is still a hot molten ball, volcanic eruptions not only demonstrate the existence of a molten core but also provide a glimpse of what the earth was like much earlier when volcanoes that dotted its surface were continually erupting.

6.4.1 CHEMICAL EVOLUTION

From monomers to polymers

First, the amino acids began to accumulate in the oceans and smaller bodies of water and they embedded into proteins and other macromolecules. Sidney Fox of the University of Miami found that heating a dry mixture of amino acids causes the formation of long proteinoidspolymers having a molecular weight of more than 10,000. Fox has suggested that such polymerizations took place in volcanic cinder cones and that the proteins formed were

then washed into the sea. J.B.S. Haldane and other considered it more likely that the first macromolecules were formed in sea water or pond water rather than formed dried mixtures of monomers. This too has been shown to be possible, for solutions of amino acids will form polypeptides in the presence of hydrogen cyanide even at the suitably low temperatures.

On other hand polymerizing monomers of various types and to wet and dry them, alternately, on the surface of the clay. The historical operation of this mechanism is particularly plausible from geological points of view. According to Miller, in which simple molecules were formed, many different conditions have been shown to be compatible with the formation of proteins and other polymers.

Microspheres

This is the accumulation of the biological polymers and other compounds into isolated droplets of increasing complexity. There are, in fact, several ways in which such accumulation can be accomplished in the laboratory.

Example: Fox found that his proteinoids have a remarkable tendency to form microspores approximately 2μm in diameter when hot, concentrated solution of the proteinoids is slowly cooled. These microspheres show a double layered boundary resembling a membrane and they swell and shrink as the salt concentrations in the solution is changed. If allowed to stand for several weeks, the microspores absorb more proteinoid material from the solution produce buds and sometimes divide to produce second generation microspheres. Cleavage or division can also be induced by changing pH or adding magnesium chloride. These microspheres should not be taken to be the ancestors of life.

One method for the accumulation of chemical substance into partially organizedstructures was proposed by the Irish physicist J.D. Bernal. This method involves some clay particles, such particles have electrical charges that attract and bind substances such as protein. Methane, ammonia and water vapour can be subjected to electrical discharge and among the products are spheres, one-quarter of a micrometer in diameter, consisting of mixtures of biological molecules bound to clay-like particles eroded from the glass of the reaction chamber.

Theory of chemical evolution

It is possible that the immediate precursors of the living organism were capsules of chemical reaction similar to coacervate droplets. Some coacervates would enclose reactions that led to

the early breakup of the droplets; other would enclose reaction that made them stable. The more stable coacervates would survive longer and could possibly grow at the expense or their surroundings by absorbing chemical substances derived from the remains of the less stable droplets.

If wave action of other chemical forces broke a large coacervate into many small droplets, each of these might be able to absorb the material and grow on its own. This stage of evolution would be purely a matter of chemical competition. Any non-biological catalysts that accelerated the rate of favorable reactions in a given type of coacervate would give it a great advantage over more slowly reaction droplets. Chemical selection, therefore, would favor catalyzed reactions. It is not hard to imagine more and more efficient catalyst would be developed and retained by chemical selection until finally, the evolving system stumbled on to the ultimate improvement of protein like catalysts enzymes.

Oparin postulated the existence of organized metabolizing but non-reproducing systems that he called protobionts. According to this reasoning, the breakthrough that led to truly living organism was the development of reproduction, the ability of a successful chemical system to ensure its survival by duplicating itself. The molecules in which the instructions for duplication are stored in modern living creatures of DNA or RNA. Yet the living unit of life is not just the nucleic acid as a computer without a program, but the DNA or RNA alone can be more live than a program without a computer can also do the calculation. Any simple biological molecules released into today's environment are quickly consumed by already living things. For another, such molecules are no longer accumulating through the mechanism. Earth atmosphere has changed. Oxygen too can oxidize biological molecules. In addition, it gives rise to the ozone that filter ultraviolet from the sunlight falling on the planet. In doing so, it blocks one of the sources of energy once available for promoting chemical reactions. In sum, spontaneous generation is a thing of the past.

Meteorites and extraterrestrial life

The most primitive Precambrian bacteria were probably compared with non-living matter. Their discovery sheds no light on the central question of chemical evolution. Earth is steadily bombarded with showers of meteors presumably the debris the shattered asteroids, andsome of this material contains organic molecules also found in living systems. Most meteoritesare metallic, but a relatively small number are soft and crumbly, with high carbon content. These soft meteorites are called carbonaceous chondrites, and the meteorites that fell in a shower

around Orgueil belong to this category. A variety of hydrocarbons have been found and some of the organic compounds are optical isomers, which are usually associated with synthesis carried out by living organism. Some amino acids found in meteorites are ones not found in organisms on this planet and, hence, cannot be contaminants introduced after the meteorites fell. Spheroids and other organized bodies of some complexity have been reported, but a continuation of the meteorites samples by airborne spores and pollen has confused the issue. In at least on the instance, the organized bodies turned out to be ragweed pollen. Most of the complex organized bodies have proved to be terrestrial contaminants and those that are definitely meteoric in origin are sufficiently simple that they may be natural mineral formation rather than artifacts of life.

The presence of hydrocarbons and other biochemical compounds in the meteorites indicates that at least the first step in molecular evolution for the formation of complex organic compounds can occur spontaneously even in space. These meteorites are not evidenced for life on some shattered planet; they may be evidence for the universality of the organic chemical-rich environment in which life could develop.

Origin of primitive living organism

The coacervates showed some chemical reactions which produced special proteins and enzymes. This led to self-replication of compounds; those processing this property might be regarded as a free gene. Such a structure is comparable with the free-living virus and is supposed to be, formed of nucleoproteins. Self-replication and mutation of a gene could lead to the formation of gene aggregates. Such gene aggregates may be regarded as independently existing chromosomes. It is believed that some of the smallest bacteria represent such a stage in the evolution. The mutation might be led to the accumulation of metabolites around the chromosomes. The complex so formed represents the exposed nucleus. Some of the bacteria showed this kind of structure. The cytoplasm has been acquired but not separated from the nuclear material as in blue-green algae and in some large bacteria.

Miller's Experiment

Stanley L. Miller proved the important evidence in support of chemical synthesis of life. A mixture of some gasses like ammonia, methane, and hydrocarbon was taken in a special flask. A high-frequency spark by tungsten electrodes was discharged in a constantly circulating mixture of gases for about a week. During the period of the experiment, steam is supplied from the boiling water which mixes with the other gases. The steam thus formed

condenses to water through the condenser and flows back to the boiling water flask. After the experiment is completed, the resulting fluid collected in the U-shaped tube and analyzed. The mixture consisted of various acid and amino acids e.g. glycine, alanine, B-alanine and aspartic acid,important for protein synthesis.

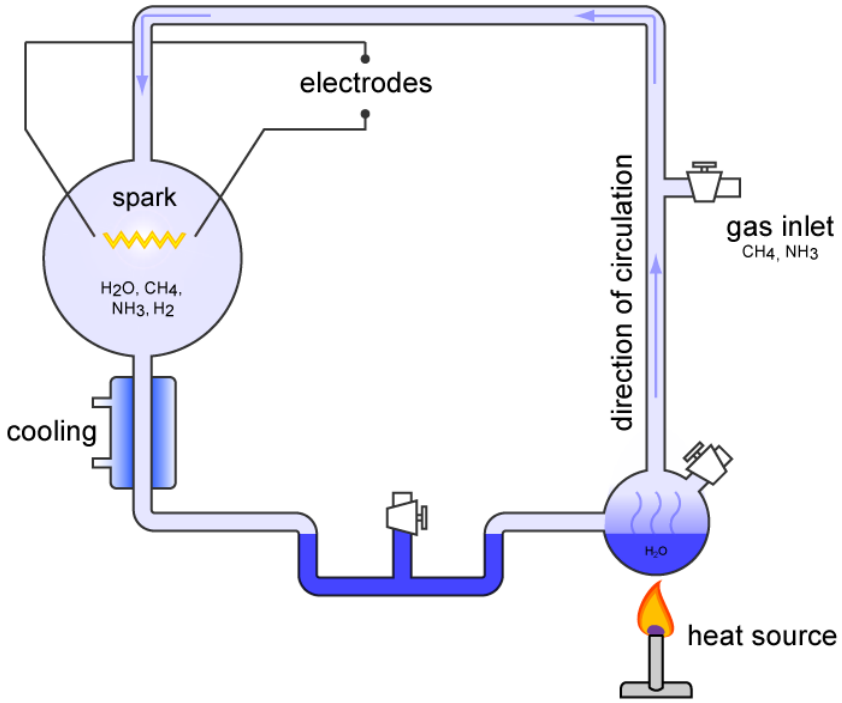

Fig. 6.1 Miller–Urey experiment

6.4.2ORIGIN OF PRIMARY ORGANISM

Oparin'scoacervates had common properties and still definite individualism ties and structures. These could grow in size as a result of absorbing substances dissolved in the surrounding water thus, became more complex and created diversity among them, Due to the presence of some substances like iron, copper, and calcium etc. first rudiments of future enzymes were formed. The primitive organisms were successful coacervates. Blum states that the source of free energy available for the first living thing was the absorption of ultraviolet rays. According to others thought, coacervates utilized energy during fermentation of organic substances absorbed from seawater. The production of energy was done through anaerobic respiration. The sea water provided the necessary raw material for the duplication of nucleoprotein and thus, the amount of it was increased. From nucleoprotein virus-like organisms developed.

Cellular life

Horowitz in 1945 and Orgel in 1976 stated that life originated in its simplest form in the sea. The genes along with proteins developed long chains of nucleoproteins that can be compared with chromosomes. The molecules of nucleoproteins along with organic compounds of sea developed a membranous covering and thus, the cells similar to prokaryotic cell were evolved. This cell has protein and some other organic substance in the colloidal state around

DNA molecules but devoid of the nucleus, mitochondria, chloroplast, Golgi apparatus, lysosome and other organelles. These cells were holozoic as far as their nourishment is a concern. They can use the dissolved organic material present in marine water. They used solar energy and synthesized their own food. Now, for the first time, free oxygen was liberated out in the atmosphere.

6.5 SUMMARY

In the end, it can be concluded that the process of evolution is an ever continuing process; it has not stopped but is occurring more rapidly today than in many of the past decades. In the last few hundred –thousand years, hundreds of species of animals and plants have come become extinct and other hundreds arise.

Numbers of simpler and lower animals are aquatic and since the cell and body fluids of all animals contain salts, it is inferred that life began in the ocean. Many biologists believe that life originated in the tidal zone which is rich in oxygen, CO2, light and minerals and is most suitable for plant and animal growth. The earliest animal remains are all in rocks of marine origin. Various organisms later invaded the freshwater and land.

6.6 SELF ASSESSMENT QUESTIONS

1- Theory of abiogenesis was put forward by

a- Spallanzani

b- Van Helmont

c- F.Redi

d- Pasteur

Ans- b

2-Who disproved the theory of spontaneous generation

a- LazzaroSpallanzani

b- A.I Oparin

c- Francesco Redi

d- Anaximander

Ans- a

3.According to which theory, life came from another planet in the form of celestial bodies and small

particles carrying viable germs or spores

a-cosmozoic theory

b-spontaneous generation

c-chemical evolution

d-synthetic theory

Ans- a

4- Coacervates were formed by

a- polymerisation and aggregation

b- DNA

c- replication

d- polymerisation

Ans- a

5-life originated in its simplest form in the

a-land

b-sky

c-underground

d-sea

Ans- d

6-…… proved the important evidence in support of chemical synthesis of life.

Ans- Stanley L. Miller

UNIT 7: ECOLOGICAL CONCEPT

CONTENTS

7.1 OBJECTIVES

To the study of Basic concept of ecology, definition, types of ecology, significance, concepts of habitat and ecological niche.

7.2 INTRODUCTION

Ecology is mainly concerned with the biological connections and processes of organisms, land, water etc. It can be referred as the scientific study of the interactions that determine the distribution and abundance of organism. The term ecology (oekologie) is derived from two Greek words- oikos= means 'house ` or place of live` and-logos means 'a discussion or study` Ecology is the study of organism at home in their native environment.The term was first of all introduced by Reiter in 1868, but because the German biologist Ernst Haeckel (1869) first of all fully defined ecology as the study of reciprocal relations between organism and environment.

Ecology is divided into the two main divisions:

1. **Autecology:** It is also called species ecology. It is concerned with the study of individual organism or the population of individual animals or plant species in relation to environment.
2. **Synecology**: The branch of ecology that studies about the relationship of various groups organism to their common environment.

7.3 BASIC CONCEPT OF ECOLOGY

The four basic concepts of ecology are Holism, ecosystem, succession, and conservation.

Holism

Ecology as a basic division of biology attempts to define and explain patterns within and among organisms, at each level of organization. The hierarchical levels at which we discus interacting units of ecology are, individual < population < community < ecosystem < biome < Biosphere. Each level of organization has characteristics peculiar to it that are not identifiable at the levels below. Each unit is a whole built up by the interactions of lower level wholes

into a higher level whole in this kind of Hierarchy Williams Ophuls (1974) considered holism as the real base of ecology. It focuses on the system paradigm of interrelationships.

The term holism (from Greek word holon, meaning entity) was coined by the south African statesman, Jan Christian Smuts in his book Holism and evolution in 1926 to explain the process of evolution by the coming together of lesser wholes in order to create the universe.

Holism or the Holistic philosophy as one of the basic concepts of ecology explains the characteristics of units at successive higher level of organization of organisms.

Ecosystem

The concept of Ecosystem was first formulated by A.G.Tensley in 1935.An ecosystem is the whole biotic community in a given area plus its abiotic environment. It therefore includes the physical and chemical nature of the sediments, water and gases as well as all the organisms. Ecosystem ecology emphasizes the movements of energy and nutrients (chemical elements) among the biotic and abiotic components of ecosystem.

The biotic components of any ecosystem are linked as food chains. Food chains are interlinked to form complex food webs. Food webs are the basic units of ecosystem ecology. Thus ecology begins with populations and culminates in ecosystems. Food webs are basic units of ecosystem ecology the ecology begins with population and culminate in ecosystems Food webs are basic unit since it is around then that energy and nutrients transfers take place.

Succession

All living organisms and their environment are mutually reactive, affecting each other in various ways. Animal population, flora, and vegetation are interdependent through the environment and are mutually reactive.

Under natural condition, different kinds of population undergo succession. Ecosystems undergo an orderly process of change with time, passing from a less complex to a more complex state. This process involves not only change in species composition but also changes in the physical environment of a community. The terminal or stabilized state is known as climax.

Succession is thus an ecological phenomenon of replacement of an earlier ecosystem by a higher biomass-rich and trophically- diversified ecosystem. It is usually a longer term process taking centuries for a time-series procession of more resistant system of producer, consumer

and decomposer organisms resulting into a stable system accompanying biotically transformed terrain or habit under a given climate.

7.3.1 CONCEPT OF ECOLOGY

The world in which we live consists of living organisms and non-living structures. Often, relationships between organisms or between organisms and non-living structure are clearly visible. The science of ecology in its pure form studies the relationships of organisms with their environment. "Organisms" means all living entitles; this definition excludes relationships between non-living entities as a possible objects of study for ecology.

The term "environment" is meant in the sense of "the surrounding world," i.e., all entities, living or not, which surround a living entity.

Ecology is divided into the two main divisions:

1. **Autecology:** Autecology deals with the study of the individual organism or an individual species. It is also called species ecology. It is concerned with the study of individual organism or the population of individual animals or plant species in relation to environment.

2. **Synecology** : Synecology is the study of inter-relationship of the organisms, such as populations, biotic communities and ecosystem and ecosystems and there environment, which are associated together as unit (i.e., community).It can be differentiated into 5 types which are:

1.Organism (physiological and behavioral ecology): organism forms a basic unit of study in ecology. At the level of organism, we know to understand the form, physiology and behaviour, distribution and adaptations in relation to the environmental conditions.

2.Population Ecology: Population ecology is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study of how the population sizes of species change over time and space. The term population ecology is often used interchangeably with population biology or population dynamics.

A **population** is a group of interacting organisms of the same species, and contains stages: pre-reproductive juveniles and reproductive adults. Most populations have a mix of young and old individuals, and characterizing the numbers of individuals of each age or stage indicates the **demographic structure** of the population. In addition to demographic structure, populations vary in the number of individuals in the group, called **population size**, and how densely packed together those individuals are, called **population density**. A

population's **geographic range** has limits, or bounds, established by the encroachment of other species, by the physical limits that the organisms can tolerated, such as temperature or aridity.

3.Community Ecology: Community ecology is the study of the interactions between population and coexisting species. Community is made up of populations of different species, or animals, plants, fungi, and bacteria, living in the same area.

4.Ecosystem Ecology: Ecosystem ecology is the combined study of the physical and biological components of ecosystem. It focuses on how matter and energy flow through both organisms and the abiotic components of the environment**.**

Ecosystem ecology is the integrated study of living (biotic) and non-living (abiotic) components of ecosystems and their interactions within an ecosystemframework. This science examines how ecosystems work and relates this to their components such as chemicals, bedrock, soil, plants, and animal

6. **Global ecology:** A landscape is a unit of land with a natural boundary having a mosaic of patches. These patches generally represent different ecosystem.Globalecology is the study of the interactions among the Earth's ecosystems, land, atmosphere and oceans. Global ecology is very important because it is used to understand large scale interactions and how they influence the behavior of the entire planet, including the earth's responses to future changes.

7.3.2 DEFINITION OF ECOLOGY

Ecology has been defined variously by different classical and modern ecologists with different viewpoints. The traditional definition of ecology is '*the study of an organism and its environment*` however, different ecologists have defined it variously.

Ernst Haeckel (1869): defined ecology as '*the total relation of the animal to both its organic and its inorganic environment*.

Taylor 1936,: defined ecology as '*the science of all the relations of all organisms to all their environments.*

Charles Elton 1947: in his pioneer book Animal Ecology defined ecology as '*scientific natural history.*

Allee*et all.*1949: Ecology may be defined broadly as '*the science of the inter-relation between living organism and their environments, including both the physical and biotic environments, and emphasizing interspecies as well as intra-species relations.*

G.L Clarke (1954): defined ecology as '*the study of inter-relations of plants and animals with their environment which may include the influences of other plants and animals present as well as those of the physical features'.*

Woodbury (1953): regarded ecology as 'the science which investigates organisms in relation to their environment: a philosophy in which the world of life is interpreted in terms of natural processes.'

Clarke (1954): Ecology is the study of inter-relations of plants and animals with their environment.

Kendeigh (1961): It is the study of animals and plants in their relations to each other and to their environment.

Odum(1963): Ecology is the study of the structure and function of nature.

Misra (1970): In a broad sence, ecology is the study of ecosystems.

C.J.Krebs: Ecology is the scientific study of the interactions that determine the distribution and abundance of organism.

7.3.3 TYPES OF ECOLOGY

1: Habitat ecology- It deals with the study of different habitats of the biosphere. According to the kind of habitat, ecology is subdivided into marine ecology, freshwater ecology, and terrestrial ecology. The terrestrial ecology too is further subdivided into forest ecology, cropland ecology, grassland ecology, etc.

2: Ecosystem ecology-It deals with the analysis of ecosystem from structural and functional point of view including the interrelationship of physical (abiotic) and biological (biotic) components of environment.

3: Community ecology –It deals with the study of the local distribution of animals in various habitats, the recognition and com-position of community units, and succession.

4: Conservation ecology- It deals with methods of proper management of natural resources such as land, water, forests, sea, mines, etc., for the benefit of human beings.

5:Production ecology- It is the modern subdivision of ecology which deals with the gross and net production of different ecosystems such as freshwater, sea water, crop-fields and tries to do proper management of these ecosystems so that maximum yield can be obtained from them.

6: Radiation ecology- It deals with the study of gross effects of radiations and radioactive substances over the environment and living organisms.

7: Taxonomic ecology- it is concerned with the ecology of different taxonomic groups and eventually includes sub division of ecology – plant ecology, insect ecology, invertebrate ecology, vertebrate ecology, microbial ecology and so on.

8: Human ecology-It deals with the study of relationship of man with his environment.

9: Space ecology- It is a modern subdivision of ecology which remains concerned with the development of partially or completely regenerating ecosystems for supporting life of man during long space flights or during extend exploration environments.

10: System ecology- The system ecology is the most modern branch of ecology which is concerned with the analysis and understanding of the function and structure of ecosystem by the use of applied mathematics such as advanced statistical techniques, mathematical models and computer science.

11: Palaeoecology-It is the study of environmental conditions, and life of the past ages, to which palynology, palaeontology, and radioactive dating methods have made significant contribution.

12: Applied ecology- It deals with the application of ecological concepts to human needs and thus, it includes following applications of ecology: wild-life management, range management, forestry, conservation, insect control, epidemiology, animal husbandry, aquaculture, agriculture, horticulture, land use and pollution ecology.

13. Fire ecology: Studies the role of wild land fire in the environment (i.e, how it affects ecosystem processes, etc) and causes for these fires. Some species are fire-adapted while some are fire-dependent and require fire for part of their life cycle. The latter are pyrophytic plants. For instance, lodgepole pine requires the heat of fire to melt the resin on its cone, opening it up and disbursing its seeds. At my undergraduate institution (Humboldt State University) they had a fire lab to study fire ecology.

7.3.4 SIGNIFICANCE OF ECOLOGY

Ecology is about the interactions between organisms, their habitat (home) in nature. And we are all part of the ecosystem, dependent on it for our survival, since in many ways we are just

one more species. But we are also in the unique situation that we can change the ecosystem in many different ways. And understanding what all the effects of changing an ecosystem will be, is important in order to avoid our actions having unintended consequences (like the famine in the Sahel region of Africa being largely because of human changes to the ecosystem). But that is just the part of ecology that has direct consequences for us as humans.

If we want to conserve and protect nature in general and prevent the extinction of species, we need to know how they all fit together, what their habitat requirements are, how they influence each other, what the minimum population sizes are to ensure their survival, etc. So both for managing natural areas, as well as the sustainability of agriculture and our own continuous survival as a species, ecology is important. In the end, without a good knowledge of ecology, all the other fields of study will be useless… an extinct human species will no longer do any science at all.

7.4 BASIC CONCEPTS OF HABITAT

Habitat approach to nature is very important, as it aims to study organisms and non-living thing factors operating there. Thus we become well acquainted with organisms as they grow in different kinds of habitats in nature. Such an approach is mainly descriptive whenwe describe the environmental conditions and organisms present in different type of habitat. There are four major types of habitats in the biosphere- freshwater, marine, estuarine, and terrestrial ecology. The terrestrial ecology too further subdivided into forest ecology, cropland ecology, grassland ecology, etc.

1. Fresh water Habitats:

Fresh water habitats occupy a relatively small portion of earth's surface as compared to marine and terrestrial habitats. But the fresh water habitats are much importance to mankind. Such habitats are of two general types:

1. Standing water or (Lentic ecosystem) - Lentic habitats are represented by the ponds , lake swamps, bog etc.
2. Running water or (lotic ecosystem)-Lotic habitats are those existing in relatively fast running streams, springs, rivers.

The classification of the freshwater environments is based on two conditions: currents and the ratio of the depth to surface area. However, temperature, light, currents, amount of respiratory gases, and concentration of biogenic salts are important limiting factors influencing the organisms of all freshwater.

- **Temperature** in freshwater habitats does not show much range of variations, which is due to several unique thermal properties of water. Although temperature in such habitats shows less variations, it is a major limiting factor in distribution of organisms, as aquatic organisms generally have narrow tolerances i.e. are stenothermal. Temperature of water is measured with the instrument, thermistor. Turbidity of water depends upon the kind and amount of suspended materials, chiefly as silt clay particles and living organisms etc. Turbidity affects the penetration of light (transparency), and thus is important limiting factor in the distribution of organisms.

- **Transparency** (that is directly related to turbidity) of water is generally measured with a very simple instrument called a secchi disk. Current action water, especially in streams, has direct very important effect on the organisms. The current generally affect the distribution of vital gases, salts, and small organisms. Concentrations of respiratory gases O_2 and CO_2 is often limiting factor in such habitats. Their concentration is measured in the terms of D.O. - dissolved oxygen, and B.O.D.- biological oxygen demand etc. **Lentic Community**:

Lentic waters are generally divided into three zones or sub-habitats: littoral, limnetic, and pro fungal. A small pond may consist entirely of littoral zone. However, a deep lake with an abruptly sloping basin may possess an extremely reduced littoral zone.

Lake Zonation: The three major zones of a lake described as follows:

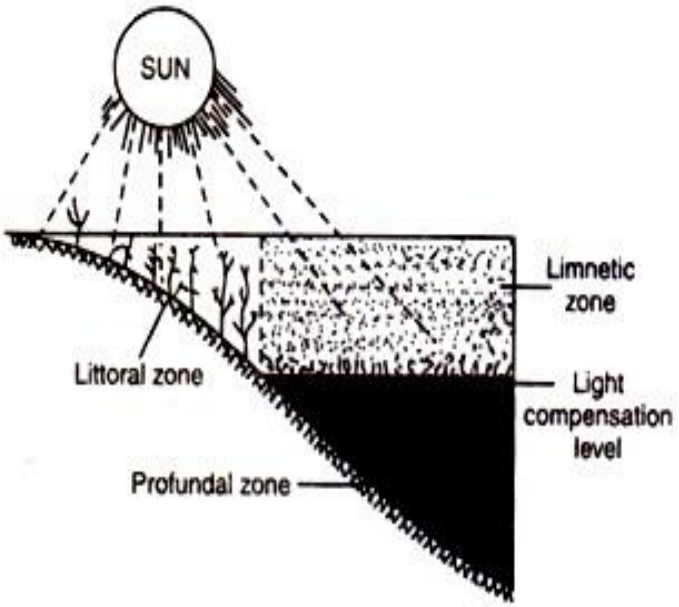

Fig: 7.1 Three Major zones of fresh water lake

(a) Littoral zone:

The littoral zone adjoins the shore (and is thus the home of rooted plants) and extends down to a point called the light compensation level, or the depth at which the rate of photosynthesis equals the rate of respiration. Within the littoral zone producers are of two main types: rooted or benthic plants, and phytoplankton (plant plankton) or floating green plants, which are mostly algae.

The littoral zone is the home of greater variety of consumers than are the other zones. The zooplankton (animal plankton) of the littoral zone is rather characteristic anddiffers from that of the limnetic zone in preponderance of heavier, less buoyant crustacean which often cling to plants or rest on the bottom when not actively moving their appendages. Important groups of littoral zooplankton are large, weak-swimming species of Daphnia and Simocephalus, some species of copepods, many families of ostracods and some rotifers.

The nekton of littoral zone is often rich in species and numbers. Adult and larval diving beetles and various adult Hemipetra are conspicuous. Various Diptera larvae and pupae remain suspended in the water, often near the surface. Pond fish, frogs, turtles, and water snakes are almost exclusively the members of the littoral zone community. Tadpoles of the frogs are important primary consumers, feeding on algae and other plant material.

Periphyton of the littoral zone exhibits a zonation paralleling that of the rooted plants, but many species occur almost throughout the littoral zone. Among the periphyton forms, for example, pond snails, damselfly nymphs and climbing dragonfly nymphs, rotifers, flatworms, bryozoa, hydra, and midge larvae rest on, or are attached to stems and leaves of the plants.

Another group containing both primary and secondary consumers may be found resting or moving on the bottom or beneath silt or plant debris— for example, sprawling odonata nymphs (which have flattened rather than cylindrical bodies), crayfish, isopods, and certain mayfly nymphs. Descending more deeply into the bottom mud are burrowing odonata and ephemeroptera, clams, true worms, snails, chironomids (midges), and other diptera larvae.

(b) Limnetic Zone:

The limnetic zone includes all the waters beyond the littoral zone and down to the light compensation level. The limnetic zone derives its oxygen content from the photosynthetic activity of phytoplankton and from the atmosphere immediately over the lake's surface. The atmospheric source of oxygen becomes significant primarily when there is some surface disturbance of water caused by wind action or human activity.The community of the limnetic zone is composed only of plankton, nekton, and sometimes neuston (organisms resting or swimming on the surface).

Phytoplankton producers consist of diatoms, green algae, blue- green algae, and algae- like green flagellates, chiefly the dinoflagellates. The limnetic zooplankton consists of few species but the number of individuals may be large. Copepods, cladocerans, and rotifers are generally of first importance; but their species are largely different from those found in the littoral zone. The limnetic nekton consists almost entirely offish. In ponds, the fish of the limnetic zone are the same as those of the littoral zone, but in large bodies of water a few species may be restricted to the limnetic zone.

(C) Profundal Zone:

The bottom and deep water area of a lake, which is beyond the depth of effective light penetration, is called the pro-fundal zone. In north-temperate latitudes, where winters are long and severe, this zone has the warmest water (4°C) in the lake in winter and coldest water in summer.

The major community consists of bacteria and fungi and three groups of animal consumers:

(a) Blood worms, or haemoglobin containing chironomid larvae and annelids

(b) Small clams

(c) Phantom larvae, or Chaoborus (corethra)

The first two groups are benthic forms, the last are plankton that regularly move up into the limnetic zone at night and down to the bottom during the day. All the animals of the pro-fundal zone are adapted to withstand periods of low oxygen concentration, whereas many bacteria are anaerobic. Large numbers of bacteria in the bottom ooze constantly bring about decomposition of the organic matter (plant debris, animal remains, and excreta) that accumulates on the bottom.

Eventually the organic sediments are mineralized and nitrogen and phosphorus are put back into circulation in the form of soluble salts. In this way, the pro-fundal zone provides rejuvenated nutrients, which are carried by currents and swimming animals to other zones.

2. Marine Habitats:

The marine habitat is the largest of all habitats. The seas, oceans and bays have occupied about 70% of the earth's surface. The physical features of the marine habitat are relatively stable. All oceans are interconnected .Temperature salinity, and depths are the chief barriers to free movements of marine organisms.

In marine habitat, the most important physical factors as light, temperature, pressure, salinity, tides and currents.

Light:-

Light acts as a very important factor in the life of marine organisms due to its connection with photosynthesis, heating, radiation and vision. It is the amount of light available that determines plant life and in turn affects animal life. Penetration of light is affected by the angle of light rays. Only perpendicular rays reach deeper while slanting rays are reflected. Loss of light by reflection is about 10% and it is only the rest that penetrates.

Light determines diurnal migration of marine organisms. It also regulates color pattern of marine animals. Deep sea fauna exhibit either colorlessness or uniform coloration. It is also related with the development of visual sense organs.

Temperature:-

Ocean is the largest store house of the sun's heat and it occupies much space. Stored heat of the ocean is able to regulate the temperature of the world. Thus it also regulates the terrestrial life. Large amounts of heat reserved by the sea are lost by evaporation and these vapors are condensed over the land masses. Likewise the various tributaries of rivers and streams that merge with the sea cause a variation in the temperature of the oceans.

Temperature gradually drops in seas as depth increases. At certain intermediate depths the fall in temperature exceeds that of the surface waters and deeper water. This is called thermocline and is supposed to occur between 50 and 150 meters depth. Life in the seas has been considerably influenced in the course of evolution by the thermal variation.

Pressure:-

Pressure in the ocean varies from one atmosphere at the surface to 1,000 atmospheres at the greatest depth. Pressure changes are many times greater in the sea than in terrestrial environments and have a pronounce defect on the distribution of life in seas.

Certain organisms are restricted to surface waters where the pressure is not so great, whereas certain organisms are adapted to live at great depths. Some marine organisms like sperm-whale and certain seals can dive to great depths and return to surface without difficulty.

Animals that have a great vertical range in the sea are called eurybathic like many pelycypods. *Natica* extends between 35-225 meters. On the hand animals which are limited to a narrow range of depth are called stenobathic animals. The fish Chimarea and the sanilTurris are Setnobathic.

Salinity:-

Salinity of sea water varies from place to place depending on the amount of inflow of fresh water rivers or melting glaciers or the amount that is concentrated by evaporation.

Salinity of the open ocean at about 300 meters depth is about 3.5%. The salinity in the Mediterranean is 3.95%, while in the Red sea it is 4.6%. Salinity of the sea is due to two elements, sodium and chlorine which account for 80% of the salts in sea. In the sea water cations and the anions are not balanced against each other. As a result sea water is weakly alkaline (pH 8 to 8.3) and strongly buffered. This factor is of much biological significant.

Animals absorb and utilize many substances like Ca, K, Na ,Mg, S, CI etc. they also use in many inorganic materials like Na, Mg, Ca and silica acid to build their bodies. A few animals even use and store rare elements. Strontium sulphate is utilized by some radiolarians. Bromine and iodine are stored by horny corals and vanadium by Ascidians.

3. Estuarine Habitats

Estuarine or Brackish zone is formed in those regions where a river meets a sea. The composition of water in this zone undergoes constant change. The concentration of dissolved substances in such habitats is unstable. At high tides such habitats experience maximum salinity. Salinity decreases during low tide and periods of heavy rain.

The rate of flow of the water or current varies greatly in different estuaries, also in various regions of any one. The constant turnover in the water of estuaries brings about considerable changes in temperature of comparatively short duration. Thus the conditions prevailing in different estuaries vary greatly depending upon topography and other factors.

4. Terrestrial Habitats

Of the three major types of habitats, terrestrial habitat is the most variable. In altitude it ranges from below sea-level (Death-valley) to mountain peaks more than 28,000 feet in height. A considerable variation of temperature is encountered in terrestrial habitat.

The lowest recorded temperature is —60°C and the highest recorded temperature is 60°C in certain deserts. The chemical and physical nature of the soil, sand and surface rocks varies greatly. The amount of moisture or relative humidity and rate of precipitation are extremely variable in different- regions of the globe.

The major subdivisions of the terrestrial habitat are given below:

(i) Tundra:

The arctic region of North America, Europe and Asia is known as Tundra region. This treeless region is characterized by long-cold winter with no or little sunlight. The summer is cool, short and is with long daylight hours. Frosting is very common and may appear at any time in this region.

Soil is never thawed beyond a depth of few inches from the surface. Bogs, marshes and ponds are the common features of this region. Mosses, Lichens and low herbs are the common vegetation. Migrant birds, like water fowls make their summer nesting grounds in the region. Resident birds of North America are Snowy owls and Ptarmigan. Amongst the mammals, Lemmings, Arctic hares, Arctic foxes, Caribou, Musk-oxen and Weasels live in this region. The alpine community on the top of many high mountains of both temperate and tropical region resembles the tundra biomes in many respects. The plant and animal species of tundra and alpine regions are almost identical.

(ii) Taiga:

The broad band just south of the tundra region of Eurasia and North America is known as taiga region. The taiga region in the southern hemisphere is poorly developed because of the absence of land mass. The region bears evergreen coniferous forests.

Climatic condition of this region is represented by bleak winter and cool summer. Precipitation is of moderate type. The summer lasts from three to six months. Red foxes, Lynx, Caribou, few reptiles and birds are found here. Spruce, Firs, Pines and Cedars are the common vegetation.

(iii) Temperate deciduous forest:

This region is characterized by warm summer and cold winter. There is about 40 inches of rainfall throughout the year and the rainfall is uniform throughout the year. The dominant trees of this region bear broad leaves. The leaves are shed in summer and new leaves develop in the following spring.

Beech, Maples, Oaks, Walnuts are the common plants of this region. Deer, Gray foxes, Racoons, flying squirrels, many snakes and amphibia are the major vertebrates present in this region.

(iv) Grass lands:

Large areas in both temperate and tropical regions do not support trees but remain covered with heavy growth of grass. This is because of lack of sufficient moisture. All the grass lands are ecologically similar in appearance.

These grass lands are also known as Steppes, Prairies, and Savannas etc. The rainfall in these regions is usually 12 to 40 inches per year. The rainfall is limited to few weeks in the year. Dominant plants of this region are Blue stem and Grama grasses. Characteristic grass land vertebrates are Bison, Pronghorn antelope, Coyotes, Prairie dogs, Rabbits, Larks, several snakes and lizards.

(v) Deserts:

Deserts occur both in temperate and tropical regions. Precipitation of moisture is the controlling factor in all deserts. The average rainfall in a desert is less than 10 inches per year and that too is very erratic with half or more than half of the annual rainfall occurring in one or two heavy downpour. Summer temperature is very high. The rate of evaporation too is very high.

The plants of the deserts are highly modified for the purpose of conservation of water. The leaves are reduced or absent or modified into thorns. The roots are long and go deep inside the soil. Many plants possess internally spongy tissue collect and store water obtained during rainy season.

Cacti, Yucca are the dominant plants. Kangaroo, rats, Foxes, Coyotes, many lizards, several snakes and toads are the common vertebrates present in the desert.

Deserts may be snowy too. The sage brush area of North America and the Sierra-Cascade mountain system are deserts of this type. The climate in these deserts is very dry. The deserts are hot in summer and cool in winter. Pronghorn antelope, Coyote, ground squirrels and many reptiles are found in these snowy deserts.

(vi) Rain forests:

Abundant rainfall in the tropics, subtropics and few regions in the temperate zone results in the formation of luxuriant vegetation of broad-leaved evergreen trees. Vines, Orchids and Epiphytes are plentiful in these regions. Characteristic vertebrates of these regions are: Monkeys, Sloths, Ant -eaters, Bats, many colourfull birds, frogs and salamanders, turtles and snakes.

A close similarity between terrestrial zonation and the zonations in mountains of high altitude is found. The zonation in a high mountain consists of a number of vegetational belts located various altitudes along a mountain slope.

Temperature and rainfall play a role on the distribution of these vegetational belts. In a high mountain temperature decreases correspondingly at higher altitudes and thus produces communities of both animals and plants located along the slopes similar to more spacious biomes that occupy large areas within certain latitudes from the equator to the poles

7.4.1 ECOLOGICAL NICHE

An ecological niche is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment. Biotic factors are living things, while abiotic factors are nonliving things. It is advantageous for a species to occupy a unique niche in an ecosystem because it reduces the amount of competition for resources that species will encounter.

7.5 SUMMARY

Ecology is a multidisciplinary science. Because of it focused on higher levels of the organization of life on earth and the interrelationship between organisms and their environment. Habitat is the natural abode or locality of an animal, plant or person.It includes all features of the environment in a given locality.

7.6 GLOSSARY

Adaptation: any feature of an organism that substantially improves its ability to survive and leave more offspring. Also, the process of a species' or a population's genetic variability changing due to natural selection in a manner that improves its viability.

Community: an integrated group of living organisms inhabiting a given part of an ecosystem.

Ecosystem: is a dynamic complex of plant, animal and microorganism communities and their abiotic environment, all interacting as a functional unit

Primary Production – The process of converting inorganic energy, such as Sun light, into biological energy, usually glucose.

Niche – A role or position that a creature can role within an ecosystem.

Nutrient cycling – The process through which different elements pass from organism to organism, and are used in different ways or returned to the environment.

Biosphere – The sum of all ecosystems on the planet, acting as one ecosystem.

Population: a group of individuals with common ancestry that is much more likely to mate with one another than with individuals from another such group.

Organism: an individual plant or animal.

Habitat: the natural environment in which an organism normally lives.

7.7 SELF ASSESSMENT QUESTION

1. Write short account of basic concepts of ecology.
2. Define the term ecology?
3. Write short notes on:
   (1) Autecology (2) Synecology (3) Population ecology
4. What is the importance of the study of ecology?
5. Describe various kinds of lake and pond.
6. Write the difference on fresh water habitats and marine water habitats.
7. Write a note on Rain forest and Desert forest.
8. Write an essay on Terrestrial ecology.

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UNIT 8: THE CONCEPT OF BIODIVERSITY, CONSERVATION AND MANAGEMENT

CONTENTS

8.1 OBJECTIVES

Develop the understanding of current global issue such as global warming, pollution, environmental deterioration, loss of biodiversity and climate change and study of the various aspect of conservation biology through the study of protected are network.

8.2 INTRODUCTION

In the present time biodiversity of the organism is the main issue regarding their utility as well as conservation. Diversity of animals, plants and microbial life has been evolving billions of years. As more and more forms of life evolve, replacing some and helping the development of others, the networking of life becomes more encompassing and complicated. The evolving nature of natural organism was the resultant of their diversification. In the same way biodiversity spans the whole spectrum of life from microorganism to plants and animals. In present time there are many causes which are directly or indirectly responsible for the loss of biological organism in order to their flora and fauna. Exact number of exiting species on earth is still unknown. The estimated global species diversity contains approximately 13-14 million species. In which 1.75 species are described so far and many more still being discovered. Today's need to focus on this aspect of life science. And in the same way a lot of conservational programmers and resource management is necessary for the benefit of flora.

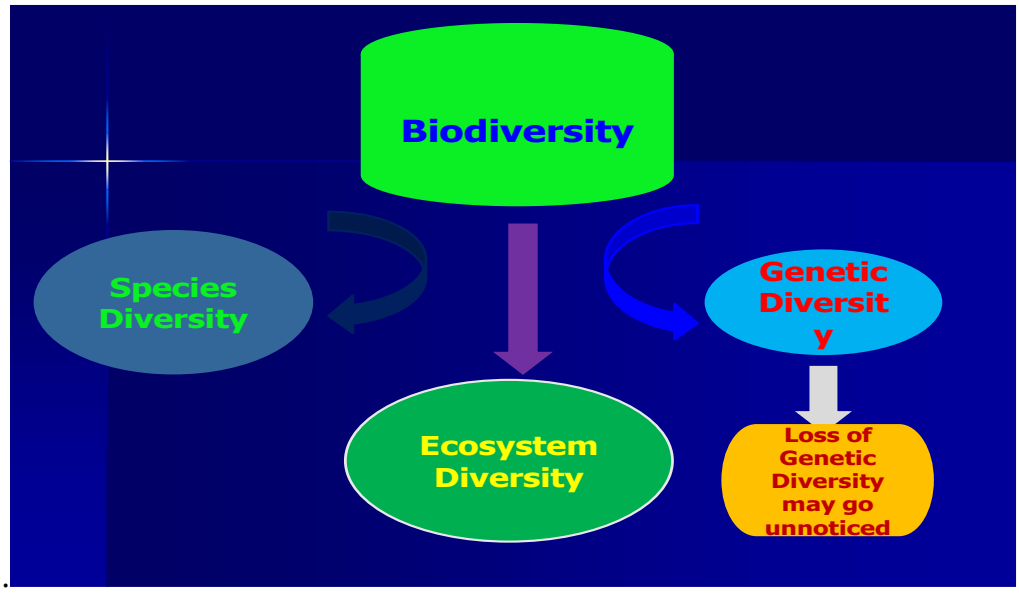

Fig 8.1 Combination of biodiversity

8.3 BASIC CONCEPT OF BIODIVERSITY

8.3.1 DEFINITION OF BIODIVERSITY

Variability of biological organism is called biodiversity. Bio- diversity is interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment. In present time biodiversity of the organism is the main issue regarding their utility as well as conservation. Diversity of animals, plants and microbial life has been evolving billions of years. As more and more forms of life evolve, replacing some and helping the development of others, the networking of life becomes more encompassing and complicated. The evolving nature of natural organism was the resultant of their diversification. In the same way biodiversity spans the whole spectrum of life from microorganism to plants and animals. In fishes morphological variations are the resultant of either environment or genetic or the combination of both. Biological diversity is the fundamental interest of biology in which intraspecific diversity is considered as a component of biological diversity. Biodiversity can be measured in term of species, genes ecosystem. Species diversity can be classified into two type's i.e. interspecific and intraspecific diversity. According to the article 2 of conventions of biodiversity, *Biological diversity"* means the variability among living organisms fromall sources including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.*"Biological resources'* includes genetic resources, organisms or parts of their populations, or any other biotic component of ecosystems with actual or potential use or value for humanity.

8.3.2 TYPES OF BIODIVERSITY (GENETIC, SPECIES & ECOSYSTEM BIODIVERSITY)

Biodiversity can exemplify in term of species, level of genes and at broad level ecosystems.

1) Species diversity is the combination of the different species, as well as the differences within and between different species.
2) Genetic diversity is all the different genes contained in all the living species, including individual plants, animals, fungi, and microorganisms
3) Ecosystem diversity is all the different habitats, biological communities and ecological processes, as well as variation within individual ecosystems.

Genetic Diversity

Simply Genes are the segments of DNA, but their complexity is increases from prokaryotes to eukaryotes. In prokaryotes a set of genes are regulated by single promoters and operator's on the other hand eukaryotic gene is regulated by each promoter and operator. Genes regulated the overall process of organism including morphological traits, physiological traits in combination with the environmental plasticity. Genetic polymorphism has important implications for the conservation and evolution of species. Genetic diversity is blue print of the species in order to their single nucleotide (SNPs) variation. The number of genes is variable in the organism which exhibit by the genome of the organisms. Genetic diversity retains a variety of genetic information of all the individual plants, animals and microorganisms.

Fig 8.2 Total No. of genetic characteristic of a specific species within a population

Simply it is the variation of genes in their promoter region as well as in the coding sequence, with in species and populations. Species evolution is driven by a number of different factors, including migration and settlement in different environments, genetic mutation, natural selection, and genetic drift. The product of these different forces is genetic diversity within a population. The genetic variability in the organism is driven by the many factors as fig2. These factors are crossing over which is the primary source of variation for evolution while the mutation is the ultimate source of evolution. The other factors such as independent segregation of alleles (alleles are the alternative forms of genes), random fertilization. These factors lead to the sexual recombination as resultant genetic reshuffling occurs.

Genetic Variation can be measured by Several Methods

Genetic variation can be measured by the different markers such as single nucleotide polymorphism(SNPs) are the preferred markers for measuring genetic variation, other

markers also have been used for the quantification of genetic variation. Including microsatellites. These are variable number tandem repeat (VNTR) sequences in the genome. VNTRs can be “short” (involving two to five nucleotide repeats) or “long” (involving more substantial repeat sequences). VNTRs are still used in studies today and are especially useful where the candidate gene is known or a specific region is being scanned. Earlier studies used restriction enzymes to identify different VNTRs and SNPs. To determine VNTR genotypes, one or more restriction enzymes that cut the DNA sequence above and below the region encoding the VNTR sequences can be used and DNA fragments of different sizes can be obtained. After digestion with the appropriate enzyme(s), the DNA sample can be run by electrophoresis on either an agarose gel or a polyacrylamide gel to reveal the size(s) of the fragments and thus the number of sequence repeats in each individual sample. Genotypes can be assigned based on the pattern obtained on the gel. This method is known as restriction fragment length polymorphism (RFLP) analysis. RFLP analysis was also used to detect SNPs where the differences in the DNA sequence can be detected by use of restriction enzymes that cut the DNA at a particular sequence encoded by one allele, but not the other. Multiple enzymes were often used when genotyping SNPs in order to obtain readable accurate results. Different enzymes are used to detect different polymorphisms. Later studies substituted RFLP genotyping for more reliable polymerase chain reaction (PCR) genotyping using primers specific for the gene sequence of interest. This method uses a polymerase enzyme purified from the hot-springs “thermophilic” bacteria Thermusaquaticus to amplify multiple copies of the gene sequence. These amplified sequences are then run out on a gel using the same process as that used with RFLP fragments and genotypes can be assigned from the specific banding patterns obtained for each sample.

Species Diversity

Diversification of species is known as species diversity. Species diversity can be measured as either within the species or between the species. Species diversity and genetic diversity are influenced by a complex set of processes across a range of spatial and temporal scales (Huston 1994; Rosenzweig 1995; Hedrick 2000; Frankham et al. 2002) Species diversity can be classified into two types: i.e. Intraspecific and Interspecific diversity. Species diversity

Fig 8.3 Species diversity

also described by the following ways, *Species Richness* – Species richness may defined as the total numbers of species defined in area. Various indices are used including the Mangalet and Menhink index. This refers to the total count/number of species in a defined area. Various indices are used including the Mangalet index and Menhink index.

Species Abundance:-

Species abundance may be defined as the relative numbers among species. If all the species have the same equal abundance, this means that the variation is high hence high diversity,

Taxonomic or phylogenetic diversity - This considers the genetic relationships between the different groups of species. The measures are based on analysis, resulting into a hierarchical classification representing the phylogenetic evolution of the taxa concerned.

Ecosystem Diversity

Ecosystem is the unit of environment. Diversity of organism in relation to ecosystem is considered as ecosystem diversity. This relates to the variety of habitats, biotic communities and ecological processes in the biosphere. The variety of ecosystem found on Earth-the forest, desert, lakes, costal coral and other ecosystem. "Ecosystem"i. e. a dynamic complex of plant, animal and micro-organismal communities and their non-living environment interacting as a functional unit. **(Article 2 of the Convention on Biological Diversity).**The Ecosystem Approach is the primary framework for action under the Convention on Biological Diversity and is defined as a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It isbased on the application of appropriate scientific methodologies focused on levels of

biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognises that humans, with their cultural diversity, are an integral component of ecosystems. This approach will be implemented over time in management practices in relation to key ecosystems. India has very diverse terrestrial and aquatic ecosystems rangingfrom ice-capped Himalayas to deserts, from arid scrub to grassland to wetlands andtropical rainforests, from coral reefs to the deep sea. Each of these comprises a greatvariety of habitats and interactions between and within biotic and abiotic components. Themost diversity-rich are western-ghats and the north-eastern region. A very large number ofspecies found in these ecosystems are **endemic** or found in these areas only in India i.e.they are found nowhere else except in India. The endemics are concentrated mainly innorth-east, western-ghats, north-west Himalaya, and Andaman and Nicobar Islands. About33% of the flowering plants recorded in India are endemic to our country. Indian region isalso notable for endemic fauna. For example, out of recorded vertebrates, 53% freshwaterfish, 60% amphibians, 36% reptiles and 10% mammalian fauna are endemic.

8.3.3 IMPORTANCE OF BIODIVERSITY

Biodiversity has a great importance because it includes a variety of plant, animal life and microorganisms, and the variety of these types of Earth's ecosystems supports life. It supports the survival strategy of human either directly or indirectly. Biodiversity is the very stuff that supports the evolution and differentiation among the varying species. Resource management is an important aspect for proper utilization of resources and energy transfer across the ecosystem. Biodiversity contained ecosystems of forest, grassland, desert marine lake, river, and pond even our aquarium also which retains and supports many organism in term of shelter and food .Nature and its natural things has a great importance. Biodiversity has a direct value in food, agriculture, medicine and in industry also. Biodiversity maintains an ecological balance and continues as evolutionary process.

8.3.4 HOT SPOTS OF BIODIVERSITY

The constant diversity of organism is not throughout across the green planet.Certain regions of the earth are very rich in biodiversity; such biodiversity rich regions are called “mega diversity zones According to him, the hot spots are the richest and the most threatened reservoirs of biodiversity on the earth. The criteria for determining a hot spot are:

A. The area should support >1500 endemic species

B. It must have lost over 70 % of the original habitat

There are thirty four identified hot spots of the world in which four are found in India. These four are Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaland. The endemic species are those species which are confined in a specific geographic area or a particular area The hotpots of the worlds are shown in the Figure no 8.3.

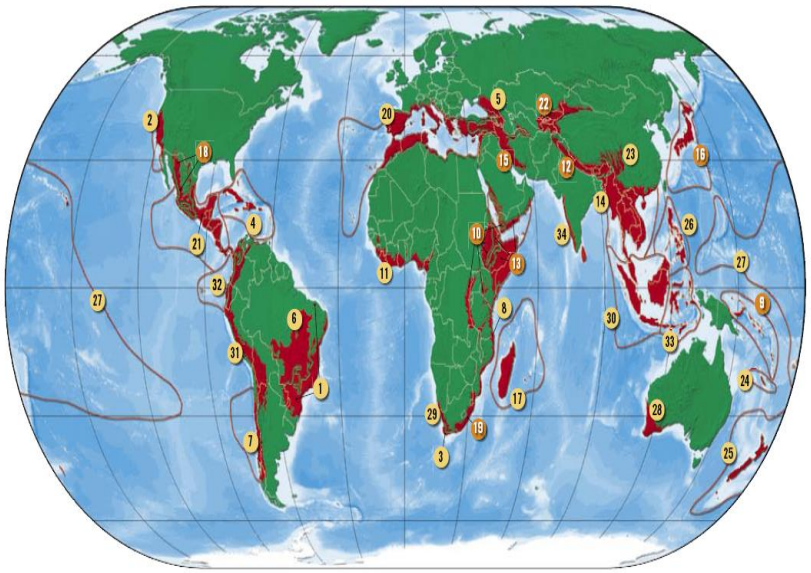

Fig.8.3 Hot –spot area

1) Atlantic Forest
(2) California Floristic Province
(3) Cape Floristic Region
(4) Carribbean Islands
(5) Caucasus
(6) Cerrado
(7) Chilean Winter Rainfall
(8) Valdivian Forest
(9) Coastal Forest of Eastern Africa
(10) East Melanesian Islands
(11) Eastern Afromontane
(12) Guinean Forests of West Africa
(13) Eastern Himalaya
(14) Horn of Africa
(15) Indo Burma
(16) Irano Anatolian
(17) Japan
(18) Madagascar and Indian Ocean Islands
(19) Maderan Pine-oak woodlands
(20) Maputaland-Pondoland Albany
(21) Mediterranean Basin
(22) Mesoamerica
(23)Mountains of central Asia
(24) Mountains of southwest China
(25) Wallace
(26) New celedonia
(27) New Zealand
(28) Philippines
(29) Polynesisa Micronesia
(30) Southwest Australia

(31) Succulent caro (32) Sunderland

(33) Tropical Andes (34) Southwest Australia

Thirty four biodiversity hot spots have been identified in the world. These hot spots are characterized by posing exceptionally high biodiversity. For example the total area of these 25 hot spots cover 1.4% of the total land area, support 44% of plant and 35% terrestrial vertebrates. (Refer to the Fig. 15.3) Among the 25 hot spots of the world, 2 are found in India namely Western Ghats and the eastern Himalayas. These two areas of the country are exceptionally rich in flowering plants, reptiles, amphibians, butterflies and some species of mammals. The eastern Himalayan hot spot extends to the north – eastern India and Bhutan. The temperate forests are found at an altitude of 1780 to 3500 m. Many deep and semi isolated valleys are exceptionally rich in endemic plant species. The Western Ghat region lies parallel to the western coast of Indian peninsula for almost 1600 km, in Maharashtra, Karnataka, Tamil Nadu and Kerala. These forests at low elevation (500 m above mean sea level) are mostly evergreen, while those at 500- 1500 m height are generally semi-evergreen forests.

1. Tropical Andes, 2. Mesoamerica, 3. Caribbean, 4. Brazil's Atlantic Forests, 5. Choco/Darien/Western Ecuad
6. Brazil's Cerrado, 7. Central Chile, 8. California Floristic Province, 9. Madagascar, 10. Eastern Arc & Coastal Fores
of Tanzania/Kenya, 11. West African Forests, 12. Cape Floristic Province, 13. Succulent Karoo, 14. Mediterrane
Basin, 15. Caucasus, 16. Sundland, 17. Wallacea, 18. Philippines, 19. Indo-Burma, 20. South-Central Chir
21. Western Ghats/Sri Lanka, 22. Southwest Australia, 23. New Caledonia, 24. New Zealand, 25. Polynesia/Micrones

Biodiversity hotspots in India

1. Himalaya: Includes the entire Indian Himalayan region.

2. Indo-Burma: Includes entire North-eastern India, except Assam and Andaman group of Islands (and Myanmar, Thailand, Vietnam, Laos, Cambodia and southern China)

3. Sunderland's: Includes Nicobar group of Islands (and Indonesia, Malaysia, Singapore, Brunei, Philippines)

4. Western Ghats and Sri Lanka: Includes entire Western Ghats (and Sri Lanka)

HIMALAYA

The Himalaya Hotspot is the home of the world's highest mountains, including Mt. Everest. The mountains rise abruptly, resulting in a diversity of ecosystems that range from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line. Vascular plants have even been recorded at more than 6,000 m. The hotspot is home to important populations of numerous large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffalo.

INDO-BURMA

Encompassing more than 2 million km² of tropical Asia, Indo-Burma is still revealing its biological treasures. Six large mammal species have been discovered in the last 12 years: the large-antlered muntjac, the Annamitemuntjac, the grey-shanked douc, the Annamite striped rabbit, the leaf deer, and the saola. This hotspot also holds remarkable endemism in freshwater turtle species, most of which are threatened with extinction, due to over-harvesting and extensive habitat loss. Bird life in Indo- Burma is also incredibly diverse, holding almost 1,300 different bird species, including the threatened white-eared night-heron, the grey-crowned crocias, and the orange-necked partridge.

SUNDERALAND

The spectacular flora and fauna of the Sunderland Hotspot are succumbing to the explosive growth of industrial forestry in these islands and to the international animal trade that claims tigers, monkeys, and turtle species for food and medicine in other countries. Populations of the orang-utan, found only in this hotspot, are in dramatic decline. Some of the last refuges of two Southeast Asia rhino species are also found on the islands of Java and Sumatra. Like many tropical areas, the forests are being cleared for commercial uses. Rubber, oil palm, and

pulp production are three of the most detrimental forces facing biodiversity in the Sunderland Hotspot

WESTERN GHATS AND SRI LANKA

Faced with tremendous population pressure, the forests of the Western Ghats and Sri Lanka have been dramatically impacted by the demands for timber and agricultural land. Remaining forests of the Western Ghats are heavily fragmented; in Sri Lanka, only 1.5% of the original forest remains. Population levels are also applying increased stress on the fringes of protected areas where many farms, loggers, and poachers use the resources illegally. Due in part to the varying effect of the yearly monsoons and the high mountain regions, this hotspot is home to a rich endemic assemblage of plants, reptiles, and amphibians. Sir Lanka alone may be home to as many as 140 endemic species of amphibians. The region also houses important populations of Asian Elephants, Indian Tigers, and the Endangered Lion-tailed Macaque. Freshwater fish endemism is extremely high as well, with over 140 native species.

8.3.5 THREATS TO BIODIVERSITY

Losses in biodiversity Today's threats to species and ecosystems are the greatest recorded in recent history and virtually all of them are caused by human mismanagement of biological resources often stimulated by misguided economic policies and faulty institutions. Principal threats to biodiversity A threat by definition refers to any process or event whether natural or human induced that is likely to cause adverse effects upon the status or sustainable use of any component of biological diversity. Habitat alteration / destruction Increased insatiable demand for resources results to land use changes hence loss to genetic diversity, species reduction and increased ecosystem changes such as random population changes, disease outcrops, habitat fragmentation among others resulting in biodiversity losses. Overharvesting/over-exploitation of biological resources. This results when individuals of a particular species are taken at a higher rate than can be sustained by the natural reproductive capacity of the population being harvested.

This can be through hunting, fishing, trade, food gathering etc. Overharvesting will lead to extinction of resources or the biological resources, eventually leading to loss of species. Pollution Chemical or thermal pollution is a threat to biodiversity. Species in habitats are increasingly being harmed by industrial activities and pollution from excessive use of agro-chemicals such as DDT, oil spills, acid precipitation etc. Introduced species / biological invasions This can be intentional or accidental. Species introduced in an ecosystem will cause

changes in the ecosystem. Introduced species are organisms arising in areas/ habitats in which they were previously not native. Such introduced species are usually referred to as biological pollutants. Some of the ecological impacts of the invasion include hybridization, out competition, disruption of original ecosystem, plant pathogenic influences, disease transmission, and disruption of food webs and to some situations extinction. Species may be introduced intentionally for Ornamental concerns; Agriculture; Hunting and spotting activities; Biotechnology for scientific research.

This is of great concern especially when global CO2 increases in the atmosphere resulting to global warming. Most species originate within a very narrow physiological limit; hence nature has a range of tolerance maintained for ecosystem stability. Changes may be gradual or abrupt such that if the limit is exceeded the upper or lower species suffers extinction.

Population As the human population is increasing; there exists insatiable demand for raw materials which is bound to cause changes in biodiversity. It is therefore vital to control human population which will result in biodiversity conservation. Institutional / policy failure Some institutions are created to manage biological resources. However, the institutions/policy fail to internalize the values of biodiversity within the decision making process of their Nations and individuals. Such institutions/policies in place should have a holistic approach towards biodiversity conservation rather than part conservation.

8.3.6 CONSERVATION OF BIODIVERSITY

Conservation of biodiversity is must for ensuring the future generation. Each organism in nature has its specific significance in order to their priority in ecosystem.

This incorporates the preservation, maintenance, sustainable use (conservation), recovery and enhancement of the components of biological diversity, where. Conservation - is the sustainable use of resources and encompasses protection as well as exploitation and Preservation is an aspect of conservation meaning to keep something without altering or changing it. A balance between the environment, development and society results to sustainable development which ensures biodiversity conservation. This is only possible in the presence of good enforced and implemented policies/ conventions, environmental institutions (e.g. NEMA for Kenya) and political stability among others (Figure 1).Conservation measures of biodiversity Ex-situ conservation, Refers to conservation of components of biodiversity outside their natural habitats, e.g. zoos, museums, gene banks, botanic gardens/arboretums; Used for threatened and endangered species to avoid their extinction; also known as captive conservation. In-situ conservation, Refers to conservation of

ecosystems and natural habitats including maintenance and recovery of viable populations of species in their natural habitats.

Convention on biological diversity (CBD) Conservation of biological diversity and sustainable use of its components came into the limelight in 1972 (United Nations Conference on Human Environment; Stockholm). In 1973, UNEP identified conservation of biodiversity as a priority area, hence there was need to get the legal mandate for conservation of world resources. There were negotiations for a legally binding instrument to address biological diversity and its loss to enhance fairness and equity in sharing of the benefits of biodiversity; this led to the opening of the Convention on Biological Diversity in 1992; Rio de Janeiro under the United Nations Conference on Environment and Development (UNCED)/ Earth Summit. The convention was inspired by the growing concern all over the world for sustainable development. The convention objectives were Conservation of the biological diversity; Sustainable use of its components; A fair and equitable sharing of its benefits. This was the first global comprehensive agreement that addressed all the aspects of biological diversity; genetic resources, species diversity and ecosystem diversity. Figure 1, Concept of sustainable development. Biodiversity conservation other international biodiversity conventions and conservation organizations African Convention on Conservation of nature and natural resources. The Ramsar Convention on Wetlands of international importance. International Union for the Conservation of nature (World Conservation Union). Convention on International trade for endangered species (CITES). International Convention for the Protection on birds.

International Board for Plant genetic resources. World Resources Institute. World Wide Fund for Nature. Convention on Conservation of migratory species of wild animals. International Convention for the Regulation of whaling. UNESCO programme on Man and biosphere. Existing Measures for Conserving Biodiversity in Kenya Zoological gardens - These are refuge areas for rare animals that could disappear without captive breeding e.g. zoos and aquariums. They are conservation areas for preservation of genetic stocks for re-introduction to the wild when conditions become favourable. They are also used for educational and scientific research. Botanical gardens/Arboretums - These are areas for research and exhibition of plants, documentation of local flora, preserving samples of rare and endangered species and maintenance of specimen collections for future use. It acts like a museum for plants e.g. the East African Botanical Garden in Nairobi. Seed banks - Ex-Situ approach where storage of conservation materials in form of seeds is monitored with regard to viability through germination tests and purity analysis. The objective is to ensure that genetic

continuity is maintained. National parks and game reserves - These are different from zoological gardens and are established on terrestrial and aquatic ecosystems with the objective to preserve wildlife that cannot co-exist with human beings and human activities. National parks are under the jurisdiction of central government while game reserves are managed by the local county council.

8.4 PRINCIPLES WILDLIFE

Protected Area Network in India India is one of the 17 mega diverse countries of the world. With only 2.4% of the world's land area, 16.7% of the world's human population and 18% livestock, it contributes about 8% of the known global biodiversity, however, putting enormous demands on our natural resources. India is home to world's largest wild tigers population and has got unique assemblage of globally important endangered species like Asiatic lion, Asian Elephant, One-horned Rhinoceros, Gangetic River Dolphin, Snow Leopard, Kashmir Stag, Dugong, Gharial, Great Indian Bustard, Lion Tailed Macaque etc. Protected Area Network in India: A National Board for Wildlife (NBWL), chaired by the Prime Minister of India provides for policy framework for wildlife conservation in the country. The National Wildlife Action Plan (2002-2016) was adopted in 2002, emphasizing the people's participation and their support for wildlife conservation.

India's conservation planning is based on the philosophy of identifying and protecting representative wild habitats across all the ecosystems. The Indian Constitution entails the subject of forests and wildlife in the Concurrent list. The Federal Ministry acts as a guiding torch dealing with the policies and planning on wildlife conservation, while the provincial Forest Departments are vested with the responsibility of implementation of national policies and plans. A network of 668 Protected Areas (PAs) has been established, extending over 1,61,221.57 sq. kms. (4.90% of total geographic area), comprising 102 National Parks, 515 Wildlife Sanctuaries, 47 Conservation Reserves and 4 Community Reserves. The State/Union Territory wise details of PAs in the country with year of notification and area is given at Annexure-I. 39 Tiger Reserves (Annexure-II) and 28 Elephant Reserves (Annexure-III) have been designated for species specific management of tiger and elephant habitats. UNESCO has designated 5 Protected Areas as World Heritage Sites.

As the ecosystems and species do not recognise political borders, the concept of Transboundary Protected Areas has been initiated for coordinated conservation of ecological

units and corridors with bilateral and/or multilateral cooperation of the neighbouring nations. There are 4 categories of the Protected Areas viz, National Parks, Sanctuaries, Conservation Reserves and Community Reserves. Sanctuary is an area which is of adequate ecological, faunal, floral, geomorphological, natural or zoological significance.

The Sanctuary is declared for the purpose of protecting, propagating or developing wildlife or its environment. Certain rights of people living inside the Sanctuary could be permitted. Further, during the settlement of claims, before finally notifying the Sanctuary, the Collector may, in consultation with the Chief Wildlife Warden, allow the continuation of any right of any person in or over any land within the limits of the Sanctuary. National Park is an area having adequate ecological, faunal, floral, geomorphological, natural or zoological significance. The National Park is declared for the purpose of protecting, propagating or developing wildlife or its environment, like that of a Sanctuary.

The difference between a Sanctuary and a National Park mainly lies in the vesting of rights of people living inside. Unlike a Sanctuary, where certain rights can be allowed, in a National Park, no rights are allowed. No grazing of any livestock shall also be permitted inside a National Park while in a Sanctuary, the Chief Wildlife Warden may regulate, control or prohibit it. In addition, while any removal or exploitation of wildlife or forest produce from a Sanctuary requires the recommendation of the State Board for Wildlife, removal etc., from a National Park requires recommendation of the National Board for Wildlife (However, as per orders of Hon'ble Supreme Court dated 9th May 2002 in Writ Petition (Civil) No. 337 of 1995, such removal/ exploitation from a Sanctuary also requires recommendation of the Standing Committee of National Board for Wildlife).

Conservation Reserves can be declared by the State Governments in any area owned by the Government, particularly the areas adjacent to National Parks and Sanctuaries and those areas which link one Protected Area with another. Such declaration should be made after having consultations with the local communities. Conservation Reserves are declared for the purpose of protecting landscapes, seascapes, flora and fauna and their habitat. The rights of people living inside a Conservation Reserve are not affected. Community Reserves can be declared by the State Government in any private or community land, not comprised within a National Park, Sanctuary or a Conservation Reserve, where an individual or a community has volunteered to conserve wildlife and its habitat. Community Reserves are declared for the purpose of protecting fauna, flora and traditional or cultural conservation values and practices. As in the case of a Conservation Reserve, the rights of people living inside a

Community Reserve are not affected. Regulations/ laws relating to Protected Areas (PAs): The PAs are constituted and governed under the provisions of the Wild Life (Protection) Act, 1972, which has been amended from time to time, with the changing ground realities concerning wildlife crime control and PAs management. Implementation of this Act is further complemented by other Acts viz. Indian Forest Act, 1927, Forest (Conservation) Act, 1980, Environment (Protection) Act, 1986 and Biological Diversity Act, 2002 and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. The Wildlife Crime Control Bureau of the Central Government supplements the efforts of provincial governments in wildlife crime control through enforcement of CITES and control of wildlife crimes having cross-border, interstate and international ramifications. In order to strengthen and synergise global wildlife conservation efforts, India is a party to major international conventions viz. Convention on International Trade in Endangered Species of wild fauna and flora (CITES), International Union for Conservation of Nature (IUCN), International Convention for the Regulation of Whaling, UNESCO-World Heritage Committee and Convention on Migratory Species (CMS). Main issues concerning the management of Protected Areas.

Wildlife conservation and management in India is currently facing a myriad of complex challenges that are both ecological and social in nature. Issues such as habitat loss/fragmentation, overuse of biomass resources in the context of biotic pressures, increasing human-wildlife conflicts, livelihood dependence on forests and wildlife resources, poaching and illegal trade in wildlife parts and products, need for maintaining a broad base of public support for wildlife conservation exemplify and characterize the contemporary wildlife conservation scenario in India. The government and the civil society are taking several measures to address these issues. Improved synergies and better coordination amongst the wide array of stakeholders are needed to meet the challenges of conserving India's diverse wilderness resources.

8.4.1 PROTECTED AREAS

Protected Areas of India from 2000 to 2017 (as on January, 2017)

Year	No. of National	Area Under National	No. of Wild Life	Area Under Wild	No. of Community	Area Under Commu	No. of Conservation	Area Under Conserva	No. of Protected	Total Area under

	Parks	nal Parks	Sanctuaries	Life Sanctuaries	Reserves	nity Reserves	Reserves	tion Reserves	Areas	Protected Areas
2000	89	37593.94	489	117881.68	-	-	-	-	578	155475.63
2006	96	38183.01	506	120244.39	-	-	4	42.87	606	158470.27
2007	98	38219.72	510	120543.95	4	20.69	7	94.82	619	158879.19
2008	99	39232.58	513	122138.33	4	20.69	45	1259.84	661	162651.45
2009	99	39232.58	513	122138.33	4	20.69	45	1259.84	661	162651.45
2010	102	40074.46	516	122585.56	4	20.69	47	1382.28	669	164062.99
2011	102	40074.46	517	122615.94	4	20.69	52	1801.29	675	164512.37
2012	102	40074.46	524	123548.33	4	20.69	56	1998.15	686	165641.62
2013	102	40074.46	526	124234.52	4	20.69	57	2017.94	689	166347.6
2014	103	40332.89	525	116254.36	4	20.69	60	2037.11	692	158645.05
2015	103	40500.13	531	117607.72	26	46.93	66	2344.53	726	160499.31
2016	103	40500.13	537	118005.30	26	46.93	67	2349.38	733	160901.74
2017	103	40500.13	537	118005.33	26	46.93	67	2349.38	733	160901.77

Source: National Wildlife Database Cell, Wildlife Institute of India

8.5 REFERNCES

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2. Kenya Electricity Generating Co., Ltd. GEOTHERMAL TRAINING PROGRAMME Geothermal Development Company BIODIVERSITY CONSERVATION Thecla M.

3. Mutia Geothermal Development Company Limited P.O. Box 100746-00101, Nairobi KENYRelated Links

UNIT 9: ENVIRONMENTAL POLLUTION AND MANAGEMENT

CONTENTS

9.1 OBJECTIVES

After reading this unit the readers will be able to:

- Define Environmental Pollution
- Discuss the sources, effects and control of Air pollution
- Discuss the sources, effects and control of water pollution
- Discuss the sources, effects and control of Noise pollution
- Discuss the sources, effects and control of soil pollution
- Explain the Biodegradable and Non-biodegradable pollutants
- What is Biomagnifications?
- What is Bioremediation?

9.2 INTRODUCTION

The word Environment has been taken from French word "environ" which means "surrounding". Fundamentally, our environment is composed of atmosphere, earth, water space, plants, animals and microbes. In the absence of pollution, it remains clean and habitable for millions of species. Environmental pollution is one of the biggest issue of the globe and many components of environment being polluted due to different types of anthropogenic or manmade activities. These activities include industrialization, urbanization, construction, transportation, poor agricultural practices, navigation etc. Such activities, although important for human development and welfare, lead to generation and release of objectionable materials into the environment thus become polluted.

However, in order to keep pace with the rapid industrialization world over, a developing country like India cannot afford to prevent its industrial growth. But, it is necessary to undertake pollution control measures, so as to enable us to keep our environment as clean as possible. In this unit you will learn about sources, effects and control of different forms of environmental pollution, biodegradable and non-biodegradable pollutants, biomagnifications and bioremediation.

9.3 ENVIRONMENTAL POLLUTION AND MANAGEMENT

THE WORD "POLLUTION" HAS BEEN TAKEN FROM the Latin word *Pollutionem* which means "defile" or "make dirty".

Definitions of Environmental Pollution

- According to National Academy of Science, USA (1966) "An undesirable change in physical, chemical and biological characteristics of water, air and soil that may harmfully affect human, animal and plant life, industrial progress, living conditions and cultural assets."
- According to Odum (1971) "Pollution is an undesirable change in physical, chemical and biological characteristics of air, water and soil that may harmfully affect the life or create a potential health hazard for living organisms".
- According to Edward (1972) "Pollution is the release of harmful substances into the environment by man in quantities that damage health and resources".
- According to Tiasmann (1975) "Pollution is the accumulation of substances in the environment which exceed the capacity of the eco-system to either neutralise or disperse them to harmful levels".

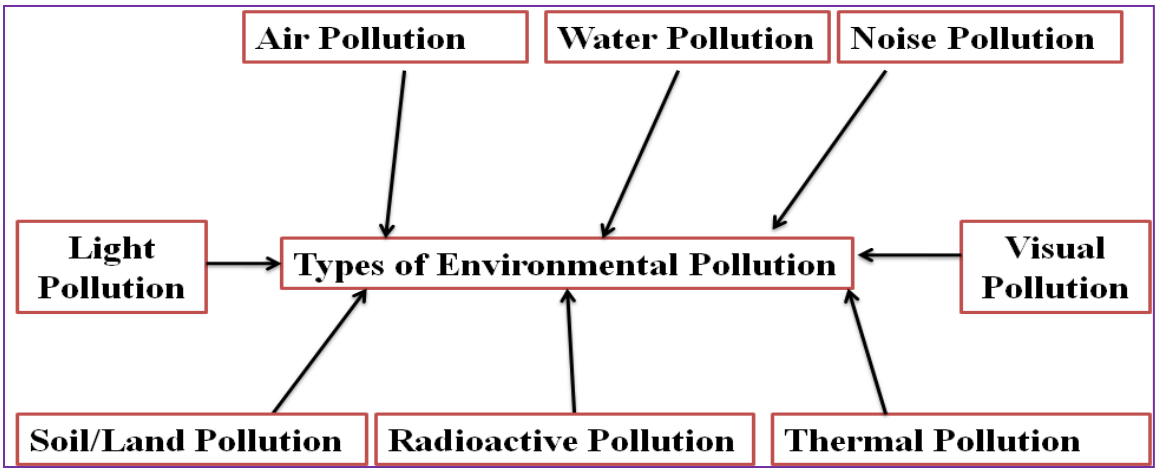

Fig.9.1 showing different forms of Environmental Pollution

9.3.1AIR POLLUTION

A physical, biological or chemical alteration to the air in the atmosphere can be termed as **air pollution**. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive.

Physical Parameters of Air:

a. Visibility
b. Temperature
c. Humidity
d. Suspended Particulate Matter (SPM)
e. Respirable Suspended Particulate Matter (RSPM)
f. Wind Velocity

Chemical parameters of Air:

a. Carbon Mono Oxide (CO)

b. Ozone (O_3)
c. Oxides of nitrate
d. Oxides of sulphur
e. Heavy metals
f. Ammonia
g. Hydrocarbons

Biological Properties of Air

a. Bacteria and other microbes

SOURCES OF AIR POLLUTION: There are mainly two types of sources of air pollution and these are described below:

1. **NATURAL SOURCES:** These sources produce naturally and these are responsible for air pollution. However, these sources are comparably less harmful as compared to anthropogenic sources. Some of the important natural sources of air pollution are given below:

I. **Volcanic eruption:** Volcanic eruption is responsible for release harmful gases such as CO_2, SO_2, H_2S etc. in atmosphere. These gases are responsible for global warming and formation of acid rain. Acid rain not only damages property like cars and buildings but also pollutes the water. These harmful gases may travel 10 kilometres into the air and then blow hundreds of kilometres away from the site of the volcano to affect air quality. This cloud of volcanic gases settles over the land like smog, and called **"volcanic smog."** These gases are responsible for irritation in eyes, skin or lungs diseases in people.

II. **Forest Fire:** Forest fire is another natural cause of air pollution which releases certain amount of pollutants in the atmosphere. RSPM and SPM generally increase due to the forest or wildfires.

III. **Natural organic decay:** It is another form of natural source of air pollution. Organic decay is responsible for release many harmful gases such as **methane (Marsh gas)** and **ammonia** in atmosphere which cause air pollution. These gases make unpleasant environment in surrounding area.

IV. **Biological agents:** Pollens are important for reproduction in plants but some noxious species of certain plants cause air pollution. These toxic species cause eye irritation, skin diseases, and respiratory problems in human being. Some fungal spores are also cause air pollution.

2. **ANTHROPOGENIC OR MANMADE SOURCES:** These sources produce by human activities and cause air pollution. Some of the important anthropogenic sources of air pollution are given below:

I. **Transportation/Vehicular Emission:** Vehicular emission is major contributor of air pollution. This type of emission release many harmful air pollutants such as carbon mono oxide, sulphur di oxides, benzene, acetaldehyde etc in to the atmosphere. Pollution emitting from vehicles including trucks, jeeps, cars, trains, airplanes cause immense amount of air pollution. As we know that we depend on fuel to fulfill our daily basic needs of transportation. But, there overuse is major source of air pollution. Carbon Monooxide caused by improper or incomplete combustion and generally emitted from vehicles is another major pollutant.

II. **Fuel combustion:** Toxic gases such as **s**ulfur dioxide emitted from the combustion of fossil fuels like coal, petroleum and other factory combustibles is one the major cause of air pollution.

III. **Industrialization:** Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the air quality. Manufacturing industries can be found at every corner of the earth and there is no area that has not been affected by industrial emission. Petroleum refineries also release hydrocarbons and various other chemicals that cause air pollution.

IV. **Deforestation:** As you know that plants are absorbers of many pollutants from atmosphere, hydrosphere and lithosphere. Carbon dioxide is one of the greenhouse gases that help to hold heat in the atmosphere and trees remove some of this carbon dioxide from the air through photosynthesis and store that carbon in their tissues and in the soil. This process is known as **carbon sequestration**.

V. **Agriculture activities:** Agricultural practices release the various harmful gases such as ammonia in atmosphere which is a very common by product from agriculture related activities and is one of the most hazardous gases in the atmosphere. Excessive use of insecticides, pesticides and fertilizers in agricultural activities has grown at tremendous rate, these are also responsible for air pollution.

VI. **Mining operations:** Mining is a process in which minerals below the earth are extracted by using large equipments. During the process dust and chemicals are released in the air causing massive air pollution. This is also important reason which is responsible for the deteriorating air quality.

Effects of Air Pollution:

1. Respiratory and heart problems: The effects of Air pollution are very dangerous. Air pollution is responsible for respiratory disorder & heart problems. Several millions are known to have died due to direct or indirect effects of Air pollution. Air pollution may leads to asthma, pulmonary diseases, cardiovascular disease, neurological disease, skin problems, lung diseases, muscles fatigue. Various air pollutants and their effects on human being also given in table-1.

2. Global warming: Air pollution is directly responsible for global warming. Air pollution introduces many harmful gases such as CO_2, Nitrous Oxide, methane etc in atmosphere which ultimately leads in to global warming. As you know that Global warming is increase average temperature of earth, which leads in to certain problems such as sea level rise, melting of glaciers, droughts, change in weather etc.

3. Acid Rain: During burning of fossil fuels various harmful gases such as **nitrous oxides** and **sulphur oxides** released in to the atmosphere. The droplets of water react with these gases and forms **sulphuric acid** and **nitric acid** and lead in to acid rain. Acid rain can cause great damage to aquatic life, human beings, buildings as well as crops.

SO_2 (Sulphur Di Oxides) $+H_2O \longrightarrow H_2SO_4$ (Sulphuric Acid)

NO_2 (Nitrous Oxide) $+H_2O \longrightarrow HNO_3$ (Nitric Acid)

4. Effect on Wildlife: Toxic chemicals present in the atmosphere can force wildlife species to move a new place and change their habitat.

5. Ozone layer depletion: Ozone layer also depleting by different air pollutants. Ozone layer exists in stratosphere of atmosphere and protects life from harmful Ultra violet rays. This layer is depleting due to release of chloroflorocarbons and hydro-chlorofluorocarbons in atmosphere which ultimately leads in to different types of skin cancer in human being and other animals.

Table-1 Important Air pollutants, their sources and effects on human health

Name of Pollutants	Main Source	Effects	Types
Carbon mono oxide (CO)	Fuel combustion from vehicles and engine	Oxygen deficiency in body, aggravates heart diseases, chest pain	Primary Pollutant
Lead (Pb)	Metal refineries, metal	Damage in Nervous system,	Primary Pollutants

	industries, waste incineration (combustion), battery manufacturing industries	IQ loss, memory loss, renal effects, cardiovascular diseases.	
Nitrogen Dioxide (NO_2)	Fuel combustion, wood burning, Industrial emission	worsen lung diseases leading to respiratory problems	Primary Pollutants
Sulphur Di Oxide (SO_2)	Fuel combustion and Volcanoes, Industrial emission	Ashtma	Primary Pollutants
Volatile organic compounds VOCs)	incomplete combustion and industrial sources	Lung Problems	Primary Pollutants
Particulate matter	Dust, ash, salt particles, Sand storm	Lung Problems	Primary Pollutants
Ground level Ozone (O_3) (Harmful only in troposphere)	Formed by chemical reaction of volatile organic compounds and NOx in the presence of sunlight	Decrease lung function, coughing, shortness of breath, asthma.	Secondary Pollutants
Per Oxy Acyl Nitrates (PAN)	By the reaction of Nitrate, hydrocarbons with oxygen in presence of light	Powerful respiratory and eye irritant	Secondary Pollutants

in india worst effect of air pollution has been notice in 1984.a leakage of the killer gas, methyl isocynate, affect bhopal (m.p) in the early morning hours of december 3, 1984 & caused over 2500 death besides affecting 100000 peoples.

types of pollutants: on the basis of emission, pollutants may be categorized as two types which are described below:

Primary Pollutants: These pollutants directly emitted from the sources. classic examples of primary pollutants are sulphur-dioxide, nitrous oxide, co. co_2 because they are directly emitted from the industries.

Secondary pollutants: these pollutants are formed by the inter mingling and reactions of primary pollutants. Some examples of secondary pollutants are: peroxyacylnitrates (pan) ozone (o_3), sulphuric acid, nitric acid.

CONTROL OF AIR POLLUTION:-

1. **Use Public Mode of Transportation:** As you know that vehicular emission is major source of air pollution. In many cities millions of vehicles running on the roads and emitted harmful gases. If we use public transport instead of personal vehicles we can minimize the air pollution significantly.
2. **Regular services of Vehicles:** Automobile engines should be redesigned in such a way that their emissions cause minimum pollution. Old automobile engines should be replaced by new ones. People should be encouraged to share the vehicle, and to avoid vehicles for short distances.
3. Set up the industrial area away from residential area
4. Stack of the industries should set up as high as possible
5. Follow the concept of reduce, reuse and recycle: As you know that burning of solid waste release various harmful gases in atmosphere. If we can follow the 3R concept which is Reduce, Reuse and Recycle then we can minimize the air pollution.

5. Plantation: As you know that forests are great absorbers of air pollutants therefore, forest cover should be protected. Sufficient forest cover is essential for maintaining the quality of air. Green belts should be created specially near the roads and industries. There should be strict restriction for establishment of large buildings and industries along the Green belt areas.

6. Follow the rules and regulations prescribed by government for air quality.

7. Advanced research should be done on air quality at regular basis.

8. Public awareness

9.3.2 WATER POLLUTION

Water is one of the most important constituents of life support system. It is an essential ingredient of animal and plant life. Different human activities, like **industrial, domestic, agricultural activities etc.** are responsible for water pollution. The major sources of water pollution are domestic waste from urban and rural areas, and industrial wastes which are discharged into natural water bodies. According to the report of World Health Organization (WHO) about Five million people die annually from water-borne diseases**.**

Physical Properties of water

1. Temperature
2. Turbidity
3. Transparency
4. Total solids
5. Total dissolved solids

6. Total suspended solids
7. Conductivity

Chemical Properties of water

1. Dissolved oxygen
2. pH
3. Bio-chemical oxygen demand
4. Chlorides
5. Total Hardness
6. Calcium
7. Magnesium
8. Heavy metals

Biological properties of water

1. Bacteria
2. Microorganisms

Water pollution is any undesirable changes in, physical, chemical or biological properties in the quality of water that has a harmful effect on any living thing that consume or lives in it. When humans drink polluted water it often has serious effects on their health.

SOURCES OF WATER POLLUTION

There are different source of water pollution in which some of the pollutant may expose human beings and other lives to series problem. Some of the important sources of water pollution are given below:

1. **Domestic sewage:** Domestic sewage is one of the major causes of water pollution special in the riverine ecosystems of earth. Sewage cause low DO contents and high BOD in aquatic ecosystem. Sewage contaminates water with pathogens causing degradation of sewage take up most of the oxygen present dissolved in water. Detergents present in sewage degrade very slowly and therefore, these accumulate and render the water unfit for human and animal use. The phosphates present in detergents further stimulate algal growth that adds to the organic loading of water, which ultimately cause eutrophication like condition in lake or ponds.
2. **Industrial effluents:** Industrial effluent content high concentration of heavy metals such as Arsenic (As), cadmium (Cd), mercury (Hg), chromium (Cr) and lead (Pb) which ultimately leads in to different types of diseases such as minamata disease (Hg) and itai itai (Cd) etc. These heavy metals generally present in industrial effluent are describe below:

i) Mercury (Hg): It is released by combustion of coal, smelting of metallic ores, chloralkali, paper and paint industries. Mercury is persistent. Methyl mercury was responsible for famous **Minamata disease** in which mercury was accumulated in the tissue of shellfishes and fishes

in Minamata Bay (Japan) and when these fishes eaten by local population, resulted in mercury poisoning. Mercury poison is responsible for kidney disorder (damage).

(ii) Lead (Pb): The sources of lead are smelters, battery, industry, paint, chemical and pesticide industries, automobiles etc. It is mutagenic and causes anaemia, headache, and bluish lines round the gums.

(iii) Cadmium: It shows biological amplification and accumulates inside kidneys, liver, pancreas and spleen. It causes renal damage, emphysema, hypertension, testicular necrosis and damage to placenta. **Itai itai** disease was happened due to exposure of cadmium.

3. **Poor agricultural practices:** It includes use of pesticides, harmful chemicals, fertilizers etc. These chemicals are certainly harmful to the human beings and other biota of aquatic reservoirs. Agricultural practices also responsible for releasing high quantity of nitrates and phosphates in aquatic ecosystem which cause eutrophication.
4. **Release of Solid waste:** Million tons of solid waste either dumped in the peripheral zone of aquatic bodies or directly in the aquatic bodies which cause high bio-chemical oxygen demand, low dissolved oxygen high turbidity, high total solids and high total dissolved solids.
5. **Improper fishing methods:** Many fishermen use toxic chemicals such as bleaching powder to harvest the fishes. These toxic chemicals not only harmful to aquatic plants and animals but also responsible for water pollution.
6. **Oil Spills:** Oil spill is the release of a liquid petroleum hydrocarbon into the aquatic ecosystem especially in marine ecosystem where navigation takes place. It is also decrease the dissolved oxygen and reduce water quality in aquatic environment.

Effect Of Water Pollution:

- Polluted water from pesticides, insecticides causes reproductive damage within animals especially in wild animals.
- Sewage, fertilizer, and agricultural run-off contain organic materials that when discharged into waters increase the growth of algae, which causes the depletion of oxygen and cause eutrophication. Various valuable species of fishes cannot survive in low oxygen content.
- Water pollution causes skin rashes, cancer, reproductive problems, typhoid fever and stomach sickness in humans.

- Oil spills in the water causes animal to die when they ingest it. Oil does not dissolve in water so it causes suffocation in aquatic ecosystem. Many species of birds and fishes going threatened due to oil spills.

Table-2: Important water pollutants and their effect on human health

Name of Chemical	**Formula /Symbol**	**Atomic Number**	**Health Impacts on Human**	**Environmental Impacts**
Arsenic	As	33	Headach, confusion, diarrhea, changing the function of about 200 enzymes in body, Cancer (in Skin, lung, liver, kidneys), arsenicosis	
Cadmium	Cd	48	Improper functioning of liver and kidneys, Osteomalacia (softening of bones), Osteoporosis (loss of mineral density in bones), Itai Itai disease	
Mercury	Hg	80	Muscles weakness, Falconi syndrome (improper function of Kideny), Minamata Disease. Neurological and gastrointestinal disorders.	
Chromium	Cr	24	Renal effect, liver effect, Mutagenic effects	
Nitrates	NO_3		Difficulty breathing, Nausea, diarrhea, vomiting,	Eutrophication
Phosphates	PO43		Nausea, vomiting, diarrhea	Eutrophication

Eutrophication: The word “Eutrophication” has been taken from Greek word, Eutrophia in which Eu=well and Traphein = Nourish. It is also called hyper-trophication. Eutrophication means enrichment of nutrient in aquatic bodies such as streams and lakes. The enrichment is often increased by human activities such as agriculture, sewage discharge. Eutrophication is mainly caused by addition of nitrates and phosphates in aquatic bodies.

Eutrophication may lead in to following situations in aquatic body.

1. High level of nitrates and phosphates in aquatic body.
2. Formation of algal bloom and increased biomass of phytoplankton
3. High turbidity (Haziness of water)
4. Low transparency (Sun light cannot penetrate)
5. Loss of biodiversity
6. Low Dissolved oxygen contents
7. High Bio-chemical oxygen demand
8. Low process of Photosynthesis
9. Toxic or inedible phytoplankton species
10. Loss of desirable fish species

CONTROL OF WATER POLLUTION:-

The various methods for the control of water pollution are discussed below:

1. The sewage and industrial effluents should be treated before release in to aquatic bodies. Generally, sewage or industrial waste treat by the three general processes in first step which is called primary treatment or mechanical treatment (In this treatment large size of solid waste separated from the polluted water through sieve), in secondary treatment which is also called biological treatment certain bacteria or microbes used to degrade the remaining organic matter. In tertiary treatment which is also called chemical treatment, certain chemicals such as chlorine, NaOH, CO_2, are used to improve water quality.

2. Use of biofertilizers and biopesticides instead of chemical fertilizers and chemical pesticides.

3. Thermal pollution can be prevented by techniques like cooling, cooling ponds, evaporative or wet cooling towers and dry cooling towers.

4. Promote techniques like phytoremediation, myco-remediation, bacterial remediation and compost bioremediation to reduce water pollution. We will discuss these points in chapter i.e. bioremediation

5. Plants are also important to reduce water pollution. Plants like Water hyacinth popularly known as Kaloli and Jalkumbhi can purify water polluted by biological and chemical wastes.

6. Plants should be developed in the peripheral region of river, streams and other aquatic bodies.

7. Minimize the generation of solid waste in and around the water bodies.

8. General awareness among one and all.

9. Follow the rules and regulations prescribed by Government.

9.3.3 NOISE POLLUTION

As we know that we cannot communicate without sound. Sound is vibrations that travel through the air and can be heard when they reach ear of individual. Noise is unwanted Sound. The word "noise" is derived from the Latin word "nausea," which means feeling sickness at the stomach with an urge to vomit. Literally Noise means “Unwanted or unpleasant sound”. The noise of sound measurement is called decibels (dB). The frequency or amount of air pressure change vibration is measured in Hertz therefore; unit of sound frequency is hertz (Hz). Generally Sound level meter is used to analyze the sound or noise pollution. The normal range of human hearing is from 0 to 100 dB (A), before sound becomes uncomfortably loud. Human ear is able to hear sounds with frequencies from 20 Hz to 20,000 Hz.

SOURCES OF NOISE POLLUTION:-

(i) **Industrial Sources:** It is primary source of noise pollution in industrial area. Various industries such as: textile mills, printing presses, engineering establishments etc. contribute heavily in the noise pollution.

(ii) **Transportation/ Vehicles:** Automobile revolution in urban centers has proved to be a big source of noise pollution. Increasing traffic has given rise to traffic jams in congested areas where the repeated hooting of horns. Noise from airplanes constitutes an increasing serious problem in big cities. Airport situated in the vicinity of population centers and the air planes pass over residential areas.

(iii) **Domestic noise:** The household is an industry in itself and is a source of many indoor noises such as the, noise of playing children, crying of infants, moving of furniture, loud conversation of the inhabitants, constructional activities etc. Besides these are the entertainment equipment in the house, namely the radio, record-players and television sets. Domestic gadgets like the mixer-grinders,

pressure cookers, desert coolers, air- conditioners, exhaust fans, vacuum cleaners, sewing and washing machines are all indoor sources of noise pollution.

(iv) **Celebration of social/religious functions:** In India people need only the slightest of an excuse for using loud speakers. The reason may be a religious function, birth, marriage, elections, demonstration, or just commercial advertising. Therefore, these contribute towards noise pollution.

(v) **Agricultural Machines:** Tractors, thrashers, harvesters, tube wells, powered tillers etc. have all made agriculture highly mechanical but at the same time highly noisy.

(vi) **Defense Equipment**: A lot of noise pollution is added to the atmosphere by artillery, tanks, launching of rockets, explosions, exercising of military airplanes and shooting practices.

(vii) **Miscellaneous Sources:** The automobile repair shops, construction-works, blasting, bulldozing, stone crushing etc. are other sources of noise pollution.

effects of noise pollution: noise is generally harmful and a serious health hazard. it has far-reaching consequences and has many physical, physiological as well as psychological effects on human beings.

(i) **Physical Effects:** The physical effects of noise pollution are the effect on hearing ability. Repeated exposure to noise may result in temporary or permanent shifting of the hearing threshold of a person depending upon the level and duration of exposure. the immediate and acute effect of noise pollution is impairment of hearing. Human ears have sensory cells for hearing. if these cells are subjected to repeated sounds of high intensity before they have an opportunity to recover fully, they can become permanently damaged leading to impairment of hearing. Besides the sensory cells, the delicate tympanic membrane or the ear drum can also be permanently damaged by a sudden loud noise such as an explosion.

(ii) **Physiological Effects:** the physiological effects of noise pollution are several as described below:

(a) Headache.
(b) Increase heart rate.
(c) Narrowing of arteries.

(d) Decrease in heart output.

(e) Impairment of night vision.

(f) Decrease in the rate of colour perception.

(g) Lowering of concentration and affect on memory,

(h) Muscular strain and nervous breakdown.

The psychological effects of noise pollution are:

(a) Depression which considerably reduces the efficiency of an individual.

(b) Insomnia (lack of refreshing sleep)

(c) Affecting of psychomotor performance of a person by a sudden loud sound

(d) Emotional disturbance

Besides the above effects noise pollution is also responsible to change the behaviour of many wild animals.

CONTROL OF NOISE POLLUTION:

Noise pollution could be controlled by either reducing the noise at the sources or by preventing its transmission or by protecting the receiver. There are various methods to control noise pollution.

At the sources

1. Reduction in source of noise
2. Proper servicing of machinery and equipments.
3. Tightening the lose nuts
4. Decibel meter should be installed along highways and in factories to check and control the intensity of noise pollution.

In the path

1. A green belt effectively reduce the noise
2. A 20 foot wide plantation inside the compound protects the house from the noise of vehicular traffic
3. Noise making machine should be kept in containers with sound absorbing media.
4. Use of sound absorbing silencers

At the receiver end: If by the above methods we are not able to bring down the noise level up to required level the only alternative is to provide air plugs while working or moving in a noisy area.

General methods to control noise pollution:

1. Sound reducing device should be implemented in each and every industry.

2. Plantation especially around the roads and industries.
3. Minimum use of pressure horns
4. Make the people/communities/societies aware about the effects of noise pollution
5. Follow the rules and regulations for noise pollution prescribed by Government.
6. Regular monitoring or analysis of noise pollution.

9.3.4. SOIL POLLUTION

Soil is top most layer of earth crust and responsible for growth and productivity of crops. Soil pollution has led to a series of issues that we have come to realize in recent times, after decades of neglect. The increasing numbers of barren land plots and the decreasing numbers of forest cover is at an alarming. Moreover the extension of cities and towns due to increasing population is leading to further exploitation of the land. Also due to the lack of green cover, the land gets affected in several ways like soil erosion occurs washing away the fertile portions of the land.

Physical Properties of Soil

1. Temperature
2. Conductivity
3. Moisture content
4. Water holding capacity

Biological properties of water

1. Bacteria
2. Microorganisms

Chemical Properties of water

1. pH
2. Nitrates
3. Phosphates
4. Chlorides
5. Calcium
6. Magnesium

Cause of Soil Pollution:

1. Deforestation and soil erosion: Deforestation is removal of trees from the land and makes the land for non-forest use. As you know that forest holds the soil and prevent soil erosion. Rhizosphere (area of root) keeps the soil moisten, fertile and highly productive. Due to rapid eradication of forest soil becoming infertile.

2.Solid Waste: Each household produces tonnes of garbage each year. Waste like aluminum, plastic, paper, cloth, wood is collected and sent to dumping sites. Items that cannot be recycled become a part of the landfills that cause soil pollution. Industrial wastes also consists variety of chemicals which are extremely toxic to living beings. When these waste dumped in to soil cause soil pollution.

3. Agricultural activities: As you know that human population growing at tremendous rate and demand of food also increases. Therefore, farmers often use highly toxic fertilizers and pesticides to get maximum productivity. However with the overuse of these chemicals, they result in contamination and poisoning of soil. Insecticides, pesticides, molluscides, rodenticides, herbicides, weedicides are being used in modern agriculture which is responsible for soil pollution.

4. Mining Activities: During extraction and mining activities, several land spaces are created beneath the surface.

5. Industrialization: Due to increase in demand for food, shelter and house, more goods are produced. This resulted in creation of more waste that needs to be disposed of. To meet the demand of the growing population, more industries were developed which led to deforestation.

EFFECTS OF SOIL POLLUTION:

1. **Pollution:** Soil Pollution is another form of land pollution in which upper most layers of soil is damaged. This situation is caused by overuse of chemical fertilizers, soil erosion which leads in to soil quality degradation. Many pollutants which are present in soil may reach to higher tropic level through biomagnifications.
2. **Effect on human health:** The soil when contaminated with toxic chemicals and pesticides lead to problem of skin cancer and human respiratory system. The toxic chemicals can reach our body thorough foods and vegetables that we eat as they are grown in polluted soil.

3. **Effects on plants:** Soil pollution my leads to low productivity in agricultural field. Several agricultural crops damaged by the high acidity and alkalinity of the soil coming from chemical industries which reduces the rate of production.
4. **Loss of Biodiversity:** As you know that biodiversity is variety and variability among species. Soil contains millions of microbes which are necessary for the soil composition certain metallic contaminants like Hg, Pb, Zn, As, Cd, Cr, Na, K, Cu etc destroy bacteria and beneficial microorganism in soil and reduced biodiversity of soil.

Control of soil pollution:

Use of biopesticides instead of synthetic pesticides such as insecticides, herbicides, rodenticides, molluscides etc. improve agricultural practices make the people aware about the concept of reduce, reuse and recycle. Promote the use of biofertilizers and biopesticides instead of chemical fertilizers and chemical pesticides and insecticides. Promote the use of biodegradable item instead of non-biodegradable items.

9.4 BIODEGRADABLE AND NON-BIODEGRADABLE POLLUTANTS

Pollutant is any chemical substance which causes pollution. On the basis of degradation pollutants may be of two types:-

9.4.1 BIODEGRADABLE POLLUTANTS

These pollutants can be broken down into simpler, harmless, substances in nature in due course of time by the enzymatic action of micro-organisms like certain bacteria and fungi are called biodegradable pollutants. There are various biodegradable pollutants such as domestic wastes, urine, faecal matter, sewage, agriculture residues, paper, wood, cloth, cattle dung, animal bones, leather, wool, vegetable stuff or plants present in atmosphere.

The degradable pollutants can be further sub-divided into two categories:

(i) Rapidly biodegradable or non-persistent pollutant:

These pollutants degraded at very fast rate. The domestic sewage can be rapidly decomposed by natural processes. However, the problems become complicated when the input into environment get exceeded of the decomposition or dispersal capacity.

(ii) Slowly degradable or persistent pollutant:

These pollutants takes very long time to degrade, for example, degradation of synthetic compounds and radio-active elements like Iodine 137, Strontium 90 or Plutonium 239 takes a longer period of time to degrade.

Table-3: Biodegradable pollutants and their impacts on human health and Environment

Name of Biodegradable pollutant	Effect on human health	Effect on Environment
Domestic waste	Cause Bacterial diseases	Eutrophication in Aquatic body, change the pH of water, increase the biochemical oxygen demand
Faecal matter	Cause Bacterial diseases	Eutrophication in Aquatic body, change the pH of water, increase the biochemical oxygen demand
Papers, animal bones	-	Increase organic matter in aquatic ecosystem

9.4.2 NON-BIODEGRADABLE POLLUTANTS

These pollutants cannot be broken down into simpler, harmless substances in nature by the enzymatic action of bacteria and fungi, are called non-biodegradable pollutants. DDT, plastics, polythene, insecticides, pesticides, mercury, lead, arsenic etc. metal articles like aluminum cans, synthetic fibres, glass objects, iron products etc. are non-biodegradable pollutants.

Table-4: Non-biodegradable pollutants and their impacts on human health and Environment

Name of Non-Biodegradable pollutant	**Effect on human health**	**Effect on Environment**
DDT	Abnormalities of liver	Biomagnifications

	function, skin and the nervous system	
Insecticides	decreased fertility, breast cancer, diabetes and obesity, neurological disorders	Loss natural productivity of soil, Air and water pollution
Plastic and polythene	-	Loss of Biodiversity, Loss soil productivity, Air, Water pollution

9.4.3. BIOMAGNIFICATION

Bio=life

Magnify=Increase

Biomagnifications is increasing concentration of toxic chemical in each trophic level of food chain. As you know that food chain is linear network in food web in which green plants (producers) use the sun energy and transfer this energy to higher trophic levels (primary consumer, secondary consumer and tertiary consumer). Certain Pollutants such as lead, mercury, arsenic, Dichlorodiphenyl trichloroethene (DDT) that exist in small amounts in the environment (water, soil, air etc.) become concentrated in organisms near the top of the food chain, this process called biomagnifications. These pollutants are produced in several industrial processes and release into streams and rivers. These rivers eventually lead to the ocean where the mercury builds up and is ingested by small organisms.

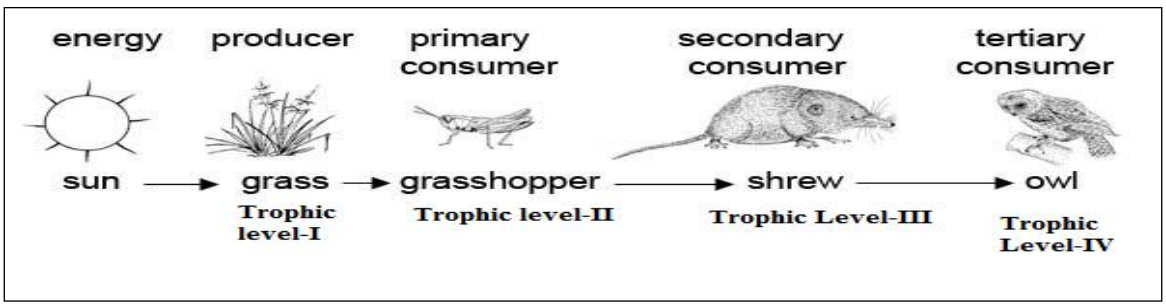

Fig.9.2 Showing simple food chain in an ecosystem

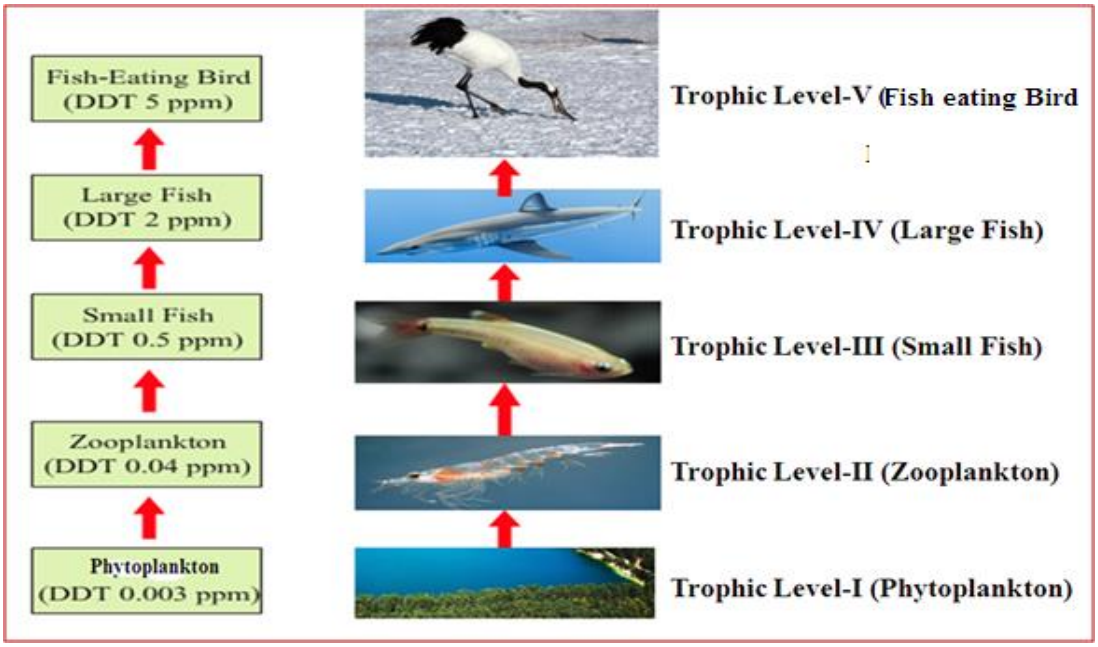

Fig.9.4 Showing magnification of toxic chemical (DDT) in aquatic food chain

9.4.4 BIOREMEDIATION

Bioremediation is technique in which microorganisms are used for the degradation of hazardous substances in soil, sediments, water or other contaminated matters. Certain species of bacteria fungi, algae and plants have used for bioremediation. **Bioaugmentation** is process in which microorganisms are imported to polluted site to enhance degradation of hazardous material.

On the basis of degradation procedure bioremediation may be of following types:

1. **Biotransformation:** It is alteration of contaminants in to less or non-hazardous substances.
2. **Biodegradation:** It is the breakdown of organic substances in smaller organic or inorganic molecules.
3. **Mineralization:** It is the complete biodegradation of organic material in to inorganic substances such as CO_2 or H_2O_4

On the basis of type of organisms used, bioremediation may be of following types:

1. **Bacterial Remediation:** It is the process of using bacteria to breakdown molecular contaminants like hydrocarbons in to simpler and safer components. ***Deinococcus radiodurans*** is genetically modified bacteria which can breakdown the heavy metals as well as toluene. ***Geobacter sufurreducens*** can turn uranium in to non-soluble form.

Bacteria namely ***Thermus brockianus*** breaks down hydrogen peroxide 8000 times faster than current chemicals in use. ***Alcaligenes eutrophus*** another type of bacteria can degrade 2-4-D (Herbicide used in United States)

2. **Mycoremediation:** It is the process of using fungi to breakdown molecular contaminants in to simpler and safer components.
3. **Phyto-remediation:** It is the process of using plant species to breakdown molecular contaminants to simpler and safer components.

Table-5: Sowing different phytoremediation techniques

Technique	**Plant mechanism**	**Medium**
Phytoextraction	Uptake and concentration of metal via direct uptake in to plant with subsequent removal of the plants	Soil
Phytotransformation	Plant uptake and degradatyion of organic compounds	Surface water and Ground water
Phytodegradation	Enhance microbial degradation in rhiosphere	Soil, ground water within rhizosphere
Rhizofilteration	Uptake of metals in to plant roots	Surface water and water punped

Many plants are used in bioremediation in which **Transgenic Arabidopsis** can transforms mercury in to gaseous state, **Bamboo** can accumulates silica, Indian mustard (***Brassica juncea***) can accumulates sulphur, lead, selenium, chromium, cadmium, nickel, zinc and copper, Chinese ladder fern (***Pteris vittata***) can accumulates arsenic, **cottonwood** can accumulates mercury, tomato and alpine can accumulate lead, zinc and cadmium.

4. **Compost bioremediation:** In this process large number of beneficial bacteria can be introduced in to soil by brewing something called compost tea. Compost tea is water based, oxygen rich culture containing large population of beneficial aerobic bacteria, nematodes, fungi and protozoa which can be used to bioremediate toxins. This brew is applied to contaminated sites where microbial population breakdown the toxic substances.

In Situ Bioremediation: In situ bioremediation techniques are those technique in which "Bioremediation applied to soil or water at the site with minimum disturbances. It is technologies that are used "in place" without removal contaminated matrix. These techniques are the most desirable options due to lower cost and lesser disturbance since they provide the treatment in place avoiding excavation and transport of contaminants.

Ex Situ Bioremediation: These are the bioremediation technologies that require removal of contaminated matrix by excavation so it can be manipulated in some way through the use of slurry reactors, compositing, biopiles etc. in this technique the contaminants degraded our site of the contaminated place.

Advantages of Bioremediation:

Bioremediation is natural process and has no harmful impacts on local communities or population. Various advantages of bioremediation are given below:

1. Bioremediation is useful for the complete destruction of a wide variety of toxic substances. By using this technique many substances that are legally regarded as hazardous can be transferred in to harmless compounds.
2. Bioremediation can be used on site (in situ) or off site (ex situ).
3. Bioremdiation is less expensive than other technologies that are used for cleanup of hazardous waste.
4. Bioremediation is fully based on natural microbes therefore it has no side effect on plants, animals and human being.

Disadvantages of Bioremediation:

1. Bioremediation generally takes longer time as compare to other technologies.
2. It may be possible that product of bioremediation may high toxic as compared to parental product.
3. Bioremediation is limited to biodegradable compounds.

9.5 SUMMARY

Environmental pollution is any undesirable changes in physical, chemical and biological changes in environmental components. Environmental pollution may be air pollution, water pollution, soil pollution, noise pollution, radioactive pollution; light pollution etc. Various sources of air pollution such as vehicular emission, industrial emission, agricultural practices

etc. effects of air pollution are very dangerous and can leads in to respiratory problems, lung disorders, skin cancer, cardiovascular diseases etc. Besides this air pollution may leads in to acid rain, ozone layer depletion, global warming and climate change. Main sources of water pollution are domestic sewage, industrial effluent, agricultural practices etc. Water pollution may leads in to various disorders in kidneys, liver, bones, nervous system, reproductive system etc. excessive amount of nutrients in lakes or ponds is referred as eutrophication. We can control water pollution by treat the domestic sewage and industrial sewage, thorough bioremediation technologies etc. Noise is unwanted sound and there are various forms of noise pollution such as industrial noise, vehicular noise, domestic noise etc. noise may responsible for physical, physiological and psychological effect. Soil is upper most layer of earth surface and polluting by dumping of solid waste, excessive use of chemical fertilizers, deforestation etc. Different pollutants can reach the higher trophic level by soil. If we use various methods such as afforestation, use of biofertilizers and biopesticides, proper management of solid waste, then we can control soil pollution. Biodegradable pollutants are pollutants which can degrade by the action of bacteria in natural environment. Examples of biodegradable pollutants are sewage, papers, cow dung etc. Non-biodegradable pollutants mean pollutants which do not degrade by the action of bacteria and fungi in natural environment. Examples of non-biodegradable pollutants are DDT, Mercury, plastic and polythene. Biomagnifications is process in which concentration of toxic chemicals increase in trophic level of food chain. On the view of above account you surely aware about the impacts of different pollution and we should promote technique like bioremediation which is technique in which various organisms are use to degrade the pollutants in environment.

9.6 GLOSSARY

Environmental pollution: Undesirable changes in physical chemical and biological properties of air, water and soil which cause harmful effect on organisms.

Eutrophication: Eutrophication means enrichment of nutrient (especially nitrates and phosphates) in aquatic bodies such as streams and lakes.

Primary Pollutants: These pollutants directly emitted from the sources. Classic examples of a primary pollutant would be the sulfur-dioxide, Nitrous Oxide, CO. CO_2 emitted from the industries.

Secondary Pollutants: These pollutants are formed by the inter mingling and reactions of primary pollutants. Some examples of secondary pollutants are: Peroxy Acylnitrates (PAN)

Ozone (O_3), Sulphuric Acid, Nitric Acid.

Biodegradable pollutants: Those pollutants which can be broken down into simpler, harmless, substances in nature in due course of time (by the action of micro-organisms like certain bacteria) are called biodegradable pollutants. Domestic wastes (garbage), urine, faecal matter, sewage, agriculture residues, paper, wood, cloth, cattle dung, animal bones, leather, wool, vegetable stuff or plants are biodegradable pollutants.

Non-Biodegradable pollutants: Those pollutants which cannot be broken down into simpler, harmless substances in nature are called non-biodegradable pollutants. DDT, plastics, polythene, bags, insecticides, pesticides, mercury, lead, arsenic etc. metal articles like aluminum cans, synthetic fibres, glass objects, iron products and silver foils are non-biodegradable pollutants.

Minamata disease: This disease was happened due to the exposure of methyl mercury.

Itai Itai disease: This disease was happened due to the exposure of cadmium.

Bioaccumulation: Accumulation of toxic chemicals in the tissues of organisms.

Biomagnification: Increase toxic chemicals at higher trophic levels.

Bioremediation: Cleaning of environmental by organisms it may be phytoremediation, bacterial remediation, mycoremediation and compost bioremediation.

RSPM: Respirable Suspended Particulates (RSP) with diameter less than or equal to 10 micrometers, thus also named as PM_{10}.

SPM: Total Suspended Particles is the fraction sampled with high-volume samplers, approximately particle diameters <50-100 μm.

Bio-chemical oxygen Demand (BOD): It is amount of oxygen required by microorganisms to decompose organic matter in aquatic ecosystem.

Dissolved Oxygen (DO): It is amount of dissolved oxygen present in water bodies.

Turbidity: It is haziness of water and may be due to TS, phytoplankton and zooplankton. It is negatively correlated with transparency.

Industrial Effluent: Industrial waste is the waste produced by industrial activity which contains certain heavy metals such as mercury, arsenic, chromium, nickel cadmium etc.

Domestic Sewage: It is raw material of house hold which contain organic waste, nitrates and phosphates and primary source of water pollution.

Insecticides: Insecticides are chemical substances used to kill harmful insect, these include larvicides ovicides used against larvae and egg, respectively.

9.7 SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

9.7.1 MULTIPLE CHOICE QUESTIONS

1. TDS is:
   (a) Physical Property of water (b) Biological Property of water
   (c) Chemical Property of water (d) None of above
2. Minamata disease was happened due to:
   (a) Mercury (b) Arsenic
   (c) Cadmium (d) Chromium
3. Itai itai disease was happened due to:
   (a) Arsenic (b) Cadmium
   (c) Iron (d) Phosphorus
4. Main cause of Eutrophication in lake is:
   (a) Calcium (b) Carbon
   (c) Phosphorus (d) Iron
5. The word noise has been taken from which language:
   (a) Latin (b) Greek
   (c) French (d) Sanskrit
6. Which is biological property of water?
   (a) DO (b) pH
   (c) BOD (d) Bacteria
7. PAN is:
   (a) Primary Pollutant (b) Secondary Pollutant
   (c) Both (a) and (b) (d) Non of above
8. Cleaning of Environment by organisms is called:
   (a) Biomagnification (b) Bioagumentation

(c) Bioremediation (d) Biopreservation

9. Ozone is harmful in:

(a) Stratosphere (b) Ionosphere

(c) Troposphere (d) Exosphere

10. Increasing toxic chemicals in each trophic level is called:

(a) Bioremediation (b) Toxicity

(c) Biomagnification (d) Bioaccumulation

11. Which one of the following is heavy metal:

(a) Calcium

(b) Cadmium

(c) Chlorides

(d) Nitrates

12. Ex Sit Bioremediation means:

(a) Degrade pollutants at contaminated site (b) Both (a) and (b)

(c) Degrade pollutants at outside contaminated site (d) None

13. Which of the following will have maximum concentration of toxic chemical in food chain:

(a) Zooplankton (b) Fish

(c) Phytoplankton (d) Fish eating bird

14. Atomic number of arsenic is:

(a) 33 (b) 80

(c) 38 (d) 83

15. Which of the following is not pollutant?

(a) As (b) Cd

(c) Hg (d) DO

9.7.2 VERY SHORT QUESTIONS

1. Word Environmental has been taken from which language?
2. Pollution word has been taken from which word?
3. Acid rain forms by
4. Eutrophication means
5. RSPM means

6. The use of living microorganism to degrade environmental pollutants is called
7. The increasing of toxic chemicals in higher trophic level is called.
8. The pollutants which are directly emits from the source are called?
9. Environmental impacts of Air pollution are.
10. Eutrophication also known as?
11. Decibel is unit of.
12. Give the name of some plants which used in bioremediation?
13. Which is commonly known as marsh gas?
14. PAN is which type of pollutant?

ANSWERS

8.7.1. 1.(a); 2.(a); 3.(b); 4.(c); 5.(a); 6.(d); 7.(b); 8.(c); 9.(c); 10.(c); 11.(b); 12.(c); 13.(d); 14.(a); 15.(d)

8.7.2. 1. French; 2. Pollutionem; 3. SO_2 and NO_2; 4. Nutrient enrichment in water bodies; 5. Respirable Suspended Particulate matter; 6. Bioremediation; 7. Biomagnification; 8. Primary pollutants; 9. Golbal warming, Acid Rain and Ozone depletion 10. Hypertrophication; 11. Sound/Noise; 12. Bamboo, Indian Mustard, Cottonwood, Chinese ladder fern; 13. Methane; 14. Secondary pollutant.

9.8 TERMINAL AND MODEL QUESTIONS

1. Define pollution. Describe the sources, effects and control of Air pollution
2. Describe the sources, effects and control of water pollution.
3. What is Noise? Describe the sources, effects and control of noise pollution.
4. Describe the sources, effects and control of soil pollution.
5. Differentiate between biodegradable and non-biodegradable pollutants.
6. What do you understand by biomagnifications? Explain biomagnifications with suitable example.
7. Define bioremediation. Describe the types and in-situ and ex-situ methods of bioremediation.

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UNIT 10: OVERVIEW OF IMMUNE SYSTEM

CONTENTS

10.1 OBJECTIVES

- To describe the concepts of innate immunity and acquired immunity
- To list the types of innate immunity and acquired immunity
- To explain the mechanism of innate immunity
- To explain the differences between active and passive immunity

10.2 INTRODUCTION

Immunology is “a branch of science that covers the investigation of safe frameworks in all living beings” by **Janeway** (**2001)**. Immunology is the examination of the immune system and is a basic branch of the helpful and natural sciences. The safe framework shields us from infection through various lines of watch. If the resistant framework isn't functioning as it should, it can realize disease, for instance, autoimmunity, excessive touchiness and tumor. It is similarly now winding up clear that insusceptible reactions add to the headway of various fundamental issue not by and large observed as immunologic, including metabolic, cardiovascular, and neurodegenerative conditions, for instance, Alzheimer's.

10.3 IMPORTANCE OF IMMUNOLOGY

From Edward Jenner's leading work in the 18^{th} Century that would finally provoke immunization in its present day shape (an advancement that has likely secure a greater number of lives than some other helpful advance), to the various legitimate breakthroughs forward in the nineteenth and twentieth many years that would incite, notwithstanding different things, safe organ transplantation, the recognizing verification of blood get-togethers, and the now inescapable usage of monoclonal antibodies all through science and social protection, immunology has changed the substance of current arrangement. Immunological research continues extending horizons in our cognizance of how to treat basic restorative issues, with advancing exploration tries in immunotherapy, safe framework diseases, and antibodies for rising pathogens, for instance, Ebola. Pushing our appreciation of key immunology is essential for clinical and business application and has supported the revelation of new diagnostics and solutions to manage a wide group of diseases. Despite the above, joined with impelling development, immunological research has given fundamentally

basic research techniques and mechanical assemblies, for instance, stream cytometry and balancing specialist advancement.

10.4 HISTORY AND ORIGIN

In **1798, Edward Jenner** built up the first run through **vaccination** process, for smallpox issues. His work was great to the point, that several of individuals respected him for his decision that vaccination with **cowpox** (identified with cow like steers) could offer resistance to **smallpox**. Like this, the idea of **inoculation** (in Latin 'vacca' signifies 'bovine') was begun. In **1878, Louis Pasteur** inadvertently used a debilitate chicken cholera culture and watched, that the debilitated shape spared the chickens from the destructive type of ailment. Later on a contender of Pasteur, **Robert Koch** was the first to isolate the Bacillus anthracis living being and, insensible of Pasteur's work, he could show that it caused the medical problem. By then in 1882, Koch could show that the germ hypothesis of sickness associated with human ailments and also animals, when he isolated the microorganism that caused **tuberculosis**. His "Koch's proposes" are up 'til now used to recognize infective living things.

10.5 IMMUNE SYSTEM

The immune organization is a reticule of tissues, organs and cells that work along to protect the body against assaults by “stranger” intruders. These are fundamentally microorganisms (germs), small, disease-causing living beings, for example, viruses, bacteria, fungi and parasites as the human body gives a perfect situation to numerous microorganisms. The insusceptible framework is incredibly intricate. It can perceive and recollect a large number of various foes, and it can create discharges and cells to coordinate with and wipe out every last one of them. The way to its prosperity is a detailed and dynamic correspondence arrange. Millions of cells, sorted out into sets and subsets, accumulate like billows of honey bees swarming around a hive and pass data forward and backward. When resistant cells get the caution, they experience strategic changes and start to create effective chemicals. These substances enable the cells to manage their own particular development and conduct, enroll their colleagues, and direct newcomers to inconvenience spots. The way to a solid safe framework is its capacity to recognize the body's own particular cells—self—and outside cells—non self. The body's invulnerable barriers regularly exist together gently with cells that convey particular "self" marker atoms. In any case, when invulnerable protectors experience cells or living beings conveying markers that say "remote," they rapidly dispatch an assault.

Anything that can trigger this safe reaction is called an antigen. An antigen can be a microorganism, for example, an infection, or even a piece of an organism. Tissues or cells from someone else (with the exception of an indistinguishable twin) additionally convey non self markers and go about as antigens. This clarifies why tissue transplants might be rejected. In unusual circumstances, the safe framework can mix up self for non self and dispatch an assault against the body's own particular cells or tissues. The outcome is called an immune system malady. A few types of joint pain and diabetes are immune system sicknesses. In different cases, the resistant framework reacts to an apparently safe remote substance, for example, ragweed dust. The outcome is hypersensitivity, and this sort of antigen is called an allergen. Practically, a resistant reaction can be separated into two related exercises acknowledgment and reaction. Insusceptible acknowledgment is astounding for its specificity.

10.6 THE STRUCTURE OF THE IMMUNE SYSTEM

Immunity the condition of security from irresistible sickness has both a not so much particular but rather more particular segment. Immune system is a standout amongst the most critical systems of the body that is vital for human existence. It includes tissues and cells that are related with the protection of our body from various pathogens and irresistible operators. The resistance (or ability to battle an irresistible operator without delivering the indications of sickness) is by and large arranged into two unique sorts: to be specific natural invulnerability and versatile insusceptibility.

10.6.1 INNATE IMMUNITY

The innate immune system, otherwise called the non-particular insusceptible framework or in-conceived resistance framework, is a vital subsystem of the general safe framework. Intrinsic invulnerability alludes to nonspecific resistance components that become possibly the most important factor quickly or inside hours of an antigen's appearance in the body. These components incorporate physical obstructions, for example, skin, chemicals in the blood, and safe framework cells that assault remote cells in the body. The intrinsic safe reaction is enacted by compound properties of the antigen The less particular segment, natural insusceptibility, gives the primary line of guard against contamination. Most segments of intrinsic insusceptibility are available before the beginning of contamination

and constitute an arrangement of infection protection systems that are not particular to a specific pathogen but rather that incorporate cell and atomic segments that perceive classes of particles impossible to miss to as often as possible experienced pathogens. Phagocyte cells, for example, macrophages and neutrophils, hindrances, for example, skin, and an assortment of antimicrobial mixes blended by the host all assume imperative parts in intrinsic insusceptibility. Intrinsic invulnerable framework is additionally alluded to as quick reaction resistant framework. This framework actuates inside minutes to hours after an outside operator attacks inside the human body. Natural safe framework is made out of two lines of barriers.

The significant elements of the intrinsic insusceptible framework include:

- Recruiting invulnerable cells to locales of disease, through the generation of substance factors, including specific compound middle people, called cytokines.
- Activation of the supplement course to distinguish microscopic organisms, actuates cells, and advances leeway of neutralizer buildings or dead cells.
- Identification and evacuation of remote substances show in organs, tissues, blood and lymph, by particular white platelets.
- Activation of the versatile insusceptible framework through a procedure known as antigen introduction.
- Acting as a physical and compound hindrance to irresistible specialists.
  Intrinsic invulnerability can be believed to contain these sorts of cautious hindrances: anatomic, physiologic, phagocytic, supplement framework and incendiary.

PHYSICAL AND ANATOMIC BARRIERS: The physiologic and anatomic obstructions that add to natural insusceptibility incorporate temperature, pH, and different dissolvable and cell related atoms. These keep the passage of pathogens in a creature's initially line of safeguard against disease. The skin and the surface of mucous films are incorporated into this class since they are viable boundaries to the passage of generally microorganisms. The skin comprises of two unmistakable layers: a more slender external layer—the epidermis—and a thicker layer—the dermis. The epidermis contains a few layers of firmly pressed epithelial cells. The external epidermal layer comprises of dead cells and is loaded with a waterproofing protein called keratin. The dermis, which is made out of connective tissue, contains veins, hair follicles, sebaceous organs, and sweat organs. The sebaceous organs are

related with the hair follicles and create a slick emission called sebum. Sebum comprises of lactic corrosive and unsaturated fats, which keep up the pH of the skin in the vicinity of 3 and 5; this pH hinders the development of generally microorganisms. The skin may likewise be entered by gnawing creepy crawlies (e.g., mosquitoes, parasites, ticks, insects, and sand flies); if these harbor pathogenic life forms, they can bring the pathogen into the body as they nourish. The conjunctivae and the wholesome, respiratory, and urogenital tracts are lined by mucous films, not by the dry, defensive skin that covers the outside of the body. These films comprise of an external epithelial layer and a fundamental layer of connective tissue. Various nonspecific resistance systems have a tendency to forestall section of pathogens for instance, salivation, tears, and mucous discharges act to wash away potential trespassers and furthermore contain antibacterial or antiviral substances.

INFLAMMATORY BARRIERS: Tissue harm caused by an injury or by an attacking pathogenic microorganism prompts an unpredictable grouping of occasions all things considered known as the provocative reaction. Aggravation is one of the main reactions of the resistant framework to contamination or disturbance. Irritation is animated by substance factors discharged by harmed cells and serves to build up a physical boundary against the spread of disease, and to advance mending of any harmed tissue following the freedom of pathogens. The incendiary reaction is portrayed by the accompanying side effects:

- redness of the skin, because of privately expanded blood dissemination
- heat, either expanded neighborhood temperature, for example, a warm looking about a restricted disease, or a fundamental fever
- swelling of influenced tissues, for example, the upper throat amid the normal icy or joints influenced by rheumatoid joint inflammation
- increased creation of bodily fluid, which can cause side effects like a runny nose or a beneficial hack
- pain, either nearby torment, for example, excruciating joints or a sore throat, or influencing the entire body, for example, body hurts
- possible brokenness of the organs or tissues included

The inflammation process is started by cells effectively show in all tissues, essentially occupant dendritic cells, macrophages, Kupffer cells, mastocytes and histiocytes. These cells exhibit receptors contained at first glance or inside the cell, named pattern recognition receptors (PRRs), which perceive atoms that are comprehensively shared by pathogens

however recognizable from have particles, aggregately alluded to as pathogen-associated molecular patterns (PAMPs). At the beginning of a contamination, consume, or different wounds, these cells experience enactment (one of their PRRs perceives a PAMP) and discharge incendiary middle people in charge of the clinical indications of aggravation. Synthetic elements created amid irritation are histamine, bradykinin, serotonin, leukotrienes, and prostaglandins which sharpen torment receptors, causing nearby vasodilation of the veins, and pull in phagocytes, particularly neutrophils. Neutrophils at that point trigger different parts of the resistant framework by discharging factors that summon extra leukocytes and lymphocytes. Cytokines delivered by macrophages and different cells of the intrinsic invulnerable framework intervene the incendiary reaction. These cytokines incorporate TNF, HMGB1, and IL-1. The "four cardinal indications of irritation" are rubor (redness), tumor (swelling), calor (warmth), and dolor (torment). The cardinal indications of aggravation mirror the three noteworthy occasions of an incendiary reaction.

VASODILATION - an expansion in the measurement of veins of adjacent capillaries exists as the vessels that divert blood from the influenced region choke, bringing about engorgement of the capillary system. The engorged vessels are in charge of tissue redness (erythema) and an expansion in tissue temperature.

An expansion in capillary penetrability encourages a flood of liquid and cells from the engorged vessels into the tissue. The liquid that collects (exudate) has a significantly higher protein content than liquid regularly discharged from the vasculature. Aggregation of exudate contributes to tissue swelling (edema).

Influx of phagocytes from the vessels into the tissues is encouraged by the expanded piousness of the vessels. The resettlement of phagocytes is a multistep procedure that incorporates adherence of the cells to the endothelial mass of the veins (margination), trailed by their displacement between the narrow endothelial cells into the tissue (diapedesis or extravasation), and, at long last, their relocation through the tissue to the site of the intrusion (chemo taxis). As phagocyte cells aggregate at the site and start to phagocytose microorganisms, they discharge lytic proteins, which can harm adjacent solid cells. The aggregation of dead cells, processed material, and liquid structures a substance called discharge. The final product of aggravation might be the marshaling of a particular resistant reaction to the attack or leeway of the trespasser by segments of the natural invulnerable framework. Once the fiery reaction has died down and the vast majority of the garbage has

been gathered up by phagocytic cells, tissue repair and recovery of new tissue starts. Vessels develop into the fibrin of blood coagulation. New connective tissue cells, called fibroblasts, supplant the fibrin as the coagulation breaks up, as fibroblasts and vessels amass, scar tissue is framed.

Complement system: the complement system is a biochemical cascade of the immune system that helps, or “complements”, the ability of antibodies to clear pathogens or mark them for destruction by other cells. The cascade is composed of many plasma proteins, synthesized in the liver, primarily by hepatocytes. the complement system facilitates following actions:
trigger the recruitment of inflammatory cells
"tag" pathogens for destruction by other cells by opsonizing, or coating, the surface of the pathogen
form holes in the plasma membrane of the pathogen, resulting in cytolysis of the pathogen cell, causing the death of the pathogen
rid the body of neutralised antigen-antibody complexes.
Phagocytic barriers/cells of the innate immune response: another critical innate protection component is the ingestion of extracellular particulate material by phagocytosis. phagocytosis is one sort of endocytosis, the general term for the take-up by a cell of material from its condition. in phagocytosis, a phone's plasma layer grows around the particulate material, which may incorporate entire pathogenic microorganisms, to shape vast vesicles called phagosomes. most phagocytosis is directed by particular cells, for example, blood monocytes, neutrophils, and tissue macrophages. most cell sorts are equipped for different types of endocytosis, for example, receptor-intervened endocytosis. the inborn cells incorporate natural executioner cells, pole cells, eosinophils, basophils; macrophages, neutrophils, and dendritic cells, which work inside the invulnerable framework by distinguishing and wiping out pathogens that may cause contamination.
mast cells: these cells are a sort of natural insusceptible cell that dwells in connective tissue and in the mucous films. They are personally connected with wound mending and barrier against pathogens, but on the other hand are frequently connected with sensitivity and anaphylaxis. When enacted, pole cells quickly discharge trademark granules, rich in histamine and heparin, alongside different hormonal arbiters and chemokines, or chemotactic cytokines into nature. Histamine widens veins, causing the trademark indications of aggravation, and enlisted people neutrophils and macrophages.
macrophages: macrophage from the greek, signifying "substantial eaters," are extensive

phagocytic leukocytes, which can move outside of the vascular framework by moving over the dividers of narrow vessels and entering the territories between cells in quest for attacking pathogens. in tissues, organ-particular macrophages are separated from phagocytic cells introduce in the blood called monocytes. Macrophages are the most effective phagocytes and can phagocytose considerable quantities of microscopic organisms or different cells or microbes. the official of bacterial particles to receptors on the surface of a macrophage triggers it to inundate and devastate the microorganisms through the age of a "respiratory burst", causing the arrival of responsive oxygen species. pathogens likewise fortify the macrophage to deliver chemokines, which summon different cells to the site of disease.

Neutrophils: Neutrophils alongside two other cell sorts (eosinophils and basophils), are known as granulocytes because of the nearness of granules in their cytoplasm, or as polymorphonuclear cells (pmns) because of their unmistakable lobed cores. neutrophil granules contain an assortment of dangerous substances that slaughter or restrain development of microscopic organisms and growths. like macrophages, neutrophils assault pathogens by actuating a respiratory burst. the fundamental results of the neutrophil respiratory burst are solid oxidizing operators including hydrogen peroxide, free oxygen radicals and hypochlorite. neutrophils are the most rich sort of phagocyte, regularly speaking to 50-60% of the aggregate coursing leukocytes, and are generally the main cells to land at the site of a contamination. the bone marrow of an ordinary sound grown-up produces more than 100 billion neutrophils for each day, and more than 10 times that numerous every day amid intense aggravation.

Dendritic cells (dcs): dendritic cells are phagocytic cells show in tissues that are in contact with the outside condition, for the most part the skin (where they are regularly called langerhans cells), and the inward mucosal covering of the nose, lungs, stomach, and digestive organs. they are named for their similarity to neuronal dendrites, however dendritic cells are not associated with the sensory system. dendritic cells are vital during the time spent antigen introduction, and fill in as a connection between the intrinsic and versatile insusceptible frameworks.

Basophils and eosinophils: basophils and eosinophils are cells identified with the neutrophil. at the point when enacted by a pathogen experience, histamine-discharging basophils are vital in the protection against parasites and assume a part in hypersensitive responses, for example, asthma. upon actuation, eosinophils emit a scope of exceptionally lethal proteins

and free radicals that are profoundly compelling in murdering parasites, however may likewise harm tissue amid an unfavorably susceptible response. enactment and arrival of poisons by eosinophils are, in this manner, firmly directed to keep any improper tissue pulverization.

Natural killer cells (Nk cells): nk cells are a segment of the inborn resistant framework that does not specifically assault attacking organisms. or maybe, nk cells devastate traded off host cells, for example, tumor cells or infection contaminated cells, perceiving such cells by a condition known as "missing self." this term depicts cells with anomalous low levels of a phone surface marker called mhc i (real histocompatibility complex) - a circumstance that can emerge in viral diseases of host cells. They were named "normal executioner" due to the underlying thought that they don't require enactment with a specific end goal to murder cells that are "missing self." for some years, it was vague how nk cell perceive tumor cells and contaminated cells. it is presently realized that the mhc cosmetics on the surface of those cells is adjusted and the nk cells end up plainly initiated through acknowledgment of "missing self". typical body cells are not perceived and assaulted by nk cells since they express in place self mhc antigens. Those mhc antigens are perceived by executioner cell immunoglobulin receptors (kir).

Gamma/delta t cells / γδ t cells: like other t cell receptors (tcrs) and natural killer t cells, γδ t cells show attributes that place them at the outskirt amongst intrinsic and versatile resistance. on one hand, γδ t cells might be viewed as a segment of versatile invulnerability in that they rework tcr qualities to create junctional decent variety and build up a memory phenotype. in any case, the different subsets may likewise be considered piece of the inborn safe framework where a limited tcr or nk receptors might be utilized as an example acknowledgment receptor.

10.6.2 ADAPTIVE IMMUNITY

The versatile immunity network, otherwise called the gained invulnerable framework or, all the more once in a while, as the particular insusceptible framework, is a subsystem of the general safe framework that is made out of profoundly specific, fundamental cells and procedures that dispose of or counteract pathogen development. the versatile insusceptible framework is one of the two principle insusceptibility systems found in vertebrates. versatile insusceptibility alludes to antigen-particular invulnerable reaction. the versatile invulnerable reaction is more unpredictable than the inborn. the antigen initially should be prepared and

perceived. Once an antigen has been perceived, the versatile safe framework makes a multitude of resistant cells particularly intended to assault that antigen. Versatile invulnerability likewise incorporates a "memory" that makes future reactions against a particular antigen more proficient. Versatile insusceptibility reacts to the test with a high level of specificity and additionally the exceptional property of "memory." Typically; there is a versatile resistant reaction against an antigen inside five or six days after the underlying presentation to that antigen. Introduction to a similar antigen at some point later on brings about a memory reaction: the invulnerable reaction to the second test happens more rapidly than the to begin with, is more grounded, and is regularly more compelling in killing and clearing the pathogen. The real specialists of versatile insusceptibility are lymphocytes and the antibodies and different atoms they deliver. Versatile framework is predominantly in charge of more mind boggling responses. This framework initiates after inborn reaction is completely actuated. at first, the antigen entered in body is distinguished by the particular insusceptible cells, and afterward a course of responses is begun as antigen immune response to assault the antigen. This resistant framework likewise incorporates creating memory of antigens, which will spare their personalities in the memory cells with the goal that a particular reaction will be started not long after section of a similar pathogen in future. Versatile invulnerability is equipped for perceiving and specifically killing particular remote microorganisms and particles (i.e., outside antigens). Dissimilar to natural resistant reactions, versatile insusceptible reactions are not the same in all individuals from animal varieties however is response particular to antigenic difficulties. Versatile resistance makes immunological memory after an underlying reaction to a particular pathogen, and prompts an upgraded reaction to ensuing experiences with that pathogen. This procedure of obtained invulnerability is the premise of inoculation. Like the intrinsic framework, the versatile framework incorporates both humoral insusceptibility parts and cell-interceded resistance segments. Gained invulnerability is activated in when a pathogen avoids the inborn safe framework and creates a limit level of antigen and produces "outsider" or "risk" signals enacting dendritic cells. Not at all like the intrinsic invulnerable framework, is the versatile resistant framework very particular to a specific pathogen. versatile insusceptibility can likewise give dependable insurance; for instance, somebody who recuperates from measles is presently ensured against measles for their lifetime. in obtained resistance, pathogen-particular receptors are "procured" amid the lifetime of the living being. the procured reaction is additionally called as "versatile" on the grounds that it readies the body's

insusceptible framework for future difficulties. Obtained resistance is activated when a pathogen dodges the inborn insusceptible framework and creates a limit level of antigen likewise produces "outsider" or "threat" signals enacting dendritic cells.

The significant elements of the procured safe framework include:

- Recognition of particular "non-self" antigens within the sight of "self", amid the procedure of antigen introduction.
- Generation of reactions that are custom fitted to maximally dispose of particular pathogens or pathogen-contaminated cells.
- Development of immunological memory, in which pathogens are "recollected" through memory B cells and memory T cells.

Adaptive immune responses can be divided into humoral and cell-mediated responses.

HUMORAL IMMUNE RESPONSE: Humoral resistance is that piece of insusceptibility which is intervened by macromolecules found in extracellular liquids, for example, discharged antibodies, supplement proteins, and certain antimicrobial peptides. Humoral insusceptibility is so named in light of the fact that it includes substances found in the humors, or body liquids. Humoral resistance alludes to counter acting agent creation and the extra procedures that go with it, including: Th2 actuation and cytokine generation, germinal focus arrangement and isotype exchanging, proclivity development and memory cell age. It likewise alludes to the effector elements of antibodies, which incorporate pathogen and poison balance, established supplement enactment, and opsonin advancement of phagocytosis and pathogen end. Versatile invulnerability that alludes to antigen-particular segments coursing through the plasma, for example, antibodies, their capacity, and the cells that create them. B cells, sort 2 partner T cells, antibodies, pole cells, and eosinophils are associated with the humoral insusceptible reaction.

Humoral insusceptibility alludes to the part of the versatile resistant reaction that is caused by B cells, antibodies, and sort 2 partner T cells (Th2), and also circling pole cells and eosinophils to a lesser degree. Its name originates from the possibility that blood is one of the humors of the body, since antibodies give latent or dynamic resistance through flow in the circulation system. Sort 2 partner T cells are incorporated into the humoral resistant framework since they exhibit antigens to youthful B-cells, which experience expansion to

end up noticeably particular to the displayed antigen. The B cells at that point quickly create an expansive number of antibodies that circle through the body's plasma.

Antibodies give various capacities in humoral insusceptibility. Six unique classes of antibodies give particular capacities and collaborate with various cells in the resistant framework. All antibodies tie to pathogens to opsonize them, which makes it simpler for phagocytic cells to tie to and devastate the pathogen. They likewise kill the poisons delivered by specific pathogens and give supplement pathway actuation, in which flowing proteins are joined in a perplexing course that structures a layer assault complex on a pathogen cell film, which lyses the cell.

Pole cells and eosinophils are considered piece of the humoral insusceptible framework since they can be sharpened towards specific antigens through coursing immunoglobin E (IgE), a particular sort of immunizer delivered by B cells. IgE ties to the pole cells and eosinophils when an antigen is identified, utilizing a sort of Fc receptor on the pole cell or eosinophil that has a high-restricting fondness with IgE. This coupling will cause degranulation and arrival of provocative go betweens that begin an invulnerable reaction against the antigen. This procedure is the motivation behind why memory B cells can cause touchiness (hypersensitivity) development, as circling IgE from those memory cells will actuate a quick provocative and invulnerable response.

CELL-INTERVENED REACTIONS: Adaptive invulnerability that isn't controlled by antibodies and is rather interceded specifically by insusceptible cells themselves, most eminently sort 1 aide T cells and cytotoxic T-cells. The cell of the obtained insusceptible framework is T lymphocytes; T cells are the real sorts of lymphocytes. The human body has around 2 trillion lymphocytes, constituting 20– 40% of white platelets (WBCs). B T cells are gotten from the same multi-strong hematopoietic undifferentiated organisms, and are morphologically vague from each other until after they are actuated, T cells are personally associated with cell-interceded insusceptible reactions. Sort 1 aide T cells and cytoxic T-cells are associated with cell-interceded invulnerable reaction. Cell intervened resistance is controlled by sort 1 partner T cells (Th1) and cytotoxic T cells. These cells are enacted by antigen-exhibiting cells, which make them quickly develop into frames particular to that antigen. White blood cells at that point course through the body to pulverize pathogens in a few ways. Aide T cells encourage the insusceptible reaction by directing cytotoxic T cells to pathogens or pathogen-tainted cells, which they will then pulverize.

Cytotoxic T cells murder pathogens in a few ways, including the arrival of granules that contain the cytotoxins, perforin and granzyme, which lyse little pores in the layer of a pathogen. At that point T-cell delivered proteases enter the pathogen and actuate an apoptosis reaction inside the cell. Assistant T cells discharge cytokines, for example, interferon-gamma, which can enact cytotoxic T cells and macrophages.

10.7 ACTIVE IMMUNITY

Dynamic immunity alludes to the way toward presenting the body to an antigen to create a versatile invulnerable reaction: the reaction takes days/weeks to grow yet might be durable—even deep rooted. Dynamic invulnerability is the protection created by a person because of an antigenic boost. This includes the dynamic working of the host's safe framework prompting the blend of antibodies and the creation of immunologically dynamic cells. Dynamic invulnerability sets in after an inert period which is required for the immunological hardware to gets under way. Once created dynamic invulnerability is long standing. On the off chance that a person who has been effectively vaccinated against an antigen is presented to same antigen once more, the resistant reactions happen rapidly and plentifully than amid the principal experience. This is known as auxiliary reaction. Dynamic invulnerability is related with immunological memory. This implies the insusceptible framework can hold for long stretches the memory of earlier antigenic introduction. Dynamic insusceptibility gives better insurance then uninvolved resistance. Dynamic resistance can be characteristic or simulated.

Natural dynamic insusceptibility comes about because of either a clinical or an in evident contamination by a microorganism. Such resistance is generally enduring however the length fluctuates with the kind of pathogen. Invulnerability is long lasting after viral illnesses like measles and chickenpox. In flu insusceptibility is fleeting because of antigenic variety, to resistance following the principal disease isn't compelling against second contamination caused by hostile to genically novel infection. In syphilis, an uncommon sort of invulnerability known as 'premunition' is seen. Here, the insusceptibility to re-disease endures just as long as unique contamination stays dynamic.

Artificial dynamic immunity is the protection incited by the immunizations. Antibodies are arrangements of live or executed microorganisms or their items utilized for vaccination.

10.8 PASSIVE RESISTANCE

Passive immunity alludes to the way toward giving IgG antibodies to secure against disease; it gives quick, however fleeting insurance—a little while to 3 or 4 months at most. Detached invulnerability is the protection transmitted inactively to a person in a 'readymade' shape. There is no antigenic jolt; rather, preformed antibodies are directed. There is no inactive period, assurance being taking effect right now. The invulnerability is transient, no optional reaction in aloof resistance. It is less successful then dynamic vaccination. The fundamental favorable position of uninvolved vaccination is that it demonstrations promptly and, along these lines, can be utilized when quick impact is wanted, for instance against diphtheritic serum given to a youngster giving diphtheria.

Natural detached immunity is the protection latently exchanged from mother to infant. In the human newborn children, maternal antibodies are transmitted dominatingly through the placenta. It is just by the age of three months that the newborn child obtains some measure of immunological freedom.

Artificial detached immunity is the protection inactively exchanged to a beneficiary by the organization of antibodies. The specialists utilized for this reason for existing are hyperimmune sera of creature or human starting point (Anti lockjaw serum, ATS, arranged from hyperimmune steeds) and pooled human gamma-globulin (lockjaw resistant globulin, TIG).

Some of the time a blend of dynamic and inactive inoculation is utilized, known as consolidated vaccination. For instance, security of a nonimmune individual with a lockjaw inclined injury (both TIG and Tetanus toxoid is given).

10.9 SUMMARY

Immunity is the condition of insurance against outside living beings or substances (antigens). Vertebrates have two sorts of invulnerability, inborn and versatile. Intrinsic and versatile resistance work in agreeable and reliant ways. The enactment of inborn insusceptible reactions produces flags that animate and direct consequent versatile safe reactions. Intrinsic resistance isn't particular to any one pathogen yet rather constitutes a first line of guard, which incorporates anatomic, physiologic, endocytic and phagocytic, and provocative boundaries. Versatile safe reactions display four immunologic characteristics:

specificity, assorted variety, memory, and self/non-self acknowledgment. The high level of specificity in versatile resistance emerges from the exercises of particles (antibodies and T-cell receptors) that perceive and tie particular antigens. The insusceptible framework produces both humoral and cell-interceded reactions. The humoral reaction is most appropriate for end of exogenous antigens; the cell-intervened reaction, for end of endogenous antigens. Procured invulnerability is the protection that an individual secures amid life. Gained invulnerability is of two sorts: Active insusceptibility is the protection created by a person because of an antigenic jolt. Latent insusceptibility is the protection transmitted inactively to a person in a 'readymade' shape. Both can be subdivided into common and manufactured.

10.10 GLOSSARY

Adjuvant: Any substance which nonspecifically enhances the immune response to antigen.

Allergen: An antigen which causes allergy.

Allergy: IgE-mediated hypersensitivity.

Antigen: Any molecule capable of being recognized by an antibody or T-cell receptor

Apoptosis: A form of programmed cell death, characterized by endonuclease digestion of DNA.

Basophil: A type of granulocyte found in the blood and resembling the tissue mast cell.

Cell-mediated immunity (CMI): Refers to T-cell mediated immune responses.

Chemotaxis: Movement of cells up a concentration gradient of chemotactic factors.

Complement: A group of serum proteins, some of which act in an enzymatic cascade, producing effector molecules involved in inflammatio, phagocytosis and cell lysis.

Cytokines: Low molecular weight proteins that stimulate or inhibit the differentiation, proliferation or function of immune cells.

Cytotoxic: Kills cells.

Edema: Swelling caused by accumulation of fluid in the tissues.

Eosinophil: A class of granulocyte, the granules of which contain toxic cationic proteins.

Erythema: The redness produced during inflammation due to erythrocytes entering tissue spaces.

Exudate: The extravascular fluid (containing proteins and cellular debris) which accumulates during inflammation.

Fibroblast: Connective tissue cell which produces collagen and plays an important part in

wound healing.

Granulocyte: Myeloid cells containing cytoplasmic granules i.e. neutrophils, eosinophils and basophils.

Humoral: Pertaining to extracellular fluid such as plasma and lymph. The term humoral immunity is used to denote antibody-mediated immune responses.

Immunogen: Any substance which elicits an immune response.

Inflammation: The tissue response to trauma, characterized by increased blood flow and entry of leukocytes into the tissues, resulting in swelling, redness, elevated temperature and pain.

Innate immunity: Immunity which is not intrinsically affected by prior contact with antigen, i.e. all aspects of immunity not directly mediated by lymphocytes.

Kuppfer cells: Fixed tissue macrophages lining the blood sinuses in the liver.

Leukocyte: White blood cells, which include neutrophils, basophils, eosinophils, lymphocytes and monocytes.

Lymph: The tissue fluid which drains into and through the lymphatic system.

Macrophage: Large phagocytic cell, derived from the blood monocyte.

Mast cell: A tissue cell with abundant granules which resembles the blood basophil

Opsonin: Substance, which enhances phagocytosis by promoting adhesion of the antigen to the phagocyte.

Opsonization: Coating of antigen with opsonin to enhance phagocytosis

Phagocyte: Cells, including monocytes/macrophages and neutrophils, which are specialized for the engulfment of cellular and particulate matter.

Primary immune response: The relatively weak immune response which occurs upon the first encounter of naive lymphocytes with a given antigen

Secondary immune response: The qualitatively and quantitatively improved immune response which occurs upon the second encounter of primed lymphocytes with a given antigen

10.11 SELF ASSESSMENT QUESTION AND POSSIBLE ANSWERS

Multiple Choice Questions:

(1) Which of the following does **not** protect body surfaces:

(a) Skin (b) Mucus

(c) Gastric acid (d) Salivary amylase

2) Acute inflammation characteristically involves:

(a) Constriction of arterioles. (b) Capillary endothelial cell enlargement

(c) Influx of macrophages (d) Influx of neutrophils

3) Lysozyme:

(a) Is a cytoplasmic organelle (b) Activates complement

(c) Is a proteolytic enzyme (d) Splits peptidoglycan

4) Interferons:

(a) Are found only in mammalian species (b) Are divided into 5 main families

(c) Induce enzyme synthesis in the target cell (d) Only affect infected cells

5) Natural killer (NK) cells do not:

(a) Respond to interferon (b) Contain perforin

(c) Contain tumor necrosis factor (TNF). (d) Kill only by damaging the target cell outer membrane

Answers:

1) Salivary amylase 2) Influx of neutrophils
3) Splits peptidoglycan 4) Induce enzyme synthesis in the target cell.
5) Kill only by damaging the target cell outer membrane

Fill in the blanks:

1. Humoral immunity is mediated by antibodies from _____.

2. Cell mediated immunity is mediated by _____s.

3. Adaptive immune system provides _____ & _____.

4. _____ are low molecular weight cytokines important in inflammation.

5. _____ are not part of innate immune response.

Answer:

1. B lymphocytes. 2. T lymphocytes.

3. Specificity & memory. 4.Chemokines

5. B cells

Short Answer Type Questions:

. 1. Maternal antibodies transferred to foetus through placenta provide which type of immunity?

Ans. Natural passive immunity

2. Name phagocytic cells?

Ans. Neutrophils, Macrophages & Histiocytes.

3. Define Natural killer cells in one sentence?

Ans. The cells which are able to kill virus-infected cells without prior sensitization.

4. What are the three main functions of complement system?

Ans. Promote inflammation, opsonisation & cell lysis.

5. A primary immune response in an adult human requires approximately how much time to produce detectable antibody levels in the blood?

Ans. It requires one week time to produce detectable antibody levels in blood.

Long Answers Type Questions

1. What are the differences between active and passive immunity? Describe with examples?
2. Explain innate immunity & its types with examples?
3. What is humoral immunity explain?
4. Describe working of Cell mediated immunity with suitable examples?
5. Explain adaptive immunity & its types with examples?

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UNIT 11: DIVERSITY OF MICROBES

CONTENTS

11.1 OBJECTIVES

- To understand basic study area of Microbiology.
- To study different kinds of microbes like Viruses, Archaea, Bacteria etc.,

11.2 INTRODUCTION

What is Microbiology?

Microbiology is the special branch of biology that deals with the study of microscopic organisms or microorganisms. Microorganisms comprise a large and diverse group of very small organisms that exist as single cells or cell clusters and normally observable only through a microscope. Both prokaryotic and eukaryotic types of microorganisms are found on this earth. In addition to this, non-cellular living structures called viruses are also included in this category.

Individual cell of multicellular eukaryotic creatures is different from microbial cells in the sense that they are unable to live alone in nature and can exist only as constituent part of the body of the larger organism. In contrast to higher organisms, microorganisms are generally able to exhibit essential life features like growth, energy generation and reproduction independently of other cells, either of the same kind or of a different kind.

Distribution of microorganisms in nature

Microorganisms are prevalent nearly everywhere in nature under diverse geographical conditions ranging from the bottom of ocean to the peaks of icy mountains. They can be carried by air currents from the earth's surface to the upper atmosphere. The microbes are found abundantly in places where they find food, moisture and suitable temperature and pH for growth and multiplication.

Impact of microorganisms

Understanding the life processes of microorganism is of huge importance for us. The initial attempts in this direction were limited to the study of disease related pathogenic microorganisms. It was only since the last century, the immense benefits of these tiny creatures in many industrial sectors were realized by mankind. Some microorganisms are well known to produce antimicrobial compounds in the form of wonder drug called

'antibiotics'. They have also been a source of various other important industrial products like solvents, enzymes, vitamins, growth factors, flavoring products, therapeutic agents etc. Many important steps of our agriculture system depend on microbial activities. Nitrogen fixation is one of the important activities that is carried out by bacteria by forming nodules in association with leguminous plants. Various other plant growth promoting activities of microorganisms like phosphate solubilization, production of siderophores and phytohormones etc. are also well documented and utilized for increased agricultural yield. Microorganisms have an important role in food industry also where they are utilized for manufacturing of products like cheese, yogurt and buttermilk. In addition to this, various alcoholic beverages are also produced by employing them. Microorganisms are also important in the process of waste disposal and energy production. Various types of sewage and waste disposal system have been designed where microorganism are the principal components. In many cases the waste material can also be transformed into some useful products by microorganism.

11.3 BASIC INTRODUCTION TO MICROBIOLOGY

11.3.1. KINDS OF MICROBES

Although microscopic in nature, microorganisms are highly diverse and heterogenic group of organisms. They may belong to various categories depending on their overall morphology, mode of reproduction, nutrition and various other characteristics. Broadly, they belong to different groups like viruses, archaea, Protozoa, fungi, algae and viruses which may further be sub classified into various subgroups.

11.3.2 VIRUSES

Viruses are non-cellular infectious entities having either DNA or RNA as their genome. They cannot grow in artificial media as they lack metabolic machinery of their own for growth and reproduction. They require living host such as plants, animals or other microorganisms to grow and are thus regarded as obligate endoparasites. In 1852, a Russian botanist D.I. Ivanovsky demonstrated that the extract from tobacco plants suffering from mosaic disease retained its infectious nature even when passed through a filter to prevent the passage of bacteria. Beijerink, in 1898, coined the name 'virus' to describe the infectious nature of filtered plant fluids.

Viruses come in an amazing variety of shapes and sizes. They are very small and are measured in nanometers, which is one-billionth of a meter. Viruses can range in the size between 20 to 750nm, which is 45,000 times smaller than the width of a human hair. The majority of viruses cannot be seen with a light microscope because the resolution of a light microscope is limited to about 200nm, so a scanning electron microscope is required to view most viruses.

Characteristics of viruses

- Viruses are the smallest living organisms.
- Unlike other organisms they do not have a cellular structure.
- They can only reproduce by invading living cells by utilizing the metabolic machinery of the host for their own growth.
- Structurally, they just consist of a small piece of nucleic acid, either DNA or RNA, surrounded by a protein or lipoprotein coat.
- They form the boundary between living and non-living objects
- Viruses can have a broad or narrow range of hosts

Virus multiplication

Viruses generally employ a common strategy to replicate. For this they come in contact with their host cell surface and inject their genetic material inside. The genetic material of viruses contains genes for viral coat proteins as well as those for initiating and regulating the viral DNA replication, transcription and translation. Once inside the host cell, the viral genes are expressed and genetic material is replicated many times with the help of the enzymes and cellular machinery of the host cell. Finally many copies of the viral genetic material and coat proteins are manufactured inside the host cells which are further assembled to form numerous new virus particles. These virus particles finally release from the host cell in most of the cases by rupturing and killing it.

Viruses as agents of diseases:

Viruses infect both eukaryotic and prokaryotic cells. Viruses cause a wide range of diseases among plants, animals and fungi. Diseases of humans caused by viruses include measles, chickenpox, influenza, herpes, AIDS, hepatitis, dengue etc. There are evidences that viruses may be the causative agent of some kind of cancers also.

11.3.3 ARCHAEA

Archaea are a domain of single cell prokaryotic organisms that normally inhabit the extreme environment on the earth. Like bacteria they do not have cell nucleus or any other membranous organelles inside their cells. However, they have distinct molecular characteristics separating them from bacteria e.g. archaea cell walls do not contain peptidoglycan like bacteria. They have different membrane lipid composition than bacteria.

Distribution

Archaeans include inhabitants of most extreme environments on the planet. Some live in deep sea while others live in hot spring or in extremely acidic or alkaline environment. They have been found thriving inside the digestive tracts of cows, termites and marine life where they produce methane. They live in the anoxic muds of marshes and at the bottom of the ocean, and even thrive in petroleum deposits deep underground.

Types of Archaea

There are three main types of Archaea:

1) Crenarchaeota- these are characterized by their ability to tolerate extreme in temperature and acidity.
2) Euryarchaeota- these include methane producers and salt lovers.
3) Korarchaeota - a catch-all group for archaeans about which very little is known.

11.3.4 BACTERIA

Bacteria are small, unicellular microscopic organisms approximately 0.5 to1.0 μm in diameter with variable shapes. Bacteria can survive in various extreme conditions because of their ability to reproduce faster and transform into metabolically inert yet live forms called spores. Bacteria are important part of our ecosystem as they carry out various chemical transformations which are essential for sustaining life on the earth. They are the natural scavengers on the earth which cause decaying of dead and waste matter and hence protect the environment by recycling of elements. Bacteria are important for the survival of both animal and plants. Each animal has a normal bacterial flora in its body particularly in the guts for carrying out processes for complete digestion and degradation of unused food. Plants also depend on the bacterial activity for enhancement of soil fertility. Since last

century bacteria are being used industrially for the production of a number of food items, nutrient supplements, medicines, flavouring agents, vaccines, solvents, enzymes, antibiotics etc. Unfortunately, many of them are the causative agents of various animal and plant diseases also.

11.3.5 EUKARYOTIC MICROORGANISMS

The eukaryotic microorganism includes Protozoa (unicellular), fungi and algae (unicellular or multicellular).

PROTOZOA

The protozoa are heterotrophic, single celled, eukaryotic microorganisms with diameter between 5 and 250 micrometers. They are found in almost all moist habitats and commonly present in the sea, soil and freshwater. Members of these groups are free-living as well as parasitic in nature. The locomotors of protozoa include flagella, cilia or Pseudopodia. They reproduce asexually by binary fission, multiple fission or budding and sexually by conjugation. Study of protozoa is important as many of them infect humans and cause various diseases e.g. plasmodium causes malaria in humans.

FUNGI

The fungi (sing. fungus) are a diverse group of eukaryotic heterotrophic microorganisms largely feeding on dead or decaying organic matter. They can also exist as pathogen to plant and animal cells. Fungi are spore-bearing organisms that lack chlorophyll and capable to reproduce by both sexual and asexual modes. Asexual reproduction involves processes like budding, fragmentation, sporulation etc. while sexual reproduction in fungi takes place by means of fusion of compatible nuclei of two parent cells. Several thousand species of fungi have been characterized so far and the number is expected to rise to many millions in future. The habitats of fungi are quite diverse. Some are aquatic, living primarily in fresh water and few in marine habitat. Most are terrestrial and often play crucial roles in mineralization of organic carbon in nature. Fungi can be broadly classified into two groups i.e. **yeasts** and **molds**. Yeasts are unicellular creatures which resemble bacterial colonies when grown in culture medium. On the other hand, molds are long tangled filaments of cells. These filaments called hyphae (sing., hypha) are intertwined together to form the cotton like structure called mycelium (pl., mycelia). Some fungi are dimorphic that is they exist in two

forms.

Fungi are important to us as they break down complex organic compounds, mainly the remains of animal or plant, into simpler compounds that can improve soil fertility. There is a big industrial use of yeasts for making various alcoholic beverages and bakery products. Various filamentous fungi such as Penicillium sp. are being used for the production of antibiotics for treatment of infectious diseases in humans and animals. However, fungi are undesirable at many places as they can decompose timber, textiles, food and other materials. They can also cause various diseases in humans, animals and plants.

Algae (sing., alga) are unicellular or multicellular organisms that contain chlorophyll. They form a heterogeneous group in terms of size, habitat and reproductive processes of the members. The microscopic algae are unicellular and comparable in size to bacteria. Their shape of unicellular algae may be spherical, rod like, club-like or spindle like.

Compared to other green plants algae have simple reproductive structures for sexual reproduction in which a unicellular alga itself may function as a gamete. They can also reproduce asexually by producing flagellated spores and/or non motile spores in sporangia. Algae are important for sustaining life on earth as primary producers of organic matters. They are also source of important products of commercial value such as agar, alginic acid and carrageen a. Many algal species are also being used as food or food supplements in different part of the globe.

11.3.6 TYPICAL STRUCTURE OF BACTERIA

Typical bacterial cell shapes include spherical (coccus, pl.,cocci); straight rods (bacillus, pl.,bacilli) or rods that are helically curved (spiral). Bacterial cell may also exhibit several other types of non-common shapes like, pear shaped, lobes spheres, rods with squared ends etc. Depending on the species, bacterial cells may prefer to stay together in a characteristic pattern or arrangements. For example group of two spherical bacterial cells known as ‘diplococci’, a chain of three or more spherical bacteria as ‘streptococci’ and a group of four spherical cells as ‘tetrad’. Similarly, rod shaped bacterial arrangements are called as ‘diplobacilli’ and ‘streptobacilli’ which include two cells or a chain of three or more cells, respectively. Spiral bacteria include vibrios which are curved rodes, spirilla which are helical and rigid and spirochetes which are helical and flexible (Fig.1) Based on the structure of cell wall, bacteria can be broadly classified into two groups i.e. Gram positive

and Gram negative. Compared to Gram negative bacteria, Gram positive bacteria have a thick layer of peptidoglycan in their cell wall. On the other hand, Gram negative bacteria have an additional plasma membrane as part of their cell wall which Gram positive bacteria lack. Fig. 2 depicts a typical bacterial cell structure which contains the following components.

1. **Flagellum**- Bacteria possess hair-like, helical appendages called flagella (singular Flagellum) that protrude through the cell wall and confer swimming motility to it. There are three structural parts of a flagellum i.e. basal body, hook and filament. The protein of the filament is known as flagellin. Depending on the bacterial species, a cell may have flagella at one end, at both ends or throughout the cell surface.
2. **Pili** – Pili (singular pilus) are another filamentous appendages which are hollow, non helical, thinner, shorter, and more numerous than flagella. They play no role in motility instead they are primarily required for a process of genetic recombination in bacteria known as conjugation. They are also believed to be involved in attachment of bacteria to its host cell surface.
3. **Capsule**- Some bacterial cells may be surrounded with a viscous substance made of polysaccharide of polypeptide known as 'Capsule'. Capsules serve a number of functions, which include protection against temporary drying by binding water molecules, blocking attachment of bacteriophage, making resistant against phagocyte cells in host body etc.
4. **Cell wall**- Beneath external structures as capsules, sheaths and flagella is the cell wall, a rigid structure that gives shape to the cell. All bacterial cells except Mycoplasma, contain a cell wall covering the cytoplasmic membrane that is made of Peptidoglycan, a polymer, formed by peptidyl cross linkage of linear chains of the alternating units of N-acetyl glucosamine and N- acetylmuramic linked by beta 1, 4 glycosidic bond. This is an insoluble, porous, cross-linked polymer of enormous strength and rigidity. Its main function is to prevent the cell from expanding and bursting because of uptake of water, since most bacteria live in hypotonic environments.
5. **Cytoplasmic membrane** – Beneath the cell wall is the Cytoplasmic membrane, which is approximately 7.5nm thick and is primarily composed of phospholipids and membrane proteins. The Cytoplasmic membrane serves as a hydrophobic barrier to penetration by most water soluble molecules. However, there are specific proteins embedded in the cytoplasmic membrane which facilitate the passage of small molecules

of nutrients and waste products across the cytoplasmic membrane. Various biochemical reactions of respiration and photosynthesis in photosynthetic bacteria take place across the cytoplasmic membrane.

6. **Cytoplasm** –The entire gelly like viscous material covered by the cytoplasmic membrane of a bacterial cell is known as cytoplasm. It contains bacterial chromosome which is a large single piece of supercoiled DNA confined in a region known as nuceloid. Various other macromolecules like ribosomes, m RNA, tRNA etc. are also present in the cytoplasm. Some bacteria also contain plasmid in the cytoplasm.
7. **Plasmid**- Plasmids are extra-chromosomal small, circular, double stranded DNA molecules that can replicate independently. Plasmids often carry genes that may benefit the survival of the organism for example antibiotic resistance.

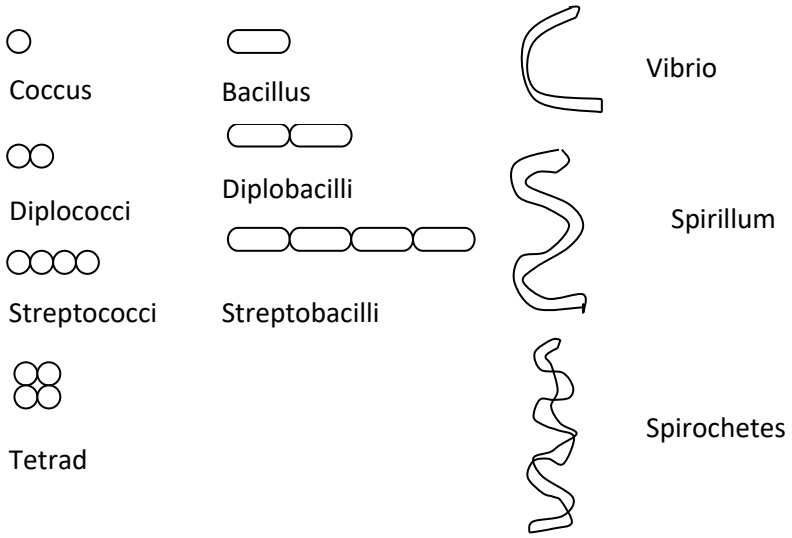


Fig.11.1 Different types of shapes and arrangements of bacterial cells.

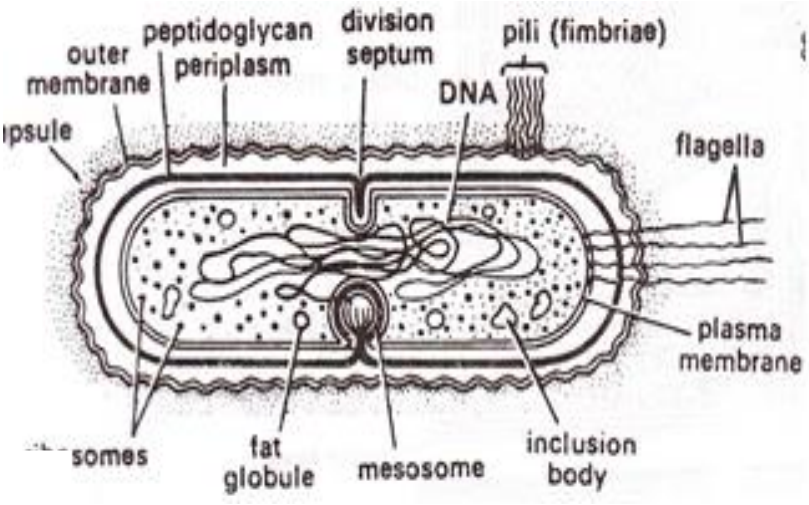


Fig. 11.2 Typical structure of a bacterial cell

11.3.7 TYPICAL STRUCTURE OF VIRUS

A complete virus particle consists of the following parts:

- **Genetic material** – All viruses have a genetic material in the form of either DNA or RNA but never both together. A virus particle may contain single or double stranded form of these nucleic acids.
- **Capsid –** This is protein coat that surrounds the genetic material and protect it. Capsid is made up of subunits known as capsomeres. A capsid is formed by the repeated joining of various capsomer molecules in a particular pattern. Capsid structure decides the shape or structure of a virus.
- **Envelope-** Some viruses such as HIV and influenza viruses, have an additional lipoprotein layer around the capsid known as envelope. The envelope is made up of a lipid bilayer derived from the cell surface membrane of the host cell. However, it also contains virally encoded proteins which may serve functions like binding to receptors on the host cell or play a role in membrane fusion and cell entry.

A virus structure can be one of the following: helical, icosahedral or complex.

a) Helical

Helical viruses have capsid with a central cavity or hollow tube with nucleic acid in the middle (Fig.3). The capsid is formed by proteins arranged in a circular fashion to create a disc like shapes which are helically attached. They are usually 15-19nm wide and range in length from 300 to 500nm depending on the genome size. Helical viruses may contain an envelope or not. Examples of enveloped and non enveloped (naked) helical viruses are

influenza and tobacco mosaic viruses, respectively.

b) Icosahedral

These viruses are more-or-less spherical in shape involving icosahedral symmetry for bonding and packaging of capsid subunits (Fig.4). The icosahedron is a regular polyhedron with 20 trianglular facets and 12 corners. The genetic material is fully enclosed inside the icosahedrally shaped capsid. Example of enveloped icosahedral viruses is herpes virus whereas poliovirus is a naked virus of this type.

c) Complex

These virus structures have a combination of icosahedral and helical shape and may have a complex outer wall or head-tail morphology. The examples are bacteriophages i.e.viruses that infects bacteria. The head of many bacteriophages has an icosahedral shape with a helical shaped tail (Fig.5). In some bacteriophages whiskers and collars are present at the top of the tail which is required for efficient tail fiber attachment during phage assembly. At the end of the tails there may occur long tail fibers which help bacteriophage attach to the host cell surface.

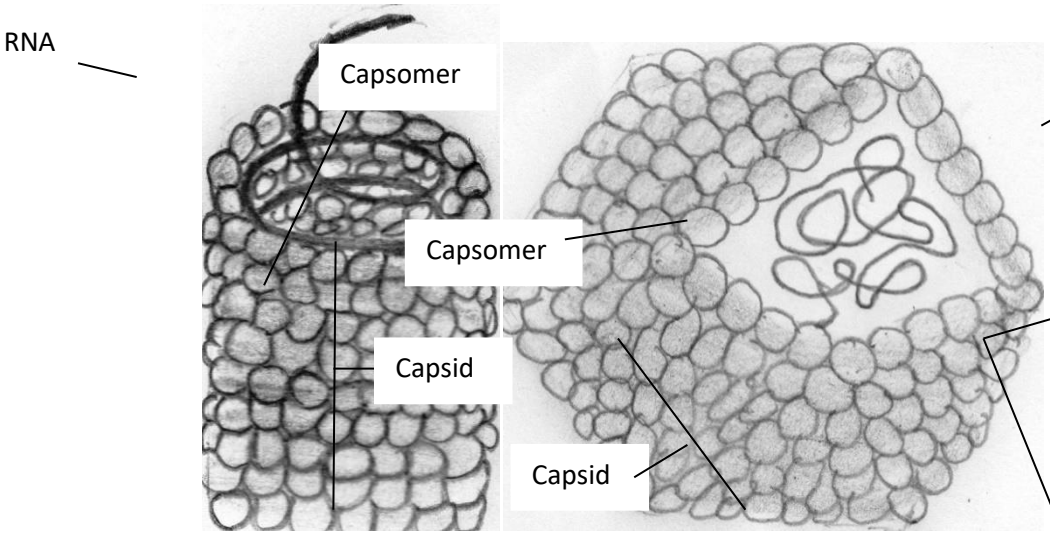


Fig.11.3 Helical virus (TMV)

Fig.11.4 Icosahedral virus

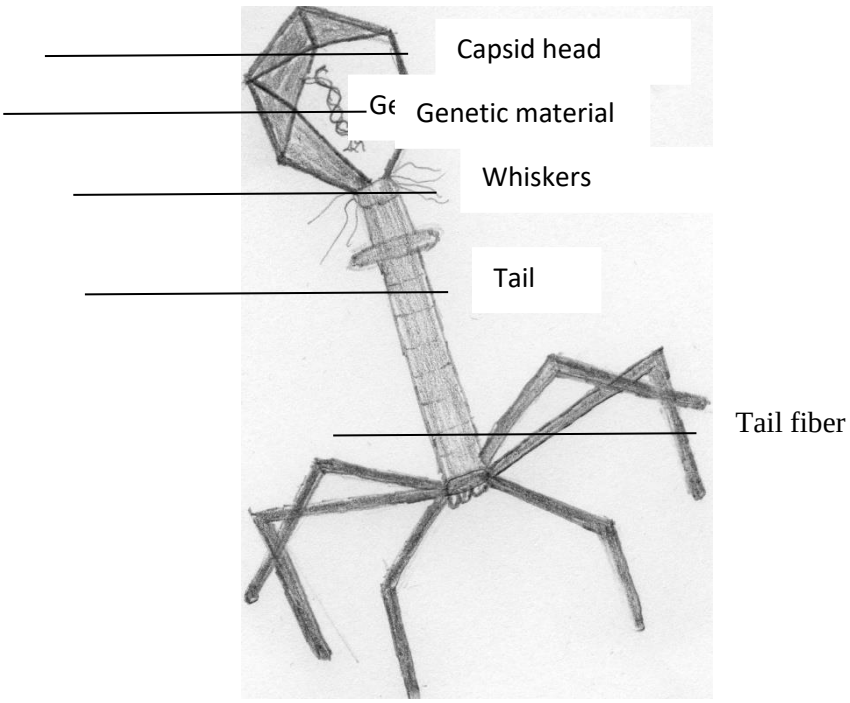


Fig.11.5 Complex virus (Bacteriophage)

11.8 SUMMARY

Microbiology is the study of living organisms which can't be seen in individual form by the naked eyes. These organisms include bacteria, fungi, unicellular algae, protozoa and viruses. Except viruses, all microorganisms have a cellular structure. Depending on their type they may undergo sexual or asexual reproduction or both. Fungi, algae and protozoa are the eukaryotic microorganisms whereas bacteria are prokaryotic. Archae are another class of microorganisms which largely resemble bacteria except few differences. May of them can cause various diseases in humans, animals and plant. However, many of them are very important for their ecological role as well as for medical and industrial applications.

11.9 GLOSSARY

1. **Algae:** chlorophyll containing organisms with simple morphological features that range from microscopic and unicellular to very large and multicellular
2. **Archaea**: Bacteria like prokaryotic organisms inhabiting extreme environment
3. **Bacteria:** a group of microscopic organisms that are prokaryotic in nature
4. **Capsid**: Protein cover that surrounds genetic material in a virus

5. **Capsomer**: Protein subunits of a capsid
6. **Flagella**: Locomotory structures of bacteria
7. **Fungi:** a type of eukaryotic microscopic organism that lacks chlorophyll
8. **Pili**: Hairlike structures on the surface of bacteria used for genetic material transfer and host binding
9. **Plasmid**: Extra chromosomal genetic elements found in some bacteria and yeasts
10. **Prokaryotes:** microscopic organisms like bacteria that lacks membrane covered genetic material
11. **Protozoa:** A type of unicellular eukaryotic microscopic organisms
12. **Virus**: Infectious particle made up of nucleic acid, proteins and sometime a proteo-lipidic envelope.

11.10 SELF ASSESSMENT QUESTIONS

i) Write short notes on the following

a) Bacterial capsule

b) Virus multiplication

c) Plasmid

d) Protozoa

e) Microscopic algae

f) Describe structure of a typical bacterial cell

g)Explain different structure of viruses with the help of labeled diagrams

11.11 REFERENCES

1. Madigan MT, Martinko JM and Parker J. Brock Biology of Microorganism 10th edition Pearson Education LTD, London, 2003.

2. Pelczar MJ, Chan ECS and Krieg NR. Microbiology 5th edition Tata McGraw- Hill Publishing Company Limited New Delhi, 1998.

11.12SUGGESTED READINGS

1. Madigan MT, Martinko JM and Parker J. Brock Biology of Microorganism 10th edition Pearson Education LTD, London, 2003.

2. Pelczar MJ, Chan ECS and Krieg NR. Microbiology 5th edition Tata McGraw- Hill Publishing Company Limited New Delhi, 1998.

11.13 TERMINAL QUESTIONS/ ANSWER

Fill in the blanks

a) Bacteria like organisms that can survive at extreme conditions are known as____

b) Helical appendages on bacterial surface for locomotion are known as _____

c) Unicellular fungi are also called_____

d) The protein subunit of capsid is called_____

e) The source of agar is _____

Answer: a) Archaea b) Flagella or flagellum c) Yeast d) Capsomer e) Algae

State True (T) or False (F)

a) Bacteria are eukaryotic organisms

b) Viruses can infect bacteria also

c) Microscopic algae do not contain chlorophyll

d) Some fungi are the source of antibiotics

e) Plasmodium is a type of protozoa

Answer: a) F b) T c) F d) T e) T

UNIT 12: PRINCIPLES AND USES OF ANALYTICAL INSTRUMENTS

CONTENTS

12.1 OBJECTIVES

In this chapter you will learn about the basic or common instrument used in the laboratory such as pH meter, UV-visible spectrophotometer, Centrifuges (clinical, high-speed and ultra- centrifuge), Geiger Muller and scintillation counters.

12.2 INTRODUCTION

In biological science there is basic requirement of having knowledge of instrument. Instrument play important role in laboratories such as soil analysis lab, diagnostic lab, molecular biology lab, microbiology lab, chemistry lab, physics lab and diagnostic lab. We cannot imagine the laboratories without basic instrument such as pH meter, centrifuge and spectrophotometer. These instruments are very necessary for analysis. Instrument not only speedup the analysis but also have accuracy, specificity and sensitivity. pH meter is one of the important instruments used in basic laboratory to measure pH of water, soil and food etc. Centrifuge is used to separate the mixture of two liquid depending on the density of liquid. UV spectrophotometer is generally used in analytical chemistry for the quantitative determination of different analyses, such as transition metal ions, highly conjugated organic compounds, and biological macromolecules. G-M counter and Scintillation counter is used for the detection of radioactivity.

12.3 PRINCIPLES AND USES OF ANALYTICAL INSTRUMENTS

12.3.1 pH METER

pH meter is generally used to determine the pH of soil, water and culture medium used for the cultivation of fungi and bacteria. There is presence of electrode which very sensitive to detect the change in H ion concentration. The electric circuit measure the electromotive force developed across the electrode pair. pH is abbreviation of “Pondus Hydrogenii”and it was proposed by Sorenson in 1909 in order to express the small concentration of hydrogen ions. pH is a unit of measure that describe acidity and alkalinity of solution. It is measured

on a scale 0 to 14 and defined as the negative logarithm of hydrogen ion activity.

$pH = -\log [H^+]$

The pH value of a substance is directly related to the ratio of the hydrogen ion and hydroxyl ion concentrations. If the H+ concentration is higher than OH- the material is acidic. If the OH^- concentration is higher than H^+ the material is basic.

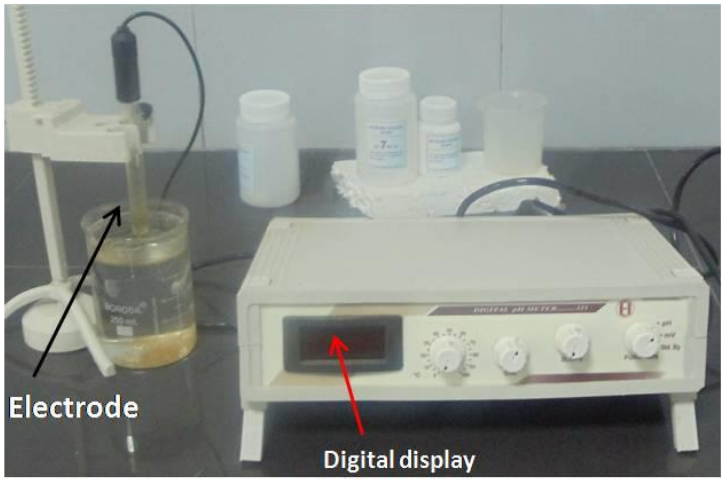


Figure 12.1. Digital pH meter

Principle of pH meter

The pH electrode consist of the pH-sensitive electrode which is a thin glass membrane whose outside surface contacts the solution to be tested. The inside surface of the glass membrane is exposed to a constant concentration of hydrogen ions (0.1 M HCl).

Inside the glass electrode assembly, a silver wire, coated with silver chloride and immersed in the HCl solution known as Ag/AgCl electrode. This electrode carries current through the half-cell reaction. The potential between the electrode and the solution depends on the chloride ion concentration, but, since this is constant (0.1 M), the electrode potential is also constant. To complete electrical circuit reference electrode is needed. So, Ag/AgCl electrode is immersed in an 0.1 M KCl solution which makes contact with the sample through a porous fiber which allows a small flow of ions back and forth to conduct the current. The potential created at this junction between the KCl solution and the test solution is nearly zero and nearly unaffected by anything in the solution, including hydrogen ions. A voltmeter in the probe measures the difference between the voltages of the two electrodes. The meter then translates the voltage difference into pH and displays it on the screen .

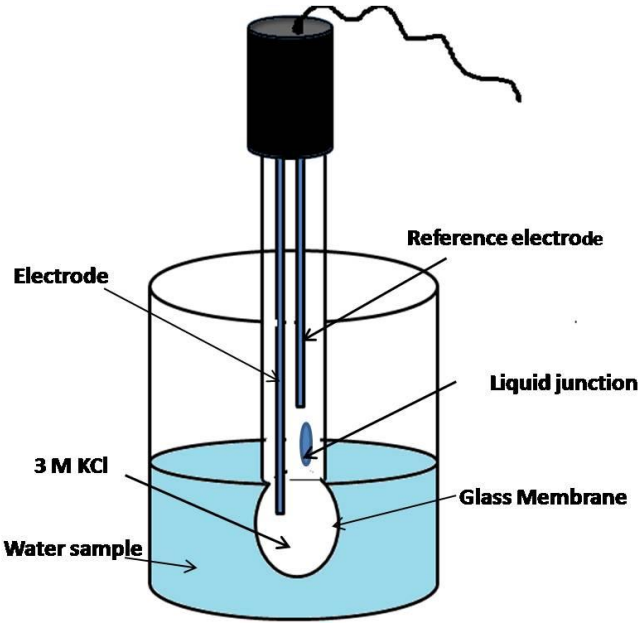


Figure 12.2: Working of pH meter

Calibration of pH meter

1. Switch on the pH meter and move the knob from stand by to pH.
2. Rinse the electrode with double distilled water and wipe out the tip gently with tissue paper,
3. Place the electrode into the solution of pH 7.0 and adjust the pH by adjustment given in pH meter.
4. After adjusting again wash the tip with distilled water and wipe out with tissue paper.
5. Dip the electrode in to solution of pH 4.0 (if your solution is acidic) and pH 9.0 (when your solution is basic)
6. Turn on the knob to slope position till it shows 4.0 or 9.0.
7. After reading the pH of sample. Again wash the electrode with distilled water.
8. Immerse the electrode in to the distilled till used for the next time.

12.3.2 UV-VISIBLE SPECTROPHOTOMETER

Spectroscopy is the measurement of (spectrum of light) electromagnetic radiation, absorbed, scattered, or emitted by atoms, molecules, or other chemical species. Each chemical species has unique energy states; spectroscopy can be used to identify the interacting species

separately. Moreover; interaction of light with different compounds offers several possibilities of qualitative and quantitative measurements. Electrons in an atom move around the nucleus in orbitals and possess characteristic energy also known as *ground state*. Energy transfer to these electrons energizes them substantially to let them leave their orbital to jump over the next level of energy orbital or level; this is called as *excited state*. Generally, on ceasing the energy supply, electrons emit the absorbed energy in the form of radiation giving rise to the *atomic spectrum* or simply *"line spectrum"*, which is represented as graph of the amount of energy absorbed or emitted by a system against wavelength or similar electromagnetic parameters. Visible light forms a part of the electromagnetic spectrum with γ rays at one end having wavelength of the order of 10^{-14} m, and radio waves at the other end having wavelength 3×10^3 m or greater. As atoms, each of the electrons in a molecule usually occupies the available lowest energy level (ground state). Electrons in a molecule change their energy level only after the absorption or emission of the distinct quanta (particular energy radiation) of radiation by the molecule. Depending upon the absorption and emission of energy quanta, there occur two viz., absorption and emission spectra respectively. For molecules, each ground and excited state is subdivided into a number of vibrational and rotational energy sublevels, molecular spectra is therefore seen as "*band spectra"*.

Types of spectra

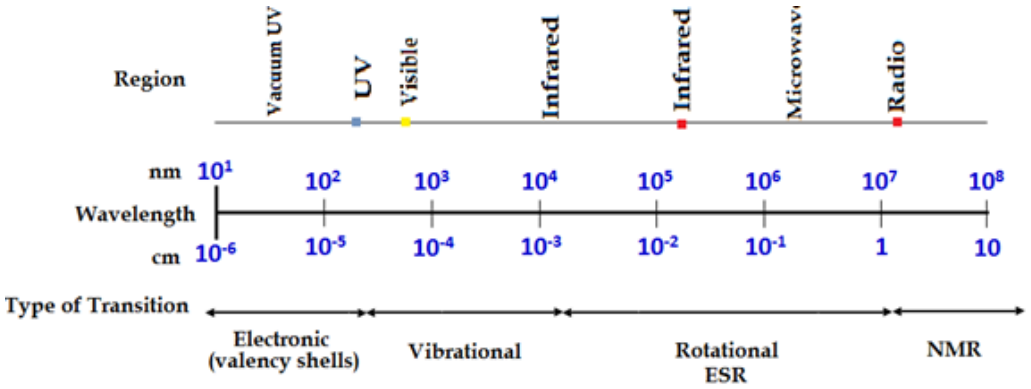


Figure 12.3 Types of spectra and their wavelength

Electronic Spectra

Electronic spectra arise due to the outer electrons of atoms changing between major electronic energy levels. Such spectra occur in the visible and ultraviolet regions and are usually accompanied by changes in the rotational and vibrational energy levels. These spectra are used routinely in biochemistry. Fluorescence spectra may also arise owing to

these transitions.

Vibration – Rotation Spectra

Vibration spectra caused by changes in the vibration energy levels. They occur in the near infra-red region and may be accompanied by changes in the rotational energy levels. Such spectra are sometimes used in studies of the detailed structure of biological macromolecules in non-aqueous environments.

Electron Spin Resonance (ESR) Spectra and Nuclear Magnetic Spectra

These spectra arise due to changes in the directions of the spins of electrons and nuclei respectively in a magnetic field. These two types of spectra are valuable for studying the structure of biological macromolecules.

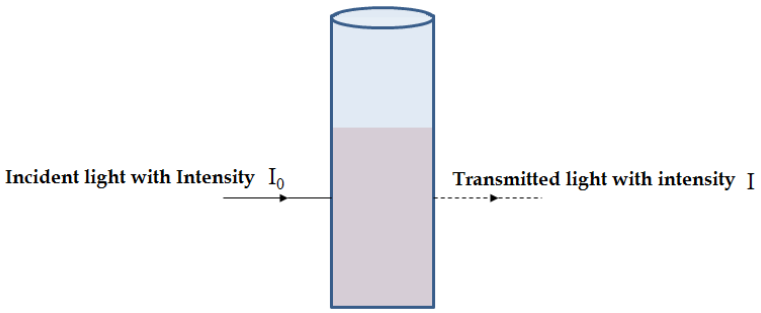
Molecular Band Spectra

Molecular band spectra may be resolved into a number of very close line spectra, corresponding to the vibration and rotational energies of the electrons only at extremely high resolution.

12.0.1 Absorption

Photons of UV and Visible light may sometimes impart their energy to materials by interaction with individual atoms or molecules. Energy is imparted to the atoms or molecules, causing the excitation of valence electrons. Molecules with excited electronic states represent an unstable state will relax by allowing their electrons to fall to the ground state as soon as possible (10^{-16} sec.).

How much radiation is absorbed?



The absorbance (A) is defined as the $\log_{10}$ of the ratio of the incident to transmitted light

intensities:

$A = log_{10}(\frac{I_0}{I})$ - The intensity is measured in the unit of power; therefore the absorbance is a unit less quantity. The intensity of light can be detected by photo-multiplier tubes. The collision of a photon of appropriate energy with the suitable molecule results in absorption of light.

Beer-Lambert Law or Law of absorption

The Beer-Lambert law relates the absorption of most molecular species to the concentration (C_n), the path length (l) and the molar absorptivity (ε).

$A = \varepsilon C_n l$

The wavelength of maximum absorption is known as λ max and is usually used as the wavelength for molar absorptivity (ε). ε is also sometimes known as extinction coefficient and is measured in $dm^3mol^{-1}cm^{-1}$. The Beer-Lambert law is sometimes expressed in terms of transmittance T as:

T = 1/A

Pathlength of 1 cm is normally chosen to simplify the calculation of the absorbance or molar absorptive. All modern spectrophotometers are designed to comply the Beer-Lambert law. A plot of absorbance versus wavelength is known as UV-Visible Spectrum and is measured by a UV-Visible Spectrophotometer.

3.0.2. Spectrometers /Spectrophotometer

A spectrometer or spectrophotometer is a device which measures the absorbance by molecules in a given sample. Spectrometers are a monochromator equipped with a photo-transducer. Single and double beam spectrophotometers are readily available in the market whereas double beam spectrophotometers are commonly used in scientific laboratories because of the ease of function and precision in readings of absorbance.

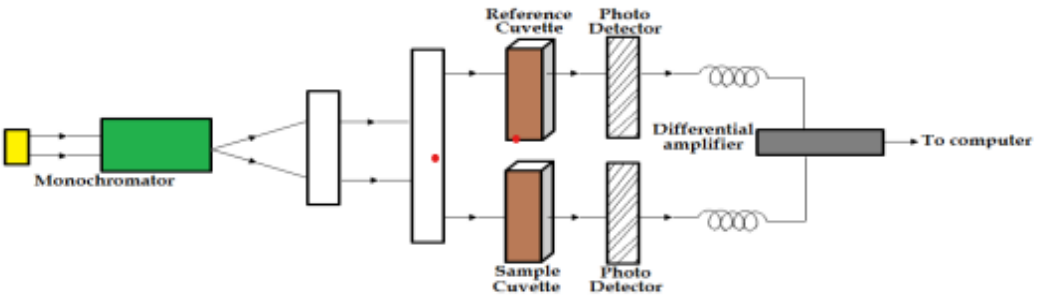


Figure 12.4. Schematic of Double Beam Spectrophotometer

Spectrophotometer comprised of several devices such as monochromatic for monochromatic light of particular wavelength, grits, photo-detectors, and a processor that send signals to the interfaced computer. To understand and to define a spectrophotometer, it is recommended to study each and every component in details.

Light Source

The irradiation of a sample for UV and Visible spectroscopy requires a light source with constant output intensity. Tungsten (W) filament lamp are used for UV and visible light (320 – 2500) nm while hydrogen and deuterium lamps UV radiation. The light source should also be sufficiently intense so as to allow sufficient transmitted radiation to be detected when the absorption falls within a range of 0 -2. In more advanced spectrophotometers, tungsten-halogen lamps are frequently used. Such lamps contain small quantity of iodine and the lamp is enclosed in *quartz* housing. The iodine (a halogen) raises the temperature of lamp to 3500K, which permits the intensity of the output radiation down to ~ 190 nm (UV range). Quartz is permeable for UV radiation whereas glass blocks the UV radiation.

Hydrogen and deuterium lamps produce high intensity UV radiation. Electrical excitation of hydrogen atoms at low pressure may produce two hydrogen of either low energy with the high energy photon or higher energy with low energy photons. As a result of this unequal uniform output the deuterium or hydrogen lamps give rise to the outputs of radiation over a wavelength range of 160 – 375 nm.

Monochromator: A monochromator is the most commonly used device to select a wavelength of light for the irradiation of a sample. Monochromators use a series of lenses, mirrors, slit and windows together with either prisms and /or diffraction gratings to isolate a narrow band of wavelengths. It is impossible to select one wavelength range. The wavelength of the radiation source will tend to follow a *Gaussian* distribution around a mean value of wavelength known as the nominal wavelength. The effective *bandwidth* is defined as the wavelength range which corresponds to the half peak height width of The wavelength distribution profile. There are two common types of monochromators viz., Monochromators based on refracting prisms and Monochromators based on diffraction grating are used in the modern age spectrophotometers. A monochromator with a bandwidth of less than ~ 0.5 nm is perfectly acceptable.

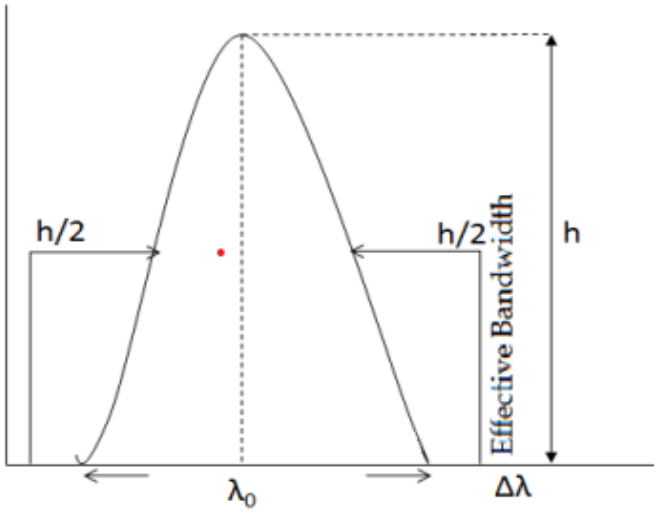


Figure 12.5 Effective Bandwidth

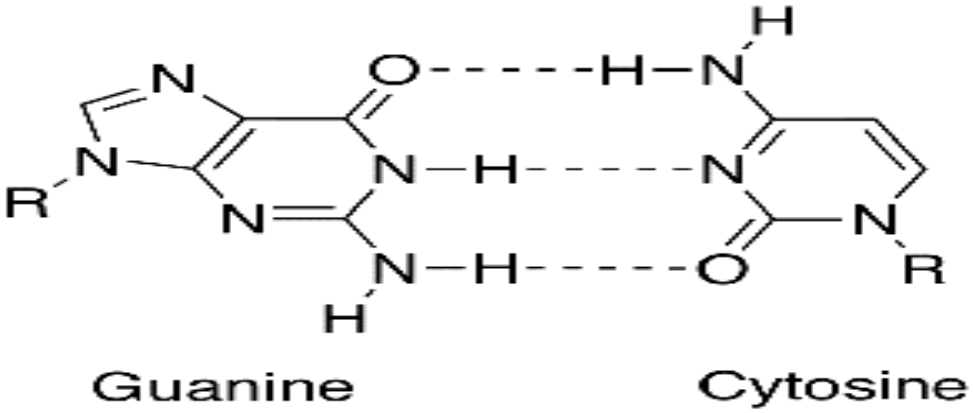


Figure 12.6 Simplified Schematic of a Prism Monochromator

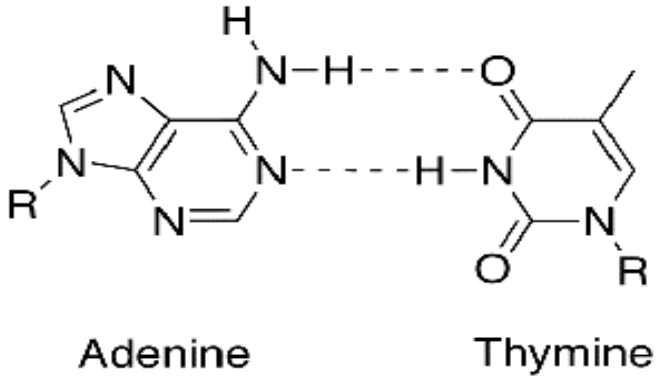


Figure 12.7 Optics of Diffraction Based

In refracting prism monochromators, the white light enters via a slit passing through a collimator into the monochromator. A collimator is equipped with collimating lens, produce a parallel beam of radiation as shown in Figure 6. The light then passes through a refraction prism that disperses the light into its component wavelengths. The light is focused by another lens on the focal point where another slit is placed. By rotating prisms, radiation of different frequency is selected.

Diffraction grating based monochromator

White light passes through an entrance slit and is focused on a diffraction grating through a concave mirror. The diffraction grating disperses the light into its component wavelengths and reflects the light onto a second concave mirror. The grating can be rotated by a stepper motor. Light is then focused on the exit slit by this second concave mirror. By rotating the grit, light of different wavelengths can be selected.

Light Detector

The absorbance of an analyte is performed by a photon tube or light detector which measures the intensity of transmitted light. A photo-multiplier tube or photon tube works on the principle of photo-emission or electronic transition involving the counting of photons enabling the monitoring of the intensity of light. Figure 12.5 show a photon tube where by the photons enter into the tube to emit electrons from the large cathode that are captured by a wire anode placed in front of the cathode. The entire circuit is encased in quartz housing under high vacuum. The circuit gets completed and the current generated is directly proportional to the intensity of light entering into the photon tube. Photon tube operates as photo-multiplier tube whereby a cascade effect is produced, which enables the collection of $10^6 – 10^7$ electrons per photon entering into the tube.

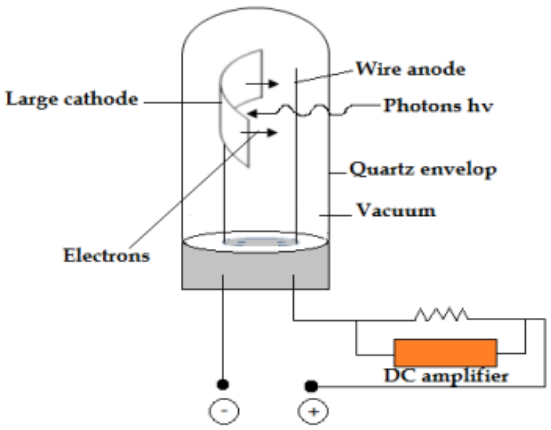


Figure 12.8: A photo-multiplier tube

12.4 CENTRIFUGE

Centrifugation is based on the principle of centrifugal force in which liquid are subjected to high speed to separate solid from liquid or liquid from liquid depending on the density. In centrifugation heavy particle settled down and light particle will rises to the top. The substance which is settled down is called “Pellet” and the remaining fluid or overlying fluid is called “Supernatant”. Centrifugation process separates two substance of different density.

Basic principle of centrifugation

When the tube is filled with fluid and allowed to spin, as the rotor spin the apparent centrifugal force act on the sample of fluid and the analyte inside the fluid is pushed both radially outwards to the side of centrifuge tube.

Relative centrifugal force $F = m\ \omega^2 r$

Where,

F= Relative centrifugal force

m= Mass of particle

r= radius of the circular motion of the centrifuge (unit meter).

ω= angular velocity of the centrifuge (unit radian per sec)

The rate of sedimentation depends upon the applied centrifugal field (G), which depend upon the radical distance of the particle from the rotation axis and square of the angular velocity.

$G = \omega^2 r$

Where angular velocity (ω) = $\frac{2\pi}{60}$ revolution/min (one revolution is equal to 2 radian)

Putting the value in G , therefore

$$G = \frac{2\,\pi\,(\text{revolution/min})^2 \times r}{(60)^2}$$

$$G = \frac{4\pi r}{3600}$$

The relative centrifugal force (RCF) in g units (g=9.8065 M/sec^2 or 980 cm /sec ^{2})

RCF = $\frac{4\pi r}{3600\ x\ 980}$= 1.11 x 10^{-5} (revolution min^{-1})^2 r

The rate of settling of particle depends upon (a) the relative centrifugal force (b) the density of the specimen, (c) the density of the fluid, (d) frictional forces, and (e) the size and shape of the specimen

Consider if the suspending particle is spherical, then the rate of settling of spherical particle can be expressed by following equation.

$$R = \frac{2r^2\ g\ (dp-df)}{9n}$$

Where,

R= Rate of settling
r= Radius of the particle
g= acceleration due to gravity
dp= Density of the particle
df=Density of the fluid
n=viscosity of the fluid

The rate of sedimentation depend on the applied centrifugal field i.e. RCF in g units (980 cm/sec^2).

Types of rotor

The centrifuge is equipped with two types of rotor

1. Fixed angle rotor: In this type of rotor, the centrifuge tube containing samples are placed in the shield in the rotor at fixed pre-set angle. The rotor holds the centrifuge at fixed inclination i.e. 35 degree to the vertical. The solute during centrifugation forced against the side of the tube resulting in faster separation of solute from the suspension. The disadvantage of this rotor is that there are chances of abrasion due to striking the particle to the wall of centrifuge tube. Another disadvantage of this rotor is there is formation of smear like sedimentation than clear pellet formation. This type of rotor has short run time (Fig 12.9).

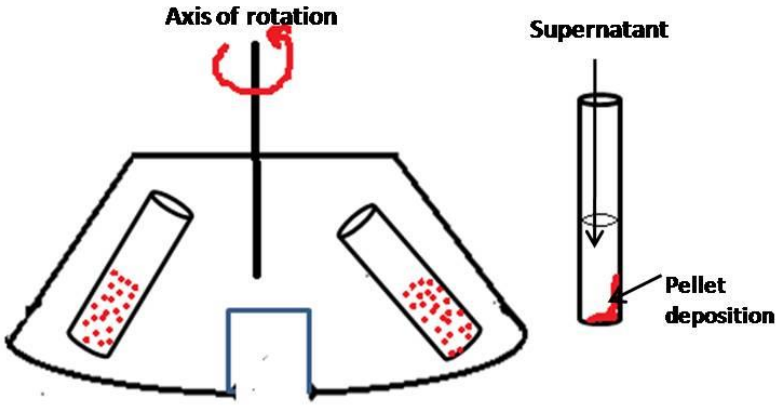


Figure 12.9: Fixed angle rotor and formation of pellet on side wall

2. Swinging bucket rotor: In this type of rotor the sample centrifuge tube are placed vertically and when the machine is started the bottom of the tube swing outward (horizontally) as the shaft rotates. This rotor has advantage than fixed rotor having clear pellet at the bottom of the tube (Fig.12.10).

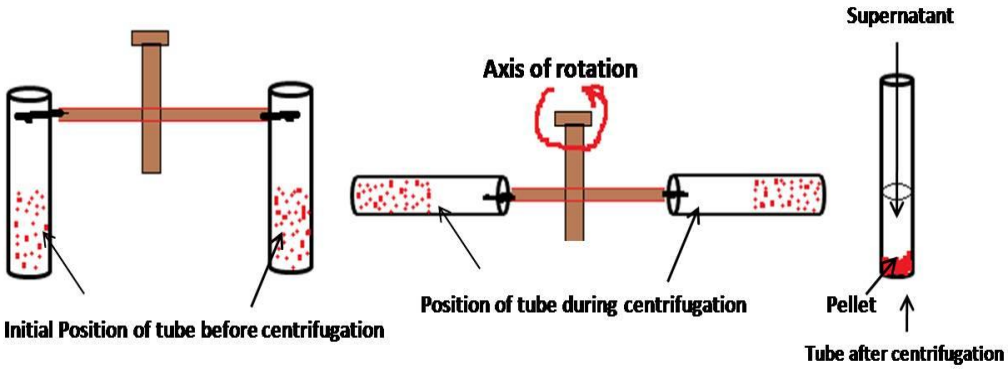


Figure 12.10: Working of swing bucket rotor before and after centrifugation

3. Vertical Rotor: In this type of rotor angle of placement of rotor is fixed but not at the slanting position it is vertical i.e. perpendicular to centrifugal field and the rotation axis as shown in Fig. 12.11. Band separate across the diameter of the tube rather than down the length of tube.

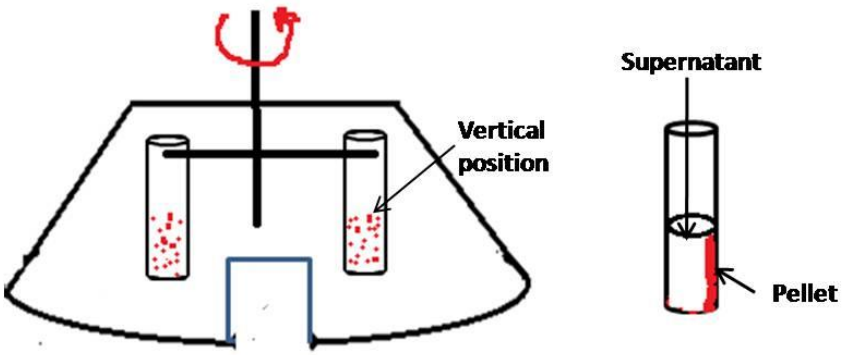


Figure 12.11: Working of vertical rotor before and after centrifugation

Types of centrifuge

Bench centrifuge: The most common type of centrifuge which generally used for common purposes such as separation of serum, plasma from blood sample required for serological reaction. It is not used for the fine substance such as organelle etc. The maximum speed of this type of centrifuge is 4000-5000 rpm and they operate is at ambient temperature. Now a day's small microphage are available which can easily put into refrigerator to keep temperature cool for sedimentation to prevent denaturation heat sensitive substance such as Protein. .

Refrigerated centrifuge (Large capacity):

Refrigerated centrifuge have inbuilt cooling system for rotor such as compressor. It has speed of 6000 rpm with relative centrifugal field 6500g. Refrigerated centrifuge is used for the heat sensitive substance. This type of centrifuge can be run with fixed type rotor or swinging bucket type rotor. The balancing and placing of sample is very important in centrifuge. Always keep balance by placing centrifuge tube opposite to each other so that the load is distributed equally around the axis of rotor as shown in Fig. The sample tubes or centrifuge tube of 10, 50 and 100 ml can be used for centrifugation. The machine comes with changeable rotor according to the requirement of researcher (Fig. 12.12).

High Speed refrigerated Centrifuge: As name indicates this type of centrifuge work on high speed i.e. 25000 rpm generating RCF of about 60000 g. It is also having flexibility of using both types of rotor i.e. fixed rotor or swinging bucket type rotor. It is used for separating bacteria, cell organelles and precipitated proteins. It is not used for the sedimentation of viruses, and small organelles such as ribosome, for this purpose ultracentrifuge is required having maximum speed.

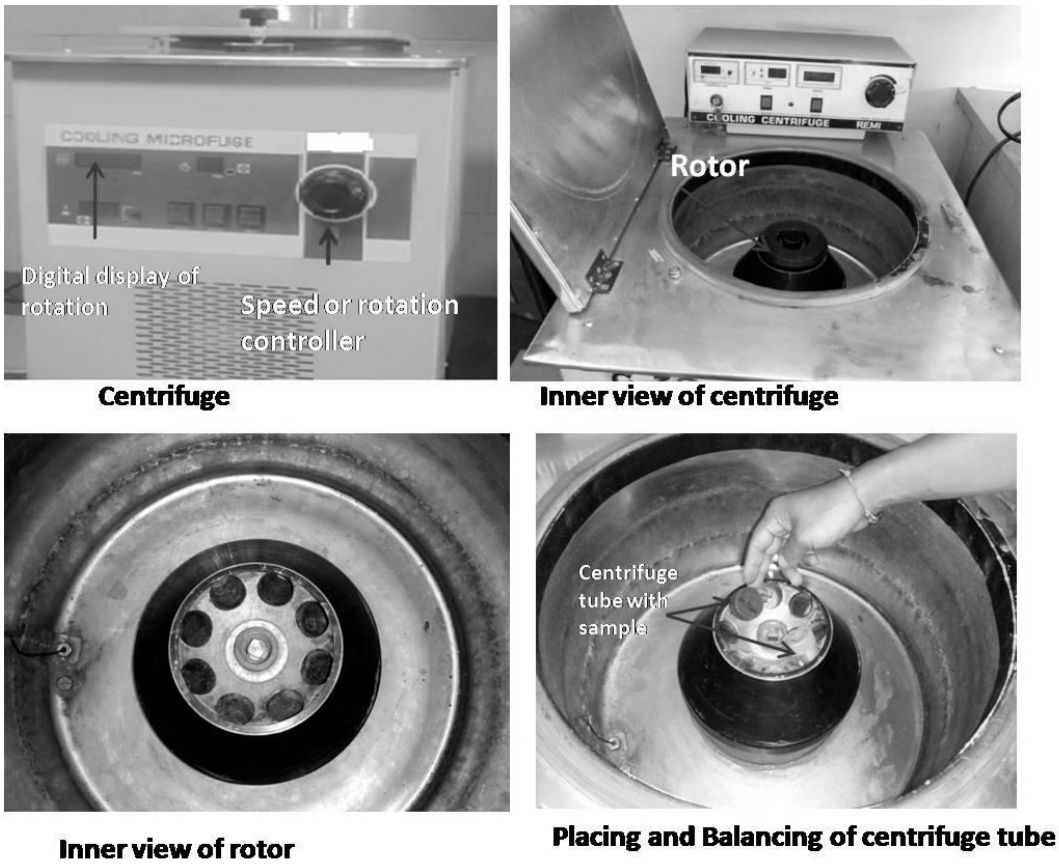


Figure 12.12: Working and parts of Refrigerated centrifuge

Ultracentrifuge: Centrifuge which is used to sediment viruses and small organelles like ribosome have speed of 80000 rpm with a relative centrifugal field of upto 600000 g. it was developed by Svedberg in 1929 and demonstrated the subunit of proteins. Ultracentrifuges are of two types:

a. Preparatory ultracentrifuge: Preparatory centrifuge is generally used for the centrifugation or separation of cellular organelles such as mitochondria, ribosome, microsome and viruses. It is also used for the gradient separation of solution containing increasing concentration of dense substance. For e.g. sucrose solution is used for the separation of cell organelles. Cesium salt is used for the separation of nucleic acid. In this centrifugation the sample is run at high speed and then rotor is allowed to come to smooth stop and gradient is taken out to isolate the separated component.

b. Analytical centrifuge (AUC): A typical analytical centrifuge generate centrifugal field of 2500000g. Analytical centrifuge is used for the determination of the purity

of macromolecule, determination of relative molecular mass of solute in their native state, for the examination changes in molecular mass of super molecular complex. It consists of optical detecting system to monitor the material during sedimentation for concentration distribution in the sample at any time during centrifugation using ultra violet light absorption and optical refractive index sensitive system. Measurement of sample concentration at wavelengths from 200 to 800 nm detection of macromolecules containing strong chromophores. It is used to analyse protein, polysaccharide, nucleic acid, drug, ligands, gases, organelles and viruses.

When the machine switched on or rotor moves the image of analyte (for e.g cells or protein) are projected by an optical system on to film or computer. The concentration of the solution at various points in the cell is determined by absorption of light of the appropriate wavelength and them measuring the degree of blackening of photographic film. This will facilitate to observe the separation of sample concentration versus the axis of rotation due to applied centrifugal force. AUC are generally used for the two types of experiment

a. Sedimentation equilibrium experiment has aim to determine the total time course of sedimentation and report on molar mass and size distribution of dissolved macromolecule

b. Sedimentation velocity experiment is dealing with the final steady state of the experiment where sedimentation is balanced by diffusion opposing the concentration gradient.

12.4.1- GEIGER MULLER COUNTERS (GM COUNTER)

The GM counter was named after its inventor Hans Geiger and Walther Muller. This instrument was first developed by Geiger in 1908 with Ernest Rutherford and name Geiger counter. At that time this device has limited used i.e. it can detect only alpha particle. Later on the research scholar of Geiger, Walther Muller improved this device for detecting more types of ionization radiation. Now a day this instrument is known as Geiger- Muller Counter which is used as particle detector that measure ionization radiation i.e. beta particle and alpha particles except gamma particle because it does not ionize the gas.

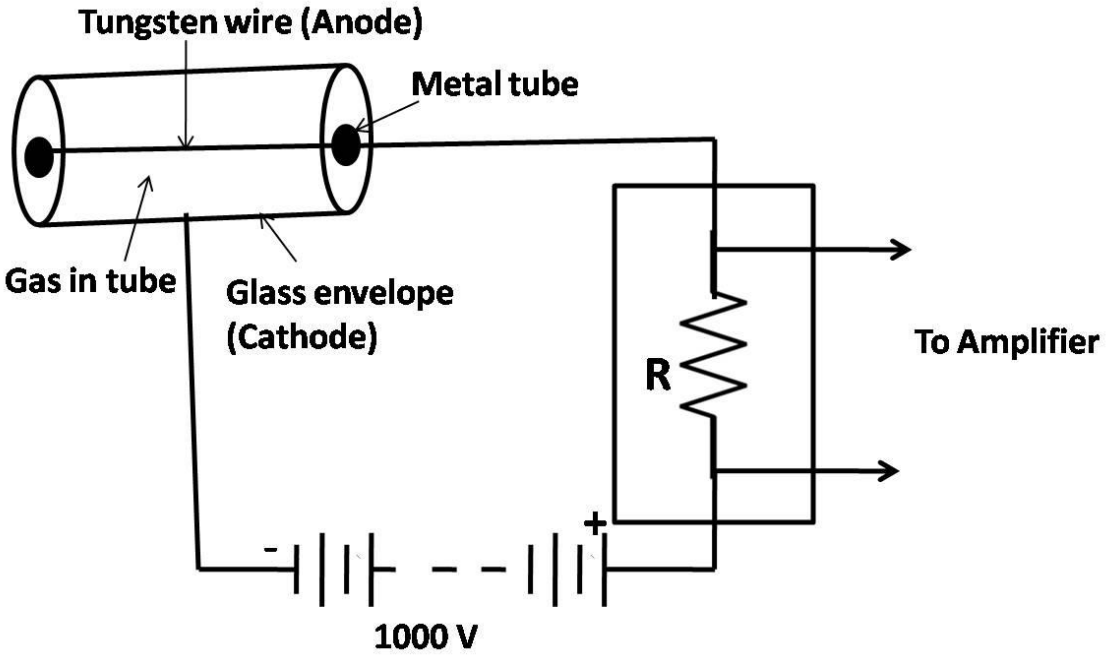


Figure 12.13. Working principle of G-M counter

GM counter consist of a metal tube covered with glass which acts as cathode and along the axis there is thin wire made up of tungsten which acts as anode. The tube is filled with inert gas such as Argon, Helium, Neon with halogen added at low pressure. There is window at one end where mica sheet is fitted, from this window radiation enter into the tube. A high potential difference of about 1000 V is applied between the electrodes through a high resistance R of about 100 mega ohm. (Fig.12.13)

Working of G-M counter

It is based on the principle of ionization as the charged particle passing through the gas medium present in the tube ionizes the atoms of gas by energy transfer.

High potential difference i.e. 1000 V is applied across the anode and cathode of the tube so that a high radial electric field nears the central wire is obtained (Fig.13). Due to the formation of high electrical field electrons generated by ionizing collisions between a high-speed particles entering the tube and the inert gas atoms are accelerated towards the anode wire by the strong electric field and acquire within a very short distance a high speed of their own. Because of this speed, they too can ionize other atoms and free more electrons. The object of the counter is to produce a single pulse for each particle entering the tube.

This can only be achieved if spurious pulses due to secondary electrons released from the cathode surface by the bombardment of ions are completely suppressed so that the tube can recover as quickly as possible to be in a state when it is able to record the next entering particle. A quenching gas (halogen or organic vapors) introduced into the tube is to serve this purpose. The idea is to allow the inert gas ions on their way to the cathode to collide with the heavy molecules thereby transfer

Their charges to the molecules and become neutralized - a process known as quenching. The molecular ions thus produced move slowly to the cathode and on reaching there, capture electrons from the cathode surface to become neutral molecules. The multiplication of charges repeats itself in rapid succession producing within a very short interval of time an avalanche of electrons. The electron avalanche is concentrated near the central wire while the positive ions, being much heavier, drift slowly toward the cathode. The number of electrons striking the wire can be measured to detect the presence of radioactive emission.

12.4.2- SCINTILLATION COUNTERS

Scintillation counter is important instrument generally used for the detection and measurement of radiation. The scintillation counter in which radioactive materials exposed to atoms within the detector that temporarily absorb the radiated energy. These excited atoms return to their unexcited state and emit photons that are detected by the scintillation counter.

Working of Scintillation Counter

In scintillation counter there is lining of phosphor in one end of the photomultiplier tube. Its inner surface is coated with photoemission called photocathode. It acts as negative terminal. There is presence of several numbers of electrodes called dynodes which are arranged in the tube at increasing positive potential. When charge particles reach and strike the photocathode in photomultiplier tube releasing an electron. These electrons accelerate toward the first dynode and strike it. More numbers of secondary electron are emitted which accelerates towards the second dynode so on. Finally the chain continues multiplying the affect of the first charged dynode. Due to this process there is release of a voltage pulse across the external resistance. This voltage pulse is amplified and electronic counter (Fig.12.14).

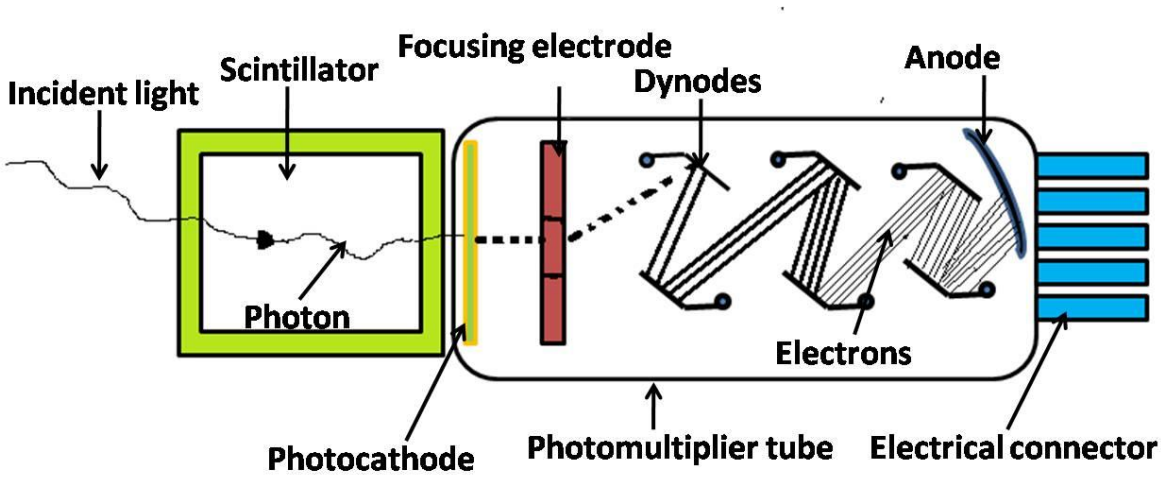


Fig.12.14 Scintillation Counter

Scintillation counter consist of two parts

1. Scintillator: Scintillation is a material may be solid, liquid (organic or inorganic) or gaseous which give luminescence or exhibit scintillation when struck by ionization radiation. The NaI crystal is the most widely used scintillation material which under UV light glows blue.
2. Photo multilplier Tube: PMT is generally used to creates strong electrical output from a weak signal developed by striking of photon on photocathode. This electron accelerates toward the first dynode and strikes it. More numbers of secondary electron are emitted which accelerates towards the second dynode so on. Lastly electron hits the anode and creates current which flow to ground through a resistor where it creates a voltage drop that can be counted.

12.5. SUMMARY

Modern laboratories of biological sciences should equipped with basic instrument like pH meter, UV-Vis spectrophotometer, centrifuge etc. pH meter is generally used to determine the pH of soil, water and culture medium used for the cultivation of fungi and bacteria. There is presence of electrode which very sensitive to detect the change in H ion concentration. The electric circuit measure the electromotive force developed across the electrode pair. Spectroscopy is the measurement of (spectrum of light) electromagnetic

radiation, absorbed, scattered, or emitted by atoms, molecules, or other chemical species. Each chemical species has unique energy states; spectroscopy can be used to identify the interacting species separately. Centrifugation is based on the principle of centrifugal force in which liquid are subjected to high speed to separate solid from liquid or liquid from liquid depending on the density. In centrifugation heavy particle settled down and light particle will rises to the top. Geiger- Muller Counter which is used as particle detector that measure ionization radiation i.e. beta particle and alpha particles except gamma particle because it does not ionize the gas. Scintillation counter is important instrument generally used for the detection and measurement of radiation. The scintillation counter in which radioactive materials exposed to atoms within the detector that temporarily absorb the radiated energy.

12.6 GLOSSARY

Bandwidth: The frequency span where constant amplitude input will produce a meter reading within a specified limit (usually 3db). In controllers, the region around the set point where control occurs.

Controller: A device capable of receiving a signal from a process and regulating an input to that process in order to maintain a selected operating condition

Electromotive force (emf): An electrical potential difference which produces or tends to produce an electric current.

Double Beam: In a double beam spectrophotometer the beam from the light source is split in two. One beam illuminates the reference cell holder and the other illuminates the sample.

12.7 SELF ASSESSMENT QUESTIONS AND POSSIBLE ANSWERS

Multiple Choice Questions:

1. Which filament lamp is used for UV and visible light:

   (a) Tungten (b) Argon

   (c) Platinum (d) Lithium

2. G-M Counter is used to measure the

(a) RBC (b) WBC

(c) Intensity of the radioactive radiation (d) intensity of visible light

3. Centrifugation is based on the principle of

(a). Gravitational force (b) Centrifugal force

(c) Frictional force (d) Vander wall force

4 pH scales ranges from

(a) 0 to 6 (b) 0 to 7

(c) 0 to 10 (d) 0 to 14

12.8 REFERENCES

1. Bair, E.J. (1962). Introduction to chemical Instrumentation, McGraw hill, New York

2. R.C.Dubey and D.K. maheshwari.(2012). Text book of Microbiology. S. Chand & company.

12.9 TERMINAL QUESTIONS

Q1. Write principle, procedure and working of pH meter.

Q2. Draw labeled diagram of GM counter.

Q3. Write different types of centrifuge used in laboratory

Q4. Write short note on

- **a.** Bench centrifuge
- **b.** Cooling centrifuge
- **c.** Ultra centrifuge

Q5. Describe the working and principle of Scintillation counter?

Q6. Explain Beer-Lambert law?

Q7. Write principle and working of UV-Vis spectrophotometer