SECONDARY STAGE
BIOLOGY

BOOK ONE

FOR CLASS XI

For

Sindh Textbook Board, Jamshoro.

CONTENTS

PREFACE

Syllabi for various science subjects taught at high school, college and university levels are regularly revised, updated and modernised all over the world to keep the students abreast with the latest developments in the subjects. For the past decade, the Ministry of Education, Govt: of Pakistan has been busy in revising and modernising the syllabi for the guidance of Provincial Education Authorities. With this idea in the background, the .Sindh Textbook Board was handed over the responsibility of publishing such science textbooks in various subjects for high school and college students.

This is the most challenging time to learn and teach Biology. The same information explosion that makes modern biology so exhilarating also threatens to suffocate students under an avalanche of facts and terminology. Most students in an introductory course do not yet own a framework of biological concepts into which they can fit the many new things they learn.

We can claim that there is drastic but positive change in the syllabus of biology. What we had studied in 6th decade of last century is gone in modern syllabus. The present book is re-written by a group of specialists in the subject. In selecting the coauthors, the Sindh Textbook Board has given preference to experienced working teachers.

There are 14 chapters in the book written by nine authors. There are independent full chapters on the topics of Biological Molecules, Enzymes, Viruses etc. Also there is a chapter captioned "Bioenergetics" dealing with some of the principles of energy transformation in living systems like photosynthesis, glycolysis and respiration. Similarly in a chapter "Nutrition" both Autotrophic and Heterotrophic nutritions are given together with digestion. Also introduced for the first time in biology is the concept of the immune system and the underlying principles involved in the natural management of the health.

For the first time some new things have been added, for example an introductory paragraphs, Information boxes and key points are given in each chapter.

No human writing is free of erros and this consideration let us to revise and update the exisiting books of Biology after first edition. The task was assigned to a group of Biology experts who did this job with pains taking endeavors. Every effort has been made to improve the subject matter, to rectify previously existing errors, to update the textual material as well as the illustrations and exercise.

The Sindh Textbook Board has taken great pains and incurred huge expenditure in publishing this revised book inspite of its limitations. Comments and suggestions of all for improving this book would be welcome.

In the end, I am thankful to our learned Co-Authors and the Subject Specialist of the Board for their relentless service rendered for the cause of education by writing biological textual material.

Chairman
Sindh Textbook Board

Section-1

INTRODUCTION

Biology or the science of life is not unfamiliar to you. It is in you and around you in greatly diverse forms. Every where you see, in water, in air, and on land, you find living things which call your attention to ponder. Why do they exist? How do they exist and what is the underlying unity among them? When and how they came into being? If you have developed this intellect than you are very close to knowing about the Creator and His creations.

Chapter 1

THE BIOLOGY

The Biology recalls your previous exposure to biology in early classes. It gives you some novel thoughts, a modern and clearer vision of the beginnings of living things, from the molecular levels up to the level of complex organisms. It provides you the basis for systematic observations, hypotheses, predictions and experimentations. Finally, this chapter gives you few examples of various brilliant biologist's endeavours, such as modern diagnostics, therapeutics, control of diseases and techniques like cloning, hydroponics etc.

1.1 BIOLOGY AND ITS MAJOR FIELDS

Biology is one of the natural sciences, which deals with the things that exhibit the properties of life. Scientists call these things as "organisms". The word biology has been derived from Greek words Bios, life + Logos, discourse. Formerly living organisms were classified into two kingdoms i.e. plant kingdom and animal kingdom. The plants were studied under the subdivision **Botany** and the animals were studied under the subdivision **Zoology**. The latest research has discarded the old concept of two kingdoms of living organisms. According to modern system of taxonomy, living organisms have been classified into the following five kingdoms:

1. Kingdom Prokaryotae (Monera):
It includes almost all the prokaryotes, e.g. bacteria and cyanobacteria.

2. Kingdom Protoctista (Protista):
It includes all the unicellular eukaryotic organisms, which are no longer classified as animals, plants or fungi, e.g. Euglena, Paramecium, Chlamydomonas, Plasmodium etc. Multicellular algae and primitive fungi have also been included.

3. Kingdom Fungi:
It includes non-chlorophyllus, multicellular (except yeast) organisms having chitinous cell wall and coenocytic body called mycelium, e.g. Agaricus (mushroom) yeast, etc. They are absorptive hetrotrophs.

4. Kingdom Plantae:
It includes all the eukaryotic, multicellular, chlorophyllus, photosynthetic autotrophs having cell wall made up primarily of cellulose, zygote retained to become embryo and exhibiting heteromorphic alternation of generation, e.g. Moss, Fern, Pines, Apples, etc.

5. Kingdom Animalia:

It includes all eukaryotic, non-chlorophyllus, multicellular, ingestive heterotrophs with no cell wall. e.g. Hydra, Earthworm. Human beings etc.
Scientists have discovered and named more than one and a half million species of living organisms which exist in a great variety of forms - shapes and sizes. For example, the smallest microscopic ones, bacteria, which may measure no more than 0.0001mm to probably the largest animal, whale, in the world, which may measure up to 40 metres in length and weigh 150 tons and trees, redwood tree, measuring over 300 feet in height.
Modern biology does not only concern with the recognition and classification of these species but also deals with their vital structural and functional aspects.
This has led to the division of biology into a large number of extremely specialised branches. Some of the major branches or fields of specialisation in biology are defined below:

Molecular Biology:
It is a recent branch of biological science that deals with the structure and function of the molecules which form structure of the cell and its organelles that take part in the biological processes of a living organism (Nucleic acids— Protein molecule).

Micro-Biology (micro = very small):
It deals with the study of micro organisms (viruses, bacteria, protozoans and pathogenic fungi), which can only be seen under microscopic.

Environmental Biology:
It deals with the study of environment and its effects on organisms. Previously it was known as ecology.

Marine Biology:
It deals with the study of organisms inhabiting the sea and ocean, and the physical and chemical characteristics of their environment.

Fresh Water Biology:
It deals with the life dwelling in the fresh water bodies, their physical and chemical characteristics affecting it.

Parasitology (Para=Beside, Sitos=Food, Logs=Science/Study):
It deals with the study of parasitic organisms, their life cycles, mode of transmission and interaction with their hosts.

Human Biology:
This branch of biology deals with all biological aspects of man regarding evolution, anatomy, physiology, health, inheritance etc.

Social Biology (Sociare=Companion):
Social biology is concerned with the social interactions within a population of a given animal species, specially in human beings, focuses on such issues as whether certain behaviour are inherited or culturally induced.

Biotechnology (Bio = life; Technologia = systematic treatment):
This is a very recent branch introduced in biological sciences. It deals with the use of the data and techniques of engineering and technology for the study and solution of problems concerning living organisms particularly the human beings.

1.2 LEVELS OF BIOLOGICAL ORGANIZATION

Living organisms are highly complex and organized. This complexity and organization Is composed of grading of structures with each level based on the

one below it, and providing the foundation for the one above it. Life is built on a chemical foundation. This foundation is based on elements, each of which is a unique type of matter. As we know, an **atom** is the smallest possible unit of an element, which retains all the properties of that element. Further division of this unit produces isolated **subatomic particles** of which an atom is composed. Atoms may combine in specific ways to form **molecules**. Simple molecules are formed spontaneously, for example, carbon dioxide. Extremely large and complex molecules are manufactured by living matter (within the bodies of living organisms). The molecules of living matter are mostly based on carbon and provide building blocks of living matter. These are called **organic molecules**. Molecules of different elements comprise a **compound**. Along with organic compounds, inorganic compounds (minerals) are also associated with living organisms, for example, human blood.

The simple organic molecules are sugar, glycerol, fatty acids, amino acids, purines and pyrimidines. In the bodies of living organisms simple organic molecules are converted into more complex organic molecules. They are recognised as the three categories of food or natural **macromolecules** and are required by living organisms. These are carbohydrates, lipids and proteins.

With different chemical arrangements and formation of complex molecules, the life emerges on the level of a **cell**. Like an atom is the smallest unit of matter, a cell us the smallest unit of life. Fundamentally, all cells contain **genes**, which are functional units of **DNA**. The genes provide necessary information needed to control the life of the cell. The sub-cellular structures, called **organelles**, function as chemical factories and use the information in the genes to keep the cell alive. A thin covering called cell membrane encloses the cytoplasm along with its inclusions. Some organisms, mostly microscopic, consist of one cell, but larger organisms are composed of many cells. In these multicellular organisms, cells of similar type form **tissues**, which perform a particular function, for example nervous tissues, connective tissues, xylem tissues etc. Various tissue types combine to make up an **organ**, for example the brain. Several organs that collectively perform a single function form an **organ system**, for example, together, the brain, spinal cord, sense organs, and nerves form the nervous system. Altogether, different organ systems functioning in a highly advanced co-ordination and co-operation make up an **individual whole organism**.

Beyond living organisms are broader levels of organization. A group of very similar interbreeding organisms constitutes a **species**. Members of the same species living in close association in a given area are considered a **population**.

Populations of several species living and interacting in the same area form a community. A community with it's environment, including land, water and atmosphere, constitute an **ecosystem**. Finally, the entire surface region of the earth inhabited by living things is called the **biosphere**.

Living world in the light of Islamic thought:

Al-Quran, the last Holy book consisting of the final word of **Allah** for the spiritual guidance of man also contains some principle facts for the pursuit of knowledge including biology. The Quran has drawn our attention to look into the mysteries of His creation and has advised us to investigate them to the best of our abilities. As far as the relationship of plant and animal life with human welfare is concerned, it is too obvious to mention. Holy Quran says in plain words that:

"Who has made the earth your couch and the heavens your canopy; and sent down rain from the heavens; and brought forth therewith fruits for your sustenance."
(Sura Al-Baqra, Ayah 22)

Then again the Holy Quran says that:

"There is not on animal (that lives) on the earth, nor a being that flies on its wings, but (forms part of) communities like you."
(Sura Al-Anaam, Ayah 38)

The English translations of the two Quranic verses, (by Abdullah Yusuf Ali 1934) reproduced here refer to important biological phenomena. In these and a number of other Quranic verses referring to biological and other scientific facts Quran emphasizes upon us to study them carefully.

"Say: Behold that is in the heavens and on earth."
(Sura-Yunus, Ayah 101)

And again the Holy Quran says that:

"Behold: In the creations of the heavens and the earth and the alternation of the night and day, there are indeed signs for men of understanding. And contemplate the (Wonders of) creation in the heavens and the earth."
(Sura Aal-e-lmran, Ayah 190-191)

Contemplation, careful observation and study of scientific phenomena leading to human welfare are of paramount importance according to the teachings of Quran. It would be a religious duty to study the biological processes, so vital a part of creation on the earth.

Living world in space:
Life arose in this world almost two and a half billion years ago. It has been postulated that the first living forms were of simple unicellular organization. As a consequence of gradual modifications in the genetic material of some or all of those Jiving forms, new types of living organisms were evolved. This provided the basis for the present day diversity in the form of organisms, which exist as millions of species all around the earth in each and every type of habitat.
Majority of living organisms occur as free-living forms but those who failed to do so have developed ways of interactive life i.e. they live in some kind of association with other living organisms i.e. Symbiosis, (Commensalism, Mutualism, Parasitism, etc.).

Living world in time:
As stated earlier, the first living forms were simple, unicellular organisms. How did we come to know this? Another query comes to mind how and when did the present day organisms develop? Such questions can be solved through the study of fossils which are the remains of ancient organisms that lived in ancient times. Fortunately, fossils of most of the groups of organisms have been discovered. Age of the fossils can be determined by using number of techniques. Through these techniques, it has been discovered that fossils of different groups of organisms have different age, supporting the concept that different organisms arose in different geological times as shown in figure 1.2.

Phyletic lineage:
As discussed earlier, living organisms arose gradually forming populations during different geological periods through the process of evolution. It provides basis for establishing a common origin of species or phyletic lineage. It is believed, to be an unbroken series of species, progressing from ancestor to descendent, with each group evolving from one immediately preceding it. If all the missing links are discovered they may lead us to the origin of life itself.

1.3 BIOLOGICAL METHODS

The methods to tackle problems in the field of biology work almost on the same principles as in any other field of science. Biologists work out the topics and recognise them as problems to be solved. A systematic method of steps is followed in order to carry out the research (Fig. 1.3). Scientists make keen **observations** and **collect the facts** already reported by others. On the basis of these facts, a scientist formulates a tentative statement, called **hypothesis**. This hypothesis is used to guide further observations and experimentations. This part of the scientific method involves **inductive reasoning**. In this, a scientist uses isolated facts to reach a general idea that explains a phenomenon. For example, Robert Hooke observed, a thin slice of cork being composed of units, which he called, cells. This led to further observations and experimentations on plant and animal material, by M.J.Schleiden and T.Schwann, who proposed the cell theory, stating that all forms of life are made up of cells.
Once the hypothesis is stated, **deductive reasoning** starts to play its role.
It often involves an "if-then" statement. Based on the results of accurate experimentation, **conclusions** are drawn. If the conclusions come true the hypothesis is taken as true, otherwise it is not accepted. On the basis of true hypothesis, **a theory** is put forward which, in turn, when proved to be true under all tested circumstances, is accepted as a **law** (general principle).

1.4 APPLICATIONS OF BIOLOGY FOR THE WELFARE OF MANKIND

The practical contributions of biology to civilization have made most people aware of its importance. Knowledge of biology ensures a higher standard of living. It helps people to participate intelligently in programs designed to promote better health, protection and conservation of environment, application of modern techniques in the field of agriculture and medical sciences etc.
It is a common observation that in recent years, through out the world, the rates of infant mortality and morbidity have been greatly reduced. Thanks to **immunization** by vaccination. It was first introduced by Edward Jenner in 1795. Through this process, vaccines are introduced to animals and man to prevent them from many infectious diseases such as polio, small pox, hepatitis, etc. In some cases such as small pox, vaccination provides long life protection. However, in many cases, the protection may not be life long.
A thorough research and experimentation has enabled biologists to develop **antibiotics**. Antibiotics are substances which in low concentration inhibit the growth of micro-organisms. The first antibiotic to be discovered was penicillin. It was derived from fungus, Penicillium notatum. The credit for the discovery, isolation and large scale production goes to Fleming, Florey and Chain who jointly received Nobel Prize (1945) for this great achievement in medical sciences. Due to these antibiotics many critical diseases of past like T. B., leprosy and anthrax etc. have been controlled successfully.
Radioactive rays (X-rays), yet another achievement of biological research, has been used in medical sciences for the diagnosis and treatment of human diseases, although electromagnetic radiation is very destructive to human tissue, when exposed to, in high doses. However, recent medical technology of treating cancers and tumours by **radiotherapy** has been successfully introduced.
With the advancement of medicinal sciences, biologists have, and still are, busy developing new medicine to tackle the problems concerning health. These days **chemotherapy**, treatment of disease that with the help of certain chemical substances that previously uncured diseases like cancers and AIDS etc., has proved to be successful,
A constant problem of mankind has always been to get food. With the increase in human population this problem has become worse. Biologists have been trying their best to tackle this problem by developing effective techniques to be introduced in agricultural field to produce better quality crops.

Hydroponics (Hydro = water; ponos = work):

It is the science of growing terrestrial plants in an aerated solution. It is also known as soil less or water culture. Hydroponic farming of vegetables and other essential plants is one of the techniques through which plantation in certain parts of the world has fulfilled the food requirement of the inhabitants. Hydroponics was developed to conduct experiments on the nutrient requirements of plants especially the micro-nutrients. The advantages of hydroponic farming are as follows:

1. It controls weeds and soil disease problems.
2. Area required for cultivation is reduced.
3. Crops are successfully grown in arid parts of the world to meet the food requirements of those areas. For example, tomato crops has been successfully grown in green-houses in some parts of the world through this technique.
4. It is used to determined which of the mineral elements are essential.

Cloning: It is the production of duplicate copies of genetic material; either cells or entire multicellular living organisms. It occurs naturally in plants and animals. The copies are referred to as clones. Some common examples are identical twins or triplets In humans, asexual reproduction in plants and animals, regeneration a development of tumours and cancers.

Artificial cloning has long been a focus of attention in biological sciences. The possibility that people might be cloned from the cells of a single adult human being had long been under study. Biologists have successfully cloned lower mammals. Recently, Dolly the sheep was a highly successful clone from a somatic cell, reported back in 1997. This has led scientists to take a step forward to clone humans. Cloning of human cells such as liver cells, skin cells and blood cells, have been very promising and scientists are quite hopeful to develop human organs in the laboratory by artificial cloning. There are enormous advantages of artificial cloning in areas such as agriculture and medicine. Vegetative reproduction of various fruits and nuts by grafting is one of the best examples. A major goal of this technique is to use it for treating diseases. Through this technology, production of medically significant substances such as insulin, growth hormones, interferon and antithrombin have been achieved.

Protection and conservation of environment:

Pollution has been the biggest problem of man for many years. Acid rain, stone cancer and green house effect are some of the aspects that have been increased with the increase in human population and industrialization.

Many of the waste products of modern technology are toxic. These toxic wastes have polluted our air, land and water, threatening not only human life but also other living forms. In this regard, improved and effective biological measures have been taken to identify different sources of pollution and techniques have been devised to help prevent and reduce pollution.

Man's activities mainly deforestation and industrialization have disturbed the balance of nature with catastrophic results. To maintain a stable and balanced ecosystem, it is very much needed to protect and conserve animal and plant species. Conservation of forests and parks helps to reduce soil erosion and flooding etc. It is also of scientific value as it provides useful information about plants that have medicinal or other importance.

1.5 CONCEPT OF BIOLOGICAL CONTROL AND INTEGRATED DISEASE MANAGEMENT

The use of natural processes to combat pathogens is very helpful. It involves introduction of pathogen's natural enemies into its environment In case of malaria, for example, introduction of small fish in ponds and ditches has been an effective method to minimize the growth of larvae and pupae of mosquito vector. Biological pest control involves exposing them to predators and parasites.

Growing plants in climates that are unsuitable for the pathogen can control plant diseases. Interplanting, as it stimulates conditions in natural ecosystems by limiting the spread of infectious diseases can also control it. Another effective method in eradication of disease, is achieved by crop rotation. It is the practice of growing different crops on the same ground in successive years rather than repeatedly growing one year after year. Through crop rotation, the chances of establishing a particular parasitic weed affecting that crop is reduced. Moreover, soil fertility can be increased by introducing a crop of leguminous family which have nitrogen fixing bacteria in their root nodules.

KEY POINTS

- Biology deals with the study of living organisms.
- Modem system of classification divided organisms into five groups or kingdoms.
- The scope of biology has increased with the introduction of technical fields or study.
- Life is built on chemical foundation.
- Living organisms exhibit a gradual complexity in structure and function. Problems in biology are dealt with biological methods.
- An advanced approach, with an evolutionary point of view, can lead us to origins of life.
- Biological applications provide better health, better food, better environment for all organisms.

EXERCISE

1. Encircle the correct choice:

(i) An autotroph may be placed in following group except:
(a) Monera (b) Protoctista
(c) Fungi (d) Plantae

(ii) Malaria is caused by:
(a) Virus (b) Bacteria
(c) Fungi (d) Plasmodium

(iii) All of the following are natural cloning except:
(a) Regeneration (b) Identical Twins
(c) Dizygotic Twins (d) Tumor

(iv) Pencillin was discovered by:
(a) Fleming (b) Jenner
(c) Robert Brown (d) Laveran

(v) Microorganisms are studied the disciplines of:
(a) Parasitology (b) Marine biology
(c) Micro-biology (d) Human biology

(vi) Hydroponics is the science of growing terrestrial plants in:
(a) Laboratory (b) Desert
(c) Lake (d) Aerated solution

(vii) Industrialization and over population has increased:
(a) Pollution (b) Disease
(c) Pest control (d) Productivity

(viii) Different communities group together to form:
(a) Populations (b) Biosphere
(c) Ecosystem (d) Multicellular organism

(ix) Life emerges at the level of:
(a) Organelles (b) Cell
(c) Water (d) Atom

(x) Crop rotation is one of the effective methods to eradicate:
(a) Disease (b) Parasites
(c) Predators. (d) Bacteria

2. Write detailed answers of the following questions:

i. Explain the levels of organization of life.
ii. How antibiotics and vaccines contribute to health?
iii. What do you mean by radiotherapy and chemotherapy?
iv. Write an essay on "applications of biology for the welfare of mankind''.

3. Write short answers of the following questions:

i. What is biological method?
ii. What do you understand by Hydroponics?
iii. What is five kingdom system?
iv. What is antibiotic?

4. Write short answers of the following questions:

(i) Biology (ii) Biotechnology (iii) Parasitology

Section II

UNITY OF LIFE

Despite the existence of great diversity that is observed among living things, they all share features like cells, cellular organelles, chemicals, etc. What does it suggest? They all have a Creator - Allah, Who is the only one and none shares His authority.

Chapter 2

BIOLOGICAL MOLECULES

Chemical substances which are supposed to be non-living, when incorporated in living protoplasm become a live and then they behave in a coordinated fashion. What turns them into life in living protoplasm?

2.1 INTRODUCTION OF BIOCHEMISTRY

The branch of biology which explains the biochemical basis of life is called **biochemistry.** It is one of the most important branch of biology especially now a days It has much excitement and activity in It due to several reasons some are given below.

Firstly, it provides information about all the processes carried out in the living organism, from construction of body structures to flow of information from the nucleus, especially DNA for enzyme (Protein) synthesis and control of all the mechanisms.

Secondly, it provides information about abnormal mechanisms which lead to diseases, ultimately opening the doors to the development of medicines and medical equipments to elucidate these abnormalities.

Thirdly, recent biochemical concepts and powerful techniques have enabled us to investigate and understand some most challenging and fundamental problems in biology and medicine e.g how does a fertilised egg give rise to different types of cells such as muscles, brain and liver etc.? How do cells find each other to form a complex organ? How is the growth of cells controlled? What are the causes of cancer? What is the mechanism of memory? These questions are satisfactorily answered by biochemistry.

To understand all these, it is important to keep in mind that most organisms are composed of organs, these organs are made up of tissues, these tissues are the group of cells, finally the cells are made up of molecules and the molecules are chemically bonded atoms. It means that fundamentally living things or organisms are made up of chemicals i.e. structure and function are dependent upon chemicals.

Therefore, it is appropriate for us to study chemical principles and structure of molecules involved in the cells to understand the structure and mechanism of living organisms.

2.1.1 Chemical Composition of Cell:

We know that all living bodies are structurally composed of cells and living cell contains a living material called **protoplasm.** The actual chemical composition of protoplasm is still not known perfectly. However, chemically it contains 70 to 90% of H_2O. If the water is evaporated, the remaining mass is called dry weight of the cell, which consists of mainly carbon containing molecules, these molecules are termed as organic molecules. As chemists synthesized these molecules in laboratory, the mystry associated with organic compounds disappeared. Now, the compounds produced by living organisms are called **biochemicals.**

Only six elements, carbon, hydrogen, nitrogen, oxygen, phosphorous and sulphur make up most (about 98%) of the bioehemlcals, which ultimately make up the body weight of organism. Following are some properties and functions of these elements.

Table 2.1

Element	Atomic No/ Weight	Molecular form of utilization	Function	Percentage by weight in human body
Carbon	6/12	CO_2	Basic element of organic compounds, fixed during photosynthesis.	18.5
Hydrogen	1/1	H_2O	During photosynthesis, used as reducing agent.	9.5
Oxygen	8/16	O_2	Used in anaerobic respiration.	6.5
Nitrogen	7/14	NO_3^{-1}, NH_4^{+1}	Used in aminoacid for protein synthesis, nucleic acids, hormones, co-enzymes.	3.3
Phosphorus	15/31	$H_2PO_4^{-}$, HPO_4^{-2}	Component of nucleic acid, ATP, phospholipids, co-enzymes NAD, NADP etc.	1.0
Sulphure	16/32	SO_4^{-2}	Component of proteins and co-enzymes.	0.3

2.1.2 Relationship between structure and function of molecules;

Biomolecules can be divided into following groups according to variability of their chemical structures and functions.

1. Proteins
2. Carbohydrate
3. Lipids
4. Nucleic acids
5. Conjugated molecules

There is a variation found in literature about the percentage of biomolecules present in the cell. It is because different cells within the same body have different amount of biomolecules. Therefore, these values are always taken as average value. Approximate percentage of chemical composition of a typical bacterial and a typical mammalian cell is given in table 2.2.

Table 2.2 Chemical composition of cells (in %)

Molecules	Bacterial Cell	Mammalian Cell
Water	70	70
Protein	15	18
Carbohydrate	3	4
Lipids	2	3
DNA	1	0.25
RNA	6	1.10
Other Organic compounds	2	2
Inorganic ions	1	1

WATER

Water is the most abundant component in living cell. It's amount varies approximately from 70 to 90%. Life activities occur in a cell due to the presence of water.

The ability of water to play its wide variety of roles, and the reasons for its importance in biological systems is due to the basic chemistry of the molecule. The chemical formula of water is H_2O which tells us that two atoms of hydrogen are joined to one atom of oxygen to make up each water molecule.

Water is a polar molecule, it means that it has a very slightly negative end—the oxygen atom and a very slightly positive end—the hydrogen atoms. This separation of electrical charge is called a **dipole**, which gives the water molecule its very important properties. One of the most important properties of this charge separation is the tendency of H_2O molecule to form hydrogen bonds.

2.2.1 Biologically important Properties of water:

Water has variety of properties which are also important in biological system. Some of the important ones are given below.

i) Behave as best solvent:

Due to polar nature of water molecules, many polar substances (solute), particularly ionic substances dissociate in ions and dissolve in water.

Water can also act as a solvent to many non-polar substances. As all the chemical reactions that go on within the cell takes place in aqueous solution, the ability of water to act as a solvent is vitally important for the process of life. Ions or molecules are dissolved in water, these ions move and collide to perform the chemical reaction.

ii) Slow to absorb and release heat (High specific heat capacity):

The specific heat capacity of a substance is a measure of the amount of energy needed to raise the temperature of 1 gm of that substance by 1°C. The specific heat capacity of water is high, it takes a lot of energy to warm up. This thermal stability plays an important role in water-based protoplasm of individual cell to allow the biochemistry of life carried at fairly constant rate.

iii) High heat of vapourization:

Due to hydrogen bonding which holds the water molecules together, liquid water requires higher amount of heat energy to change into vapours. It also gives stability to water molecules. Therefore water needs to lose a lot of energy to form ice, due to this reason the content of cell are unlikely to freeze.

iv) An amphoteric molecule:

Water molecule is amphoteric because it acts both as an acid and a base. As acid, it gives up electron to form H^+ ion. As base, it gains electron to form OH^- ions.

This ability of water molecules means that it is a perfect medium for the biochemical reactions occurring in cells. It acts as buffer. A buffer helps to prevent changes in the pH of a solution when an acid or an alkali is added. Thus water in the cells minimises any change in pH which prevent any interference in the metabolism of the cell.

v) Co-hesive force in water molecules:

Force of attraction between similar molecules is called co-hesive force. Due to polar nature water molecules attract each other to form a chain. This chain of water molecules do not break apart which help it to flow freely. They remain together because of hydrogen bonding. Water molecules also adhere to the surface. It can fill a tubular vessel and still flow so that dissolved and suspended molecules are evenly distributed throughout a system. Therefore, water is an excellent transport and matrix medium both outside and inside the cell.

2.3 ORGANIC MOLECULES

Chemists classify molecules as organic or inorganic molecules. The word organic originally meant that these molecules could only be synthesized within the living organisms. Today, however, organic chemists can synthesize many of these molecules in the laboratory. Therefore, the modern definition of organic molecule is modified as the molecules containing Carbon as basic element bounded covalently with Hydrogen atom. Most organic molecules are large, with complex structure. On the other hand inorganic molecules are those which do not contain carbon as basic element or in which hydrogen is not directly bonded with carbon as CO_2, CO and H_2O etc.

2.3.1 Synthesis of large Molecules by Condensation:

The molecules which form the structure and carry out activities of the cells are huge and highly organised molecules called **macromolecules**. These macromolecules are composed of large numbers of low molecular weight building blocks or subunits called **monomers** (for example amino acids). The macromers are called **polymers** (Poly = many; mers = molecules). Macromolecules can be divided into four major categories, proteins, polysaccharides, lipids and nucleic acids. Proteins are composed of subunits called amino acids; polysaccharides are composed of monosaccharides; fatty acid and glycerol are the subunits of fats and the nucleotides are the subunits of nucleic acid.

Macromolecules are constructed from monomers by a process that resembles coupling rail cars onto a train. The basic structure and function of each family of macromolecule is very simillar in all organisms, from bacteria to human beings. Two monomers join together when a hydroxyl (—OH) group is removed from one monomer and a hydrogen (—H) is removed from other monomer. The joining of two monomers is called **condensation**. This type of condensation is called **dehydration synthesis** because water is removed (dehydration) and a bond is made (synthesis). Condensation always takes place by proper enzyme and energy expense.

2.3.2 Breaking of large Molecules by Hydrolysis:

Another process, which is just reverse of the condensation is called **hydrolysis.** (Hydro = water, lysis = breaking). A process during which polymers are broken down into their subunits (monomers) by the addition of H_2O is called hydrolysis. During this process a water molecule breaks into H^+ and OH^- ions with the help of enzyme, whereas—OH group attaches to one monomer and —H attaches to the other. When a bond is broken, energy is released and made available.

During metabolism, macromolecules are either formed or broken down in the cell, when each cell rebuilds many of it's parts. In heterotrophic organism during digestion especially, macromolecules are broken into monomers by the process of hydrolysis with the help of hydrolytic enzymes and again, these monomers when reach to the cells form macromolecules or polymers by the process of condensation. In autotrophic organism, cell produces monomers from simple inorganic molecules like CO_2, H_2O. nitrates, sulphates etc. These monomers later on assemble to form macromolecules in source or sink cells by the process of condensation while the other cells when require these molecules either for building purpose or to produce energy, these molecules break into monomers by the process of hydrolysis.

2.4 CARBON

Chemistry of living world is the chemistry of carbon, which is called Organic Chemistry. Carbon is a unique element in a sense that it forms unlimited number of compounds which vary widely in their properties and adaptation. Therefore organic compounds are well adapted with the requirement of living processes. Now, question arises why only carbon does it, why not other elements? Carbon is a light element and has atomic number 6. It contains $4e^-$ (electron) in its outer

most shell and requires 4 more e^- (electron) to complete its outer-most shell. For this purpose, it forms 4 covalent bonds with other atoms i.e. It is tetravalent in nature (4 valency).

Loosing, gaining and sharing electrons between the atoms result in forces called **chemical bonds** that hold atoms together in molecules. There are two major types of chemical bonds, ionic and covalent bonds. The chemical bonds which are formed due to loos and gain of e- are called ionic bonds. While the chemical bonds which are formed due to shairing of e- are called covalent bonds. In organic compounds elements are held together by covalent bonds. Covalent bond stores large amount of energy.

Carbon can form four covalent bonds with other carbon atoms. This property allows the formation of skeleton and the fundamental frame work of carbon around which organic molecules are constructed. Carbon containing back bone may be linear, branched or cyclic e.g.
Carbon can be linked with other carbon either by single covalent bond as shown above or it can form double or triple covalent bond between two carbon atoms as shown below.

Biological molecules:
Biological molecules can be divided into following four main classes.

i)	Proteins	ii)	Carbohydrates
ii)	Lipids	iv)	Nucleic acids

1. Proteins (Gr; Proteios means 'First Rank')
Proteins can be defined as the polymers of amino acids, where specific amino acids link to gether in a definite manner to perform a particular function. Proteins are the most important organic compounds of the cell which carry out virtually all of the cell's activities. They constitute more than 50% of dry weight of a cell. The name protein was suggested by Berzelius in 1838 and a Dutch Chemist G.J. Murlder in 1883 recognised the importance of protein as a vital compound.
Proteins are the complex organic compounds having C, H, O and N as elements but sometimes they contain P and S also. Due to the presence of N they are called nitrogenous compounds. Proteins are the building blocks of tissues. Many common parts of the living body such as hair, skin, nails and feathers are also protein. Whereas egg, meat, fish, milk and pulses are the major sources of protein.

A) Amino acid as a building block of protein:
Proteins are macromolecules or polymers of **amino acid** monomers. These amino acids are linked together by specialised bond or linkage called **peptide linkage**. Each protein has a unique sequence of amino acids that gives the unique properties to molecules. Many of the chemical properties of a protein are based upon chemical properties of it's constituent amino acids. There are twenty basic amino acids, which are commonly found in proteins of the living organisms ranging from virus to human being.
Amino acids are organic compounds which contain at least one basic amino group ($—NH_2$) and one acidic carboxylic group (—COOH), bounded to the same carbon atom called α- carbon having following general structural formula.
Where R is the radical group, it shows the great variety of structures e.g in glycine R is H, in serine R is CH_2OH and in alanine R is CH_3 etc.

B) Linkage of Amino Acids:
During the process of protein synthesis, each amino acid become joined to two other amino acids forming a long, continuous, unbranched polymer called **poly**

peptide chain. In polypeptide chain these amino acids are linked together by condensation process.
The proteins are polypeptides with usually more than 100 amino acids, but some proteins are small in size having less number of amino acids. The sequence of amino acids in the peptide chain is specific for each protein and potentially capable of great diversity. Protein may differ in number of peptide chain per protein molecules.

C) Structure of Proteins:
There are four basic structural levels of proteins:

- **i) Primary Structure:** A polypeptide chain having a linear sequence of amino acids due to peptide bonds is called **Primary structure** e.g. insulin.
- **ii) Secondary Structure:** When a polypeptide chain of amino acids become spirally coiled this structure is called **Secondary structure** of protein. It results in the formation of a rigid and tubular structure called helix.The hydrogen and sulphide bonds are involved to hold the protein chain in spiral manner e.g. hairs, spider's webs.
- **iii) Tertiary Structure**: The term **Tertiary structure** refers to the arrangement of secondary structure into the three dimensional (fold or super fold) structure having peptide, hydrogen, ionic and disulphide bond e.g. Lysozyme.
- **iv) Quaternary Structure:** The association of two or more sub-units (polypeptide chains) into large-sized molecules is called quaternary structure, e.g Haemoglobin.

High temperature or various chemical treatments will denature a protein, causing it to lose its conformation and ability to function. If the denatured protein remains dissolved, it may renature when the environment is restored to normal.

In quaternary structure the participating units may be similar or dissimilar, if they have similar units called homogenous quaternary structure and if dissimilar called heterogenous quaternary structure.

D) Functions of Protein:
Proteins have a wide variety of structures, therefore, they perform variable notions. Proteins are the molecules which carry out the cell-activities and form the main structure of cell. It is estimated that the typical mammalian cell may have as many as, 10,000 different proteins having a diverse array of function. As structural cables, proteins provide mechanical support both within the cell and outside their perimeter. As enzymes, proteins vastly accelerate the rate of metabolic reactions. As hormones, growth factors and gene activators, proteins perform a wide variety of regulatory functions. As membrane receptors and transporters, proteins determine what type of substances should enter or leave the cells. Protein act as antibodies, antigens, fibrine etc.

2. Carbohydrate (CARBO = Carbon, HYDRATE = Water):
It is a group of organic compounds having carbon, oxygen and hydrogen, in which hydrogen and oxygen are mostly found in the same ratio as in water i.e. 2:1 and are thus called hydrated carbons.
Carbohydrates are found to occur in all living cells both as building material and as storage substances. They are found about 1% by weight and generally called sugar or saccharides due to their sweet taste except polysaccharide.
The carbohydrate can be classified into following groups on the basis of number of monomers. These are Monosaccharides, Oligosaccharide and Polysaccharides.

A) Monosaccharides (Gr; mono = One. Sakcharon = Sugar):

These are also called simple sugars because they can not be hydrolysed further into simpler sugars. Their general formula is $C_n H_{2n} O_n$. e.g Glucose, galactose, fructose ($C_6 H_{12} O_6$) and ribose ($C_5 H_{10} O_5$) etc.
All monosaccharides are white crystalline solids with sweet taste and are soluble in water.
Monosaccharides can be classified according to number of carbon atoms present in each molecule. They may be triose, tetrose, pentose, hexose and heptose having 3, 4, 5, 6 and 7 carbon atoms respectively. Some important examples are given in table below:

Class	Formula	Example
Triose	$C_3H_6O_3$	Glycerose(glyceraldehyde), Dihydroacetone
Tetrose	$C_4H_8O_4$	Erythrose, Erythrulose
Pentose	$C_5H_{10}O_5$	Ribose, Ribulose
Hexose	$C_6H_{12}O_6$	Glucose, Fructose, Galactose
Heptose	$C_7H_{14}O_7$	Glucoheptose

Monosaccharides are found in various friuts and vegetables, most of them are found in combined state e.g. sucrose.
Glucose is found in ripe friut, sweet corn and honey. On the other hand it is also found in starch. In sugar-cane it is associated with fructose.
Fructose most abundant hexose found in nature generally called fruit sugar.
Galactose is found largely in combined state in lactose (milk) disaccharide.

B) Oligosaccharide (Gr; Oligo - few; Sakcharon = sugar)
The carbohydrate molecule which yield 2 to 10 monosaccharide molecules on hydrolysis are oligosaccharide. The most common and abundant carbohydrates of oligosaccharides are disaccharides. The oligosaccharide which contains 3 to 10 monosaccharide are commonly called **Dextrin**.
The sugars which are composed of two monomers are disaccharides i.e. On hydrolysis they produce two monosaccharide sub-units. They are usually formed when two hexose sugar molecules unite by condensation. Following are some examples of disaccharide molecules.
Sucrose (Cane sugar) is found in most plants. It is stored in large amount in sugar cane and beet root. Lactose (milk sugar) is found solely in milk. Maltose (malt sugar) does not occur abundantly in nature. It can be extracted from malt, which is prepared from sprouting barley.

C) Polysaccharides (Gr; Poly = many; sakcharon = sugar):
Polysaccharides: They are of high molecular weight carbohydrates, which on hydrolysis yield mainly monosaccharides or products related to monosaccharides. These are formed by the condensation of hundreds to thousands of monosaccharide units e.g. Starch, Glycogen and Cellulose.
Starch: It is the most important reserve food material of higher plants, found in cereals, legumes, potatoes and other vegetables. It is made up of many glucose molecules joined together in straight chain, amylose and a branched chain, amylopectin. It is insoluble in water. Starch is converted into simple sugars by hydrolysis and then oxidised to produce energy to be used in metabolism of other biomolecules.

Human diet use only about 12 species of plants as food sources. Three of these are cereals, rice, corn and wheat. A grain of wheat contains a seed and fruit both

of them are fused in insepreable manner. Seed occupies most of its volume and consist of 3 parts. Endosperm (stored food), embryonic plant, seed coat alongwith protective layers. Embryonic plant is wheat grain, which is high in vitamins. The starchy endosperm is used to produce the flour from which our white breads are made. The seed coat is bran, composed mostly of cellulose, which can not be digested by humans. For this reason, bran is an excellent roughage substance that adds bulk to the diet.

Cellulose: Cellulose is a glucose polymer produced by plants. The glucose units are joined in straight chain and no branching in the cellulose molecule is Indicated. It is the main constituent of plant cell-wall and most abundant carbohydrate in nature.

Glycogen: It is also a reserve polysaccharide found mainly in bacteria, fungi, liver and muscle tissues of animal. It is commonly known as animal starch. It is insoluble in water and is stored in granular form. Its structure is smillar to starch.

Cellulose is an unbranched polysaccharide. Parallel cellulose molecules are held together by hydrogen bonds. About 80 cellulose molecules chains associate to form a microfibril, the main architectural unit of the plant cell-wall.

D) Functions of Carbohydrate:

Carbohydrates are the potential source of energy. This energy is utilized in body metabolism. Carbohydrates also act as storage food molecules. In plants excess glucose is converted into starch and in animals into glycogen. Carbohydrates also work as an excellent building, protective and supporting structure e.g Cellulose is the major component of cell-wall. In animals chitin forms the exoskeleton of arthropods. They also form complex conjugated molecules.

3. LIPIDS

Lipids are the important diverse group of biological molecules widely distributed among plants and animals.

Bloor in 1943 proposed the term lipid for those naturally occuring compounds which are insoluble in water but soluble in organic solvent These are also the compounds containing carbon, hydrogen and oxygen like carbohydrate but contain much lesser ratio of oxygen than carbohydrates.

Following are the important groups oi lipids.

i) Acylglycerol (fats and oil)
ii) Waxes
iii) Phospholipids
iv) Terpenoids

i) Acylglycerol (Fats and Oil):

These are found both in animals and plants, provide energy for different metabolic activities and are very rich in chemical energy. When compared an equal amount of acylglycerol contains over twice the energy content than carbohydrate. It is estimated that a person of average size contains approximately 16 Kg of fat which is equivalent to 144000 K Cal of energy which takes a very long time to deplete.

Acylglycerol consists of a glycerol molecule linked to three fatty acids. This condensed molecule is also called a Triacylglycerol (Triglyceride).

There are two types of acylglycerol:

(a) Saturated acylglycerol (Fats): They contain saturated fatty acids i.e. they do not contain any double bond between carbon atom. They are solid at ordinary temperature, mostly found in animals, e.g Stearin (C_{57} H_{110} O_6) found in beef and mutton.

(b) Unsaturated acylglycerol (Oils): They contain unsaturated fatty acids i.e. They contain one or more than one- double bond between carbon atom (— C = C —). They are liquid at ordinary temperature. They are found in plant also called oil. e.g Linolin (C_{57} H_{104} O_6) found in cotton seed contains linoleic acid.

ii) Waxes:

Waxes are simple lipids having one molecule of fatty acid forming ester bond with one molecule of long chain alcohol e.g Bee's Wax.

CH_3 $(CH_2)_4$ COO $(CH_2)_{29}$ CH_3

Waxes are found as protective coating on stems, stalks, leaves, petals, fruit, skins, animal skins, fur and feathers etc. Waxes are water repellant and non-reactive.

Wax esters are of considerable commercial importance because they act as superior machine lubricants. For many years, sperm whales were the principle source of these wax but now a unique plant that grows primarily in desert areas, Simmondsia chinesis or Jojoba, may serve as superior substitute because it synthesize large amounts of oxygen wax esters as storage lipids in its seed.

iii) Phospholipids:

Phospholipid is the most important class of lipids from biological point of view. A phospholipid is similar to Triacylgrycerol of an oil, except that one fatty acid is replaced by phosphate group. The phospholipid molecule consists of two ends, which are called hydrophillic (water loving) end (head) and hydrophobic (water fearing) end (tail).

Phospholipids are present in all living cells frequently associated with membranes and are related to vital functions such as regulation of cell permeability and transport processes. Properties of cell membrane depend on it phospholipid component. The function of these molecules will be discussed in chapter-4 in connection with plasma membrane.

iv) Terpenoids:

Terpenoid is a large and important class of lipids, built up of isoprenoid (C_5 H_8) units. Steroids. Carotenoids and terpens are the important classes of it. They help in oxidation reduction processes as terpens, some are components of essential oils of plants e.g Menthal, camphor, mint etc. They are also found in cell-membrane as Cholesterol. Plant pigments like Carotene, Xanthophylls are also the form of terpenoides.

(a) Terpenes:

The group of lipids based only on isoprenoid unit (C_5 H_8). Small size terpenes are volatile in nature; produce special fragrence. Some of these are used in perfumes e.g. Myrcene from oil of bay, Geranoil from rose, Limonene from lemon oil and Menthol from peppermint oil. Derivates of some terpenes are found in Vitamin A_1 and A_2. They are also important constituents of chlorophyll molecules .as well as intermediate compound for cholesterol biosynthesis. In nature they are utilized in the synthesis of rubber and latex.

(b) Steroids:

Steroids consist of three 6-membered carbon rings (A, B. C) and one 5-membered carbon ring (D). These rings are fused together as shown in fig: 2.8 with total 17 carbon atoms called steroid nucleus.

One of the most important steriod is Cholesterol, a component of animal cell membrane and a precursor for the synthesis of a number of steriods, sex hormones such as testosterone, progesterone and estrogenes.

(c) Carotenoids:

Carotenoids consist of fatty acid like carbon chain, which are conjugated by double bonds carrying 6-membered carbon ring at each end.
These compounds are pigment producing red, orange, yellow, cream and brown colours in plants. Some important carotenoids are caroten, xanthophyll etc.
Another group of pigmented compounds areTetrapyrrol which are present as an important part of familiar chlorophyll and cytochromes plgments.

4. NUCLEIC ACID

A 22-years old Swiss physician and chemist, Friedrich Miescher isolated a substance from the nuclei of pus cells, which was quite different from other biomolecules and named it as 'nuclein'. Later, it was found that the nuclein had acidic properties land hence it was renamed as nucleic acid.
Nucleic acids are present in all living things, from virus to man. These macromolecules are present either in the free-state or bound to proteins as nucleoproteins. Like proteins, the nucleic acids are biopolymers of high molecular weight with mononucleotide as their sub-units (monomers). The nucleic acids are the long chains of polynucleotide in which mononucleotides are linked to each other.
There are two kinds of nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA is found mainly in the chromatin of the cell nucleus whereas most of the RNA (90%) is present in the cell cytoplasm and a little (10%) in the nucleolus.
As we now know that nucleic acid is a polymer of nucleotide, a question arises here what is nucleotide? Nucleotide is a molecule which consists of following three parts.

i) Pentose sugar (5 carbon)
ii) Phosphoric acid ($H_3 PO_4$)
iii) Nitrogenous base (Organic base)

Pentose sugar found in nucleotide is either Ribose ($C_5 H_{10} O_5$) or Deoxyribose ($C_6H_{10}O_4$).
Ribose is found in RNA nucleotides while Deoxyribose sugar is found in DNA nucleotides, both of them are distinguished primarily on the basis of this pentose sugar. This sugar behave as basic skeleton.
Phosphoric acid is common in all nucleotides. It is attached with 5th carbon of pentose sugar in each nucleotide.
There are two basic types of nitrogenous bases i.e. Purine and Pyiimidine. Purine includes two nitrogenous bases named Adenine (A) and Guanine (G) while pyrimidine includes three nitrogenous bases cytosine (C), thymine (T) and uracil (U). The nucleotides differ on the basis of their nitrogenous bases.
Formation of nucleotide takes place in two steps. At first step the nitrogenous base combines with pentose sugar at its first carbon to form a **nucleoside**. At the second step the phosphoric acid combines with the 5th carbon of pentose sugar to form a **nucleotide**.

A) Mononucleotide:

Generally, nucleotides are found in the nucleic acid as polynucleotide but they are also found as mononucleotide and dinucleotide. Mononucleotides exsist singly in the cell or as a part of other molecules. These are not the part of DNA or RNA. Some of these have extra phosphate groups e.g ATP (Adenosine triphosphate). It is the most important among these nucleotide. It is an unstable molecule and carries energy from place to place within a cell. It is synthesized from ADP (Adenosine diphosphate) and inorganic phosphate by capturing energy during photosynthesis. This energy is utilized to derive energy demanding reactions such as in synthesis of proteins, lipids, carbohydrates, mechanical energy for cyclosis, contractility, cell-division, movement of flagella, active transport etc.

ATP consists of Adenosine (Adenine and ribose sugar) and three phosphate; among them two are energy rich phosphate bond. During conversion of ATP into ADP the tee energy releases which is considerable large i.e. 31.81 Kj or 7.3 K.Cal/ mole energy.

B) Dinucleotide:

Some times two nucleotides are covalently bounded together, to form compounds are called dinucleotide. One ofthe well-known dinucleotide is Nicotinamide adenine dinucleotide (NAD).

Nicotinamide is a vitamin constituent The two nucleotides are linked by phosphate of one another.

NAD is a co-enzyme [co-enzymes are the organic molecules (non-protein) which bind to enzyme (protein) and serve as a carrier for chemical groups or electrons] that carries electron and work with dehydrogenase enzyme. It removes two hydrogen atom (2e- + 2H+) from its substrate, both electrons, but only one hydrogen ion is passed to NAD which reduces it to NADH.

C) Polynucleotide (Nucleic acids as informational macromolecules):

As we have already discussed that the nucleic adds are the polynucleotides. They have a variety ofrole in living organisms. Inspite of all, the unique and premiere service of nucleic acid is as repositories (store house) and transmitters of genetic information. They make it possible for cells to function according to specific patterns and give rise to new cells that either function similarly or develop new functions, according to plans encoded in the nucleic acid.

Genetic information is encoded in a nucleic acid molecule in a particular and simple fashion. Four different nucleotides make up each informational nucleic acid molecule. They are three letters in a genetic code. The nucleic acid molecule is some what linear and the units (nucleotides) like letters on a printed page or digital magnetic signals on a computer tape. In the proper machinery, these codes (nucleotides) can be interpreted. The cell interpretes the information present in many nucleic acid molecules an sequence of amino acid in protein and peptide molecules. The synthesis of proteins with definite sequences of amino acid and controlled amounts of protein is observed as the expression of heredity of an organism which generally give the physical appearance of that particular character.

Dna and RNA are basically similar structure because both of these are poly nucleotide chains but the nucleotide of both are different in following ways.

i) DNA contains deoxyribose sugar ($C_5H_{10}O_4$) while RNA contains ribose sugar ($C_5H_{10}O_5$) in their nucleotides.

ii) DNA contains Adenine, Guanine, Cytosine and Thymine containing nucleotides where as RNA contain Adenine, Guanine, Cytosine and Uracil containing nucleotide.

iii) DNA is double stranded helical structure while RNA is mainly a single stranded structure except rRNA.

iv) DNA is of just one kind while RNA is of three kinds rRNA, tRNA and mRNA (r = ribosomal, t = transfer m = messenger).

D) DNA as Hereditary material!

Transformation of one type of bacteria into another type and infection of bacteria by bacteriophage provides first evidence that DNA is the hereditary malarial. Griffith discovered that living bacteria can acquire genetic material from dead bacteria and transform live bacteria from non-virulent to virulent. Avery and his colleagues showed that the genes taken up living bacteria during transformation were composed of DNA.

A bacteriophage consists solely of DNA and protein. When it infects a bacterium, the phage injects its DNA only into the bacterium, where it directs the synthesis

of more phages Hershey and Chase thus experimentally confirmed that DNA must be the genetic material.
Now, a new question arises how the DNA behaves as genetic material? As we have discussed earlier that DNA is a polynucleotide chain in which nucleotides are are arranged in a specific manner. In all nucleotides of DNA, phosphate and deoxyribose sugars are always common but the nitrogenous bases are different. In other words, we can say that each **DNA has specific sequences of nitrogenous bases.** These sequences of bases in DNA can encode vast amount of information. Since the nitrogenous bases are of four type, it is amazing that how just four different types of bases in DNA encode all of the information needed to produce thousands of proteins each with various combinations of 20 amino acids. The four different types of bases can be arranged in any linear order along a strand of DNA. Each sequence of bases represents a unique set of genetic instructions e.g. a piece of DNA with 10 nucleotide can exist in over a million different possible sequences of four bases. An average chromosome of plant and animal has millions to billions of nucleotides in a DNA molecule, thus encode a huge amount of information in the form of genetic codes.

E) RNA as a carrier of Information:
In Eukaryotic cells DNA is located in the nucleus while most of the synthesis and metabolic functions occur in the cytoplasm under the instruction of DNA. Therefore, DNA requires some intermediate molecules that cany informations from DNA to the cytoplasm. These molecules are ribonucleic acids or RNA's.
Genetic information flows in a cell from DNA to mRNA than to cytoplasm in a two step process for the synthesis of protein.

1. Transcription:
In this step information contained in a specific segment of DNA is copied into RNA. The RNA which perform this process is called the **messenger RNA (mRNA)**. It carries information from the nucleus to the ribsomes.

2. Translation:
In this step two other types of RNA; transfer RNA (tRNA) and ribosomal RNA (rRNA) translate the information of messenger RNA into the specific sequence of amino acids which help to synthesize the protein.

2.6 CONJUGATED MOLECULES
Conjugated molecules are formed when biomolecules of two different groups combine with each other acting as unit molecule. When a molecule of carbohydrate combines with protein molecules, they form glycoprotein. Following are the types of conjugated molecules.

i) Glycolipids or cerebrosides:
These are conjugate of lipids and carbohydrates also contain some nitrogenous compound. Glycolipids are also called cerebrosides because, it is important constituent of brain. Glycolipids and sulpholipids are also the example of glycolipids found commonly in chloroplast.

ii) Glycoproteins or Mucoids:
Glycoproteins are formed when a molecule of carbohydrate combine with a protein molecules. Most of the oligo and polysaccharides in the animals and plants cells are linked covalently to protein molecules and are called glycoproteins. It contains small amount of carbohydrate i.e less than 4% e.g egg albumin, gonadotrophic hormone etc. The cell membrane also possesses some amount of glycoproteins.

iii) Nucleoproteins:

These are found in the nucleus conjugated with nucleic acid. On hydrolysis nucleoproteins give rise to simple proteins and nucleic acids. These are weakly acidic and soluble in water.

iv) Lipoproteins:

They are conjugates of lipids and proteins. The prosthetic groups of these are lipids such as lecithin and cholesterol. Lipoproteins help in the transportation of lipid in the blood plasma as low density protein or free fatty acid. They also occur as component of membrane ofmitochondria, endoplasmic reticulum and nucleus. The electron transport system in mitochondria appears to contain large amount of lipoproteins. Lamellar lipoprotein system occur in the myelin sheath of nerves, photoreceptive structures, chloroplast and the membranes of bacteria.

KEY POINTS

- Branch of Biology deals with the study of biochemical and chemical process in living organism is called biochemistry.
- Protoplasm is mainly consist of H_2O, proteins, carbohydrates, lipids, nucleic acids and conjugated molecules.
- Water is most abundant and important component in living cell.
- Complex biomolecules are polymers synthesize by the process ofcondensation while decompose into monomers by hydrolysis.
- Proteins are the polymers of amino acid, most important biomolecule of the cell, carry out all cell activities as enzymes.
- Proteins are found in four basic structures, primary, secondary, tertiary and quaternary.
- Carbohydrate are the hydrated carbon, these are the immediate source of energy.
- Carbohydrates molecules are found as monosaccharide, oligosaccharide and • polysaccharide.
- Lipids are the important diverse group of non-polar bio-molecules, found as acyglycerol (fats and oils), waxes, phospholipids and terpenoids.
- Lipids provide, fats, hormones, protective layers, precursors of vitamins and aroma to bodies.
- Nucleic acids are the acidic compounds derived from nucleus found in two forms as DNA and RNA.
- Nucleotide is the basic unit of nucleic acid consist of a molecule of pentose sugar bonded with phosphate and nitrogenous base.
- ATP is a mononucleotide found in free state as energy rich molecules.
- DNA is the hereditary material; having specific sequence of nitrogenous bases which encode vast amount of information as genetic code.
- RNA behave as carrier of information from DNA to ribosome for protein synthesis.
- Two different group of biomolecules combine together to form conjugated molecule. Like glycolipids, glycoprotein, nucleoprotein and lipoprotein.

EXERCISE

1. Encircle the correct choice:

(i) Which of the following terms includes all others in the lists?
(a) Monosaccharide (b) Disaccharide
(c) Starch (d) Carbohydrate

(ii) Which of the following statement concerning unsaturated fats is correct?
(a) They are more common in animals than plants.
(b) They have double bonds in the carbon chains of their fatty acids.
(c) They generally solidify at room temperature.
(d) They have fewer fatty acid molecules per fat molecules.

(iii) Human sex hormones are classified as:
(a) Protein (b) Triglyceride
(c) Steroids (d) Carbohydrate

(iv) Which of these terms includes all others in the list:
(a) Nucleic acid (b) Purine
(c) Nucleotide (e) Nitrogenous base

(v) The difference between one amino acid and other is found in:
(a) Amino group (b) Carboxyl group
(c) R-group (d) Peptide bond.

(vi) Nucleic acid and proteins combine to form:
(a) Glycoprotein (b) Glycolipid
(c) lipoprotein (d) Nucleoprotein

(vii) The process of mRNA directed polypeptide synthesis by ribosomes is called:
(a) Transcription (b) Transpiration
(c) Transforomation (d) Transportation

(viii) Nitrogenous base not present in RNA:
(a) Adenine (b) Guanine
(c) Uracil (d) Thymine

(ix) A kinds of lipids utilized in synthesis of rubber is:
(a) Acylglycerol (b) Waxes
. (c) Phospholipids (d) Terpenes

(x) Type of polynucleotide acting as messenger:
(a) ADP (b) ATP
(c) NAD (d) mRNA

2. Write detailed answers of the following questions:

(i) Name several molecules of monosaccharides, disaccharides and polysaccharids and give function and sources of each.

(ii) Describe the four basic structures of protein with examples?

(iii) Define protein.

3. Write short answers of the following questions:

(i) Many birds must store large amounts of energy to power flight during migration. Which type of organic molecules would be the most advantageous for energy storage. Why?

(ii) Why butter solidify at room temperature but not mustured oil?

(iii) How DNA is different from RNA?

(iv) Do mononucleotides work independently as heredity material? Why?

4. Define the followin terms.

(a)	Amino acid	(b)	Triglycerides	(c)	Oligosaccharides
(d)	Nucleotides	(e)	Secondary proteins	(f)	Terpenoid

Chapter 3

ENZYMES

Life would not be possible without metabolic activities of the cell. This in turn is depends upon the Catalytic molecules called the enzymes. With-out enzymes, the dynamic, steady state of the cell would cease to exist.
Life to a complex mesh work involving a perfect co-ordination of a vast majority of chemical reactions. Some of these reactions result in synthesizing large molecules, others in cleaving large molecules and still others either utilize energy or liberate energy. All these reactions would occur very slowly at low temperature and atmospheric pressures, the conditions under which living cells carry on their life proteases. But in the living system these reactions proceed at extremely high rates. This is due to the presence of some specialised substances or Biocatalysts which are synthesized inside the living cells. These biocatalysts are called **enzymes** (Gr: En = in; zyme = yeast). The term 'enzyme' was coined by Friedrich Wilhelm Kuhne (1878). Enzymes may be defined as organic substances capable of catalysing specific chemical reactions in the living system.
Just a few years ago, it was considered that all enzymes were proteins. During the 1980s, however, Thomas Cech and Sidney Altman discovered that certain molecules of ribonucleic acid also function as enzymes. These molecules are called **ribozymes;** which catalyze reactions involved in processing genetic information to be used by a cell. But generally enzymes are proteinaceous in nature.

3.1 ENERGY OF ACTIVATION

The questions arise here, how enzymes are able to accomplish such effective catalysis and why thermodynamically favourable reactions do not proceed on their own at relatively rapid rates in the absence of enzyme?
Chemical transformation requires that certain covalent bonds be broken within the reactants. To do so the reactants must contain sufficient kinetic energy (energy of motion) to overcome a barrier called Energy of activation or Activation energy. The important role played by the enzymes during reactions is that they lower the activation energy of the reaction. The enzyme reacts with the energy rich and energy poor molecules to form an intermediate complex. This complex again breaks into product and enzyme. If activation energy of this complex is low, many molecules can participate in reaction. In this way activation energy is lowered by the enzyme but in this action equilibrium (ratio of concentration of reactant and product) is never altered, it remains the same.

3.2 CHARACTERISTICS OF ENZYME

Enzymes are biocatalysts produced in the protoplasm. They are synthesized in the cell. The basic properties of enzymes are:

i) Most of the enzymes are proteinaceous in nature. They are macromolecules of globular proteins with higher molecular weight. They may entirely consist of protein e.g. **amylase** or **pepsin** or may contain, along with protein, a non-protein part. E.g. holoenzyme.

ii) They react with both acidic and alkaline substances due to the presence of protein as their major part.

iii) Enzymes generally act within the living cell where they have been produced but sometimes they diffuse out of the cell and perform catalytic function out side the cell or in other cells. An enzyme which acts within the same cell is called intracellular enzymes or **endoenzyme** and the enzyme which acts outside the cell is called **exoenzyme**.

iv) They are specific in their nature and their action.

v) Their molecules are much greater in size than the substrate.

vi) They have particular sites to react with the substrates called **active site**.

vii) They are biocatalyst, which speed up the rate of reaction. They are required in very small quantities which are capable of bringing about a change in large amounts of substrates.

viii) Enzyme activities can be accelerated by certain ions or salts called **activators** e.g. Mn, Ni, Mg, Cl, etc.

ix) Enzymes activities can be inhibited by certain factors called inhibitors e.g. substrate concentration, enzyme concentration, pH.

x) They are heat sensitive i.e. they are thermolabile and pH sensitive i.e. they work on specific pH.

xi) They remain chemically unchanged during and after the chemical reactions.

3.2.1 Mode of action:

Action of enzyme is related to it's structure which is complex and three dimensional. Each enzyme has a dimple or groove of a specific shape called the **active site**, into which substrate can fit

In order to explain the mode of action of enzyme, Fischer (1898) proposed a 'Key-Lock' theory which was later improved by Paul Filder and D. D Woods. They proposed that a particular enzyme acts on a particular substrate like particular lock can be unlocked by a particular key. This theory depends upon physical contact between substrate and enzyme molecules.

The active site of each enzyme has a distinct shape and distribution of charge which is complementary to its substrate, like lock and key, where a lock allows very few keys to fit in. Similarly enzymes allow a few complementary molecules to fit in and react while rejecting even fairly similar molecules.

On the other hand, some molecules may be able to fit in the active site of an enzyme but do not have chemical bond upon which the enzyme can act, so no reaction occurs.

Koshland (1959) proposed **Induce Fit Model**. He stated that when a substrate combines with an enzyme, it Induces changes in the enzyme structure, this change enables the enzyme to perform its catalytic activity more effectively.

3.3 TYPES OF ENZYMES

Enzymes are generally proteinaceous in nature. They may entirely consist of protein e.g. amylase or may contain a non-protein part with protein. If an enzyme consists only of protein it is called simple enzyme (**Proteozyme**) and if it contains another group with protein it is called conjugated enzymes. Euler (1932) proposed that conjugated enzyme showing complete activity be called **holoenzyme**. It contains two parts, the protein part of enzyme is called **apoenzyme** and the non protein part is called **prosthetic** group.

On the basis of the nature of prosthetic group, conjugated enzymes or holoenzymes are of two types:

i) The holoenzymes in which prosthetic group is an inorganic ions are known as **co-factor**. Role of magnesium, manganese, calcium and potassium on enzymes like phosphatases, phosphorylase, amidase, peptidase, carboxylase are well known.

ii) The holoenzymes in which prosthetic group is an organic compound, although inorganic ions may also be present in it are called **co-enzymes**. A co-enzyme constitutes about 1% portion of the entire enzyme molecule. This part of enzyme is more or less easily separable, usually heat resistant. Some co-enzymes of oxidation and reduction processes are NAD (Nicotinamide adenine dinucleotide), NADP (Nicotinamide adenine dinucleotide phosphate), FMN (Flavin mononucleotide), ATP (Adenosine triphosphate) etc.

3.4 FACTORS AFFECTING ENZYME ACTIVITY

Following are the factors which affect the enzyme activity:

(1) Concentration of substrate (2) Temperature (3) pH

(4) Co-enzymes, activators and inhibitors (5) Water (6) Radiation.

1) Concentration of Substrate:

The rate of reaction increases with an increase in the concentration of substrate until the available enzyme becomes saturated with substrate. There is no increase in the enzymatic activity to a certain higher level of substrate concentration. At a very high concentration the substrate exerts a retarding effect upon enzyme action.

This may be due to two reasons:

(a) Higher quantity of substrate than enzyme.

(b) Accumulation of end product in high quantity.

Hence, substrate and enzyme concentration are directly proportional upto a certain maximum velocity after which further increase in substrate concentration has no effect on the rate of reaction.

2) Effect of temperature:

Enzymes are sensitive to temperature. Each enzyme has its optimum temperature for its maximum activity, above and below this temperature its rate of reaction decreases. Most of the enzymes are highly active at about 37°C and all are completely destroyed at 100°C, whereas at minimum i.e. 0°C, activity is reduced to minimum but enzymes are not destroyed.

3) Effect of pH:

The activity of enzyme varies considerably with pH and there is generally a marked optimum pH for each enzyme e.g. pepsin of stomach has an optimum pH of 1.4. It is inactive in neutral or alkaline solution.

4) Co-enzymes, activators and inhibitors:

Enzyme action is frequently accelerated or inhibited by the presence of other substances called **co-factors**. Co-factors have been divided into three categories.

i) Co-enzymes: If the co-factor is an organic molecule, its is called co-enzyme. Without co-enzyme certain enzymes are unable to function e.g. CoA,

NAD, FAD etc. Most vitamins are co-enzymes or raw materials from which co-enzymes are made.

ii) Activators: Inorganic substances which increase the activity of an enzyme are called activators. Magnesium (Mg^{+2}) is an inorganic activators for the enzyme phosphatase and Zinc ion (Zn^{+2}) is an activator for enzyme carbonic anhydrase.

iii) Inhibitors: Substances which decrease the activity of an enzyme are called inhibitors. The inhibitors may act by combining directly with the enzyme or they may react with the activator therefore, activator does not remain available to enzyme for activation.
Some inhibitors resemble the normal substrate molecule and compete for admission into the active site. These mimics, called **competitive inhibitors**, reduce the productivity of enzyme by blocking the substrate from entering into the active site. If the inhibition is reversible, it can be overcome by increasing the concentration of substrate so that as active site become available, more substrate molecule than inhibitor molecules are around to gain entery to these site.
Non-competitive inhibitors obstruct enzymatic reactions by binding to a part of the enzyme away from the active site. This interaction causes the enzyme molecule to change its shape, rendering the active site unreceptive to the substrate, or leaving the enzyme less effective at catalyzing, for the conversion of substrate to product. In non-competitive inhibition, a molecule binds to an enzyme other than its active site. This other binding site is called **allosteric site** (allo = other, steric = space or structure) and the inhibitor which acts, at this site is called allosteric inhibitor.

Feed-back inhibition:
The activity of almost every enzyme in a cell is regulated by feed-back inhibition. **Feed-back inhibition** is an example of a common biological control mechanism called **negative feedback**. When the product is in abundance, it binds competitively with it's enzyme's active site; once the product is used up, inhibition is reduced and more product can be produced. In this way concentration of the product is always kept within a certain range.

The pesticides DDT and parathion are inhibitors of key enzymes in the nervous system. Many antibiotic are inhibitors of specific enzyme in bacteria e.g. penicillin blocks the active site of an enzyme that many bacteria use to made cell-walls. These examples of enzyme inhibitors as metabolic poison may give the impression that enzyme inhibition generally abnormal and harmful

Most enzymatic pathways are also regulated by feed-back inhibition, but in these cases the end product of the pathway binds at an allosteric site on the first enzyme of the pathway. This binding shuts down the pathway and no more product is produced.

5) Effect of Water:
Water is necessary for enzyme activity as it influences the rate of enzymatic activity. In germinating seeds, with the increase in amount of water, to some extent, enzymes become active and germination proceeds.

6) Radiation:
Enzymes are generally inactivated rapidly by exposure to ultraviolet light and also to X-rays, because it alters the shape of protein i.e. enzymes.

KEY POINTS

- Enzymes are biocatalyst, speed up chemical reactions because they lower down the energy of activation. They can do this because they form a complex with their substrate(s) at the active site.
- Many enzymes have co-factors or co-enzymes that help them to carryout a reaction. Co-enzymes have non-protein organic molecules and are often derived, at least in part, from vitamins.
- Various factors affect the yield of enzymatic reactions, such as the concentration of the substrate(s), the temperature and the pH. A high temperature or a pH outside the preferred range for that enzyme can lead to denaturation, a change in structure that prevents the enzyme from functioning.

EXERCISE

1. Encircle the correct choice:

(i) Which molecule binds to the active site of an enzyme.
(a) Allosteric activator (b) Allosteric inhibitor
(c) Non-competitive inhibitor (d) Competitive inhibitor

(ii) Which metabolic process in bacteria is directly inhibited by the antibiotic pencillin.
(a) Cellular respiration (b) ATP hydrolysis
(c) Synthesis of fats (d) Synthesis of chemical components of the cell-wall

(iii) How does an enzyme increase the speed of a reaction?
(a) By adding activation energy
(b) By lowering activation energy requirements
(c) By decreasing concentration of reactants
(d) By increasing the concentration of products

(iv) An allosteric site on an enzyme is:
(a) The same as the active site
(b) Where ATP attaches and gives up its energy
(c) Often involved in feed-back inhibition
(d) At the opposite site of active site

(v) A temperature beyond optimum:
(a) Can affect the shape of an enzyme.
(b) Lowers the energy of activation.
(c) Makes cells less suspectible to disease.
(d) Both a and c.

(vi) Nucleic acid which also serve as enzymes are:
(a) Nucleoprotein (b) Ribozyme.
(c) Ribosome (d) Co-enzyme.

(vii) The activity of almost every enzyme in a cell is regulated by;
(a) Feed-back inhibition (b) Positive-feedback
(c) Negative-feedback (d) Feed-back control

(viii) The nonprotein part of an enzyme is:
(a) Prosthetic group (b) Co-enzyme
(c) Co-factor (d) All of them

(ix) The protein part of holo-enzyme is:
(a) Ribozoyme (b) Apoenzyme
(c) Acylglycerol (d) Co-enzyme.

(x) Magnessium (Mg^{+2}) is an inorganic activator for the enzyme:
(a) Manganase (b) Phosphatase
(c) Carbonic anhydrase (d) Hexokinase

2. Write detailed answers of the following questions:
(i) What are enzymes? Classify them and explain their role.
(ii) Write an essay on enzymes.

(iii) Write short notes on:
(a) Co-enzymes (b) Inhibitor
(c) Mode of action of enzyme

3. Give short answers of the following:
(i) Give three characters of enzyme.
(ii) Who proposed key and lock theory of enzyme action and how it works?
(iii) What is the effect of substrate concentration on enzyme activity?

4. Define the following terms:
(i) Enzyme
(ii) Activation Energy
(iii) Allosteric inhibitor
(iv) Active site
(v) Feedback inhibition

Chapter 4

THE CELL

Cell is the smallest entity in which life can exist. It is the least set of chemicals that with the help of "life" turns into a stable, living systems with the self-replication property.

4.1 CELL AS BASIC UNIT OF LIFE

Cell is the most puzzling mystery of nature about which it is believed that the day scientist will understand it fully, they would be able to unravel the secret of life and death. The discovery of cells and their structure became possible with the development of optical lenses and with the construction of compound microscope (Gr-mikros-small, skopein-to see, to look), which was invented by David Jensen in 1590 and in 1610 Galileo an Italian astronomer and physicist designed it properly.

The term Cell (Greek. Kytos-cell La; Cella-hollow space) was first used by Robert Hooke (1665) to describe his Investigations on the structure of cork. Later, Robert Brown (1831) discovered a spherical body, the nucleus, in the cells of orchids. The fact that living organisms have a cellular organization was emphasized by Schleiden (1838) and Schwann (1839), Schwann, observed that the nucleus was surrounded by a fluid in the cell. His observation thus, changed the definition of cell and he described the "Cell as a structure which consists of a nucleus surrounded by a semifluid substance enclosed by a membrane". Later, it was pointed out, that the structure of a cell in animals and plants is similar with only one difference, that plant cell has a cell-wall in addition to the cell membrane.

When Robert Hooke first discovered the cell as basic unit of life in 1663, he calculated over 1-billion of cells in a "cubic inch" of cork. One encounters such astonishing numbers contain frequently in the study of cell biology. A new born human baby contain 2 trillion cells; an adult 60 trillion. When you donate blood, you give away 5.4 billion cells. Each day, infact, a human body sloughs off, and replaces 1 percent of its cells or about 600 billion.

4.1.1 Emergence of Cell Theory:

In 1838, Schleiden a German botanist concluded that, despite differences in the structure of various tissues, plants were made of cells. In 1839, a German zoologist, T. Schwann, published a comprehensive report on the cellular basis of animals. Both of them proposed the cell theory which state that:

i) All organisms are composed of one or more cells.

ii) The cell is the structural and functional unit of life.

Schleiden and Schwann's ideas on the origin of cell was not convincing; both agreed that cell is a 'de novo' structure, could arise from non-cellular materials. In 1855 Rudolf Virchow a German pathologist, had made a convincing case and added a third point to the cell theory.

iii) Cells can arise only by division of pre-existing cell, it is not a 'de novo' structure.

Cell theory brought a great revolution in the field of biology which established that the function of an organism is the result of activities and interaction of the cell units.

Now, a cell is defined as the structural and functional unit of living organisms made up of **protoplasm** containing **nucleus** surrounded by **cytoplasm** and bounded by **cell membrane**.

4.1.2 Microscopes:

The study of cells and micro-organism is dependent upon the use of an instrument called microscope. Our knowledge of sub-cellular organisation has been improved by the development of better and more powerful microscopes.

Kinds of microscopes:

Various types of microscopes have been designed by scientist. According to the source of light following types of microscopes can be recognised.

i) **Light microscope** - in which visible light is used as source of illumination.

ii) **X-ray microscope** - in which short wave length X-rays are used as source of illumination.

iii) **Electron microscope** - in which electron beam is used as a source of illumination.

Resolution Vs Magnification:

Three attributes of microscopes are of particular importance, these are magnification, resolution and contrast. Magnification is a means of increasing the apparent size of the object. With a light microscope a specimen could quite easily be magnified by as much as 10,000x. Magnification of a microscope is calculated by multiplying the power of its eye pieces with its magnifying power of its objective.

Resolution or more correctly the minimum resolved distance, is the capacity to separate adjacent form or object Contrast is important in distinguishing one part of cell from another. In light microscopes contrast is often obtained by fixing and staining the material.

A very high magnification can be obtained by ordinary light microscope but their resolving power is limited. It is about 500 times better than unaided human eye, but this is still not enough for viewing some of the smaller sub-cellular structures. Electron beams have much shorter wavelength than visible light, electron microscopes are capable of resolving objects about 10,000 times better than unaided human eye. Therefore most of the sub-cellular structures are studied by electron microscope.

4.1.3 Techniques to Isolate Components of Cell:

Isolation of cellular components to determine their chemical composition, is called cell **fractionation.** For cell fractionation, first of all it is necessary to break/ open a large number of similar type of cells in ice cold environment. The cells are usually placed in a homogenizer or mortor are broken. The 'freed' content of the cells are subjected to a spinning action known as **centrifugation**. At a low speed, large particles like, cell nuclei, settle down are in the sediment. Smaller particles are still in the supernatant (fluid) which can be poured into a fresh tube and subjected to centrifugation at a higher speed until the smallest particles have been separated out, the various cell fractions can then be biochemically analysed.

4.1.4 Eukaryotes and Prokaryotes:

Eukaryotes are those organisms having a true nucleus (Eu=true, karyon=nucleus) in their cells. They also contain chromosomes and a variety of membrane bound organelles like mitochondria, Golgi apparatus, lysosomes, plastids etc. In their cells, which contribute structural and functional organisation to the cells. They may be unicellular or multicellular organisms. On the other

hand prokaryotes (Pro=early, karyon=nucleus) are those organisms which do not contain membrane bound nucleus in their cells, their nucleic material is usually coiled and concentrated in a region of the cell called the **nucleoid**. More over genetic material (DNA) never associated with histone protein and hence no true chromosome. These organisms also do not contain other membrane bounded structures like, mitochondria, chloroplast, lysosome, etc. in their cells. They only contain mesosomes, which are simple infoldings of the Plasma membrane responsible for respiration, photosynthesis, nitrogen fixation etc. They are unicellular organisms like bacteria and cyanobacteria.

4.2 EUKARYOTIC CELL

The typical Eukaryotic cells contain three major parts, but 4th component i.e. cell wall is only found in plant cells.

1. Plasma membrane.
2. Nucleus.
3. Cytoplasm and Cytoplasmic Organelles.
4. Cell Wall

4.2.1 Plasma membrane:

All cells are enclosed in a membrane that serves as their outer boundary, separating the cytoplasm from the external environment. This membrane is known as the plasma membrane. It allows the cell to take up and retain certain substances while excluding others.

All biological membranes have the same basic molecular organization. They consist of a double layer (bilayer) of phospholipids interspersed with proteins.

The phospholipid molecules in the plasma membrane are arranged in two parallel layers. Their non-polar hydrophobic ends face each other, whereas their polar hydrophillic ends are associated with carbohydrate, protein etc. Plasma membrane also contains several types of lipids like cholesterol. In certain animal cells cholesterol may constitute upto 50 percent of the lipid molecules in plasma membrane It is absent from the plasma membrane of most plant and bacterial cells.

Fluid Mosaic Model; characteristics, properties and functions:

In 1972 Singer and Nicolson proposed a working model of plasma membrane known as fluid mosaic model. In the fluid mosaic model, the lipid bilayer is retained as the core of the membrane. These lipid molecules are present in a fluid state capable of rotating and moving laterally within the membrane.

The structure and arrangement of membrane, proteins in the fluid-mosaic model are like icebergs in the sea. The proteins occur as a 'mosaic' of discontinuous particles that penetrate deeply into and even completely through the lipid sheet. The components of plasma membrane are mobile and capable of coming together to engage in various types of transient or semi permanent interaction.

The proteins associated with the lipid bilayer can be divided into two groups.

a) Integral proteins (intrinsic proteins): A class of proteins that are directly incorporated within the lipid bilayer. Some of these proteins are believed to provide a channel through which water-soluble substances, such as ions, can pass back and forth between the extracellular and intracellular compartment.

b) Peripheral proteins (extrinsic proteins): A class of protein located entirely outside of the lipid bilayer on either the extracellular or cytoplasmic surface, exhibit a loose association with membrane surface.

These proteins which may possess lipid (lipoprotein) or carbohydrate (glycoproteins) side chains, are arranged as mosaics within the cell-membrane.

Different types of cells contain different population of membrane proteins e.g. Red blood cells have special membrane proteins that label the cell, giving it A, B, AB or O blood type. Other molecular labels lead to either acceptance or rejection of a transplanted kidney, heart or other organ.

The plasma membrane performs several functions but the main and the most important functions are protection of cell cytoplasm, to regulate the flow of solutions and material in an out of the cell with certain limitation. These limitations or check in flow across the membrane is called differential or selective permeability. Transport across membranes is necessary to maintain suitable pH, ionic concentration for enzyme activity and excrete toxic substances etc. For entry or exit there are two main processes, **passive transport** i.e. diffusion and osmosis and **active transport**, the passive processes do not require energy while active require energy with these, there are two other phenomenon i.e. endocytosis and exocytosis. Definition of diffusion and osmosis is discussed in chapter 14.

i) Diffusion: It occurs spontaneously, and no extra energy is required to bring it about. A few substances freely diffuse across plasma membrane e.g. the respiratory gases (O_2 and CO_2) diffuse in and out of the cells.

ii) Osmosis: It maintains a balance between the osmotic pressure of the intracellular fluid and that of interstitial fluid, known as Osmoregulation.

iii) Active transport: Movement of molecules from lower concentration to the higher concentration by consuming energy called active transport.

iv) Endocytosis: It is the process in which the cell membrane helps to take in material by infolding in the form of vacuole. Endocytosis maybe **(a) phagocytosis** in which solid particles are picked and ingested by the cell e.g. W.B.C picked up foreign bodies from the blood stream. In this way they destroy the harmful bacteria which enter into our body. It is also called cell eating process **(b) pinocytosis** when liquid material in bulk, in the form of vesicles is taken in by endocytosis, the process is called pinocytosis which is also called cell drinking process.

v) Exocytosis: The process of membrane fusion and the movement of material out of a cell is called exocytosis.

4.2.2 Cell-Wall:

Cell-wall is the non-living component of cell. It is secreted and maintained by living portion of cell called protoplasm. The chief structural component of plant cell-wall is cellulose, a polysaccharide. In addition to cellulose, pectin and a few other compounds may also be found in cell-wall.
A plant cell-wall can be differentiated into three layers, (i) middle lamella (ii) primary wall (1.3 µm thick and elastic) (iii) secondary wall (5-10 µm in thick and rigid).

Cellulose the main constituent of plant cell-wall is use in the manufacture of paper. It is also the main component of many other house hold goods. The seed hairs of the cotton plant (Gossypium) are almost pure cellulose and their natural twist make them easy to spin for use in a variety of textiles from clothes to curtains.

Middle Lamella: The first formed cell plate works as a cementing layer between two daughter cells and is called middle lamella. It is a common layer between two

cells and the two cells are separated when middle lamella is dissolved. It is composed of calcium and magnesium pectates.

Primary Wall: Primary wall is the first product of cell, synthesised by protoplast, deposits on either side of middle lamella. In young enlarging cells primary wall remains thin and elastic, becoming thick and rigid with the approach of cell maturity. Primary wall contains hemicellulose up to 50 percent, cellulose up to 25 percent and smaller amount of pectic substances. Hemicellulose forms matrix of the wall in which cellulose micro fibrils are embedded.

Secondary Wall: Secondary wall is formed by deposition of cellulose at the inside of primary wall. It mainly consists of cellulose or varying mixtures of cellulose. Secondary wall may be modified through the deposition of Lignin and other substances.
In the cell wall cellulose deposits in the form of fibres. The cellulose fibres of each successive layer lie at different angles, increasing the strength of the cell-wall. At some places in the cell wall, the deposition of wall material does not take place, these places are known as **plasmodesmata** (Singular-plasmodesma), through which cellular contents of neighbouring cells remain in communication with each other.

Functions of cell-wall:
It performs two important functions, firstly it provides a mechanical support and gives a definite shape and protection to the cell. It acts like a skeletal frame work of plants, particularly in vascular plants the cell walls provide the major supporting frame work. Secondly, being hydrophilic in nature it is capable of imbibing water and thus helps in the movement of water and solutes towards, protoplasm i.e. Cell wall acts as permeable structure.

4.3 NUCLEUS

Nucleus was discovered by **Robert Brown** in 1831. It is the most important and prominent part of the cell which controls all its activities. It is commonly spherical or oval in shape, but may be lobed or elongated and is surrounded by a membrane called nuclear membrane. It is double-membraned structure. Usually cells have one, some have two or more nuclei. Some small organisms have several small nuclei per cell (coenocytlc). The nuclear membrane is not a complete barrier. It is perforated by **nuclear pores**. Certain substances pass freely through these pores between the nucleus and the surrounding cellular substances.
The Nucleus is filled with a protein rich substance called **Nucleoplasm** or **Karyolumph**. In the nucleoplasm are numerous fine strands in the form of network called **chromatin network or nuclear reticulum**, which is composed of **nucleic acid**. Deoxyribo-nucleic acid (DNA) and protein. During cell division, the chromatin changes to form chromosomes. Chromosomes contain the hereditary units called genes that carry the hereditary information from generation to generation. The chromosomes vary in number from species to species, e.g. 8 in the fruit fly, 46 in humans, 20 in corn etc. Chromosomes are elongated structure, visible during cell-division. A typical chromosome is composed of two parts the arm and centromere. Before cell division each chromosome consists of two threads called chromatids. These two chromatids are joined by centromere. Each chromatid has one DNA molecule. The part of chromatids from centromere to end is called arm. The chromosomes are of different types, depending on the position of centromere. These types are:

(i) **Metacentric:** Chromosome with equal arms.

(ii) **Sub-metacentric:** Chromosome with unequal arms.

(iii) Acrocentric or Subtelocentric: Rod like chromosome with one arm very small and the other very long. The centromere is subterminal.

(iv) Telocentric: Location of centromere at the end of chromosome.

Also, within nucleus is a spherical body called nucleolus. There may be more than one nucleoli in one nucleus. The number varies in different kinds of cells. It disappears during cell division and reappears afterwards. The nucleolus is believed to play an important role in the synthesis of ribonucleic acid and ribosome in Eukaryotic cells.

4.4 CYTOPLASMIC ORGANELLES AND MEMBRANE SYSTEM

The part between nuclear membrane and cell membrane is called cytoplasm. In some cells, e.g. Amoeba, the cytoplasm has two distinct parts an, outer clear ectoplasm and an inner granular endoplasm in most cells. Under light microscope, cytoplasm appears as a semi-fluid colloid that fills the cell. The cytoplasm exhibits active streaming movements around the inner surface of the cell. This movement is known as cyclosis.

Cytoplasm is consist of several types of organelles, occupying as much as half of the volume of the cell, and a fluid matrix, the cytosol (literally 'cell solution') in which the organelles reside. The cytosol is a watery solution of salts, sugar, amino acids, proteins, fatty acids, nucleotides and other materials.

Observations under electron microscope, however, reveal that cytoplasm is not a simple colloid since it contains many different kinds of minute organelles and also a mesh of tiny filaments, the microfibrils that form a sort of skeleton, giving rigidity to cell and helping unicellular organisms in movement. Many of the organelles and even individual molecules of the cytoplasm are thought to be attached to the cytoskeleton.

A variety of cytoplasmic organelles are present in cells, majority of them are membrane bound.

(i) Endoplasmic Reticulum:

The electron microscope reveals a complex network of channels, the endoplasmic reticulum (ER) which extends from plasma membrane to the nuclear membrane. It is an elaborate, tube like system of lipoprotein. There are two types of endoplasmic reticulum: (a) Agranulated or Smooth endoplasmic reticulum (SER) and (b) Rough or granulated endoplasmic reticulum (RER). Smooth endoplasmic reticulum is not associated with ribosomes. It is found in steroid producing cells like adipose cells (fat cells), interstitial cells, glycogen storing cells (liver) and the muscle cells. Rough or granular endoplasmic reticulum (RER), is heavily coated with ribosomes on its outer surface towards cytoplasmic surface. Rough ER, occurs mostly in protein synthesising cells. Such as those of the mammalian salivary glands and pancreas. Although most cells contain both rough and smooth ER but they vary from cell to cell.

Smooth E.R. in the skin converts cholesterol into the lipid compound called vitamin D whenever sunlight strikes the skin; this vitamin helps to maintain strong, healthy bones. North African women of Bedouin tribe, who wear dark, full length garment get very little exposure to sun light and thus the smooth E.R. in their skin cells cannot make vitamin 0. As a result, these women sometimes develop soft, weak bones.

The endoplasmic reticulum has many important functions. Primarily, it serves as a supporting platform for the ribosomes. The ER, forms a structural framework of the cell with increased surface for various metabolic reactions, and they themselves take an active part by means of attached enzymes. ER also provide conducting pathways for import-export and intracellular circulation of various

substances. ER also provides passage for Ribonucleic acid (RNA) to pass from the nucleus to various organelles in the cytoplasm, thereby, controlling chiefly the synthesis of proteins. It also helps in detoxification of harmful drugs, storage and release of Ca^{+2} ions and manufacture lipids.

(ii) Mitochondria:

Mitochondria or Chondriosomes are universally present in the cytoplasm of animals and plants. They appear as minute granules, vesicles, rodlets, threads or strings depending upon physiological conditions of the cells. They are seen to be in constant motion in living cells Mitochondria are the centre of aerobic respiration.

Each mitochondrion is approximately about 0.2 to 1.0 nm in diameter and about 10 µm long. There are two thin membranes which form the boundary of the mitochondrion. Both membranes are formed of lipids and proteins. The inner membrane forms irregular, incomplete partitions called Cristae. The interior of the mitochondrion contains fluid like organic matrix, with a number of chemical compounds in it. On the cristae are located enzymes and co-enzymes by means of which carbohydrates (starch) fatty acids (lipids) and amino acids (proteins) are metabolized to CO_2 and H_2O. Energy in the form of ATP is released in this process which is stored within mitochondria. Adenosine triphosphate (ATP) is energy rich compound and it provides energy to the cells of organs for various activities. Hence mitochondria are known as "Power House" where energy is stored and released wherever and whenever required by a living body.

Mitochondria have a semi-autonomous existence in the cell; they have their own DNA that directs production of some of their component proteins and they can divide in half and thus reproduce independently of the cell's normal cell-division cycle.

Surprisingly, mitochondria are passed to an animal only by mother, since mitochondria are present in eggs but not in the part of the sperm that enters the egg. Thus, people can trace their mitochondria back to their mothers, grandmothers, great grand mother etc.

(iii) Golgi apparatus (Dictyosome):

The Golgi apparatus, like the endoplasmic reticulum, is a canalicular system with sacs, but unlike the endoplasmic reticulum it has parallel arranged, flattened, membrane bound vesicles which lack ribosomes. After the name of its discoverer Golgi, it was named as Golgi-body. The Golgi complex of the plants and lower invertebrates cells is usually referred as dictyosome.

The Golgi bodies of plant cells and Golgi complex of animal cells basically have same morphology. Each of them is disc-shaped and consists of central, flattened, plate like compartments called cisternae, peripheral network of inter connecting tubules and peripherally occuring vesicles and Golgian vacuoles.

Usually in animal cells single Golgi apparatus is found in each cell, in plant cell, they may be more. Golgi apparatus are especially prominent in glandular cells. The products of E.R. are modified and stored, and then sent to other destinations. They perform the function of collection, packaging and distribution. In addition to its finishing work, the Golgi apparatus manufacture certain macro molecules by itself. Many polysaccharides secreted by cells, like cell-wall and cell plate material in plant cell are Golgi products.

(iv) Lysosomes:

These are spherical bodies, a few micrometer in diameter, surrounded by a single membrane, originated by Golgi apparatus and containing digestive enzymes. They occur only in the cytoplasm of animal cells, and function in the digestion of material taken into the cell by phagocytosis, as bacteria are ingested by white blood corpuscles. Normally they function as destroyers of foreign particles and

worn out cellular components. When the membrane of lysosomes is ruptured, the cell undergoes chemical breakdown, or lysis. Since release of the enzymes, cause a cell to destroy itself by digesting its own proteins, lysosomes have been referred as **"suicide sacs"** and this process is called **autophagy.**

Lysosomal storage diseases:
Disturbance in lysosome function has profound effects on human health. In 1965 W.G.Hers of Belgium explained how the absence of apparently unimportant lysosomal enzyme, a-glucosidase, could lead to the storage of undigested glycogen accumulate in lysosome causing swelling of the organelles and irreversible damage to the cells and tissues. Diseases of this type, characterized by the deficiency of a lysosomal enzyme, and the corresponding accumulation of undergraded substrate are called lysosomal storage disorder, over 30 disorders have been reported, out of them some are described in the following table.

Table 4.1 Sphingolipid storage diseases

Disease	Consequences
- Tay-sachs disease - Gaucher's disease - Krabbe's disease	- Mental retardation, blindness, death by age 3. - Liver and spleen enlargement, erosion of long bones, mental retardation in infantile form only. - Loss of myelin, mental retardation, death by age 2.

(v) Plastids:
They are especial protoplasmic double membrane bound organelles which function as chemical synthesizers and storage bodies. Plastids occur in greatest number in cells of plants and in the primitive single celled organisms, the Protoctists.
There are three types of plastids e.g. Chloroplast, Chromoplast and Leucoplast.

i) Chloroplast (Gr: Chloro=green, Plast=living): The most common type of plastid is chloroplast containing chlorophyll which gives plant their green colour and is of great importance in the manufacture of food by the process of photosynthesis.
Chloroplasts contain a substantial amount of DNA and are capable of programming synthesis of some other new structural components. It has its own DNA and RNA.

ii) Chromoplast (Gr: Chroma=colour, Plast=living): They have pigments like xanthophyll, and carotene. The chromoplasts are responsible for the various colour combinations found in flowers, fruits and other coloured parts except green.

iii) Leucoplast (Gr: Leuco=white): These are colourless plastids which develop in the absence of sunlight and are thus commonly found in all under-ground parts of the plants. They store the food material as carbohydrates, lipids and proteins.

Proplastids: Proplastids are immature, colourless plastids occuring in cells of meristematic tissues. They consist of double membrane enclosing granular stroma. They multiply by division. In mature cells proplastids develop into chloroplast or chromoplast or leucoplast.

Chloroplasts as energy converting Organelles:
A typical plant cell has especial type of energy converting organelles, chloroplasts. They have an ability to convert solar energy (light energy) into

chemical/food energy by the process, of photosynthesis, therefore called site of photosynthesis. Chloroplasts belong to a group of double-membrane bound organelles. They contain chlorophyll and its associated proteins.
Inside the chloroplast other membranous system, arranged into flattened sac called **thylokoids**. In some regions thylokoids are stacked forming structure called **grana** (sing: granum). The fluid outside the thylokoid called **stroma.**
During photosynthesis, chlorophyll captures the energy of sunlight and transfers it to other molecules in the thylakoid membranes. These molecules in turn transfer the energy to ATP and other energy-carrier molecules. The energy carriers diffuse into stroma, where their energy is used to derive the synthesis of sugar from carbon dioxide. Due to this movement of energy from one form to another, chloroplast is an energy converting organelle.

(vi) Peroxisome:
Peroxisome are single membrane bounded microbodies that contain enzymes for transferring hydrogen atom to oxygen, forming hydrogen peroxide (H_2O_2), a toxic molecule that is immediately broken down to water by the enzyme catalase. Peroxisome are abundant in cells that are metabolizing alcohol. Peroxisome are believed to help in detoxification of alcohol. They are found in plants and animals.

Peroxisomes contain enzymes that breakdown compounds e.g. peroxisomes within liver and kidney cells breakdown and detoxify fully, half of the alcohol a person drink.

(vii) Glyoxysome:
Another type of microbodies found in plants only which are also consider as specialized peroxisomes called **glyoxysomes**. They are found in the fat storing tissues. Each glyoxysome has a single layered bounding membrane enclosing a fine granular stroma. Glyoxysome contain enzymes that initiate the conversion of fatty acid into sugar.

Cytoskeleton: The cytosol is organised into a three dimensional network of fibrous proteins called cytoskeleton. It plays fundamental roles in mitosis, meiosis, cytokinesis, cell-wall deposition, the maintenance of cell-shape and cell differentiation.
There are three types of cytoskeleton elements found in cells.

a) Microfilaments are solid strand of about 7 nm in diameter and several cm in length especially in muscle cells. They are consists of two actin chain that intertwine in a helical fashion, some microfilaments also contain myosin protein with actin. They perform function of muscle contraction, changes in cell shape, including division of cytoplasmic in dividing animal cells, cytoplasmic streaming movement of pseudopodia.

b) Intermediate filaments are solid strands of 8 to 11 nm in diameter, 10 to 100 um in length. They are intermediate in between microtubules and microfilaments. They are made up of atleast five different types of protein, form rope like polymer of fibrous protein. Unlike the other two types of cytoskeleton elements, intermediate filaments do not assemble and disassemble. Therefore, they are important in maintaining the shape of cell, attachment of muscle cells, support of nerve cell processes (axon).

c) Microtubules are hollow tubes with an outer diameter of 25 nm, may be more than 50 um in length. They are composed of protein, tubulin. A single micro tubule consists of hundreds of thousands of tubulin sub-units usually arranged in 13 columns called proto filaments, they are responsible for the movement of

chromosomes during cell division, movement of organelles within cytoplasm, movement of cilia and flagella.

(viii) Ribosomes:

These are so named because they contain high concentration of Ribonucleic acid (RNA). These small structures are sites of protein synthesis in all cell types, prokaryotic as well as eukaryotic cells. Ribosomes are found freely dispersed in the cytoplasm in prokaryotic cells. But in eukaryotic cells they are found free as well as attached to endoplasmic reticulum. They are composed of about 50 or more different kinds of proteins. There are millions of these per cell, and they are all identical. Ribosomes may be regarded as **"Protein factories".** Under the direction of the nucleus they produce the protein needed by the cell.

Each ribosome consists of two unequal subunits. The larger summit is dome-shaped and smaller one forms a cap on the flat surface of larger subunit. Some ribosomes adhere themselves to endoplasmic reticulum by the larger subunits.

Although ribosomes are among the smallest organelles, they are among the most vital cellular components. Recent investigations reveal that the ribosomes are manufactured in the nucleolus from where they are transferred to the cytoplasm through nucleopores.

(ix) Centriole:

In animal cell, microtubules radiate from a microtubule organizing centre near the nucleus called centrosome (centro = nucleus, soma = body). Within the centrosome of an animal cell is a pair of centrioles. Centrioles are short; barrel - shaped structures of microtubules, lying perpendicular to one another. Each centriole is composed of nine sets of triplet microtubules arranged in a ring. When a cell divides, the centrioles replicate, move to opposite side of the cell and thread like fibres begin to radiate from centrioles in all directions called astral rays.

(x) Vacuoles:

Generally vacuoles (except food vacuole) are nonprotoplasmic liquid filled cavities in the cytoplasm and are surrounded by a membrane called the **tonoplast.** The tonoplast is selectively permeable, it allows certain substances to enter in the vacuole. In animal cells they are temporarily formed at the time of their need. These are conspicuous organelles of plant cells. They are more prominent in mature cells whereas less prominent in immature cells. The vacuoles in plant cells are filled with cell sap and act as store house, which often plays role in plant defence, which is necessary for plant cell enlargement. In animal cells, lysosomes are rich in hydrolytic enzymes, including proteases, ribonucleases and glycosidases. Plant vacuoles sometimes act as lysosome as they contain hydrolytic enzymes and after death of cells tonoplast lose its differential permeability and its enzyme causes lysis of the cell.

KEY POINTS

- Cell is a basic structural and functional unit of living organism consist of membrane and protoplasm.
- Microscope is an instrument to observe very small objects.
- Electron microscope use electron beam as a source of illumination to increase the resolution of object.
- Cell-fractionation is the isolation of cellular component by breaking and spinning the cell.
- There are two types of cells on the basis of the structure of their nucleus ie. prokaryotic and eukaryotic.
- The membrane which separate cytoplasm from the external environment is called cell-membrane or plasma membrane.
- Singer and Nicholson proposed working model of plasma membrane called fluid mosaic model.
- There are two components of plasma membrane, phospholipid and proteins. Glycolipids and glycoproteins are involved in making the cell specific.
- Important functions of cell membrane are protection of protoplasm and regulation of flow of solutes and material across it, due to its selective permeability.
- Plant cell has non-living part, made of mainly cellulose called cell-wall.
- Nucleus is a central, and controlling part of the cell.
- Nucleus having thread like structure called chromosomes, their number are specific in the cells of specific species.
- Endoplasmic organelles are complex network of channels extend from plasma membrane to nuclear membrane.
- Golgi apparatus is a canalicular system with sacs, parallel arranged, flattened, membrane bound.
- Lysosome are spherical, single membrane bounded saccules, containing digestive enzymes also called 'suicide sacs'.
- Plastids are found in plant cells as chemical synthesizers and storage bodies.
- Mitochondria or chondriosomes act as the powerhouse of cell because they are the site of Aerobic respiration specially kreb's cycle.
- Peroxisomes are microbodies that contain enzyme for transfering hydrogen atom to oxygen, forming hydrogen peroxide (H_2O_2).
- Glyoxysome another type of microbodies responsible for conversion of molecules of fatty acid into sugar.
- Network of fibrous protein give three dimensional structure to cell called cytoskeleton.
- Ribosome may be regarded as 'protein factories' made up of two unit, large and small.
- Centriole are the dark bodies appear near nucleus before cell-division in animal and low plant's cell.
- Vacuoles are non-protoplasmic liquid filled cavities surrounded by tonoplast

EXERCISES

1. Encircle the correct choice:

(i) A phospholipid molecule has a head and 2 tails. The tails are found:
- (a) at the surface of membrane
- (b) in the interior of the membrane
- (c) both at the surfaces and the interior of membrane
- (d) spanning of the membrane

(ii) Energy is required for:
- (a) active transport (b) diffusion
- (c) facillated transport (d) all of these

(iii) Which of these best distinguishes a prokaryotic cell from a eukaryotic cell?
- (a) prokaryotic cells have a cell-wall but eukaryotic cells do not.
- (b) prokaryotic cells are larger than eukaryotes.
- (c) prokaryotic cells have flagella but eukaryotes do not.
- (d) prokaryotic cells do not have a membrane-bounded nucleus but eukaryotic cells do have such a nucleus.

(iv) Lysosomes function in:
- (a) protein synthesis (b) processing and packaging
- (c) intracellular digestion (d) lipid synthesis

(v) Which organelle releases oxygen:
- (a) ribosome (b) golgi apparatus
- (c) mitochondria (d) chloroplasts

(vi) The protein presents in microtubules
- (a) actin (b) tubulin
- (c) keratin (d) myosin

(vii) Characteristics associated with peroxisome only:
- (a) membrane bound cell organelles
- (b) having single membrane
- (c) found only in eukaryotic cells
- (d) contain enzymes for transferring H atoms to oxygen form H_2O_2.

(vii) Lysosomal storage disease resulting in blindness
- (a) Tay-sachs (b) Gaucher's
- (c) Krabbe's (d) none of them

(viii) Chromosomes with equal arms are
- (a) metacentric (b) sub-metacentric
- (c) acrocentric (d) telocentric

(ix) Endocytosis which involve ingestion of solid material is called
- (a) pinocytosis (b) phagocytosis
- (c) solidocytosis (d) exocytosis

2. Write detailed answers of the following questions:
- (i) What is the composition of plasma membrane? What types of protein are present on it?
- (ii) What is endoplasmic reticulum? What is its function? How does rough ER differ from smooth ER?

(iii) What is the function of nucleolus? Where it is located? Is it a permanent structure?
(iv) Which of the two organelles are involved in cellular energetics? Which of them are found in plants in animals?
(v) What is cytoskeleton? Describe the types and function of cytoskeleton.

3. Write short answers of the following questions:

(i) What is function of nucleolus? Where is it located? Is it a permanent structure?
(ii) Which organelle is considered the substitute of lysosome in plant cells? Why?
(iii) Why ribosomes are called protein factories and lysosome are suicide sacs?
(iv) What type of cells contain more Golgi bodies and why?
(v) What are the three principles of cell theory?

4. Distinguish between the following:

(i) Cell-wall and cell-membrane.
(ii) Osmosis and diffusion.
(iii) Mitochondria and plastids.
(iv) Prokaryotic and eukaryotic cell.
(v) Animal and plant cell.
(vi) Lysosome and vacuole.

5. Define the following terms:

(i)	Cell	(ii)	Protoplasm
(iii)	Cell-wall	(iv)	Endoplasmic reticulum
(v)	Golgi bodies	(vi)	Lysosome
(vii)	Mitochondria	(viii)	Plastids
(ix)	Vacuole	(x)	Peroxisome
(xi)	Glyoxysome	(xii)	Centrosome
(xiii)	Chromosome	(xiv)	Nucleus

Section III

BIODIVERSITY

Life is a continuum extending from the earliest organisms through various lineages to the great variety of forms alive today. In section III we will study the diversity of life today and trace the evolution of this diversity over 3.8 billion years of history.

Chapter 5

VARIETY OF LIFE

The drawing that opens this chapter dramatizes a remarkable event; the genetic takeover of a cell by a virus. In this case, the cell is the bacterium E. coli and the virus, looking something like a miniature lunar landing craft, is the bacteriophage T_4. The phage is infecting the cell by injecting its DNA.
There are varied kinds of life ranging from Viruses (border line between the living and non-living) to most highly evolved and complex-life in the form of humans. There are unicellular organisms with or without cell-wall and with or without chlorophyll.

5.1 CLASSIFICATION

It is also called **taxonomy** (Gr. Taxis = arrangement, Nomos = law) may be defined as techniques of describing, naming and classifying living organisms on the basis of the similarities and dissimilarities.

5.1.1 Needs and Bases of Biological Classification:

Early in human history it was found useful to know in advance, which Plants were poisonous, which animals were dangerous, which were good to hunt for food and so on. It was soon noticed that all the living organisms possessed certain consistent features or characters by which they could be identified and sorted into recognizable distinct groups.
The organisms can be identified or sorted into different groups on the basis of characters, they possess. Now the question arises "what is a taxonomic character"? A character can be defined as: any attribute or descriptive phrase, referring to form, structure or behaviour of a specific organism for a particular purpose, thus character is anything or any feature whose expression can be measured or otherwise assessed. Taxonomist mostly deals with the expressions of the character.
For example, **"Petal length"** may be considered as a character; but "Petal length 12 mm" is an expression of that character.
"Corolla colour" may be considered as a character, but "Corolla colour white" is an expression of that character.
The living organisms are classified on the bases of homology, comparative biochemistry, cytology and genetics.

i) Homology:

The living organisms placed in a particular group all have many fundamental similarities in their structure. It is not always easy to recognize these basic similarities. At first sight, the flipper of a whale is used for swimming, the wing of a bat for flight, forelimb of cat for walking and the arm of man for grasping, do not seem to have much in common, yet if one examines their internal structure — the bones and muscles — it can be seen that these are very much alike (Fig. 5.1). The flipper, wing, forelimb and arm are all built on the same pattern. During the course of evolution, each has been modified from the basic pattern to serve a particular, and usually highly specialized, function, due to its adaptation to different environment/ habitat.

The flipper, wing, forelimb and arm are believed to resemble one another because they originated from the same structure in a common ancestor, and thus were once controlled by the same genes. Structures that are similar because of their common origin but may differ functionally are said to be **homologous.** It is principally the homologous structure that one consider in grouping animals in a classification scheme.
Whale
Figure 5.1 should not be misconstrued to mean that homology refers to gross structures alone. Nowadays cellular structures, especially chromosome number and type, are considered, too. Then there are physiological homologies, and even biochemical homologies. Structure and functions are always closely related.

ii) Biochemistry (Chemical Constitution):
Sometimes it is impossible to classify organisms using morphological criteria, so one resorts to comparing the chemical substances which they contain.
This is particularly useful when classifying organisms like bacteria which may all look alike and have an identical cellular structure. Using techniques such as chromatography and electrophoresis, it is possible to compare the amino acid sequence in the proteins of different organisms, or the order of bases in their DNA. This is useful not only in classifying organisms, but is indispensible when trying to establish evolutionary relationships.
Other characteristics used in classifying organisms include their immunological reactions, the types of symbionts with which they may associate.

iii) Cytology:
Although gross structure is a convenient basis for classification, sometimes microscopic features have to be used. For example, studies with the electron microscope have revealed that bacteria and cyanobacteria have a unique type of cell structure, for which reason they are now put together in a kingdom of their own. In this case microscopic observation of cell structure has been used to make a fundamental split in the classification of living things between prokaryotes and eukaryotes.
Microscopic structure can be useful at the generic and species levels too. For example, the number of chromosomes can enable entomologists to classify locusts and grasshoppers, and the surface features of seeds and pollen grains as revealed by the scanning electron microscope can be used in classifying flowering plants. Indeed, this sort of technique can show delicate differences between species or subspecies which are identical in many other respects.

iv) Genetics:
All the morphological biochemical properties and cytological characters of an individual of a species depend upon its genetic constitution. Hence the main tool helping in classifying organisms is genetics. As mentioned above the relevant base sequence in DNA is an important tool for classifying organisms.

5.1.2 Concept of Species and Hierarchy of Biological Classification:
The basic unit of biological classification is the **species**. "A species is a group of organisms which have numerous physical features in common and which are normally capable of interbreeding and producing viable fertile offspring". Nowadays, biochemical, ecological and life cycle features are included with other physical characteristics in helping to classify species.
Closely related species are grouped together into **genera** (singular: genus). Genera are grouped into **families**, families into **orders**, orders **into classes**, classes into **phyla** (singular: phylum) and phyla into kingdoms. (When classifying plants and bacteria the term 'division' is sometimes used instead of phylum. Intermediate categories are sometimes used: for example, a **sub-phylum** may

be inserted between phylum and class, and **sub-classes** between class and order and so on.

Classification of Wheat			**Classification of House Fly**		
Kingdom	—	Plantae	Kingdom	—	Animalia
Division	—	Tracheophyta	Phylum	—	Arthropoda
Class	—	Monocotyledonae	Class	—	Insecta
Order	—	Poales	Order	—	Diptera
Family	—	Poaceae	Family	—	Muscidae
Genus	—	Triticum	Genus	—	Musca
Species	—	Triticum indicum	Species	—	Musca domestica

This ascending series of successively larger, more inclusive, groups make up the taxonomic hierarchy. Each grouping of organisms within the hierarchy is called a **taxon** (plural: taxa) and each taxon has a rank and a name, for example, class mammalia or genus Homo.
Figure 5.2 shows two ways of illustrating how the hierarchical arrangement of the taxa can be represented: a 'box-in-box' arrangementor a 'tree-like' arrangement (dendrogram).

Table 5.1 Classification of three well known organisms

Taxonomic rank	Plant example	Animal example	
Kingdom	Plantae	Animalia	Animalia
Phylum	Angiospermata	Annelida	Chordata
Class	Dicotyledonae	Oligochaeta	Mammalia
Order	Ranales	Terricolae	Primata
Family	Ranunculacae	Lumbricidae	Hominidae
Genus	Ranunculus	Lumbricus	Homo
Species	Ranunculus acris	Terrestris	Homo sapiens
Common name	Meadow buttercup	Earthworm	human

Table 5.1 shows how three well-known organisms fit into the system. The lowest three taxa (family, genus and species) are named according to strict internationally agreed rules. The names of the four highest taxa (kingdom, phylum, class; and order) are often matters of opinion and are subject to the whims and fancies of individual taxonomists.

Nomenclature:
The modern system of naming species also dates from Linnaeus. Before him there had been little uniformity in the designation of species. Some species had a one-word name, others had two-word names, and still others had names consisting of long descriptive phrases. Linnaeus simplified things by giving each species a name consisting of two words: first the name of the genus to which the species belongs and second a designation for that particular species. The genus name is capitalized while the specific name is not. Both names are customarily printed in italics (underlined if handwritten or typed). This is called **Binomial Nomenclature.**

5.1.3 Two to Five Kingdom, Systems of Classification, including five kingdom systems by Robert Whittaker (1969) Margulis and Schwartz (1985):
One of the most difficult decision to make in systematic is how to divide living organisms into kingdoms.
Previously organisms were divided into two kingdoms: the animal-kingdom, which contained mainly motile organisms which are heterotrophic, lacking both

chlorophyll and cell wall and the plant kingdom which contained mainly organisms, which are autotrophic having cell wall with or without chlorophyll. Unicellular heterotrophs (protozoa) were put in the animal kingdom, and unicellular autotrophs were put in the plant kingdom with the algae. Fungi and bacteria were attached to the plant kingdom mainly on the grounds that like plants, they possessed a rigid cell wall. There are a number of problems with having only two kingdoms. The first concerns unicellular flagellates like Euglena and its relatives.

These were put with protozoa in the animal kingdom. However, some euglenoids, including Euglena itself, contain chorophyll, feed autotrophically by photosynthesis swim and move in response to light stimuli. Moreover, some flagellates can feed either autotorophically or heterotrophically depending on the conditions. With only two kingdom, we have to contend with the fact that these organisms can in fact, hop from one kingdom to the other.

Another problem concerns the fungi. Fungi are really very different from green plant. They lack chlorophyll and feed heterotrophically by an absorption method and their cellular structure differs from that of plants in several ways.

A third problem concerns bacteria. The electron microscope has revealed that bacteria and cyanobacteria (Formerly called blue-green algae) have a simple prokaryotic cell structure, so the bacteria and cyanobacteria appear to be similar to each other and markedly different from all other organisms which are eukaryotic. Indeed, if living organism have to be divided into just two kingdoms, a division into prokaryotes and eukaryotes would probably be best. However, although it may be satisfactory for all the prokaryotes to be in one kingdom, the rest would form a very large and diversified group.

The Five Kingdom System:

To solve the problems already mentioned, a number of different schemes of classification have been proposed. All have more than two kingdoms, and one has eighteen. The scheme that has gained most support was proposed in 1969 by an American biologist, Robert H. Whittaker. He based his classification on two main criteria: the level of organisation of the organisms, and their methods of nutrition. He recognised three levels of organisation: Prokaryotes, Unicellular Eukaryotes and Multicellular Eukaryotes. The methods of nutrition were: heterotrophic (which could be further subdivided into ingestive and absorptive) and photosynthetic.

On this basis, Whittaker proposed the following five kingdoms:

1. Unicellular prokaryotes which feed by a variety of different methods— **Kingdom Monera**.

2. Unicellular eukaryotes which feed by a variety of different methods — **Kingdom Protista.**

3. Multicellular non-chlorophyllous eukaryotes which feed heterotrophically by absorption. Cell wall always present — **Kingdom Fungi.**

4. Multicellular chlorophyllous eukaryotes which feed autotrophically by photosynthesis. Cell wall always present — **Kingdom Plantae.**

5. Multicellular eukaryotes which feed heterotrophically by ingestion. They have neither chlorophyll nor cell wall — **Kingdom Animalia.**

Although Whittaker's scheme received wide spread approval, it had one major snag. This relates to the protist kingdom which contained all unicellular organisms, including those that formerly had been regarded, as animals

(Protozoans) and those that had been regarded as plants (unicellular algae). Indeed it solved the problem of Euglena like organisms, but placing of unicellular algae in protist and colonoid/ multicellular algae in plantae lead to confusion.This was unfortunate because the two algal groups, share many common features. Indeed, some of the simpler multicellular algae are little more than aggregates of the unicellular forms. This may be added to the fact that the algae as a whole have rather little in common with the rest of the plant kingdom.

This led two other American biologists, L. Margulis and K. Schwartz, to put forward a modification of Whittaker's scheme. They suggested that the multicellular algae should be removed from the plant kingdom and placed alongwith all unicellular organisms, in a new kingdom called the **protoctist** kingdom which would replace Whittaker's protist kingdom. This makes the plant kingdom a more natural group, and it brings the multicellular algae close to their unicellular relatives. However it results in the protoctist being something of a 'ragbag'containing a wide range of unicellular and multicellular organisms. Indeed it has been described as the kingdom that contains all those organism which can not be fitted into any of the other kingdoms.

In grouping organisms into kingdoms there are bound to be anomalies. The important thing is that the anomalies should be as few as possible and the classification consistent. Margulis and Schwartz's five kingdom scheme offers this, and is therefore commanded until a more rational system is proposed.

Viruses are not included in the five kingdoms the reason centres on the controversy, which has been going on ever since they were discovered, as to whether or not they should be regarded as living. A virus consists simply of nucleic acid surrounded by a protein coat, and it can only survive and reproduce inside a living cell. For these reasons most biologists regard it, not as living organism, but as aggregation of molecules similar to those normally found in living cells.

Viruses appear to be on the borderline between the living and non-living worlds. They could probably form another kingdom if scientist felt like creating one. Certainty a great deal of time and effort has been spent classifying them. This is based on their physical and chemical properties and the way they reproduce, and is essential in diagnosing the diseases which they cause.

In this book we will follow the modification of Whittaker's scheme put-forwarded by L. Margulis and K. Schwartz. According to this, there are five kingdoms of living organisms as listed below.

1. **Kingdom Prokaryotae (Monera):**
   It includes almost all the prokaryotes, e.g. bacteria and cyanobacteria etc.

2. **Kingdom Protoctista (Protista):**
   It includes all the unicellular eukaryotic organisms, which are no longer classified as animals, plants or fungi, e.g. Euglena, Paramecium, Chlamydomonas, Plasmodium etc. Multicellular algae and primitive fungi have also been included.

3. **Kingdom Fungi:**
   It includes non-chlorophyllus, multicellular (except yeast) organisms having chitinous cell wall and coenocytic body called mycelium, e.g. Agaricus (mushroom) yeast, etc. They are absorptive hetrotrophs.

4. **Kingdom Plantae:**
   It includes all the eukaryotic multicellular chlorophyllus photosynthetic autotrophs having cell wall made up of primarily of cellulose, zygote retained to become embryo and exhibiting heteromorphic alternation of generation, e.g. Moss, Fern, Pine, Apple, etc.

5. Kingdom Animalia:

It includes all .eukaryotic, non-chlorophyllus, multicellular, ingestive heterotrophs with no cell wall. e.g. Hydra, Earthworm, Human etc.

5.2 VIRUSES

5.2.1 Discovery:

The word VIRUS is derived from a Latin word venom meaning "poison". This use of word goes back to many hundreds of years, long before anyone really knew whataviruswas, or that it even existed as we know it today. It was generally believed that these "viruses," or poisons, were carried in the air and could cause many unexplained diseases.

By the late 19th century pioneer biologists had demonstrated that many diseases of man and other organisms were caused by bacteria. Some diseases puzzled them. One such disease was found to occur in tobacco plants. It causes the leaves to wrinkle, and become mottled. The mottled effect has the appearance of a mosaic, and the disease was called **Tobacco Mosaic Disease.**

In 1892, a Russian biologist named Ivanowsky discovered that a virus could be transmitted from an infected organism to a healthy organism of the same kind.

By 1900, similar disease producing substance had been discovered in many organisms. The name filterable virus was given to these substances, which could pass porcelin filters through which bacteria could not pass. The list of filterable viruses was growing long.

The year 1935 was important in unravelling the story of what viruses really are and how they behave. A new kind of microscope—the electron microscope, had been constructed. It had 10000000 millimicron (m D) magnification. Wendell Stanley crystallized the infectious particle, now known as tobacco mosaic virus (TMV). Subsequently, TMV and many other viruses were actually seen with the help of the electron microscope.

5.2.2 Characteristics, Structure and Classification of Viruses

1) Characteristics:

Viruses are noncellular parasitic entities. They cannot live and reproduce outside of living cells since they lack the machinery to do so by themselves. They range in size from 20 nm to 250 nm.

Viruses are either virulent, destroying the cell in which they occur, or temperate, becoming integrated into their host genome and remaining stable there for long period of time.

The adhesion properties of viruses are determined by those of the proteins that make up their coats and envelops. The simplest viruses use the enzymes of the host cell for both their protein synthesis and gene replication; the more complex ones contain upto 200 genes and are capable of synthesizing through their host may structural proteins and enzymes.

AIDS is caused by HIV (human immunodeficiency virus), which possesses a glycoprotein on its surface that penetrates the cell membrane, sheds its protective coat, and reproduce.

Viruses are noncellular obligate parasites that always have a protein coat and a nucleic acid core.

2) Structure:

They appear like little spheres or golf-balls, rod shaped, like tadpoles and may be polyhedral.

Viruses may consist of Viral-Genomes, Capsids, Envelopes and Tail-Fibers. Their **genomes** (sets of genes) may consist of a single or several molecules of DNA or

RNA. The smallest viruses have only four genes while the largest have several hundreds.
The protein coat that encloses the viral genome is called a capsid. It may be of different shapes. Capsid is made up of protein subunits called **Capsomeres.** The number of capsomeres is characteristics of a particular virus.
Some viruses have accessory structures called **viral-envelopes** that help them infect their hosts. They are membranous, cloaking their capsids. Bacteriophages have tail piece with **Tail Fibres**.
The simplest viruses consist of a single molecule of a nucleic acid surrounded by a capsid, which is made up of one or a few different protein molecules, repeated many times (Fig. 5.4). In more complex viruses, there maybe several different kinds of molecules of either DNA or RNA in each virus particle and many different kinds of proteins. Most viruses have an overall structure that is usually either helical or isometric. Helical viruses, such as the tobacco mosaic virus, have a rodlike or threadlike appearance, isometric ones have a roughly spherical shape.

Bacteriophage (Bacterio = bacteria; phagein = to eat):
Bacterial viruses, or bacteriophages, are among the most complex viruses (Fig. 5.5). Each of them is made up of at least five separate proteins; these make up the head, the tail core, the molecules of the capsid, the base plate of the tail and the tail fibers. A long DNA molecule is coiled within the head.

3) Classification:
Viruses are generally classified on the basis of morphology and nucleic acid, they contain. On the basis of morphology, viruses are classified into rod-shaped (T.M.V.), spherical (poliovirus) and tadpole (bacteriophage). The nucleic acid present may be DNA or RNA which may be naked enveloped or complex.
The diversity of the viruses is great and is almost certainly related to their modes of origin. To provide a systematic idea of some of this diversity, we will discuss the viruses under eight main headings. The main characteristics of these groups are given below.

i) Unenveloped Plus-strand RNA Viruses (Polio viruses, Rhino viruses):
They are called plus strand because they act directly as mRNA after infecting a hostcell, attaching to the host's ribosomes and being translated. As indicated by their name, these viruses lack envelopes and consist only of a nucleic acid core surrounded by a protein capsid. They infect plants and bacteria, causing polio and cold in human beings.

ii) Enveloped Plus-strand RNA Viruses (Hepatitis A and C viruses):
The enveloped Plus Strand RNA viruses, all of which parasitize animals, are distinguished from the members of the preceding group by their lipid-rich envelopes. They infect arthropods and vertebrates, causing Leukemia and yellow fever in human beings.

iii) Minus-strand RNA Viruses (Rhabdo viruses and Pox viruses):
Minus-Strand RNA viruses are distinguished from Plus-Strand RNA viruses because they carry the RNA strand complementary to the mRNA that carries the genetic information of the appropriate mRNA, which then functions in the cell. They infect plants and animals, causing flu, mumps and rabies in human beings.

iv) Reterovirus:
A virus that is replicated in a host cell via the enzyme reverse transcriptase to produce DNA from its RNA genome. They are enveloped viruses. Retroviruses are either single stranded RNA (e.g. HIV) or double stranded DNA (e.g. Hepatitis B) viruses.

v) Double-strand RNA Viruses (Reo viruses):
These are double-stranded, icosahederal RNA viruses, infect plants and animals, causing Colorado tick fever in human beings.

vi) Small-Genome DNA Viruses (Parvo viruses):
Many DNA viruses have Small genomes; some of these viruses have Single-Stranded DNA, others have Double-Stranded DNA. Among them are the parvoviruses, which infect animals, they are icosahedral and about 20 nanometers in diameter. They infect animals causing viral hepatitis and wartz in human beings.

vii) Medium-Genome and Large-Genome DNA Viruses (Herpes viruses):
The herpesviruses, one of the major group of large-genome, double-stranded DNA viruses. They cause herpes shingles, cancer and poxes in human beings.

viii) Bacteriophage:
A long DNA molecule is coiled within the head. They infect bacteria only.

5.2.3 Life Cycle of a Bacteriophage:
The phages are the best understood of all viruses. Research on phages led to the discovery that they can reproduce by two alternative mechanisms, the lytic cycle and lysogenic cycle.

i) The Lytic Cycle:
A viral reproductive cycle that culminates in death of the host cell is known as a lytic cycle. The term refers to the last stage of infection, during which the bacterium lyses (breaks open) and releases the phages that were produced within the cell. Each of these phages can then infect a healthy cell and a few successive lytic cycle can destroy the entire bacterial colony in a few hours. A virus that produces only by a lytic cycle is a virulent virus. Figure 5.6 uses the virulent phage T_4 to illustrate the steps of a lytic cycle.

a) The T_4 phage uses its tail fibers to stick to specific receptor sites on the outer surface of an E.coli cell (Escherichia coli).

b) The sheath of the tail contracts; thrusting a hollow core through the wall and membrane of the cell. The phage injects its DNA into the cell.

c) The empty capsid of the phage is left as a "ghost" outside the cell. The cell's DNA is hydrolysed.

d) The cell's metabolic machinery, directed by phage DNA, produces phage proteins, and nucleotides from the cell's degraded DNA, are used to make copies of the phage genome. The phage parts come together. Three separate sets of proteins assemble to form phage heads, tails, and tail fibers forming daughter phages.

e) These phages then direct production of lysozyme, an enzyme that digests the bacterial cell wall. With a damaged wall, osmosis causes the cell to swell and finally to burst, releasing 100 to 200 phage particles.

During the lytic cycle of a bacteriophage, the bacterial cell dies when the viral particles burst from the cell. During the lysogenic cycle, viral DNA is integrated into bacterial DNA for an indefinite period of time.

ii) The Lysogenic Cycle:

In contrast to the lytic cycle, which kills the host cell, the lysogenic cycle replicates the viral genome without destroying the host. Viruses that are capable of usingboth modes of reproduction within a bacterium are called temperate (lysogenic) viruses. To compare the lytic and lysogenic cycles, we will examine a temperate phage called lambda, abbreviated with the Greek letter λ: Phage resemblesT$_4$, but its tail has only a single, short tail fiber which may be absent.

Infection of an E.coli cell by λ begins when the phage binds to the surface of the cell and injects its DNA (Fig. 5.7) within the host, the DNA molecule forms a circle. What happens next, depends on the reproductive, lytic cycle or lysogenic cycle. The DNA molecule is incorporated by genetic recombination into a specific site on the host cell's chromosome (chromatin body). It is then known as a prophage. One prophage gene codes for a protein that represents most of the other prophage genes. Thus, the phage genome is mostly silent with in the bacterium. How, then does the phage reproduce? Every time the E.coli cell prepares to divide, it replicates the phage DNA alongwith its own and passes on the copies to the daughter cells. A single infected cell can soon give rise to a large population of bacteria carrying the virus in prophage form. This mechanism enables viruses to propagate without killing the host cells upon which they depend.

The term lysogenic implies that prophages can, at some point, give rise to active phages that lyse their host cells. This occurs when the λ genome exits the bacterial chromosome. At this time, the genome commands the host cell to manufacture complete phages and then self-destruct, releasing the infectious phage particles. It is usually an environmental trigger, such as radiation or the presence of certain chemicals, that switches the virus from the lysogenic to the lytic mode.

5.2.4 Viroids and prions are infectious agents even simpler than viruses:

As small and simple as viruses are, the dwarf another class of pathogens, viroids. These are tiny molecules of naked circular RNA that infect plants. Only several hundred nucleotides long, viroids do not encode proteins but can replicate in host plant cells, apparently using cellular enzymes. Somehow, these RNA molecules can disrupt the metabolism of a plant cell and stunt the growth of the whole plant.

An important lesson from viroids is that a molecule can be an infectious agent that spreads a disease. But viroids are nucleic acid, whose ability to replicate is well known. More difficult to explain is the evidence for infectious proteins, called **prions**. Prions appear to cause a number of degenerative brain diseases, including scrapie in sheep and the "mad-cow disease." How can a protein, which cannot replicate itself, be a transmissible pathogen? According to one hypothesis, a prion is a misfolded form of protein normally present in brain cells. When the prion gets into a cell containing the normal of the protein, the prion somehow converts the normal protein to the prion version. In this way, prions might repeatedly trigger chain reactions that increase their numbers.

5.2.5 Viral Diseases: (Transmission/Spread and Control)

i) Animal Diseases:

Several of the animal viruses cause important diseases. **Poliomyelitis** caused by **poliovirus** was a wide spread, crippling disease through the first half of the twentieth century. Although poliomyelitis is now largely under control "by vaccination in the industrialized countries, it remains a serious and common disease in the tropics and elsewhere in the less developed parts of the world.

Colds are viral infection of the upper respiratory tract. About one third of all colds are caused by the **rhinoviruses,** which are unenveloped plus-strand RNA viruses. There are dozens of different strains of cold-causing rhinoviruses alone, each of

them with different properties and none conferring cross-immunity to the others. More than200of viruses that cause colds have been identified, which makes the development of appropriate immunization methods very difficult, if not impossible.

Virus cause many widespread diseases, such as many kinds of **encephalitis,dengu**e and **yellow fever.** They are classified as **arboviruses** (arthropod-borne viruses) together with many unrelated viruses, because they are transmitted by insects and other arthropods.

AIDS (Acquired Immune Deficiency Syndrome) caused by HIV (retro viruses) was discovered in 1985.

Rabies, which was the subject of the path-breaking discoveries of Louis Pasteure in the nineteenth century, is caused by a **rhabdovirus** (rod shaped). A second group of minus-strand RNA viruses, the **paramyxoviruses,** includes those that cause **measles** and **mumps** in humans.

Today rabies is most often spread by small, mammals such as dogs, racoons and foxes. Fortunately, it is a simple matter to vaccinate pets against rabies, and human vaccines are also being developed. The rabies virus is spread by the saliva of the host animal, often after bites, but it can also be contracted from handling a dead infected animal. An animal infected with rabies may go into a mad frenzy, often running great distances in its confusion.

The **flu viruses, minus-strand RNA viruses**, resemble balls studded with spikes. Recombination of the genetic material of the flu viruses appears to play the critical role in causing worldwide flu epidemics.

The majority of human viral diseases are spread through droplet Infections possibly via wounds in skin, infected saliva, via human faeces etc. It may be through vectors (arthropods) or sexual intercourse (homo or heterosexual), handling of contaminated objects etc. Immunity or vaccination are the two best controls of viral diseases.

Viruses cause diseases in plants and animals. They have also been implicated in the development of cancer.

ii) Plant Diseases:

We have already discussed one of the best known plant disease called tobacco mosaic virus. Plant viruses can stunt any plant growth and diminish crop yields. There are two major routes by which a plant viral disease can spread either by **Horizontal Transmission** or **Vertical Transmission**. In the first, a plant is infected from an external source of virus through injured parts or through insects. In the second, a plant inherits a viral infection from a parent.

Agriculturists have not yet devised cure for most viral diseases of plants. Therefore, their efforts have focused largely on reducing the incidence and transmission of such diseases and on breeding genetic varieties of crop plants that are relatively resistant to certain viruses.

5.2.6 Human Immuno deficiency Virus (HIV) — A RETROVIRUS

AIDS — Symptoms, Transmission and its control

In HIV, the infectious agent that causes AIDS, the glycoproteins of the envelope enable the virus to bind to specific receptors on the surface of certain white blood cells, although there are two RNA molecules. They are identical, not complementary strands.

Acquired Immune Deficiency Syndrome (AIDS) is a disorder which impairs the body's lymphocytic cell T_4 immune system in humans, in that the virus replicates within the T_4 or helper cell. Thus these cells can no longer help or induce other T cell, called killers, to fight invaders. The body's immune system breaks down, leaving the patient exposed to a variety of diseases.

It is important to realise, however, that infection with the virus (HIV) does not necessarily result in AIDS. As with other diseases, some people remain symptom less and are therefore termed carriers.

Transmission

The HIV-Virus can only survive in body fluids and is transmitted by blood or semen. In 90% of cases the transmission is achieved by sexual contact. People can contract the disease through:

i) Intimate sexual contact: It passes from the infected partner to his/ her unaffected partner through sexual contact.

ii) Infected blood entering the bloodstream:

(a) AIDS can also be contracted by intravenous drug users practising self-injection by means of unsterilised needles and syringes. HIVhas spread rapidly amongst intravenous drug users. Once in the blood stream of the drug addict it can be further passed on through sexual activity, not only to other drug users but also to the general public.

(b) Blood transfusions have unfortunately contracted the disease after being given blood or blood products already infected with HIV.

(c) Close contact between infected and non-infected people through cuts and open wounds has also been known to pass on the virus.

(d) Other ways: An infected pregnant woman can pass on the virus to her baby through the placenta at birth or through breast milk during suckling.

Signs and Symptoms and Nature of the disease:

Current information suggests that 1-2% of HIV infected persons will develop AIDS each year, and that 5-10% of HIV infected persons will develop AIDS-related symptoms each year.

First signs and symptoms are a short flu-like illness followed by no further effects for months or years. AIDS involves a defect in the cell-mediated immune response, hence the term immune deficiency. Opportunistic infections then ensue, that is micro-organisms that we normally live with, and which we can easily destroy, may cause killer diseases. Cause of death is commonly a rare type of pneumonia, many patients suffer a rare and disfiguring from skin cancer known as **Kaposi's sarcoma.** Other common signs and symptoms of AIDS included weight loss, fever, dementia, diarrhoea, septicaemia (blood poisoning) and other forms of cancer. Severity of immune deficiency varies and bouts of illness may persist for years.

By affecting lymphocytes, HIV may directly infect brain cells in more than 50% of cases, causing irreversible dementia and eventual death. The brain shrinks, with a loss of memory and mental agility, and behavioural changes occur.

Control—Treatment and Prevention

An enormous international effort is being made to devise methods of treating and preventing the disease. There are two lines of research, one into developing drugs which can be used to cure the disease, and one into developing a vaccine. Both approaches are at an early stage and require heavy financial investment. In the short-term the aim is to develop drugs to inactivate the virus, by blocking the pathogen's metabolism.

The best known drug used by 1987 was azidothymidine or zidovudine (formerly known as AZT) which slows progression of the disease and can attack the virus even in the brain (a major reservoir of infection) other drugs are being

examinedsuch as Ribavarrin a drug used to treat other viral infection which has been found to suppress the AIDS virus under laboratory conditions. Sumarin, an antiparasitic drug has also shown encouraging results inhibiting viral reproduction in host.

Prevention:
The reduction in the spread of HIV could be brought about by the use of clean needles and sterilized syringes by drug addicts.
Education about the disease has an important part to play particularly in reassuring the public about the real risk. There is no evidence that infection can occur by droplet infection through the nose or mouth, or by casual contact such as shaking hands etc.

5.2.7 Hepatitis: A Serious Health Risk:
Hepatitis is an inflammation of the liver. It may be due to viral infection, toxic agents or drugs. It is characterized by jaundice, abdominal pain, liver enlargement, fatigue and some times fever.
There are various types of hepatitis.

Hepatitis — A is transmitted by contact with faeces from infected individuals. It is caused by enveloped RNA Virus.

Hepatitis — B (serum hepatitis) is caused by unusual DNA Virus.

The causative agent of hepatitis B. contains a small, circular molecule of partly, but not completely, double stranded DNA. The viral genome encodes two kinds of proteins, a core protein and a surface protein, as well as DNA polymerase.
The amount of genetic information in the hepatitis B viral genome-359 nucleotides-is less than that of any other pathogen, except of the viroids.
The hepatitis B virus poses a serious public health problem, particularly among Asians, Africans, and male homosexuals. It often persists in carriers without causing any symptoms, but it may still be highly infectious. People infected early in life often become carriers, and it is estimated that there are about 200 million such carriers worldwide. Since most of these people are not recognized as carriers, there is a real possibility of the frequent transmission of hepatitis through skin contacts, blood transfusion, and similar medical procedures. Not only is the hepatitis itself serious, but the virus also may play a role in causing human liver cancer, even among carriers, who show no other symptoms. New vaccines against the virus have been produced by recombinant DNA techniques and are of great importance, specially for those who require frequent blood transfusions, and other who run a severe and continuing risk of infection.

Hepatitis — C passes through blood transfusion, from mother to child during pregnancy and by sexual contact.

KEY POINTS

- Living organisms are classified on the bases of homologies, comparative biochemistry, cytology and genetics.
- It is principally the homologous structure that one consider in grouping animals in a classification scheme.
- Sometimes it is impossible to classify organisms using morphological criteria, so one resorts to comparing the chemical substances which they contain.
- The basic unit of biological classification is the species.
- Previously organisms were divided into two kingdoms. The animal kingdom and the plant-kingdom.
- Whittaker proposed in 1969 that living organisms may be divided into fivekingdom.
- L. Margulis and K. Schwartz suggested that multicellular algae should be removed from the plant kingdom and placed alongwith all unicellular organisms, in a new kingdom called the Protoctist which would replace Whittaker's protistkingdom.
- The word virus is derived from a latin word meaning "Poison".
- Viruses are noncellular parasitic entities.
- Viruses may consist of viral-genomes, capsids, envelopes and tail fibres.
- A viral reproductive cycle that culminates in death of the host cell is known as Lytic Cycle.
- In contrast to lytic-cycle, which kills the host cell, the lysogenic cycle replicates the viral genome without destroying the host.
- Viruses cause many widespread diseases, such as yellow-fever, rabies, measles, mumps, aids etc.

EXERCISE

1. Encircle the correct choice:

(i) Which branch of Biology is considered as the final main helping inclassifying organisms?
(a) Homology (b) Cytology
(c) Morphology (d) Genetics

(ii) Closely related orders are grouped together into
(a) Genus (b) Family
(c) Class (d) Division

(iv) Characteristically viruses are:
(a) Acellular (b) Cellular
(c) Non-cellular (d) Unicellular

(v) The adhesion properties of viruses are determined by:
(a) Proteins that make up their coats and envelop
(b) Viral DNA that they contain
(c) Viral RNA that they contain
(d) Viral Genomes that they contain

(vi) Which characteristic is not associated with Lytic-cycle
(a) Death of host cell (b) Viruses are virulent
(c) Formation of prophage (d) Bacterial cell fails to reproduce

(vii) Measles and mumps in humans is caused by:
(a) Rhinoviruses (b) Arbovirueses
(c) Paramyxoviruses (d) Rhabdovirueses

(viii) Thing not associated with Aids:
(a) Imparing of immune system
(b) Arboviruses
(c) Virus can only survive in human body fluid
(d) HIV

(ix) Hepatitis - type which pass through blood from mother to child during pregnancy.
(a) Hepatitis - A (b) Hepatitis - B
(c) Hepatitis - C (d) Hepatitis - D

(x) Previously living organisms were divided into plant and animal kingdoms mainly due to:
(a) Presence or absence of cell-wall (b) Type of nucleus
(c) Presence or absence of chlorophyll (d) Mode of nutrition

2. Write detailed answers of the following questions:

(i) What are the bases of classification of living organisms?
(ii) What do you mean by Taxonomic Hierarchy?
(iii) What changes are proposed by Marguiles and Schwartz in the five kingdom systems of R.Wittaker?
(iv) Give structure, characteristics and classification of viruses.
(v) Describe lytic cycle and distinguish it from lysogenic cycle.

3. Write short answers of the following questions:

(i) What is species?
(ii) Define taxonomy.
(iii) Point out the three problems with having only two kingdoms.
(iv) What was the major snag in Whittaker's scheme?
(iv) What modifications were suggested by Margulis and Schwarts and Whittaker's scheme?
(v) Name the five kingdoms of living organisms.
(vi) Name the different parts of viruses.
(viii) What do you mean by plus and minus — Strand RNA viruses?

4. Define the following terms:

(i) Species
(ii) Binomial nomenclature
(iii) Bacteriophage

Chapter 6

THE KINGDOM PROKARYOTAE (MONERA)

Prokaryotes were the earliest organisms and they lived and evolved all alone on Earth for 2 billion years. They have continued to adapt and flourish on an evolving Earth and in turn they have helped to change the Earth. In this chapter you will become more familiar with prokaryotes by studying their structure and function, their origins and evolution, their diversity and their ecological significance.

Prokaryotae is a group of living organisms which are unicellular having prokaryotic or a primitive nucleus. Prokaryotes are unicellular organisms, called bacteria, in which each cell contains a single DNA molecule coiled in a loop and not enclosed in a nucleus. They are almost everywhere, indispensable links in the recycling of chemical elements in ecosystem and human use them in research and technology.

6.1 BACTERIA

6.1.1 Discovery:

Advances in our understanding of living things often depend on the invention of special Instruments. Because of their extremely small size, viruses could not be detected by the optical microscope. Their presence was assumed, however from evidence of their effects on living tissue. The electron microscope later confirmed their existence. It was not so with bacteria. Before the invention of the optical microscope, men lived in ignorance of the presence of these micro organisms.

Antony Van Leeuwenhoek (1673) was the first to observe micro organisms. He constructed a simple microscope and observed a drop of water.

Leeuwenhoek discovered life in a form that was unexpected. He was amazed at the variety of tiny living objects that he saw wriggling and darting across the field of his little microscope when he examined drops of various kinds of water or liquid.

He became so enthusiastic about what he saw that he wrote several letters to the Royal Society in London. One letter with an account of what he saw was published by the Society in 1677. This article included the very first description of bacteria.

6.1.2 Structure:

Bacteria are considered as the smallest and the simplest living organisms. Bacterial cell measures from 0.2 micron (μ) to 2 μ in breadth and 2 to 10 μ in length. Bacteria are the pioneers of cellular organization and strictly **unicellular.** However the cells of some species may remain associated after cell-division and form colonies (Fig. 6.1).

A generalized bacterial cell consists of flagella, pilli, capsule, cell-wall, cell-membrane, cytoplasm, nucleoid, plasmids, mesomes and storage bodies.

Flagella: They are extremely thin appendages. They originate from Basal-body, a structure in the cytoplasm beneath cell-membrane. They come out from cell-wall. They are made up of flagellin protein with no microtubules. Flagella help in motility.

Pill: They are hollow, filamentous appendages smaller than flagella. They help in conjugation and not in locomotion.

Capsule: It is a protective shield made up of polysaccharide and proteins. Some bacteria have slime capsule which provides greater pathogenicity and protects them against phagocytosis.
Cell-wall is totally different from ordinary plant cell-wall. It is chemically complex and made up of amino acids, sugar and chitin but cellulose is totally missing. The cell-wall of most bacteria have unique macromolecule called Peptidoglycan. It is composed of long glycan chains cross-linked with peptide fragments. In addition sugar molecules, teichoic acid, lipoprotein and lipopolysaccharides are also present.
Some bacteria may lack cell-wall. Archaebacteria do not contain Peptido-glycan. Cell-wall is found surrounding the cell-membrane. It is rigid, determines the shape and protects from osmotic lysis.

Cell-membrane lies inside cell-wall. It is attached to cell-wall at few places and has many pores. It is made up of lipids and proteins. It acts as respiratory structure as mitochondria are absent

Cytoplasm is granular, having small vacuoles, glycogen-particles and ribosomes. Other membrane bounded cytoplasmic organelles are absent.

Mesosomes are invagination of cell-membrane into the cytoplasm. Mesosomes are in the form of vesicles, tubules or lamellae. Their function is to help in DNA replication, cell-division, respiration and in export of enzyme.

Nucleoid is prokaryotic nucleus containing genetic material DNA in the form of single circular molecule aggregates as an irregular shaped dense structure called **chromatin body** or **bacterial-chromosome**. There is total absence of nuclear membrane, nucleoplasm and nucleolus.

Plasmid is small fragment of extra genetic material double stranded DNA. It is self replicating and not associated with growth and metabolism. Plasmids serve as vectors in genetic engineering.

Form (Shapes):
There are four shapes of bacteria (Fig. 6.2).

1. Cocci (Singular-Coccus= Gr. Kokkos = Berry, rounded)
Cocci are spherical and non-flagellated. According to mode of division and cell arrangments there are several types of Cocci.
Monococcus means one and **Diplococcus** means a pair of Cocci. **Streptococcus** is a long chain of Cocci. **Tetrad** having four Cocci. **Sarcina**is a cube of eight Cocci and **Staphylococcus** have grape like arrangements.

2. Bacilli (Singular-Bacillus = L. Bakulus = A rod).
Bacilli are rod-shaped.They may be found in pairs or in chains, e.g Bacillus, Pseudomonas, Diplobacillus, Streptobacillus etc. They may be flagellated.
Bacilli are of followingtypes:
Bacillus is a single rod shaped bacterium. **Streptobacillus** is a chain of bacilli. **Diplobacillus**is a pair of bacilli.

3. Spirilla (Singular-Spirillum= Gr. SPEIRA= A coil)
They are spiral or corkscrew shaped e.g. **Spirochaeta.**

4. Vibrio or Commas:
They are slightly curved e.g.: Vibrio cholera. They may be flagellated.

6.1.3 Diversity:

Bacteria are difficult to classify. The classification of bacteria poses particular challenges to taxonomists. Because bacterial reproduction is usually asexual, bacterial species cannot be defined on the basis of their ability to interbreed. In addition, the fossil record of bacteria is quite sparse. Consequently, taxonomists classify bacteria using a variety of criteria: shapes, means of locomotion, pigments, staining properties, nutrient requirements and the appearance of bacterial colonies.

On the basis of presence, pattern of attachment and the number of flagella present, bacteria are classified into different taxonomic groups. **Atrichous** means bacteria are without any flagella. When single polar flagellum is present then condition is known as **monotrichous.** If a tuft of flagella is present only at one pole of bacteria then these are **lophotrichous.Amphitrichous** is a condition when tuft of flagella at each of two poles is present. In **peritrichous** form flagella surround the whole cell. Most of bacilli and spiral shaped bacteria have flagella.

Christian Gram developed the technique of gram staining, dividing bacteria into two groups. Gram positive bacteria stained purple and gram negative stained pink.

Some microbiologists place bacteria in two Major Categories: a large division called the **eubacteria** (from the Greek words for "true bacteria") and a much smaller division, the **archaebacteria** (from the greek words for "ancient bacteria"). These two types of bacteria have striking structural and biochemical differences.

6.1.4 Occurrence:

Bacteria are most wide spread organisms, which can be found distributed on the earth from air to soil and water and from dead to living organisms. They can survive even in hot springs and also in freezing temperature. They may be soil dwellers or parasites of animals and plants.

6.1.5 Nutrition:

Most bacteria are heterotrophic with a few autotrophic. Heterotrophic bacteria are those which cannot synthesize their organic compounds from simple inorganic substances. According to their mode of feeding, heterotrophic bacteria may be saprotroph, symbiotic or parasitic.

i) Saprotrophic Bacteria:

They get their food from dead organic matter. The soil is full of organic compounds in the form of **humus**. Bacteria living in the soil have large number of enzymes that break down the complex substances of humus to simpler compounds. These bacteria absorb and utilize these simple compounds as a source of energy. Many other saprotrophic bacteria cause decay of dead animal and plant material as they convert complex organic compounds to simpler ones.

The majority of bacteria are free-living heterotrophs (saprotrophic decomposers) that contribute significantly to recycling matter through ecosystems. Many are also symbiotic heterotrophs, including those that cause disease.

ii) Symbiotic Bacteria:

They are found associated with other living organisms. They obtain food from the host without harming it. e.g. Rhizobiumradicicola occurring as symbionts in the nodulated roots of leguminous plants e.g. Pisum sativum.

iii) Parasitic Bacteria:

They grow inside the tissues of other living organisms and obtain food at the expense of host. These bacteria lack certain complex systems of enzymes e.g. Pneumococcus.

iv) Autotrophic Bacteria:
They can synthesize organic compounds from simple inorganic substances. Autotrophic bacteria may be photosynthetic or chemosynthetic.

Autotrophic bacteria include those that are photosynthetic and those that are chemosynthetic. Among the photosynthetic bacteria, there are those that evolved first and do not give off oxygen and those (cyanobacteria) that evolved later and do give off oxygen.

v) Photosynthetic Bacteria:
Bacteria are which synthesize organic compound by using light energy called photosynthetic bacteria. They have pigments very similar to the chlorophyll and named as **bacterio-chlorophyll** or **chlorobium-chlorophyll** (Von Neil-1930). These pigments are present on invaginated plasma membrane in the cytoplasm and not in the chloroplasts. During photosynthesis, bacteria utilize H_2S instead of water and liberate sulphur instead of oxygen.

vi) Chemosynthetic Bacteria:
Bacteria which synthesize organic compound by obtaining energy from oxidation of some inorganic substances like iron, hydrogen, nitrogen and sulphur compounds are chemosynthetic bacteria.

6.1.6 Respiration:
Another aspect of metabolism which can be used in the classification of bacteria is their need for oxygen in respiration.

Aerobes require oxygen for respiration.

Anaerobic respire without oxygen.

FacultativeBacteria respire with or without oxygen. Some bacteria require a low concentration of oxygen for growth and are known as **micro-aerophilic**.
Some bacteria are killed in the presence of oxygen, they are called **obligateanaerobes.** Others use oxygen but can respire without it, they are called**facultative anaerobes**. Bacteria which can only survive in the presence of oxygen are **obligate aerobes.**

6.1.7 Locomotion:
Some Bacteria can move using simple flagella that are attached with a unique wheel-like structure.
These are simpler in structure than the flagella seen in some eukaryotic cells. Bacterial flagella, which may either cover the cell or form a tuft at one end (Fig. 6.3) can rotate rapidly, propelling the bacterium through its liquid environment. Recent research has revealed a unique wheel-like structure embedded in the bacterial membrane and cell wall that allows the flagellum to rotate (Fig.6.3) Flagella allow bacteria to disperse into new habitats to migrate toward nutrients, and to leave unfavourable environments. Flagellated bacteria show orientation toward various stimuli, a behaviour called **taxis.** Some are chemotactic, moving toward chemicals given off by food or away from toxic chemicals. Some are phototactic moving toward or away from light, depending on the habitat they require. Other flagellated bacteria are magnetotactic. These detect Earths magnetic field using magnets formed from iron crystals within their cytoplasm.

6.1.8 Growth:
Bacteria have a large surface area to volume ratio and can therefore gain food sufficiently rapidly from their environment by diffusion and active transport mechanisms. Therefore, provided conditions are suitable, they can grow very

rapidly. Important environmental factors affecting growth are temperature, nutrient availability, pH and ionic concentrations. Oxygen must also be present for obligate aerobes and absent for obligate anaerobes. Four distinct phases are recognized in bacterial growth curve.

i) **LAG Phase**: Inactive phase or phase during which bacteria prepare themselves for division.

ii) **LOG Phase**: Bacteria grow and multiply very rapidly.

iii) **Stationary Phase**: Bacterial multiplication is equal to death rate.

iv) **Death/Decline Phase**: Death rate is more rapid than multiplication rate.

6.1.9 Reproduction:

Bacteria generally reproduce when conditions are favourable by asexual method called **fission.** However endospore formation takes place when conditions are not favourable. It is a method of survival under unfavourable conditions.
Bacteria lack traditional sexual reproduction and mitosis. However somebacteria undergo genetic recombination by bacterial conjugation, transduction and transformation.

Fission:
Bacteria generally reproduce asexually by a process called **binary fission**.
Fission is the fastest mode of asexual reproduction found in the living organisms particularly unicellular.
Fission takes place when there is ample supply of food and moisture with favourable conditions. During fission, first the hereditary material (DNA) in the form of chromatin-body is replicated. Chromatin bodies so formed move apart. Then a constriction appears around the middle of the cell and it splits into two parts. These parts grow in size and form mature bacterial cells. The single fission takes about 20—30 minutes to complete.

Prokaryotes reproduce asexually by binary fission. Mutations are the chief means of achieving genetic variation.

Endospore formation:
During endospore formation, the whole protoplasmic content gets shrink into a small mass. A cyst is formed inside the parental wall around this mass to formendospore. When parental wall ruptures due to decay, endospore is set-free. On the return of favourable conditions, this endospore enlarges to form mature bacterial cell.

Genetic Recombination:
The re-union of genetic material from two different sources is called genetic recombinations. Three methods by which genetic recombination takes place in bacteria are, conjugation, transduction and transformation.

a) Conjugation:
Conjugation is a simple process of genetic recombination in which genetic material is transferred from one bacterium to another through a tube called conjugating tube or cytoplasmic bridge. This process was carried out experimentally by Laderberg and Tatum in 1946.

b) Transduction:
It is a mode of genetic recombination in which genetic material is transferred from one bacterium to another by a third parry which is a bacteriophage. This process was carried out experimentally by Laderberg and Zinder in 1952.

c) Transformation (Transforming Principle):
It is a process of transmitting genetic information from one bacterium to another bacterium through environment causing it to transform (undergo change). This principle was first notified by Fred Griffth in 1928.

6.2 IMPORTANCE AND CONTROL

6.2.1 Importance of Bacteria: Useful Bacteria:

1. Decomposers: Bacteria are the important biotic component of each and every ecosystem. They act on dead plant and animal bodies decompose various organic compounds into simple forms such as nitrates, sulphates, phosphates etc. for utilization by green plants again. Nitrifying bacteria convert the proteins of these dead bodies into nitrates. Soil bacteria increase the fertility of the soil by bringing about physical and chemical changes in the soil.

2. Alimentary canal bacteria: They help herbivores in the digestion of cellulose by an enzyme cellulose. They are present in appendix or in caecum of cow. goat etc.

3. Industrial bacteria: They are symbionts which help in curing and ripening of tobacco leaves, fermentation of sugar into alcohol, ripening of cheese, retting of fibres, curdling of milk, conversion of hides into leather etc.

4. Medicinal bacteria: Valuable antibiotic drugs have been obtained from bacteria e.g. Thyrothycin, Subtilin. Riboflavin is vitamin produced by Clostridium.

5. Genetically engineered bacteria (Biotechnology): E.coli has already been programmed to make human growth hormones for the treatment of growth deficiencies and insulin for diabetics.

Harmful Bacteria:

1. Pathogenic bacteria: They are responsible for many diseases in human beings, animals and plants. They may be called as invisible enemies of man.
Some of the diseases found in man due to bacteria are typhoid, tetanus, food-poisoning, diphtheria, tuberculosis etc. Plant diseases caused by bacteria are black-rot of cabbage, citrus canker, fire-blight of pear and apple, ring-rot of potato etc.

2. Food spoilage: Bacteria spoil food by fermentation, putrification ordecomposition.

6.2.2 Control of Bacteria:
The term control of pathogenic organisms refers to bringing the infections in population to a tolerable limit. Control of bacteria is essential for the prevention diseases and to avoid spoilage of food and other industrial products. Several measures are taken to control infectious micro-organisms. Such measures involve the following:

i) Treatment of the infected individuals,

ii) Prophylactic treatment of the population at risk through immunization or vaccination.

iii) Disruption of the life cycle of the pathogen at all possible stages,

iv) In case of epidemics, prevention of the spread of infection to non-infected individuals through quarantine.

v) Identification and control or treatment of the reservoir hosts if any.

vi) Health awareness in masses primarily to reduce the risk factors related to some disease,

vii) Establishing a surveillance system.

viii) Killing of bacteria is brought about by a number of sterilization methods like exposing bacteria to ultraviolet rays or to high temperature. Certain antiseptics, antibodies and chemotherapy agents are used to kill the bacteria present in a living tissue.

6.3 IMMUNIZATION AND VACCINATION

Immunization refers to various processes of induction of specific immunity by injecting antigens, antibodies or immune cells. It can be protective or curative in nature. It promotes increased immunity against specific diseases. Moreover, it not only provides long lasting protection against some diseases but also helps the infected individuals to fight with the pathogens.

There are many ways of immunization, one is called **vaccination** or active immunization. It is a prophylactic in nature and refers to the inoculation of host with inactive or weakened pathogens or pathogenic products to stimulate protective immunity. Thus in case of subsequent natural infection with the same pathogen, the immune system easily recognizes the invader and comfortably manages to overcome the pathogen. In such cases, either no symptoms appear at all or mild symptoms appear. A vaccine is either taken orally (e.g. polio vaccine) or injected into the body (e.g. tetanus vaccine).

Immunization procedures are not only beneficial to the individuals but are effective public health procedures because disease spreads poorly through a population in which a large proportion of individuals are immune.

6.4 USE AND MISUSE OF ANTIBIOTICS

Antibiotics are chemical substance produced by certain micro-organisms that inhibit or kill some other micro-organisms. They have a dramatic impact on the treatment of infectious diseases. Since the discovery of the first antibiotic, penicillin which was derived from fungi in 1940, a large number of antibiotics have been discovered from other fungi and bacteria, while many are synthesized artificially.

Some antibiotic drugs are effective against only certain types of bacteria while others known as broad spectrum antibiotics are effective against wide range of bacteria. The targets of antibiotics in bacteria are cell-wall, plasma membrane and biosynthetic processes of proteins and nucleic acids.

Besides, medical usage, they are also used in agriculture both as growth promoting substances in animal feeds and as prophylactics (disease preventing).

However, either medically or agriculturally, their inappropriate and extensive use is leading to the rapid development of antibiotic resistance in pathogenic microorganisms. Antibiotic resistance refers to the acquired ability of an organism to resist the effect of an antibiotic to which it is normally susceptible. Antibodies also have many side effects and their unnecessary and prolonged use distributes the metabolic activities of the user. The most common adverse reaction is many types of allergic reactions.

6.5 CYANOBACTERIA (Blue-green algae)

6.5.1 Salient features:

1. They are prokaryotes.
2. They are unicellular or may occur in colony form.
3. Cell-wall is double layered.
4. Protoplasm is differentiated into an outer coloured region**chromoplasm** and an inner colourless region **centroplasm**.
5. Chromoplasm contains various pigments-in which chlorophyll—α and phycocyanin are in abundance imparting bluish green colour.
6. They are aquatic (fresh water, with a few marine forms).
7. Total absence of sexual reproduction.
8. Asexual reproduction takes place by means of hormogonia, zoospores, akinetes and fragmentation.

Nostoc may be taken as a typical example of Blue-green algae.

6.5.2 Nostoc:

i) Structure:

Nostoc is unicellular, fresh water, prokaryotes found in colony called filament. The filaments are intermixed in a gelatinous mass forming a ball like structure called **coenobium.** It floats on water. A single filament (Trichome) look like a chain of beads. Each filament is unbranched and has a single row of rounded or oval cells. Each cell has double layered wall. The outer thicker layer is made up of cellulose mixed up with pectic compound. The inner thin layer is purely made up of cellulose. The protoplasm is differentiated into an outer coloured region, chromoplasm and an inner colourless region centroplasm. The chromoplasm is coloured due to the presence of various pigments like chlorophyll - **α**, xanthophyll, carotene, phycocyanin and phycoerythrin. These pigments are not located in plastids but inside an invaginated plasma membrane (a primitive character).

There is total absence of endoplasmic reticulum, mitochondria, Golgi bodies and vacuole. However ribosomes, pseudovacuoles and reserve food in the form of cyanophyceae starch are present.

The centroplasm, also called central-body has hereditary material in diffused form, because there is no nuclear membrane, nucleolus and typical chromosomes.

At intervals there are found slightly larger oblong, colourless cells with slightly thicker walls. These are called **heterocyst**. Each heterocyst is the centre of nitrogen fixation. But they are specially concerned in the multiplication of filaments during unfavourable conditions.

ii) Nutrition:

Nostoc is an autotroph like all other blue-green-Algae. It is also capable of fixing atmospheric nitrogen and converts it into nitrates to make amino-acids and proteins. This activity takes place in heterocyst.

iii) Reproduction:

There is no report of sexual-reproduction in nostoc. But asexual reproduction taker place by following methods.

a) Hormogonia (Sing=Hormogonium): Hormogonium is a portion of filament between two heterocysts. During favourable conditions, filament breaks up at the junction of each heterocyst. This results inthe formation of a number of pieces called hormogonia. The end cells of each hormogonium divide to form long filament ofnostoc.

b. Akinetes: Akinetes are non-motile spores formed from certain vegetative cells during unfavourable conditions.

When conditions are not favourable, certain vegetative cells become enlarge and thick-walled containing reserve food, called akinetes. These are somewhat oval with outer layer **exosporium** and inner **endosporium**. At the approach of favourable conditions, they germinate by rupturing exospore and form independent filaments by simple cell division.

6.5.3 Importance of Cynobacteria:

They are capable of making organic compounds from water and carbon dioxide, they flourished, and changed the world by releasing O_2 as a by-product of their photosynthesis. Many are able to fix atmospheric nitrogen, and this together with their ability to photosynthesis means that their nutritional requirements are simple (mainly CO_2 and nitrogen from the air plus some minerals). For this reason they are often the first colonisers of moist soils.

Nostoc anabena is used as nitrogen fertilizer in agriculture due to their high nitrogen fixing abilities. They are grown in fields for improving soil fertility.

KEY POINTS

- Prokaryotes are unicellular organisms in which each cell contains a single DNA molecule coiled in a loop and not enclosed in a nuclear membrane.
- Antony Van Leeuwenhoek, was the first to observe micro organisms. He constructed a simple microscope and observed a drop of water.
- Bacteria are the pioneers of cellular organization and strictly **unicellular**. However the cells of some species may remain associated after cell-division and form colonies.
- Mesosomes are invagination of cell-membrane into the cytoplasm. Mesosomes are in the form of vesicles, tubules or lamellae. Their function is to help in DNA replication, cell-division, respiration and in export of enzyme.
- Bacteria are difficult to classify. Taxonomists classify bacteria using a variety of criteria: shapes, means of locomotion, pigments, staining properties, nutrient requirements and the appearance of bacterial colonies.
- Some bacteria are killed in the presence of oxygen, they are called obligate anaerobes. Others use oxygen but can respire without it, they are called facultative aerobes. Bacteria which can only survive with oxygen present are obligate aerobes.
- Some Bacteria can move using simple flagella that are attached with a unique wheel-like structure.
- Bacteria act on dead plant and animal bodies and decompose various organic compounds into simple forms such as nitrates, sulphates, phosphates etc. for utilization by green plants again.

- Valuable antibiotic drugs have been obtained from bacteria e.g. Thyrothycin, Subtilin. Riboflavin is vitamin produced by clostridium.

- Genetically engineered bacteria, E.coli has already been programmed to make human growth hormones for the treatment of growth defeciencies in children and the insulin for diabetics.

- Antibiotics are chemical substance produced by certain microorganisms that inhibit or kill some other microorganisms. They have a dramatic impact on the treatment of infectious diseases.

- Nostoc found in colony called filament. The filaments are intermixed in a gelatinous mass forming a ball like structure called coenobium.

EXERCISE

1. Encircle the correct choice:

(i) Extremely thin appendages helping during conjugation in bacteria:
(a) Flagella (b) Pili
(c) Celia (b) Tentacles

(ii) Spirochaeta is an example of:
(a) Cocci (b) Bacilli
(c) Spirilla (d) Vibrio

(iii) Inactive phase or phase of growth during which bacteria prepare themselves for division:
(a) Lag-phase (b) Log-phase
(c) Stationary phase (d) Decline phase

(iv) Bacteria having flagella all over the surface:
(a) Atrichous (b) Lophotrichous
(c) Peritrichous (d) None of them

(v) Non-motile spores formed from certain vegetative cells during unfavourable conditions in nostoc:
(a) Heterocyst (b) Hormogonium
(c) Akinete (d) Coenobium

(vi) Photosynthetic bacteria liberate:
(a) CO_2 (b) O_2
(c) S (d) H_2S

(vi) Type of cocci having group eight:
(a) Streptococcus (b) Sarcinia
(c) Staphyloccous (d) Diplococcus

2. Write detailed answers of the following questions:

(i) Describe structure and modes of reproduction in bacteria.
(ii) Describe salient features of cynobacteria and reproduction in nostoc.
(iii) Distinguish between bacterial and nostoc cell. Give positive importance of bacteria and nostoc.

3. Write short answers of the following questions:

(i) How bacteria were discovered?
(ii) What are Photosynthetic bacteria?
(iii) How bacteria are classified on the bases of flagella?
(iv) What are cyanobacteria?
(v) Does genetic recombination takes place in bacteria? Define any one method.

4. Define the following terms:

(i)	Hormogonia	(ii)	Heterocyst	(iii)	Prokaryotae
(iv)	Mesosomes	(v)	Plasmid	(vi)	Nucleoid (bacteria)

5. Distinguish between the following:

(i) Flagella and pili
(ii) Photosynthetic and chemosynthetic bacteria

Chapter 7

THE KINGDOM PROTOCTISTA (PROTISTA)

Protoctists are eukaryotic and thus even the simplest ones are much more complex than the prokaryotes. The first eukaryotes to evolve from prokaryotic ancestors were probably unicellular and would therefore be called protists. The primal eukaryotes were not only the predeccessors of the great variety of modern protists but were also ancestral to all other eukaryotes-plants, fungi and animals. The most controversial group of organisms is the **Protista (protoctists)** because it is probably an unnatural group. It contains eukaryotes that are generally regarded as identical or similar to the ancestors of modern plants, animals and fungi. The Protoctista includes two groups, the algae and the protozoan, which formerly had separate taxonomic status, and which are now regarded as containing organisms too widely different to be placed in one phylum. In addition, it includes one group of organisms which were previously placed in the fungi, the oomycota or oomycetes, but which are now regarded as ancestral to fungi. The slime molds, a group of organisms which are motile but which produce spores in sporangia, are also included in the Protoctista.

Diversity among Protista (Protoctista)

Due to diversification, biologists regard protist kingdom as a polyphyletic group of organisms. It means they do not share a single common ancestor. Here we have divided them into three groups:

1. Plant-like Protoctists-Algae
2. Fungi-like Protoctists-Primitive fungi
3. Animal-like Protoctists-Protozoa

7.1 PLANT-LIKE PROTOCTISTS: ALGAE (Chlorella and Ulva)

Algae (Sing Alga)-Algin = Sea-weed

Algae are responsible for more than half of the amount of photosynthesis being carried in the world.

Previously Algae were regarded as plants due presence of cell-wall and chlorophyll-b as an accessory photosynthetic pigment.

Algae differ from plants being aquatic whereas plants are nearly all terrestrial. Living on land poses very different problems from living in water, and it is a set of structural, chemical and reproductive adaptations for terrestrial living that distinguishes plants from algae. Zygote is not protected by parent body.

The protists are usually single-celled organisms that are grouped according to their mode of nutrition. There are the heterotrophic protozoans, the photosynthetic algae, and slime molds and water molds, which somewhat resemble fungi.

Algae ranges from unicellular to filamentous and to huge multicellular structures. In addition to green chlorophyll, carotenoids, xanthophylls and phycoerythrin are also present. Classification of algae is largely based on their pigment composition.

7.1.1 CHLORELLA

It is fresh water algae found floating in stagnant water of ponds, pools, ditches etc. It is easily cultured and has been used as an experimental organism in research on photosynthesis as well as being investigated as an alternate source of food.

The body is one-celled, spherical in outline and solitary. It contains a single nucleus and a cup-shaped chloroplast with or without a pyrenoid.

The sole method of reproduction is by aplanospores, which involves the division of protoplast into 8-16 daughter protoplast. Each daughter protoplast secrets a wall to produce a nonmotile aplanospore. On release from the parent cell each aplanospore forms a new vegetative cell. Zoospores and gametes are unknown. It is of great economic importance as recently an antibiotic called chlorellin useful for the control of bacterial diseases has been prepared from the plant.

7.1.2 ULVA

It is a marine alga commonly called 'sea-lettuce'. It is found growing along the sea-coasts between high and low tides. It is found attached to rocky edge of Manora and Kiamari areas of Karachi coast. The body called thallus is composed of elongated wrinkled blade about 30 cms, long. It is attached to rock and other objects in the sea by means of hold fast, consisting of long thread like cells. The thallus is very thin only two cells in thickness. Thallus in Ulva is of two types. The one with 26 chromosomes is called **sporophyte** and the other with 13 chromosomes is called **gametophyte**. Morphologically both gametophyte and sporophyte are exactly alike hence called **isomorphic**.

Ulva reproduces asexually as well as sexually

Asexual reproduction takes place in asexual Ulva (Diploid sporophyte with 26 chromosomes or 2n) by quadri-flagellate zoospores. These spores are formed by meiosis in all the cells of the body (thallus) except the basal cells. Eight to sixteen haploid zoospores are formed in a single parent cell. The zoospore production continues until all the cells are used and nothing remains of the thallus blade but a filmy mass of empty cell-walls. Liberation of zoospores usually takes place at the time when the plant is reflooded by an incoming tide. The liberated haploid zoospores after a period of swimming and rest lose their flagella and grows into Ulva thalli.

Green algae are a diverse group that have some of the same characteristics as plants. The haplontic life cycle is typical but Ulva has a life cycle that has 2 distinct generations, like that of plants.

Sexual reproduction is isogamous. The gametes are biflagellate and produced in sexual plants (haploid gametophytes with 13 chromosomes(n)). These gametes are smaller than the zoospores. The fusion takes place only between two haploid gametes produced by different plants. The fusion results in the formation of quadriflagellate diploid zygote which, after a period of swimming and rest, loses its flagella and secretes a wall and after repeated divisions it develops into another Ulvaplant (Sporophyte) which is similar to sexual plant (Gametophyte) in morphology.

Alternation of Generation in Ulva shows there is distinct and regular isomorphic alternation of generation. The haploid gametophyte alternates with diploid sporophyte which are similar in morphology but differ in chromosome numbers.

Euglena is typical of protoctists that have both animal-like and plant-like characteristics. A very long flagellum propels the body, which isenveloped by aflexible pellicle made of protein. A photoreceptor allows Euglena to find light, after which photosynthesis can occur in its numerous chloroplasts. In addition to the pyrenoids, which store starch, there are starch granules in the cytoplasm.

7.2 FUNGI-LIKE PROTOCTISTS

The organisms which fall into this category superficially resemble fungi in that they are non-photosynthetic and bodies formed of hyphae.

There are some organisms which superficially resemble fungi in having bodies formed of thread like structures called **Hyphae**. Many of them have centrioles and cell-wall having cellulose.
Two major groups of fungi-like protoctists are Slime molds and Water molds — oomycetes (Phytophthora).

7.2.1 Slime Mold (Gymnomycota):

A common slime mold is of no practical value whatever. You cannot make anything useful out of it, and it does not cause of serious disease. However, a slime mold is a strange and truly wonderful "thing", its structure and behaviour have raised many questions, some of which are still unanswered.
At one stage in their life cycle, some species of slime molds are creeping masses of living substance, having the consistency of an unboiled egg white and the colour of the yolk. The movement of this living thing brings to mind a giant amoeba, for it sends out arms that engulf and digest bacteria from the surface of rotting log or leaves. This amoeboid stage of the slime mold is called a plasmodium. In nature, a large plasmodium may cover several square centimetres. It can crawl over grass, creep up the sides of trees, or go almost anywhere there is food and moisture. The Plasmodium consists of cytoplasm in which are embedded many nuclei, food vacuoles, and undigested food particles.
Plasmodia move along the forest floor, onto dead leaves that are bathed in sunlight. In this dry, often warm, environment a miraculous metamorphosis takes place. In a matter of hours, the plasmodium changes into clusters of fruiting bodies called **sporangia**. Depending on the species, the fruiting bodies look like small golf balls, or feathers, or bird cages, or worms, in a great variety of colours. Part of each sporangium called **capsule**, produces a large number of microscopic, asexual reproductive cells called spores. Each spore has a single nucleus and a thick, protective wall.
A spore may remain inactive for a long time, or it may germinate soon after it has been shed from the fruiting body. Germination of the spore occurs when there is plenty of water and a suitable temperature. The fruiting stage and the thick-walled spores of the slime mold are very plant like. They are very important reproductive cells. When a slime mold spore germinates, it produces one or more tiny cells. Each cell has a pair of flagella that propel it through the film of water that must be present for spore germination. These flagellated cells may function as gametes (Sex cells) and fuse in pairs. This is true sexual reproduction, even though the gametes appear to be identical in structure.
Cells resulting from the fusion of gametes become amoeboid and form a new plasmodium that is multinucleate (containing many nuclei). The multinucleate condition can arise by growth of the amoeboid cell and subsequent divisions of the nucleus. It can also result from the fusion of many individual amoeboid cells, which thus lose their separate identity. This is a most unusual way for an organism to be formed. In slime mold, we can see that it combines characters of animals and plants.
If we observe only the plasmodium, we would certainly call slime mold an animal. If fruiting bodies and spores were the only parts we could see, we would call the organism a plant. Is it plant or animal? Can we really relate this strange organism to other living things? What was its evolutionary origin? We can get some help answering these questions by examining some other, more familiar fungi, which are called molds.

7.2.2 Water molds (Oomycotes):

Phytophthora Infestans:
It is an example of water molds (oomycotes). It is a pathogenic organism causing Late blight of potato (fig:7.6).

Structure of Mycelium:
The mycelium consists of hyphae having a cellwall madeup of cellulose which are endophytic, branched, aseptate, coenocytic, hyaline and nodulated. The rounded or branched haustoria are found which absorb food material from the host cells.

Reproduction:
The reproduction takes place by means of asexual and sexual methods.

Asexual reproduction takes place by means of biflagellate zoospores produced inside the sporangia.

Sexual reproduction is oogamous (Clinton, 1911). The female sex organ is oogonium and the male organ is antheridium. The antheridium develops first and the oogonium later. Both the sex organs may develop on the same hypha or-on two adjacent hyphae lying side by side.

7.2.3 Economics importance of Phytophthora Infestans:
The most important species phytophthora infestans causes the "late" blight of potato. This is a havoc to potato crop and causes sufficient damage. The symptoms of the disease appear both upon aerial and underground parts. The whole plant becomes blighted in severe conditions. Dry and wet rots damage the tubers.
The first sign of the disease is appearance of small brown patches on leaves which in cloudy and muggy weather rapidly increase to the whole leaf surface.
In bad cases the crown also shows similar symptoms which becomes a rotten pulpy mass emitting foul odour. On the under surface of such infected leaves a cotton growth of mycelium consisting of fortification of the fungus is seen. This growth is absent in dry weather.
The underground parts especially the tubers are also affected which often remain smaller in size and show dry rot with rusty brown markings in the flesh and brown depressions at certain places, in the skin.

7.3 ANIMAL LIKE PROTOCTISTS (PROTOZOA)

Protozoa (protos=first formed, zoa=animals):
They are earlist formed eukaryotic, unicellular organisms which primarily feed by ingestive method.
The protozoans are unicellular organisms. Like animals, they are heterotrophs. Typically protozoa have a single nucleus and lead an independent existence but some have multinucleated cell, and in other species the cells are joined together to form a colony. A colonial protozoan can be distinguished from a multicellular animal, because its cells are quite similar and non specialized for any function. Most of the individuals in a population of protozoa are produced by simple cell division of the parent, although sexual reproduction by the mating of two individuals does occur. Protozoa are primarily aquatic and live in fresh, brakish and marine water. Some species of protozoa can form inactive spores or cysts that can be dried and distributed with particles of dirt or dust from one habitat to another. Parasitic protozoa live in the body of animals or in the plants. About30,000 species of protozoa are divided into five classes, which differ in their means of locomotion.

1. Class Flagellata (Mastigophora)
2. Class Sarcodina (Rhizopoda)
3 Class Ciliata (Ciliophora)
4 Class Suctoria
5. Class Sporozoa

1. The Flagellata so called because they have one or more flagella. These organelles, constructed like those of higher animals, have a membranous covering and microtubules. Many members of this group are photosynthetic and they are as much like plants as animals e.g. Euglena.
The flagellates are generally considered to be the basic stock from which evolved not only other kinds of protozoa but also higher plants and animals e.g. Trypanosoma (Fig. 7.7).

2. The Sarcodina: The members of this class have no specific organelles for locomotion. They extend blunt or slender cytoplasmic projections called **pseudopodia** and then the cell content flows into the pseudopodium which can be pushed out and retracted repeatedly, such type of locomotion is called amoeboid locomotion.
Some parasitic Amoebae (Entamoeba-histolytica) can cause human dysentery. Marine shelled sarcodinians through geological time have deposited billions of skeletons, which now make layers on the bottom of the sea. The **"Radiolarian Ooze"** and **"Globigerina Ooze"**(Fig. 7.8) are studied by oil prospectors because the presence of certain species gives clues to possible petroleum deposits.

3. The Ciliata, Protozoa with both micro and macro nucleus and numerous short cilia, so named because of the resemblance of cilia to eyelashes (the word really means "eyelid"). They use their accurately synchronized cilia either to move themselves through water or, if they are attached, to bring water containing food particles near or into the animal's body. Many ciliates have a groove or depression called a gullet through which food can be brought inside the body by a process of engulfing e.g. Balantidium, Opalina (Fig. 7.9) and Paramecium (Fig. 7.10). Mostly reproduction is asexual, but conjugation between compatible strains of ciliates occurs, with a resulting exchange of genetic material.

4. The Suctoria: Suctorians are closely related to ciliates and appear to have been derived from them in evolution. The suctorians, have both a macronucleus and a micronucleus. Young individuals have cilia and swim about, but the adults are sedentary and have stalks by which they are attached to the substratum. The body bears a group of delicate cytoplasmic tentacles, some of which are pointed to pierce their prey, whereas others are at their tips rounded adhesive knobs to catch and hold the prey. The tentacles secrete a toxic material which may paralyse the prey. Reproduction is asexual by budding e.g. Acineta (Fig. 7.11).

5. Sporozoa: The sporozoans comprise a large group of parasitic protozoa, among which are the agents causing serious diseases such as Coccidiasis in poultry and malariain man. Sporozoans have neither locomotory organelles nor contractile vacuole. Most sporozoans live as intracellular parasites in the host cells during the growth phase of their life cycle and absorb nutrients through their cell membrane. Common example of sporozoan are Plasmodium (malarial parasite) and Monocystis which lives in the seminal vesicles of earthworm.

7.3.1 Life-cycle of Malarial Parasite:

Life-cycle of Plasmodium is completed in two hosts: man and female Anopheles mosquito. Man serves as primary host whereas mosquito serves as secondary host. The parasite completes its life cycle in two main phases: a) asexual cycle in man and b) sexual cycle in mosquito.

Asexual cycle in man (Schizogony):

A healthy person acquires infection when a female Anopheles mosquito, containing infective stages **(sporozoites)** of the parasite in its salivary glands, bites him for sucking his blood. Schizogony comprises of the following phases:

1. Pre-erythrocytic phase: Once within the human blood, the sporozoites invade the hepatic cells within an hour. After penetrating the hepatic cells, each sporozoite grows for number of days and becomes a schizont. It divides to form a large number of uninucleate **exoerythrocytic (EE) merozoites.** These are liberated when the liver cell bursts. The exoerythrocytic (EE) merozoits may invade fresh liver cells and multiply producing enormous number of new generation. This phase is referred to as pre-erythrocytic phase.

2. Erythrocytic phase: It takes place in R.B.Cs. The exoerythrocytic (EE) merozoits, after escaping into the blood stream, invade the red blood corpuscles. Each becomes rounded and is called **trophozoite.** When it grows in size, the nucleus ispushed to one side into the peripheral cytoplasm. It resembles a signet ring and is referred to as **signet ring stage.** The **trophozoite** ingests a large amount of cytoplasm of the R.B.C. The blood haemoglobin is broken downinto its protein component, which is used by the trophozoite. It develops into an active **amoeboid trophozoite.** Afteractive feeding it becomes rounded, grows in size and becomes a schizont. It now undergoes schizogony and produces **erythrocytic (E) merozoites.** With the rupture of R.B.C; the erythrocytic (E) merozoites along with malarial pigments formed by the residue of haemoglobin are liberated into the blood plasma. These erythrocytic merozoits invade fresh corpuscles to repeat the cycle. The time taken to complete one erythrocytic cycle depends upon the species of Plasmodium.

3. Gametocytogenesis: After few erythrocytic generations, erythrocytic merozoites which invade the R.B.C; increase in size to become gametocytes; male or microgametocytes, and female or macrogametocytes. The gametocytes do not divide, but remain within their host blood corpuscle until they are ingested by the vendor, in which they continue their development.

Sexual cycle in mosquito (Sporogony):
Sexual life-cycle of Plasmodium is completed in the gut of female Anopheles mosquito resulting in the infective sporozoites. The cycle comprises of the following three stages.

Gametogony: The gametocytes are taken up along with the blood into the stomach of the mosquito. The female gametocytes soon become macrogamete, which is ready to be fertilized. Each male gametocyte forms 6 to 8 sperm-like microgametes by a process of exflagellation.

Fertilization: The two gametes of the opposite sexes fuse together to form a zygote. The process is called **Syngamy.** The zygote becomes worm-like **ookinete.** It penetrates the stomach wall to settle down just under the midgut. Here after absorbing the nutrients, it becomes rounded and encycts to form the oocyst.

Sporogony: In 6 to 7 days the nucleus of the oocyst divides into thousands of slender sporozoites by the process of sporogony. The cyst bursts, and the liberated sporozoites are released into the haemocoele from where they migrate towards the salivary glands and wait to be transferred to a human host.

Symptoms of Malaria:
The symptoms of malaria first appear when infected R.B.Cs are broken. The time taken by the parasite its entry into man upto the breaking down of R.B.Cs is called incubation period. The symptoms that appear in this period of infection include fever, nausea, loss of appetite, constipation and insomnia. Soon headache, muscular pains, aches in the joints develops followed by chills.

At the onset of malarial fever the patient, suffers from shaking chills and sweating. The body temperature may rise as high as 106°F. After few hours of fever, there is a profuse sweating and finally fever disappears. The recurrence of symptoms occurs usually after 48 hours or sometimes earlier.

KEY POINTS

- Protoctista a group of unicellular eukaryotes which cannot fit any of the other four kingdoms.
- Due to diversification, biologist regard protists kingdom as a polyphyletic group of organisms.
- Plant like protoctists are Algae (Chlorella, Ulva).
- Fungi like protoctists are slime mold and water molds—oomycetes (Phytophthora).
- Animal like protoctists include all protozoans.
- Algae differ from plants by being aquatic and their zygote is not protected by parent body.
- Chlorella is fresh water alga found floating in stagnant water. Ulva shows isomorphic alternation of generation.
- Phytophothora is a pathogenic organism causing late blight of potato.
- Protozoa are divided into five classes, which differ in their means of locomotion. Amoeba histolytica causes human dysentery.
- Common example of sporozoan is Plasmodium (malarial parasite) causing malaria fever.
- At the onset of malarial fever, the patient suffers from shaking chills and sweating. The body temperature may rise as high as 106°F.

EXERCISE

1. Encircle the correct choice:

(i) Ulva reproducing by quadriflagellate zoospores which has:
(a) 13 Chromosomes (b) Sexual reproduction
(c) Gametophytic phase (d) 26 Chromosomes

(ii) Protoctist having isomorphic alternation of generation
(a) Chlorella (b) Ulva
(c) Euglena (d) Phytophthora

(iii) Animal like phase of slime-mold
(a) Plasmodium (b) Fruiting bodies
(c) Spores (d) Sporangia

(iv) Pyhtophthora infestans causes disease known as
(a) Early blight of potato
(b) Late blight of tomato
(c) Late blight of potato
(d) Early blight of tomato

(v) Plant-like character found in euglena
(a) Flagellum (b) Pellicle
(c) Photoreceptor (d) Pyrenoid

(vi) Class of Protozoa where adults are sedentary
(a) Flagellata (b) Mastigophora
(c) Ciliata (d) Suctoria

(vii) Skeletons of marine shelled sarcodanias gives clues to possible deposits of
(a) Calcium (b) Magnessium
(c) Petroleum (d) Chromium

(viii) Which one is not the stage of Plasmodium in mosquito?
(a) Schizogony (b) Gametogony
(c) Syngamy (d) Sporogony

(ix) Term used for asexual cycle of Plasmodium in man:
(a) Schizogony (b) Gametogony
(c) Syngamy (d) Sporogony

(x) Which one is not the symptoms of malaria?
(a) Nausea (b) Loss of appetite
(c) Dysentary (d) Shivering

2. Write detailed answers of the following questions:

(i) Describe structure and reproduction in ulva.
(ii) Describe two fungi like protoctists.
(iii) Describe in detail protozoa and its classes with examples.
(iv) Describe life cycle of malarial parasite.
(v) Describe diversity among protoctists.

3. Write short answers of the following questions: -

(i) Why asexual ulva is diploid?
(ii) Why we say that ulva has isomorphic alternation, of generation?
(iii) Name the pathogene of late blight of potato and African sleeping sickness.
(iv) What are the symptoms of malaria?
(v) Why asexual and sexual ulva plants are called as sporophyte and gametophyte?

4. Define the following terms:

(i) Protoctista (ii) Protozoa

5. Distinguish between the following:

(i) Sexual and Asexual Ulva
(ii) Flagellata and sarcodina

Chapter 8

THE KINGDOM FUNGI

The words fungus and mold may evoke some unpleasant images. Fungi rot timbers, attack plants, spoil food and afflict humans with athlete's foot and worse maladies. However, ecosystem would collapse without fungi to decompose dead organisms, fallen leaves, feces and other organic materials, thus recycling vital chemical elements back to the environment in forms other organisms can assimilate.

It includes non-chlorophyllus, multicellular (except yeast) organisms having chitinous cell wall and coenocytic body called mycelium, e.g. Agaricus (mushroom) yeast, etc. They are absorptive hetrotrophs.

More than hundred thousands species are found. This group includes pathogens such as harmful rusts, smuts (on wheat and corn), molds growing on food-stuff and crops; edible as well as poisonous mushrooms and fungi of commercial importance (Penicillium, yeasts). Fungi are best decomposers alongwith bacteria.

Previously fungi were regarded as plants as they resemble plants in having cell-wall, lacking centrioles and being non-motile. But fungi resemble with animals also as they are heterotrophic, lack cellulose in their cell-wall and contain chitin.

It means that fungi are neither completely plants nor animals. Their DNA studies also confirm that they are different from all other organisms. They have a characteristic mitosis called **nuclear-mitosis** during which nuclear membrane does not break and spindle is formed within nucleus.

8.1 THE BODY OF FUNGUS

The body of a fungus, called **mycelium**, consists of long, slender, branched tubular thread like filaments called the **hyphae** (singular **hypha**). Hyphae spread extensively over the surface of substratum. Chitin in their wall is more resistant to decay than are cellulose and lignin which make up plant cell wall. Hyphae may be septate or non-septate. **Septate** hyphae are divided by cross-walls called **septa** (singular **septum**) into individual cells containing one or more nuclei. Non-septate hyphae lack septa and are not divided into individual cells; instead these are in the form of an elongated multinucleated large cell. Such hyphae are called **coenocytic** hyphae, in which cytoplasm moves effectively, distributing the materialsthroughout. Septa of many septate fungi have a pore through which cytoplasm flows from cell to cell, carrying the materials to growing tips and enabling the hyphae togrowrapidlywhenfood and water are abundant and temperature is favourable. All parts of fungus growing through the substrate are metabolically active.Extensive spreading system of hyphae provides enormous surface area for absorption.

Hyphae may be packed together and organized to form complex reproductive structures such as mushrooms, puff balls, morels etc. which can expand rapidly. Yeast are non-hyphal unicellular fungi.

All fungal nuclei are **haploid** except for transient **diploid zygote** that formsduring sexual reproduction.

A single mycelium may produce upto a kilometre of new hyphae in only one day. A circular clone of Armillaria, a pathogenic fungus afflicting conifers, growing out from a central focus, has been measured upto 15 hectares (1 hectare = 10000 m^2). Could it be the world's largest organism?

8.1.1 Nutrition in Fungi:

All fungi lack chlorophyll and are heterotrophs (obtaining carbon and energy from organic matter). They obtain their food by direct absorption from the immediate environment and are thus **absorptive heterotrophs.** Most fungi are **saprotrophs (or saprobes), decomposers** that obtain their food (energy,

carbon and nitrogen) directly from dead organic matter. They secrete out digestive **enzymes** which digest dead organic matter, and the organic molecules thus produced are absorbed back into the fungus. Saprobic fungi anchor to the substrate by modified hyphae, the **rhizoid.** Fungi are the principal decomposers of cellulose and lignin, the mam components of plant cell walls (most bacteria cannot break them). Extensive system of fast growing hyphae provides enormous surface for absorptive mode of nutrition. Saprobic fungi, alongwith bacteria, are the major decomposers of the biosphere, contributing to the recycling of the elements (C, N, P, O, H etc.) used by living things.

Some fungi are **parasites**, some are even **predators**, and still others are **mutualists. Parasitic** fungi absorb nutrients directly from the living host cytoplasm with the help of special hyphal tips called **haustoria**. They may be obligate or facultative. **Obligate** parasites can grow only on their living host and cannot be grown on available denned growth culture medium. Various **mildews** and most rust species are obligate parasites. **Facultative parasites** can grow parasitically on their host as well as by themselves on artificial growth media.

Some fungi are active **predators**. The oyster mushroom (Pleurotus ostreatus) is a carnivorous (predatory) fungus. It paralyses the nematodes (that feed on this fungus), penetrate them, and absorb their nutritional contents, primarily to fulfil its nitrogen requirements. It fulfils its glucose requirements by breaking the wood. Some species of Arthrobotrys trap soil nematodes by forming **constricting ring**, their hyphae invading and digesting the unlucky victim. Other predators have other adaptations, such as secretion of sticky substances.

Fungi form two key mutualistic symbiotic associations (associations of benefit to both partners). These are **lichens** and **mycorrhizae**.

Lichens are mutualistic and have symbiotic associations between certain fungi (mostly Ascomycetes and imperfect fungi, and few Basidiomycetes (about 20 out of 15000 species of lichens) and certain photo autotroph either green algae or a cyanobacterium, or some times both. Most of the visible part of lichen consists of fungus, and algal components are present within the hyphae (Fig. 8.3). Fungus protects the algal partner from strong light and desiccation and itself gets food through the courtesy of alga. Lichens can grow at such places where neither of the components alone can, even at harsh places such as bare rocks etc. Lichens vary incolour, shape, overall appearance, growth form (Fig.8.3). They are ecologically very important as **bioindicators** of air pollution.

Mycorrhizae are mutualistic association between certain fungi and roots of vascular plants (about 95% of all kinds of vascular plants). The fungal hyphae dramatically increase the soil contact, total surface area for absorption, help in the direct absorption of phosphorus, zinc, copper and other nutrients from the soil into the roots. Such plants show better growth than those without this association. The plant on the other hand, supplies organic carbon to fungal hyphae.

There are two main types of mycorrhizae (Fig.8.4). **Endomycorrhizae**, in which the fungal hyphae penetrate the outer cells of the plant root, forming coils, swellings and minute branches, and also extend out into surrounding soil; and**ectomycorrhizae**, in which the hyphae surround and extend between the cells but do not penetrate the cell walls of the roots. These are mostly formed with pines, firs etc. However, the mycelium extends far out into the soil in both kinds of mycorrhizae.

Fungi grow best in moist habitats, but are found wherever organic matter is present. They survive dry conditions in some resting stage or by producing resistant spores. They can also tolerate a wide range of pH from 2 - 9, a wide temperature range, and high osmotic pressure such as in concentrated salt/sugar solutions as in jelly, jam etc. These features also help them in their survival on land. Fungi store surplus food usually as lipid droplets or glycogen in the mycelium.

8.1.2 Reproduction:

Most fungi can reproduce asexually as well as sexually (except imperfect fungi in which sexual reproduction has not been observed).

1. Asexual reproduction:

Asexual reproduction takes place by **spores**, **conidia, fragmentation** and **budding**. **Spores** are produced inside the reproductive structures called **sporangia**, which are cut off from the hyphae by complete septa. Spores may be produced by sexual or asexual process, are haploid, non-motile and not needing water for their dispersal. These are small, produced in very large number and dispersed by wind to great distances and cause wide distribution of many kinds of fungi, including many plant pathogens. When spores land in a suitable place, they germinate, giving rise to new fungal hyphae. Spores may also be dispersed by insects and other small animals and by rain splashes. Spores are a common means of reproduction in fungi.

Conidia (singular conidium) are non-motile, asexual spores which are cut off at the end of modified hyphae called **conidiophores**, and not inside the sporangia,usually in chains or clusters. These may be produced in a very large number, can survive for weeks and cause rapid colonization on new food.

Fragmentation is simple breaking of mycelium of some hyphal fungi, each broken fragment giving rise to a new mycelium.

Unicellular yeasts reproduce by **budding** (an asymmetric division in which tiny outgrowth or bud is produced which may separate and grow by simple relatively equal cell division.

2. Sexual reproduction:

Details of sexual reproduction vary in different groups of fungi but fusion of haploid nuclei and meiosis are common to all. When fungi reproduce sexually, hyphae of two genetically different but compatible mating types come together, their cytoplasm fuse followed by nuclear fusion. In two of the three main groups of fungi (Basidiomycetes, Ascomycetes), fusion of nuclei **(karyogamy)** does not take place immediately after the fusion of cytoplasm **(plasmogamy)**; instead the two genetic types of **haploid** nuclei from two individuals may coexist and divide in the same hyphae for most of the life of the fungus. Such a fungal hypha/cell having 2 nuclei of different genetic types is called dikaryotic (also **heterokaryotic)** hypha/ cell (Fig.8.1).

Different groups of fungi produce different types of haploid sexual spores, such as **basidiospore** and **ascospores**, subsequent upon meiosis in zygote. These spores may be produced by their characteristic structure/fruiting bodies such as **basidia/basidio carps** and **asci/ascocarps**.

8.2 CLASSIFICATION OF FUNGI

There are four major division/phyla of fungi.

1.	Zygomycota	2.	Ascomycota
3.	Basidiomycota	4.	Deuteromycota

The four divisions of fungi are distinguished primarily by their sexual reproductive structures. In the zygomycetes, the fusion of hyphae leads directly to the formation of a zygote, which divides by meiosis when it germinates. In the other three groups, an extensive growth of **dikaryotic** hyphae may lead to the formation of massive structures of interwoven hyphae within which are formed the distinctive kind of reproductive cell characteristic of that particular group, **syngamy,** followed immediately by meiosis, occurs within these cells, and haploid spores are formed. On release the spores are dispersed, some of them giving rise to new hyphae.

Fungi aresaprotrophic heterotrophic eukaryotes composed of hyphae (a mycelium). Fungi produce spores during both sexual and asexual reproduction, and the major groups of fungi are distinguishable on the basis of sexual reproduction.

1) Zygomycota:

The zygomycetes lack septa in their hyphae except when they form sporangia or gametangia. Zygomycota are by far the smallest of the four groups of fungi, with only about 600 named species. Included among them are some of the more frequent bread molds (Fig. 8.7), as well as a variety of other microscopic fungi found on decaying organic material. The group is named after a characteristic feature of the life cycle of its member, the production of temporarily dormant structures called **zygospores**.

In the life cycle of the zygomycota (Fig. 8.8), sexual reproduction occurs by the fusion of gametangia, which contain numerous nuclei. The gametangia are cut off from the hyphae by complete septa. These gametangia may be formed on hyphae of different mating types or on a single hyphae. If different mating types are involved, fusion between the pairs of nuclei occurs immediately. Once the haploid nuclei have fused. They form diploid zygote nuclei, the fused portion of hyphae develops into a zygospores. Except for the zygote nuclei, all nuclei of the zygomycota are haploid. Meiosis occurs during the germination of the zygospore.

Asexual reproduction occurs much more frequently than sexual reproduction in the zygomycetes. During asexual reproduction, haploid spores are produced within more or less specialized sporangia formed on specialized erect hyphae calledsporangiophores. Their spores are thus shed above the substrate, in a position where they may be picked up by the wind and blow about.

(2) Ascomycota:

The second division of fungi, the ascomycota is a very large group of about 30,000 named species with many more being discovered each year. Among them are such familiar and economically important fungi as yeasts, common molds, morels, and truffles. Also included in this division are many of the most serious plant pathogens e.g. powdery meldew etc.

During sexual reproduction, the black bread molds produce spores in sporangia, the sac fungi produce spores in sac like cells, and the club fungi produce spores in club-shaped structures. The sac and club fungi typically have fruiting bodies. The sexual life cycles for certain fungi that parasitize humans are unknown.

The ascomycota are named for their characteristic reproductive structure, the microscopic, club-shaped **ascus** (plural, **asci**). The zygote, which is the only diploid nucleus of their life cycle is formed within the ascus. The asci are differentiated within a structure that is made up of densely interwoven hyphae, corresponding to the visible portions of a morel or cup fungus, called the ascocarp (Fig. 8.9).

Asexual reproduction is very common in the ascomycota. It takes place by means of conidia (singular, conidium), spores cut off by septa at the ends of modified hyphae called conidiophores. Many condia are multinucleate. The hyphae of ascomycetes are divided by septa, but the septa are perforated and the cytoplasm flows along the length of each hyphae. The septa that cut off the asci and conidia are initially perforated like all other septa, but later they often become blocked.

The hyphae of ascomycetes may be either homokaryotic or heterokaryotic. The cells of these hyphae usually contain from several to many nuclei, as do the gametangia. The female gametangia, which are called ascogonia, having a beaklike out growth called a **trichogyne**. When the antheridium, or male gametangium is formed, it fuses with the trichogyne of an adjacent ascogonium;

nuclei from the antheridium then migrate through the trichogyne into the ascogonium and pair with nuclei of the opposite mating type. Initially, both kinds of gametangia contain a number of nuclei. Heterokaryotic hyphae then arise from the area of the fusion. Throughout such hyphae, nuclei that represent the two different original mating types occur (dikaryoticy). Several nuclei, some derived from each of the parents of their mitotic products, are present within each cell of the hyphae. These hyphae are dikaryotic and heterokaryotic.

The asci are cut off by the formation of septa at the tips of the heterokaryotic hyphae. There are two haploid nuclei within each ascus, one of each of the two mating types represented in the dikaryotic hyphae. Fusion of these two nuclei occurs within each ascus, forming a zygote, each zygote divides immediately by meiosis, forming four haploid daughter nuclei; these usually divide again by mitosis, producing eight haploid nuclei that become walled ascospores. In most ascomycetes the ascus becomes highly turgid at maturity and ultimately bursts, often at a perforated area. When this occurs, the ascospores may be thrown as far as 30 centimetres, an amazing distance considering that most ascospores are only about 10 micrometers long (Fig: 8.10).

Ascocarps or fruity bodies (Fig: 8.9), are made up of tightly interwoven monokaryotic and dikaryotic hyphae. Within an ascocarp, on special fertile layers of dikaryotic hyphae, the asci are formed. The ascocarps of the cup fungi and the morels are open, with the asci lining the open cups called **opothecium**. Other ascocarps are closed or have a small opening at the apex called **cleistothecium** and **perithecium** respectively; the ascocarps of **neurospora**, an important organism in genetic research, are of this latter kind.

YEASTS:

Yeasts, which are unicellular, are one of the most interesting and economically important groups of microscopic ascomycota (Fig. 8.11). Yeasts being single celled, they might be considered primitive fungi and belonging to protoctist but they are originally derived from multicellular ancestors, most of which were ascomycetes. More over, under favourable nutrition it may develop rhizoidal hyphae. Most of their reproduction is asexual and takes place by cell fission or budding (the formation of a smaller cell from a larger one). Sometimes, however, whole yeast .cells may fuse. One of these cells, containing two nuclei, may then function as an ascus with syngamy followed immediately by meiosis; the resulting ascospores function directly as new yeast cells.

The ability of yeasts to ferment carbohydrates, breaking down glucose to produce ethanol and carbon dioxide in the process, is fundamental in the productionof bread, beer and wine. Through the millennia, many different strains of yeast have been domesticated and selected for these processes. Wild yeast—ones that occur naturally in the areas where wine is made were important in wine making historically, but domesticated yeasts are normally used now. The most important in all these processes is **saccharomyces cerevisiae**. This yeast has been used by humans throughout recorded history. Other yeasts are important pathogens and cause diseases such as thrush and cryptococcosis; one of them, **candida,** causes a common vaginal infection.

Over the past few decades yeasts have become increasingly important in genetic research.

(3) Basidiomycota:

The basidiomycetes, have about 16,000 named species. More is known about some members of this group than about any other fungi. Among the basidiomycetes are not only the mushrooms, toadstools, puffballs, jelly fungi, and shelf fungi, but also many important plant pathogens among the groups called rusts and smuts. Many mushrooms are used as food, but others are deadly poisonous. Still other species are poisonous to some people and harmless to others.

Basidiomycetes are named for their characteristic sexual reproductive structure, the **basidium**. A basidium is club shaped, like an ascus. Syngamy, or nuclear fusion, occurs within the basidium, giving rise to the zygote, the only diploid cell of the life cycle (Fig. 8.12). As in all fungi, meiosis occurs immediately after the formation of the zygote. In the basidiomycetes, the four haploid products of meiosis are incorporated into basidiospore; in most of the members of this division, the basidiospore are borne at the end of the basidium on slender projections called **sterigmata** (singular: sterigma). In this way the structure of a basidium differs from that of an ascus, although functionally the two are identical. The septum that cuts off the young basidium is initially perforated but often becomes blocked, as it does in the asomycetes.

It has been estimated that a mushroom with a cap that is 7.5 centimetres across produces as many as 40 million spores per hour!

Some species of basidiomycetes are commonly cultivated; for example, the button mushroom, **agaricus campestris**, is grown in more than 70 countries.
Although we are more familiar with the mushrooms, another kind of basidiomycete is represented by the rusts and smuts, which are important plant pathogens.

(4) Deuteromycota (Fungi imperfecti):

Most of the so-called Fungi Imperfecti, are ascomycota that have lost the ability to reproduce sexually. The fungi that are classified in this group, however, are simply those in which the sexual reproductive stages have not been observed.
There are some 17,000 described species of Fungi Imperfecti. Even though sexual reproduction is absent among Fungi Imperfecti, there is a certain amount of genetic recombination. This becomes possible when hyphae of different genetic types fuse, as sometimes happens spontaneously. Within the heterokaryotic hyphae that arise from such fusion, genetic recombination of special kind called **parasexuality** may occur. In parasexuality, the exchange of portions of chromosomes between the genetically distinct nuclei within a common hypha takes place. Recombination of this sort also occurs in other groups of fungi and seems to be responsible for some of the production of new pathogenic strains of wheat rust.
Among the economically important genera of fungi imperfecti are penicillium and aspergillus. Some species of Penicillium are sources of the well-known antibiotic penicillin, and other species of the genus give the characteristic flavours and aromas to cheese. Species of Aspergillus are used for fermenting soya sauce and soya paste, processes in which certain bacteria and yeasts also play important roles. Citric acid is produced commercially with members of this genus under highly acidic conditions. In addition, the enrichment of livestock feed by the products offermentation of other species is being investigated.

8.3 LAND ADAPTATIONS OF FUNGI

Following characteristics enable fungi to live on land.

1. Hyphae that absorb water and soluble nutrients also anchor the plant.

2. Thick-walled drought resistant spores are produced in large number.

3. Instead of forming gametes having flagella, special gametes are produced which need no water for fertilization.

8.4 ECONOMIC IMPORTANCE

In many ways bacteria and fungi are similar in their importance to man. Like bacteria, fungi show both harmful and useful activities to human beings.

8.4.1 Useful Fungi:

a) Food: Many kinds of edible fungi in the form of mushrooms are a source of nourishing and delicious food-dishes. Today they are grown as a crop in many places throughout the world. But one must bear in mind that not all the mushrooms are edible. Some of them are poisonous and popularly called **toad-stools** or **death-stool**. Yeasts, another kind of fungi, are utilized in baking industry. Others are used in brewing and in cheese and organic acid producing industries.

b) Medicines: Fungi have explored a new field in medicine by producing antibiotics like penicillin, chloromycetin, neomycin, terramycin etc.

c) Soil-fertility: They maintain soil fertility by decomposing the dead organic matter e.g. Mycorrhizal fungi.

8.4.2 Harmful Fungi:

a) Food-spoilage: Fungi cause tremendous amounts of spoilage of foodstuff by many of the saprophytic fungi.

b) Human-diseases: Fungi cause a number of diseases in humanbeings like aspergillosis (ear, lungs disease), moniliasis (skin, mouth, gums disease).
Most of the fungi that cause skin diseases in humans, including athlete's foot and ringworm, are also fungi imperfecti.

c) Plant-diseases: Fungi destroy many agricultural crops, fruits, ornamentals and other kinds of plants. Some of the diseases are loose-smut of wheat, downy and powdery mildews etc.

d) Spoilage: Many fungi spoil leather-goods, wool, books, timber, cotton etc.

8.4.3 Economic losses due to Fungi:

Fungi are responsible for many serious plant diseases because they produce several enzymes that can breakdown cellulose, lignin and even cutin. All plants are susceptible to them. Extensive damages due to rusts and smut diseases of wheat, corn and rice prompted mass displacement and starvation to death of many people.
Powdery mildews (on grapes, rose, wheat etc.), **ergot of rye, red rot ofsugarcane,** potato wilt, cotton root rot, **apple scab** and brown rot of peaches,plums, apricots and cherries are some other common plant diseases caused by fungi.
Fungi also cause certain animals diseases. Ring worm and athlete's foot are superficial fungal infections caused by certain imperfect fungi. Candida albicans, a yeast, causes oral and vaginal thrush. **Histolplsmolysis** is a serious infection of lungs caused by inhaling spores of a fungus which is common in soil contaminated with bird's feces. If infection spreads into blood stream and then to other organs (which is very occassional), it can be serious and even fatal. Aspergillus fumigatus caused **aspergillosis**, but only in person with defective immune system such as AIDS and may cause death. Some strains of aspergillus flavus produce one of the most carcinogenic (cancer-causing) mycotoxins (toxins produced by fungi), called **aflatoxins**. Aspergillus contaminates improperly stored grains such as peanuts and corn etc. Milk, eggs and meat may also have small traces of aflatoxins. Any moldy human food or animal forage product should be discarded. **Ergotism** is caused by eating bread made from purple ergot-contaminated rye flour. The poisonous material in the ergot causes nervous spasm, convulsion, psychotic delusion and even gangrene.

Saprobic fungi are not only useful recyclers but also cause incalculable damage to food, wood, fiber and leather by decomposing them. 15-50 percentage of world's fruit is lost each year due to fungal attack. Wood-rotting fungi destroy not only living trees but also structural timber. Bracket/ shelf fungi cause lot of damage to stored cut timber as well as stands of timber of living trees.
A pink yeast (Rhodotorula) grows on shower curtains and ether moist surfaces.

KEY POINTS

- It includes non-chlorophyllus, multicellular (except yeast) organisms having chitinous cell wall and coenocytic body called mycelium.e.g. Agaricus (mushroom) yeast, etc. They are absorptive hetrotrophs.
- There are four major division/phyla of fungi. Zygomycota, Ascomycota, Basidiomycota and Deuteromycota.
- The four divisions of fungi are distinguished primarily by their sexual reproductive structures.
- Sexual reproduction occurs by the fusion of gametangia, which contain numerous nuclei in zygomycota.
- The ascomycota are named for their characteristic reproductive structure, the microscopic, club-shaped ascus.
- Basidiomycetes are named for their characteristic sexual reproductive structure, the basidium.
- Most of the so-called Fungi Imperfecti, are ascomycota that have lost the ability to reproduce sexually. The fungi that are classified in this group, however, are simply those in which the sexual reproductive stages have not been observed.
- Among the economically important genera of **fungi imperfecti** are penicillium and aspergillus.

EXERCISE

1. Encircle the correct choice:

(i) Which chemical substance is more resistant to decay?
(a) Cellulose (b) Cutin
(c) Lignin (d) Chitin

(ii) Zygomycota hyphae have:
(a) No septa (b) Septa
(c) Perforated septa (d) Double septa

(iii) Ascocarp or fixating bodies having small opening at the apex are called:
(a) Opothecium (b) Cleistothecium
(b) Perithecium (c) Porothecium

(iv) Yeast which are unicellular belongs to kingdom:
(a) Prokaryotae (b) Protoctista
(c) Fungi (d) Monera

(v) Most serious plant pathogens e.g. powdery meldew belongs to:
(a) Zygomycota (b) Ascomycota
(c) Basidiomycota (d) Deuteromycota

(vi) Which one is mis-match :

(a)	Zygomycota	Zygospore
(b)	Ascomycota	Club-shaped Ascocarp
(c)	Deuteromycota	No sexual reproduction
(d)	Basidiomycota	Club- shaped basidum

(vii) Which one is not basidiomycota?

(a) Cup-Fungi (b) Jelly-Fungi
(c) Shelf-Fungi (d) Smut-Fungi

(viii) Parasexuality occur in

(a) Zygomycota (b) Ascomycota
(c) Basidiomycota (d) Deuteromycota

(ix) Serious infection of Lungs

(a) Aspergillosis (b) Histoplasmolysis
(c) Moniliasis (d) Amoebiosis

(x) Aspergillus flavus produce carcinogenic toxin called

(a) Aflatoxin (b) Neurotoxin
(c) Haematoxin (d) Mycotoxin

2. Write detailed answers of the following questions:

(i) What are fungi? Describe its one division in detail.
(ii) Write an essay on economic importance of fungi.
(iii) Describe nutrition and reproduction in fungi.
(iv) What do you know about fungi? Describe fungal body and mode of reproduction in fungi.
(v) Give diagnostive features of four classes of fungi.

3. Write short answers of the following questions:

(i) Name the four groups of fungi with their reproductive structures.
(ii) What is the economic importance of yeast?
(iii) Why fungi imperfecti are so called?
(iv) Why fungal non-septate hyphae are called coenocytic?
(v) Why yeast is placed in fungi, when it is unicellular?

4. Define the following terms:

(i) Fungi (ii) Mycelium
(iii) Zygomycota (iv) Ascomycota

5. Distinguish between the following:

(i) Zygomycota and ascomycota.
(ii) Fungi and plants.

Chapter 9

THE KINGDOM PLANTAE

The terrestrial communities founded by plants transformed the biosphere. Consider, for example, that humans would not exist had it not been for the chain of evolutionary events that began when certain descendants of green algae first colonized land.

The evolutionary history of the plant kingdom is a story of adaption to changing terrestrial conditions.

All plants are multicellular eukaryotes that are photosynthetic autotrophs. However, not all organisms with these characteristics are plants: such characteristics also apply to some algae. Plant cells have walls made mostly of cellulose, and plants store their surplus carbohydrate in the form of starch. Plants share even more characteristics with their closest algal relatives, the green algae. For example, the chloroplasts of both green algae and plants contain chlorophyll-**b** as an accessory photosynthetic pigment. (All photosynthetic eukaryotes, remember, usechlorophyll-**a** as the pigment directly involved in conversion of light energy to chemical energy).

So, how do we distinguish plants from multicellular algae? First, plants as we are defining them are nearly all terrestrial organisms, although some plants, such as water lilies, have returned secondarily to water during their evolution. Living on land poses very different problems from living in water, and it is a set of structural, chemical and reproductive adaptations for terrestrial living that distinguishes plants from algae.

In terrestrial habitats, the resources a photosynthetic organism needs are found in two very different places: Light and carbon dioxide are mainly available above the ground, while water and mineral nutrients are found mainly in the soil. Thus the complex bodies of plants show varying degrees of structural specialization into subterranean and aerial organs—roots and leaf-bearing shoots, respectively. In most plants, exchange of carbon dioxide and oxygen between the atmosphere and the photosynthetic interior of leaves occurs via stomata, microscopic pores through the surfaces of leaves.

Terrestrial adaptations of plant structure are complemented by chemical adaptations. For example, aerial parts of most plants, such as leaves, have a waxy coating called a cuticle, which helps to prevent excessive water loss, a major problem on land.

Plants are multicellular photosynthesizers that are adapted to living on land. All plants protect their embryos from desiccation.

The waxes of the cuticle are examples of secondary products, so named because they are not produced by the primary, mainstream metabolic pathways common to all plant.

Another example of secondary products as terrestrial adaptations is lignin, the substance that hardens the cell walls of "woody" tissues in many plants.

A secondary product particularly important in the evolutionary move of plants onto land was **sporopollenin,** a polymer that is resistant to almost all kinds of environmental damage. In fact, the fossil record of plants is due mainly to the durability of sporopollenin, lignin, and the materials of cuticles.

The move onto land paralleled a new mode of reproduction. In contrast to theenvironment in which algae reproduce, gametes now had to be dispersed in a non-aquatic environment, and embryos, like mature body structures, had to beprotected against desiccation.

Early plants produced their gametes within gametangia, organs having protective jackets of sterile (nonreproductive) cells that prevent the delicate gametes from

drying out during their development. The egg is fertilized within the female gametangium, where the zygote develops into an embryo that is retained and nourished for some time within thejacket of protective cells. In contrast, developing algae are not retained as embryos within a parent. This difference is so fundamental that plants are sometimes referred to as embryophytes, a term that emphasizes a key adaptation that contributed to success on land.
Now plants may be defined as multicellular eukaryotes that are photosynthetic autotrophs (Chlorophyllous) with cell wall primarily made up of cellulose, exhibiting heterophorphic alternation of generation and zygote retained and develops into embryo.

9.1 CLASSIFICATION OF PLANTS

Plant biologists use the term division for the major plant groups within the plant kingdom. This taxonomic category corresponds to phylum, the highest unit of classification within the animal kingdom. Divisions, like phyla, are further subdivided into classes, orders, families and genera.
The classification scheme used in this book recognizes two main groups called **bryophyta** (non vascular plants) and **tracheophyta** (vascular plants). This division is based on the presence or absence of vascular tissues.

All plants have a life cycle that shows an alternation of generations; some have a dominant gametophyte and some have a dominant sporophyte.

An outline of classification of Plantae:

Division I:	**Bryophyta** (Non-vascular plants)
Class	Hepaticae (liverworts)
Class	Musci (Mosses)
Class	Anthocerotae (Hornworts)

Division II:	**Tracheophyta** (Vascular plants)
Subdivision	Psilopsida (Psilopsids)
Subdivision	Lycopsida (Club mosses)
Subdivision	Sphenopsida (Horse tails)
Subdivision	Pteropsida (Ferns)
Subdivision	Spermopsida (Seed plants)

9.2 BRYOPHYTES (Bryon = a moss; Phyton = Plant)

Bryophytes are non-vascular plants showingheteromorphic alternation of generation with dominant gametophytes having amphibious nature.
Gametophytes are chlorophyllous, photosynthetic autotrophs having thalloid body or differentiated inrhizoids, pseudo stemand leaves. Sporophytes are semi-parasite on gametophytes having a body differentiated in to foot, seta and capsule.

9.2.1 General Characteristics and Amphibious nature:

The nonvascular plants; liverworts, hornworts and mosses are grouped together in a single division bryophyta (Gr, bryon, "moss").
Bryophytes display a key adaptation that first made the move onto land possible: the embryophyte condition. Their gametes develop within gametangia. The male gametangium, known as an **antheridium**, produces flagellated sperm. In each female gametangium, or archegonium, one egg (ovum) is produced. The egg is fertilized within the archegonium, and the zygote develops into an embryo within the protective jacket of the female organ.
Even with their protected embryos, bryophytes are not totally liberated from their ancestral aquatic habitat. First of all, these plants need water to reproduce: their sperm, like those of most green algae, are flagellated and must swim from the

antheridium to the archegonium to fertilize the egg. For many bryophyte species, a film of rainwater or dew is sufficient for fertilization to occur.
Bryophytes lack the lignin-fortified tissue required to support tall plants on land. Although they may sprawl horizontally as mats over a large surface, bryophytes always have a low profile. Most are only 1-2 cm in height, and even the largest are usually less than 20 cm tall.
There is regular heteromorphic alternation of generation with gametophyte is the dominant generation in the life cycles of bryophytes.

The bryophytes include the inconspicuous liverworts and mosses, plants that have a dominant gametophyte. Bryophytes lack vascular tissue and fertilization requires an outside source of moisture. Windblown spores disperse the species.

9.2.2 Adaptation to Land habitat:

The first evidence that plants had invaded the land from the sea is found in fossils of the Silurian/Devonian periods. All the biologist agree that the land plants and animals evolved from aquatic ancestors. The conquest of the land must have been a long and difficult process. The plants had to become adopted by developing new structures.
Life for aquatic organisms is an easylife. Water is necessary for the growth of all living things and there is little danger in the sea of any lack of water. Carbon containing compounds, so essential for autotrophs, are present abundantly in solution. These autotrophs, in turn, provide a continuous supply of oxygen for all the living organisms in the sea. The temperature in the seas does not fluctuate as much as the temperature on land. Hence, the aquatic environment is more uniform and better supplied with some of the necessities of life than in the rigorous land environment.
When plants invaded the land from the sea, they faced many problems such as of obtaining and conserving water; of absorbing carbon dioxide from the atmosphere for photosynthesis.
To solve these problems, land invading plants adopted themselves first to amphibious-habit and later developed a complete terrestrial form of life. The amphibious form of land plants includes all the bryophytes. We will consider the following adaptive characters exhibited by them.

1.	Rhizoids for water absorption	2.	Conservation of water
3.	Absorption of CO_2	4.	Heterogamy
5.	Protection of reproductive cells	6.	Formation of embryos

1. Rhizoid for water absorption:

The study of Marchantia thallus and other bryophytes show that they have rhizoids for water absorption. These are long, filamentous extensions of the cells of the lower surface of the thallus. They greatly increase the surface for absorption of water from the soil.

2. Conservation of water:

The plant-body called thallus of all bryophytes is multilayered. **Marchantia** is one of the common liverworts. The cross section of this organism shows that its thallus is many cell thick (Fig. 9.1). Of the hundreds of thousands of cells comprising the thallus, only a small percentage have surfaces directly exposed to the drying effects of the atmosphere. Moreover, the outer and uppermost layer of cells is covered with cuticle. It is non-cellular layer of wax-like substance called cutin. This is very efficient in reducing the rate of evaporation and is also found in the stem and leaves of highly evolved land plants.

3. Absorption of CO_2:

Land plants need an efficient means for the exchange of gases with the environment in contrast to aquatic plants which exchange gases dissolved in water. The upper surface of the marchantia thallus is provided with a number of aerating pores. Each pore leads inside into an air-chamber. This is partially filled with branching filaments of photosynthetic cells, CO_2enters through the pores and absorbed by the wet surfaces of the photosynthetic cells in the air chambers and diffuses into the cytoplasm. Because of branching nature of the inner structure of the thallus, the cells present a very large surface area available for the absorption of CO_2. No doubt, at the same time, evaporation of water can occur from the wet surfaces of these cells. To replace this evaporating water, Marchantia has special structures called rhizoids as already mentioned.

4. Heterogamy:

Heterogamy is the most successful kind of reproduction that has evolved in bryophytes. It is defined as production of two different types of gametes, one is male (motile) and the other is female (non-motile) full of stored food.

5. Protection of reproductive cells:

The land environment requires special protection for the reproductive cells. In amphibious plants, reproductive cells are very well protected as in **Funaria** (moss) plant. The male gamete, (sperm) and female gamete, (ovum) are produced in multicellular reproductive sex organs called antheridia and archegonia respectively. These organs are present at the apices of leafy shoots. Moreover, together with these organs, hair like structures called **paraphyses** are also present which help to prevent drying of the sex organs.

6. Formation of embryos:

Embryo formation in amphibious plants is of universal occurrence. The fertilized egg called oospore (zygote) is formed inside the archegonium. An embryo develops from the oospore as it divides, still inside the protective coverings of the archegonia. Thus the coverings formed by the female organ protect the growing embryo from drying out and from mechanical injury.

9.2.3 The three classes of Bryophytes:

1. Hepaticae (Liverworts):

They have been named so because thallus has lobed structure resembling the lobes of liver. Also because the plants were once used to treat complaints of die liver.

Hepaticae have dorsoventrally differentiated, externally simple gametophytes. Sex organs are always formed from superficial cells on the dorsal side. Some time they may develop on special branches called **antheridiophores** and **archegoniophores** Sporophytes are simple having foot, seta and capsule e.g. Ricca, Marchantia, Porella.

2. Musci (Mosses):

The most familiar bryophytes are mosses. In contrast to other bryophytes they grow equally well in fairly dry places. However, water is essential in the reproduction. A mat of moss actually consists of many plants growing in a tight pack, helping to hold one another. Each plant of the mat grips the substratum with rhizoids.

The musci have a gametophyte with transitory prostrate stage called **protonema.** It bears erect sexual branches which continue to grow has independent plants after degeneration of protonema. The sexual branches are differentiated into pseudo stem and leaves. The sporophyte consists of foot, seta and capsule. Capsule has photosynthetic cells, e.g. Funaria, Sphagnum etc.

3. Anthocerotae (Hornworts):

Hornworts resemble liverworts but are distinguished by their sporophytes, which are elongated capsules that grow like horns from the matlike gametophyte (Fig. 9.3) e.g. anthroceros. This is the most advanced group. The sporophyte shows many advanced characters suited for land environment. The sporophyte has stomata and chloroplasts and can undergo photosynthesis. Further more, it has **meristem** which keeps on adding cells. Due to these characters, sporophyte can continue to survive even often the death of gametophyte.

9.2.4 Life cycle of bryophyte (Moss):

All bryophytes show heteromorphic alternation of generation with gametophytes as dominant generation including funaria hygrometrica (a moss). The gametophyte is haploid consisting of rhizoids, pseudo stem and leaves. Gametophytes may be uni or bisexual depending upon whether stem is branched or un branched, the sex organs called **antheridia** (male) and **archegonia** develop at the tips of stem which are always **diocuous** having either male or female sex organs. There is **protoandry** because antheridia mature earlier and liberate their anthrozoids, which start swimming with the help of their flagella in dew or rainwater. When archegonia mature, they have single ovum in the **venter** and few neck canal cells in the neck. Swimming sperms are attracted by scent of sugare cane secereted by mature archegonium but a single antherozoid fuses with the ovum to form **diploid** (2n) oospore (zygote). This is retained within archegonium and form an **embryo** (2n). This embryo undergo repeated mitotic-divisions to form sporogonium (a sporophyte) which is diploid. It consists of foot, seta and capsule. Within capsule spore mother cells are present. Each spore mother cell divides by meiosis to form four haploid spores. Each spore germinates into a filamentous body called **protonema.** Later on gametophyte (haploid) develops from protonema to complete life cycle (fig: 9.4).

9.3 TRACHEOPHYTES

9.3.1 Tracheophyta (The Vascular Plant):

Though most bryophytes live on land, in a sense they are not fully terrestrial. The tracheophytes, by contrast, have evolved a host of adaptations to the terrestrial environment that have enabled them to invade all the most inhospitable land habitats. In the process they have diverged sufficiently from the one another.

9.3.2 Major Groups of Vascular plants:

The major groups of vascular plants are as follows:

1. Subdivision Psilopsida (psilopsids)
2. Subdivision Lycopsida (club mosses)
3. Subdivision Sphenopsida (horse tails)
4. Subdivision Pteropsida (ferns)
5. Subdivision Spermopsida (seed plants)

The subdivisions psilopsida, lycopsida, spheynopsida and pteropsida are non flowering plants and placed under a group called **pteridophyta** (Pteridos = pteris like; phyton = plant). **Spermopsids** have flowers and all have seeds and thus called spermatophyte (Sperma = seed; phyton = plant). Spermopsida are further divided into **gymnosperms** and **angiosperms**.

All members of Tracheophytes (with a few minor exceptions) possess four important characters; i) a protective layer of sterile **jacket** cells around the reproductive organs; ii) multicellular embryos retained within the archegonia, iii) culticles on the aerial parts and iv) xylem. All are four fundamental adaptations for a terrestrial existence. Many other such adaptations, absent in the earliest tracheophytes, appear in more advanced member of the division; a history of the evolution of these adaptations is a history of the increasingly extensive

exploitation of the terrestrial environment by vascular plants. Let us briefly trace the history of adaptation to life on land.

1. Psilopsida:

The oldest undisputed fossil representatives of the vascular plants can be placed late in the Silurain period, which means that they lived more than 395 million years ago, they are classified in the psilopsida, most of whose members lived during the Devonian period and then became extinct for example Rhynia. Two living genera Psilotum and Tmespteris, have traditionally been regarded as members of this ancient group. But recent evidence from, embryology andmorphology ofthe Gametophytes D.W. Bierhorst of the university of Massachusetts has pointed out that they may actually be very primitive ferns. If this is so, then **Psilopsida** contains only extinct species. Whether **Psilotum** and **Mesipteris** should be retained in Psilopsida despite the differences between them and the ancient members of that class, from which they are separated by about 400 million year with no intervening fossils.

The psilopsid sporophytes are simple dichotomously branching plants that lack leaves and have no true roots, although they have underground stems that bear unicellular rhizoids similar to root hairs (Fig. 9.5). The aerial stems are green and carry out photosynthesis. There is no cambium and hence no secondary growth. Sporangia develop at the tips of some of the aerial branches. Within the sporangia meiosis produces haploid spores.

Rhynia Illustrating Vascular Organization:

One of the most primitive vascular plant is Rhynia, which is pteridophyte. Rhynia an extinct-genus, was named often the village Rhynia of Scotland, where the first fossils of Rhynia were discovered. It belongs to Devonian period which started about 400 million years ago. The fossils of this plant are so well preserved that the stomata are still intact.

The plant-body (Sporophyte) of Rhynia was simple (Fig. 9.6-a), it consisted of slender, dichotomously branched creeping rhizome, bearing erect, dichotomously branched aerial stem. Instead of roots, rhizoids were given out from rhizome. The aerial branches were leaf-less having terminal fusiform naked sporangia.

The internal structure of branches show a solid central core of vascular tissue surrounded by Cortex. The outer most layer is Epidermis having stomata. The vascular tissue is differentiated into centrally placed xylem and surrounded by phloem (Fig. 9.6-b).

In**Psilotum** and **Mesipteris** the spores give rise to minute subterranean gametophytes. Each gametophyte bears both archegonia and antheridia and thus produces both eggs and sperm. When the gametes unite in fertilization, they form diploid zygotes that develop into the sporophyte plants described above, thus completing the life cycle. Note that although the diploid sporophyte (stages) is more prominent in the modem genera and hence may be said to be dominant, the haploid gametophyte (stage 2) is still relatively large e.g. Psilophyton (fossil).

EVOLUTION OF THE LEAF

The leaf is the most important organ of a green plant because of its photosynthetic activity. It is very interesting to trace the origin of leaf in the green plants.

The evolution of one-veined leaf (microphyllous) can be explained by assuming that a thorn like outgrowth (Enation) emerged on the surface of the naked stem. With an increase in size of the out growth, the vascular tissues were also formed for the supply of water and support to the leaf. Another possibility is that a single veined leaf originated by a reduction in size of a part of the leafless branching system of the primitive vascular plant. This is how the leaf of Lycopodium (club mosses) and equistium (horse tail) came into existence (Fig. 9.7).

Many veined leaf (megaphyllous) originated much later. These are the evolutionary modifications of the forked branching system in the primitive plants. The first step in the evolution of this leaf was the restriction of forked branches to a single plane. The branching system became flat. The next step in the evolution was filingthe space between the branching and the vascular tissue. The leaf so formed looked like the web foot of a duck (Fig. 9.8).

2. Lycopsida (The Club Mosses):

The first representative of Lycopsida appeared in the middle of the Devonian period, almost 10 million years after the first psilopsida. During the late Devonian and the Carboniferous periods these were among the dominant plants on land. Some of them were very large trees that formed the earth's first forests. Toward the end of the Paleozoic era, however, the group was displaced by more advanced types of vascular plants, and only five genera are alive today. Two of these, Selaginella and Lycopodium (often-called running pine or ground pine), are common in many parts of the Pakistan (Fig. 9.9-a).

The vascular plants evolved during the Silurian period. They are the most diverse and widely distributed of the plants.

Unlike the Psilopsids, Lycopsids (Fig. 9.9-b) have true roots. It is generally supposed that these arose from branches of the ancestral algae that penetrated the soil and branched underground. Lycopsids also have true leaves, which are thought to have arisen as simple scale like outgrowth (emergence) from the outer tissues of the stem.

Certain of the leaves that become specialized for reproduction bear sporangia on their surfaces. Such reproductive (fertile) leaves are called sporophylls. In many Lycopsids the sporophylls are congregated on a short length of stem and form a cone like structure (strobilus) (Fig. 9.9-c). The cone is rather club-shaped; hence the name "Club Mosses" for the Lycopsids, though Lycopsids are not related to the true mosses, which are bryophytes.

The spores produced by **Lycopodium** are all alike, and each can give rise to a gametophyte that will bear both archegonia and antheridia. However, some Lycopsids (e.g. **Selaginella**) have two types of sporangia, which produced different kinds of spores. One type of sporangium produces very large spores called megaspores, which develop in female gametophytes bearing archegonia; the other type produces small spores called microspores, which develop into male gametophytes bearing antheridia. Plants like Lycopodium that produce only one kind of spore, and hence have only one kind of gametophyte that bears both male and female organs, are said to be **homosporous**. Plants like Selaginella that produces both magaspores (female) and microspores (male) i.e. in which the sexes are separate in the gametophyte generation are said to be **heterosporous**.

Evolution of Seed:

We have studied in Selaginella that two types of spores are present. One is smaller in size called microspore and the other bigger in size called megaspore. This type of condition is known as **heterospory**. These spores have different functions to perform. Instead of growing into a gametophyte of similar structure, the heterosporous plants produce two different gametophytes. Microspore grows into a sperm forming gametophyte. The other kind megaspore, grows into egg forming gametophyte. The two kind of spores are formed in two different kinds of sporangia. These like the sporangia of club mosses, horse tails and ferns have become protected as a result of the evolution of various enveloping structures. The carboniferous era reveals some fern like plants that bore scale like structures. Each of their sporangia containing one or more spores was nearly surrounded by outgrowth from the sporophyte. These outgrowth were little

branch like structures which during evolution have become fused as an envelop or integument around the sporangia.
In contrast with other green plants, in the seed plants megaspores are retained and protected inside the integumented sporangia. They develop into active female gametophyte protected by integument. There are three steps in the evolution of seed: (1) Origin of heterospory, (2) Development of integument for the protection megasporangia of and (3) Retention of the mature megaspores in the sporangia to develop female gametophyte. The examination of immature seed reveals, that integument is not only a protective covering but also a food supplying organ to the female gametophyte. The development of seed has given the vascular plants better adaptation to their environment.

3. Sphenopsida (The Horse tails):

The Sphenopsides first appeared in the fossil record late in the Devonian period. They became a major component of the land flora during the Carboniferous period and then declined. Members of the one living genus, **Equisetum** (Fig. 9.10-a), are commonly called horse tails. Though most of these are small (Less than one meter), some of the ancient sphenopsids were large trees (Fig.9.10b). Much of the coal we use today was formed from the dead bodies of these plants.
Like the lycopsids, sphenopsids possess true roots, stems and leaves. The stems are hollow and are jointed. Whorls of leaves occur at each joint (Fig.9.10-a). Many of the extinct sphenopsids had cambium and hence secondary growth, but the modern species do not. Spores are borne in terminal cones (Strobili). In Equisetum all spores are alike (i.e. the plants are homosporous) and give rise to small gametophytes that bear both archegonia and antheridia (i.e. the sexes are not separate) e.g. Sphenophyllum.

4. Pteropsida (The Ferns):

In the opinion of many biologists, the ferns evolved from the Psilosida. They first appeared in the Devonian period and greatly increased in importance during the Carboniferous, period. Their decline late in the Paleozoic era was much less severe than that of the Psilopsids, Lycopsids and Sphenopsids. There are many modem species belonging to this group. The ferns are fairly advanced with a very well developed vascular system and with true roots, stems and leaves. The leaves are thought to have arisen in another way than those of the Lycopsids. Instead of emergence, they are probably flattened and web branched stems, i.e. a group of small terminal branches probably became arranged in the same plane and the interstices filled with tissue. Such leaves are large and provide a muchgreater surface area for photosynthesis, than the emergence leaves of the Lycopsids and Sphenopsids.
The leaves of ferns are sometimes simple, but more often they are compound being divided into numerous leaflets. In a few ferns (e.g. the large trees ferns of the tropics), the stem is upright, forming a trunk. But in most modern ferns, specially those of temperate regions, the stems are prostrate on or in the soil, and the large leaves are the only parts normally seen.

In the non seed vascular plants, such as fern, there is a dominant vascular sporophyte, which produces windblown spores. These plants have an independent nonvascular gametophyte, and flagellated sperm swim in external water to reach the egg.

The large leafy fern plant is the diploid sporophyte phase (Fig. 9.1 l-a).Spores are produced in sporangia located in clusters on the underside of some leaves (Sporophylls) (Fig. 9.11-b). In some species the sporophylls are relatively little modified and look like the nonreproductive leaves. In other species the sporophylls look quite different from vegetative leaves. Some times they are so

highly modified that they do not look like leaves at all forming spike like structures instead.
Most modern ferns are homosporous i.e. all these spores are alike. After germination, the spores develop into gametophytes that bear both archegonia and antheridia (Fig. 9.11-c), these gametophytes are tiny (less than one centimetre wide), thin and often more less heart-shaped.
In some respect, the ferns (and also the three primitive groups of vascular plants discussed above) are no better adapted for life on land than the bryophytes. Their vascularized sporophytes can live in drier places and grow bigger, but for a number of reasons-because their non-vascularized free-living gametophytes can survive only in moist places, their sperms are flagellated and must have a film of moisture through which to swim to the egg cells in the archegonia, and because the young sporophyte develops directly from the zygote without passing through any protected seed like stage—these plants are most successful only in those habitats where there is at least a moderate amount of moisture e.g.Pteris.

Life cycle of a fern:
The life cycle of fern (Adiantum) or dryopteris shows heteromorphic alternation of generation in which sporophytic-phase is dominant. All ferns are homosporous producing single types of spores.
The sporophyte (2n) which is diploid, consist of adventitious roots, underground stem a rhizome and pinnately compound leaves.
Reproduction takes place by means of haploid-spores formed from the spore-mother cells after meiosis inside sporangium. A number of sporangia develope inside single **sorus.**
The **sori** (plural of sorus) are green but when ripe, they become dark brown. The leaves of bearing sori are called sporophyll.
Each sporangium consists of a stalk called **sporangiophore** and a biconvex capsule consisting of **annulus** and **stomium**. The annular cells are thickened whereas stomial cells are thin-walled. Within sporangium spore mother cells are present. Each spore mother cell divides by meiosis to form four haploid spores. The spores are liberated through stomium.
Each spore on germination gives rise to miniature bisexual gametophyte called **prothallus.**
The prothallus is independent autotropic, heart shaped, dorsoventrally flattened lying prostrate on some wet substratum. It is fixed to soil whit the help of rhizoid which absorb water and nutrients. The prothallus is monoecious having archegonia and antheridia on the same prothallus.
Archegonium consists of venter with an ovum and a neck and secrete malic acid at maturity. Each antheridium produces a number of antherozoids (sperms): A number of sperms, by making chemotactic movement in water reach to the archegonium. Only one sperm fuses with ovum to form oospore (zygote) which is diploid. Young sporophyte develops from the oospore. In the meantime, prothallus degenerate, in this way life cycle is completed (Fig. 9.12).

5. Spermopsida (The Seed plants):
The seed plants have been by far the most successful in fully exploiting the terrestrial environment. They first appeared in the late Devonian, and in the Carboniferous they soon replaced the lycopsids and sphenopsids as the dominant land plants, a position they still hold today. In these plants the gametophytes are even more reduced than in the ferns, they are not photosynthetic or free-living, and the sperms of most modern species are not independent free-swimming flagellated cells. In addition, the young embryo, together with a rich supply of nutrients, is enclosed within a desiccation-resistant seed coat and can remain dormant for extended periods if environmental conditions are unfavourable.
The seed plants have traditionally been divided into two groups, the Gymnospermae and the Angiospermae.

i) The Gymnosperms: (Gymnos = Naked; Sperma = Seed)

They have naked seeds because ovules are not covered by ovary. The first gymnosperms appeared in the fossil record in the late Devonian, some 350 million years ago. Many of those first seed plants had bodies that closely resembled the ferns, and indeed for many years their fossils were thought to be fossils of ferns. Slowly, however, evidence accumulated that some of the "ferns" that were such important components of the coal-age forests produced seeds, not spores. Today these fossil plants, usually called the seed ferns, are grouped together as the class Pteridospermae of the subdivision Spermopsida. No members this class survive today.

Another ancient group, the cycads and their relatives, may have arisen from the seed ferns. These plants first appeared in the Permian period and became very abundant during the Mesozoic era. They had large palm like leaves; the palm like plants so often shown in pictures of the dinosaur age are usually cycads, not true palms. The cycads declined after the rise of angiosperms in the cretaceous period, but nine genera containing over a hundred species are in existence today (Fig. 9.13). They are generally called sago palms and are fairly common in some tropical regions.

The Ginkgoae are still another widespread group now nearly extinct. There is only one living species, the Ginkgo (Fig. 9.14) or maidenhair tree, often planted as a lawn tree, but almost unknown in the wild.

By far the best-known group of gymnosperms is the conifers. The leaves of most of these plants are small evergreen needles or scales with an internal arrangement of tissues that differs somewhat from that in angiosperms.

Gymnosperms:	
Cycads (division Cycadophyta)	Ginkgo (divisionGinkgophyta)
Gnetae (division Gnetophyta)	Conifers (division Coniferophyta)

Let us follow in some detail the life cycle (Fig. 9.15) of **Pinus longifolia** (pine tree) as an example of the seed method of reproduction. The large pinus tree is the diploid sporophyte stage. This tree produces reproductive structures called **cones**, of which there are two kinds: large female cones (Fig. 9.16), in whose sporangia meiosis gives rise to haploid megaspores, and small male cones, in whose sporangia meiosis gives rise to haploid microspores (Fig. 9.17). (Production of distinctive male and female spores, heterospory is characteristic of all seed plants, both gymnosperms and angiosperms.) In both kinds of cones the sporangia are produced by highly modified leaves (sporophylls).

Each scale (megasporophyll) of a female cone bears two sporangia on its upper (adaxial) surface. Meiosis takes place inside the sporangium, producing four haploid megaspores, three of which soon disintegrate. Next, the single remaining megaspore gives rise, by repeated mitotic divisions, to a multicellular mass, which is the female gametophyte (megagametophyte). When mature, the female gametophyte produces two to five tiny archegonia at its micropylar end. Egg cells develop in the archegonia. Note that the megaspore is never released from the sporangium, and that the female gametophyte derived from it remains embedded in the sporangium, which is still attached to the cone scale. The composite structure consisting of integument, sporangium, and female gametophyte is called an **ovule**.

Each of the many microspores produced by meiosis in a sporangium of a male cone becomes a **pollen grain** (Fig. 9.18). It develops a thick coat, which is highly resistant to loss of water, and wing like structures on each side, which helps its dispersal by wind. Within the pollen grain the haploid nucleus divides mitotically, walls develop around each daughter nucleus. In this manner the pollen grain becomes four-celled (Fig. 9.18). Two of the cells soon degenerate; the two cells that remain are called the generative cell and the tube cell. The mature pollen grain is released from the cone when the sporangium bursts. A single male cone

may release millions of tiny pollen grains, which may be carried many miles (sometimes as many as a hundred) by the wind. Note that the pollen grains are multicellular haploid structures (if four cells may be said to be "multi") and that they constitute the male gametophyte (microgametophyte) in (Fig. 9.18).

Among the first seed-producing plants were the gymnosperms, which produce naked seeds. The 4 divisions of these plants are probably not closely related.

Most of pollen grains released by a pine tree fail to reach a female cone. But of the few that sift down between the scales of a female cone, some land in a sticky secretion near the open micropylar end of an ovule. As this secretion dries, it is drawn through the micropyle, carrying the pollen grains with it. The arms of the integument around the micropyle then swell and close the opening. When a pollen grain comes in contact with the end of the sporangium just inside the micropyle, it develops a tubular outgrowth, the **pollen tube**. The nucleus of the tube cell enters the tube, followed by the generative cell. The generative cell then divides, and one of the daughter cells thus produced divides again, producing two sperm cells. Thus a germinated pollen grain contains four active nuclei plus the two nuclei of the degenerated cells; this six-nucleate condition is the male gametophyte.
The pollen tube grows down through the tissue of the sporangium and penetrates into one of the archegonia of the female gametophyte. There it discharges its sperm cells, one of which fertilizes the egg cell. The resulting zygote then divides mitotically to produce a tiny embryo sporophyte consisting of a hypocotyl and an epicotyl. The embryo is still contained in the female gametophyte, which is itself contained in the sporangium. Finally, the entire ovule is shed from the cone as a **seed**, which consists of three main components: a seed coat derived from the old integument stored food material derived from the tissue of the female gametophyte, and an embryo.

A conifer it the most typical example of a gymnosperm. In the conifer life cycle, windblown pollen grains replace swimming sperm. Following fertilization, the seed develops from the ovule, a structure that has been protected with in the body of the sporophyte plant. The seeds are uncovered and dispersed by the wind.

ii) The Angiosperms: (Angion = Cup or Vessel (Fruit) Sperma = Seed)

They have their seeds enclosed in fruit because ovules are covered by ovary. These plants became the dominant land flora of the Cenozoic era. The reproductive structures of angiosperms, are flowers and the ovules are enclosed within modified leaves called carpels
Flower may be described as compressed reproductive shoot with four whorls of modified (floral) leaves called sepals, petals, stamens and carples; and which often pollination and fertilization produces seeds within fruits.

The angiosperms became the dominant land plants in the Cenozoic era. They have flowers, which attract pollinators and produce seeds enclosed by fruits. Also, their vascular tissue is more complex than that of the gymnosperms.

A flower is generally interpreted as a short length of stem with modified leaves attached to it The modified leaves of a typical flower (Fig. 9.20) occur in four sets attached to the enlarged end thalamus (receptacle) of the flower stalk: (1) The **sepals** enclose and protect all the other floral parts during the bud stage. They are usually small, green, and leaf like, but in some species they are large and brightly coloured. All the sepals together form the **calyx**. (2) Internal to the sepals are the **petals,** which together form the **corolla**. In flowers pollinated by insects, birds, or other animals, the petals are usually quite showy, but in those,

pollinated by wind they are often reduced or even absent (3) Just inside the circle of the corolla are the **stamens**, which are the male reproductive organs: i.e. they are the micro-sporophylls that produce the microspores. All the stamens together form the androecium. Each stamen consists of a stalk, called**filament,** and a terminal ovoid pollen-producing structure called an **anther**. (4) In the centre of the flower is the female reproductive organ, the **pistil** or **carpel** (some species have more than one pistil per flower). All the carpels together form the gynoecium. Each pistil consists of an **ovary** at its base, a slender stalk (more than one in some species) called **style,** which arises from the ovary, and an enlarged apex called **stigma**. The pistil is derived from one or more sporophylls, which in flowers are called **carpels.** All four kinds of floral organs, sepals, petals, stamens and carpels are present in so-called complete flowers, but some flowers, which are said to be incomplete, lack one or more of them.

Within the ovary are one or more (at least one for each carpel) mega sporangia, called **ovules,** which are attached by short stalks to the wall of the ovary. Meiosis occurs once in each ovule, with the formation of four haploid megaspores, three of which usually soon disintegrate. The remaining megaspore then divides mitotically three times, producing, in most species, a structure composed of seven cells, one of which is much larger than the others and contains two nuclei, called polar nuclei (Fig. 9.23). This haploid seven celled eight-nucleate structure is the much-reduced female gametophyte (often called an embryo sac). One of the cells located near the micropylar end will act as the egg cell.

Each anther has four micro sporangia in each of which many cells undergo meiosis, producing numerous haploid microspores. The wall of each microspore thickens, and the nucleus divides mitotically, producing a generative nucleus and a tube nucleus. The resulting thick-walled two-nucleate structure is a pollen grain, a male gametophyte, which is released from the anther when the mature micro sporangium splits open.

In angiosperms, the reproductive structures are located in the flower, which consists of highly modified leaves.

A pollen grain germinates after pollination (transfer of pollens from anther to stigma) when it falls (or is deposited) on the stigma of a pistil, which is usually rough and sticky. A pollen tube begins to grow, and the two nuclei of the pollen grain move into it. The generative nucleus (which is surrounded by a plasma membrane and is thus technically a cell, though with virtually no cytoplasm) then divides, giving rise to two sperm cells. The pollen tube grows through the tissues of the stigma and style and enters the ovary with tube nucleus at its tip. When the tip of the pollen tube reaches an ovule, it enters the micropyle and then discharges the two sperm cells into the female gametophyte (embryo sac). One of the sperm fertilizes the egg cell, and the zygote thus formed develops into an embryo sporophyte. By the time fertilization occurs, the two polar nuclei of the female gametophyte have combined to form a diploid **fusion nucleus,** with which the second sperm unites, to form a triploid nucleus. This nucleus undergoes a series of division, and a triploid tissue, called **endosperm**, is formed. The endosperm functions in the seed as a source of stored food for the embryo.

Double fertilization is a special type of fertilization which occurs only in angiospermic plants. During this process a sperm fuses with the ovum to form oospore. The other sperm fuses with secondary nucleus to form triploid endosperm nucleus.

After fertilization, the ovule matures into a seed, which, as in pine, consists of seed coat stored food, and embryo. However, the angiosperm seed differs from that of pine in being enveloped by the ovary. It is the ovary that develops into the fruit, usually enlarging greatly in the process. Sometimes other structures associated with the ovary, such as the receptacle, are also incorporated into the fruit. The ripe fruit may burst, expelling the seeds, as in peas (where the pod is

the fruit). Or the ripe fruit with the seeds still inside may fall from the plant, as in tomatoes, squash, cucumbers, apples, peaches. The fruit not only helps to protect the seeds from desiccation during their early development, before they have fully ripened, but often also facilitates their dispersal by various means, the wind, say or an animal, which, attracted by the fruit, carries it to other locations or eats both fruit and seeds and later releases the unharmed seeds through its faeces. The life cycle of an angiosperm is shown in Fig. 9.22.

9.4 SPERMOPSIDA AS SUCCESSFUL GROUP OF LAND PLANTS

Having studied representatives of the major groups of land plants we can return to consider why the conifers and angiosperms are so well adapted to life on land. Their major advantage over other plants is related to their reproduction. Here they are better adapted in three important ways.

(1) The gametophyte generation is very reduced. It is always protected inside sporophyte tissue, on which it is totally dependent. In mosses and liverworts, where the gametophyte is conspicuous, and in ferns where it is a free-living prothallus, the gametophyte is susceptible to drying out.

(2) Fertilization is not dependent on water as it is in other plant groups, where sperms swim to the ovum. The male gametes of seed plants are non-motile and are carried within pollen grains that are suited for dispersal by wind or insect. Final transfer of the male gametes after pollination is by means of pollen tubes, the ova being enclosed within ovules.

(3) Conifers and flowering plants produce seeds. Development of seeds is made possible by the retention of ovules and their contents on the parent sporophyte.

Other ways in which spermatophytes are adapted to life on land are summarised below:

(a) Xylem and sclerenchyma are lignified tissues providing support in all vascular plants. Many of these show secondary growth with deposition of large amounts of wood (secondary xylem). Such plants become trees or shrubs.

(b) True roots, also associated with vascular plants to absorb soil water efficiently.

(c) The plant is protected from desiccation by an epidermis with a waterproof cuticle, or by cork after secondary thickening has taken place in dicot stems.

(d) The epidermis of aerial parts, particularly leaves, is perforated by stomata, allowing gaseous exchange between plant and atmosphere.

(e) Plants show many other adaptations to hot dry environment.

9.5 GENERAL ACCOUNT OF ROSACEAE, SOLANACEAE, LEGUME FAMILIES(FABACEAE, CAESALPINLACEAE, MIMOSACEAE) POACEAE WITH EMPHASIS ON FLORAL PARTS

1. ROSACEAE: Rose Family

It has about 100 genera and 2000 species, found growing all over the earth. 213 species of about 29 genera are reported from Pakistan.

Inflorescence: Variable, solitary flowered to racemose and cymose cluster.

Flowers: Bisexual and actinomorphic, hypogynous to epigynous.

Calyx: Sometimes epicalyx is present-sepals 5 free or fused.

Corolla: Petals 5, or numerous in multiple of 5, free imbricate rosaceous, large and showy and usually conpicuous.

Androecium: Numerous stamens, sometimes only 5 or 10 free usually bent inward in the bud state; anther small.

Gynoecium: A simple pistil of 1 to numerous separate carpels or 2 to 5 carpels, united into a compound pistil, often adinate to the calyx tube; ovary superior to inferior; ovules usually 2 or more per carpel; plancentation basal when the carpel is one or apocarpous, but axile when the carpels are many and syncarpous; style simple, as many as the carpels, free or united, stigma linear, spathulate or capitate.

Diagnostic characters: Rosaceous corolla, stamens numerous, polyandrous, monocarpellary or polycarpellary syncarpous may be apocarpous.

Economic importance:
Economic importance of this family is great in providing the pleasure and welfare of mankind. The members of this family are important in temperate regions for fruit and ornamentals. Perhaps, they rank third in commercial importance in the temperate zone among the families of flowering plants.
A large number of plants are ornamental and all grown in gardens for their beautiful and scented flowers. Perhaps the most widely cultivated genus for decorative purpose is Rosa. Many others genera are also grown for their beautiful flowers in the parks and gardens.
The branches of crataegus and cotoneaster provide excellent walking sticks and wood. The wood of Pyruspastia is used for making tobacco pipes.
In Asian countries the petals of common rose usually called gulabs are used in making gulkand, and are also used in extraction of an essential oil, rose oil, used as perfume when distilled with water the petals give Rose-water or Ark-Gulab, which is used in eye disease, and for many other purpose.

Familiar Plants:

Botanical names		Common names	Local names
1.	Pyrus malus	Apple	Seb
2.	Pyrus communis	Pear	Nashpati
3.	Prunus persica	Peach	Aru
4.	Prunus amygdalus	Almond	Badam
5.	Rosa indica	Rose	Gulab

2. SOLANACEAE: Night shade or Potato family
It has about 2000 species belonging to about 90 genera found growing in tropical and temperate regions. 52 species belonging to about 52 genera have been reported from Pakistan.

Inflorescence: Typically an axillary cyme.

Flowers: Bisexual usually actinomorphic or weakly zygomorphic bracteate or ebracteate, hypogynous, usually penatamerous.

Calyx: 5 united sepals, usually persistant.

Corolla: 5 united petals, corolla rotate, tubular or infundibuliform.

Androecium: 5 Stamens, polyandrous, epipetalous inserted on the corolla tube and alternate with its lobes, filament usually of unequal length.

Gynoecium: Bicarpellary syncarpous, ovary obliquely placed, superior bilocular or Imperfectly tetra-locular by false septum, style terminal, simple or lobed, placentation axile, ovule numerous.

Diagnostic characters: Flower actinomorphic penta-merous, stamen 5, epipetalous ovary bi-locular, obliquely placed, placentation axile, fruit berry or capsule.

Economic importance:
Members of the family solanaceae provides drugs and food, some are weedy, some are poisonous, and others are handsome ornamentals. The most important plants in the family are potato and tomato.
Other important food plants are egg plant or brinjal vern; bengan, the fruit of capsicum and capsicum frutenscens are rich in vitamin C and A, are used as condiment. Physalis (Ground-cherry vern. Rasbhari) produces an edible fruit enclosed in a bladder-like persistant calyx the husk, hence the name husk tomatoes.
Another plants of great commercial value is tobacco plant leaves of which are dried and made into tobacco, which is used in making cigarettes. Many members of this family yield powerful alkaloids, e.g. Atropa belladonna, Datura (james town weed) which are rich in atropine and daturine respectively, which are used medicinally.
Many plants are cultivated in the gardens for their beautiful flowers, these includes Petunia, Nicotiana, Cestrum Schizanthus, Brunfelsia Solanum etc.

Familiar Plants:

Botanical names		**Common names**
1.	Solanum tuberosum	Potato
2.	Solanum melongena	Brinjal
3.	Lycopersicumesculentum	Tomato
4.	Capsicum annum	Red-pepper
5.	Petunia alba	Petunia
6.	Solanum nigrum	Black Night shade
7.	Datura alba	Thorn apple
8.	Nicotiana tabacum	Tobacco
9.	Atropa belladonna	Deadly Nightshade
10.	Cestrum nocturnum	Lady of the night

3. LEGUME FAMILIES

(A) FABACEAE: Papilionaceae /Pea family

It has about 9000 spectra belonging to 400 genera found distributed to all parts of the world, 587 species of 82 genera have been reported from Pakistan.

Inflorescence: Racemose or solitary axillary.

Flowers: Bisexual, isomorphic, bracteate, pedicellate, hypo-to perigynous.

Calyx: 5 sepals, more or less united in a tube, mostly hairy.

Corolla: Papilionaceous, Petals 5, the odd outer petal is large and conspicuous and is called standard orvexillum, two lateral ones fire called wings and 2 anterior

inner most that fuse to form a boat-shaped structure called the keel or carina, descendingimbricate.

Androecium: 10 stamens, mostly diadelphous nine fused to form sheath round the pistal, while 10th posterior one is free.

Gynoecium: A simple pistil 1- carpeled, with 1 - locule; ovary superior; ovule 1 or more;style long, bent at its base flattened and hairy, stigma simple.

Diagnostic character: Papilionanaeous corolla, 10 stamens, diadelphous, monocarpellary.

Economic Importance:
The family is of considerable importance as a source of high-protein food, oil and forage as well as ornamentals and other uses. Main importance lies in the pulses, belonging to this family, and are used as food, some important and common species of pulse yielding plants are:-
Cicer arietinum (gram or thick Pea vern. Channa), Pisum Satinvum (Pea vern. Muttor), Lens esculanta (ver. Masure), Phaseolus aureus (mung beans vern. Mung), Phaseolus mung (vern. Mash or urad), Phaseolus vulgaris (kidney bean). These pulses are rich in protein contents.
Medicago Sativa Alfalfa vern. Lusan is one of the worlds best forage crop for horses. Vicia, Melilotus and Trifolium are also cultivated as main fodder crops. Many trees of this family provide excellent timber for building, furniture and fuel. Main timber plants are butea, Dilburgia etc.
The seed of Arachis hypogea Peanut or moong phali are edible and also used for extraction of Peanut oil which after hydrogenation is used as a vegetable oil. Indigo dyes are obtained from indigofera tinctoria (vern. Neel) and Butea monosperma, yielding yellow dye from flowers.
Many plants of this family are important for medicines, these include Glycyrrhiza glabra for cough and cold, clitoria termatea used against snake bite. The red and white seeds of Abrus precatorious are used by jewellers as weights called ratti. Some important ornamental plants includes Lathyrus, Lupinus, Clitoria, Butea etc.

Familiar Plants:

Botanical names		**Common names**
1.	Lathyrus odoratus	Sweet-pea
2.	Arachis hypogea	Pea-nut
3.	Cicer arietinum	Gram
4.	DalbergiaSisso	Red-wood
5.	Pisum sativum	Edible-pea
6.	Sesbania aegyptica	Sesbania

(B) CAESALPINIACEAE: Casia family
It has about2300 species belonging to 152 genera have been reported all over the world. 60 species belonging to 16 genera have been reported from Pakistan.

Inflorescence: Axillary or terminal raceme.

Flowers: Bisexual, zygomorphic, rarely actinomorphic, perigynous.

Calyx: Of 5 sepals free, or connate at base, imbricate or rarely valvate, often coloured.

Corolla: Of mostly 5 petals, free, imbricate, the posterior petal inner most in bud.

Androecium: Of 10 stamens or fewer, rarely numerous free or variously connate, extra staminal disc sometimes present; sometimes staminodes present.

Gynoecium: A simple pistil of 1 carpel; ovary superior, unilocular placentation marginal; ovule 1-many;-style 1 simple, long; stigma simple.

Diagnostic characters: 5 polysepalous, 5 polypetalous, 10 stamens, polyandrous few stamenodous, monocarpellary.

Economic Importance:
The family is of great importance. Some plants are ornamental, some have medicinal importance, a few have food and other values.
The leaves of cassia fistula are used to cure ring worm and skin diseases.C.senna and C.obovata are cultivated for the leaves which yield the drug senna, which is the base for a laxative. Oil extracted from the seeds of cynometera cauliflora is applied externally for skin diseases.
Common ornamental plants are Bauhinia variegata (Kachnar) cassia fistula (Amaltas), Parkinsonia, poinciona regia.
The leaves and flowers bud of Bauhinia varigata are used as vegetable. The acidic fruit of Tamarindus indica are edible and are rich in tartaric acid. The bark of Bauhinia perpurea Tamarindus indica are used in tanning. The heart wood of Haematoxylon (Long wood) yield the dye hematoxylin.

Familiar Plants:

Botanical names		Common names	Local names
1.	Tamarindus indica	Tamarind	Imli
2.	Cassia fistula	Amaltus	
3.	Bauhinia verigata.	Camel's foot	Kachnar
4.	Poinciana regia	Flame of the forest	Gul-e-mohar
5.	Parkinosia roxburgai	Vilayati Kikar	

(C) MIMOSACEAE: Acacia Family
It has about 3000 species belonging to 56 genera are found growing in the world. 49 species of 11 genera have been reported from Pakistan.

Inflorescence: Racemose.

Flowers: Actinomorphic, bisexual, Hypogynous, bracteate; bract small.

Calyx: Usually of 5 sepals imbricate or valvate, generally fused toothed or lobed, mostly green.

Corolla: 5 petals, valvate, free or fused, corolla lobed.

Androecium: 5 to numerous stamens, free monadelphous, adnate to the base of corolla; anther versatile often crowned by a decidous gland.

Gynoecium: A simple pistil of I carpel, ovary unilocular superior ovules many, placentation marginal, style long filiform, stigma terminal minute.

Diagnostic characters: 5 fused sepals, 5 free or fused petals, androecium monoadelphous monocarpellary.

Economic importance:
Many trees of this family including species of Acacia, Albizzla and Xylia provide commercially important wood, which is used for construction purpose or for

furniture or as a fuel. The wood of Albizzla lebbek is used in cabinet work and railway carriages.
Arabic gum is obtained from Acacia nilotica and A. Senegal Katha a dye is obtained from Acacia catechu. The tender leaves of Accacia nilotica are used as blood purifier.
Some common garden Plants grown for their beautiful flowers Mimosa Pudica, Acacia melanoxylon. A few species of Prosopis are planted in the arid zones for breaking the wind pressure.

Familiar Plants:

Botanical names	**Common names**	**Local names**
1. Acacia nilotica	Gumtree	Bauble, Kikar
2. Albizzia lebbek	Siris	
3. Mimosa pudica	Touch-me-not	Chhui mui
4. Prosopisglandulosa	Prosopis	Devi
5. Acacia catechu	Katha plant	

(D) POACEAE/GRAMINAE: Grass family
It has about 3000 species belonging to 56 genera are found growing in the world. 49 species of 11 genera have been reported from Pakistan.

Inflorescence: Composed of units called spikelets, variously arranged, spikelets consisting of bracts, distichoisly arranged along a slender axis (rachilla) the two lower bracts (glumes) which are empty.

Flowers: Bisexual or unisexual, zygomorphic, hypogynous, protected by palea. Perianth is represented by to minute scales called the **Lodicules** (may be absent).

Androecium: It has usually 3, or 6 stamens, anthers versatile and pendulous.

Gynoecium: It is tricarpellary syncarpous or monocarpellary, ovary unilocular superior, styles may be 2, stigmas feathery.

Diagnostic characters: Perianth, 3 to 6 stamens free, versatile anthers, gynoecium monocarpellary flowers are unisexual.

Economic Importance:
This family has the great economic importance as it provides food, fodder, ornamentals etc. Cereals and millets which are chief food stuff of mankind belong to this family, like Wheat, Oats, Rice, Corn, Barley, Millets-Jawar, Bajra, Guar etc. Sugar is obtained from sugar-cane, bamboo-shoots are eaten as a vegetable or soup dish. Nearly all the cereal and millet crops are given to animals as fodder.

Familiar plants:

Botanical names	**Common names**
1. Triticum indicum	Wheat
2. Avena sativa	Oats
3. Zeamays	Indian Corn
4. Oryza sativa	Rice
5. Saccharum officinarum	Sugar-cane
6. Hordeum vulgare	Barley
7. Pennisetum typhoideum	Bajra

KEY POINTS

- Plants may now be denned as multicellular eukaryotes that are photosynthetic autotrophs where the zygote develops into an embryo.
- The gametophyte is the dominant generation in the life cycles of bryophytes.
- Heterogamy is the most successful kind of reproduction that has evolved in bryophytes. It is defined as production of two different types of gametes, one is male (motile), and the other is female (non-motile) full of stored food.
- The first representative of Lycopsida appeared in the middle of the Devonian period, almost 10 million years after the first psilopsida.
- The Sphenopsides first appeared in the fossil record late in the Devonian period. They became a major component of the land flora during the Carboniferous period and then declined. Members of the one living genus, **Equisetum.**
- In the opinion of many biologists, the ferns evolved from the Psilosida. They first appeared in the Devonian period and greatly increased in importance during the Carboniferous period. Their decline late in the Paleozoic era was much less severe than that of the Psilopsids, Lycopsids and Sphenopsids.
- The seed plants have been by far the most successful in fully exploiting the terrestrial environment. They first appeared in the late Devonian, and in the Carboniferous they soon replaced the lycopsids and sphenopsids as the dominant land plants, a position they still hold today.
- The first gymnosperms appeared in the fossil record in the late Devonian, some 350 million years ago.
- In the centre of the flower is the female reproductive organ, the pistil or carpel (some species have more than one pistil per flower).

EXERCISE

1. Encircle the correct choice:

(i) Tamarind belong to taxonomic family:
(a) Poaceae (b) Brassicaceae
(c) Solanaceae (d) Caesal pinaceae

(ii) Filament is a part of:
(a) Sepal (b) Petal
(c) Stamen (d) Carpel

(iii) Stigma is the part of:
(a) Sepal (b) Petal
(c) Stamen (d) Carpel

(iv) Pollen grain are produced in:
(a) Stigma (b) Ovary
(c) Anther (d) Ovule

(v) Which one is not a group of conymnosperms.
(a) Pteridospermae (b) Ginkgoae
(c) Cruciferae (d) Coniferae

(vi) Club mosses are placed in:
(a) Musci (b) Hepaticae
(c) Lycopsida (d) Bryophyta

(vii) Which one is mis-match:
(a) Musci _____ Mosses
(b) Lycopsida _____ Lycopodium
(c) Sphenopsida _____ Selaginella
(d) Anthcerotae _____ Anthoceros

(viii) Group of plants in which each spore germinates into protonema:
(a) Bryophyta (b) Hepaticae
(c) Musci (d) Anthocerotae

(ix) Group of Tracheophytes having neither roots nor leaves:
(a) Psilopsida (b) Sphenopsida
(c) Lycopsida (d) Pterropsida

(x) Taxonomic family in which ovary is obliquely placed:
(a) Rosaceae (b) Solanaceae
(c) Poaceae (d) Caesalpinaceae

2. Write detailed answers of the following questions:

(i) Give general characteristics and amphibious nature of Bryophytes.
(ii) Give salient features of major groups of Tracheophytes.
(iii) What do you know about Kingdom Plantae? Give characteristics, adaptation to land habit and three main divisions of bryophyta.
(iv) What are tracheophytes? Describe briefly the five major groups of them.
(v) What are spermopsida? Describe angiospermic flower.
(vi) Describe life cycle of funaria or fern.
(vii) Give floral characters of any one angiospermic family.
(vii) Give two familiar plants with botanical names from each of the six taxonomic families that you have studied.

3. Write short answers of the following questions:

(i) Explain the term Heterogamy.
(ii) Name the four types of floral leaves.
(iii) Name the different parts of a stamen.
(iv) Explain the term rotate and papilionaceous corolla.
(v) Give economic importance of Poaceae.
(vi) What are the three steps in the evolution of seed?
(vii) Why hornworts are so called?
(viii) Why gymnosperms have nacked seeds but not angiosperms?
(ix) What is double fertilization?

4. Define the following terms:

(i) Kingdom plantae (ii) Bryophyta
(iii) Tracheophyta (iv) Heterospory
(v) Gymnosperm (vi) Angiosperm
(vii) Flower (viii) Rosaceous corolla
(ix) Perianth (x) Floral formula

5. Distinguish between the following:

(i) Gynoecium of Rosaceae and Solanaceae
(ii) Algae and Plants
(iii) Bryophyta and Tracheophyta
(iv) Homospory and Heterospory

Chapter 10

THE KINGDOM ANIMALIA

In this chapter we trace the long evolutionary history of the animals; in it we encounter the simplest members of this kingdom—sponges, jellyfish and several kinds of worms. These animals are important ecologically and they illustrate the advent of the major characteristics that are important in the more advanced animal phyla. These characteristics include the development of tissues and organs, the use of internal digestion, the appearance of radial and then bilateral body organization and the appearance of internal body cavities.

DIVERSITY AND COMPLEXITY

Animals, the members of this kingdom are the most conspicuous living organism in the world around us. As individuals, animals are greatly out numbered by plants, bacteria and even fungi. Yet there are more kinds of animals than any other type of organism. A total of about 1.3 million species of animals are included in this kingdom. It constitutes around 75% of the total known species of living organisms.

An organism is a complete living being.

Animals range in size and complexity from a merely microscopic parazoan **Trichoplax** to the giant blue whale **Balaenoptera**that reaches a length of nearly 40 meters and weighs more than 160,000 Kilograms (Fig. 10.1). Between these extremes is an immense diversity of animals that differs a great deal not only in size, appearance and habitat but also in having virtually no organs to a highly specialized organ system. The members of most of the phyla are found in shallow water or moist soil. True land dwelling forms are found in phylum Arthropoda and Chordata.

Such a diversified group of animals is thought to had arisen from an ancestral colonial, probably volvox like protist (protoctist) as a result of division of labour among their aggregated cells. Some cells became specialized for movement, others for nutrition and still others differentiated into gametes. These co-ordinated groups of cells evolved into larger and more complex organisms that we now call animals. Multicellular animals have arisen from the protists at least three times. The sponges (phylum Porifera), cnidarians (phylum Cnidaria), and flat worms (phylum Platyhelminthes) probably represent the three separate evolutionary lines. The other animal phyla probably evolved from a flatworm or flatworm like ancestor.

10.1 ANIMAL CLASSIFICATION

In order to better understand such a large number of organisms, it is necessary to arrange them in groups. This arrangement presents a great deal of information in an orderly way. In the traditional two-kingdom-system of classification (not followed these days) the multicellular animals were referred to as Metazoa to distinguish them from one-celled Protozoa. In modern five kingdom classification scheme, the Protozoa belongs to kingdom Protoctista whereas the true animals are placed in kingdom Animalia. A true animal is now defined as "a eukaryotic, multicellular, heterotrophic (ingestive mode of feeding) organisms which are diploid and developed from an embryo formed by the fusion of two different haploid gametes, a larger egg and a smaller sperm". Most of animals are motile, a few, however, are sessile.

The kingdom Animalia is divided into 33 groups called phyla, out of which we will deal with only nine major ones. Each of these groups include a sufficient number of species and individuals which play an important role in an ecological community. These major phyla are Porifera, Cnidaria, Platyhelminthes,

Nemathelminthes, Annelida, Mollusca, Arthropoda, Echinodermata and Chordata (see chart No. 1). Rest of the groups are called minor phyla.
This classification or grouping of animals is called Taxonomy or Systematics. It is carried out primarily on the basis of their evolutionary relationships. Clues to these relationships are found in (i) the comparative study of their morphology (general appearance) and (ii) their internal architecture which includes their cellular organization, symmetry and the embryological developmental pattern of their coelom and blastopore etc. The structure of DNA and the study of their comparative biochemistry and physiology also help in tracing their relationships.

10.1.1Developmental Patterns:

An animal starts its life as a **zygote**, which is a diploid cell, formed as a result of fertilization. It develops by a sequence of mitotic division, called **cleavage**, into a multicellular structure, first a solid ball of cells the **morula** and then a hollow ball of cells the **blastula**. In most of the animals the blastula invaginates i.e. foldsinwards, at a point to form **gastrula**, has a hollow sac having an opening called **blastopore** (Fig. 10.2). Further development and movement of cells produce a hollow digestive system called an **enteron** if it is open at one end only and a **gut**, if it has developed a second opening.
The details of further embryonic development differ widely from phylum to phylum but are fairly constant within each phylum. Such developmental details provide very important criteria for determining relationship between the phyla.

10.1.2Cellular Organization:

Animal, phyla described in the next pages are in approximate order of increasing complexity. All the animals are multicellular and their cells are eukaryotic. These cells are joined together into tissues, tissues into organs and organs into organ-system. One phylum Porifera, is grouped in a separate sub-kingdom **Parazoa** because its members lack a proper tissue organization. Rest of the eight phyla constituting sub-kingdom **Eumetazoa** (True Metazoans) have tissues organized into organs (in the lower groups) and organs into organ systems (in higher forms).

10.1.3Diploblastic and Triploblastic Organization:

The process of gastrulation leads to the development of three tissue layers in almost all **eumetazoa**. These tissue layers, often called germ layers, are the masses of cell from which organ systems of animals develop. These germ layers called **ectoderm**, **endoderm** and **mesoderm** are the outer, inner and middle layers, respectively. In Porifera any such fully developed layer is lacking. In Cnidarians only two layers ectoderm and endoderm develop (Fig. 10.3) and they are called **diploblastic**. In the rest of the phyla, however, all the three germ layers are formed and hence they are called **triploblastic** animals (Fig. 10.4).

10.1.4Symmetry:

There are two branches of Eumetazoa. One consists of radially symmetrical organisms, the Coelenterata (Cnidaria) while the rest of all the phyla show bilateral symmetry.
What is symmetry? Symmetry is the overall shape of an animal body. All the symmetrical animals can be divided, along at least one plane, into two identical halves. Animals that have no plane of symmetry are said to be **asymmetrical** e.g. sponges. A body with **radial symmetry** has one main axis around which body parts are arranged and the organism can be divided into identical halves by any plane that passes through the main axis. Cnidarians and Echinoderms are the examples of radially symmetrical animals. A **bilaterally symmetrical** animal can be divided into identical right and left halves only by a cut through the mid-line of its body (Fig. 10.5).

10.1.5 Coelom:

The bilaterally symmetrical animal phyla may be divided into three groups: **Acoelomata** (Platyhelminthes) are those which lack a body cavity; **Pseudocoelomata** (Nematodes) are those which develop a body cavity but lack a true coelom. The **Coelomata** (from Annelida to Chordata) are all those which develop a true coelom (Fig.10.6and chart No.1). In coelomates the meso-dermal layer splits open to contain a space that widens and eventually forms a body cavity in which digestive, reproductive and other organs develop and are suspended. This true body cavity, being lined by mesodermal layers, is called the **coelom**. A pseudocoelom is though a body cavity which also encloses the intestine but it is not formed by the splitting of mesoderm. Acoelomate animals have no such body cavity at all.

10.1.6 Fate of Blastopore:

Blastopore is the opening which develops in an embryo at the gastrula stage. This opening eventually forms either the mouth or anus of the animal.

10.1.7 Protostomes and Deuterostomes:

Coelomate animals are distinguished according to the fate of the blastopore into two groups, the **Protostomata** and **Deuterostomata** (see Fig. 10.2). In group Protostomata (Proto = First; Stoma=Mouth) the blastopore eventually becomes the mouth of adult whereas in group deuterostomata (Deutero = Second; Stoma = Mouth) the blastopore develops into anus and a second opening which develops later forms the mouth. Out of the major coelomate phyla annelida, mollusca and arthropoda are protostomates whereas echinodermata and chordata are deuterostomates.

10.2 PHYLUM PORIFERA (Pore Bearing)

Phylum porifera which includes about 5,000 species are the simplest living animals usually called sponges. They are so called because they have thousands of pores called **ostia** or the incurrent pores through which water enters and one or few larger openings called **oscula** or excurrent pores through which water leaves the body. These pores are connected with a system of canals through which water flows.

Sponges are usually asymmetrical, sessile, aquatic organisms. Most of them are marine whereas about 150 types live in fresh water. They lack mouth, intestine, respiratory, excretory and nervous systems. Oxygen diffuses in through the body wall and food is filtered out from water which flows through their body. Waste particles and fluids simply diffuse out of the body or flow out through oscula.

A sponge may be described as an assemblage of loosely organized cells rather than a well defined multicellular organism. The **pinacocytes** are the contractile flattened cells forming the epidermis, **porocytes** form the pores whereas **choanocytes** are flagellated cells lining the inner hollow cavity the **spongocoel** (Fig. 10.7).

The spongocoel may be a single cavity or divided and redivided into thousands of small chambers and canals thus increasing the surface area available. Three types (Fig. 10.8) i.e. **Ascon type** (spongocoel single cavity, not divided), **Sycon type** (spongocoel divided into secondary chambers) and **Leucon type** (spongocoel divided and redivided into secondary and tertiary chambers) of canal systems are found in sponges.

Between pinacocytes and choanocytes is a gelatinous mesenchyme which consists of **amoebocytes** and **spicules**. Spicules which may be **calcareous** or **siliceous**constitute the skeleton of sponges. The skeleton of bathroom sponges, however, is a network of **spongin fibres**. Many sponges look coloured due to symbiotic algae or due to the presence of pigments in amoebocytes.

A 10 cms sponge filters more than 20 litres of water everyday.

Most sponges are hermaphrodite whereas in a few sexes are separate. During sexual reproduction eggs and sperms formed by amoebocytes. The sperms are carried out by water current to neighbouring sponges where fertilization takes place. The fertilized egg develops into a multicellular free swimming **Amphiblastula** larva which settles to the bottom and grows into an adult.

Asexual reproduction takes place either by regeneration of fragments of sponges or by spore like **Gemmule** formation. Gemmules (Fig. 10.9) are actually nutrient laden amoeboid cells surround by layers of epithelial cells. Gemmule is resistant to drought or winter and when conditions become favourable it grows into a new sponge, Sycon (Fig. 10.10), Euplectella (Fig. 10.11) and Euspongia (Fig. 10.12) are the common examples of this phylum.

Sponges, with a skeleton of spongin fibre network, are of commercial value being dried and used as bathroom sponges. Sponge fishing and sponge culture was very common in the past though in the recentyears it has been very much replaced by the artificial sponges.

Three classes on the basis of skeleton are:

i) **Calcarea:** Skeleton of needle shaped lime-crystals e.g. Ascon, Sycon.

ii) **Hexactinellida:** Spicules silicious (glass material) with six rays e.g. e.g. Euplectella.

iii) **Demospongiae:** Skeleton of proteinacious fibers (spongin fibers) either with or without spicules, e.g. Spongilla, etc. Spicules when present are siilceous but never six rayed.

10.3 PHYLUM CNIDARIA (With Nematocytes)

Phylum Cnidaria which includes about 9000 species is also commonly called Coelenterata (with hollow enteron). This group of morphologically leastcomplex metazoa includes the common Hydras, Jelly fishes, Sea Anemones and the microscopic animals responsible for building coral reefs. Cnidarians are all aquatic, majority of them are marine whereas a few live in fresh water. They are radially symmetrical and diploblastic. Their body wall encloses a hollow cavity the gastro-vascular cavity or **coelenteron**, hence the name coelenterata (Fig. 10.13). Coelenteron which serves as a rudimentary gut opens to the exterior through just one opening which serves both as mouth and anus. The development of an enteron and a rudimentary network of nerves in cnidarians is the first evolutionary step towards formation of organ system. The cnidarians have no respiratory, excretory or circulatory system because all the cells of the body are close enough to the external medium so that respiration and excretion occur directly by diffusion through the cell membranes.

All cnidarians are carnivorous. They paralyse or kill their prey with the help of special stinging cells called **cnidocytes** (Fig. 10.13), hence the name cnidaria.

10.3.1 Diploblastic Organization:

Cnidarians are called diploblastic animals because their body wall is composed of two cellular layers, an outer ectoderm and an inner endoderm (Fig. 10.14). In between these two cellular layers is a plate of non-cellular gelatinous mass called **mesogloea.** The cellular layers in cnidarians are more complex than those in porifera and consist of cells whose activities are co-ordinated to form tissues. Thus cnidaria are considered to have evolved to tissue grade of organization but lack true organs.

As a group cnidarians have two distinct body forms, **Polyp** and **Medusa.**Polypsare cylindrical with mouth and tentacles situated at the upper end. Medusae, on the other hand are umbrella shaped whose mouth and tentacles are

on the lower surface (Fig. 10.15). Hydra, Sea anemone and Corals occur only in polyp form being adapted to sessile life style whereas Jelly fish occurs only in medusa form and are adapted to a free-living, motile life style.

10.3.2 Alternation of Generation:

Some cnidarians alternate between two body types during their life cycles. Inthese species the asexual polyp produces male or female medusae which as a result of sexual reproduction form zygote which transforms into a **planula larva** (Fig. 10.16-a) which eventually develops into a new asexual polyp. This phenomenon of producing asexual form by sexual form and vice versa is called **Alternation of Generation** (Fig. 10.16-b).

10.3.3 Polymorphism:

Many cnidarians live as a part of a large colony in which many individuals become physically attached to one another and occur in many different forms or zooids. These zooids are interdependent and perform special function for whole of the colony. This ensures an efficient division of labour. It is a common feature of hydrozoan colonies. The occurrance of a species in two or more structurally and functionally different kind of zooids is known as **Polymorphism.** Physalia (Fig. 10.17) is a common example of a polymorphic colony in which many types of polypoid and medusoid forms live together, in a colony, and perform specific functions.

10.3.4 Corals and Coral reefs:

Many polypoid cnidarians secrete certain chemicals which form a hard but dead protective covering around them. These coverings are of various shapes, sizes and chemical composition and are called **corals. Coral reefs** are underwater limestone ridges near the surface of the sea. These are usually formed by the combined secretions of several species of coelenterates and other carbon precipitating protoctist organisms. Coral reefs which are usually restricted to warm shallow waters provide a heaven to a large number of marine species. **Great Barrier Reef** of Australia's eastern coast is spread over hundred of miles. Jewellery and other decorative items are carved from the red corals. Red coral by the name of 'MARJAN' is used by Hakeems in preparing eastern medicines.

10.3.5 Phylogeny:

Phylogenetically it is believed that the cnidarians have evolved along one of the three evolutionary lines from protoctista. No other phylum of animals is thought to have evolved from cnidaria.
There are following three classes based upon the dominant phase.

i) **Hydrozoa:** Mesoglea noncellular, both polypoid and medusoid phases showing alternation of generation e.g. Hydra, Obelia, Physalia (portuguese man of war).

ii) **Scyphozoa:** Mesoglea cellular; predominantly medusoid e.g. Aurelia (Jelly fish). Polyp occurs during development.

iii) **Anthozoa:** Mesoglea fibrous, polpoids forms only e.g corals, sea-anemone.

10.4 PHYLUM PLATYHELMINTHES (Flat worms)

There are found about 15000 species of Platyhelminthes. They are soft bodied flat or ribbon shaped worms thought to have evolved from a coelenterate like worm which resembled a planula larva. Of all the animals that have a head, platyhelminthes are the least complex. They have a mouth which opens into a gut but no anus. They are acoelomate, bilaterally symmetrical, triploblastic animals

with organs and organ systems. They have a much branched intestine and a network of excretory tubule with a large number of ciliated protonephridia. These moving cilia look like a flickering flame hence called **flame cells.** A rudimentary nervous system is also present whereas circulatory and respiratory systems are not needed hence absent.

Flat worm are mostly hermaphrodite with complex life cycles which may include many larval stages. They are mostly external or internal parasites of animals to which they remain attached by their special adhesive organs, the hooks and suckers (Fig. 10.21). These parasitic flat worms complete their life cycle in one or two hosts hence called **Monogenic,** when one host is involved and **Digenic,** when two animal hosts are involved.

Commonexamplesof Platyhelminthes are **Dugesia** (Planaria Fig. 10.21). **Fasciola** (Liver fluke Fig. 10.22) and **Taenia saginata** (Tape worm Fig. 10.23)

10.4.1Parasitic Adaptations:

Platyhelminthes have developed a number of adaptations which made them suitable for their parasitic mode of life. Their thick body covers protect them against defence mechanisms of host body. The spines, suckers and hooks developed for attachment and have replaced the locomotory organs which are not needed by parasitic animals. Alimentary canal is reduced, even absent as in Taenia, because of the availability of digested food from host. Neurosensory organs are not developed due to their passive mode of life; Reproductive, system is very much developed. In Taenia a set of reproductive organs is present in almost every segment. Fertility rate is very high to cope with chances of danger from the defence mechanism of the host body.

It is worth while to be aware of parasitic worms because they cause diseases, multiply rapidly and are wide spread. Many are spread due to poor sanitary conditions. Hygienic living, careful inspection of edibles and thorough cooking of meat are the ways to avoid their infection.

There are three classes in this phylum, according to their mode of living.

i) **Turbelaria (Turbella = A little sting):** Free living, e.g.Dugesia (Planaria).

ii) **Trematoda(Trema = hole, cavity of sucker):**Ecto or endoparasites; alimentary canal bifurcated. e.g. Fasciola hepatica (sheep liver - fluke).

iii) **Cestoda (Kestos = ribbon, eidos = like):** Exclusively endo parasite; alimentary canal absent body ribbon shaped e.g. Taenia saginata (Beef tape - worm).

10.5 PHYLUM NEMATHELMINTHES-ASCHELMINTHES (The roundworms):

Nemathelminthes commonly called round worms are the most wide spread and abundant animals on earth. Though about 20,000 species have been identified, incredible numbers of nematodes are found every where particularly in the soil. In one count90,000round worms of several different species were found within a single rotting apple.

Nemathelminthes, which range in their size, from microscopic forms to a 9 meters length, have long bilaterally symmetrical, triploblastic and cylindrical bodies with pointed ends. They are basically constructed as a tube within a tube body plan. Inner tube is a relatively simple straight digestive tract with mouth and anus at opposite ends. Outer tube is a complex body wall being covered over by a non-living cuticle. Between the tubes is a fluid filled body cavity, the pseudocoel.

Round worms have a varied mode of existence from free living scavengers to predators and parasitic on animals and even plants. At least 50 different species of round worms can inhabit the human body. Millions of human beings in the

world are infected with **Ascaris** (Fig. 10.24) alone. It is the most common human round worm and lives as an endoparasite in the intestine of man. They, like other nematodes, are sexually dimorphic, males being shorter than females. Enormous number of eggs are produced by females. Their eggs containing the developing embryo enter the human body with contaminated food or water.

A female Ascaris may produce as many as 2,00,000 eggs every day.

The thread worm like **Wuchereria** transmitted by blood sucking mosquitoes inhabit the lymphatic vessels of many animals including man where it produces a disease called **Filariasis** causing excessive inflammation of legs, arms and scrotum; a condition called **Elephantiasis** (Fig. 10.25). Another common nematode parasite **Ancylostoma,** the Hook worm whose larva can penetrate through the skin of man to reach the intestine where it matures and sucks the blood.

10.6 PHYLUM ANNELIDA (Segmented Worms)

Annelida, commonly called segmented worms, have the most complex body structures of all the worms. They are distinguished by their ring like (Annulus: little ring) external segments. They look like a large number of rings put on and arranged one behind the other. These rings or external segments, called metameres, coincide with the internal partitions called septa of the body cavity.

There are about 15000 species of annelida known. They are all triploblastic, bilaterally symmetrical coelomates with an organ system level of body organization. Their segmentation is said to be metameric because external segmentation corresponds with internal segmentation and some of their organs such as excretory and reproductive organs are repeated in each segment. Another important characteristic is the development of coelomic compartments in their body. Chitinous chaetae also called setae with or without parapodia are usually present in the most of annelids and help in locomotion whereas in some annelids suckers perform this function. The excretory organs are a pair or more, tubular nephridia per segment. Digestive, excretory, nervous and reproductive systems are well developed. Respiration takes place by diffusion through the moist skin. Annelida is the first group to have a circulatory system of closed type with definite blood vessels and many pulsatile hearts. Blood is usually red with haemoglobin dissolved in it.

Annelids live on land, in moist soil, in fresh water or in sea. Many annelids are active free swimming predators, some are aquatic filter feeder living in tubes burried in mud whereas leeches are ectoparasites and suck the blood of their host. There are also many type of burrowing forms called the earthworms, which feed upon dead organic matter.

Polychaetes, the most ancient annelids, are supposed to have evolved from a primitive flat worm like ancestor in the sea. Oligochaetes evolved from polychaetes whereas leeches evolved from oligochaetes.

Phylum Annelida is divided into three classes mainly on the basis of number and type of setae.

Class Polychaeta (With many setae):

Polychaetes are usually free living active swimmers or sedentary filter feeding tubuculous forms. They are mostly marine having a pair oflateral flap like fleshy lobes the parapodia on each segment of the body. Each parapodium has a bundle of bristles called setae or chaetae. Sexes are usually separate. Development passes through a **Trochophore** larval stage. Common examples are Sabella (Peacock worm) and Nereis (Clam worm) (Fig. 10.26).

Class Oligochaeta (Few Setae):
Oligochaeta are usually terrestrial, free living, burrowing forms withoutparapodia but with a few setae per segment arranged in a ring. All are hermaphrodite. Common example is **Pheretima** the common earthworm (Fig. 10.27).

Class Hirudinea (Leeches):
This group of annelids includes the leeches, in which setae and parapodia both are absent instead an anterior and a posterior suckers are present for blood sucking and attachment. Some are free living predator whereas others are ectoparasite of vertebrates and invertebrates. They live usually in fresh water and are all hermaphrodite. Common example is **Hirudinaria** (Fig. 10.28) the common Indian leech.

A substance in a leech's saliva called hirudin prevents blood from clotting.

10.6.1Advantages of Segmentation and Coelom:
Segmentation increases flexibility allowing various parts of the body to bend independently of the other parts. Increased flexibility enhances locomotory power. The coelom improves swimming or burrowing activities of the annelids by serving as a hydrostatic skeleton. In many annelids coelom collects metabolic wastes discharged by excretory organs. It also provides space for maturation of eggs and sperms.

10.6.2Importance:
Earth-worms being farmer is friend, are one of the most beneficial animals for the mankind. They help the farmers by continuously ploughing the soil and adding nitrogenous wastes into it, thus making the soil more fertile. They are used by Chinese, Japanese and Indians in preparation of various fancy medicines. They are also used as fish bait, as food offish and also in laboratories for dissections and other research activities.
Leeches are ectoparasites and suck the blood of their aquatic hosts. They are also used in remote areas, for sucking foul blood from a patient. A few are also carrier of some diseases.

10.7 PHYLUM MOLLUSCA (Soft Bodied)
Molluscs are soft bodied animals; most have an external and some have an internal shell. About 50,000 species of living and 35,000 of fossil mollusca have so far been described making it the second largest phylum after Arthropoda.
As a group mollusca underwent one of the most remarkable of animal evolutionary radiation in shape and also in size. The smallest molluscs are not bigger than the sand grain whereas the giant squids, the largest invertebrate known, may grow to meters long (including the tentacles) and 1800 Kg in weight.
All the molluscs are triploblastic, coelomate. Bilaterally symmetrical animals with organ-system grade of body organization. They are mostly unsegmented. Though coelom has reduced to a few pockets the large fluid filled cavities of the open circulatory system become the major component of hydrostatic skeleton. Majority are provided with a rasping feeding structure, the radula in their buccal cavity. The alimentary canal is a straight or coiled tube, with a mouth and anus at the opposite ends.
Excretory and nervous systems are also well developed. Respiration takes place by gills in aquatic form and by a rudimentary lung in terrestrial forms.
Though molluscs have most varied body forms yet they share at least three common characters (Fig. 10.29).

(i) Ahead-foot portion primarily concerned with sensation, feeding and locomotion.

(ii) A dorsal visceral mass that includes the major organs.

(iii) A mantle, which is a fold of delicate tissue, surrounding the entire body.

In most of the molluscs sexes are separate and fertilization takes place in water. They all pass through a **trochophore** larva stage. As the animals of phylum annelida also have a trochophore larval stage it is believed that segmented worms and molluscs are related.
Although phylum mollusca is usually divided into six classes; Monoplacophora, Amphineura, Scaphopoda, Gastropoda, Bivalvia and Cephalopoda, only the last three classes will be discussed here.

Class Gastropoda (Foot on visceral mass):
This is the largest class of mollusca which includes whelks, snails and slugs. They are mostly marine, though some live in fresh water and still others are terrestrial. Many of them become, secondarily, asymmetrical by the twisting of visceral mass at 180° by a phenomenon called **torsion**. They have a prominent head and a broad muscular foot developed on the visceral mass. External shell may be present or absent, whenever present it is usually spirally coiled e.g. Pila (Fig. 10.30).

Class Bivalvia (Shell with 2 halves):
This group is the second largest class of phylum Mollusca. They are called **Bivalvia** because their bodies are enclosed in a shell which consists of a right and a left piece. These pieces called valves are movably hinged together. The muscular foot is ventral and laterally compressed suited for creeping and burrowing in the soft mud orsand. Bivalves are both marine and fresh water forms. Common examples of this class are Unio (Fig. 10.31 -a). Mytilus and Pearl Oysters (Fig. 10.31-b).

Class Cephalopoda (Foot on the head):
Cephalopods are all marine and exhibit a high degree of development. Foot in cephalopods is transformed into suckers bearing tentacles and arms. It is present in a ring around the mouth. Nautilus, Sepia (cuttle fish), Loligo (Squids) and Octopus (devil fish) are the common cephalopods. Nautilus (Fig. 10.32-a) has an external shell. Sepia (Fig. 10.32-b) and Loligo have developed an internal one whereas Octopus (Fig. 10.32-c) has none.

Squids are the largest invertebrates.

10.7.1 Economic Importance:
Since the earliest recorded time molluscs have been used by human beings. They are important in palaentological studies and as index fossils to underlying oil deposits. A variety of molluscs called shell fish, together with crustaceans, are still an important source of food. Their shells are decorative and their inner lustrous layer which is a mixture of calcium carbonate and proteins is called **Necre** or mother of pearl. In some bivalve molluscs, called **Pearl Oyster**, concentric layer of necre are deposited around any foreign particle that comes to lie between the mantle and the shell. This particle transforms into the most beautiful and precious jewellery item, the pearl. Pearl culture industry is being successfully run in Japan and China by artificially introducing the fragment of man made particles, of a variety of shapes, in pearl oysters.

10.8 PHYLUM ARTHROPODA (Jointed legs)
Arthropoda is the largest phylum of the animal kingdom, and includes about one million species. They are found everywhere on the earth wherever the life is possible, even in the oil wells. Arthropods are bilaterally symmetrical, triploblastic

and metamerically segmented animals. The bodies of the most of arthropods are divided into a head, a thorax and an abdomen. Coelomic space in arthropoda is called **haemocoel** because it is occupied by blood sinuses of the open circulatory system. Respiration takes place through gills in aquatic forms, by tracheae in insects and by book-lungs in scorpions. Alimentary canal is well developed and assisted by jaws. Excretory organs are mostly malpighian tubules. Nervous system is developed and of annelidan type. Compound eyes with mosaic vision is also a factor of advantage in arthropods. Sexes are usually separate and metamorphosis is of common occurrence.

10.8.1Metamorphosis:

It is a set of changes which transforms a larva into its developed adult form. A larva is a creature which in some animals, comes out of the egg in an immature and undeveloped stage.

Metamorphosis is said to be **complete** when a larva hatches out of the egg and develops into a resting stage the **pupa** which in turn transforms into an adult. **Incomplete metamorphosis**, on the other hand is that in which a tiny, immature but adult like creature called **nymph** comes out of the egg and grows directly, into an adult.

10.8.2Advantages of exoskeleton, jointed appendages and wings:

A significant advancement in this group is their jointed appendages, hence the name Arthropoda. These appendages serve many functions which include walking, swimming, food capture, copulation and sensory perceptions.

Another important features of Arthropoda is their exoskeleton which covers, externally, whole of the body and appendages. This exoskeleton is water proof and made tip of chitin. It is non-living and as the animal outgrows it is shed and a new one is formed. This mechanism of regular changing over of exoskeleton and formation of the new one is called **Moulting** or **Ecdysis**.

The evolution of exoskeleton and jointed legs are the most important features which made the distribution of arthropods that much diversified so as to make them the most successful group of animals. Exoskeleton not only protects the body organs but also provides sites for muscle attachment which together with the advantage of developed jointed appendages resulted in efficient swimming in water and running on land. Further more the development of wings made possible their invasion into the atmosphere (Fig. 10.33).

Arthropoda has the largest kinds of animals but Nematoda has the largest number.

About 80% of the animal species are arthropods and 90% of the arthropods are insects.

10.8.3Economics Importance:

Arthropods are of great economic importance. The predominant group of arthropoda, the insects, not only helps in pollination but also predates on plant pest. Many cause diseases, in plant and animals, by transmitting bacteria and viruses. In human beings they are responsible for the transmission of **Trypanosoma,Plasmodium** and **germs of cholera** etc. Arthropods are an important source of food for many animals and carnivorous plants. Sea food, that is not fish or mollusc, is generally arthropods. Farming of honey bees called **apiculture** and those of silk worms called **sericulture** are being carried out at a large scale and are of great economic importance to mankind. Phylum Arthropoda is divided into following five classes.

Class Merostomata (mouth plates):
It is a small group of marine arthropods in which mouth is surrounded by many small plates. It includes **Limulus** (Pig. 10.34) the King Crab which is considered a living fossil.

Class Arachnida (spider like):
It is a group of terrestrial arthropods with four pairs of walking legs. They respire by the help of book lungs, tracheae or general body surface. The most well known examples are scorpions (Fig. 10.35-a). They are comparatively large and possess a sting at the end of their narrow segmented posterior abdomen. The largest number of species of arachnids are spiders (Fig. 10.35-b). They are predators. They possess silk glands which secrete a protein that on exposure to air forms silk threads used in building nest and webs for trapping the preys.

Class Crustacea (with carpaee):
Prawns, shrimps, lobsters, crabs and many other arthropods belong to this class. They are marine, fresh water and even terrestrial creatures. Crustaceans possess two pairs of antennae, a pair of mandibles and two pairs of maxillae around their mouth. The body is divided into head, thorax and abdomen. In many cases, e.g. prawn (Fig. 10.36-a) (Fig, 10.36-b), head and thorax become fused to form **cephalothorax**which is covered over by a single plate of exoskeleton called **carapace.** Their appendages are modified for walking, swimming, feeding, respiration and as accessory respiratory structures. There are usually five pairs of walking legs. Majority of crustaceans are free living whereas a few e.g. **Sacculina** are parasite.
Daphnia and cyclops are the common microscopic fresh water forms. Economically important crustaceans being used as food are prawns, shrimps and lobsters.

Class Myriapoda (many legs):
These are terrestrial arthropods leading a hidden life in the soil. Their body consists of a head and a very long trunk consisting of many similar segments. The head bears a pair of antennae and trunk is provided with paired lateral appendages. This class includes Centipedes (Fig. 10.37-a) with one pair and Millipede (Fig. 10.37-b) with two pairs of appendages per segment.

Class Insecta or Hexapoda (six legs):
This is the largest class of the animal kingdom. It includes more than 90% of the arthropod species. Members of this large group are called insects and their study is called **entomology**. Insect body is divided into head, thorax and abdomen. This class is also called Hexapoda because they possess on their thorax three pairs of walking legs. They are found in all types of habitats but majority are terrestrial. The success of insects can partly be attributed to the development of flight. In flying insects one or two pairs of wings develop dorsally on thorax. The group of insects with wings is called **Pterygota** whereas the group without wings is called **Apterygota.** A pair of antennae on head is also a characteristic of insects. Insects have developed many types of specialized mouth parts to suit their mode of feeding. They may be **biting and chewing** type as in cockroach, **piercing and sucking** type as in mosquito, **chewing and lapping** type as in honey bee, **sponging** type as in house fly and **siphoning** type as in butter fly. They mostly lead an independent life; a few ants, termites and honey bees live in large colonies, with a marked division of labour, and are called **social insects.** Flies and mosquitoes (Fig. 10.38-a) are involved in transmission of many diseases e.g cholera, dysentery and malaria. Fleas are ectoparasite on many warm blooded animals whereas rat fleas are involved in the transmission of a deadly human disease the Plague. Grasshoppers, moths, butter flies and beetles are

regarded as pest of plants. Cockroaches (Fig. 10.38-b) are very common in warm damp places including our kitchens and bath rooms whereas silver fish (Fig. 10.38-c), actually an insect, is found in the book shelves.

10.8.4Insects — a successful group:

Insects are found everywhere in the world from low land upto the tops of Himalaya and from hot springs to Antaratican temp: of— 65°C. They are even found in the oil wells. This great diversity of habitats has become possible due to various structural and physiological modifications and social adaptations the insects have undergone. Structural modifications include developed brain and sense organs, developed mouth parts in accordance with the requirements of food available, a protective exoskeleton, development of wings and jointed appendages. Physiological modifications include the production of a variety of digestive enzymes, high reproductive potential and metamorphosis which have collectively increased their chances of survival even in the extreme environments. As social insects, they live in a co-ordinated society which increases the adaptability to the environment and enhances the chances of their survival.

10.9 PHYLUM ECHINODERMATA (Spiny Skinned)

Echinodermata is a group of about 6000 species of exclusively marine animals. They begin their lives as free swimming bilaterally symmetrical larvae but as adults they have radially symmetrical bodies. As the bodies of most of the echinoderms have five symmetrically radiating parts or arms they are referred to as Pentaradial (Pentamerous).

None of the Echinoderms lives out of the sea.

Adult echinoderms though lack head, brain and segmentation; are triploblastic, coelomate deuterostomes with organ-system grade of body organization. The body is covered over by a delicate epidermis stretched over a firm endoskeleton of fixed or movable calcareous plates with spines. These spines, which are present all over the body may be long as in Sea Urchin or short as in sand dollars. These spines are the characteristic of this group and inspired the name Echinodermata. The calcareous plates covering the body are perforated over certain areas through which special organs the tube feet project out. These thousands of **tube feet** are a part of a unique **water vascular system** (Fig. 10.39) which is also a characteristic of echinodermata.
These tube feet serve for locomotion, holding of food and respiration. Most echinoderms exhibit the remarkable power to regenerate their lost parts. Reproduction is usually sexual. In some cases, however, it is asexual. Development is indirect passing usually through a **bipinnaria** larval stage. Common echinoderms are star fish (Fig. 10.40), brittlestar (Fig. 10.41), sea cucumber (Fig. 10.42) and sea urchin (Fig. 10.43).

10.9.1Affinities:

Affinities mean similarities of characters suggesting relationship. Echinoderms are thought to be the relative of chordates and hemichordates on the basis of the embryological similarities like their style of cleavage, pattern of blastulation and gastrulation and the deuterostomy of the blastopore. The tornaria larva of hemichordata and bipinnaria larva of echinodermata has a large number of morphological, biochemical and anatomical resemblances. In fact the tornaria larva when first discovered was mistaken as an echinoderm. These affinities have led to the conclusion that echinoderms evolved as a side branch from a common **Dipleura** like ancestor which also gave rise to hemichordata and chordata.

HEMICHORDATA (Half Notochord):
Phylum Hemichordata is a small group of animals which includes about 90 species. They are all soft bodied animals which usually live in shallow 'U' shaped burrows in the sandy or muddy sea bottom. These cylinderical or vase shaped animals are bilaterally symmetrical and lack any segmentation. They may be solitary or colonial and usually range between a few millimetre and 250 centimetres in length. **Balanoglossus gigas**, however, may reach a length of 1.5 meters. Their circulatory system is open and coelom is divided into three chambers. A dorsal and a ventral nerve cord are present being connected together by transverse rings.

Sexes are separate in hemichordate though no sexual dimorphism is seen. As the blastopore of the embryo develops into anus hemichordates are deuterostomes.

Embryological studies of tornaria larva of hemichordata, however, reveal a close and fundamental resemblance with bipinnaria larva of echinodermata. Hence, it is believed that echiondermata, hemichordata and chordata are closely related and might have evolved from a common ancestor.

10.10 PHYLUM CHORDATA (Forms with notochord)

Members of this phylum, are the best known of all the animals. They include about45000species including many animals of major economic importance. All the chordates show all or at least any one of the following three fundamental characters (Fig. 10-44).

1. Notochord:
It is a flexible cartilagineous skeletal rod which forms in the early stage in the embryos of all the chordates in the mid-dorsal line, dorsal to the gut but ventral to the nerve cord. It extends the length of the body and persists in a few chordates, throughout their life whereas in most of them it is surrounded and replaced by a vertebral column.

2. Hollow, dorsal, tubular nerve cord:
In all the chordates a hollow, tubular, fluid filled, nerve cord always develop in the mid-dorsal line. In the group craniata it becomes differentiated into brain and spinal cord.

3. Pharyngeal gill slits:
In all the chordates, in an early embryonic stage, walls of pharynx become perforated. In aquatic forms these pharyngeal slits develop gills whereas in terrestrial forms they close and disappear.
Chordates, in general, are bilaterally symmetrical, triploblastic, deuterostome, animals having a complete digestive tract with a mouth and an anus. Coelom is well developed and internal organs are suspended in the coelomic cavity by a thin membranous tissue called mesentery. They all, as a rule, reproduce sexually. A majority have a post-anal tail.
According to the recent classification Phylum Chordata is divided into two groups (i) Acraniata or Protochordata and (ii) Craniata or Vertebrata.

Group: Acraniata or Protochordata (First chordates; without brain box):
Protochordates or Acraniates as their name indicates are the first or simple chordates in which brain box (Cranium) is absent and hence brain is not prominent. In this group of chordates notochord does not transform into vertebral

column. Protochordata or Acraniata is divided into two sub phyla Urochordata and Cephalochordata.

Sub-phylum: Urochordata (Notochord in the Tail)
Urochordates are also called Tunicata because their body is enclosed in a sac called **Tunic**. They are all marine and mostly sessile. The tunic is provided with two openings, an **incurrent**or **buccalsiphon** and an **excurrent** or Atrial siphon. It is through these openings that water currents bring food and oxygen and take away the excretory wastes and gametes. An adult Ascidia (Fig. 10.45) shows little chordate characters. It is actually its motile larva, which resembles a tadpole, and exhibits chordate characters. It contains a nerve cord and a short notochord in its tail only, hence the name Urochordata. As the larva reaches maturity it attaches to the sea bottom and undergoes **retrogressive metamorphosis** by losing its tail and most of the chordate characters. Many species of **Herdmania** are found in our seas.

Sub-Phylum: Cephalochordata (Notochord from head to tail)
This is a small group and includes **Branchiostoma**which is commonly called Amphioxus (Fig. 10.46). It is a small marine animal with its both ends pointed. It lives burried in sand in shallow water with its anterior end protruded out. Though a small animal it is a typical chordate and exhibits, quite clearly, all the fundamental chordate characters i.e. a hollow dorsal nerve cord, a number of pharyngeal gills slits and a notochord which extends right in the mid dorsal line from anterior to posterior tip of the body. Out of only two genera found around the world **Branchiostoma** is found on our coasts.

Group: Craniata or Vertebrata (With cranium and vertebral column):
These are the chordates in which brain is protected inside a skeletal brain box called **cranium**. They are also called vertebrates because in the members of this group notochord is replaced by a vertebral column. This group is divided into two sub-phyla (i) Agnatha and (ii) Gnathostomata.

Sub-Phylum: Agnatha (Mouth with out jaws):
This is a small group of vertebrates which includes only one class Cyclostomata hence Agnatha are also commonly called cyclostomes. As the members of this group superficially resemble the fishes but lack the jaw they are often known as Jawless Fishes. This group includes Hag Fish and Lamprey (Fig. 10.47-a.b). They are elongated eel like animals without jaws, scales or paired fins. They have a rounded suctorial mouth with many rings of teeth. Both are parasites.

Sub-Phylum: Gnathostomata (Mouth with Jaws)
This is a large group of vertebrates in which both upper and lower jaws are present though teeth may be present or absent. Gnathostomata are divided into two super classes Pisces and Tetrapoda.

As more than half of the chordates are fishes hence they are in grouped is a super class called pisces.

Super Class Pisces (Fish):
Thisis the largest group of chordates which includes about25000 species of fishes. Study of fishes is called **Ichthyology.**
A fish is an aquatic gill breathing gnathostomates whose streamlined body is provided with paired fins and covered over by dermal scales.
Super class Pisces is divided into two classes: (i) Chondrichthyes and (ii) Osteichthyes.

Class Chondrichthyes (Cartilagineous fishes):
This group also called class **Elasmobranchi** comprises of marine fishes whose endoskeleton is made up of **cartilages** while their skin contain an enormous number of tiny sharp enamel coated denticles called **placoidscales**(Fig. 10.48) which form their exoskeleton. Their wide mouth is ventral in position and their tail fin is **heterocercal.** There are present many usually 5 **exposed gill** slits on each side which are not covered over by a gill cover the operculum. This group includes sharks (Fig. 10.49-a), skates and rays including shock producing Electric ray-Torpedo (Fig. 10.49-b). Many types of skates and rays are found on our coasts. **Scoliodon** called Dog fish is a small shark which is common in our seas.

Class Osteichthyes (Bony Fishes):
This group also called **Teleostomi** is actually the largest class of chordates. They are marine and fresh water fishes in which mouth openning is present at the anterior tip. The endoskeleton in these fishes is **bony** and the exoskeleton which is made up of thin bony plates which are called **cycloid** (Fig. 10.50-a) or **ctenoid** (Fig. 10.50-b) scales according to whether their outer edge is smooth or spiny. The gills are covered over on each side, by a gill cover called **operculum**. Most of these fishes have an air bladder which acts as a hydrostatic organ. Tail fin is usually **homocercal** or **diphycercal.** This group includes Eel (Fig. 10.51-a), Sea horse (Fig. 10.51-b), Flying fish (Fig. 10.51-c), Globe fish (Fig. 10.51-d) etc.
Most of the delicious edible fishes also belong to this group. The commonly liked edible fishes of Pakistan (Fig .10.52) are Perches (Pomfret), Hilsa (Pallah), Carps (Rohu), Mackrels (Surmai), Cat fishes (Khagga), and Salmon (Trout).

Some fishes travel thousands of kilometres to their spawing areas.

A small group of zoogeographically important fishes called **Lung fishes** (Fig. 10.53) belonging to order **Dipnoi**are also included in the Class Osteichthyes. Only three genera of such fishes are found in the world. They respire by the help of gill as well as, at times during drought period; by lungs which are actually the modified air bladders. They are found isolated, one type each in South America, Africa and Australia hence called American lung fish, African lung fish and Australian lung fish respectively.

10.10.1 Adaptations for an Aquatic life:
The fishes are well adapted to aquatic life due to their streamlined body shape, which is helpful in swimming, by the presence of paired and unpaired fins and tail for balance and propulsion, by losing hard armour and developing air bladder for bouncy and by developing the gills for aquatic respiration. To overcome the deficiency of sense of hearing and sight in water their sense of smell has developed remarkably.

Super class Tetrapoda (Four legs):
This is the group of vertebrates which have developed two pairs of pentadactyl limbs for walking, running, flying or for offence and defence. This group of Gnathostomates is divided into 4 classes (i) Amphibia (ii) Reptilia (iii) Aves and (iv) Mammalia.

Class Amphibia (Living at both places; water and land):
This is a comparatively small group of tetrapod comprising of about 2000 species. This is the only group of vertebrates which lacks any sort of exoskeleton. Hence their naked skin is soft and moist. They respire by lungs, gills, skin and lining of buccal cavity. They lay eggs in water where they spend at least their early life. Hence, they have become partially aquatic and partially terrestrial. Their name amphibia also indicates this double mode of life.

Amphibians are poikilothermic vertebrates; they cannot maintain their body temperature at a constant level. To avoid extremes of temperature they undergo **hibernation** in winter by burrying themselves in the mud to avoid low temperatures of the environment. In hot summers they do so again; the process is called **aestivation**.
The common amphibians are the limbless worm like caecilians, lizard like salamanders with limbs and tail and frog like creature with limbs but no tail. Frogs and toads (Fig. 10.54) are common in Pakistan.

A number of aquatic amphibian called permanent larval forms, do not metamorphose at all.

10.10.2 Trends towards a land habitat:
The greatest event in the phylogenic history of animals was a transition from aquatic to terrestrial mode of life. Amphibians were the first animals to attempt it though failed to adapt it completely. The most important adaptation was the development of lungs for breathing air in terrestrial habitat. Another important factor was the modification of fins into legs for walking on the land.

10.10.3 Origin of Amphibia:
An ancient bony fish called **Rhipidistian** (lobe finned fishes) lived some 350 million years ago when the land was covered over by shallow, swampy bodies of stagnant water which often become warm and oxygen deficient. The rhipidistian were adapted to these conditions due to the presence of lungs in their body that could inhale oxygen from the air. They also had fleshy lobed fins with bony endoskeleton. These fins were probably used to support the bodies as they pushed their head out of water for a breath of air or dragged their bodies from one shrinking pond to another. This practice made these animals more and more adapted to terrestrial life. The first amphibian known from the fossil record was primarily aquatic and fish like but with four legs. The limb bones of these early amphibians were remarkably similar to those of rhipidistians (Fig. 10.55). Hence, itisconcluded that rhipidistians were the ancestors of amphibian and consequently of all four legged vertebrates. A near relative of rhipidistian are **coelocanth** fishes still surviving, as living fossil in the sea, in small numbers.

10.10.4 Amphibia as Unsuccessful Land Vertebrates:
Amphibia is a diminishing group of animals. The number of amphibian species is reducing day by day and is subjected to regent researches. They are said to be unsuccessful land vertebrates because they failed to adapt completely to the land environment. As they are cold blooded and do not possess any exoskeleton they cannot cope with the extremes of temperature which has restricted their distribution, around the water bodies. Their thin naked skin cannot prevent the continuous loss of water and hence makes them vulnerable to desiccation. Their eggs are small and without a shell and external fertilization is a rule. Being endangered to desiccation amphibian eggs are laid in water. Because the quantity of yolk in the egg is not sufficient enough for the complete development of the embryo, the larva hatches out at an early stage and undergoes metamorphosis which passes through an aquatic gill breathing larval stage. It is, therefore, evident that to live, to mate and to propagate amphibians are always in need of water but unfortunately their physique did not allow them to invade the sea.

Class Reptilia (To crawl and creep):
Reptilia is a group of about 5000 vertebrate species with dry skin which is covered over by epidermal scales. They are terrestrial and crawl on land with the

help of two pairs of limbs which are pentadactylous and provided with horny claws. Snakes, however, have no limbs.
Reptiles are poikilothermic (cold blooded). They lay eggs on land which are covered over by leathery shells. The embryo develops on the large quantity of yolk and albumen present in the egg. Due to the presence of a protective membrane called**amnion** in the egg the three groups of higher vertebrates i.e. Reptiles, Birds and Mammals are called **Amniota**. The vertebrates without it i.e. Fishes and Amphibian are called **Anamniota.**

10.10.5 Past History:

Though reptiles evolved much earlier, the mesozoic era, 225-70 million years ago was the time when reptiles dominated the earth. This era was ruled by the best known giant reptiles called the Dinosaurs which mean "Terrible Lizards". Ancestors of the present day reptiles also appeared during the same period. About 70 million years ago when mesozoic era came to an end and Cenozoic Era started the dinosaurs perished.
Brontosaurs 82 ft. long and 16ft. high was the largest whereas **Tyranosaurs** 60 ft. long and 20 ft. high with both of its powerful jaws containing a large number of almost one foot long powerful teeth, was the most terrifying creature ever to roam the earth.

10.10.6 Successful Land Vertebrates:

Reptilia is the first group of vertebrates fully adapted for life on dry places on land. Unlike amphibians they do not have to go to water to reproduce. Key to their success on land is their internal mode of fertilization and the amniotic egg with a leathery shell which is relatively impermeable to water but permeable to gases. The ability to sustain the frequent temperature changes on land and to slow down the loss of the body water was brought about by the development of an exoskeleton of horny scales and plates on the skin. This was supplemented by much more developed kidney to retain enough water and excrete concentrated urine. Their developed limbs and appearance of claws made them fit not only to move, dig and climb but also to defend themselves against the predators and last but not the least their developed lungs and heart made possible the increased supply of oxygen for much higher muscular activity needed for a more active life on the land.
The common reptiles found around the world are tortoise and turtles, lizards and snakes crocodiles and alligators. **Sphenodon** a living fossil, the only reptile of its kind, is restricted to Newzealand only.
Many species of tortoises and turtles including the endangered green turtle the **Chelone mydas** (Fig. 10.56) are found in Pakistan. Among the lizards wall lizard, garden lizard (Fig. 10.57-a,b), and Uromastix are common. Snakes are the limbless reptiles which creep on land by the undulating movement of their body. Some of the snakes are poisonous. Their poison called **Venom** which may be haemotoxic or neurotoxic is injected into the body of the prey by the help of specially designed sharp and curved teeth called **Fangs.** Cobra (Fig. 10.58-a), Viper. Krait, Python and many types of sea snakes (Fig. 10.58-b) are common in Pakistan.

- Snakes have no limbs, no eyelids and no ears.
- Green turtle lays eggs on the same coast where it was born.

Among the larger reptiles Crocodiles (Fig 10.59) are present in Pakistan in small numbers.

Class Aves (Birds):
Birds are the most beautiful animals in the world. They attract the people because of their flight, colourful plumage (feathers), spring-time songs, strange migrations, parental care and considerable economic value in respect of food and as game animals.
There are about9000 species of birds and their study is called **Ornithology.** They are among the most successful vertebrates due to their enormous number, adaptation to a variety of environment and their distribution throughout the world. The variation in size is also remarkable. They range from a 2 gms West Indian humming bird to a 150 kg Ostrich.
A bird can be defined as a feather covered bipedal flying vertebrate possessing wings. Feathers which cover the body all over constitute a unique and basic identifying character of birds. It not only serves as a protective insulating garment but is directly involved in two most important aspects of avian biology: Endothermy and Flight. Endotherms or Homeotherms are the animals whose body temperature remain constant irrespective of the temperature of the environment they are living in. Flight that gives the, birds an unmatched freedom among the vertebrates is brought about by the modification of its fore-limbs into wings and an astonishing reduction of its skeletal weight owing to its hollow construction (Pneumatic bones).
Though the birds are present in large numbers and live in very different habitats, they all have a compact spindle shaped body, reduced number of bones, large eye ball with keen eye sight and a large, powerful, four chambered heart. They have a sound producing sac, the syrinx instead of larynx present in other vertebrates. They have a tooth less beak. The shape of beak and type of its feet and claws tell about the habit and habitat of a bird. Fertilization is internal and eggs are large, amniotic and covered over by hard calcareous shells.

A bird's respiratory system delivers a plentiful supply of oxygen to its flight muscles

The modern birds are divided into two group i.e. Ratitae and Carinatae.

Sub class Ratitae (Sternum raft like):
This sub class of birds includes the modern big sized flightless birds. These birds cannot fly because they have comparatively heavyweight (Ostrich about 150 Kg in weight) and their wings are either vestigial or rudimentary. They have a flat sternum without keel and accordingly their flight muscles are poorly developed.
The distribution of ratitae is also restricted. None of them is found in Pakistan. Ostrich (Fig. 10.60-a), the largest bird is found in Arabian countries and Africa. Rhea is found in South America. Emu and Cassowary in Australia and Kiwi (Fig. 10.60-b) is restricted to Newzealand only. Penguin another unique aquatic flightless bird is confined to the frozen shores of Antarctica.

Sub class Carinatae (Sternum with keel):
Almost all the modern flying birds are included in this sub class. They are usually small, lightweight birds whose wings are highly developed and feathers of their wings have an interlocking mechanism. Their sternum is provided with a crest like keel to accommodate the highly developed pectoral flight muscles. The flying birds are distributed all around the world.
Pakistan is a zone with rich avifauna and enjoys the presence of a large variety of resident and visiting migratory birds. The common birds of Pakistan are sparrow, pigeons (Fig. 10.61-a), myna, bulbul, hoopoes, crow (Fig. 10.61-b), doves, parrots (Fig. 10.61-c), fowls, cuckoo and ducks. Kites, falcon and owl (Fig. 10.61 -d) are the common birds of prey. Ducks, Sea Gulls Terns and Cranes are common migratory birds. **Peacock** (Fig. 10.61-e) and **Houbara** are among the most beautiful birds of Pakistan.

10.10.7 Origin of Birds:

Birds are often called glorified reptiles because they have evolved from this group and have many characters in common but show a much more specialization and a marked superiority over reptiles. They are also called feathered dinosaurs because of their evolution some 200 million years ago from a small and bipedal insect eating lizard called **Thecodont** which also gave rise to dinosaurs.
Archaeopteryx (Fig. 10.62) is thought to be the earliest bird whose fossils have been found from the rocks 150 million years old.

10.10.8 Flight Adaptations:

The birds have undergone a number of adaptations which helped them to meet the requirement of a perfect flying animal.

1. **Shape of the body**: The streamlined compact, spindle shaped body which offers least resistance to air is the primary requisite of flight.

2. **Loss of weight**: The hollow bones are light, strong and pneumatic (air filled). Teeth are lost and so are the tail vertebrae. The urinary bladder and an ovary and an oviduct have also disappeared.

3. **Wings**: Fore-limbs are modified into wings which are moved up and down by strong flight muscle keeping the body afloat.

4. **Energy requirement**: It is brought about by a rich oxygen supply to the tissues by a powerful heart and an extra-ordinary respiratory system made efficient by the presence of many air sacs (Fig. 10.63) which are connected with lungs on one side and with the pneumatic bones on the other.

5. **Maintenance of Body temperature:** Active muscular activity tends to rise the temperature of body which is kept within normal limits by the ventilating action of the air sacs.

Class Mammalia (With mammary glands):

Class Mammalia which includes about 4500 species are the most complex and most successful group of vertebrates living to-day. They are adapted for life in a variety of ecological niches from land and trees to water and even in the air. As far as their size is concerned they range from a tiny pygmy shrew weighing only about 2 gms to a blue whale which measures upto 40 meters long and weighs upto 160,000 Kg, the largest living animal on the earth.

Human beings are also animals being included in class mammalia and given the scientific name **Homo sapiens.**

Two important mammalian characters which distinguish them from other vertebrates are **hair** and **mammary glands**. All the mammals have a protective and insulating hair cover on their skin. It is luxuriant in most of the species, reduced to patches in humans and restricted to sensory whiskers on snout in whales and dolphins.
Mammals are unique among animals in suckling their youngs with a nutritive fluid, the milk, secreted by special mammary glands.
Other important mammalian characters include the presence of a muscular transverse partition the **diaphragm** which divides the body cavity into a thoracic and an abdominal compartment. Presence of seven cervical (Neck) vertebrae, and internal mode of fertilization are also among the important mammalian characters. Teeth though few are **thecodont** (lodged in sockets of the Jaws) and

heterodont (of different shapes) being differentiated into 4 types i.e. incissors, canines, premolars and molars. All of them with the exception of egg laying mammals are **viviparous** that is they give birth to live young ones because the embryo develops in the uterus inside the body of mother.

10.10.9 Origin:

Mammals appeared in the early part of the Mesozoic era as a branch of the now extinct order **Therapsida** of class reptilia. Ancient mammals were small no bigger than rat and mouse. They were nocturnal and burrowing or arboreal forms. Thus co-existed with dinosaurs and other reptiles for 150-200 million years and when the large reptiles and dinosaurs disappeared, at the close of mesozoic era, the mammals increased dramatically in numbers, diversity and size.
Class Mammalia is divided into three sub classes Prototheria, Metatheria and Eutheria, on the basis of the mode and developmental conditions of their new born babies.

Sub-Class Prototheria (Egg laying mammals):

This sub class contains the most primitive mammals being grouped in a single order Monotremata, hence also called **monotremes.** They are represented by just 2 genera which include only three species being found only in Australia and New Guinea. These mammals are the Echidna, the spiny anteater (Fig. 10.64-a) and duck billed Platypus (Fig. 10.64-b). Like their reptilian ancestors they are oviparous hence, called **egg laying mammals**. Like reptiles they have a cloaca (common rectal and urinogenital opening) and also lack an external ear (Pinna) but like mammals they possess hair and produce milk on which they nourish their youngs when they hatch out of egg. They are, hence, considered to be a connecting link between reptiles and true mammals.

Sub-Class Metatheria (Pouched mammals):

It is also a relatively small group of mammals which contains a single order Marsupialia represented by about 250 species, most of which live in Australia. A few, however, are found in South America and North America. Marsupials are **viviparous.** They give birth to live young ones. Their eggs are not laid but retained and fertilized inside the body of the female. As the eggs do not contain enough yolk to feed the embryo for the entire period of development, hence marsupials are born in an immature form. The rest of the development of the new born tiny marsupial occurs outside the uterus in a special bag like pouch, that contains openings of mammary glands. Each baby attaches itself to a nipple of mammary gland by its mouth. This pouch is called the **marsupium** and hence the metatherians are commonly known as **pouched mammals** or **marsupial mammals**. Examples include Kangaroo (Fig. 10.65-a), Koala bear (Fig. 10.65-b) and Opossum.

Sub-Class Eutheria (Placental mammals):

This group includes about 95% of the mammals which are wide spread and adapted to almost each and every habitat on the earth. They are viviparous placental mammals because the nourishment of the developing embryo before birth takes place, in the uterus of mother, by a special organ called the **placenta.** The placenta is a connection between the mother and its developing young. Embryo receives oxygen and food from the mother's circulation and discharges the wastes into her blood through the placenta. Embryo of placental mammals is much more secure in the uterus where all the essentials of life are guaranteed hence they are born in a far more advanced and almost completely developed form.
Hedge hogs (Fig. 10.66-a), shrews, rats, squirrels, rabbits (Fig. 10.66-b) and ant-eater are small Eutherians. Ungulates, the hoofed mammals which includes sheeps, goats, cows, boars, deers (Fig.10.66-c), camels (Fig. 10.66-d), giraffe,

horses, donkey (Fig. 10.66-e), zebra, rhinoceros (Fig. 10.66-f) and hippopotamus are all herbivores and most of them are very useful to mankind. Small and big cats are a group of carnivores. Bear is an omnivore. Primate, the most evolved and intelligent group of animals includes lemurs, monkeys, apes, gorilla and man himself.

Among the large placental mammals elephants (Fig. 10.66-g) are terrestrial whereas whale the largest of all the animals are aquatic. Bats (Fig. 10.66-h) are the only flying mammals.

Pakistan has a large number of Bats and small placental mammal and a large variety of beautiful and useful ungulates. Goats, Buffalo and Donkey are found only in Pakistan and a few neighbouring countries. Markhor (wild goat) (Fig. 10.66-i), of which many varieties are found in our country, is the national animal of Pakistan. Rhesus monkey (Fig. 10.66-j) is a native of Pakistan whereas the beautiful snow leopard, of our northern areas, is an endangered species. Among the aquatic mammals blind dolphin (Fig. 10.66-k) still persists in small numbers in our river Indus.

Pakistan has 174 species of mammalia, 670 species of birds, 177 species of reptiles, 22 amphibians and 788 species of fishes, 1182 species of invertebrates in addition to around 500 species of insects.

KEY POINTS

- Animals the members of kingdom Animalia are eukaryotic, multicellular heterotrophs which reproduce sexually and are usually motile.
- Animalia is the most diversified group as far as number of species is concerned. They range in size from microscopic to very huge organisms.
- They vary from simplest to most complex individuals.
- Animals are thought to have evolved from a volvox like protoctist.
- Kingdom Animalia is classified into about 33 major groups called phyla, on the basis of their phylogenic relationship.
- Phylogeny is traced on the basis of comparative study of their body plan and their developmental patterns.
- Most animals have a recognizable symmetry, either radial or bilateral. Sessile animals usually exhibit radial symmetry whereas motile animals are usually bilaterally symmetrical.
- All animals but sponges have a digestive cavity. Most animals have a body cavity (a pseudocoelom, coelom or haemocoel) between their body wall and digestive tube.
- Protostome and deuterstomes differ in early embryological development and fate of blastopore. In protostomes blastopore forms the mouth whereas in deuterostomes blastopore transforms into anus.
- Sponges are aquatic animals circulating water in the canals present in their bodies to trap the food and discharge wastes and gametes.
- Cnidarians are aquatic, radially symmetrical diploblastic animal with two body forms polyp and medusa. They are equipped with special stinging cells the cnidocytes.
- Platyhelminthes, commonly called flatworms are thought to be ancestors of most of the phyla except porifera and cnidaria.
- Some flatworms are free living but most are endoparasites. They are bilaterally symmetrical with well developed organ systems. They exhibit beginning of cephalization.
- Round worms of phylum Nemathelminthes are the most abundant animals. Most of them are free living whereas many are parasites. They are bilaterally symmetrical, cylinderical organisms with a fluid filled pseudocoelom.

- Annelids are bilaterally symmetrical, segmented worms with a true coelom and well-developed head and organ systems.
- Mollusca are bilaterally symmetrical, non-segmented coelomate animals whose body can be divided roughly into a head-foot, a visceral mass and a mantle. A teeth bearing redula is a unique molluscan structure as is the shell.
- Arthropoda constitute the most diverse phylum. They are bilaterally symmetrical, segmented animals that are covered over by a chitinous exoskeleton and are equipped with jointed appendages. The coelom is reduced whereas a fluid filled body cavity the haemocoel is prominent.
- Insects evolved wings and became the first animals to fly.
- Echinoderms are radially symmetrical pentramous animals with a unique water vascular system. Body is covered over by spiny calcareous plates and thousands of tiny multipurpose tube feet.
- Hemichordata, once considered true chordates, are now classified as a small separate phylum, between invertebrata and chordata.
- Chordata, the most advanced phylum includes a small number of invertebrate protochordates and the vertebrates (Fishes, Amphibians, Reptiles, Birds and Mammals).
- All chordates are bilaterally symmetrical animals that are characterized by a notochord, a hollow dorsal nerve cord and pharyngeal gill slits. Many have post-anal tail.

EXERCISE

1. Encircle the correct choice:

(i) True animals are:
(a) Non-cellular (b) Unicellular
(c) Multicellular (d) Prokaryotic

(ii) Annelids are:
(a) Acoelomate (b) Pseudocoelomate
(c) Coelomate (d) Haemococoelomatic

(iii) Group deuterostomata includes phylum:
(a) Chordata (b) Annelida
(c) Arthropoda (d) Deuterostomes

(iv) Insects have:
(a) 3 pairs of legs (b) 4 pairs of legs
(c) 5 pairs of legs (d) 6 pairs of legs

(v) Largest fishes are:
(a) Whales (b) Sharks
(c) Cuttle fish (d) Jellyfish

(vi) Farming of honey bees is called:
(a) Agriculture (b) Apiculture
(c) Sericulture (d) Culture

(vii) Which one of these is a fish:
(a) Starfish (b) Jellyfish
(c) Sea horse (d) Cuttlefish

(viii) A characteristic feature of Echinoderms is:
(a) Water vascular system (b) Canal system
(c) Tracheal system (d) None of them

(ix) Lamprey has:
(a) No jaws (b) No tongue
(c) No teeth (d) No vertebra

(x) Chondrichthyes have an exoskeleton
(a) Placoid scales (b) Cycloid scales
(c) Ctenoid scales (d) Epidermal scales

(xi) Skin in amphibia is:
(a) Naked (b) Covered by scales
(c) Covered by hair (d) Calcareous plates

(xii) Sound producing organ in birds is:
(a) Syrinx (b) Tongue
(c) Larynx (d) Pharynx

(xiii) Teeth in mammals are:
(a) Homodont (b) Heterodont
(c) Acrodont (d) Polyphydont

(xiv) Kangaroo is:
(a) An egg laying mammal (b) Marsupial mammal
(c) A placental mammal (d) Oviparous

(xv) Bat is:
(a) A bird (b) An insect
(c) A mammal (d) A reptile

2. Write detailed answers of the following questions:

(i) Discuss the basic factors which help in classification of animals.
(ii) Describe the important characters of phylum Cnidaria. Also discuss diploblastic organization, polymorphism and alternation of generation.
(iii) Discuss the parasitic adaptations in worms. Name three parasitic nematodes and their pathogenicity.
(iv) Write down the important characters of phylum Annelids. Give the names, characters and examples of its classes.
(v) Write down the basic characters of phylum Arthropoda and three of its classes. Give examples.
(vi) Classify mollusca upto classes. Give characters and examples of each class.
(vii) Discuss the salient features of class Insects. What structural and physiological modifications they have undergone to become the most successful group of animals.
(viii) Discuss the important characters of Echinodermata and its affinities.
(ix) How did reptiles become fully adapted for a complete terrestrial life? Name some important reptiles of Pakistan.
(x) What are mammals? Name its sub-classes. Give the characters and examples of each sub-class.

3. Write short answers of the following questions:

(i) Name various types of canal system in Porifera. What are its functions?
(ii) Define the terms alternation of generation and polymorphism.
(iii) What features made the arthropods a successful group?
(iv) What is coelom, pseudocoelom and heamocoel?
(v) What are the three most common characters of molluscs?
(vi) Name various types of mouth parts present in insects. Give one example of each.
(vii) Describe the three basic Chordate characters.
(viii) How would you differentiate between a bony and a cartilagineous fish?
(ix) Name the common groups of edible fishes. Mention their common names.
(x) What are lung fishes? What is their importance?
(xi) Differentiate between hibernation and aestivation.
(xii) Archaeopteryx is a connecting link between reptiles and birds. Prove.
(xiii) What adaptations made the birds capable of flight?
(xiv) What is a placenta? What are its functions?
(xv) Define diploblastic and triploblastic.

Section-IV

FUNCTIONAL BIOLOGY

When a hummingbird sips nectar from a flower, it eats the products of photosynthesis. Photosynthesis in the plant's leaves had converted the energy of sunlight into the chemical energy of organic molecules such as the sugar in nectar. To supply its enormous energy needs— the highest of any animal—the hummingbird must eat its weight in nectar daily. Then its cells must efficiently extract energy from the glucose in the nectar.

Chapter - 11

BIONERGETICS

Energy is defined as the "capacity to do work." It exists in a number of different forms: heat, light, electrical, magnetic, chemical, atomic, mechanical and sound. The laws which apply to energy conversion are the laws of thermodynamics.

11.1 Need for energy in living organisms:

All living cells carry out numerous activities e.g. they generally assemble macromolecules of all types (which are discussed in chapter 3) from raw materials, waste products are produced and excreted, genetic instructions flow from the nucleus to cytoplasm, vesicles are moved from Golgi bodies to the plasma membrane, ions are pumped across the membranes etc. For these high level of activities, a cell needs energy. The energy is used as fuel for life which is derived from light energy trapped by plant cells and converted into energy rich compounds. Other organisms, which do not have the ability to trap light energy, obtain their energy by eating plants or by eating the organisms that eat plants. Capturing and conversion of this energy from one form to another in the living system and its utilization in metabolic activities is called **bioenergetics.**
In other words bioenergetics is the quantitative study of energy relationships and conversion into biological system. Biological energy transformations obey the laws of thermodynamics.

Nearly all living things break down organic nutrients for energy, only about half a million species can built those nutrient through solar powered carbon fixation, photosynthesis. Those half million support themselves and all other living species. The tempering with environment could lead to disastrous change in the fundamental interdependence of autotrophs and heterotrophs, aerobic respiration and photosynthesis.

11.1.1 Role of ATP as energy currency:

Living organisms use organic food as an energy source. These organic molecules especially carbohydrates are degraded to release energy, CO_2 and H_2O. Some of this energy is used to produce ATP. It shows that ATP is the common energy currency of cells. When cells require energy, they spend ATP for that.
As we have already mentioned (chapter 2) that ATP is composed of adenine and ribose sugar with 3-phosphate groups. ATP is also called a "high energy compound because its phosphate groups are easily removed. Under cellular condition it produce 7.3 K.Cal/mole on conversion into ADP.
Wavy lines between the phosphate bonds indicates the high potential energy (the use of the wavy line is for convenience only, it is not an actual means of energy).
ATP acts as a mediator, capable of receiving energy from one reaction and transfer this energy to drive another reaction e.g. oxidation of glucose can provide energy through ATP for the synthesis of a number of cellular materials. ATP plays role in several **endergonic**reaction such as synthesis of protein, lipids,

carbohydrates, active transport etc. In **exergonic** reactions like anaerobic glycolysis and oxidative phosphorylation, it also plays its role and acts as co-enzyme.

11.1.2 Photosynthesis and Respiration: The main energy processing processes:

Most of the energy or ATP of a living organism is processed in two ways. Among them first is the photosynthesis, which occurs in chloroplast. It is the process in which solar energy is converted into ATP. Another process is cellular respiration in which most of the energy producing process occurs in mitochondria during which the chemical energy of carbohydrate is converted to ATP.

11.2 PHOTOSYNTHESIS: (as energy trapping and energy converting process)

The ultimate energy source for most living things is sunlight, and that the organism that transform the light energy into chemical energy are primarily the plants. Algae and some photosynthetic bacteria also perform this transformation. The process by which this transformation is carried out is called **photosynthesis** (photo-light: synthesis-to produce).

On the basis of end product, photosynthesis is called as the formation of carbon containing compound from carbon dioxide and water by illuminated green cells, water and oxygen being the by-products.

In terms of energy we can define that the photosynthesis is a metabolic process during which light energy is converted into chemical/food energy in the presence of chlorophyll and electron carriers. Now photosynthesis may be defined as biochemical anabolic process during which simple carbohydrates are manufactured from CO_2 and water in chlorophyllus cells and in presence of sunlight. O_2 is given out as by-product.

11.2.1 Reactants and Products of photosynthesis:

The reactants of photosynthesis are water, carbon dioxide and light energy. In the vascular plants, water is absorbed by the roots from soil and translocated upto the photosynthetic organs through xylem. The carbon dioxide enters into the plant from the atmosphere through the stomata present on the leaves. The source of light is the sun, when sunlight falls on the green parts of plant, the photosynthetic apparatus captures this energy as solar cells do. In case of unicellular and multicellular organisms living in water, CO_2 is absorbed which is dissolved in the surrounding water. Similarly the oxygen released during this process diffuses into surrounding water.

The important product of photosynthesis is glucose. This is the fundamental material or the 'starter' for complex food molecules. Part of it is converted into complex carbohydrates like starch if remains in chloroplast A part of it is utilised to produce sucrose in the cytosol and other parts are converted into oil and with nitrogen, sulphur, phosphorous it is used in the synthesis of protein and other complex organic compounds.

11.2.2 Role of chlorophyll and other pigments:

As light is flashed on matter, it maybe reflected, transmitted or absorbed. Substances in plants that absorb visible light are called pigments. Different pigments absorb light of different wavelengths. These pigments are most important in the conversion of light energy to chemical energy. The most important pigments required in the process are the chlorophylls, the carotenoid and phycobilin pigments.

Evidences for photosynthetic pigments:
Plants look green, and other pigment can be extracted from a plant by grinding leaves with acetone and filtering. The filtrate looks green, so how it comes to know that there are other five pigments? We can separate these pigments by paper chromatography with suitable solvent these pigment travel up by the paper at different speed due to their structures and size, In this way they are readily separated. Carotene, phaelophytin, xanthophyll, chlorophyll-a, chlorophyll b will give orange, grey, yellow, blue-green and yellow green appearance respectively.

Chlorophyll can be distinguished into a, b, c, d and e. The empirical formula of the chlorophyll-a molecule is C_{55} H_{72} O_5 N_4 Mg and that of Chlorophyll-b molecules is C_{55} H_{70} O_6 N_4 Mg.
Chlorophyll-a is almost identical to chlorophyll-b but the slight structural difference between them is enough to give the two pigments slightly different absorption spectra and hence different colours. Chlorophyll **'a'** is bluish green, whereas chlorophyll-**b** is yellowish green.
Chlorophyll is organised along with other molecules into photosystem, which has light gathering **"antenna complex",** consisting of a cluster of few hundred chlorophyll **'a'**, chlorophyll **'b'** and carotenoid molecules. The number and variety of pigment molecules enable a photosystem to harvest light over a large surface than single pigment molecule. When any antenna molecule absorbs a photon, the energy is transmitted from pigment molecules to pigment molecules until it reaches a particular chlorophyll-**a**, which is structurally same to other chlorophyll molecules but located in the region of photosystem called **"reaction centre",** where the first light driven chemical reaction of photosynthesis occur as shown in Fig. 11.2.
The chloroplast also has a family of carotenoids, which are in various shades of yellow and orange. These are present in the thylakoid membrane along with two kinds of chlorophyll. Carotenoids can absorb wavelength of light that chlorophyll can not absorb and transfer to chlorophyll-**a**. On the other side excessive light can damage chlorophyll. Instead of transmitting energy to chlorophyll, some carotenoids can accept energy from chlorophyll, thus providing a function known as photoreception.

In photosynthetic organisms, chlorophyll is accompanied by carotenoid pigments, which absorb green, blue and violet wave length and reflect red, yellow and orange. They are generally masked by chlorophyll and thus tend to be unnoticed in green leaves, however they give bright and obvious colour to many non photosynthetic plant structures e.g. carrot (root), daffodils (flower), tomatoes (fruit) and com (seed). They give glorious colour to plant in autumn.

11.2.3Role of light:

The plant is capable of using only a very small portion of incident electromagnetic radiation that falls on a leaf or the radiation that is absorbed by the pigment complex of the leaf. Each pigment has its own absorption spectrum.
Light has a dual nature and can be described both as a wave and a particle. It is composed of packets of energy called photon (or quanta). Light energy captured in the light harvesting complexes which is efficiently and rapidly transferred to the chlorophyll molecules present in the photosynthetic reaction centres. When a photon of light hits these chlorophyll-**a** molecules the energy of these photons is absorbed and results in the elevation of an electron from the ground state to an excited state. The excitation state achieved depends upon the energy of the incident photon. A photon of red light has enough energy to raise an electron to

excited state-1 and this energy is sufficient to initiate useful chemical reactions and all other events of photosynthesis. Although a photon of blue light contains more energy than a photon of red light and carries electron to a more energetic excited state-2, the energy transferred by blue or red photons to the photosynthetic electron transport chain is exactly the same, the extra energy delivered by the absorption of a blue photon is rapidly lost by radiationless de-excitation producing an electron in excited state-1.
The movement of energy within the thylakoid membrane is very quick occurring within nanoseconds. During the transfer of electrons some energy is lost. The excitation energy can be used or lost in different ways. It can be used for photochemistry (i.e. it enters the photosynthetic electron transport chain) alternatively it can be dissipated as heat or re-emitted as fluorescence.

11.2.4 Role of water:

Photosynthesis is a redox process. It requires H^+ and electron, to fulfill this requirement H_2O is split and electrons are transferred along with Hydrogen ion (H^+) from H_2O to CO_2, reducing it to sugar.
As water molecules are split, their oxygen atoms combine to form molecules of oxygen (O_2). From this discussion we can conclude that the water thus provides H^+ and e^- necessary for the reduction steps leading to assimilation of CO_2.

11.2.5 Role of CO_2:

Scientists have been studying the diffusion of CO_2 through the stomatal pores of a leaf for more than sixty years. This CO_2 provides the carbon for the basic skeleton to photosynthetic product. The opening and closing of stomata have an important effect on the regulation of photosynthetic activity; particularly in C_3 plants, which incorporate CO_2 directly into phosphorylated sugar intermediate biphospate.

11.3 PROCESS OF PHOTOSYNTHESIS

The process of photosynthesis consists of two main types of reactions (i) light reaction and (ii) dark reaction.

1. In the light-dependent reactions, chlorophyll and other molecules in the membrane of the thylakoids capture light energy and convert some of it into the chemical energy-carrier molecules i.e. ATP and NADPH + H^+.

The overall equation for photosynthesis does not indicate that the process involves the light-dependent reaction and the light independent reactions. The light dependent reactions, located in the thylakoid, capture the energy of sunlight needed by the light independent reactions, located in stroma, to reduce carbon dioxide to carbohydrate.

2. In the dark reactions or light-independent reactions, enzymes in the stroma use the chemical energy of the carrier molecules (ATP and NADPH + H^+) to drive the synthesis of glucose or other organic molecules.

11.3.1 Light reaction (The Light Dependent Reaction):

. In the choroplast, the light capturing chlorophyll molecules, membrane-bound proteins and electron carriers are components which together constitute the electron transfer chain. Four major groups of complexes are present in the membrane. These are photosystem I (PS I), Photosystem II (PS II), the cytochrome b/f complex (cyt b/f) and an ATPase complex. Mobile electron carriers transport the excited electrons between the complexes. These mobile electron carriers are plastoquinone(Pq), plastocyanin(Pc) and ferredoxin(Fd).
These complexes are not evenly distributed throughout the thylakoid membrane which is structurally differentiated into two inter-connected regions, appressed

and non-appressed. The PS I and ATP synthase complexes are located mainly in the non-appressed (non-stacked) stromal lamellae whereas the PS II and associated light harvesting complexes (LHCII) are present in the appressed (stacked) membranes. The Cyt b/f complexes are randomly distributed throughout the membrane.
Photosystem I and II both contain special chlorophyll-a molecules at their centres. These chlorophyll molecules are identical to all other chlorophyll-a molecules if they are isolated away from their binding proteins. Therefore, the changes in these chlorophyll molecules are due to their association with the chlorophyll-bound proteins. The chlorophyll-**a** molecule at the reaction centre of PS I has a maximum absorbance at 700 nm, while those of PS II absorb at 680 nm. Therefore, these reaction centres are called P_{700} and $P_{680}$where P simply stands for pigment.

a) Electron transport:
The 'light' reactions of photosynthesis start from the reaction centre of PS II (P_{680}) which consists of a chlorophyll-a dimer. When a photon of light hits these chlorophyll-a molecules the energy of these photons is absorbed and results in the elevation of an electron from the ground state to an excited state. The excited electron produced within P_{680} is rapidly transferred to the primary electron acceptor phaeophytin and then to plastoquinone molecules which are associated with a ferrous ion.

Photosynthesis seems to have evolved in organisms similar to the green sulphur bacteria, which use an array of chlorophyll molecule (a photocentre) to channel photon excitation energy to one pigment molecules, referred to as P_{840} in green sulphur bacteria and in plant P_{700}. It donates an e^- to e^- transport chain for driving a proton pump and returns the e^- to P_{700} in a process called cyclic photophosphorylation.

The P^+_{680} produced by this primary charge separation and electron transport is re-reduced by an e^- from H_2O. The water-splitting complex is present on the luminal side of the thylakoid membrane and consists of a manganese cluster, Z (the immediate electron donor to P_{680}) and an associated protein. The water splitting complex produces $4e^-$ from two water molecules and releases $4H^+$ and one molecule of O_2, into the lumen. However, the sequence of electron, proton and O_2 release is not yet clear.
Electrons are transferred from PQ, a rapidly turned over plastoquinone (PQ) molecules which accept two electrons and takes up two proton from the stroma. Both electrons and protons are then passed into the plastoquinone pool within the thylakoid membrane. Plastoquinone carries charge from the PS II complex to the Cyt b/f complex. This is thought to be the rate limiting step of electron transport. The electrons from PQ are passed via an FeS centre to cytochrome f within the complex oxidising the PQ and releasing protons into lumen. The second mobile electron carrier plastocyanin (PC) is reduced and is situated in the lumen.
Plastocyanin acts as an electron donor to PS I. PS I has not been studied to such an extent as PS II and therefore its structure and function is less understood. A second excitation event within PS I leads to the eventual transfer of an electron via a series of three FeS centres to Fd. This in turn is used to reduce NADP to $NADPH+H^+$ at the stromal side of the membrane.

b) Formation of ATP (Photophosphorylation):
The energy made available by the passage of electrons down the cytochrome system is coupled to build up ATP in an indirect manner. Some of the carrier of the cytochrome system pump hydrogen ion (H^+) from the stroma into the thylakoid space. This thylakoid space, acts as a reservoir for hydrogen ionsalso because for every water molecule that splits in the beginning, 2 hydrogen ions

stay behind in the thylakoid space. The hydrogen ion taken up by NADP comes from the stroma, not from the thylakoid space.
Because of the large number of hydrogen ions in the thylakoid space compared to the stroma, an extreme electrochemical gradient is present. When these hydrogen ions flow out of the thylakoid space byway of a channel protein present in a particle, called the **ATP synthase complex**, energy is provided for the ATP synthase enzyme to produce ATP from ADP+Pi. This is called **chemosmotic** ATP synthesis because chemical and osmotic events join to permit ATP synthesis. The transport of three protons through the ATPase complex are normally required for the production of one ATPmolecule.
The linear flow of electrons from water to NADP coupled to ATP synthesis is non-cyclic photophosphorylation because the electrons pass on to a terminal acceptor and never back to an initial source. In cyclic photophosphorylation, the electrons are cycled from PS I back to cytochrome complex and from there continue on to the P_{700} chlorophyll. The only product of this process is ATP which can be utilized to meet the ATP demand of CO_2 fixation or other processes such as protein or starch formation.
Finally, four important events take place during light dependent reaction of photosynthesis.

(i) Photolysis of water
(ii) Electron transport chain i.e PS II and PS I
(iii) Reduction of NADP to $NADPH+H^+$
(iv) Synthesis of ATP by photophosphorylation

ATP and $NADPH+H^+$, products of light dependent reaction, play an important role in the light-indepent reaction that follows.

11.3.2Light independent reaction (Dark reaction) or Calvin-Benson Cycle:
The second phase of photosynthesis results in the fixation of atmospheric CO_2 into sugar phosphates. This part of photosynthesis does not require light energy directly, therefore it is generally termed as the 'dark reaction'. These reactions, which require chemical energy in the form of ATP and $NADPH_2$, are collectively known as the Calvin-Benson Cycle (reductive pentose phosphate cycle). During this cycle CO_2 is reduced to triose-phosphate (phosphoglyceraldehyde and di-hydroxyacetone phosphate) and subsequently via other metabolic pathways to carbohydrates. Type of plants in which first stable product is glycerate, 3 phosphate (PGA) contains 3 carbon atom are called C_3 plants and the cycle called C_3 cycle.
The Calvin cycle consists of 13 main reactions catalysed by 11 enzymes as shown in figure 11.5. The C_3 cycle is divide into three distinct phases for the convenience to study.

(i) **Carboxylation** or carbon fixation - during which CO_2 is fixed into organic molecules.

(ii) **Reduction** of synthesis of phosphoglyceraldehyde (PGAL) by the reduction of organic molecules.

(iii) **Regeneration** where the reduced carbon can be utilized either to regenerate the carbon acceptor molecules or for metabolism. These phases are discussed in detail in the following section.

i) Carboxylation: This is the first and key reaction of Calvin cycle where ribulose-1, 5-bisphosphate (RuBP) is combined with atmospheric CO_2 to produce a short lived, six carbon intermediate, which breaks into two molecules ofglycerate-3-phosphate (G3P).

This reaction is catalysed by the enzyme ribulose-1, 5-bisphosphate carboxylase/oxygenase (Rubisco).

Rubisco is an enzyme which function as carboxylase as well as oxygenase. If the supply of CO_2 inside the leaf is inadequate, most of RuBP combines with O_2, giving one molecule of PGA and one molecules of phosphoglycolate, where phosphoglycolate rapidly breaks down to release CO_2.
This process is named as photo-respiration because in the presence of light (photon), oxygen is taken up and CO_2 is evolved (respiration).

ii) Reduction: This phase of the calvin cycle comprises a series of freely reversible reactions. During this phase G3P is reduced to glycerate-1, 3-biphosphate (G1, 3P) and then triose phosphate [3 Phosphoglyceraldehyde (GA3P) and Dihydroxyacetonephosphate (DHAP)] at the cost of ATP and NADPH produced during light reaction.

iii) Regeneration: Many carbon rearrangement takes place during this phase. Three carbon compounds are rearranged to form 5 carbon units including the primary acceptor molecule, RuBP. This stage involves enzymes 5-11.
During this cycle 3 molecules of CO_2fix by 3 molecule of RuBP (3 x C_5), which produces 6 molecules of 3-carbon compounds i.e. triose (6 x C_3). From these 6 molecules five are required to regenerate RuBP (5 x C_3 —-> 3 x C_5). Therefore, only one molecule of 3C is produced (generally called triose-phosphate) which can (a) re-enter the cycle, or (b) be used for starch synthesis within the chloroplast or (c) be exported via a phosphate translocator to cytosol for sucrose synthesis.
For the net synthesis of one G3P molecule, the Calvin cycle consumes a total of nine molecules of ATP and six molecules of $NADPH+H^+$. The light reactions regenerate the ATP and $NADPH+H^+$. The G3P spunoff from the Calvin cycle becomes the starting material for metabolic pathways that synthesize other organic compounds, including glucose and other carbohydrates.

11.3.3Alternative mechanisms of Carbon fixation in hot, arid climate:

On a hot, dry day, most plants close their stomata, a response that conserve water. This response also reduces photosynthetic yield by limiting access to CO_2, with stomata even partially closed, CO_2 concentration begins to decrease in the air spaces within the leaf, and concentration of O_2 released from photosynthesisbegins to increase. These conditions within the leaf favour a wasteful process called photo-respiration. In certain plant species alternate mode of carbon fixation that minimize photo-respiration even in hot, arid climates have evolved. The two most important of these photosynthetic adaptations are C_4 photosynthesis and CAM.
The **C_4 plants** are so named because they go through the Calvin cycle with an alternate mode of carbon fixation that forms four carbon compound (oxaloacelate) as its first product i.e. oxaloacetate. The four carbon compounds release CO_2, which is reassimilated into organic material by Rubisco and the Calvin cycle. Among the C_4 plants important to agriculture are sugar-cane and corn, members of grass family.
A second photosynthetic adaptation to arid conditions has evolved in succelent plants, many cacti, pineapples and representatives of several other plant families. These plants open their stomata during the night and close them during the day, just reverse of normal behaviour. Closing stomata during the day helps desert

plants conserve water, but it also prevents CO_2 from entering the leaves. During the night, when their stomata are open, these plants take up CO_2 and incorporate it into a variety of organic acids. This mode of carbon fixation is called **crassulacean acid metabolism** or **CAM**. The CAM plants store these organic acids unit moving in their vacuoles. During the day, when the light reactions can supply ATP and NADPH+H for the Calvin cycle. These acids release CO_2 to compete with O_2. In this ratio of CO_2 maintain inside the leaves. This CO_2 is fixed through C_3 cycle.

11.4 CELLULAR RESPIRATION: As energy releasing process

Every living cell requires steady supply of energy to carry out varied functions. This energy comes from fuel molecules such as glucose. In cellular respiration glucose molecule in the presence of oxygen is dismantled. Its bonds break-up. Energy is released in small amounts. Some of the energy is stored by cell in the form of ATP while rest is lost as heat. Thus a cell transfers energy from glucose to ATP through coupled exergonic and endergonic reactions. Thisaerobic breakdown of glucose molecule with accompanying synthesis of ATP is called **cellular respiration**. Carbon dioxide and water are produced as by-products.

Since water molecules appear on both the sides, the equation can be simplified as under.

On hydrolysis of ATP, under the action of enzyme ATPase, the terminal phosphate is removed with the result that ADP and Pi are formed and certain amount of energy is released.

11.4.1 Oxidative phosphorylation:

In the process of respiration glucose loses hydrogen atoms as it is converted to carbon-dioxide. Simultaneously molecular oxygen gains hydrogen atoms and is being converted to water. Each hydrogen atom contains one electron and one proton. Thus transfer of hydrogen atoms is the transfer of electrons and protons. The movement of electrons from one molecule to another is an oxidation and reduction or redox reaction. Redox reaction is coupled reaction and requires both donor and acceptor of electrons. In the process of respiration glucose is oxidized with the loss of electrons and oxygen is reduced by the gain of electrons. During redox reaction, electrons give up energy which is used in synthesis of ATP from (ADP) Adenosine di phosphate and inorganic phosphate (Pi). This synthesis of ATP is called **Oxidative phosphorylation**.

11.4.2 Aerobic and Anaerobic Respiration:

There are two types of cellular respiration.

i) Aerobic (Aero = air, bios = life) respiration.

ii) Anaerobic (An = without Aero = air, bios = life) respiration.

i) Aerobic respiration: Most of the organisms called aerobes, breakdown sugar, involving participation of molecular oxygen and release carbon dioxide, water and sufficient amount of energy. This type of respiration is known as aerobic respiration.

ii) Anaerobic respiration: A small but significant minority of organisms can obtain energy by breaking down sugar in absence of oxygen. This type of respiration is known as anaerobic and organisms are called anaerobe. Many microorganisms including yeasts and some bacteria can respire anaerobically. Certain species of annelids that live in oxygen deficient mud, gut parasites such as tapeworms, roots of plants growing in water logged area and certain tissues under certain conditions respire anaerobically. Two types of anaerobe are recognised a) obligate anaerobe which never need oxygen at all and b) facultative

aerobes which respire aerobically in presence of oxygen and switch over to anaerobic respiration when oxygen is absent or in short supply.
The products of anaerobic respiration are either ethyl alcohol and carbon-dioxide or lactic acid. The process is less efficient in terms of energy production as only a small amount of energy is released. This is because glucose molecule is incompletely oxidized and most of the potential energy is left in end products.
Fermentation: Originally defined by W. Pasteur as respiration in the absence of air, it is an alternative term used for anaerobic respiration, the production of ethyl alcohol from glucose is called Alcoholic fermentation and that of lactic acid as lactic acid fermentation.

Economic importances of fermentation:
Fermentation, though an inefficient method of harvesting biological energy, is an efficient source of many valuable products such as ethyl alcohol, lactic acid, propionic acid and butanol. Thus it has been of great interest to human beings. Brewing and dairy industries rely on fermentation. It is the source of ethyl alcohol in wines and beers. Wines are produced by fermenting fruits particularly grapes. Beers are produced fermenting malted cereals such as barley.
Yeast cells are used to make dough rise before it is baked to make bread. Cheese, yoghurt and other dairy products are produced by microbial fermentation. Lactic acid which is slightly sour, acid imparts flavour to yoghurt and cheese. Dairy products containing lactic acid are more resistant to spoilage. The characteristic flavour of pickles is due to lactic and acetic acid. Acetone and other industrially produced solvents are also by-products of fermentation.

11.4.3Glycolysis: (Glyco = sugar, Lysis = splitting)
The process of aerobic respiration is a continuous one, but for the sake of study it is divided into three main stages.

(i) Glycolysis (ii) Kreb's cycle (iii) Electron transport chain.

In Glycolysis, Glucose; a six carbon molecule is degraded through sequential enzyme dependent reactions into two molecules of pyruvic acid, a three carbon compound.
Glucose is a stable molecule i.e. It has little tendency to breakdown into simpler products. If the energy locked in its molecular configuration is to be released, the glucose must first be made more reactive. A small amount of energy must be invested by the cell to initiate glycolysis. It is adenosine tri phosphate (ATP) that provides the energy for initiating glycolysis.
The first step in glycolysis is the transfer of phosphate group from ATP to No. 6 carbon of glucose. Adenosine di phosphate and glucose 6-phosphate are formed. After an enzyme catalyses, the conversion of glucose 6-phosphate to its isomer fructose-6-phosphate (F-6-P). Another molecule of ATP is invested which transfers its phosphate group this time to No. 1 carbon of F-6-P forming fructose-1, 6-di phosphate and ADP. These reactions are known as **phosphorylation** reactions because phosphate groups are added to glucose and fructose molecules. The next step in glycolysis is enzymatic splitting of fructose 1, 6-di phosphate into two fragments. Each of these two molecules contain three carbon atoms. One is called phosphoglycer aldehyde (PGAL) and other is Dihydroxy acetone phosphate (DHAP). These two sugar molecules are isomers to each other and are interconvertible. This is the reaction from which glycolysis derives its name. Normally both these molecules are converted into pyruvic acid through subsequent enzyme controlled reactions. Since two molecules of ATP are used this part of glycolysis is the energy investment phase. In the remaining part of glycolysis ATP molecules are synthesized hence it is called energy yielding phase.
In the following reaction, an enzyme dehydrogenase and a co-enzyme nicotinamide dinucleonde NAD^+ work together. The enzyme strips off two

hydrogen atoms from PGAL. These electrons are captured by NAD^+. This is a redox reaction where PGAL is oxidized by removal of electrons and NAD is reduced by the addition of electrons. With the loss of two hydrogen atoms PGAL is converted into phosphoglyceric acid (PGA). Now PGA picks up phosphate group (Pi) present in cytoplasm and becomes 1-3 di phosphoglyceric acid (DPGA). In the very next step DPGA loses its phosphate group to ADP forming ATP and 3-phosphoglyceric acid. The phosphate group attached with carbon atom No.3 of PGA changes its position to carbon atom No.2 forming an isomer 2-phosphoglyceric acid. With removal of water molecule 2 PGA is converted into phospho-enol pyruvic acid (PEPA). Finally phosphate group is transferred to ADP forming ATP and pyruvic acid. Synthesis of ATP during glycolysis is known as substrate level phosphorylation because phosphate group is transferred directly to ADP from another molecule.

Glycolysis is the universal energy harvesting process of life. Metabolic machinery of glycolysis is found in all organisms from unicellular bacteria and yeasts to multicellular bodies of plants, animals and human beings. Glycolysis occurs freely in anaerobic environmentwithin cytoplasm without being associated with organelle or membrane structure. Net input and output of glycolysis can be summarized as under.

Looking back over glycolysis for energy yield, 4ATP molecules are produced at substrate level phosphorylation and 2 ATP molecules are consumed to initiate the process. Thus there is net gain of two ATPmolecules. The process also yields two pairs of energized electrons and two NADH.

11.4.4Break down of Pyruvic acid:

The molecular remains of glycolysis are two molecules of pyruvic acid. There are three major pathways by which it is further processed. Under anaerobic conditions it either produces ethyl alcohol (Alcoholic fermentation) or lactic acid (Lactic acid fermentation) or produces carbon dioxide and water via Kreb's Cycle under aerobic conditions.

a) Alcoholic fermentation:

Each pyruvic acid molecule is converted to ethyl alcohol in two steps. In the first step pyruvic acid is decarboxylated under the action of enzyme to produce acetaldehyde, a two carbon molecule. $NADH+H^+$ reduces acetaldehyde to ethyl alcohol.

Ethyl alcohol is toxic. Plants never use it. Neither it can be converted to carbohydrate nor it breaks up in presence of oxygen. Accumulation of ethyl alcohol is tolerable to certain level. Plants must revert to aerobic respiration before the concentration exceeds that tolerable limit, other wise they will be poisoned.

b) Lactic acid fermentation:

When $NADH+H^+$ transfers its hydrogen directly to pyruvic acid, it results in formation of lactic acid.

During extensive exercise such as fast running, muscle cells of animals and human beings respire anaerobically. Due to inadequate supply of oxygen, pyruvic acid is convert into lactic acid. Blood circulation removes lactic acid from muscle cells. When lactic acid cannot be removed as fast as it is produced, it accumulates in the cells and causes muscle fatigue. This forces the person to quit or reduce exercise until normal oxygen levels are restored to deprived cells.

11.4.5Formation of Acetyl Co A:

Aerobes utilize molecular oxygen to extract large amount of energy from two products of glycolysis i.e. Pyruvic acid and $NADH+H^+$. Pyruvic acid diffuses from cytoplasmic fluid (Cytosol) into mitochondrion, the site of Kreb's cycle. Before entering into Kreb's Cycle it undergoes chemical changes. It loses one molecule of

CO_2. The remaining 2 carbon fragment is oxidized to form acetyl group, the ionized form of acetic acid and NAD^+ is reduced to $NADH+H^+$. Finally Coenzyme A (CoA), a sulphur containing compound derived from Vitamin B is attached to acetyl group. The product is Acetyl Coenzyme (Acetyl CoA).
Acetyl CoA links glycolysis with Kreb's cycle. It feeds its acetyl group into Kreb's cycle for further oxidation. For each molecule of glucose that entered glycolysis, two molecules of acetyl CoA enter the Kreb's Cycle.

11.4.6 Kreb's Cycle:

Acetyl coenzyme A, a two carbon compound now participates cyclic series of reactions during which oxidation process is completed. This series of cyclic reactions is called Kreb'scycle or citric acid cycle. The first name honours the biochemist Sir Hans Kreb who worked out these cyclic reactions. The second reflects the first step in the cycle i.e. Citric acid.
An enzyme strips CoAfrom Acetyl CoA. The remaining acetyl fragment reacts with four carbon compound oxalo acetic acid to form 6-carbon compound, citric acid. One molecule of water is used and co-enzyme A is recycled again. Citric acid possesses three carboxyl groups. Hence, Kreb's cycle is also known as tricarboxylic acid cycle or (TCA Cycle).
A molecule of water is removed and another added back so that Citric acid is isomerised to isocitric acid through Cis-aconitic acid.
Isocitric acid undergoes an oxidative decarboxylation reaction. It is first oxidized yielding a pair of electrons (2H) that reduces a molecule of NAD to $NADH+H^+$. The reduced carbohydrate intermediate is decarboxylated. With the removal of CO_2 molecule a 5 carbon compound α-ketoglutaric acid is formed.
α-ketoglutaric acid is again oxidatively decarboxylated. A CO_2 molecule is lost. The remaining four carbon compound is oxidized by transfer of a pair of electron ($2H^+$) reducing NAD^+ to $NADH+H^+$. The four carbon fragment combines with CoA by an unstable bond forming succinyl CoA. Substrate level phosphorylation takes place in the next step. CoA is replaced by phosphate group which is then transferred to Guanosine di phosphate (GDP) to form Guanosine tri phosphate (GTP).
GTP transfers its phosphate group to ADP forming ATP. With addition of water molecule succinic acid is formed.
With loss of two electrons ($2H^+$) Succinic acid is converted to Fumaric acid and $FADH_2$are formed. With addition of one water molecule fumaric acid is converted to malic acid. The last step in kreb's cycle is regeneration of oxalo acetic acid. This is formed by removal of electrons ($2H^+$) from malic acid to NAD^+ forming $NADH+H^+$.
Glucose molecule splits into two molecules of pyruvic acid during glycolysis. Thus two turns of cycle are required for each glucose molecule. For each pyruvic acid molecule, three carbon atoms are removed as CO_2 and five pairs of hydrogen atoms are used to reduce NAD andFAD to $NADH+H^+$ and $FADH_2$, the carrier molecules. The inputs and outputs of kreb's cycle are shown as under.

11.4.7 Electron transport system:

Respiration is an oxidation process in which hydrogen atoms in pairs are removed from oxidizing substrate at various stages during glycolysis and subsequent degradation of pyruvic acid via Kreb's cycle. A pair of hydrogen atom disassociate into a pair of electron and a pair of proton.
In respiration there are six steps at which hydrogen atoms in pairs are released (one in glycolysis and five in kreb's cycle). The electrons thus released at these stages are accepted by Nicotinamide adenine dinucleotide (NAD) and flavin adenine dinucleotide (FAD) from where they are passed along a chain of electron carriers such as cytochrome "b", cytochrome "c" cytochrome "a" and cytochrome 'a-3' as shown in fig: 11.10. While passing from one carrier to another, these cytochromes are alternately reduced (receive electrons) and oxidized (give up

electrons) with it energy is released which is used in the formation of ATP (adenosine tri phosphate) from ADP and inorganic phosphate. This formation of ATP is called oxidative phosphorylation and takes place in mitochondria. Complete oxidation of a glucose molecule (hexosesugar) results in a net gain of 36 ATP molecules which are released in cytoplasm available for different metabolic reactions.

11.5 ENERGY FLOW THROUGH THE ECOSYSTEM

In an ecosystem, organisms are linked together in energy and nutrient, relationship. The energy can be defined as the capacity to do work. The term work can be used to any energy consuming process such as living cells maintain electrical gradient across membrane and the active transport process which requires expenditure of energy. However, the ecological studies relating food requirement and energy relationship among living components of an ecosystem are referred as bioenergetics. Energy is found in four main forms i.e. radiant energy, heat energy, chemical energy and mechanical energy. Only a small part of solar energy is visible spectrum.

11.5.1Sun as a source of energy:

The ultimate source of energy in an ecosystem is the sun light. It travels as electromagnetic waves and about 40% is reflected back from clouds and other 15% is absorbed by ozone layer and is converted to heat energy by the atmosphere; remaining 45% reaches to earth, of which a small fragment i.e. 2-3% is absorbed by green plants while rest is reflected and dispersed.

11.5.2Unidirectional flow of energy and its subsequent losses:

Energy from sun flows in one way traffic and is not recycled as nutrients, though transforms form one form to another. The producers or green plants directly absorb it from sun and than pass it to organisms.

The plants convert solar energy into chemical energy present in the bonds of chemical substances (mainly ATP molecules). Different forms of energy are interchangeable and they followthe set rules of thermodynamics. According to first law, energy may be transformed from one form into another form but can neither be created nor destroyed. Whereas, second law states that no conversion can be 100 percent accurate and some energy must escape as heat.

Let us consider a simplified energy flow diagram, where one square meter of an ecosystem for example receives 3000 calories of light energy, half of it is absorbed by autotrophic plants i.e. producers of which only about 1 to 5 percent of it is converted to food energy. Thus, only 15 to 75 calories are passed to consumers of various levels. Further loss takes place due to respiration and only 10 percent of iti.e. 1.5 calories reaches to secondary consumers. Thus at each trophic level there is ten time reduction in availability of energy.

11.5.3Trophic Levels: (Trophos = feeding)

In an ecosystem heterotrophs depend upon autotrophic organisms for their food. The autotrophic organisms produce organic substances which are used by heterotrophs. In a food chain a set of organisms is used by other set of organisms, thus eating and being eaten at each stage a particular set of organisms is referred as **trophic level**. In an ecosystem, the first set or 1st trophic level consists of autotrophic plants which take energy from sun and convert it into chemical energy in the form of ATP molecules. The plants are also referred as **producers**. The producer are mainly photosynthetic organisms. Second trophic level consists of herbivores, they feed on producers hence they are known as **primary consumers**. The third trophic level consists of **secondary consumers.** They depend for the food source on primary consumers or herbivores and hence they are carnivores. Similarly the secondary consumers are eaten by tertiary consumers which are also carnivores, hence they form fourth

trophic level. The secondary and tertiary consumers may be **predators**. Thus an ecosystem may have 4 to 5 trophic levels. The primary, secondary or tertiary consumers after their death are eaten by decomposers which are saprotrophs (bacteria or fungi) in this way they form 4th or 5th tropic level.

Pyramid of Energy:
The quantitative studies of an ecosystem are carried out by two way i.e. by studying the food chain or food web, and by ecological pyramids. The ecological pyramids are the pyramid of numbers. It is diagrammatic representation of trophic levels i.e. producers, herbivores and carnivores. Pyramid is drawn on the basis of their number. The second way is the use of pyramid of biomass, instead of numbers at each level it involves total mass of the living organisms present at each trophic level. The third way of study is pyramid of energy.
The relationship between different trophic levels is shown by means of pyramid of energy. It provides best picture of ecosystem. It depends upon rate at which food is being produced, however the pyramids of number and biomass provide the picture of existing situation or standing situation. The base of pyramid is represented by primary producers showing the amount of energy they trap during photosynthesis and convert it into chemical energy. Hence, the energy flow from one trophic level to another is calculated and represented diagrammatically in pyramid. Each bar of pyramid represents the amount of energy per unit area in a given period of time. E.P. Odum calculated the energy flow for silver spring, Florida as shown in figure 11.113.

11.5.4The Efficiency of Energy flow and its significance:
The efficiency of energy flow depends upon productivity of an ecosystem which in turn depends upon radiant energy.
Duringphotosynthesis green plants trap sunlight and convert it into food energy. The energy stored in food material by primary producers is said to be **primary productivity.** It depends upon the rate and amount of energy available to an ecosystem. Only a part of it is absorbed by chlorophyll in production of organic molecules. The rate at which this chemical energy is stored by plants is, called **Gross primary productivity (GPP).** About twenty percent of it is used by plants themselves in respiration and other functions, whereas the remaining is stored and is called **net primary productivity (NPP).**
The herbivores feed upon producers and thus the energy is transferred to second trophic level i.e. primary consumers. The production by heterotrophic consumers of various levels is called **secondary production**. The average efficiency of energy transfer from plants to herbivores is about 10 percent and from animal to animal is about 20 percent.

Advantages of short food chains:
Man plays an important role in various food chains, being omnivore, man eats both plants and animals, hence when man eats plants acts as primary consumers, when man eat other primary consumers like cowand sheep he becomes secondary consumers, similarly when man eats carnivorous fishes, he becomes tertiary consumer. So, in ecosystem as it is clear from pyramid of energy, there is great loss of energy at each trophic level, and very short amount of energy is transferred at next trophic level. Most of the energy is lost as heat, this is due to this fact that the total biomass decreases at each level.

The lesson from the pyramid of organic matter was summarized by a popular 1970s phrase "Eat low on the food chain". This refers to the fact that it takes 10 kg of grain to build 1 kg of human tissues if the person eats the grain directly but it takes 100 kg of grain to build 1 kg of human tissue if a cow eats the grain first and the person eats the beefs. Eating lower on the food chain-eating producers, not consumers-save

precious resources on a small planet.

Thus, longer food chains such as in food web consume large amount of energy because loss in form of heat is greater as compared to short food chains. As man is the end source of several food chains, so these large food chains or food webs are nothelpful for solving food problems. Consider a food chain like grass-sheep-man; is a simpler and linear food chain, where loss of energy is very little. So short food chains are helpful in providing food for larger populations while food webs or longer food chains sustained lesser population.

KEY POINTS

- Capturing and conversion of solar energy from one form to another in the living system and its utilization in metabolic activities called **bioenergetics**.
- Plant and other autotrophs are the producers of the biosphere.
- Photo autotrophs use the energy of sunlight to synthesize organic molecule from CO_2 and H_2O.
- Light reaction in grana produces ATP and splits water, releasing oxygen and forming NADPH by transferring electrons from water to NADP.
- Alternative mechanisms of carbon fixation has evolved in hot, arid climate i.e. C_4 plants and CAM plants.
- Cellular respiration and fermentation are catabolic i.e. energy yielding processes.
- Redox reaction release energy for ATP synthesis, this synthesis of ATP is called **oxidative phosphorylation.**
- Respiration is a cumulative function of glycolysis, Kreb's cycle and electron transport.
- Glycolysis harvests chemical energy by oxidizing glucose to pyruvate, occurs in cytosol, produces net two molecules of ATP.
- Pyruvic acid may go to 3 major pathways, i.e. alcoholic fermentation, lactic acid fermentation and Kreb's cycle.
- Krebs cycle completes theenergy yielding oxidation of organic molecule, CO_2 is given off, one ATP is formed and e^- are passed to 3 NAD^+ and one FAD^+.
- Energy from sun absorbed by plant convert it into chemicals, transfer to consumers.
- Energy flow from tropic level to another follows 1st and 2nd law of thermodynamics.
- Each stage in a food chain with a particular set of organisms is called **trophic level.**
- The diagrammatic representation of trophic levels is called **pyramid**.
- Energy stored in food material by primary producers is said to be **primary productivity** and the rate at which this energy is stored called **grossprimary productivity.**

EXERCISE

1. Encircle the correct choice:

(i) Photosynthesis is measured in leaf of a green plant exposed to different wavelength of light:

(a) highest in green light (b) highest in red light
(c) highest in blue light (d) highest in red and blue light

(ii) Where do the light-dependent reaction of photosynthesis occur:
(a) in the guard cells of stomata
(b) stroma of chloroplast
(c) in the thylakoid membrane of chloroplast
(d) Cytoplasm of leaf

(iii) Oxygen produced during photosynthesis comes from:
(a) the break down of CO_2 (b) the break down of H_2O
(c) break down of both CO_2 and H_2O
(d) Photo respiration

(iv) Where does respiratory electron transport occur:
(a) cytoplasm (b) matrix of mitochondria
(c) inner membrane of mitochondria
(d) outer membrane of mitochondria

(v) What are the economically important products of fermentation of grape juice by yeast.
(a) Lactic acid and NAD^+ (b) ATP and CO_2
(c) ATP and ethanol (d) $CO_2$and ethanol

(vi) Process which convert pyruvate in to three molecules of CO_2 is
(a) C_3Cycle (b) C_4Cycle
(c) TCA Cycle (d) Banson and calvin cycle

(vii) The generation of ATP by electron transport chain coupled with H^+ ion pump process is called:
(a) Chemosmosis (b) Endosmosis
(c) Exosmosis (d) None of them

(viii) The primary electron acceptor in photosystem II is:
(a) Plastoquinone (b) Plastocyanin
(c) Pheophytin (d) Ferrodxin

(ix) Flow of energy in an ecosystem is:
(a) Cyclic (b) Non-cyclic
(c) Unidirectional (d) Multidirectional

(x) Enzyme responsible for the carboxylation in Banson and Clavin cycle is:
(a) RUBISCO (b) PEPC
(c) Pepsin (d) Isomerase

2. Write detailed answers of the following questions:

(i) Define photosynthesis? Describe the process of photosynthesis?
(ii) What do you mean by energy producing process during which O_2 is consumed? Describe the aerobic degradation of pyruvic add?
(iii) What do we mean by energy flow in an ecosystem? What is the role of this flow is the living world?

3. Write short answers of the following questions:

(i) Why ATP is called currency of energy in living system?
(ii) Why light independent phase of photosynthesis is called C_3 cycle?

(iii) Why ATP formation during photosynthesis is called non-cyclic photophosphorylation?
(iv) Why kreb's cycle is also called TCA cycle?
(v) Why ATP formation during glycolysis is called substrate level phosphorylation?
(vi) Why photo respiration is called waste full process?
(vii) How plants adopt themselves to avoid from photo respiration?

4. Write short notes on the following:

(i) Chloroplast (ii) Photosystems of photosynthesis
(iii) Glycolysis (iv) Kreb's cycle
(v) Significance of energy flow in ecosystem

5. Define the following terms:

(i) Bioenergetics (ii) Photosynthesis
(iii) Chloroplast (iv) Antenna complex
(v) reaction centre (vi) Photophosphorylation
(vii) Chemosmotic (viii) Photolysis
(ix) Carboxylation (x) Oxidative phosphorylation
(xi) Fermentation (xii) Glycolysis
(xiii) Trophic level (xiv) Ecological pyramids
(xv) Primary productivity

6. Distinguish between:

(i) Photosynthesis and respiration
(ii) Light dependent and independent phase of photosynthesis
(iii) PSI and PSH
(iv) Photophosphorylation and oxidative phosphorylation
(v) Aerobic and anaerobic respiration

Chapter - 12

NUTRITION

In a very real sense, you are what you eat. Atoms from your food make up most of the molecules of your body, energy derived from food powers your brain, your muscles and all the cells of your body. Even the first cells must have obtained materials and energy from their environment to grow and carry on cellular processes. An organism evolved the ways they gained material diversified dramatically.

12.1 INTRODUCTION

Every living organism requires energy to perform its metabolic functions and molecules to build up its body. For this, they adopt the way familiarly known as **nutrition**. So, nutrition is the process by which the organisms obtain energy to maintain the function of life, to build the matter and maintain their structures. Nutrients are food or any substance which supplies elements and energy to the living body for its metabolic activity.

Both the synthesis of new protoplasm and the respiratory oxidation of high energy organic compounds demand the procurement of two main categories of molecules from the environment: (1) already synthesized high energy compounds or else the raw materials from which new protoplasm can be synthesized and (2) the oxygen used in cellular respiration.

The main nutrients for living organisms are generally CO_2 and H_2O used directly or indirectly. On one hand, CO_2 and H_2O used directly by living organisms to produce high energy organic molecules with the help of light or chemical energy where CO_2 is used as source of carbon for organic molecules. On the other hand, CO_2 and H_2O are used indirectly in the living organisms, they use already fixed CO_2 (organic molecules) as a source of carbon and energy for the synthesis of other biomolecules.

12.2 AUTOTROPHIC AND HETEROTROPHIC NUTRITION

Living organisms can be divided into two groups on the basis of their mode of nutrition.

(i) **Autotrophic** organisms prepare their own food from the law material.

(ii) **Heterotrophic** organisms obtain the prepared food from the surroundings.

Autotrophic nutrition is the type of nutrition in which organic compounds are manufactured by living organisms from available inorganic raw materials taken from their surroundings. These molecules of raw materials are small and are soluble enough to pass through cell membrane. In autotrophic nutrition the nutrients do not require to be pretreated or digested before taking them into their cells. There are two methods of autotrophic nutrition i.e. **prototrophic** and **chemotrophic** nutrition.

Most of the autotrophic organisms have phototrophic mode of nutrition although a few have chemotrophic nutrition. All the plants, algae and some bacteria are phototrophic while some bacteria are chemotrophic.

Heterotrophic nutrition is the type of nutrition in which organic compounds are not manufactured from simple inorganic nutrients. Such heterotrophic organisms must obtain pre-fabricated organic molecules from their environment. Many of the organic molecules found in nature are too large to be absorbed unaltered through cell-membranes, they must first be broken down into smaller, more easily absorbable molecular units i.e. they must be digested. Most bacteria, fungi and animals have heterotrophic mode of nutrition. Carbohydrates, fats and

proteins are the main classes of organic compounds serving as energy and carbon sources for heterotrophic organisms.

12.3 AUTOTROPHIC NUTRITION

As we already discussed that the mode of nutrition in which organic molecules are manufactured from simple inorganic molecules by using light energy or chemical energy is called autotrophic nutrition.
There are two types of autotrophic nutrition:

(1) Phototrophic nutrition (2) Chemotrophic nutrition

1. Phototrophic nutrition:

The organisms which have ability to convert solar energy into food energy are called phototrophic organisms. The raw materials needed by these organisms are carbon dioxide and water which supply the carbon, hydrogen and oxygen for the synthesis of organic molecule. CO_2 and H_2O are not the only nutrients material for green plants. The minerals like **Nitrogen, Phosphorous, Sulphur** and **Magnesium** etc. are also required to produce different molecules. It means three classes of nutrients are needed by green plants i.e. CO_2, H_2O and minerals. Besides all these three types of nutrients, the phototrophic organisms require green pigments i.e. chlorophyll **'a', 'b'** or other to absorb the energy from the universal source i.e. sun light. In the presence of the light these nutrients are used to synthesize energy rich compound, carbohydrate. This process is called **photosynthesis.**
Detailed process of photosynthesis is already discussed in chapter 11.
Other types of photosynthetic autotrophs are photosynthetic bacteria. They are unique because they are the only organism which are capable of synthesizing carbohydrate food without chlorophyll 'a'. This photosynthesis is different from photosynthesis in green plants, because they grow in light, and usually in sulphur spring where hydrogen sulphide (H_2S) is normally present. Hydrogen is provided by donor substances such as H_2S instead of water and sunlight is used as a source of energy. Therefore free oxygen is not released as a by product in Bacterial photosynthesis. The process takes place at low expenditure of energy.
Two common examples of photosynthetic bacteria are the purple-sulphur bacteria and green sulphur bacteria. The former contain **bacterio-chlorophyll** and **carotenoids** as photosynthetic pigments and later **chlorobiumchlorophyll**. Both use H_2S as a donor of hydrogen. Light splits hydrogen sulphide in both cases. Hydrogen combines with carbon dioxide to form CH_2O.
There are non-sulphur purple and brown bacteria found in the mud and stagnant water. They are photosynthetic and contain bacterio chlorophyll pigment. They use organic hydrogen donors whereas sulphur is not the by product in their cases. Light is still the source of energy.

2. Chemotrophic nutrition:

Their is another mode of autotrophic nutrition in which light is not used as the source of energy for nutritional requirement. In this type of nutrition, energy is produced by the oxidation of certain inorganic substances such as ammonia, nitrates, nitrites, ferrous ions, hydrogen sulphide and a number of metallic and non-metallic materials available in the environment. This energy is used for the synthesis of carbohydrates. This type of nutrition is called **chemotrophic nutrition** and the process of manufacturing food is called Chemosynthesis (chemo=chemical, synthesis=to produce). The organisms which synthesize high energy organic compounds by chemosynthesis are called chemosynthetic organisms. Chemosynthetic organisms are mainly bacteria, e.g. Ammonia using bacteria.
Details of chemosynthetic bacteria are already discussed in section III, chapter-6.

The chemosynthetic bacteria that act on nitrogen compounds do play an extremely important rob in the maintenance of nitrogen balance within the life system.

12.4 MINERAL NUTRITION IN PLANT

In plants, the source of inorganic requirements are minerals obtained directly or indirectly from the soil. These elements are known as mineral nutrients and the nutrition is called **mineral nutrition**. Nitrogen is also included in the mineral nutrients because it is normally obtained by the plant from soil whereas it is not a mineral element.

12.4.1 Role of some important mineral nutrients and their deficiency symptoms:

Analysis of plant shows the presence of a large number of mineral elements. The amount and number of elements present in plant may also differ from plant to plant, place to place and medium to medium in which the plant grows. Some important mineral nutrients which are required in large quantities (macronutrients) are as follows.

Nitrogen, phosphorus and potassium are most important elements, used in the manufacture of modern fertilizers. Modern commercial fertilizers are often designated by their N-P-K percentages e.g. the widely used garden fertilizers called 5-10-5 contains 5% nitrogen, 10% phosphoric acid and 5% soluble potash by weight.

i) Nitrogen (N):

It is found in the soil in the form of nitrates or ammonium salts. It is an essential constituent of proteins, nucleotides, nucleic acids and many other organic molecules like chlorophyll, so the biosynthesis of these molecules require nitrogen.

Deficiency symptoms:

Absence or low supply of nitrogen develops the following symptoms.

1. Leaves turn pale yellow due to loss in chlorophyll content called chlorosis.
2. Process of cell-division and cell enlargment are inhibited.
3. Rate of respiration is affected.
4. In certain plants veins turn purple or red due to the development of Anthocyanin pigment e.g. tomato and apple leaves.
5. Plant growth remains stunted and lateral buds remain dormant as a result cereals do not show characteristic tillering.
6. Prolonged dormancy and early senescence including leaf falls.

ii) Phosphorous (P):

Plants absorb phosphorous in the form of soluble phosphates such as H_3PO_4 and HPO_4. It is present abundantly in the growing and storage organs such as fruits and seeds. It promotes healthy root growth and fruit ripening by helping translocation of carbohydrates.

It is an essential element involved in the formation of cell-membrane as phospholipids, nucleic acid, co-enzyme (NADand NADP) and organic molecules such as ATP and other phosphorylated products. It plays an important role in the energy transfer reaction in oxidation-reduction processes.

Deficiency symptoms:

In the case of phosphorous deficiency a few symptoms resemble that of nitrogen deficiency, like premature leaf fall and development of purple red anthocyanin pigment. Deficiency of phosphorous also shows some other symptoms.

1. Cambial activity is checked.
2. Tillering of crop plant is reduced.
3. Dormancy is prolonged.
4. Growth is retarded and dead necrotic patches appear on leaves, petioles and fruits.
5. Variable colours develop e.g. plate green in **Pisum**, olive green in **Phaseolus**.
6. Causes accumulation of carbohydrates.
7. Thickening of tracheal cells are reduced and phloem differentiation becomes incomplete.

iii) Potassium (K):

Potassium is widely distributed in soil minerals. It is strongly fixed in soil, therefore, found in less available form. Exchangeable potassium appears to be readily available to the plants.

The best known function of potassium is its role in stomatal opening and closing. It is found in highest concentration in the meristematic regions of plant. It is an essential activator for enzymes involved in the synthesis of certain peptide bonds and carbohydrate metabolism.

Deficiency symptoms:

The deficiency symptoms vary with the extent of the shortage of the element. In acute deficiency:

1. The colour of leaf may turn into dull or bluish green.
2. An irregular chlorosis occurs first, which is followed by the development of necrotic areas of the tip and margin of the leaf.
3 Plant is stunted in growth with a pronounced shortening of internodes and reduced production of grains.
4. Lamina of broad leaved plants curl backward towards the under surface or roll forward towards the upper surface parallel with midrib.

iv) Magnesium (Mg):

Magnesium is present in the soil in water-soluble, exchangeable and fixed form and is present in primary minerals. It is found as carbonates similar to that of calcium and held in soil as exchangeable base.

It is a constituent of chlorophyll and therefore essential for the formation of green pigment. It acts as phosphorous carrier in plant, particularly in connection with the formation of seeds of high oil contents which contains compound lecithin. It is readily mobile and when its deficiency occurs, it is apparently transferred from older to young tissues where it can be reutilized in growth processes.

Magnesium is essential for the synthesis of fats and metabolisms of carbohydrates and phosphorous.

Deficiency symptoms:

1. Deficiency symptoms develop first on the older leaves and then proceed systematically towards younger leaves.
2. Chlorosis occurs.
3. Severly affected leaves may wither and shed or absciss without the withering stage. Defoliation may be quite severe.
4. Leaves, sometimes, develop necrotic spots.

Some kinds of plants have specific nutritional requirements that are not shared by others, e.g. silica, essential for the growth of many grasses, cobalt-necessary for the growth of nitrogen fixing bacteria-essential for the growth of nodules and legumes. Nickel, essential for soyabean. Sodium, important in maintaining osmotic and ionic balances, required by some desert and salt marsh species.

12.5 HETEROTROPHIC AND SPECIAL MODE OF NUTRITION IN PLANT

Plants which are not capable of manufacturing their own organic molecules entirely or partially depend for these organic molecular requirements on outside sources and are called **heterotrophic** plants.

Among heterotrophic plants those which depend on living plants and animals for their nutritional requirements are known as **parasites.** Parasites which depend for their nutrition entirely on other living organisms are known as **obligate** or **total parasites** and those which depend for these requirements partially on other living organisms are called **facultative** or **partial parasites** or **facultative parasites**. On the other hand, the plants which depend on dead or rotten organic remains of plants and animals are called **saprophytes.** Like parasite, the plants which depend entirely on dead organic matter are known as **total saprophytes** and those which depend for these requirements partially on dead organic matter are called **partial saprophytes.**

12.5.1 Parasitic plants:

For obtaining their food requirements parasitic plants develop haustoria, which penetrate into host tissues for absorbing nutrients requirements.

Parasitic angiosperm

Parasitic angiosperms are broadly classified into:

i) Partial stem parasite.
ii) Total stem parasite.
iii) Partial root parasite.
iv) Total root parasite.

i) Partial stem parasite: Loranthus is a partial stem parasite. It has well developed thick green leaves, a somewhat woody stem and elaborated haustorial system. It can manufacture some of its food with the help of nutrients and water absorbed from the host plants through haustoria. The seeds get stuck up to the stem of the host plant and germinate, sending its haustoria in the tissue of the host. Loranthus is commonly found on shrubs, roseaceous trees, Bauhinia and mango, often causes serious damage. Other examples of partial stem parasites are:

Viscum — produce haustorial branches for an internal sucking system.

Cassytha filiformis — found in tropics, a leaf less, wiry stem, send the haustoria that penetrate in the stem to develop connection with vascular tissue of host plants.

ii) Total stem parasite: The plants like Cuscuta (Amer-bail) is a common parasite which attacks stems of many herbs, shrubs and trees. They send haustoria inside the tissue of host. The xylem of parasite comes in contact with the xylem of host and phloem of parasite to phloem of host. Through xylem it sucks the water and nutrients and through phloem prepared organic food material. The host plant eventually dies off due to exhaustion.

iii) Partial root parasites: The example or types of this category are rare. The sandal wood tree is an important example. Its seedling can grow for a year but not so independently. Within a year the sucking roots of plant attack the root of neighbouring trees and from them nutrients are absorbed.

iv) Total root parasite: They suck their nutritional requirements from the roots of host e.g. Orobanche, attacks the roots of plants belonging to the families Cruciferae and Solanaceae. Cistanche parasitizes on the roots of Calatropis. Striga is found as parasite on the roots of sugarcane, commonly found on Sorghum or Jowar crop.

12.5.2Saprophyte:

Plants which break up complex dead organic food material into simple compound and use them for their growth and development are saprophytes. There are some examples found among flowering plants like Neotia (bird's nest or orchid)and Monotrapa (Indian pipe), in these cases the roots of the plant form a mycorrhizal association with fungal mycelium to help in the absorption process.

For centuries, farmers have rotated crops to take advantages of such relationships. They observed that if grew clover or alfalfa one, the following year's crop of wheat grow more luxuriantly. Likewise; rice farmers have encouraged the growth of water in their flooded rice paddies because cyanobacteria living symbiotically in the ferns fix atmospheric nitrogen and enrich the growth of rice plants. In water logged bogs, where soils tend to be too acidic for bacteria to survive, insectivorous plants such as the venous fly trap and the pitcher plant, have evolved the ability to gain needed nitrogen by trapping and digesting insects.

12.5.3Carnivorous plants (Insectivorous plants):

There are plants which have insects and small birds as their prey. J.D.Hooker suggested that the digestion of carnivorous plants is like that of animals. Infact enzymes secreted by these plants are similar to those found in human stomach e.g. Pepsin.

Partially autotrophic plants and partially heterotrophic plants are carnivorous which possess the green pigments and can manufacture carbohydrates but are not capable of synthesizing nitrogenous compounds and proteins. For their nitrogen or proteins requirement carnivorous plants have to depend on insects which they catch and digest by specific devices developed in them.

These plants commonly grow in areas where nitrogen is deficient due to unfavourable atmosphere for nitrifying bacteria but favourable atmosphere for denitrifying bacteria. They have to depend on insects for their nitrogen and protein requirements. Some common examples are:

i) Pitcher plant: It has a modified leaf of pitcher shape. Common example are Nepenthes, Sarracenia, Cephalotus, Heliamphora, Dorlingtonia. Common pitcher plant is Sarracenia pupurea or yellow pitcher plant Sarracenia flava.

ii) Drosera intermedia or Sundew: A plant with loose and about half a dozen prostrate radiating leaves. The tiny leaves bear hair like tentacles with glands at its tip. The insect, attracted by plant odour, are traped.

iii) Dionaea muscipula or Venus fly trap: It is most well known of all carnivorous plants. Charles Darwin called it "the most wonderful plant in the world".

It has a rosette of prostrate radiating leaves with the inflorescence in the centre. The junction of petiole and lamina is constricted upto the mid-rib, the petiole is

merged and lamina has two halves, with mid-rib in centre. Each half has 12-20 teeth. The teeth of one half can interlock with the teeth of the other half. In thecentre of the dorsal surface of lamina are numerous secretory glands, three hairs projecting outwards which are sensitive to touch.

iv) Aldrovanda (water fly trap): A rootless aquatic plant with floating stem. It has rosettes of modified leaves, which have two lobed mobile lamina having teeth at the margin and sensitive jointed hairs and stalked gland on the surface.

v) Utricularia or Bladder Wort: Rootless plant have much branched slender stem Leaves are also much divided, some of the leaflets are developed into bladder like traps of about 1/16to 1/8 Inches in diameter. The trapes have trapdoor enterances which allow small aquatic animals to get in with no return.

12.6 HETEROTROPHIC NUTRITION IN ANIMALS

The heterotrophic nutrition is that nutrition in which the organisms are dependent upon other organisms, plants or animals for complex ready made organic food. Their carbon source is organic. They use it as a source of energy for their vital activities, building materials for repair, growth and to get (procure) vitamins, that cannot be synthesized in these organisms. All animals, fungi and the majority of bacteria fall into this category and are known as **heterotrophs**.

The manner in which heterotrophs procure and take in food varies considerably, but the way in which it is processed into a utilisable form within the body is similar. It involves digestion, reducing complex food into soluble molecules and absorption by which soluble food molecules are absorbed into the body. This particular type of nutrition is known as **holozoic** and is found in animals. The other modes of heterotrophic nutrition are **saprotrophic** and **parasitic.**

The organisms which feed on dead or decaying organic matter of plants and animals are called **saprotrophs**. Many fungi and bacteria are saprotrophs.

Some animals feed upon fragments of decomposing material (detritus) and contribute to the process of break down. They are called **detritivores** (earth worm). Some animals hunt, capture and kill their prey to eat. These are known as **predators** (lion). Some animals feed on plants, primary producers and are known as **herbivores** (cow). Some feed on other animals are known as **carnivores** (dog) and those that eat meat as well as vegetable matter are termed **omnivores** (crow and man).

Some animals are called**filterfeeders** such as sponges. If the food is ingested in liquid form, they are known as **fluid feeders** (honey bee). Even the size of the food varies in different animals. If they take in small food particles, they are known as **microphagous feeders**. When they take food in the form of large pieces, are termed as **macrophagous feeders.**

12.7 HOLOZOIC NUTRITION

The nutrition in which complex, non-diffusible food is taken in and digested into smaller diffusible molecules which can be absorbed and assimilated is known as holozoic nutrition. It is found in free living animals which have a specialized digestive tract in which various processes occur.

The holozoic nutrition is achieved by the following processes.

1. **Ingestion** — The taking in of complex organic food.

2. **Digestion** — The breakdown of large complex insoluble organic molecules.

3. **Absorption** — The uptake of soluble molecules from the digestive region, across a membrane into the body cells.

4. **Assimilation** — The utilization of the absorbed food molecules by the body to provide energy or materials for tissue building.

5. **Egestion** — The elimination of the undigested food from the body.

12.8 DIGESTION AND ABSORPTION

12.8.1 Digestion:

It is the process by which large complex insoluble organic food substances are broken down into smaller simple soluble molecules by the help of enzymes. This is achieved by mechanical breakdown and enzymatic hydrolysis.

1. Need for digestion:

For holozoic nutrition digestion is the most important process, as the organic food which is taken in (ingested) is complex and cannot be diffused into the body tissues until it is made simple and diffusible which can readily be absorbed into the body. Hence, there is a need for digestion by which large molecules can be converted into smaller soluble molecules which can be easily diffused.

2. Types of digestion:

The digestion is of two types, extracellular and intracellular. The **extracellular digestion** takes place outside the cells. The **intracellular digestion** takes place inside the cells. Both the types of digestion involve the mechanical and chemical breakdown of the complex food. In **mechanical digestion**, the food is broken into small pieces mechanically, by churning or mastication. The **chemical digestion**is the enzymatic hydrolysis, during which the mechanically digested food particles are acted upon by the enzymes in the presence of water, modifying them chemically into simple soluble molecules; which can be absorbed readily within the digestive tract.

Sac like and tube like digestive system:

The organs which are involved in all these processes (ingestion, digestion,absorption, assimilation and egestion) constitute the digestive system. It may be sac-like or tube like. In **sac-like digestive system**, there is only a single opening which is known as the mouth. The mouth opens into a large sac-like body cavity which also functions as the digestive cavity. The food is partially digested here by the help of digestive juices. The undigested food is egested through the mouth. Since it lacks the anal opening the digestive system is termed as incomplete.

In **tube like digestive system** the digestive cavity is separate from the body cavity. It has both the openings, mouth and anus. The ingestion takes place through the mouth and the egestion through the anus. Such digestive system is known as complete digestive system. The tubular digestive system has an advantage over the sac-like, that the food is completely digested within the digestive tract.

3. Ingestion:

As already mentioned earlier the ingestion is the initial process of holozoic nutrition by which the food is taken in either directly by phagocytosis or through the mouth. The phagocytosis is seen in protozoans like Amoeba, Paramecium etc., in which the food is taken into, the food vacuole either through pseudopodia or through ciliary action, where it is subjected to intracellular digestion.

In metazoans, the ingestion takes place through the mouth which is a permanent opening of the digestive tract. In microphagous feeders such as filter feeders e.g. Daphnia, thelimb with stiffbristles move forward to drawwater containing suspended food particles towards themselves. The bristles filter off the food from this feeding current. When the limbs move backward, the food is propelled towards the mouth. In Mytilus (common mussel) and other bivalves, the movement of cilia present on the gills causes a current of water to enter the body via an inhalent siphon and leave through an exhalent siphon. The water which enters contains the food particles, which get entangled in the mucus. This trapped food is then swept by cilia towards the mouth.
In macrophagous feeders, the ingestion is facilitated by tentacles or arms which seize the prey orradula which scraps the algae or by some other means. In fluid feeders the mouth parts are modified for piercing and sucking.

12.8.2Absorption:
It is the post digestion process in which the digested soluble food substances are absorbed directly into the body cells or through body fluids, blood and lymph. In protozoans, the digested food is diffused into the cytoplasm, from where it is circulated to all the parts of the body through cyclosis. In metazoans, it is diffused into the body cells either directly or through the transport medium (blood and lymph).

Assimilation is the ultimate goal of the nutrition. The digested food is utilized within the cells either to provide energy or materials to be corporated into the body.

Egestion is elimination of the undigested food either through a temporary anus or a permanent anal opening. The mouth is used for egestion in case where the anus is absent.

12.9 NUTRITION IN AMOEBA, HYDRA, PLANARIA AND COCKROACH

12.9.1Nutrition in Amoeba:
Amoeba is a microphagous feeder. It feeds upon small aquatic organisms like bacteria, flagellates, ciliates and minute food particles.
When a hungry Amoeba approaches to some food particle, it produces out its pseudopodia in the form of food cup which engulf the food particle by turning into **food vacuole**. The food also contain some water. This completes ingestion. The next step is digestion which is facilitated by the lysosomes. A few lysosomes surround the food vacuole and get fused with the membrane; to discharge their enzymatic contents (proteases, amylases and lipases) into it. Hence the digestion is intracellular. At this stage the vacuole becomes a digestive vacuole. It decreases in size as the water is withdrawn and its contents first become acidic (pH 5.6) and then alkaline (pH 7.3). When the digestion is completed, the digestive vacuole membrane is drawn into numerous fine canals. The soluble food particles are passed into the canals and finally into the surrounding cytoplasm by micropinocytosis. The digested food, water and minerals are absorbed (absorption) into the cytoplasm and circulate in it, through cyclosis where the food is assimilated into new protoplasm or is oxidized to liberate energy. The undigested food is egested by exocytosis at the rear end.

12.9.2Nutrition in Hydra:
Hydra is one of the simplest heterotroph to carry out extracellular digestion within the body cavity. It is a macrophagous feeder and feeds upon small aquatic animals like crustaceans, small annelids and insect larvae. When these organisms brush against the projecting cnidocils of nematocysts located on the tentacles, their contents are discharged and the prey is paralyzed. The tentacle then bends

over the mouth along with other tentacles. The mouth opens widely, enabling the prey to enter the body resulting in ingestion.
The mouth opens into the body cavity (coelenteron), bounded by the endoderm having glandular and flagellated musculo-epithelial cells. The former secrete proteolytic enzymes which initiate extracellular digestion. The flagellated cells and the contraction of the body wall help in the circulation of food and enzymes and result in mechanical digestion. Hydra can digest proteins, fats and some carbohydrates but not the starch. Extracellular digestion is completed in about four hours. The semi-digested food particles are engulfed by the phagocytic action of the flagellated cells where they are completely digested. Thus the digestion in Hydra is extracellular as well as intracellular. The soluble food particles are diffused through mesogloea into the ectodermal cells and the undigested food is egested through the mouth.

12.9.3Nutrition in Planaria:

Planaria is a free living flat worm. It is carnivorous and feeds upon small worms, crustaceans, snails and dead animal debris. Planaria perceives the presence of food at a distance and moves towards it. The prey gets entangled in the slimy secretion produced by the mucous glands. Soon the pharynx is everted out through the mouth situated on the mid ventral surface and seizes the prey. It is withdrawn quickly into the pharyngeal sheath along with the prey, where the extracellular digestion starts by pumping action of the pharynx, and the enzymes. The pharynx opens into the intestine which consists of three branches, an anterior and two lateral. All these branches give off numerous branching diverticula which ramify throughout the body penetrating into the tissues, ending blindly. Anus is absent and the undigested food is thrown out directly by the mouth. Thus the digestive system is sac type.
The much branched intestine is a means of increasing the surface area for digestion, absorption and distribution of food.
Digestion is both extracellular as well as intracellular. Partially digested food particles are taken into the cells lining the diverticula, where they are completely digested. The digested food is then diffused into the mesenchyme cells which help in the distribution.

12.9.4Nutrition in Cockroach:

Cockroaches are omnivorous and can eat any kind of organic matter. They search their food by their antennae. Their digestive system is tubular, having a straight slightly coiled digestive tube opening at both the ends. Hence, the digestive system is complete. The mouth lies at the base of the pre-oral cavity which is bounded by the mouth parts, **labrum** (upper lip), **labium** (lower lip), **mandibles** and **maxillae**. The maxillae pick up and bring food to the mandibles for mastication, where it is mixed with saliva produced by a pair of salivary glands. The saliva contains amylase which acts upon the carbohydrates.
The mouth opens into a tubular **pharynx** which in turn opens into the **oesophagus** lying in the thorax. It dilates into a large thin walled pear shaped **crop** which opens into a small rounded thick walled **gizzard** lined by cuticle in the form of teeth, which grind and strain the food. This portion from pre-oral cavity to gizzard is known as **fore gut** or **Stomodaeum.**
The **mid gut** or **mesenteron** is a narrow tubular portion having eight hepatic caeca which hang into the haemocoel, ending blindly but opening into the gut. They are lined by glandular cells, which secrete enzymes. The enzymes produced by the mid gut and hepatic caeca flow back into the crop where proteins and fats are digested. The digested food forms a bolus which gets enclosed in a thin chitinous tube secreted by the gizzard, which is a device to protect the lining of mid gut from hard food particles. It is permeable to enzymes and the digested food. The digestion is completed here. The digested food is absorbed in the mid gut.

The **hind gut** or **proctodaeum** has a cuticular ectodermal lining. It has a short tubular **ileum**, a long coiled colon and a broad **rectum** opening out through the **anus**. The rectum absorbs and conserves the much needed water from the undigested food before expelling out the faeces.

12.10 HUMAN DIGESTIVE SYSTEM

Man is the most advanced heterotroph, having a perfect digestive system with perfect extracellular digestion. The digestive system of man consists of a one way tube into which food is admitted at one end and faecal matter is expelled out from the other end. This tube is commonly known as **gastro-intestinal tract** which runs from the mouth to the anus. It is specialized at various places along its length with each region designed to carry out a different role in the overall processes of ingestion, digestion, absorption and egestion.

It begins with the mouth and buccal cavity which is followed by the pharynx, oesophagus, stomach, small intestine comprising the duodenum, jejunum and ileum. The large intestine consists of the caecum bearing appendix, colon and rectum, terminating at the anus.

Mouth:

It is the anterior opening of the gut, which is bounded by fleshy lips. The lips not only close the mouth but also help in ingestion. The mouth opens into the oral cavity.

12.10.1 Oral Cavity:

It is a wide cavity supported by the bones of the skull. The cheeks forming its side walls, the tongue its floor and the palate its roof. The jaws form the boundary of the mouth. The upper jaw is fixed but the lower jaw is movably attached. Both the jaws bear teeth which are used to masticate food into smaller pieces, resulting in mechanical digestion which increases the surface area of food for action of the enzymes.

Teeth:

Humans have two sets of teeth (diphyodont), deciduous or milk teeth appear first, but are replaced by the permanent teeth. The teeth are of different shapes and sizes (heterodont) and are embedded within the gums (thecodont). This is correlated with their different functions and different diet. The permanent teeth are 32 in number, consisting of 8 incisors, 4 canines, 8 premolars and 12 molars. The molars have no deciduous predecessors. The incisors are cutting and biting teeth and have flat sharp edges by which the food is cut into smaller pieces for ingestion. The canines are pointed tearing teeth poorly developed in human beings but well developed in carnivores, where they are used for piercing and killing the prey and tearing the flesh. The molars and premolars are the grinders and are specialised for crushing and grinding the food. The human dental formula is

Plaque and dental diseases:

The plaque is a mixture of bacteria and salivary materials. If it is allowed to accumulate, the bacteria cause inflammation of the gums. If this condition continues, the inflammation may spread to the root of the tooth and destroy the peridental layer. Eventually the tooth becomes loose and falls off or may have to be extracted. This diseases is known as **periodontal disease**. Plaque also combines with certain chemicals in the saliva which become harden and calcified forming deposits of **calculus** which cannot be removed by brushing. Some of the bacteria in plaque convert sugar into acid which causes **dental caries.** In which the enamel is dissolved slowly. When the dentine and pulp of the tooth are attacked, produce toothache and loss of tooth. The dental caries is spread by several factors. Prolonged exposure to sugary food stuffs, disturbance of saliva

composition, lack of oral hygiene and low levels of fluoride in drinking water. Prevention of dental caries may be achieved by adding fluoride in drinking water or food like milk, or by taking fluoride tablets and using fluoride tooth paste.

Tongue:
The tongue is a muscular fleshy structure lying in the floor of the oral cavity having taste buds and tongue papillae. It is attached posteriorly but free anteriorly. It functions as the spoon and mixes the masticated food with saliva and afterwards helps in swallowing. It also helps in sucking and tasting the food.

Salivary Glands and Saliva:
The oral cavity has three pairs of salivary glands, which produce about 1.5 dm^3 of saliva each day. The **Parotid** glands lie at the base of the pinnae, **sublingual** glands at the base of the tongue and the **Submandibular** glands at the base of the lower jaw.
The saliva is a watery secretion containing 95% water, some mucus, amylase and lysozyme enzymes. The mucus moistens and lubricates the food for comfortable swallowing. The salivary amylase begins the digestion of starch, first to dextrins (shorter poly saccharides) and then to disaccharide maltose. Lysozyme destroys the oral cavity pathogenic bacteria. Ultimately the semisolid, partially digested food particles stick together by mucus and molded into a rounded mass **bolus** by the tongue which then pushes it into the pharynx.

12.10.2 Pharynx and Swallowing:
It is the posterior narrow part of the oral cavity which contains the openings of the oesophagus and glottis in addition to the openings of the internal nostrils and the eustachian tubes.

Without the palate we could either breathe or swallow the food, but not both.

The swallowing is initially a voluntary action but afterwards it continues as involuntary action. The soft palate helps in swallowing during which the elastic cartilagenous flap **epiglottis** is pushed flat over the glottis by the upward movement of the larynx, so that no food enters the wind pipe. However when accidentally something other than gases, comes in between the epiglottis and glottis, a powerful coughing reflex expels it out and throws it back into the mouth cavity. The swallowed food in the form of bolus passes down into the oesophagus.

12.10.3 Oesophagus:
This is a narrow muscular tube containing mucous glands about 25 cm long running through the thoracic cavity. It conveys the food and fluids by peristalsis from pharynx to the stomach.

Peristalsis:
The basic propulsive movement of the gastro-intestinal tract is peristalsis. These are alternate rhythmic contractions and relaxations of the gut wall. The usual stimulus for peristalsis is distension.

To swallow water peristaltic movements are required although it can flow down easily.

Antiperistalsis:
In the early stages of excessive gastro-intestinal irritation or over distension, antiperistalsis begins to occur, often minutes before vomiting appears. When the abdominal muscles contract, the stomach is squeezed. Finally the gastro-

oesophageal sphincter relaxes allowing the expulsion of the gastric content upward through the oesophagus in the form of vomiting.

12.10.3 Stomach:

The stomach is a distensible muscular bag lying below the diaphragm on the left side of the abdominal cavity. It performs three functions: storage of food, mechanical digestion by peristalsis and the chemical digestion of food by enzymes, which is reduced to a creamy paste called **chyme**.

The stomach has three regions. Anterior **cardiac region** having mucous glands, which joins the oesophagus through a cardiac sphincter. The middle region is the **fundus** which is the main part and has gastric glands. These gastric glands contain three types of cells; Mucus secreting cells, Zymogen cells secreting pepsinogen and Oxyntic cells which secrete dilute hydrochloric acid having a pH of 1.5 to 2.5. This collective secretion is known as **gastric juice**. The mucus lubricates and protects the stomach lining from self digestion by pepsin. The HCl kills the bacteria and activates the inactive enzyme pepsinogen into **pepsin** which acts upon proteins and convert them into short chain polypeptides, peptones. The posterior part is the terminal narrow **pyloric region** which like the cardiac region produces mucus. It opens into the duodenum through pyloric sphincter or pylorus which acts as a valve and servesto retain food in the stomach for about four hours. Periodic relaxation of pyloric sphincter releases small quantities of chyme into duodenum.

Pepsin is secreted in an inactive state otherwise it would digest its own cells.

In infants, another proteolytic enzyme **renin** is secreted which curdles the milk and converts soluble milk proteins (caseinogen) into insoluble proteins (casein) in the presence of calcium ions. This is then digested by pepsin.

Stomach also produces a hormone gastrin in the presence of partially digested proteins which activates the gastric glands to produce gastric juices. The secretions come immediately into contact with that portion of the stored food lying against the mucosal surface of the stomach. When stomach is filled, weak peristaltic waves also called mixing waves move along the stomach wall once every 20 seconds. As these waves move down the stomach, they not only cause secretions to mix with the stored food but also provide weak propulsion to move these mixed contents within the cavity of stomach.

12.10.4 Small Intestine:

Next to the stomach is the small intestine, about 6 metres long and 2.5 cm wide. Its coiled loops fill most of the abdominal cavity. There are three divisions of small intestine, duodenum, jejunum and ileum.

Duodenum:

Duodenum begins just after the pyloric stomach. It is about 30 cm long and runs parallel to the stomach. It receives a common bile duct and a pancreatic duct opening by a common aperture. The chyme on entering the duodenum meets the bile from the liver and the pancreatic juice from the pancreas. Bile is yellow in colour but on exposure to air it changes to green. It contains water, bile salts and bile pigments but no enzyme. The bile salts (sodium bicarbonate) neutralize the acid of the gastric juice and make the chyme alkaline. The other salts emulsify the fats into small fat globules which can mix with water to form an emulsion. Fats can be digested only when emulsified.

The bile pigments **bilirubin** (red) and **biliverdin** (green) are excretory products formed by the breakdown of haemoglobin of worn out R.B.Cs in the liver.

Pancreatic juice is secreted by the pancreas, under the stimulation of another hormone **secretin** produced by the duodenum. Secretin is produced under the stimulus of HCl carried with chyme. The pancreatic juice is a watery, colourless alkaline fluid having four enzymes, trypsin (protease), chymotrypsin, amylase and lipase.

Trypsinis secreted as an inactive precursor **trypsinogen** which is activated by an enzyme **enterokinase** produced by the duodenum. It acts upon the polypeptides and proteins and convert them into polypeptides, **chymotrypsin** converts casein (milk proteins) into short chain amino acids. **Amylase** converts starch and glycogen into maltose and **lipase** converts emulsified fats into fatty acids and glycerol, which are the soluble end products of fat. Thus the digestion of fat is completed in the duodenum.

Duodenum passes into **jejunum** which is about 2.4 metres long. The digestion of food is completed within the jejunum by a number of enzymes such as maltase, sucrase, lactase and peptidase. Here the final hydrolysis of disaccharides, tri and dipeptides occur. The end products are monosaccharides and amino acids respectively which are liberated into the lumen of the small intestine. Also present in the small intestine is nucleotidase which converts nucleotides to nucleosides.

Jejunum passes into **ileum** which is about 3.6 metres long. It receives much diluted food **chyle** containing digested food in the true solution form. The inner wall of the small intestine contains circular folds with finger-like microscopic projections called villi whose walls are richly supplied with blood capillaries and lymph vessels called **lacteals** and contain smooth muscles. They are able to contract and relax, constantly thus bringing themselves into close contact with the food in the small intestine. This increases the absorptive surface area. Each villus is lined by epithelial cells having microvilli on their free surface. The monosaccharides and amino acids are absorbed into the blood capillaries either by diffusion or active transport, while the fatty acids and glycerol enter the epithelial cells of the villi. Here they are reconverted into simple fats (triglycerides) which then enter the lacteals and pass into the blood stream. The blood capillaries converge to form the hepatic portal vein which delivers the absorbed food to the liver where it is stored and is distributed to all the cells of the body.

Active transport is employed in the absorption of digested food as their concentration is lower than the blood.

12.10.5 Large Intestine:

Small intestine opens into large intestine. It has a large diameter about 6.5 cm. It is divided into a short caecum, a long colon and a terminal rectum. The **caecum** is placed in the lower right side of the abdominal cavity and gives off a blind tube of about 18 cm long from its lower portion known as **vermiform appendix** which is a vestigial organ. It is of great significance in herbivores lodging symbiotic bacteria which help in thedigestion of cellulose. The **colon** is the longest part and has three regions, **ascending colon**, **transverse colon** and **descending colon**. **Inorganic salts**, vitamins and water are absorbed in the colon.

The **rectum** is the last portion of the large intestine. The undigested and unabsorbed food material passes down into the colon and rectum where water and inorganic nutrients are absorbed while some metabolic waste and inorganic substances notably calcium in excess in the body are excreted as salts, along with the faeces, which are stored in the rectum for some time. When the rectum is full, the faeces pass out through the process known as egestion. Many symbiotic bacteria present in the large intestine synthesize amino acids and some vitamins especially vitamin K which are absorbed into the blood stream.

12.10.6 Liver and Pancreas:

Liver and pancreas are two important glands which are closely related to digestion. Liver is the largest gland as well as the largest organ of the body. It is reddish brown in colour and lies behind the diaphragm more towards the right side. It has two main lobes, a right and a left lobe joined by a ligament. The left lobe is further divided into two lobes.

A pear shaped gall bladder lies on the under surface of the liver. It stores bile which is secreted by the liver cells. The bile is collected by two hepatic ducts which join the cystic duct coming from the gall bladder forming a common bile duct which joins the pancreatic duct and opens into duodenum.

Liver is a metabolic factory, detoxification center and storage organ. One of its functions is to maintain an appropriate quantity of level of nutrients in the body. It Is performed in three ways. Surplus amount of glucose is deposited in the liver cells after every meal. Here the glucose is transformed into glycogen in the presence of insulin, a hormone released from the pancreas. The glycogen can later be hydrolized through glucagon for energy to meet the body's energy requirements. The amino acids are also stored after deamination (removal of NH_2 group), which forms the urea. The liver also processes fatty acids and stores the products as ketone bodies which later are released as nutrients for active muscles. Liver also prevents certain poisons from harming the body by breaking them into harmless compounds. In addition to these functions liver stores vitamins, produces necessary substances for coagulation of blood. It keeps the composition of blood fairly constant. It excretes out the bile pigments and other waste products.

The pancreas lies behind the stomach horizontally within the curve of the duodenum. It is exocrine as well as endocrine in function. The exocrine part produces pancreatic juice and the endocrine part produces insulin and glucagon hormones.

12.10.7 Anus and Egestion:

The external opening of the anal canal is known as anus. It is used in egestion. The bulk of the faeces consists of dead bacteria, cellulose and other plant fibres, dead mucosal cells, mucus, cholesterol, bile pigment derivatives and water, pass out through the anus. Two sphincters surround the anus, an internal one of smooth muscle, under the control of the autonomic nervous system, and an outer one of striated muscle controlled by the voluntary nervous system.

Table 12.1 Summary of digestive secretions and their actions

Secretion	Enzymes	Site of action	Optimum pH	Substrate	Products
Saliva (from salivary glands)	Salivary amylase	Buccal cavity	6.5-7.5	Amylose in starch	Maltose
Gastric juice (from stomach mucosa)	(Pro) rennin (in young) Pepsin (ogen) Hydrochloric acid (not an enzyme)	Stomach Stomach Stomach	2.00 2.00 -----	Caseinogen in milk Proteins Pepsinogen Nucleoproteins	Casein Peptides Pepsin Nucleic acid and proteins
Membrane-bound enzymes in small intestine	Amylasae Maltase Lactase Sucrase	Microvilli of brush border of epithelial	8.5 8.5 8.5 8.5	Amylose Maltose Lactose Sucrose	Maltose Glucose Glucose + galactose Glucose+ fructose
Exopeptidases	Aminopeptidases Dipeptidases	mucosa of small intestine	8.5 8.5	Peptides and dipeptides	Amino acids Amino acids
Intestinal juice	Nucleotidase Enterokinase	Small intestine Small intestine	8.5 8.5	Nucleotides Trypsinogen	Nucleosides Trypsin
Pancreatic juice (from pancreas)	Amylase Trypsin (ogen)	Small intestine Small intestine	7.00 7.00	Amylose Proteins Chymotrypsinogen	Maltose Peptides Chymotrypsin
Endopeptidases*	Elastase Chymotyrpsin (ogen)	Small intestine Small intestine	7.00 7.00	Proteins Proteins	Peptides Amino acids
Exopeptidases*	Carboxypeptidase Lipase Nuclease Bile salts (not enzymes)	Small intestine Small intestine Small intestine Small intestine	7.00 7.00 7.00 7.00	Peptides Fats Nucleic acid Fats	Amino acids Fatty acids+ glycerol Nucleotides Fat droplets

* Exopeptidases split off terminal amino acids from proteins (polypeptides)
* Endopeptidases break bonds between amino acids within proteins thus producing smaller peptides.

12.7 DISORDERS OF THE GASTRO-INTESTINAL TRACT

(1) Diarrhoea

Diarrhoea or loose motions results from rapid movement of faecal matter through the large intestine. Diarrhoea may occur due to several causes.

Entritis caused by a virus or by bacteria in the intestinal tract. Due to infection the mucosa becomes irritated. The motility of the intestinal wall increases many folds. Sometimes **cholera** may cause diarrhoea, causing extreme quantities of bicarbonate ions to be secreted into the intestinal tract along with the massive amounts of sodium ions and water, leading to death. **Psychogenic Diarrhoea** is caused by nervous tension.

(2) Dysentary:
Dysentary is an acute inflammation of the large intestine characterised by diarrhoea with blood and mucus in the stool. It is caused by bacillary or amoebic infection.

(3) Constipation:
Constipation means slow movement of faeces through the large intestine and is often associated with large quantities of dry hard faeces in the descending colon which accumulates because of the long time available for absorption of fluid.
A frequent cause of constipation is irregular bowel habits that have developed through a life time of inhibition of normal defecation reflexes.

(4) Piles:
Piles are also known as **haemorrhoids**. These are dilated veins occurring in relation to the anus. Such haemorrhoids may be external or internal to the anal opening. The external piles are covered by skin while the internal piles lie beneath the anal mucous membrane.
The most common cause of piles is the constipation. The pressure exerted by the persons to defecate stretches the skin along with the veins resulting in their dilations forming haemorrhoids. Piles can be avoided by regular habit of defecation and the use of fibre diet, which is coarse in texture and makes it easier to pass out.

(5) Dyspepsia:
Dyspepsia is commonly known as epigastric discomfort following meals. It may be due to peptic ulcer. This is characterized by heart-burn, flatulance, by the anorexia, nausea and vomiting with or without abdominal pain.
Some persons have persistent dyspepsia for which no cause can be found. This is non-ulcer or functional dyspepsia caused by disturbances in the motor function of the alimentary tract.

(6) Peptic ulcer:
A peptic ulcer is a damaged area of the mucosa caused by the digestive action of gastric juice, in the first few centimeters of the duodenum. In addition, peptic ulcers frequently occur in the stomach or more rarely in the lower end of the oesophagus where stomach juices frequently reflux.
It is believed that duodenal ulcers are caused by excessive secretion of acid and pepsin by the gastric glands. The development of duodenal peptic ulcer is strongly hereditary. In addition to hereditary factors psychogenic factors that cause stress, anxiety seem to play a role in peptic ulceration.

(7) Food poisoning:
Food poisoning or gastro-enteritis can be due to many causes like the infection by virus, bacteria, protozoa or non infective by some allergy. It presents with vomiting, diarrhoea or both, usually within 48 hours of consumption of the contaminated food or drink.
Salmonella species are very common causes of food poisoning. The domestic fowl is the commonest source of infection which may be contracted from inadequately defrosted and uncooked chicken or from under cooked or raw eggs.

(8) Malnutrition:

When an organism is deficient in or receives excess of one or more nutrients over a long period of time is said to have malnutrition. The deficiency is known as under-nutrition and the excess, over-nutrition. Under-nutrition is the most common problem of underdeveloped countries. Extreme protein deficiency causes kwashiorker disease resulting in edema. Whereas obesity with heart ailment and reduced life expectancy are the symptoms of over nutrition which is more common in developed countries.

(9) Over weight and obesity:

Obesity is the most common nutritional disorder. Obesity may be defined as a condition in which there is an excessive amount of body fat. Excess fat accumulates because there is imbalance between energy intake and expenditure. Obesity is most prevalent in middle age but can occur at any stage of life. It can be a family tendency.

Over weight is associated with an increased rate of mortality at all ages. A substantial reduction of the body weight of obese people is alone sufficient to reduce the death rate.

(10) Anorexia nervosa:

Anorexia nervosa is loss of apetite for food, a psychological condition usually seen in girls and young women, characterized by severe and prolonged inability or refusal to eat. Some times accompanied by spontaneous or induced vomiting.

(11) Bulimia nervosa:

It is almost exclusively confined to women and the age of onest is slightly older than for anorexia. The symptoms of bulimia nervosa are recurrent bouts of binge eating, lack of self-control over eating during binges. The binges occur at least twice weekly and involve rich foods such as cakes, chocolates and dairy products. It is an exclusively abnormality found in the adult women.

12.12 PARASITIC NUTRITION

Parasitism is an association between two living organisms of different species in which one partner is benefited and the other is at loss. The benefited partner is known as **parasite** and the partner at loss is called the **host.**

The parasite obtains food either through absorptive or ingestive method from the host. A successful parasite is able to live with the host without causing it any harm. Parasites which live on the outer surface of the host are called **ectoparasites.** Those that live within a host are **endoparasites**. The parasites may be **obligatory** when they are total parasites and live parasitically permanently within the host. The **facultative** parasites live within the host. After the death of the host continue to feed saprotrophically on the dead body.

The parasites are highly specialized, possessing numerous adaptations, many of which are associated with their hosts and mode of lives.

The parasites may be pathogenic which cause diseases to their hosts or nonpathogenic in case no harm is done to the host.

Examples of some endoparasites of man:

Viruses which cause several diseases like influenza, rabies, yellow fever, poliomyelitis, measles etc.

Bacteria cause tuberculosis, typhoid, cholera, plague, tetanus, leprosy etc.

Fungi are mostly dermatophytes which cause ring worm disease. Athlete's foot and other skin diseases.

Protozoans diseases such as malaria caused by Plasmodium, trypanosomiasis by Trypanosoma, leishmaniasis by Leishmania, amoebiasis by Entamoeba histolytica and many others are common human diseases.

Several **helminths** cause human diseases, such as taeniasis caused by Taenia saginata, hook worm disease caused by Ancylostoma. Round worm (Ascaris) is a common inhabitant of intestines of children causing **Ascarisis.** Enterobius vermicularis causes itching around the anus. Filariasis is caused by **Filaria.**
The examples of ectoparasites of man are Mosquitoes, lice, bed-bugs, fleas etc.

KEY POINTS

- Nutrition is the intake of nutrients by living organisms.
- Nutrients are the food or elements required to get energy and matter for growth and metabolism.
- In autotrophic nutrition energy is produced by the oxidation of inorganic substance.
- Minerals required by plants are selectively absorbed from the soil by roots.
- Plants require nine elements, the macronutrients in fairly large amount.
- Symptoms of mineral deficiency depend on the function and mobility of elements.
- Carnivorous plants obtain nitrogen and minerals by killing and digesting insects.
- Organisms which feed on organic food are said to have **heterotrophic nutrition** and are called **heterotrophs**.
- The problem facing any heterotroph is how to acquire and take in food and then break it down into soluble products capable of being absorbed.
- Heterotrophs can be classified into **holozoic, saprotrophic** and **parasitic**.
- Holozoic nutrition involves **ingestion, digestion, absorption, assimilation** and **egestion.**
- Digestion may be **intracellular** or **extracellular** involving **mechanical digestion** and **chemical digestion.**
- Extracellular digestion maybe through **sac-like digestive system** or **tube like digestive system.**
- The digestive enzymes work by splitting specific chemical bonds in the molecules of the food substances.
- The absorption of digested food takes place by diffusion either directly into the cytoplasm or through villi into the blood for transportation.
- Diarrhoea, Dysentary, Constipation, Piles, Dyspepsia, Peptic ulcer and Food poisoning are **disorders** of the gastro-intestinal tract.
- Animals which live as a parasite on other animals have parasitic nutrition and cause serious diseases in their hosts.

EXERCISE

1. Encircle the correct choice:

(i) Most of the mass of organic material of a plant comes from:
(a) Water (b) Carbon dioxide
(c) Soil minerals (d) Atmospheric oxygen

(ii) Carnivorous adaptations of plants mainly compensate for soil that has a relatively low content of:
(a) Potassium (b) Nitrogen

(c) Calcium (d) Phosphate

(iii) Which of the following nutrients is incorrectly paired with its function in a cell-wall:
(a) Calcium — Formation of cell-wall.
(b) Magnesium—Constituent of chlorophyll.
(c) Iron — Component of chlorophyll.
(d) Phosphorous — Component of nucleic acid.

(iv) An autotrophic nutrition in which energy is produced by the oxidation of inorganic substances is:
(a) Photosynthesis (b) Chemosynthesis
(c) Chemosmosis (d) Chemotrophic

(v) Colour of leaf turns into dull or bluish green due to deficiancy of:
(a) Nitrogen (b) Phosphates
(c) Potassium (d) Magnessium

(vi) In which of the organism, digestion is intracellular:
(a) Earthworm (b) Planaria
(c) Grass-hopper (d) Amoeba

(vii) Digestion is brought about by:
(a) Acid (b) Alkaline solution
(c) Enzymes (d) Minerals

(viii) Bile contains:
(a) Pepsin (b) Trypsin
(c) Amylopsin (d) None of them

(ix) Most of the absorption of food takes place in:
(a) Stomach (b) Small intestine
(c) Large Intestine (d) Caecum

(x) Largest gland of the body is:
(a) Liver (b) Pancreas
(c) Pituitary gland (d) Thyroid gland

2. Write detailed answers of the following questions:

(i) What is heterotrophic nutrition? How does it differ from autotrophic nutrition? Give various types of heterotrophs according to their mode of nutrition with examples.
(ii) Describe the human digestive system by the help of a labelled diagram.
(iii) Write down the disorders of human GIT.
(iv) Describe the nutrition in cockroach and planaria.
(v) What is digestion? What are its types? Describe the process of digestion in man.

3. Write short answers of the following questions:

(i) WhyN_2 is included in mineral nutrient, although it is not mineral?
(ii) Write some symptoms of N_2 deficiency.
(iii) Why carnivores plants use insects as food?
(iv) What is meant by intracellular and extracellular digestion?

(v) Why hydra has both types of digestion?
(vi) Give the dental formula of human being.

Chapter 13

GASEOUS EXCHANGE

No work can be done without energy. Likewise this universal truth, the body of an organisms cannot perform various activities without energy. The process of respiration resolves the mystery of releasing energy contained within chemical bonds of some bio-molecules.

All living organisms require energy to perform various activities. In order to obtain energy, they oxidize energy-rich molecules like ATP (Adenosine tri phosphate). The continuous supply of ATP to living cells is made possible through the process of respiration. It is a complex process of oxidation-reduction in which food is oxidized to release energy. An organism can generate greater number of ATP using oxygen molecules, which can be obtained from its external environment. But during the chemical pathway, carbon dioxide is released as by-product. Carbon dioxide must be given out of organism, as it is harmful if remained in cell. Thus, living organisms are always in need of gaseous exchange (take in oxygen and give out carbon dioxide) with their environment.

In addition to the process of respiration, autotrophs like plants perform gaseous exchange for the process of photosynthesis. During this process, plants obtain carbon dioxide and release oxygen into their environment. But in the following discussion, we will consider the exchange of respiratory gases, only.

The gas exchange in organisms takes place by the process of diffusion. Efficient gas exchange depends upon following factors:

(i) Maintenance of diffusion gradient,

(ii) Large surface area in relation to the volume of organism, and

(iii) Presence of moist membrane or **respiratory surface** for exchange of gases.

13.1 RESPIRATORY MEDIA

The source of oxygen called **respiratory media** for aquatic and terrestrial organisms are water and air, respectively. Aquatic organisms obtain oxygen dissolved in water while terrestrial organisms obtain it from the atmospheric air. The latter is the main source of oxygen on earth, which contains about 21% oxygen. On the contrary, same volume of water when fully saturated with oxygen contains about 5% oxygen. Moreover, water is denser than air. Thus it is more difficult for aquatic organisms particularly animals to obtain oxygen.

13.2 GASEOUS EXCHANGE IN PLANTS

All plants exchange gases for respiration as well as photosynthesis. The process of respiration occurs constantly day and night in all living cells of plants. However, photosynthesis occurs during daytime, and in chlorophyll containing cells only.

Gas exchange in unicellular organisms and lower plants especially the aquatic ones, takes place by diffusion across a moist cell membrane and wet body surface, respectively. Surface area in such organisms is greater than their volume so diffusion alone is sufficient for the transport of gases from surface cells to inner ones. But in higher land plants gas exchange through entire surface of leaves and stem is prevented due to external, waxy covering called **cuticle.**It is an adaptation to avoid excessive evaporation of water. However, the cutilarized epidermis of leaves has numerous pores called **stomata** (singular-stoma) for the exchange of gases as well as evaporation of water. Each stoma (Fig. 13.1) is formed by two modified epidermal bean-shaped, **guard cells**. Unlike other epidermal cells, guard cells bear chloroplast with thicker inner and thinner outer

walls. Stomata can be opened or closed depending upon the turgidity of guard cells.
In woody stems, epidermis is replaced by impervious layer of closely packed cork cells that hamper the diffusion of gases through it. But the problem is overcome by numerous **lenticels** which are localized regions of loosely arranged cells with intercellular air spaces between them (Fig. 13.2). Through lenticels, respiratory gases can move freely in and out of stem. Gas exchange also occurs in roots by diffusion through epidermal cells and root hair in presence of moisture in the soil.
Though all living cells of different organs like stem, root. etc. constantly respire, yet there is no transport system within plants for respiratory gases. Such gases are therefore, transported by diffusion only. In order to facilitate the process of diffusion of gases, plant tissues are permeated by air spaces.

13.2.1 Photorespiration:

It is a metabolic process that occurs commonly in plants like wheat, rice, sugar cane, etc. Such plants are termed biochemically, as C_3 plants. It occurs during hot and dry days. In this process, C_3 plants consume oxygen and produce carbon dioxide during daytime, in chloroplast without production, of energy, so it is termed as **photorespiration**.
During hot and dry days, stomata are closed to conserve water. But due to the on going process of photosynthesis, the concentration of oxygen increases than the concentration of carbon dioxide inside the leaves. Under such condition, oxygen competes with carbon dioxide to combine with an enzyme called **Ribulose biphosphate carboxylase/oxygenase** or **Rubisco**. Normally, during photosynthesis, rubisco is involved in catalyzing the fixation of carbon dioxide with Ribulose biphosphate (RuBP) to form an unstable hexose sugar. But now RuBP combines with oxygen rather than carbon dioxide and breaks into one molecule of Phospho-Glyceric Acid (PGA) and one molecule of Phosphoglycolate. The latter rapidly breaks down to release carbon dioxide. The process of photorespiration can be summarized by the following equation.
Thus photorespiration is an oxidation process similar to respiration in which oxygen is consumed and carbon dioxide is released. But unlike respiration, it does not produce any ATP. So from the energy point of view, it is a useless and wasteful process. Moreover, it reduces photosynthetic output, which is ultimately related to decline in the crop yield.

13.3 GASEOUS EXCHANGE IN ANIMALS

Like other living organisms, animals also exchange gases with their environment during respiration. They take in oxygen and give out carbon dioxide continuously through their moist, respiratory surfaces. Respiratory gases move across moist, respiratory surfaces by diffusion. The concentration gradient is maintained across the respiratory surface as oxygen is consumed and carbon dioxide is liberated constantly. Thus, there is greater concentration of oxygen and lesser concentration of carbon dioxide, outside the respiratory surface than inside. The respiratory gases are passed across the respiratory surface by dissolving in water. Moreover, respiratory surfaces must be large enough in relation to the volume of that animal for efficient gas exchange.

13.3.1 Properties of respiratory surfaces:

Respiratory surface of animals bear following properties: (i) Permeable, (ii) large surface area in relation to volume, (iii) wet, and (iv) thin.
Respiratory surface in animals depends upon the structure, habitat and activity of animal. In order to maintain greater surface to volume ratio for efficient gas exchange, animals have evolved different adaptations in their respiratory surfaces. In unicellular organisms, gas exchange occurs over the entire surface area (plasma membrane).

13.3.2 Respiratory organs of aquatic and terrestrial animals:

1. Respiratory organs of Hydra:

Hydra is a multicellular animal with tissue level of organization but has no organs. It has a large surface area in relation to its volume. Being diploblastic, it has two layers of cells in its body. Since most of its cells are in direct contact with water, so the ectodermal cells exchange gases with external water while endodermal cells with water that comes within gastro-vascular cavity (Fig. 13.3).

2. Respiratory organs of earth worm:

Earthworm has a tubular body pattern with developed organs and systems but there are no specialized respiratory organs so it uses its wet skin as respiratory surface (Fig. 13.4) that offers enough surface area for efficient gas exchange. In order to keep the skin moist, earthworm has to live in damp soil. The moisture is absorbed by mucous secreted from the goblet glands in the skin of earth worm. However, due to larger size and complexity of the body of earthworm, distribution of respiratory gases from skin to each cell of the body and vice versa posses a problem since diffusion alone can not distribute gases rapidly to distant cells within the animal. So the earthworm has developed a blood vascular system, which can efficiently and rapidly transport respiratory gases within the body.

3. Respiratory organs of cockroach:

Cockroach (as well as other insects) has evolved a special type of invaginated respiratory system, called **tracheal system**. It is specially adapted for intake of oxygen, terrestrial mode of life, high metabolic rate and the compact body of aninsect.

The tracheal system consists of number of internal tubes called **tracheae**, which on side, open outside the body through minute, slit-like pores known as **spiracles** while on the other side ramify throughout the body into fine branches or **tracheoles**. Both, the trachea and the tracheoles are lined internally by thin cuticle. There are ten (10) pairs of spiracles on lateral sides of the cockroach; two (2) lie in the thoracic segments while eight (8) in the first abdominal segments. Spiracles are opened or closed by valves which are operated by special muscles. Tracheoles, finally end as blind, fluid filled, fine branches which are attached with the cells of the tissues.

The cockroach takes in air directly from the atmosphere into the tracheae through spiracles. Since oxygen diffuses directly into the cells of the tissues at the level of fluid filled tracheoles hence their blood vascular system is devoid of haemoglobin. However, the removal of carbon dioxide from the cells of the body is largely dependent upon plasma of the blood, which takes up carbon dioxide for its ultimate removal through the body surface via the cuticle.

4. Respiratory system of fish:

Respiratory organs in fish are called **gills** (Fig. 13.6). They are formed as outgrowth of pharynx and lie internally within the body so that they are protected from mechanical injuries. Each gill is a highly vascularized structure. It is composed of two rows of hundreds of **filaments,** which are arranged in V-shape and are supported by a cartilage or a long curved bone, the **gill bar** or **gill arch**. Each filament is folded to form numerous plate-like **lamellae** which greatly increase the surface area of the gill. Each lamella is provided by a dense network of blood capillaries.

In bony fishes ventilation is brought about by the combined effect of mouth and **opercula** (sing. Operculum). Water is drawn into mouth. It passes over the gills through pharynx and ultimately exits at the back of opercula. Since concentration of oxygen in water is low and also water is denser than air, fish must use considerable energy to ventilate its gills. Gas exchange is also facilitated in gills due to **counter current flow** of water and blood. In the capillaries of each

lamella, blood flows in direction opposite to the movement of water across the gills. Thus the most highly oxygenated blood is brought close to the water that is just entering the gills and that has even higher oxygen content than the blood. As the water flows over the lamellae, gradually losing its oxygen to the blood, it encounters blood that is also increasingly low in oxygen. In this way, the gradient encouraging oxygen to move from water into the blood is maintained across all the lamellae. Counter current flow is very effective as it enables the fish to extract up to 80%-90% of the oxygen from water that flows over the gills.

5. Respiratory organs of frog:

Frog can live in water as well as on land. Although, its larval stages respire by gills, the adult has to develop some special respiratory organs adapted for terrestrial mode of life. Like other terrestrial vertebrates, frog has evolved vascularized, paired out growths from the lower part of pharynx known as **lungs**. They are located inside the body and are simple sac-like structures with shallow internal folds that increase the inner surface to form many chambers called **alveoli.** These are separated from each other through septa. The inner surface of alveoli is single cell layer and attached with blood capillaries. Alveoli are the site of exchange of gases. Each lung is connected to outside by system of hollow tubes. From each lung arises a tube or **bronchus**. Both bronchi open into the **larynx** or sound box which leads into the buccal cavity through **glottis** (Fig. 13.7).

Like all other amphibians, in frog, ventilation is a single, two-way path. Frog uses positive pressure (i.e. it pushes the air into the lungs) to move air in and out of lungs. The frog draws air into the buccal cavity by lowering its buccopharyngeal floor. During this process, it opens the nares and closes the glottis. Then with the nostrils closed and glottis opened, it raises the buccopharyngeal floor, thus pushing the air into the lungs. This type of ventilation does not allow the lungs to be completely emptied or refilled by air, hence termed as **incomplete ventilation**. Thus the air forced into the lungs mixes with the air already in lungs and depleted in oxygen. The exchange of gases on land through lungs is termed as **pulmonary respiration**. However, when frog goes into water or buries itself in mud, it exchanges gases by its moist and highly vascularized, thin skin. This is known as **cutaneous respiration**. Moreover, it can also exchange gases through its thin, vascularized lining of the buccal cavity. It is called **bucco-pharyngeal respiration.**

6. Respiratory system of Bird:

Birds are exclusively lung breathers. The lungs of a bird are internally subdivided into numerous, small, highly vascularized, thin membranous channels called**parabronchi.** These channels are responsible for continuous flow of air in one direction. In addition to a pair of lungs, a bird has 8 to 9 thin walled, non-muscular, non-vascular **air sacs** (Fig. 13.8) that penetrate the abdomen, neck and even the wings. The air sacs work as bellows that ensure the unidirectional flow of air or **complete ventilation**. Thus a bird must take two breaths to move air completely through the system of air sacs and lungs. The first breath draws fresh air into the posterior air sacs of the lungs. The second breath pushes the first breath into anterior air sacs and then out of the body. This one way flow of air enables a bird to fly at very high altitude without any shortage of oxygen, as the air coming in lungs is always oxygen-rich.

13.4 RESPIRATORY SYSTEM OF MAN

The respiratory system of man consists of paired lungs and the air passage ways. Paired lungs of man are situated in the thoracic cavity. The walls of thoracic cavity are formed of inter-costal muscles, which are attached with a bony cage formed by 12 pairs of ribs, vertebral column, and sternum bone. The thoracic

cavity is separated from the abdomen by a muscular partition called **diaphragm** (Fig. 13.9).

13.4.1Air Passage ways:

Air is drawn into the lungs by inter-connected system of branching ducts. Atmospheric air enters into these ducts through a pair of openings called **external nares** (nostrils), which lead separately into **nasal cavity**. It is lined internally by vascularized, ciliated epithelium containing mucous secreting cells. Hairs are also present in nasal cavity. Thus the air drawn in becomes warm, moist and filtered out of dust particles and microorganisms. It also contains sensory cells for smell. The air then leads through the **internal nostrils** into the **pharynx.** It is a common passage for food as well as air. The openings of nostrils into pharynx are guarded by soft palate.

Pharynx leads air into **larynx** through an opening called **glottis**. Glottis is guarded by a flap of tissue called **epiglottis.** During swallowing, soft palate and epiglottis close the nostril opening and glottis, respectively so the food is prevented to go either into the nasal cavity or glottis. Larynx or sound box is a small chamber. It consists of a pair of vocal cords for producing sound. Larynx leads the air into a flexible air duct or **trachea** that lies in thoracic cavity. It bears C-shaped cartilage rings, which prevent it from collapsing during drawing air in. Its internal lining is ciliated and bears mucus secreting **goblet cells**. Due to mucus and upward beating of cilia, any residues of dust and germs are always pushed outside the trachea into the oesophagus through pharynx. At its lower end, trachea bifurcates into two smaller branches called **bronchi.**Each bronchus leads the air into lung of its side. Bronchi are also supported by C-shaped cartilage rings in their walls upto the point where they enter into lungs.

The air passage way described above is normal way, but sometimes air can be drawn in through mouth also.

13.4.2Lungs:

Lungs are paired, soft, spongy, and highly vascularized structures. The right lung is partitioned into three lobes while the left lung into two lobes. The lungs occupy most of the chest cavity. Each lung is enclosed by two, thin membranes known as **pleural membranes.** Within the pleural membranes, there is a fluid filled, narrow cavity called **pleural cavity**. This fluid acts as a lubricant.

Inside each lung, each bronchus progressively divides into very fine branches called **bronchioles.** Each bronchiole terminates at a tiny, hollow sac-like alveolar duct (Fig. 13.10) containing a number of **air sacs** or **alveoli.** The alveoli are considered as the **respiratory surfaces** of lung. A single alveolus is composed of single layer of epithelial cells with a slightly larger diameter than the blood capillary. Each alveolus is surrounded by extensive network of blood capillaries. It is the site of exchange of respiratory gases. The internal area of an alveolus is provided with a thin layer of fluid containing **surfactant**. It reduces the internal surface tension to prevent it from collapsing during gas exchange.

It has been estimated that both lungs contain about 700 million alveoli with a surface area equal to that of tennis court or 20 times the body's entire skin surface.

13.5 BREATHING IN MAN

13.5.1Mechanism of breathing:

Breathing is the process of taking in **(inspiration/inhalation)** and giving out of air **(expiration/exhalation)** from the atmosphere up to the respiratory surface and vice versa. In man including other mammals, breathing is termed as **negative pressure breathing**. In this kind of breathing, air is drawn into the

lungs due to negative pressure (decrease in pressure in thoracic cavity in relation to atmospheric pressure) (Fig. 13.11).

Inspiration (Inhalation): Inspiration or the process of taking in of air is energy consuming process in which volume of thoracic cavity is increased due to contraction of inter-costal muscles and diaphragm. Contraction of external inter-costal muscles moves the ribs as well as sternum outward and upward while contraction of the diaphragm makes it flat. As a consequence, the thoracic cavity enlarges and a negative pressure is developed inside the thoracic cavity and ultimately in the lungs. So the air through the respiratory passage rushes into the lungs up to alveoli where exchange of gases occurs.

Expiration (Exhalation): Expiration or the process of giving out of air is just reverse of inspiration. It is a passive process, which takes place due to increased pressure in thoracic cavity as well as lungs. It is caused by relaxation of external inter-costal muscles and the contraction of internal inter-costal muscles, which move ribs as well as sternum inward and downward. Similarly, diaphragm also relaxes which makes it dome shaped thus reducing the volume of the thoracic cavity. As a consequence, lungs are compressed so the air along with water vapors is exhaled outside through respiratory passage.

13.5.2 Rate of breathing:

It can be observed that we can hold our breath for a short time or can breathe faster and deeper at our will. This is termed as **voluntary control.** But mostly, rate of breathing is controlled automatically. This is termed as **involuntary control** (Fig. 13.12). This automatic control is maintained by coordination of respiratory and cardiovascular systems. It has been found that increased concentration of carbon dioxide and H^+ in blood are the basic stimuli to increase the rate of breathing. Their concentrations are monitored by chemo-receptors known as **aortic** and **carotid bodies** situated in aorta and carotid arteries, respectively. Any change in the concentrations of carbon dioxide and H^+ are detected by medulla oblongata (a part of brain). Moreover, medulla oblongata is itself sensory to changes in the concentrations of carbon dioxide and H^+ present in the cerebro-spinal fluid. In response to increased concentrations of carbon di oxide and H^+, it sends impulses to inter-costal muscles and diaphram to increase breathing rate.

13.5.3 Disorders of respiratory tract:

i) Lung cancer: It is usually a consequence of smoking either actively or passively. As the smoke passes through the respiratory passage, its toxic contents like nicotine, SO_2, etc, cause gradual loss of cilia of epithelial cells of the respiratory passage so that dust and germs are settled inside the lungs. Later, cells with abnormal nuclei appear in the thickened epithelial lining, which start dividing rapidly without following normal cell cycle. Finally, these cells with abnormal nuclei break the thickened epithelial lining and penetrate into the other tissues causing cancer.

ii) Emphysema: It is a degenerative disease in which alveoli gradually deteriorate. It happens when some toxic substance such as nitrogen oxides, sulfur di oxide, etc. are constantly inhaled. Due to such toxic substances, the elasticity of the lungs decreases. As a consequence, alveoli are ruptured and lungs become harder. So the tissues of the body including brain are supplied less and less oxygen. Thus, the victim's breathing becomes labored day by day. It also makes him depressed, irritable and sluggish.

iii) Asthma: It is another respiratory tract disorder in which there are recurrent attacks of breathlessness, characteristically accompanied by wheezing when breathing out. It may be caused by external factors like pollens, dust, animal fur, common cold, cough, smoke, etc. In many cases, there is no apparent cause. Heredity is a major factor in the development of asthma. Severe case of asthmatic attack can be fatal.

iv) Tuberculosis: It is an infectious disease of the lungs. It is caused by a bacterium called Mycobacterium tuberculosis. Commonly known as T.B., was once a major killer disease of human. Main symptoms are coughing (sometimes with blood in sputum), pain in chest, shortness of breath, fever, sweating at night, weight loss and poor appetite. It can cause complication leading to death. Infection is passed from person to person in air-borne droplets produced by coughing or sneezing.

13.6 TRANSPORT OF GASES IN MAN

13.6.1 Oxygen and carbon dioxide carrying capacities of blood and factors affecting these capacities:

Oxygen and carbon dioxide are exchanged in alveoli of lungs by the simple process of diffusion. Blood returning into lungs from all parts of the body is depleted from oxygen. This deoxygenated blood is dark maroon in color and appears bluish through the skin. The air inhaled into lungs has greater concentration of oxygen. Thus due to the difference in concentration across the respiratory surfaces, oxygen moves into blood flowing into capillaries around alveoli. Now the blood becomes oxygenated. It is bright red in color.

Blood returning from tissues contains carbon dioxide, which is a respiratory by-product. Due to its higher concentration, carbon dioxide diffuses from the tissues into the blood, which is brought in the lungs. In lungs, due to greater concentration of carbon dioxide in blood, it moves out into alveoli where its concentration is lower.

Blood takes in oxygen much more rapidly than water. Thus it can transport enough oxygen to tissues to meet their demand of oxygen. Many factors (e.g. concentration gradient presence of any competitor such as carbon/mono oxide, moisture, surfactant etc.) influence this transport of respiratory gases across the alveolar wall.

13.6.2 Lung capacities:

The total average lung capacity of adult human being is about 5 liters (5000 cm^3) of air. During normal breathing a person takes in and gives out air approximately half of a litre (450 cm^3 to 500cm^3). This is called **tidal volume.** It is only about 10% of the total capacity of lungs. With an extra deep breath, the maximum volume of air inspired and expired called **vital capacity** averages about 4 liters. The remaining volume approximately 1 liter of air remained in the lungs is termed as **residual volume**. It remains in there due to the fact that thorax cannot collapse completely. Residual volume is not stagnant since inspired air mixes with it at each time. Aging, emphysema, etc. can increase the residual volume at the expense of vital capacity.

13.6.3 Role of haemoglobin and myoglobin:

i) Haemoglobin, an iron containing protein is a respiratory pigment present in the red blood corpuscles of vertebrates. Each haemoglobin molecule has 4 iron containing groups called heme. It is the iron, which reversibly binds with oxygen. Nearly, all oxygen carried by blood is bound to Hb. Thus due to Hb, blood could carry 70 times more oxygen than plasma. So it plays an important role in maintaining a high concentration gradient of oxygen from air to blood. Hb binds

to oxygen to form a loose compound called oxyhaemoglobin. It is carried to the tissues where due to low concentration of oxygen in tissues, oxyhaemoglobin dissociates releasing oxygen, which enters in tissues. The whole process can be represented by the following equation.

Each haemoglobin molecule binds up to 4 oxygen molecules. Since there are about 280 million Hb molecules in each R.B.C. so each R.B.C. is capable of carrying more than a billion molecules of oxygen.

ii) Myoglobin, a smaller protein than haemoglobin, found in the musclescan bind to oxygen more tightly than haemoglobin. It gives red colour to muscles.
Haemoglobin is also involved in the partial (35%) transport of carbon dioxide from tissues to alveolar blood capillaries in alveoli. Carbon dioxide due to its higher concentration in tissues diffuses out into the blood where it combines with amino group of haemoglobin to form a molecule called carbaminohaemoglobin. In alveoli, it breaks and carbon dioxide diffuses out into alveoli.
Rest of the carbon dioxide is transported by the water of plasma and also by the water of RB.C. as shown by the following equations.
Water of R.B.C. transports 60% carbon dioxide
Water of plasma transports 05% carbon dioxide
These reactions are facilitated by an enzyme called carbonic anhydrase present in the RBCs.

KEY POINTS

- Energy is required by living organisms to do different activities.
- Gaseous exchange plays key role in release of energy from food.
- Gaseous exchange depends upon maintenance of concentration gradient and large surface to volume ratio.
- Gaseous exchange and cellular respiration contribute to oxidation of food.
- Air is better medium for exchange of gases than water.
- Gaseous exchange occurs in all plants for respiration as well as photosynthesis.
- In plants there is not transport system for the respiratory gases.
- Plants during hot and humid days consume oxygen and release CO_2, a process termed as photorespiration.
- Photorespiration does not produce any ATP. It reduces crop yield.
- Like other insects cockroach respires by tracheal system.
- Fish respire through gills.
- Gaseous exchange in gills is facilitated by counter current flow of blood and water.
- Frog respires through skin, lungs and buccal cavity.
- Frog uses positive pressure breathing.
- Lungs of a bird are internally divided into numerous parabronchi.
- In addition to lungs, birds have air sacs that work as bellows.
- In man, breathing is termed as negative pressure breathing.
- Smoking is the major cause of lung cancer.
- Dust, pollens, smoke, etc may contribute in the development of asthma.
- Blood takes in oxygen much more rapidly than water.
- In vertebrates, haemoglobin is involved in the transport of nearly all oxygen and some carbon dioxide.
- Muscle fibers have a respiratory pigment or myoglobin.
- Myoglobin gives red color to muscles.

EXERCISE

1. Encircle the correct choice:

i) _____ cells have chloroplast.
(a) Goblet cells (b) RB.C.
(c) Guard cells (d) None of these

ii) _____ have the most efficient respiratory system.
(a) Fish (b) Amphibia
(c) Birds (d) Mammals

iii) Haemoglobin carries _____ times more oxygen than plasma.
(a) 20 (b) 50
(c) 70 (d) 100

(iv) T.B. is caused by _____
(a) Allergy (b) Bacterium
(c) Nicotine (d) All of these

(v) Rate of breathing is increased due to increase in concentration of _____ in blood:
(a) Oxygen and hydrogen (b) Oxygen and CO_2
(c) CO_2 and proton (d) CO and oxygen

(vi) Which of the following has complete ventelation?
(a) Frog (b) Bird
(c) Man (d) All of these

(vii) The average lung capacity of human is:
(a) 2 Litres (b) 3 Litres
(c) 4 Litres (d) 5 Litres

(viii) Each haemoglobin molecule carries oxygen molecule:
(a) 2 (b) 3
(c) 4 (d) 5

(ix) Lungs of bird consist of:
(a) Alveoli (b) Parabronchi
(c) Both a and B (d) None of the these

(x) Which of the following transports more CO_2?
(a) H_2O (b) Sodium ion
(c) Potassium ion. (d) None of these

2. Write detailed answers of the following questions

(i) Give an account on exchange of gases in plants.
(ii) Explain the respiratory system of cockroach.
(iii) State and explain the respiratory system of man.
(iv) What is breathing? Explain its mechanism and control in man.
(v) Discuss the process of transport of gases in man.
(vi) Explain the common respiratory tract disorders.

3. Write short answers of the following questions:

(i) What are the factors affecting gas exchange?
(ii) Why air is better respiratory medium than water?
(iii) What do you understand by 'counter current flow' of water and blood in gills of fish?
(iv) Differentiate between positive pressure breathing and negative pressure breathing.
(v) What are lung capacities?
(vi) Distinguish between inspiration and expiration.
(vii) what is the role of air sacs in birds.

Chapter 14

TRANSPORT

Every living cell, whether it exists alone as a single celled organism or is a component of a multicellular one, must perform its own metabolic activities. It must synthesize its own ATP by cellular respiration. It follows, then, that every cell must obtain the necessary raw materials to support its metabolism. Obviously, some mechanism is needed for transporting substances between the specialized systems of procurement, synthesis or elimination and the individual living cells throughout the body.

14.1 INTRODUCTION: Need for transportation of materials

All living organisms must perform metabolic activities in their cells. Each living cell must synthesize its own ATP by cellular respiration/ photosynthesis and carry out for itself those activities necessary for its growth and maintenance. It follows, then, that every cell must obtain the necessary raw materials to support its metabolism. It must obtain nutrients, and. if it uses aerobic respiration, it must obtain oxygen. At the same time, it must get rid of metabolic wastes such as carbon dioxide and in animals nitrogenous compounds. In short, every cell must be exposed to a medium from which it can extract raw materials and into which it can dump wastes.

In unicellular organisms and some of the structurally simpler multicellular ones, each cell is either in direct contact with the environment or only a short distance from it. But in the large and structurally more complex multicellular organisms, the more internal cells are far from the body surface and from the general environmental medium. In these organisms nutrient procurement gas exchange and waste expulsion take place in certain restricted regions of the body specialized for those functions. Obviously, some mechanism is needed for transporting substances between the specialized system of procurement, synthesis, or elimination and the individual living cells throughout the body.

14.2 TRANSPORT IN PLANTS

Materials to be transported in plants:

Plants are in contact with both soil and atmosphere. Various materials from atmosphere and soil are transported in and out of plant body. At the same time certain materials are transported through out the plant.

Transport in plants occurs on three levels; i) Water, gases and solutes move in and out across cell membrane, ii) loading of food from photosynthetic cells into sieve tubes (short distance transport); iii) conduction of water with dissolved minerals and food along the whole plant through xylem and phloem, respectively (long distance transport).

14.3 UPTAKE AND TRANSPORT OF WATER AND MINERALS

Soil is the source of water and minerals for plants. They are taken up by roots. Various processes are involved in uptake of these minerals. These are diffusion, facilitated diffusion, osmosis, imbibition and active transport.

14.3.1 Processes involved in the uptake:

i) Diffusion:

If a few crystals of a coloured soluble salt like ($KMnO_4$) are dropped in a beaker containing water, the crystals dissolve and permagnate ions move in alldirections. As a result, the colour of water changes from colourless to purple. Initially, the concentration of ions is greater in the proximity of crystals, so the ions move away from higher concentration to lower concentration. This movement of ions or

molecules from the region of higher concentration to the region of lower concentration is known as **diffusion**. One of the most common example of diffusion is, if a bottle of perfume is opened in a comer of a room, it can be smelt in the entire room after some time.
The rate of diffusion depends upon size and nature of molecule, small molecules move faster than large ones and vice versa. The rate of diffusion is high at high temperature. The other factor which affects rate of diffusion is concentration gradient. It is the difference in concentration of ions or molecules between two regions. Greater the difference in concentration and shorter the distance between two regions greater will be the rate of diffusion. When ions or molecules are evenly distributed through out the system, an equilibrium is established. Even after equilibrium there is movement but then equal number of ions or molecules move from, one point to other.
In principle, all solutes diffuse in solvent, but through a cell membrane which is living and differentially permeable, certain molecules move freely while the passage of others is resisted. Small, non-polar molecules such as gases like CO_2 and O_2 and fats soluble molecules move freely across the cell membrane. Their movement will continue till the concentration on either sides equalizes.

ii) Facilitated diffusion:
Charged particles and large molecules such as glucose do not pass through cell membrane. Certain intrinsic proteins that reach from one side of membrane to other help them to cross the barrier. These proteins are membrane transport proteins such as channel proteins and carrier proteins. The shape of channel protein molecule is such that it forms a water filled pore in the membrane. Theseproteins facilitate passage of water soluble substances. Carrier proteins being highly selective like enzymes, combine with certain molecules or ions and transport them across the membrane. This movement of ions or molecules in and out of cell is called **facilitated diffusion**. Diffusion, whether simple or facilitated is called **passive transport** because it does not require input of cell's metabolic energy (ATP) and takes place down the concentration gradient and kinetic energy accounts for molecular movement.

iii) Osmosis:
Osmosis is diffusion of water molecules across the plasma membrane from a region of its higher concentration to a region of its lower concentration. This can be proved by an experiment.
Consider a U shaped tube with side A filled with pure water and side B with same quantity of sucrose solution (sugar dissolved in water) separated by a membrane permeable to water and impermeable to sugar. Since membrane is permeable to water molecules, it can move from side "A" to "B" and from "B" to "A". At side "A"there are only water molecules whereas at side "B"the presence of sucrose molecules means concentration of water molecules is less than at side "A". Thus in unit time more water molecules will diffuse from side "A" to "B" than from "B"to "A". In other words there is net movement of water molecules from "A"to "B". As a result, level of sugar solution will begin to rise and that of water will begin tofall. This movement of water molecules from region of higher concentration to the region of lower concentration through a semipermeable membrane is known as **osmosis.**
Biological membranes in strict sense are not semipermeable because they are not completely impermeable to solutes. They allow passage of solutes as well as solvent though not at the same rate. All that is necessary for osmosis to occur is that the solvent molecules diffuse rapidly than the solute molecules.

iv) Active transport:
Certain molecules or ions move across the cell membrane against the concentration gradient i.e. from lower concentration to higher concentration with

the help of specific transport proteins embedded in cell membrane. The transport takes place at the expense of cell's metabolic energy-ATP and is called **active transport.** The cells or tissues carrying out active transport are characterized by presence of numerous mitochondria, high rate of respiration and high concentration of ATP.

In plants, phloem loading is an active translocation process. In source cell of leaves the sucrose concentration of the sieve elements and companions cells is much greater than that of mesophyll cells. It means that the sucrose is transported against its chemical potential gradient which requires metabolic energy.

Active transport is of utmost importance because it enables the cell to take up nutrients from outside and wastes to be expelled against the concentration gradient as shown in figure 14.1.

v) Imbibition:

Adsorption of water and swelling up ofhydrophilic (water loving) substances is known as **imbibition**. Substances such as starch, gum, protoplasm, cellulose and proteins have great affinity for water and are called **hydrophilic**. Living and dead plant cells are hydrophilic colloids as they possess large amount of carbohydrates and as such they have very strong affinity for water. Seeds which have very low water potential swell up when placed in water. Wrapping up of wooden framework during rainy season is another example of imbibition.

14.3.2Water status in plants:

Water is important in the life of plants because it makes up the matrix and medium in which biochemical processes essential for life occur. In most land plants, water is continually lost to the atmosphere and is taken from the soil. The movement of water may occur by diffusion, osmosis, bulk flow or some combination of these fundamental transport mechanisms. Diffusion moves water from region of high water concentration (low solute concentration) to region of low water concentration (high solute concentration). It occurs because molecules are in constant thermal agitation. Bulk flow occurs in response to a pressure difference, whenever, there is a suitable pathway for bulk movement of water. Osmosis is the process by which water moves across differentially permeable membrane. It depends upon the chemical potential of water or water potential, osmotic potential of two separating solution and pressure potential across the membrane and wall of the cells. Therefore, it is necessary to understand these terms to explain the process of water movement across the membrane.

i) Water potential:

The chemical potential of water is a quantitative expression of the free energy associated with the water. Thermodynamically, free energy represents a potential for performing work. All living things including plants, require a continuous input of free energy. In the case of water movements this free energy is involved in water flow. The unit of chemical potential is energy per mole of a substance (joules per mole).

For practical reason, it turns out that the unit of chemical potential is inconvenient for most work in plant physiology. Therefore, plant physiologist have defined another parameter called **water potential** as the difference between the free energy ofwater molecules in pure water and energy ofwater in any other system (e.g. water in solution or in cell sap of plant). Now, the free energy of water is expressed in pressure unit such as megapascals and symbolised by Greek letter Ψ psi [MPa; IMPa=9.87 atmosphere].

Pure water has been assigned the value ofwater potential 0 MPa. Addition of solute particles lowers the mole fraction (number of mole of substance divided by total number, of all substances in the system/solution) of water. Hence, there is a

decrease in water potential. Therefore, values ofwater potential remains less than zero or in negative value.

ii) Osmotic Pressure:

The pressure exerted upon a solution to keep it in equilibrium with pure water when the two are separated by a semipermeable membrane is known as **osmotic pressure.** Therefore, the osmotic pressure of a solution is a measure of the tendency of water to move by osmosis into it. In other words we can say that the osmotic pressure is the pressure that must be exerted on a solution to prevent the passage of solvent molecule into when the solvent and solution are separated by a differentially permeable membrane. Thus, it prevents the process of osmosis proceeding.

iii) Osmotic Potential or Solute Potential:

Osmotic potential is the tendency of a solution to attract water molecules when the solutions of two different concentrations are separated by a differentially permeable membrane. Pure water is assigned the osmotic potential zero as the highest value. Since the osmotic potential decreases as the osmotic concentration (theno: of osmotically active particles per unit volume) increases, all solutions have value of less than zero. Under constant temperature and pressure, water moves from the solution of lower osmotic potential to the solution of higher osmotic potential when the two solution are separated by a differentially permeable membrane. It is represented by $\Psi_s$or solute potential.

Another term used in relation to water potential is pressure potential, which is defined as the hydrostatic pressure in excess of atmosphere pressure.

14.3.3Water relations of Plant Cell:

For practical purposes a plant cell can be divided into three parts: (i) Cell Wall: This is non-living, permeable, outer most boundary of cell made up of cellulose, (ii) Cytoplasm alongwith nucleus forms protoplasm—the living material bounded by cell membrane, (iii) In the centre, there is a vacuole enclosed by tonoplast, central vacuole is filled with cell sap—an aqeous solution of salts, organic acids and sugar.

Tonoplast, the membrane of the central vacuole is the another important site of regulation in plant cell after plasma-membrane. Transport proteins embedded in the tonoplast control the movement of solutes between the cytosol and the vacuole e.g. it has proton pumps that expel H^+ from the cytoplasm into vacuole.

The presence of solute particles lowers the water potential Ψ of cell sap. Greater the number of solute particles, the more negative will be the water potential of cell sap. The concentration of solute particles in a solution is known as **solute potential** Ψ_s. (This has been previously referred as osmotic potential). The value of solute potential is always negative.

When a cell is placed in pure water or in an aqueous solution with higher water potential (less negative) than the cell sap, water flows into the vacuole by osmosis through plasma membrane and tonoplast. As more water flows into the vacuole, the tension developed by cell wall causes an internal hydrostatic pressure to develop. This is called **pressure potential** Ψ_p and it opposes the continued uptake of water into the cell by osmosis. When the cell wall is fully stretched and pressure potential reaches at its maximum, the cell cannot take any more water, and is said to be fully **turgid**. The relationship between water potential Ψ, solute potential Ψ_s and pressure potential Ψ_p is represented by following equation.

$\Psi = \Psi_s + \Psi_p$

In a turgid cell $\Psi_p$is equal and opposite to Ψ_s, so Ψ = o.

14.3.4Plasmolysis and deplasmolysis:

If a turgid cell is placed in a hypertonic solution which has more negative solute potential and water potential than the cell sap, it will lose water by exosmosis. At first there will be slight decrease in the volume of cell content. Eventually, the cytoplasm begins to separate from cell wall leaving a noticeable gap between cell wall and cell membrane. This withdrawal of protoplasm from cell wall is known as **plasmolysis**. The point when cytoplasm just starts to separate from cell wall is called **incipient plasmolysis**. When protoplasm completely separates from cell wall, full plasmolysis is achieved. In a plasmolysed cell Ψ_p is zero and $\Psi_w=\Psi_s$

When a plasmolysed cell is placed in pure water, or hypotonic solution, water begins to flow into the vacuole by endosmosis. Protoplasm expands gradually and presses the cell wall. Pressure potential begins to develop. With rise in pressure potential water potential also increases becoming less negative. Eventually, the cell become, turgid. This recovery of cell from plasmolysis is known as **deplasmolysis.**

14.4 WATER AND MINERALS UPTAKE BY ROOT

Absorption of water and mineral salts takes place through root system. Roots are provided by enormous number of tiny root hairs which are outgrowths of epidermal cells and found at the root tips. The root hairs greatly increase the surface area of root. Because of large root surface area plants absorb enough quantities of water and inorganic ions for their survival and growth.

Root hairs possess sticky walls and adhere tightly to soil particles which are usually coated with water and dissolved minerals salts. Most of the absorption takes place near the root tip where epidermis is permeable to water and root hairs. From root hairs and epidermal cells water flows through cortex endodermis, pericycle and enters xylem. Since transport of water takes place in radial direction it is also termed as **lateral transport.**

Three pathways are available for water to enter xylem. The first route is from **cell to cell**. Water enters the root hair or epidermal cell down a gradient of water potential. It flows out of one cell across the cell wall, cell membrane vacuole and enters the adjacent cell which may again pass the substance along the next cell in the pathway. This is known as **cellular path way.**

The second pathway is **symplast.** Through the pores in the cell walls, cytoplasm of cortical cells remain connected with cytoplasm of adjoining cortical cells. These cytoplasmic connections through pores are known as **plasmodesmata** (sing: Plasmodesma). These cytoplasmic connections provide another pathway for transport of water and solutes known as **symplastic pathway**. This requires only one crossing of plasma membrane at root hair.

The third pathway is **apoplast.** The cell walls of epidermal cells and that of cortical cells form a continuous matrix. These walls are hydrophilic. Soil solution flows freely through hydrophilic walls of epidermal and cortical cells. This movement of soil solution through extracellular pathway provided by continuous matrix of cell walls is known as **apoplastic pathway**. As solutes move along extracellular pathway some of the water and solutes are taken up by the cells of cortex thus changing the route from apoplast to symplast.

The inner limiting layer of cortex is endodermis which serves as a barrier or checkpoint because of **casparian strip** a waxy belt that extends through the walls of endodermal cells. Thus, water and minerals cannot cross the endodermis and enter xylem via apoplast (extracellular pathway). Symplast is the only way to cross the barrier. Endodermal cells actively transport salts to pericycle resulting in high concentration of salts. This causes a low water potential and water moves into them by osmosis. From pericycle water flows into xylem both via symplast and apoplast

14.5 ASCENT OF SAP

Water is absorbed by roots and transpired through leaves. Before transpiration-water is conducted upto leaves. This upward movement ofwater from absorptive surfaces (roots) upto transpiring surfaces (leaves) against the downward pull of gravity is known as **ascent of sap**. The distance travelled by water in upward direction is the shortest in plants like herbs and longest in case of tall trees. In tall trees like eucalyptus and red wood the distance is more than 90 meters.
Two aspects of the problem need to be explained.

(i) Path of ascending stream of water.

(ii) The mechanism of ascent of sap.

14.5.1 Path of movement of water and minerals:

Experimentally it has been proved that the path of ascending stream ofwater is xylem. Xylem is a complex tissue consisting of two types of water conducting cells. These are open ended cells called vessels and porous cells called tracheids.

(i) Vessels: These are thick walled tube like structures which extend through several feet of xylem tissue. They range in diameter from 20 µm to as much as 70 µm (0.7 mm). Their walls are lignified and perforated by pits. At the pit lignin is not deposited and cell wall is thin made up of cellulose. The pits match up with pits of adjacent cells so that cell cavities are connected to adjacent cells cavities. Xylem vessels arise from cylindrical cells which are placed end to end. At maturity, the end walls of these cells dissolve and cytoplasmic contents die. Thus a continuous duct is formed which offers a better route for long distance transport of water from roots upto leaves. The rate of flow of water is 10 times faster than tracheids. Vessels are mostly found in angiospermic plants.

(ii) Tracheids: These are individual cells about 30µm in diameter and several mm in length. They can be distinguished from vessels by their angular walls and smaller size. They taper at each end and tapered ends of one cell overlap tapered ends of other cells, like xylem vessels they are dead with thick lignified walls. Their walls are perforated by small holes called pits which are of two types; simple and bordered. The pits in the cross walls connect upper tracheid with lower one. Through these pits water and minerals flow freely from one tracheid to another. In ferns and conifers, tracheids are the only water conducting ducts.

14.5.2 Mechanism of ascent of sap:

Water and dissolved mineral salts present in xylem (sap), flow to upward direction at the rate of 15 meters per hour. Xylem sap ascends against the downward pull of gravity without the help of any mechanical pump. The rise of sap in xylem is either due to push from below or a pull from above. Several theories have been advanced to explain to ascent of sap in tall trees against the force of gravity but no single theory seems to offer a complete explanation due to objections. Among these are two theories seem to explain the mechanism of ascent of sap better. Let us examine the contribution of the two possible mechanisms.

(i) Root pressure theory.

(ii) Adehesion - cohesion theory.

i) Push from below— Root pressure theory:

If the stem of well watered potted plant is cut a little above the soil, the cut end exudes water for some time suggesting that there is a force pushing water upto

the stem from roots. This force is known as **root pressure.** It was discovered by Stephen Hales in 1727. According to Hales, this force could be responsible for raising water to a height of 6.4 meters. He also observed that the pressure develops at certain times of a year.

Root pressure, which is active primarily at night, is caused by the continued active accumulation of ions by the roots of a plant at times when transpiration from leaves is very low or absent.

Root pressure also causes **guttation**. The exudation of water droplets can be seen on the tips of grass blades and leaf margins of small herbaceous dicot plants. During night when rate of transpiration is very low, the root pressure pushes xylem sap into shoot system. More water enters leaves than is transpired. The excess of water is forced out in the form of liquid (droplets) through openings, called **hydathodes**.
While root pressure is a demonstrated fact, it seems unlikely that it can account completely for upward conduction of water in xylem because it raises water upto few meters only. Moreover, many tall trees do not generate root pressure. Thus it is not a potent factor and we must look for an alternative mechanism.

ii) Transpiration pull (Adhesion—Cohesion—Tension theory):
Ascent of sap mainly depends upon two factors. These are (i) transpiration which generates pulling force and (ii) physical properties of water i.e. adhesion and cohesion. Adhesion is the sticking together of molecules of different kinds. Water molecules tend to adhere to cellulose molecules of the walls of xylem vessels. Cohesion is the clinging together of molecules of same kind. Extensive hydrogen bonding in water gives rise to property of cohesion. It also gives water a high tensile strength defined as the ability to resist the pulling force. The cohering water molecules in xylem vessels form a continuous column.

Californian red wood trees are over 100 meter tall. Transpiration from their leaves pulls water up the trunk. On the other side a village pump working based on atmospheric air to raise water. The maximum column of water that can be raised is about 10 m only.

Transpiration pull results from chain of events that starts when leaves begin to absorb solar radiation in the morning. Sunlight raises temperature of leaves so the water begins to evaporate from moist walls of mesophyll cells. The evaporated water is immediately replaced from water inside the cell which is replaced with water from neighbouring cell deeper in the leaf. Ultimately, water is pulled from xylem to meet the loss ofwater. Thus water in xylem is placed under tension which is transmitted to root through vessels. This downward transmission of tension is because of cohesive property of water columns in vessels and tracheids. Water column moves upward by mass flow due to transpiration pull. Adhesion ofwater molecules to hydrophilic walls of xylem cells, small diameter of vessels and tracheids are important factors in overcoming the force of gravity.
To transport water over a long distance, plants do not use their metabolic energy. Forces like adhesion, cohesion and evaporating effect of sunlight are mainly responsible for upward conduction ofwater. Thus ascent of sap is solar powered.

14.6 TRANSPIRATION
Plants absorb large quantities of water from soil. Only 1 -2% of the absorbed water is used in photosynthesis, in other metabolic activities and in the maintenance of turgor of the cells. The remainder is lost from leaves and other aerial parts in the form of vapours. This loss of water in vapour form through aerial parts of plant body is known as **transpiration.**

Transpiration takes place at three sites. These are stomata, cuticle and lenticels. Accordingly, there are three types of transpiration: i) stomatal transpiration ii) cuticular transpiration and iii) lenticular transpiration.

i) Stomatal transpiration:
In lamina of leaf there are microscopic pores known as stomata (sing: stoma). Through these pores water in vapour form escapes into outer atmosphere. This loss of water in vapour form through stomata is known as stomatal transpiration. Since greater loss of water takes place through stomata, therefore, leaves are regarded as chief transpiring organs.

ii) Cuticular transpiration:
Cuticle is a layer of waxy substance cutin found outside the epidermis of leaves and stems. Loss of water in vapour form from epidermal cells through cuticle is known as cuticular transpiration.

iii) Lenticular transpiration:
Lenticels are also pores found in old dicot stems which are formed as a result of secondary growth. Smaller quantities of water are also given out through lenticels. This is known as lenticular transpiration.

14.6.1 Mechanism of transpiration (Stomatal):
Since greater loss of water in vapour form takes place through stomata, therefore, we shall discuss here only the mechanism of stomatal transpiration. Two processes are involved in this type of transpiration. These are: i) evaporation ii) diffusion. Water absorbed by roots is conducted to aerial parts (leaves) through xylem, Mesophyll cells, of leaves are supplied with water through xylem (veins). These mesophyll cells are water filled (turgid). Their walls remain saturated with water are in contact with intercellular spaces, which are connected with outer atmosphere through stomata. In the first step water evaporates from wet surfaces of turgid mesophyll cells. The vapours are collected in the intercellular spaces. In the next step, water vapours diffuse out from intercellular spaces (where they are in higher concentration) to outer atmosphere (where vapour, are in lower concentration) through stomata.

14.6.2 Structure of stomata:
Stomata are microscopic pores present in the epidermis of leaves and herbaceous stems. Each stoma is bordered by two modified epidermal cells called **guard cells**. These guard cells unlike epidermal cells are provided with chloroplasts and shaped like kidneys. In general, the stomata remain open during day time and close at night. Thus light appears to be the prime factor which initiates opening of stomata.

14.6.3 Mechanism of opening and closing of stomata:
The opening and closing of stomata and even widening and narrowing of the gap between two guard cells depend upon the turgidity of guard cells, which is due to increase or decrease in the osmotic potential of the guard cells. The changes in water potential that result from the osmotic changes cause water to move in or out of the guard cells. If water move in, the cells expand (become turgid); if water moves out they go flaccid. When guard cells are turgid, the stomata are open, when the guard cells are flaccid, the stomata are closed. To affect this movement ofwater, an exchange must take place between the guard cells and the surrounding mesophyll and epidermal cell.
There are two main factors which greatly influence the opening and closing of stomata. These are light and concentration of K^+ ions.

Light: Generally, the stomata of a leaf are open when exposed to light and remain opened under continuous light. When darkness returns, the stomata are closed. In the presence of light, chlorophyll containing guard cells synthesize sugars which in turn increase the osmotic potential of guard cell. The increase results in endosmosis and ultimately to turgidity. While in dark these guards cells consume carbohydrate or these carbohydrate translated to neighbouring cell which decrease the osmotic potential in guard cells. This decrease result in exosmosis which ultimately leads to flaccid state.

Concentrating of K^+ion: Evidences indicate that the turgidity of guard cells of many species of plants is regulated by K^+ion concentration.
During day time guard cells actively transport K^+ ion from neighbouring cells, Accumulation of K^+ions lowers the water potential of guard cells. This causes in flow of water by osmosis from epidermal cells. When they lose K^+ions water potential increases. Water flows out of guard cell causing them to become flaccid which result in closure of pore.

14.6.4Factors affecting transpiration:

i) Light: Plants transpire more rapidly when exposed to light than in dark. This is because light stimulates the opening of stomata. In bright sunshine stomata are wide open causing rapid diffusion of water vapours from air space of spongy layer to outside. Light also speeds up transpiration by warming the leaf.

ii) Temperature: Plants transpire more rapidly at higher temperature than at low. Rise in temperature, on one hand increases kinetic energy of water molecules which results in rapid evaporation of water and decreases relative humidity of air on other hand. Both these conditions greatly enhance the rate of transpiration.

iii) Wind: Wind has a profound effect on humidity. During high velocity of winds transpiration becomes more active because water vapours are readily removed and area around transpiring plants is replaced by fresh, drier air.

iv) Humidity: The rate of transpiration is also affected by relative humidity of air. Therate of diffusion of any substance is decreased as the difference in concentration of substance in two regions decreases. The reverse is also true. The diffusion of water from air spaces of leaf to outside goes on rather slowly when the surrounding air is humid. When the surrounding air is dry, diffusion proceeds more rapidly.

At night, when the relative humidity may approach 100%, there maybe no transpiration, however, under these circumstances, the negative pressure component of water potential caused by evaporation, become very small or non-existent.

v) Soil Water: Aplant cannot continue to transpire rapidly if its moisture loss is not made up by absorption of fresh supplies of water from the soil. When absorption of water by roots fails to keep up with rate of transpiration, loss of turgor occurs and wilting of leaf takes place.

14.6.5Transpiration as necessary evil:

Transpiration has its advantages and thus it is necessary. On the other hand it has grave disadvantages and thus it is an evil.

Advantages of transpiration:
In normal circumstances, the fate of transpiration is directly proportional to the rate of absorption. It means rapid transpiration increases the rate of absorption. Transpiration helps the intake of raw food material from the soil.
It is universally accepted that transpiration plays an important role in the ascent of sap. Transpiration helps in keeping plants cool and saving them from overheating which might be injurious to protoplasm. It helps in evaporating excess amount of water.

Disadvantages of transpiration:
Sometimes excessive transpiration may cause death of a plant. Some plants shed their food organs (leaves) particularly in autumn in order to reduce the rate of transpiration during unfavourable season. In certain plants, leaves are modified into scales or spines in order to minimize the rate of transpiration.

14.7 TRANSLOCATION OF ORGANIC SOLUTES (Phloem translocation)
The products of photosynthesis move from mature leaves to the growing and storage organs of plants. The direction of transport is determined by the relative locations of the sources and sinks of photosynthates. This movement of photoassimilates and other organic materials takes place via the phloem, and is therefore called **phloem translocation**. Transport occurs in specialized tissues called sieve elements.

14.7.1Source-sink Movement:
The translocation of photosynthates always takes place from source to sink tissues, therefore, this phloem transport is also referred as **source-to-sinkmovement**. This pathway follows developmental changes as some sink and source tissues are interconvertible during the development of the plant e.g. developing and germinating seeds, developing and mature leaves.
A number of steps are involved in the movement of photosynthates from mesophyll chloroplasts to the sieve elements in the phloem of mature leaves. Sucrose is synthesized in the cytosol of mesophyll cells. This sucrose is translocated from the mesophyll cells to the vicinity of the sieve elements in the smallest veins of the leaf. This is generally termed as the short distance transport pathway because the solutes cover only a distance of two or three cell diameters. The sucrose is then actively transported into sieve elements in a step commonly called**phloem loading**.
The pathway of phloem loading may be either symplastic or apoplastic depending upon the species.
The sucrose in sieve elements is exported away from source tissues. The photoassimilates can be moved a long distance hence this is termed as longdistance transport. Finally, the photoassimilate or sucrose is unloaded at the sink in a process referred to as **phloem unloading.**
The driving force for this translocation of photosynthates is believed to be generated by the processes of phloem loading and unloading. Therefore, this source to sink movement has great agricultural importance, because the productivity of a crop could potentially be increased by increasing the accumulation of photosynthates in edible sink tissues like cereal grains.

14.7.2The mechanism of Phloem Translocation:

Pressure flow Hypothesis:
Phloem translocation is mainly explained by a theory called the pressure flow hypothesis proposed by **Ernst MUnch** in 1930, which states that the flow of solution in the sieve elements is driven by a pressure gradient produced due to differences in osmotic pressure between sources and sinks as expained in the model given in figure 14.6b. This pressure gradient is produced due to phloem

loading and unloading at the source and sink, respectively. A high osmotic pressure generated due to active phloem loading in the sieve elements of the source tissue, causes a decline in the water potential. In response to this decline in water potential, water enters into the sieve elements and produces a high turgor pressure. In the sink tissues, present at the other terminal of the translocation pathway, phloem unloading occurs, which produces a low osmotic pressure in the sieve elements of the sink tissues. As a result of this low osmotic pressure, the water potential of the phloem rises above that of the xylem and water tends to leave the phloem in response to the water potential gradient, which causes a decrease in the turgor pressure of the phloem sieve elements of the sink (Fig. 14.6 a).

An equilibrium between the two ends (source and sink pressure) would be reached very soon if the entire translocation pathway were a single membrane bound compartment. The sieve plates which are present in the sieve elements increase the resistance along the pathway and maintain the pressure gradient in the sieve elements between source and sink. The sieve elements contents are physically pushed along the translocation pathway by bulk flow, much like water flowing through a garden hose.

Water movement in the translocation pathway is therefore driven by the pressure gradient rather than the water potential gradient. The passive, pressure driven long distance translocation in the sieve tube ultimately depends on the active short-distance transport mechanism involved in phloem loading and unloading. These active mechanisms are responsible for setting up the pressure gradient in the first place.

14.8 TRANSPORT IN ANIMALS

Like plants, animals also have efficient means of transportation which are according to their complexity. In unicellular organisms, such as Amoeba and Paramecium, food is taken in by direct and simple mechanism. Oxygen diffuses in through the body surface. The digested nutrients and the diffused oxygen are transported within the body by diffusion and cyclosis. The CO_2 and other metabolic wastes are also removed by simple diffusion through body surface. This is possible because, the distances between the external and internal environment and within the internal environment are much smaller and are easily covered by diffusion. However, in multicellular large sized animals due to increase in size and complexity, some other means are adopted for transportation, involving some kind of mass flow.

14.8.1 Transport without special Circulatory system in Hydra and Planaria:

1. HYDRA:

Hydra is the simplest multicellular animals. Its body is composed of two layers, ectoderm and endoderm, with a non-cellular mesogloea in between. The gastrovascular cavity (coelenteron) serves for the dual functions of digestion and distribution of substances through out the body. The fluid inside the cavity is continuous with the water outside through the mouth. Thus both inner and outer layers are bathed by the water. Moreover it possesses a large surface area to volume ratio. So the diffusion is sufficient for the transportation of digested food, oxygen, carbon dioxide and other metabolic waste.

2. PLANARIA:

Plan aria is a triploblastic, much larger and complex animal with a dorsoventrally compressed body. Due to which the cells are close to the external environment. The gaseous exchange takes place by direct diffusion across the general body surface. However, the transport of digested food to the body cells takes place by combining diffusion process with special organization of the intestine.

Planaria possesses an extensively branched intestine. These branches reach very close to the cells of the body. The digested food is pumped into the branches by muscular action of the digestive tube. So that the nutrients reach directly to the cells and diffuse into them.
Planaria has no circulatory system for the transportation of digestedfood and gaseous exchange. However, one special transport system is present to dispose off the excess amount of water along with nitrogenous waste (Protonephridia).

14.8.2Transport by Special Circulatory System:
Due to the development of a body cavity (coelom), the distances are increased between the external and internal environments. The coelom separates the body wall from the internal organs and confers the advantage of independence of movement of the gut. Materials need to be moved efficiently over long distances within the body by some means. So that metabolic processes may be maintained and toxic materials may be removed from the body. This generally takes the form of a mass flow system or circulatory system.

14.9 CIRCULATORY SYSTEM
The purpose of a circulatory system is to provide rapid mass flow of materials from one place of the body to the other place, covering sufficient distances which cannot be easily covered by diffusion. On reaching their destination the materials must be able to pass through the walls of the circulatory system into the organs and tissues. Like wise materials produced must be able to enter the circulatory system, for disposal.

General characteristics of a circulatory system:
The characteristics of circulatory system are as follows:

(i) It has a circulatory fluid, the blood.
(ii) The blood is pumped by a contractile device around the body which may be a modified blood vessel or a heart.
(iii) The blood circulates through the tubes which are known as blood vessels.
(iv) It has one way valves to keep the medium flowing in one direction.

14.9.1Types of circulatory system:
The blood circulatory system is basically of two types: (i) open type and (ii) closed type. They both allow the transported materials to be exchanged between the blood and the cells, but there is a different relationship between the blood and the surrounding tissue in each case.

i) Open type circulatory system:
The open type circulatory system is found in Arthropods, Molluscs and Tunicates. The blood circulates within the open body sinuses and bathes the surrounding tissue. These blood sinuses are collectively known as **haemocoel**. Since there is no distinction between blood and interstitial fluid, so the general body fluid is more correctly known as **haemolymph.** The blood is pumped by a heart which propels it into the arteries. The arteries open into the body sinuses, from where it is driven back into the heart. Distribution of blood to the tissues is poorly controlled. Since the blood flows within the sinuses and comes in direct contact with the body tissues, the system is known as open type circulatory system. Because the blood is in large spaces and the heart is weakly muscular, the blood pressure can never be very high. This limits the efficiency of the open system, that is why it is not found in large animals. In insects, gaseous exchange takes place through the tracheal system, so that the circulatory system is not concerned with transportion of gases and lacks any respiratory pigment. How ever, it does play an important role in distributing food substances and eliminating nitrogenous waste.

A comparative chart showing open and closed circulatory system with reference to the transport systems in cockroach and earthworm.

Main features	Cockroach	Earthworm
1. Type	Open type	Closed type.
2. Circulation	The blood flows through blood filled sinuses (Haemocoel).	The blood flows through closed blood vessels.
3. Contact of blood	The blood comes in contact with the surrounding tissues.	The blood does not come in contact with the tissues.
4. Body cavity	The coelom is greatly reduced.	The coelom is large.
5. Interstitial fluid	There is no difference between the interstitial fluid and the blood.	The interstitial fluid is separated from the blood.
6. Distribution of blood	It is poorly controlled.	Fairly controlled and is adjustable.
7. Vessels	A single dorsal vessel runs mid dorsally from head to the posterior end.	One dorsal vessel runs above the alimentary canal and one ventral vessel below the alimentary canal from anterior to the posterior end.
8. Flow of blood	Forward in dorsal vessel.	Forward in dorsal vessel and backward in ventral vessel.
9. Hearts	Modified posterior part of dorsal aorta having thirteen chambers.	Modified circular vessels connecting the dorsal and ventral vessel in 7th, 9th, 12th, 13th segment.
10. Veins and capillaries	Absent.	Present.
11. Blood	Colourless, having no haemoglobin.	Red, haemoglobin is dissolved in plasma.
12. Transport	It transports, digested food and excretory products but no gases.	It transports digested food, excretory products as well as gases.

ii) Closed type circulatory system:

The closed type circulatory system is more commonly found in annelids, echinoderms, cephalopods and vertebrates. The blood circulates through closed blood vessels and is distinct from the interstitial fluid. It does not come out at any place in direct contact with the surrounding tissues. The blood is pumped by the

heart rapidly around the body under sustained high pressure and back to the heart. The distribution ofblood is controlled fairly and is adjustable. Exchange of materials occurs across the walls ofblood capillaries, which ramify through the organs and come into close association with the body cells.
Animals with closed circulatory system are generally larger and often more active than those with open systems. A disadvantage of a closed circulatory system is that the blood is in vessels and their walls form a barrier between the blood and the surrounding tissue cells. The transporting materials have to cross this barrier into the surrounding tissue fluid and hence into the cells. At the same time, waste products diffuse from the cells into the tissue fluid and then into the capillaries.
The open type circulatory system and the closed type circulatory system can be understood well by explaining the transport system in cockroach and earthworm, through a comparative chart.

14.9.2Single circuit plan as in Fish:

The heart offish is two chambered, consisting of an atrium and a ventricle. Blood from the body circulation enters the atrium through a thin walled sinus venosus which opens into a muscular ventricle. When the ventricle contracts the blood is pumped into the ventral aorta via conus arteriosus. All these chambers have valves which prevent backward flow of blood. From the aorta, the venous blood passes into the afferent branchial arteries (4-5 pairs) into the gills for oxygenation. Since the blood flows through the heart only once during each circuit of the body, the fishes are said to possess a single circuit plan.

In fishes the blood flows in one direction and the heart never receives oxygenated blood for pumping.

14.9.3Double circuit plan:

From amphibians onward upto the mammals, the circulatory system has double circuit plan with separate pulmonary and systemic circulation. In amphibians and reptiles, the heart consists of three chambers, two atria and one ventricle. The oxygenated blood from the lungs is returned to the left atrium through the pulmonary veins, whereas the deoxygenated blood from the body is passed to the right atrium via sinus venosus by the anterior and posterior vena cava. These two types of blood remain separated due to atrial septum in between the right and left atria, but get mixed to some extent within the ventricle. Since the oxygenated and deoxygenated blood are mixed, the circulation is known as **incomplete double circulation.**

In crocodile (Reptilian) the ventricle is completely divided and the heart is four chambered.

14.9.4Pulmonary and Systemic circulation in Birds and Mammals:

In birds and mammals the heart is four chambered with two atria and two ventricles. The right atrium and right ventricle are completely separated from the left atrium and left ventricle by inter atrial and inter ventricular septum. The right side receives deoxygenated blood and the left side oxygenated blood. The blood circulates through the heart twice. Once as deoxygenated blood on the right side, from where it is pumped to the lungs for oxygenation (pulmonary circulation). Next time as oxygenated blood on the left side to be distributed to all the parts of the body except lungs (systemic circulation). Thus it is known as **complete double circulation**. Birds and mammals are endotherms, hence, need more oxygen to release more heat energy.

14.9.5Evolution of Heart in Vertebrates:

In the evolution of heart many changes have taken place.

In **fishes**, the heart is S-Shaped having only two chambers. The atrium receives the blood through a thin walled chamber of the veins, the sinus venosus that opens into ventricle which pumps the blood through conus arteriosus a chamber of the aorta into the body.

In **amphibians**, the heart is tri-chambered; two atria and one ventricle. The right atrium receives deoxygenated blood from the body and left atrium receives oxygenated blood from the lungs. But these two types ofblood get mixed in ventricle, to some extent.

In **reptiles,** the same tri-chambered heart is found with a beginning of the partition of the ventricle by inter ventricular septum which is complete in crocodilians.

Birds and **Mammals** have four chambered heart. Two atria and two ventricles. The two types ofblood remain separate. The oxygenated blood circulates through the left side and the deoxygenated through the right side. This brings about a complete double circulation.

14.10 TRANSPORT IN MAN

14.10.1 Blood Circulatory system (Cardio-vascular system):

The fluid circulatory system, with blood as the transporting material has assumed its highest development in man. It consists of a powerful heart, arteries, veins and capillaries.

Blood: Blood is a viscous, red fluid connective tissue, comprising a colourless plasma in which the blood corpuscles float.

Plasma: It constitutes about 55% of the blood. It is a viscous fluid containing a mixture of inorganic salts in true solution form and blood proteins (albumins, globulins and fibrinogen) in colloidal form. In addition, plasma contains glucose, amino acids, triglycerides, urea, hormones, enzymes and auto-toxins. The water is the most abundant component and forms 90% of plasma. The dissolved substances are only 10%.

Blood corpuscles: These are the blood cells which form the remaining 45% of the blood. They are of two types.

Red blood corpuscles (Erythrocytes) are biconcave, non-nucleated circular platelike cells. Their average diameter is 7-8 μm. They contain a respiratory pigment **haemoglobin** which is an iron bound protein and has an affinity for oxygen. The oxygen molecules get attached to the haemoglobin forming **oxyhaemoglobin** which is bright red in colour.
The R.B.Cs are formed in bone marrow of sternum and ribs etc. and are destroyed after 120 days by phagocytosis in spleen or liver. The iron is retained and the rest is passed as bile pigments **bilirubin** and **biliverdin**. R.B.Cs also contain an enzyme **carbonic anhydrase** which plays a role in carbon dioxide transport.
White blood corpuscles (Leucocytes) are irregular, nucleated cells, larger but less numerous than the R.B.Cs. They are formed in bone marrow, spleen, thymus and lymph nodes. They have a short life and are destroyed with in a few (20-30) hours.
The leucocytes maybe **granulocytes** (polymorphonuclear) or **agranulocytes** (mononuclear) on the presence or absence of granules in the cytoplasm. **Neutrophils, Eosinophils** and **Basophils** belong to the first category whereas **monocytes** and **lymphocytes** belong to the second category.

Neutrophils and monocytes are phagocytic whereas lymphocytes, eosinophils and basophils produce antitoxins, histamine and heparin.

Platelets are irregular cell fragments, non-nucleated, produced within the bone marrow. They help in blood clotting.

Mammalian R.B.Cs are non-nucleated and have no other organelles. The lack of nucleus permits more haemoglobin to be packed into the cell.

14.10.2 Functions of Blood:

Blood performs many important functions which are given below. The first five are carried out by plasma.

1) **Transport of Nutrition**: Blood transports digested food, water and other substances, from the alimentary canal to the various parts of the body for storage, oxidation or assimilation.

2) **Transport of Waste Substances:** From the tissues to the excretory organs for their discharge.

3) **Transport of Metabolic By-products:** Prom the area of production to other parts of the body.

4) **Transport of Hormones:** From the endocrine glands to the target organs.

5) **Distribution of Body Heat:** To maintain a uniform body temperature.

6) **Transport of Oxygen and Carbon dioxide:** Oxygen is transported from the lungs to all the parts of the body and carbon dioxide from the cells to the lungs for removal.

7) **Defense against Diseases:** By phagocytosis through neutrophils and monocytes, which engulf and digest the germs that enter the blood stream or by antibodies or antitoxins produced by lymphocytes.

8) **Protection against its Own Loss:** By clotting, making a clot over the injured part.

14.10.3 Leukaemia:

Leukaemia is a malignant disorder of the haemopoietic tissues, associated with increased number of leucocytes in the blood. They obstruct normal blood cell formation in the bone marrow. These are progressive and fatal conditions resulting in death, most often from haemorrhage or infection. The cause of leukaemia is unknown. Several factors however are associated with the development of leukaemia like ionising radiation, cytotoxic drugs, retroviruses, genetic etc.

14.10.4 Thalassaemia:

Thalassaemia is an inherited impairment of haemoglobin production. When the abnormality is heterozygous, the synthesis of haemoglobin is only mildly affected and little disability occur. Synthesis is grossly impaired when the person is homozygous.

Failure to synthesize beta chains (β - thalassaemia) is the most common type. Heterzygotes have thalassaemia minor with mild anaemia. Homozygotes

(thalassaemia major) are either unable to synthesize haemoglobin or produce very little and after 4 months of life, develop a profound hypochromic anaemia. It is more common in children. It results to the enlargement of the kidney. The regular blood transfusion is the only remedy.

14.11 HUMAN HEART

The human heart is the most powerful organ in the circulatory system. It works continuously like a muscular pump and keeps the blood in circulation. The heart lies in the thoracic cavity between the lungs slightly towards left, enclosed with in the rib cage with the sternum in front and vertebral column behind. It is surrounded by a double layered **pericardium**. A **pericardialfluid** is secreted in between the two. It functions as a lubricant and reduces friction between the heart walls and surrounding tissue during the beating of heart.

14.11.1 Structure:

The heart is conical in shape. It is reddish in colour and consists of four chambers. Two upper, thin walled atria and two lower, thick walled ventricles. Two large veins, superior and inferior vena cava enter the right atrium and two pairs of pulmonary veins open into the left atrium. Similarly, two large arteries emerge out, one from the right ventricle pulmonary aorta and the other from the left ventricle, systemic aorta.

Internally, the right and left atria are separated by a vertical membranous **inter-atrial septum**. The right atrium opens into the right ventricle by an aperture guarded by a **tricuspid value**. The left atrium opens into the left ventricle by the aperture guarded by a **bicuspid valve** (Mitral Valve). Semilunar valves guard the emergence of the pulmonary and systemic aorta. These valves prevent backward flowofblood and allow it to move in forward direction.

The right and left ventricles are also separated by a thick muscular **inter-ventricular septum**. The inner walls of the ventricles have **papillary muscles** for the attachment of delicate fibres **chordae tendinae** which are attached to the cusps of the valves. These fibres do not let the valves open back into the atria when the ventricles contract.

The cavity of the left ventricle is narrower than the right ventricle because of more muscular walls. It is due to the fact that the right ventricle has to pump blood into the lungs only (pulmonary circulation) while the left ventricle pumps blood to the entire body (Systemic circulation).

14.11.2 Cardiac Cycle:

Heart muscles contract rhythmically without external stimulation. They are **myogenic.** Their rhythmical contractions arise from within the muscle tissue itself. Following one contraction, the next will not start till the whole has relaxed. There is a short pause between two contractions. This property enables proper timings of the heart beats.

The sequence of events which take place during the completion of one heart beat is called cardiac cycle. The resting period of the heart chambers is known as **diastole** and the period during which they contract is known as **systole**. The right atrium in its diastolic phase, receives deoxygenated blood from the vena cava and the left atrium receives oxygenated blood from the lungs. These chambers become distended and extend a pressure on the atrio-ventricular valves, by which they are pushed open. When the atrial diastole ends, the two atria contract simultaneously. This event is known as **atrial-systole** and the blood contained with in the atria is pumped into the respective ventricles. Immediately, the ventricles contract. This event is termed as **ventricular systole** during which atrio-ventricular valves are closed and the aortic, pulmonary valves are opened. The blood is pumped into the respective aortae. The volume of blood pumped per minute by the left ventricle into the systemic circuit is called **cardiac output.**

14.11.3 Heart Beats:

The contractions of the heart chambers are known as heart beats which are rhythmically and regular. A human normal heart beats 72 times per minute at rest. These beats are audible and are known as heart sounds.

During the ventricular systole blood is forced against the closed **AV-valves.** This produces the first heart sound LUB. Ventricular systole is followed by ventricular diastole. The high pressure developed in the aortae, tends to force some blood back towards the ventricles which closes the aortae valves. This impact of the back flow against the valves causes the second heart sound DUP.

Thus ventricular systole is LUB and the ventricular diastole is DUP. One complete heart beat consists of one systole and one diastole and lasts for about 0.8 second. A defect in one or more of the valves causes a condition known as **heart murmur**, which may be detectable as a **hissing sound**.

Heart starts beating before the birth and never stops till death.

14.11.4 S-ANode:

The stimulus for contraction of the heart originates in a specific region of the right atrium called **sino-atrial node** (S-A Node) close to the point of entry of the superior vena cava. It is a vestige of sinus venosus. It consists of cardiac musclefibres, possessing few myofibrils and a few nerve endings of autonomic nervous system.

14.11.5 Pace Maker:

The S-A node initiates the heart beat. Thus the S-A node is known as pace maker because each wave of excitation for the contraction of atria begins here, and acts as the stimulus for the next wave of excitation.

14.11.6 A-V Node:

The tissues of the A-V node are similar to those of the S-A node. It is located in the right atrium below S-A-Node. They are stimulated by the wave of excitement send by the S-A node. It's excitation travels all parts of the ventricles, through two bundles of specialized muscle fibres of the bundle of His in the ventricular septum and thence into the walls of the ventricle; through a net-work of fibres called **purkinjefibres,** consequently the two ventricles contract. There is a delay of about 0 15 seconds in conduction from the S-A node to A-V node permitting atrial systole to be completed before ventricular systole begins.

14.11.7 Artificial Pace Maker:

It is a device that supplies electrical impulses to the heart to maintain the heartbeat at aregular rate. It consists of a small electronic device and power source connected to heart via an electrical wire. It is implanted beneath the skin in the chest when a person's SAN is not functioning properly or when there is some impairment to the passage of the normal electrical impulses.

Blue Babies:

It is a lay man terminology. In medical science it is known as **cyanosis** (Cyano-blue, Sis-process).

Cyanosis is a blueish discolouration of the skin and mucous membrane due to excessive concentration of reduced haemoglobin in the blood. The most common pause of cyanosis is cyanotic heart disease.

In cyanotic congenital heart disease, there is abnormal connection between right and left side of heart which leads to mixing of oxygenated and deoxygenated blood. This abnormal connection may be due to several reasons, but the commonest causes are the atrial septum defect (ASD), ventricular septum defect (VSD) and persistant ductus arteriosus.

14.12 BLOOD VESSELS

The closed vessels through which transporting medium (blood) circulates within the body are known as blood vessels. They are of two types, arteries and veins. The arteries carry blood away from the heart and the veins towards the heart.

14.12.1 Arteries:

Arteries are thick walled vessels consisting of three layers. The outer **tunica externa** composed of fibrous connective tissue having collagen fibres. The middle layer **tunica media** has smooth muscles and elastic fibres. The inner **tunica interna** (intima) consists of squamous endothelium. The arteries are elastic and dilate during ventricle systole but do not get ruptured. When systole ceases, the arteries contract and promote an even flow of blood along their length. They are pulsatile and maintain the blood pressure. Their lumen is small and does not contain semilunar valves. Blood flows rapidly with jerks in pulsations indicating the ventricular systole. The smaller arteries are known as arterioles. They contain sphincters at their capillary ends which regulate the flow of blood into the capillaries. When the sphincters contract, blood is prevented from flowing through the capillary network, or the contraction of smooth muscle layer in the wall of the arteriole constricts the arteriole decreasing blood flow through it to a capillary bed. The arteries carry oxygenated blood except the pulmonary arteries which carry deoxygenated blood into the lungs for oxygenation. The arteries are deep seated and do not collapse when empty.

14.12.2 Veins:

Veins are thin walled blood vessels. They are also composed of the same three layers as that of arteries, but possess less muscles and less elastic fibres. Their lumen is large. Semilunar valves are present which prevent the back flow of blood. The pressure of blood flowing through them is low and are non-pulsatile. The blood flows slowly and smoothly. The veins carry deoxygenated blood except the pulmonary reins which transport oxygenated blood from the lungs to the heart. The veins are super-ficial and collapse when empty.

14.12.3 Capillaries:

The intimate relationship between the circulatory system and the tissues is achieved by, at the level of capillaries in the form of capillary network. The capillaries are extremely narrow (7-10 μ in diameter), thin walled microscopic vessels. Their walls consist of a single layer of endothelium, which presents very little resistance to the diffusion of dissolved substances in or out. The cells of the tissues are bathed in tissue fluid which provides a medium through which diffusion of materials can take place. The close approximity between the capillaries and the tissue cells facilitates the exchange of materials. It is only here that exchange by **diffusion** or **active transport** can occur. The oxygen carried by the blood is diffused out into the oxygen deficient tissue and the carbon dioxide of the tissue cells is diffused in simultaneously. The nitrogenous waste is**filtered** through the capillaries into the excretory tubules for discharge.

14.12.4 Blood Pressure:

Blood pressure is the hydrostatic force exerted by the blood against unit area of the vessel wall. It is measured in millimetres of mercury (mm Hg). Mercury manometers are being used for measuring the blood pressure which are known as **sphygmomanometer**. Blood pressure is determined partly by cardiac output and partly by the diameter of the arterioles. When wall of the arterioles are constricted (vasoconstriction), the blood pressure rises: when they axe dilated (vasodilation), the blood pressure falls. The constriction and the dilation of

arterioles are due to the constriction and relaxation of the smooth muscles of the arterioles, respectively. These muscles are largely under the control of nerve Impulses, and hormones.
Blood in the arteries of the average adult exerts a pressure equal to a column of mercury about 120 mm high in the glass tube during systole of the ventricles and 80 mm during diastole. This is expressed as a B.P of 120/80. The difference between systolic and diastolic pressure is called **pulse pressure**.

14.12.5 Blood Flow:
Blood flows through the vessels at an uneven speed. It flows much faster in large arteries and much slower in capillaries. Although an individual capillary is much narrower, but the capillary beds have an enormous number ofsuch capillaries, So that the total diameter of these vessels is much greater than the arteries. For this reason the blood flows slowly in the capillaries, permitting the exchange of materials between the blood and interstitial fluid. As blood leaves the capillary bed and passes to the venules and veins, it speeds up again due to the reduction in total cross sectional area.

14.13 LYMPHATIC SYSTEM
A system of blind vessels (lymphatics) that drains lymph from all over the body back into the blood stream is called lymphatic system. In addition to lymphatics and lymph it consists of lymph nodes, spleen, thymus, tonsils and some of the patches of tissues in vermiform appendix and small intestine.

14.13.1 Lymph vessels, Lymph and Lymph nodes:
The lymph vascular system starts at capillary bed, where tissue fluid (interstitial fluid surrounding the cells of the tissues) enters the **lymph capillaries,** which are closed towards the tissue sinuses. These are thin walled anastomosing microscopic vessels, which form a network in every organ except the nervous system. The lymph capillaries merge into **lymph vessels** which have a larger diameter. These vessels contain smooth muscles in their walls as well as internal valves to prevent backward flow of lymph. The lymph circulates through the lymph vessels by the contraction of surrounding skeletal muscles in one direction, towards the heart. These vessels converge into collecting ducts that drain into veins in the lower neck.
All body tissues are bathed in a watery fluid derived from the blood stream. This intercellular or tissue fluid is formed when blood passes through the capillaries. The capillary walls are permeable to all components of blood except the R.B.Cs and blood proteins. The fluid passes from the capillary into the intercellular spaces as the inter-cellular or tissue fluid. About 85% fluid returns into the blood at the venous end of the capillary. The rest 15% of the tissue fluid drains into blindly ending lymphatic capillaries as lymph along with W.B.Cs, cell debris and micro-organisms like bacteria, are transported back to the heart through lymphatic system. Thus **lymph** can be defined as a colourless body fluid, that contains lymphocytes (agranular W.B.Cs). small proteins and fats. Lymph takes fluid substances from cells of tissues and Intercellular spaces, which cannot penetrate the blood capillaries. It is a medium of exchange between blood and body cells.
Through-out the course of lymphatics lie **lymph nodes**, through which lymph flows. Lymph nodes vary considerably in size from microscopic to about one inch in diameter. Each node consists of a thin, fibrous, outer capsule and an inner mass of lymphoid tissue. Penetrating the capsule are several small, lymphatic vessels which carry lymph into the lymph node, while a single large vessel carries it out. The lymphoid tissue contains antibodies, lymphocytes and macrophages. These nodes act as filters that trap microorganisms and other foreign bodies in the lymph. The lymphocytes and macrophages present here, neutralize and engulf the microorganisms, respectively.

14.13.2 Functions of Lymphatic system:

Drainage system: Lymphatic vessels act as drainage channels for water and plasma proteins that have leaked away from blood at capillary bed and that must be delivered back to blood circulation, without which death can occur in 24 hours.

Defense of the body: Microorganisms, foreign cells, cellular debris in the lymph are removed by macrophages residing in the lymph nodes. These are also the site for differentiation of the B cells into antibody secreting cells.

Absorption and delivery of fats: Lymph capillaries called lacteals penetrate the villi of the small intestine where fats are absorbed and delivered to the blood circulatory system.

14.13.3 Edema:

Whenever, the tissue fluid accumulates, rather than being drained into the blood by the lymphatic system, tissues and body cavities become swollen. This condition is known as edema. Any factor that increases the tissue fluid pressure high enough than normal value can cause excess tissue fluid volume causing edema like high blood pressure, kidney failure, heart failure etc.

Causes of Edema:

One of the common cause of edema is severe dietary protein deficiency. When starved for amino acids, the body consumes its own blood proteins. This reduces the osmotic potential of the blood causing tissue fluid to accumulate in body tissues rather than being drawn back into the capillaries, resulting in edema.

Another cause of edema is lymphatic obstruction which results in more and more protein collection in the local tissue fluid, hence, the increased volume. The commonest cause of lymphatic obstruction is **filariasis** (infection by nematodes). Sometimes increased permeability of the capillaries due to burns or allergic reactions causes edema.

14.14 CARDIOVASCULAR DISORDERS (CVD)

Diseases of heart, blood vessels and blood circulation are generally termed as cardiovascular disorders. Some important CVD are discussed as follows:

14.4.1Atherosclerosis:

It is a disease of the arterial wall (intima) which loses its elasticity. Gradually its inner layer thickens causing narrowing of the artery and consequently impairing the blood flow. The narrowing is due to the formation of fatty lesions called **atheromatous plaques** (raised patches) in the inner lining of the arteries. These plaques consist of low density lipoproteins or LDL (cholesterol and proteins), decaying muscle cells, fibrous tissue, clumps of blood platelets and some times calcium.

The arteries become extremely hard and the disease is called arteriosclerosis or simply hardening of the arteries.

Causes: The possible causes of atherosclerosis are smoking, hypertension, male gender, obesity, physical inactivity, a high serum cholesterol level, severe diabetes, family history of arterial disease and possibly an anxious or aggressive personality. The risk of atherosclerosis increases with age.

Effects: Unfortunately atherosclerosis produces no symptoms until the damage to the arteries is severe enough to restrict blood flow. Restriction of the blood flow to the heart muscles due to atherosclerosis can cause angina pectoris (pain in the chest and arms or jaws usually during exercise or stress).

14.14.2 Hypertension:

When the mean arterial pressure is greater than the upper range, accepted normality, the person is said to be hypertensive having hypertension. Usually a mean arterial pressure of greater than 110 mm Hg under resting conditions is considered to be hypertensive. This level normally occurs when the diastolic blood pressure is greater than 90 mm Hg and the systolic pressure greater than 135—140 mm Hg.

Hypertension is called as "Silent Killer", because the affected individuals may show no outward symptoms until a stroke or heart attack occurs. It promotes atherosclerosis. As a prolonged consequence the heart may enlarge and fail to pump the blood effectively. Several factors such as heredity, higher intake of salts in diet, smoking, obesity and disorders of kidney or adrenal gland are responsible for hypertension.

14.14.3 Thrombus formation:

The formation of blood clot (thrombus) within an intact blood vessel is initiated by atherosclerotic plaques. The plaques when destroy the endothelium of the blood vessel, platelets gather at the damaged site to initiate the process of clot. As the growth of the plaque and clot progresses, the lumen of the artery narrows or completely blocks. Ultimately, the blood supply to the concerned organ is either reduced or prevented. Thus due to the lack of oxygen and nutrient, the function of the target organ is impaired. Thrombus of the coronary artery or carotid artery may cause the death of the victim due to heart attack (myocardial infarction) and stroke.

If a clot dislodges and travels in the blood stream, it is termed as embolus. It can obstruct any small artery such as coronary artery, the out come may ranges from angina to heart attack.

14.14.4 Coronary Thrombosis:

Narrowing or blockage of one of the coronary arteries (which supply blood to the heart muscle) by a thrombus is called coronary thrombosis. This causes a section of the heart muscles to die because it has been deprived of oxygen. It is one of the main processes involved in coronary heart disease. Sudden blockage of a coronary artery can cause acute myocardial infarction.

14.14.5 Myocardial infarction—Heart attack:

It refers to the death of the part of heart muscles characterized in most cases by severe continuous chest pain. This is commonly, known as heart attack. Due to the blockage of any of the coronary artery either by thrombus or embolus, the blood supply to some cardiac muscles stops. The area of heart muscle which has zero or little flow of blood that it cannot sustain cardiac muscle function is said to be infarcted and the process is called myocardial infarction. As a consequence the affected cardiac muscles die due to lack of nutrients and oxygen. If the damaged area is small, the victim may recover from the heart attack but death of the large area of cardiac muscles is fatal.

14.14.6 Stroke and Prevention:

Stroke implies to damage to part of the brain caused by interruption to its blood supply (either by a thrombus or embolus) or leakage of blood outside of vessel walls. It is characterized by the impairment of the sensation, movement, or function controlled by damaged part of the brain. Damage to any one cerebral hemisphere can cause weakness or paralysis of one side of the body called **hemiplegia**. Hypertension and atherosclerosis are among the most common causes.

The stroke can be prevented by keeping the blood pressure at normal range, through a proper diet. Salts should be used in less quantities as they increase blood pressure. Fats should also be reduced especially those which are rich in cholesterol. They cause thrombus formation resulting in atherosclerosis of the arteries particularly the coronary arteries. Exercise should be made a regular habit of life. At least 30 minutes brisk walk per day. Smoking should be avoided. Tension is the major cause of hypertension. The life should be made easy and free of extra worries.

Haemorrhage: The haemorrhage is defined as the escape of blood from the vessels. Small haemorrhages are classified according to their size. The massive accumulation of blood within a tissue is called **haematoma.**

The haemorrhage may occur any where in the body. But the most dangerous is the brain haemorrhage causing stroke.

14.15 THE IMMUNE SYSTEM

Immunity:
Animal body is always exposed to the invasion of countless infectious microorganisms such as virus, bacteria, etc. However, due to the defense mechanisms evolved by the animals, such invasions in number of cases, are overcome. The ability of the body to resist microorganisms, their toxins if any, foreign cells, and abnormal cells of the body is termed as **immunity.**

Immune System:
Immunity is conferred, to animals through the activities of the **immune system** which combats infectious agents. The study of the functioning and disorders of the immune system is termed as **immunology.**
Immune system is a collection of cells and proteins that work to protect the body from potentially harmful, infectious microorganisms. It also plays role in the control of cancer, allergy, hypersensitivity, and rejection problems when organs or tissues are transplanted.
The immune system can be divided into two functional divisions:

(1) Innate immune system, and (2) Adaptive immune system.

14.15.1 Innate Immune System:
It is responsible for innate or natural immunity which is **non-specific** in nature since it combats all microorganisms. It consists of physical (e.g. skin, mucous membranes) and chemical (e.g. lysozyme, gastric juice, etc.) barriers against infectious micro-organisms.
Skin and mucous membrane with their secretions act as **first line of defense**. The intact skin provides an impenetrable barrier to the vast majority of infectious agents, most of which can enter only through the mucus membranes that lines the digestive, respiratory, and urino-genital tracts. However, these areas are protected by the movement of mucus and secretions (e.g. lysozyme in tears) to destroy many microbes. Most of the micro-organisms present in food or trapped in swallowed mucus from the upper respiratory tract arc destroyed by the highly acidic gastric juice of the stomach.
If some how micro-organisms are able to penetrate the outer layer of the skin, or mucous membrane, they encounter a **second line of defense** offered by the innate immune system. It is also non-specific in nature and comprises of phagocytes, antimicrobial proteins, and inflammatory response.
Phagocytes are certain type of W.B.C. which can ingest, internalize and destroy the particles including infectious agents. The short-lived phagocytic cells called **neutrophils** (polymorphonuclear neutrophils) ingest bacteria very actively. The

other phagocytic cell, the **monocyte** can develop into large, long-lived **macrophage** (big-eaters) when they reside in various tissues of the body. Macrophages not only, destroy individual microorganisms but also play a crucial role in the further immune response by "presenting" parts of the that micro-organisms to other cells of the immune system. For this reason they are termed as **antigen presenting cells.**

Another group of W.B.C, the **natural killer cells (NK cells)** destroy virally infected own cells of the body. They also attack abnormal cells (cancerous cells). NK cells do not phagocytize the target cells. Instead, they bind to their target cell, release some pore forming proteins into the target cell which eventually cause lysis of the target cell. This kind of destroying the target cells is called **cytotoxicity.**

Among **antimicrobial proteins**, important are lysozyme, compliment proteins and interferons. Lysozyme is an enzyme present in tears, saliva and mucus secretion. It causes the lysis of bacteria. **Complement proteins** work in innate as well as adaptive immune systems. They directly cause lysis of bacteria, serve as chemoattrants for macrophages, and promote phagocytosis ofbacteria. **Interferons** are secreted by virally infected cells or some lymphocytes to induce a state of antiviral resistance in uninfected tissues of the body.

Inflammation (to set on fire) is the body's reaction to an injury or by the entry of microorganisms. Acascade of chemical reactions takes place during inflammatory response. It is characterized by redness, heat, swelling and pain in the injured tissue. When injured, basophils and mast cells release a substance called histamine which causes increase in the permeability of the adjacent capillaries, local vasodilation, and also make capillaries leakier. Due to chemotaxis, phagocytes and macrophages are attracted at the injured site. Thus phagocytes literally eat up microorganisms, dirt, cell debris, etc. forming pus.

In case of warmblooded animals, a number of micro-organism which escape away from the inflammatory response to infect some large part of the body, trigger **fever.** It is usually caused by certain W.B.Cs. that release substance called pyrogen. It sets the temperature of the body higher than the normal. Very high fever is dangerous but moderate fever contributes to the defense of the body. It inhibits the growth of some micro-organism, facilitates phagocytosis, increases the production of interferon, and may speed up repair of the damaged tissue.

14.15.2 Adaptive Immune System:

The adaptive immune system is extremely complex. It produces **specific immune response** against a range of different invading organisms, toxins, transplanted tissues and tumor cells. This is the **third line of defense** which comes into play simultaneously with the second line of non-specific defense.

The responses of the adaptive immune system are provided chiefly by two types of lymphocytes called **B cells** and **T cells**. Depending upon their migration and maturity during the early development in either bone marrow or thymus, they are designated as B and T cells, respectively. Although, B cells and T cells play quite different roles in the immune system, yet they share the basic key features of the immune response.

In order to develop a specific immune response, the immune system must recognize the invading organisms and/or foreign proteins from its self tissues and proteins. A foreign substance that elicits immune response is called **antigen**. The immune system responds to an antigen by activating lymphocytes and producing specific, soluble proteins called **antibodies**. The antibody combines with the antigen and helps to eliminate it from the body. The immune system of a vertebrate has virtually unlimited capacity to generate different antibodies which recognize and bind millions of potential antigens or foreign molecules.

The immune system has also the ability to memorize antigens it has encountered. Thus upon subsequent exposure to the same pathogen, it responds very quickly and effectively.

The adaptive immune system mounts two types of attacks, termed as humoral immunity and cell-mediated immunity (CMI), on invading micro-organism.

i) Humoral Immunity:

Immunity provided by the antibodies secreted in the circulatory system by B cells is termed as humoral immunity. This is particularly helpful in bacterial invasion. It has been determined experimentally that each B cell has specific type of antibodies on its cell surface. This antibody serves as **antigenic receptor**. When an infection occurs, the antibodies borne by a few B cells will bind to antigens on the surface of the micro-organism. Antigen-antibody complex binding causes such B cells to divide rapidly to give rise enlarged, effector cells called **plasma cells** whichsecrete antibodies into the circulation that help eliminate that particular antigen. Some of the effector cells do not secrete antibody, they become **memory cells**. The memory cells play important role in future immunity to this specific organism in case of re-infection. When circulating antibodies bind to antigens, the micro-organism bearing such antigens are easily phagocytized, or lysed by the complement proteins (just like the NK cells do). Moreover, antibodies neutralize the toxins released by bacteria, and also cause agglutination of the microorganisms.

ii) Cell Mediated Immunity (CMI):

Cell mediated immunity is contributed by the second family of lymphocytes called T cells, which do not secrete antibodies. They mediate immunity by killing infected cells, and aiding in inflammation. This is particularly important in the defense against virus as well as some parasites that hide within the host cells, tumor cells and fungi. Several types of T cells contribute to cell mediated immunity: Helper T cells (T_H), Cytotoxic T cells (T_C), and Suppressor T cells (T_S).
LikeBcells, helperTcells and cytotoxic T cells have antigenic receptors, called **T cell receptors (TCRs)** on their plasma membrane. HelperTcells receptors actually recognize a combination of antigen fragment and one of the body's own self marker called **"Major Histo-compatibility Complex (MHC) Class II"** molecules on the surface of macrophage or B cells.
On the other hand, the receptors on the surface of cytotoxic T cells recognize a combination of antigenic fragment and self surface maker molecules called **MHC Class I,** which are found on every nucleated cells of its own body.
After the infection is conquered, another group of T cells called **suppressor T cells** seems to shut off the immune response in both B cells and cytotoxic T cells.
During CMI response, some T cells turn into **memory T cells** to protect the body in case of re-infection in future.

14.15.3 Cytokines (lymphokines):

Cytokines, or the hormones of the immune system are protein molecules secreted by the cells of the immune system to regulate the immune responses. Various cytokines including a range of interleukins (IL), interferons, etc. have been recognized and their roles have been studied.
Interferons belonging to the group of cytokines are a group of proteins produced naturally by body cells in response to viral infections and other stimuli. They inhibit viral multiplication and increase the activity of the natural killer cells.

14.15.4 Primary and Secondary immune responses:

The first exposure of an antigen to the immune system elicits formation of clones effector cells to develop specific immunity. This response of the immune system is termed as primary response. Beginning from the infection to the development of maximum effector cells takes about 5 to 10 days.
Indeed, there is always risk of re-infection with the same pathogen. In such case, the immune response is always quicker than the first one. This is known as secondary immune response. It develops to its maximum within 3 to 5 days. This

quicker response is made possible due to the ability, called **immunological memory**, of the immune system. It is based upon the long lasting memory cells produced with the short lived effector cells of the primary immune response. The development of memory cells may provide life long protection against some diseases like chicken pox.

15.15.5 Active and Passive Tin inanity

i) Active Immunity:
Immunity acquired by own immune response is called active immunity. If it is a consequence of natural infection, it is said to be **Natural Active Immunity**. Active immunity can be acquired artificially by vaccination. In this case it is said to be **Artificial Active Immunity**. The concept of vaccination is already familiar to you as it was introduced in Bacteria (chapter 6). Active immunity, due to the development of immunological memory provides long term protection, even in some case (e.g. in chicken pox) life long protection is provided.

ii) Passive Immunity:
It depends upon the antibodies transported from another person or even an animal. It could be **Natural Passive Immunity,** if antibodies transferred to one person were derived from another of the same species. For example, a pregnant woman passes some of her antibodies to her fetus through placenta. Also, the first breast feeding, the colostrums, of mother pass certain antibodies to her newly born infant. Such immunity is short lived and provides temporary protection.
Passive immunity can also be transferred artificially by introducing antibodies derived from animals or human being who are already immune to that disease. This is termed as **Artificial Passive Immunity**. For example, rabies is treated in man by injecting antibodies derived from persons who have been already vaccinated against rabies. This confers rapid immunity to combat the rapidly progressing rabies in the new victim. Although acquired passive immunity is short lived, it boosts the immune response of the victim several folds.

Immunization:
Immunization is the process of inducing immunity as a preventive measure against certain infectious diseases. The incidence of a number of diseases (e.g. diphtheria, measels, etc.) has declined dramatically since the introduction of effective immunization programmes. Once thought to be the dreadful diseases like tuberculosis, etc. is now under control through immunization and treatment.

KEY POINTS

- Each living organism obtains necessary raw materials, to synthesize molecules for metabolism. These materials are transported within the living organism or from environment to living organism.
- Soil is the source of water and minerals for plants, various processes likes diffusion, facilitated diffusion, osmosis, imbibition and active transport help in the absorption of H_2O and minerals from soil.
- Water is important in the life of plants because it makes up the matrix and medium in which biochemical processes essential for life occur.
- Water potential is a quantitative expression of the freeenergy associated with the water.

- Osmotic pressure is the pressure that must be exerted on a solution to prevent the passage of solvent molecules into when the solvent and solution are separated by differentially permeable membrane.
- Plasmolysis is the withdrawn of protoplasm from cell-wall due to exosmosis and the finish of plasmolysed condition due to endosmosis is called deplasmolysis.
- Symplastic pathway is the transport of water and solutes through plasmodesmata.
- Apoplastic pathway is the transport of water and solutes through extra-cellular pathway.
- Upward movement of water from root to leaves against the downward pull of gravity is known as ascent of sap. The movement takes place through xylem.
- Root pressure was thought to be responsible for ascent of sap as well as guttation.
- Transpiration pull and-cohesion forces are responsible for ascent of sap.
- Loss of water in the form of vapours through aerial parts of plant is known as transpiration, it takes place through stomata, cuticle or lenticle.
- Light, temperature, wind, humidity and soil water are some factor which affect the rate of transpiration.
- Photosynthate move from source to sink, this movement of organic solutes called translocation, takes place through phloem, therefore, also called phloem translocation.
- In small animals the transport of materials can take place by **diffusion.** However larger animals generally require special transport system.
- The circulatory system is of two types; **open circulatory system** and **closed circulatory system.**
- Arthropods, molluscs and tunicates have open circulatory system in which the blood flows within the body cavities and bathes the tissue.
- Annelids, echinoderms, cephalopods and vertebrates have closed type circulatory system in which the blood circulates within the closed blood vessels and the exchange of materials takes place through capillaries.
- A circulatory system in which the blood flows only once through the heart for every complete circuit of the body is called a **single circuit plan** or **simple single circulation.**
- A **double circulation** is one in which the blood flows through the heart twice for every complete circuit of the body.
- **Leukaemia** and **thalassaemia** are two disorders of blood.
- **Cyanosis** (blue babies) is caused by cyanotic heart disease.
- **Edema** is the swelling of the body by the accumulation of lymph.
- **Immunity** is conferred to animals through the activities of the **immune system.**
- **Primary immune response** is against the first exposure of an antigen to the immune system, forming clones of effector cells.
- **Secondary immune response** is against the second infection by the same pathogen which is much quicker than the first one.
- Immunization is the process of inducing immunity as a preventing measure against certain infectious diseases.

EXERCISE

1. Encircle the correct choice:

(i) Which of the following is NOT involved in the cohesion tension theory ofwater movement in plants.
(a) Presence of hydrogen bonds holding water molecules together.
(b) Attraction of H_2O molecule to the walls of xylem.
(c) Diffusion of H_2O from ceils in the root to the cells in the shoot.
(d) Transpiration.

(ii) In the morning when the sunrises, plants open their stomata by:
(a) Pumping H_2O out of the guard cells.
(b) Pumping H_2O into the guard cell.
(c) Pump K^+ ion into the guard cells.
(d) Pump K^+ out of the guard cells.

(iii) Excess water is forced out in the form of droplets through:
(a) Stomata (b) Cuticle
(c) Hydathodes (d) Lenticles

(iv) The point when cytoplasm just starts diffusion to biperant from cell wall is:
(a) Plasmolysis (b) Incipient plasmolysis
(c) Deplasmolysis(d) All of them

(v) Active transport of sucrose into sieve element is a step commonly called:
(a) Phloem loading (b) Unloading
(c) Diffusion (d) Osmosis

(vi) In closed circulatory system blood is completely enclosed within:
(a) Skeleton (b) Sinuses
(c) Vessels (d) Hearts

(vii) The blood corpuscles in earthworm are:
(a) Colourless (b) Yellow
(c) Red (d) Orange

(viii) The body cavity in grasshopper is known as:
(a) Schizocoele (b) Pseudocoele
(c) Haemocoele (d) None of the three

(ix) Blood vessels carrying oxygenated blood from lungs to heart is:
(a) Pulmonary vein (b) Pulmonary arteries
(c) Coronary artery (d) Coronary vein.

(x) Which of the following has no muscular walls?
(a) Artery (b) Vein
(c) Capillary (d) Vena cava

(xi) Living part of blood is:
(a) Plasma (b) Lymph
(c) Serum (d) Corpuscles

2. Write detailed answers of the following questions:

(i) How does the pressure flow theory explain the movement of sugar through the plant?

(ii) Describe the cohesion - tension theory of water movement through xylem? What supplies the cohesion and what is the source of tension? How do these two interact to move water through a plant?
(iii) Describe the structure of human heart and explain the cardiac cycle.
(iv) What is lymphatic system? What functions it performs?
(v) What are cardio-vascular disorders? Give a brief description of each.
(vi) What is immune system? Describe the innate immune system and adaptive immune system.
(vii) What is immunity? What are active and passive immunity? Describe humoral and cell mediated immunity.
(viii) Describe the structure of blood and its function

3. Write short answers of the following questions:

(i) Why the circulatory system of grasshopper is called open type?
(ii) Why we say that, amphibians and reptiles have incomplete double circulation?
(iii) Why white blood corpuscles are known as soldiers of the body?
(iv) Why the capillaries have a single layer of endothelium?
(v) What are LUB and DUP?