Senior Secondary Course

BIOLOGY (314)

1

Course Coordinator
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विद्याधनम् सर्वधनं प्रधानम्

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Chairman's Message

Dear learner,

As the needs of the society in general, and some groups in particular, keep on changing with time, the methods and techniques required for fulfilling those aspirations also have to be modified accordingly. Education is an instrument of change. The right type of education at right time can bring about positivity in the outlook of society, attitudinal changes to face the new/fresh challenges and the courage to face difficult situations.

This can be very effectively achieved by regular periodic curriculum renewal. A static curriculum does not serve any purpose, as it does not cater to the current needs and aspirations of the individual and society.

For this purpose only, educationists from all over the country come together at regular intervals to deliberate on the issues of changes needed and required. As an outcome of such deliberations, the National Curriculum Framework (NCF 2005) came out, which spells out in detail the type of education desirable/needed at various levels of education - primary, elementary, secondary or senior secondary.

Keeping this framework and other national and societal concerns in mind, we have currently revised the curriculum of Biology course at Senior Secondary level, as per the Common Core Curriculum provided by National Council of Educational Research and Training (NCERT) and the Council of Boards of School Education in India (COBSE) making it current and need based. Textual material production is an integral and essential part of all NIOS programmes offered through open and distance learning system. Therefore, we have taken special care to make the learning material user friendly, interesting and attractive for you.

I would like to thank all the eminent persons involved in making this material interesting and relevant to your needs. I hope you will find it appealing and absorbing.

On behalf of National Institute of Open Schooling, I wish you all a bright and successful future.

(Prof. C. B. Sharma)
Chairman, NIOS

A Note From the Director

Dear Learner,

Welcome!

The Academic Department at the National Institute of Open Schooling tries to bring you new programmes, in accordance with your needs and requirements. After making a comprehensive study, we found that our curriculum is more functional related to life situations and simple. The task now was to make it more effective and useful for you. We invited leading educationists of the country and under their guidance, we have been able to revise and update the curriculum in the subject of Biology.

At the same time, we have also removed old, outdated information and added new, relevant things and tried to make the learning material attractive and appealing for you.

I hope you will find the new material interesting and exciting with lots of activities to do. Any suggestions for further improvement are welcome.

Let me wish you all a happy and successful future.

(Dr. Kuldeep Agarwal)
Director (Academic)
National Institute of Open Schooling

Mukta Vidya Vani

Mukta Vidya Vani is a pioneering initiative of the National Institute of Open Schooling (NIOS) for using Streaming Audio for educational purposes. This application of ICT will enhance accessibility as well as quality of programme delivery of NIOS Programmes. This is a rare accomplishment of NIOS as the first Open and Distance Learning Institute to start a two way interaction with its learners, using streaming audio and the internet.

Keeping in mind the fact that the transmission is done through the web, the NIOS website (www.nios.ac.in) has a link that will take any user to the Mukta Vidya Vani. Mukta Vidya Vani thus enables a two way communication with any audience that has access to an internet connection, from the studio at its Headquarters in NOIDA, where NIOS has set up a state-of-art studio, which will be used for this purpose as well as for recording educational audio programmes meant for NIOS learners, though others can also take advantage of this facility.

Mukta Vidya Vani is a modern interactive, participatory and cost effective programme, involving an academic perspective along with the technical responsibilities of production of audio and video programmes, which are one of the most important components of the multi channel package offered by the NIOS. These programmes will attempt to present the topic/ theme in a simple, interesting and engaging manner, so that the learners get a clear understanding and insight into the subject matter.

NIOS has launched a scheme to motivate the learners to participate in the Mukta Vidya Vani by sending their Audio CD's to the respective regional centre on various subjects such as-

1. Poetry / Shloka recitation
2. Story telling
3. Radio Drama
4. Music
5. Talks on various topic related to the NIOS curriculum including Painting, Vocational Subjects etc.
6. Quiz
7. Mathematics puzzles etc.

The selected CD can be webcast on Mukta Vidya Vani and the winner participant be rewarded suitably.

Learners may visit the NIOS website and participate in live programmes from 2pm to 5pm on all week days and from 10.30am to 12.30pm on Saturdays, Sundays and all Public Holidays. The Subject Experts in the Studio will respond to their telephonic queries during this time. A weekly schedule of the programmes for webcast is available on the NIOS website. The Studio telephone number are 0120-4626949 and Toll Free No. 1800-180-2543.

A Letter to Learner

Dear Learner,

Welcome to the revised Biology course of National Institute of Open Schooling (NIOS) based on the common Core Curriculum prescribed by COBSE/ NCERT. Biology is the science of life and the revised course includes both Classical and Modern Biology. The course content begins from Biodiversity classification; Structure and function of the living; their reproduction and development and also Genetics, Molecular Biology, Biotechnology and Immunology which are the modern fields of Biology. An exhaustive treatment of the environment in all its aspects is also contained in the curriculum and so are topics like some common human diseases and health and nutrition which are closely related to human welfare.

The Biology course has three parts. Parts 1 and 2 have theoretical part and Part 3 has laboratory work. The book has 5 Modules broken up into 31 lessons. The modules are:

***Module-I** Diversity and Evolution of Life**, Module-II** Forms and Functions of Plants **and Animals Module-III** Reproduction and Heredity **Module-IV** Environment and Health and Module-**V** Emerging Areas in Biology*

*Please note that now the load on final public examination has been reduced. Out of 31 lessons, 09 lessons have been kept apart for you to study and be assessed through Tutor Marked assignments (TMA) only. These are **Origin and Evolution of Life and Introduction to Classification**, **Cell Structure and Function**, **Root system**, **Respiration in Plants**, **Nutrition and Digestion, Homeostasis: The Steady State**, **Genetics and Society**, **Pollution** and **Some Common Human Diseases** that you work upon throughout the year. The Public examination (PE) or final exam shall have the lessons other than those earmarked for TMA. For self evaluation there are intext questions and terminal exercises. Also a summary, at the end of each lesson and glossary at the end of the book have been provided for ready reference. Kindly submit your work in time and complete the practical at your PCP centres.*

Hope you will enjoy your journey with this "Teacher in print". A course in science is known to lead students into becoming critical thinkers and decision makers and cultivate "scientific attitude and scientific temper".

For any queries feel free to contact us and share your views and comments regarding the book. All help is assured. Our website is www.nios.ac.in

We hope you will enjoy the course and find it interesting.

Wish you all the success,

(Dr. Sanghmitra Suryapani)
Course Coordinator, Biology
E-mail: aobio@nios.ac.in

BIOLOGY IN THE SERVICE OF HUMANITY
INDIA'S CONTRIBUTION TOWARDS BIOLOGY

The study of Biology started with the human curiosity to identify plants and animals. However, as an independent discipline biology has now taken many steps forward with lot of research at the molecular level and has given rise to fields like cell biology, Neurology, Immunology, Biotechnology, Biophysics, Biochemistry, Micro-Biology. sociobiology Earlier, Biology was thought of as a descriptive science but nowadays, it has become an integrated science subject wherein the Biological concepts have their alliance with Chemistry, Physics, Mathematics, Biotechnology and other disciplines of Science.

*History of Biology in India can be traced back to the period of **Charaka** and **Sushruta**. Charak was born around 200 AD. Charak was an "**Ayurvedacharya**" and was in fact a wandering doctor treating patients as walked from place to place and making people aware about medical sciences. His famous book "**Charaka Samhita**" which is a treatise on medicinal properties of herbs.*

***Sushruta** was probably the first surgeon of India. Maharishi Sushruta was not only a very capable surgeon but also an able author. His book **Sushruta Samhita** is well known. He would have his students cultivate surgical skills by using razors on vegetables first and then dead bodies.*

*Among the Indian Biologists**, Sir J. C. Bose** is famous for discovering that plants also have life just like the animals, **Birbal Sahni** who is well known for studies in palaeobotany in India. He established Birbal Sahni Institute of palaeobotany in Lucknow. **Dr. Har Gobind Khorana** became World famous for in-vitro synthesis of first artificial gene; **Dr M. S. Swaminathan** created high-yielding varieties of wheat that became the basis of "Green Revolution" in India; **Dr P. Maheshwari**, Delhi University as the pioneer for studies in plant-development process in vitro; **Dr. S. C. Maheshwari** and **Shipra Guha** at Delhi University obtained first androgenic haploid in test tube culturing anthers of Datura innouxia; **H. D. Kumar and R. N. Singh** from Banaras Hindu University, who discovered that cyanobacteria exhibit genetic recombination through the process of transformation and conjugation; **Sh. Lalji Singh** is famous for his studies on Molecular basis of sex-determination, DNA-finger printing and Wildlife conservation.*

***Salim Ali** has been known as the "**Birdman of India**", and was the first Indian Naturalist to develop all the aspects of Ornithology or the study of birds. **Ram Deo Mishra** is famous as the **Father of Indian Ecology** who worked on nutrient cycling in tropical forest and grassland ecosystems in India and established National Committee for Environment planning and coordination in 1972. **Shiv Ram Kashyap** is famous as **Father of Indian Bryology** and is known for studies on sexual generation of Equisetum; He is also famous for the theory of Retrogressive evolution in Liverworts.*

K.C. Mehta**, basically Plant Pathologist, worked on Blackrust in cereals and proved that the infection of wheat rust, spreads through uredospores from Himalayas in the North and Nilgiri Hills in the South. **A. K. Sharma** is known for studying the physical and chemical nature of* *chromosomes, adopted all over the world for plant, animal and human systems.* ***R P Roy *is known for his work on genomic analysis of the species of Aegilops and for detection of sex determination and genetic system in cucurbit (Coccinea indica).* ***Ganapathi Thanikaimoni*** *is famous as a palynologist who emphasised the role of pollen morphology at the species level along with the morphology of the plant organs, and also established the fact that the mangrove ecosystem played an important role in protecting coastlines from tidal waves (tsunami) and land erosion.*

Ananda Shiv Prasad *is known for discovering the role of zinc in the human metabolism.* ***Autar Singh Paintal*** *is known for pioneering discoveries in the area of neurosciences and respiratory sciences.* ***Mohd. Shamim Jairajpuri*** *is known for his contributions to the field of nematology.*

S. K. Brahamachari *is known for contributions in neurological and psychiatric disorders, and identified the genes associated with schizophrenia and bipolar disorder.****P. Majumder*** *developed statistical methodologies applicable to mapping and transmission of complex human traits, and recognised mitochondrial DNA markers present in linguistic groups in India.* ***A. K. Parida*** *applied frontier technology for solving major challenges in global and national declining agriculture productivity threatened due to climate change, sea level rise and reduced precipitation.*

Vinod Scaria *is known for sequencing the first Indian genome, first Sri Lankan Genome, the first Malaysian Genome and the genome of Wild-type strain of Zebrafish. He has identified human micro-RNA which can target HIV virus.* ***S. P. Agharkar*** *is famous for discovering a new species of jellyfish.* ***S. R. Bose*** *is credited for identifying the antibacterial properties of fungi.*

M. O. P. Iyengar *is an algae specialist who studied researched the structure, cytology, reproduction and taxonomy of Algae and is known as the "****Father of Indian phycology****" or "****Father of algology****".*

Thus, Indian Biologists have been pursuing research in the multifarious branches of Biology and we are proud of them. We hope that one day some of you learners will be well known biologists. Knowledge of Biology opens many avenues which you may select as a career. Once you are initiated into Biology and wish to pursue a course related to biology you have the following options:

- *Teacher, Environmentalist, Research Scientist, Marine Scientist,*
- *Medicine paramedical Sciences such as physiotherapy, Forensic scientist*
- *Pharmacy, Food technology, Nursing, Biotechnology,*
- *Microbiology, Bio-Chemistry and Bio-physics,*
- *Professionals in the field of Intellectual Property Rights for biologists looking after sanctuaries, zoos and Botanical gardens.*

Awards Won by NIOS

Several projects have been implemented by the NIOS to tap the potential of Information and Communication Technology (ICT) for promoting of Open and Distance Learning (ODL) system. The Ni-On project of NIOS won the National Award for e-governance and Department of Information and Technology, Govt. of India. In further recognition of its On-line initiatives and best ICT practices, the NIOS received the following awards:

NIOS WINS National Award for e-Governance 2008-09

Silver icon for Excellence in Government Process Re-engineering, Instituted by Government of India Department of Administrative Reforms and Public Grievances & Department of Information Technology.

NIOS receives NCPEDP MPHASIS Universal Design Awards 2012

National Institute of Open Schooling (NIOS) has been awarded THE NCPEDP - MPHASIS UNIVERSAL DESIGN AWARDS 2012 instituted by National Centre for Promotion of Employment for Disabled People. The award was given by **Sh. Mukul Wasnik, Hon'ble Minister for Social Justice and Empowerment, Govt. of India** on 14th August, 2012. NIOS has been selected for its remarkable work done for the learners with disabilities through ICT by making its web portal www.nios.ac.in completely accessible for such learners.

The Manthan Award South Asia & Asia Pacific 2012

The Manthan Award South Asia & Asia Pacific 2012 to recognize the best ICT practices in e-Content and Creativity instituted by Digital Empowerment Foundation in partnership with World Summit Award, Department of Information Technology, Govt. of India, and various other stakeholders like civil society members, media and other similar organisations engaged in promoting digital content inclusiveness in the whole of South Asian & Asia Pacific nation states for development. The award was conferred during **9th Manthan Award Gala South Asia & Asia Pacific 2012 at India Habitat Centre on 1st Dec. 2012.**

How to use the Study Material

Your learning material has been developed by a team of Biology experts in open and distance learning. A consistent format has been developed for self-study. The following points will give you an idea on how to make best use of the print material.

Title is an advance organisor and conveys an idea about the contents of the lesson. Reflect on it.

Introduction highlights the contents of the lesson and correlates it with your prior knowledge as well as the natural phenomena in operation in our immediate environment. Read it thoroughly.

Objectives relate the contents to your desired achievements after you have learnt the lesson. Remember these.

Content of the lesson has been divided into sections and sub-sections depending on thematic unity of concepts. Read the text carefully and make notes on the side margin of the page. After completing each section, answer intext questions and solve numerical problems yourself. This will give you an opportunity to check your understanding. You should continue reading a section till such time that you gain mastery over it.

At some places you will find some text in **italics and bold**. This indicates that it is important. You must learn them.

Solved Examples will help you to understand the concepts and fix your ideas. In fact, problem solving is an integral part of training in Biology. Do them yourself and note the main concept being taught through a particular example.

Activities are simple experiments which you can perform at your home or work place using readily available (low cost) materials. These will help you to understand Biology by doing. Do them yourself and correlate your findings with your observations.

Intext questions are based on the concepts discussed in every section. Answer these questions yourself in the space given below the question and then check your answers with the model answers given at the end of the lesson. This will help you to judge your progress. If you are not satisfied with the quality and authenticity of your answers, turn the pages back and study the section again.

What have you learnt is essentially summary of the learning points for quick recapitulation. You may like to add more points in this list.

Terminal exercises in the form of short, long and numerical question will help you to develop a perspective of the subject, if you answer these meticulously. Discuss your responses with your peers or counsellors.

Answers to intext questions : These will help you to know how correctly you have answered the intext questions.

Audio: For understanding difficult or abstract concepts, audio programmes are available on certain content areas. You may listen to these on FM Gyanvani or may buy the CDs from Priced Publication Unit, NIOS

Video: Video programmes on certain elements related to your subject have been made to clarify certain concepts. You may watch these at your study center or may purchase these CDs from Priced Publication Unit, NIOS.

www These are few selected websites that you can access for extended learning.

Studying at a distance requires self-motivation, self-discipline and self-regulation. Therefore you must develop regular study habit. Drawing a daily schedule will help you in this endeavour. You should earmark a well-ventilated and well-lighted space in your home for your study.

SENIOR SECONDARY BIOLOGY COURSE
Overview of the Learning Material

Module	Lesson No.	Name of the Lesson	Mode of Assessment TMA/PE	
Module-I Diversity and Evolution of Life	01	Origin and Evolution of Life and Introduction to Classification	TMA	
	02	The Kingdom Monera, Protoctista and Fungi		PE
	03	Kingdom Plantae and Animalia		PE
	04	Cell Structure and Function	TMA	
	05	Tissues and other Level of Organization		PE
Module-II Forms and Functions of Plants and Animals	06	Root system	TMA	
	07	Shoot system		PE
	08	Absorption, Transport and Water Loss in Plants		PE
	09	Nutrition in plants - Mineral Nutrition		PE
	10	Nitrogen Metabolism		PE
	11	Photosynthesis		PE
	12	Respiration in Plants	TMA	
	13	Nutrition and Digestion	TMA	
	14	Respiration and Elimination of Nitrogenous Wastes		PE
	15	Circulation of Body Fluids		PE
	16	Locomotion and Movement		PE
	17	Coordination and Control - The Nervous and Endocrine Systems		PE
	18	Homeostasis: The Steady State	TMA	
Module-III Reproduction and Heredity	19	Reproduction in Plants		PE
	20	Growth and Development in Plants		PE
	21	Reproduction and Population Control		PE
	22	Principles of Genetics		PE
	23	Molecular Inheritance and Gene Expression		PE
	24	Genetics and Society	TMA	
Module- IV Environment and Health	25	Principles of Ecology		PE
	26	Conservation and Use of Natural Resources		PE
	27	Pollution	TMA	
	28	Nutrition and Health		PE
	29	Some Common Human Diseases	TMA	
Module- V Emerging Areas in Biology	30	Biotechnology		PE
	31	Immunobiology: An Introduction		PE

Total Lessons = 31
Lessons for Public Examination (PE) = 22
Lessons for Tutor Marked Assignment (TMA) = 09

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		Page No.	Mode of Assessment TMA/PE	
Module-I: Diversity and Evolution of Life				
01	Origin and Evolution of Life and Introduction to Classification	1	TMA	
02	The Kingdom Monera, Protoctista and Fungi	29		PE
03	Kingdom Plantae and Animalia	49		PE
04	Cell Structure and Function	79	TMA	
05	Tissues and other Level of Organization	117		PE
Module-II : Forms and Functions of Plants and Animals				
06	Root system	137	TMA	
07	Shoot system	156		PE
08	Absorption, Transport and Water Loss in Plants	196		PE
09	Nutrition in plants - Mineral Nutrition	217		PE
10	Nitrogen Metabolism	330		PE
11	Photosynthesis	242		PE
12	Respiration in Plants	262	TMA	
13	Nutrition and Digestion	283	TMA	
14	Respiration and Elimination of Nitrogenous Wastes	304		PE
15	Circulation of Body Fluids	332		PE
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MODULE - I
DIVERSITY AND EVOLUTION OF LIFE

01 Origin and Evolution of Life and Introduction to Classification

02 The Kingdom Monera, Protoctista and Fungi

03 Kingdom Plantae and Animalia

04 Cell Structure and Function

05 Tissues and other Level of Organization

1

ORIGIN AND EVOLUTION OF LIFE AND INTRODUCTION TO CLASSIFICATION

The planet earth came into existence sometime between 4 and 5 billion years ago. Life evolved on planet earth about 3.5 billion years ago. Since then, approximately 15 million different species of organisms have evolved. But only about two million have been identified so far. In this lesson we will learn how life of these, at first originated on earth and how such a vast variety of organisms, popularly known as biodiversity, evolved through variation and natural selection.

The study of such a wide variety of organisms becomes convenient only when they are grouped according to similarities and differences, named, and their evolutionary relationships established. We will also learn about the importance and method of classification of organisms in this lesson and understand the position of viruses and viroids vis-a-vis the web of the living world.

OBJECTIVES

After completing this lesson, you will be able to :

- *describe the widely accepted 'theory of origin of life';*
- *explain what is organic evolution;*
- *give morphological, palaeontological, embryological and molecular evidences in favour of organic evolution;*
- *state modern theory of evolution;*
- *explain the sources of organic variations (gene and chromosomal mutations, recombination, gene flow and genetic drift);*
- *explain natural selection with examples;*
- *explain the role of isolation in evolution;*
- *list the various isolating mechanisms;*
- *explain speciation;*
- *understand Hardy–Weinberg Equilibrium to relate genetics and evolution.*
- *define classification;*

- *justify the need for classification of organisms;*
- *list the bases of classification;*
- *trace the changes in bases of classification from morphotaxonomy to systematics.*
- *State the position of virus and differentiate between virus and viroids.*

1.1 ORIGIN OF LIFE

The earth was formed about five billion years ago. At that time it was extremely hot. The existence of life in any form at that high temperature was not possible. As such, two questions arise pertaining to life:

1. How did life originate on earth?
2. How did primitive organisms evolve into new forms resulting in the evolution of a variety of organisms on earth.

> **Origin of life** means the appearance of simplest primordial life from non-living matter.
>
> **Evolution of life** means the gradual formation of complex organisms from simpler ones.

1.1.1 Chemosynthetic Theory of Origin of Life

Several theories have been put forth to explain the origin of life. The widely accepted theory is the Chemosynthetic theory of origin of life, proposed by A.I. Oparin. Other theories such as the theory of Spontaneous Generation are of historical importance only.

> **Chemosynthetic Theory**
>
> Life might have originated at first on earth through a series of combinations of chemical substances in the distant past and it all happened in water.

- The earth originated about 5 billion years ago.
- It was initially made up of hot gases and vapours of various chemicals.
- Gradually it cooled down and a solid crust was formed.
- The early atmosphere contained ammonia (NH_3), water vapour (H_2O), hydrogen (H_2), methane (CH_4). At that time there was no free oxygen. This sort of atmosphere (with methane, ammonia and hydrogen) is still found on Jupiter and Saturn (Fig. 1.1).
- Heavy rains fell on the hot surface of earth, and over a very very long period the water bodies appeared that still contained hot water.
- Methane and ammonia from the atmosphere dissolved in the water of the seas.
- In this water, chemical reactions occurred and gave rise to amino acids, nitrogenous bases, sugars and fatty acids which further reacted and combined to give rise to biomolecules of life such as proteins and nucleic acids.

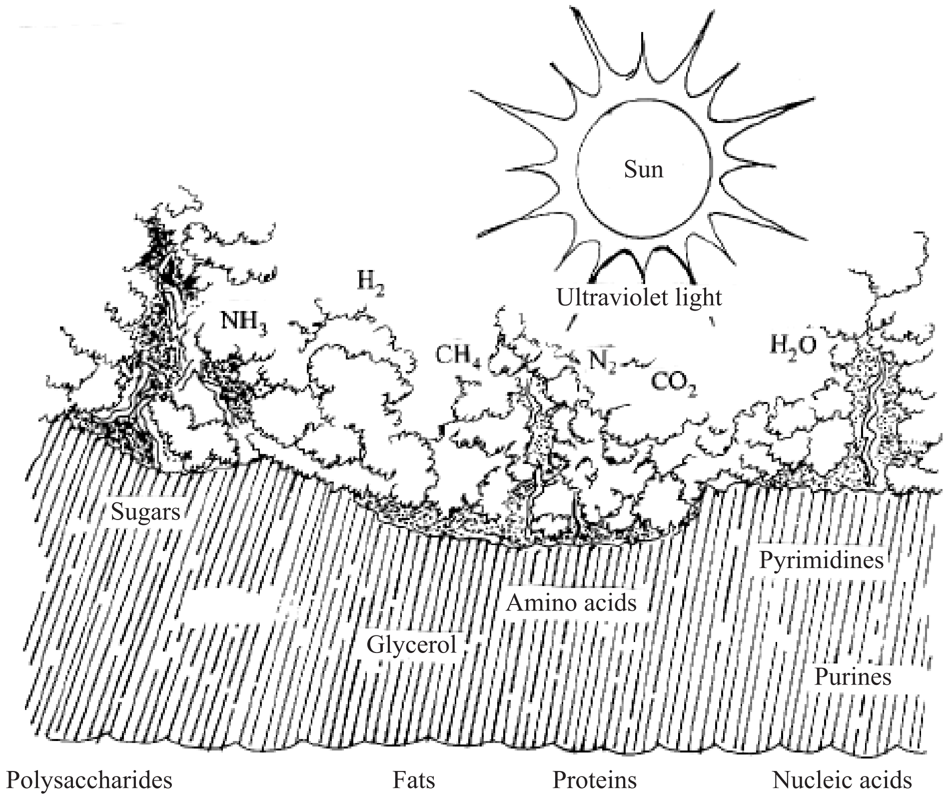


Fig. 1.1 Primitive conditions on earth

1.1.2 Probable stages in the origin of life

First stage

The sources of energy were the ultraviolet rays or electric discharge (lightening) or heat. Either alone or a combination of these energy sources caused reactions that produced complex organic compounds (including amino acids) from a mixture of ammonia (NH_3), methane (CH_4), water (H_2O) and hydrogen (H_2). The amino acids are the building blocks of proteins which are the main components of protoplasm.

Stanley Miller and Harold C. Urey in 1953 set up an experiment with an air-tight apparatus (Fig. 1.2) in which four gases (NH_4, CH_4, H_2 and H_2O) were subjected to an electric discharge for one week. On analyzing the liquid, they found a variety of organic substances in it, such as amino acids, urea, acetic acid, and lactic acid (Fig. 1.2).

Second Stage

Simple organic molecules combined to form large molecules which included peptides (leading to the formation of proteins), sugars, starch and fat molecules.

Third stage

The large molecules of different kinds combined together to form multi-molecular heaps or complexes. Some simple fat molecules arranged themselves around this molecular complex in a sort of membrane. It was observed in the laboratory experiments that when such complexes reached a certain size they separated from the surrounding solution in the form of what were termed "**coacervate drops**" of microscopic size, moving in the liquid with a definite boundary (**coacervate means "heap"** referring to the combining together of the molecules).

Coacervate like aggregates were probably the precursors of the first living cells.

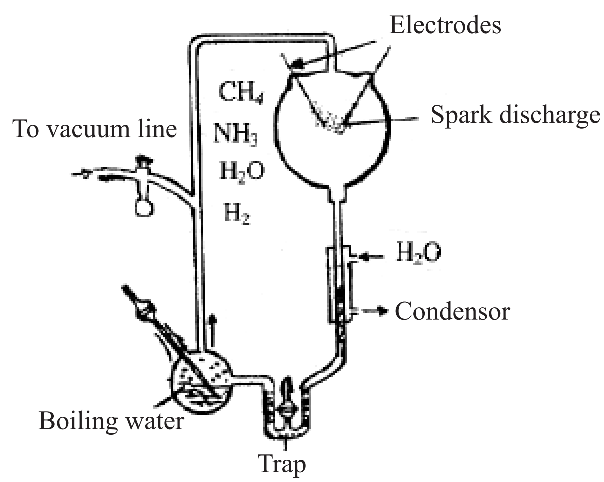


Fig.1.2 The apparatus used by Stanley Miller and Harold C. Urey to demonstrate the synthesis of amino acids under conditions that existed on the primitive earth

Now, some sort of "metabolism" could occur within these coacervates with synthesis of certain substances and breakdown of others. The latter (i.e. breakdown reactions) could provide energy.

Some of the earliest formed proteins might have acted like enzymes and would have affected the rates of reactions. It is also believed that RNA molecules might have shown enzymatic activity in the "primordial soup" of chemical compounds. Such molecules have been termed **ribozymes.**

Fourth stage

Some sort of nucleoproteins or nucleic acids may have evolved by random combinations which have provided two more properties to coacervate–like bodies. These include :

(i) chemical reactions from the nucleic acids, and

(ii) the capacity to reproduce through duplication of the nucleic acids (Fig. 1.3).

Thus, cells were produced that could be called the simplest primordial life. Figure 1.3 depicts the probable stages of origin and evolution of living beings.

The primitive "drop"–like forms of life were all heterotrophs, unable to manufacture their own food but derived it from environment.

One of the innumerable changes in genetic make up of the primitive heterotrophs led to the formation of chlorophyll (green colouring matter of the leaves) molecules.

– The chlorophyll–bearing units of life for the first time started using solar energy for production of food as well as for the first time started liberating free oxygen into the atmosphere.

> Early atmosphere of earth had no free oxygen, the forms until then could at best be only "anaerobic". Chlorophyll–bearing organisms later released free oxygen which gave greater possibilities for life to evolve.

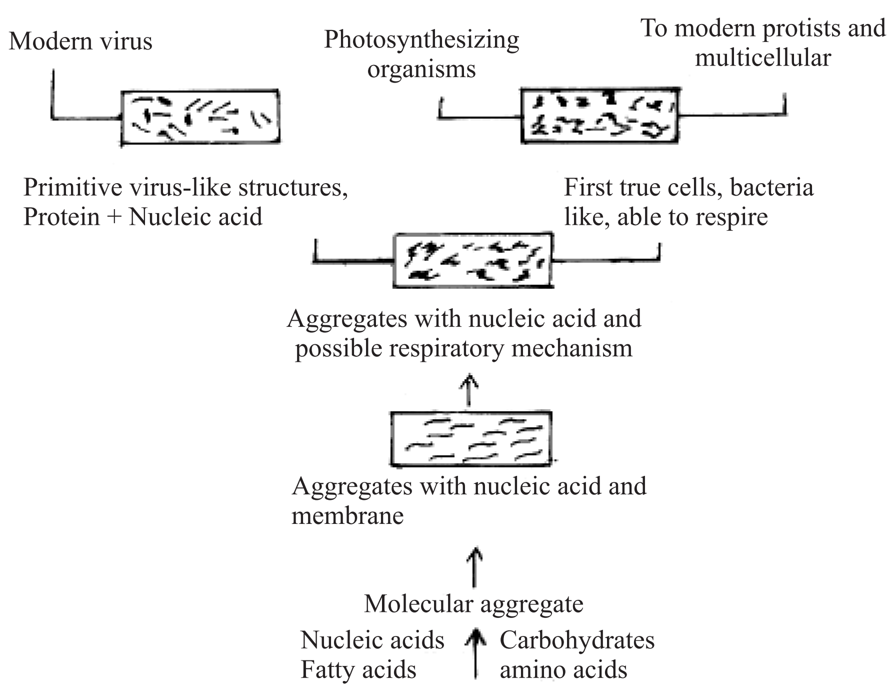


Fig. 1.3 Steps of the events which led to the origin of life

Thus, the simplest form of life originated through four main stages. Thereafter, a wide variety of organisms came into existence through **biological evolution**.

INTEXT QUESTIONS 1.1

1. Approximately how many years ago was the earth formed?

   ....

2. Who gave the Chemosynthetic Theory for origin of life?

   ....

3. Name the four gases present in the primitive atmosphere of the earth.

   ....

4. Name one source of energy which was used for chemical combination in primitive atmosphere.

   ....

5. Where did life originate in water or on land?

   ....

6. What are 'coacervates'?

   ....

7. In the origin of life, first large molecules were formed from inorganic compounds. Name any two such large molecules.

   ....

8. Name the two scientists who experimentally tried to verify Oparin's hypothesis.

   ....

1.2 ORGANIC EVOLUTION

1.2.1 What is Evolution ?

The formation of complex organisms through 'gradual change' from simple ancestral types over the course of geological time is termed Evolution or Organic Evolution.

According to the Theory of Organic Evolution

- The various present day organisms were not created in the same form in which they exist today, but have gradually evolved from much simple ancestral forms from a common ancestor.
- The characteristics of organisms had been changing in the past; they are changing even today, and will continue to do so in the future as well. This is due to the fact that the environment in which organisms live also changes and organisms need to adapt to the changed environment in order to survive.
- Several living organisms of the past have become extinct.
- The origin of the various forms (species) found on earth has been a gradual and extremely slow process, requiring hundreds or even thousands of years. However, the evolution of black peppered moth or polyploid varieties of some crops or pesticide resistant mosquitoes happened in much shorter periods of time.

This process of slow and gradual change is called Organic Evolution.

> The theory of organic evolution states that "All living things on earth are here as a result of descent, with modifications from a common ancestor".

1.2.2 Evidences of organic evolution

The evidences supporting organic evolution are derived from a number of fields of Biology. Those discussed here are :

1. Morphological evidences
2. Embryological evidences
3. Palaeontological evidences
4. Molecular evidences

1. Evidences from Morphology

Though organisms of different species and groups are quite different from each other, they still retain certain common features. Morphological evidences for evolution are derived from -

(i) Homologous and analogous organs (Fig. 1.4 and Fig. 1.5)

(ii) Vestigial organs

(iii) Connecting links

The comparative study of various organs in different groups of vertebrates exhibit common features which show that they evolved from a common ancestor. Take for example the heart of the vertebrates (Fig. 1.4).

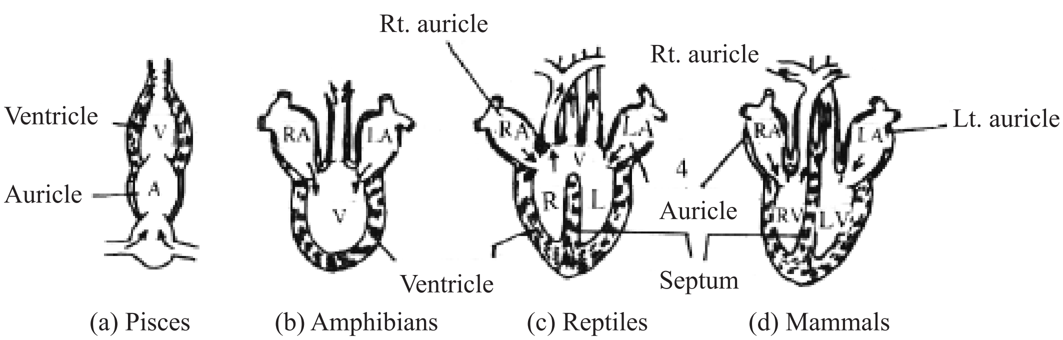


Fig. 1.4 Comparative study of heart of different groups of vertebrates

(ii) Homologous Organs

Homologous organs are the organs which are similar in structure and origin but may look very different and perform different functions.

– Forelimbs of vertebrates are a good example of homologous organs. They are built on the same fundamental plan yet they appear different and perform different functions (Fig. 1.5).

– In each case the forelimb consists of humerus, radius and ulna, carpals, metacarpals and phalanges. This basic similarity in the structure of the apparently different forelimbs of different kinds of vertebrates is due to the fact that all these limbs have evolved from a common type called the **pentadactyl** (five-fingered) limb.

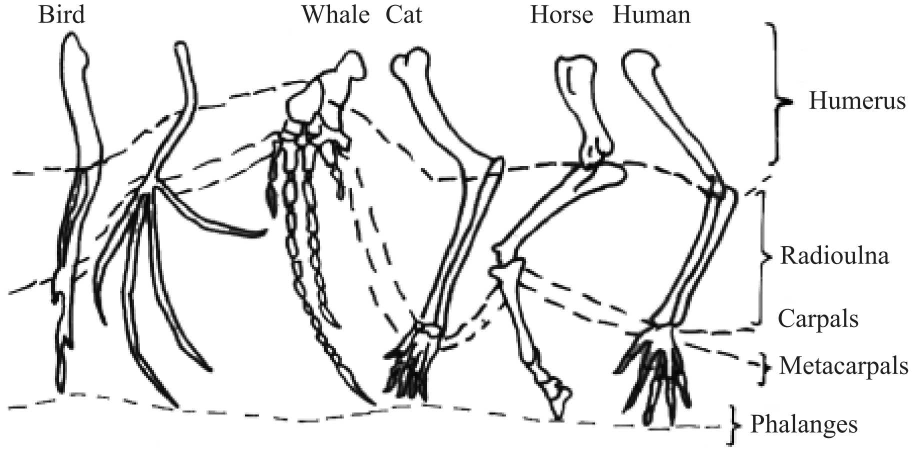


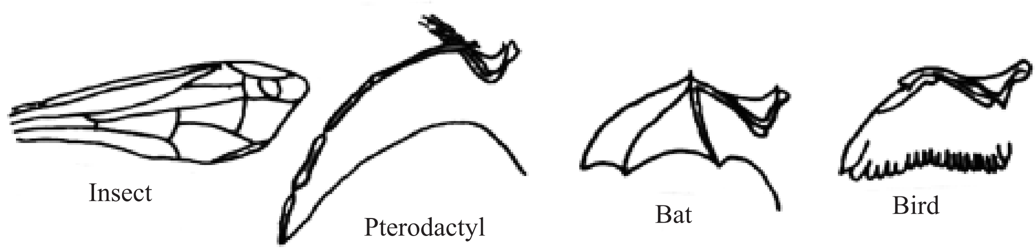
Fig. 1.5 Homology and adaptation in bones of the forelimbs of some vertebrates

The homologous organs, therefore, prove that different kinds of organisms came into existence through evolution.

Analogous organs

The structures which are functionally similar but structurally different are called analogous organs.

The wing of an insect, and that of a bird or bat or pterodactyl are examples of analogous organs (Fig. 1.6). The function of the wing is the same (for flying) but the insect wing has no structural resemblance with that of the vertebrates.



(a) Wing of insect (b) Wing of bird

Fig. 1.6 Analogy between wings of insects and of different vertebrates

(iii) Vestigial Organs

Vestigial organ is any small degenerate or imperfectly developed (non-functional) organ or part which may have been complete and functional in some ancestor.

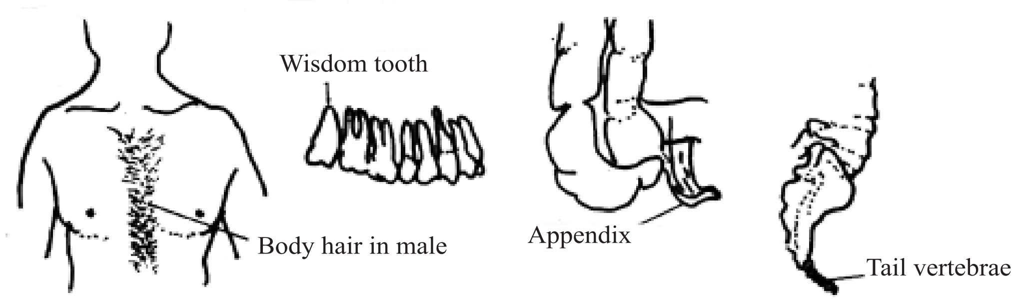


Fig. 1.7 Some vestigial organs in human body

The only rational explanation for the presence of these non-functional organs is that they have been inherited from ancestors in which they were functional. Fig. 1.7 shows some of the vestigial structures in the human body.

(iv) Connecting Links

The animals or plants which possess characters of two different groups of organisms are known as connecting links. The **connecting links** establish continuity in the series of organisms by proving that one group has evolved from the other. A good example is that of a fossil bird *Archaeopteryx*, which was a connecting link between reptiles and birds. This bird had a beak with teeth and a long tail (with bones) like the lizards. It had feathers on the wings and on the body like the birds. (Fig. 1.8).

Fig. 1.8 An extinct bird - *Archeopteryx*

2. Evidences from Embryology

Embryology is the study of development of an organism

The aspects of embryology which support the doctrine of organic evolution are :

- similar stages of early development (morula, blastula or gastrula) in all the animals;
- the embryos of all vertebrates are similar in shape and structure in their early stages.

This resemblance is so close that it is difficult to tell them apart (Fig. 1.9).

- All the vertebrates start their life from a single cell, the zygote.
- All of them during their life history, pass through two-layered blastula and three layered gastrula stage and then through fish like stage with gill-slits.

All the different aspects of embryology strongly support the fact that the different classes of vertebrates had common ancestors.

3. Evidences from Paleontology

Paleontology is the study of **fossils**. Fossils are the remains or traces of animal and plant life of the past, found embedded in rock either as petrified hard parts or as moulds, casts or tracks.

The fossils of the earliest era in the geological time scale were those of bacteria, then invertebrates and then successively of fishes, amphibians, reptiles and lastly of birds and mammals and among mammals primitive fossils of humans are the most recent.

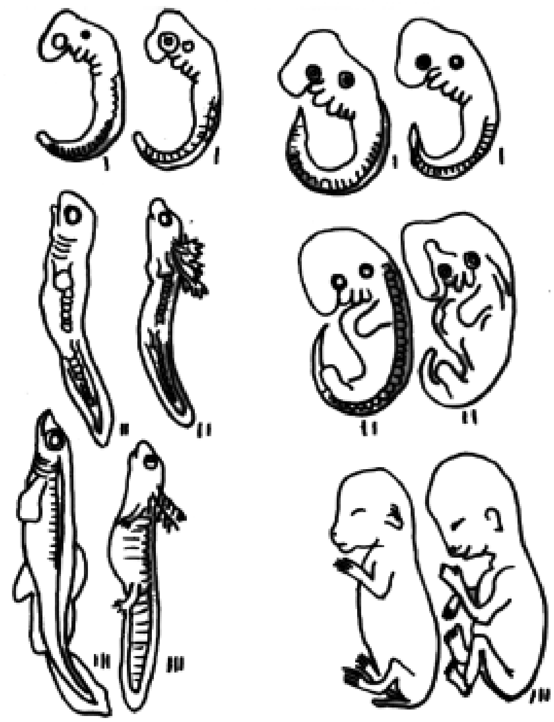


Fig. 1.9 Series of vertebrate embryos in comparable stages of their development a-Fish, b-Chick, c-Man

The discovered fossils of the horse, elephant, camels, and humans provide their ancestral history (Fig. 1.10). The number of toes decreased for greater speed, size gradually increased and teeth adapted to eat grass.

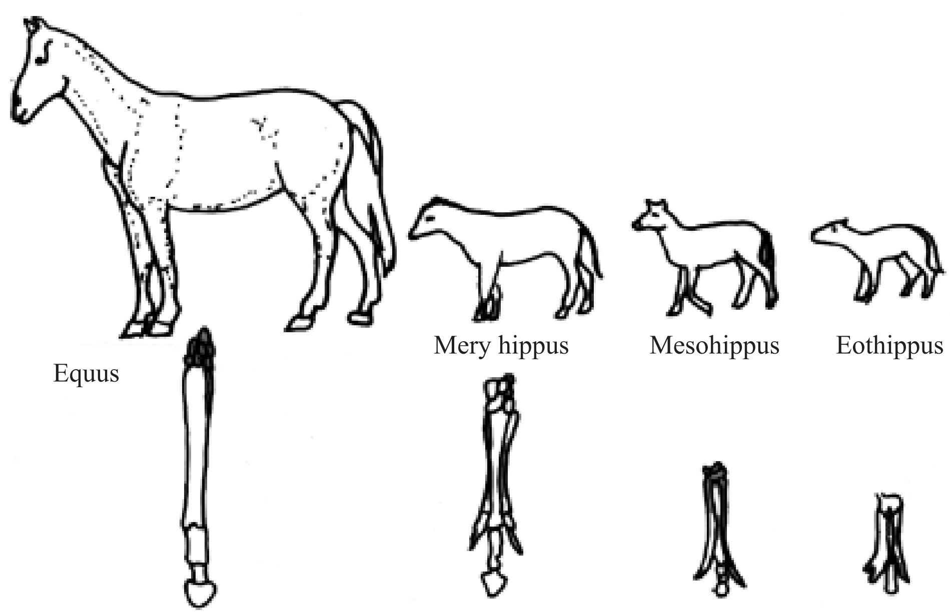


Fig. 1.10 Fossil record of bone of hind legs of horses from *Eohippus* to *Equus* showing decrease in the number of toes

4. Molecular Evidence of Evolution

- All organisms have cell as the basic unit of life. The cell is made of **biomolecules** common to all organisms.
- Ribosomes, the cellular organelles are of universal occurrence in organisms.
- DNA is the hereditary material of all organisms, except for some viruses.
- ATP is the molecule which stores and releases energy for biological processes.
- The same 22 amino acids form the constituents of proteins of almost all organisms.
- The genetic code is universal (exceptions are very few).
- The central dogma which deals with the transfer of genetic information in cells is the same.
- The basic steps of transcription and translation for protein synthesis are similar in all organisms.
- The sequence of nucleotides such as that for the promoter gene (TATA box) is common to all organisms.

However, organisms sharing same chemical characteristics show closer evolutionary relationships. For example (i) human blood proteins are most similar to those of the chimpanzee among all apes, or (ii) only plants and some algae have chlorophyll so they are more closely related. Similarity in chemical constituents between organisms is termed **molecular homology** or **biochemical homology** and are used in recent times, to establish evolutionary relationships and form the basis of systematics.

INTEXT QUESTIONS 1.2

1. Define organic evolution.

   ....

2. Name one fossil animal which forms a connecting link between reptiles and aves.

   ....

3. Which organ of man is homologous to the wings of birds?.

   ....

4. Define vestigial organ.

   ....

5. Give one example of a connecting link among the living beings.

   ....

6. Give two examples from molecular biology which support organic evolution.

   ....

1.2.3 Mechanism of Evolution

Various theories about the mechanism of evolution have been proposed; some of them such as Lamarck's theory of "Inheritance of acquired characters" and De Vries' theory of 'mutation' are now of historical importance only.

Darwin's theory of Natural selection still holds ground but was modified with progress in genetics and developed into the **Modern synthetic theory** which is regarded as the most valid theory of evolution.

Darwin's Theory of Natural Selection

An English Scientist, Charles Darwin (1809-1882) explained the mechanism of evolution through his theory of natural selection. He is still regarded as 'the father of evolution' because of two very significant contributions. He suggested (i) that all kind of organisms are related through ancestry and (ii) he suggested a mechanism for evolution and named it **natural selection.**

According to Darwin, organisms produce more offspring than can survive. Because environmental resources are limited there ensues struggle for existence. Organisms with advantageous variations are protected and allowed to reproduce while the disadvantageous variants are eliminated from nature. This is what was termed **natural selection** by Darwin.

According to Darwin when the environment changes, new adaptations get selected in nature and after many generations sufficient characteristics will have been changed so as to alter the species into a new one (origin of species).

Darwin talked about variation but did not know about the sources of variation. With progress in genetics the sources of variation were discovered and Darwin's original theory of Natural Selection modified. This new theory was termed **Neo-Darwinism** or **Modern Synthetic Theory**.

According to this theory :

1. The unit of evolution is 'population' which has its own gene pool. Gene pool is the group of all different genes of a population.
2. Heritable genetic changes appear in the individuals of a population.
   These heritable changes or variations occur due to small mutations in the genes or in the chromosomes and their recombinations.
3. Natural selection selects the variations which helps in adapting to the environment.
4. A change in the genetic constitution of a population selected by natural selection is responsible for evolution of a new species, since through interaction of variation and **Natural Selection** more offsprings with favourable genetic changes are born. This is called 'differential reproduction'.
5. Once evolved, **Reproductive Isolation** helps in keeping species distinct.

INTEXT QUESTIONS 1.3

1. Who gave the theory of natural selection?

   ....

2. What is the modern interpretation of Darwin's theory of evolution called?

   ....

3. What are the two major contributions of Charles Darwin regarding evolution?

   ....

4. Give two main features of Neo-Darwinism.

   (i) ....

   (ii) ....

5. What do you mean by "differential reproduction"?

   ....

1.2.4 Elemental Forces of Organic Evolution

Evolution is caused by action of forces on **Natural Selection** of **Variation**. Reproductive Isolation keeps the species distinct therefore the elemental forces of Organic Evolution are: (i) Variation (ii) Natural Selection (iii) Isolation.

(i) Sources of organic variation

Variation arises in an individual member of a population, and if favourable, spreads into the population through "differential reproduction" by the action of natural selection. Variations may occur by

1. **Mutation,** which is a sudden genetic change. It may be a change in a single gene (genic mutation or point mutation) or may affect many genes (chromosomal mutation).

2. **Genetic recombination**, which occurs in sexually reproducing organisms at every reproduction. The chromosomes and thus genes of the parents mix at random during zygote formation. That is why offspring of same parents are different from each other as they have different combinations of parental genes. Variation is also brought about when crossing over occurs during gamete formation.

3. **Gene flow** is when there is chance mixing of genes of closely related species through sexual reproduction.

4. **Genetic drift** occurs in small populations when a part breaks off from a large population. Only representative genes of the large population are present which undergo change at a right time and the small population may evolve into a new subspecies or species.

(ii) Natural Selection

Natural selection considered to be responsible for "differential reproduction of genes" which means that more of favourable genes get reproduced in a population.

Many examples of natural selection in action are available now. Given below are three such examples.

Example 1 : DDT resistant mosquitoes

About 50 years back, the mosquito population had been kept in control with the help of DDT. Thereafter, it was found that mosquitoes could not be killed with DDT any longer. There appeared DDT-resistant mosquitoes. What had happened was that a **gene mutation** (variation) had conferred (given) on the mosquito, the ability to resist the effect of DDT. While DDT killed other mosquitoes, those with the gene mutation survived and slowly within a few generations DDT resistant mosquitoes replaced the DDT-sensitive ones. In other words, the DDT resistant mosquitoes 'reproduced differentially' by the action of natural selection.

Example 2 : Metal tolerance in grasses

Certain metal residues sometimes collect in the soil near some industries using heavy metals. Being poisonous they kill the grasses. However, resistant grasses are found to evolve after some time through the action of genetic variation and natural selection.

From the above example, can you explain the evolution of the heavy metal-tolerant grasses?

Example 3 : Industrial melanism

A commonly quoted example of natural selection in action is that of the peppered moth, *Biston betularia*. The moth with its light coloured wings dotted with spots blended well with the lichens growing on the houses and trees on which it rested. Once in a while if a mutated form of the moth which was black in colour appeared, it was eaten up by birds as it was conspicuous because of its black wings. This was observed in the British Isles before the industrial revolution. After the industrial revolution, the genes for black wings proved favourable on the soot covered lichens growing on the walls of houses. Natural selection acted through the agency of the birds which now ate up the conspicuous light coloured winged peppered moth. These were therefore, soon replaced by the black variety (Fig. 1.10).

There are several such examples in which human activities have changed the environment and natural selection has been observed to play its role. But it is an established fact now that all of biodiversity over these millions of years have also evolved through the interaction of variation and natural selection.

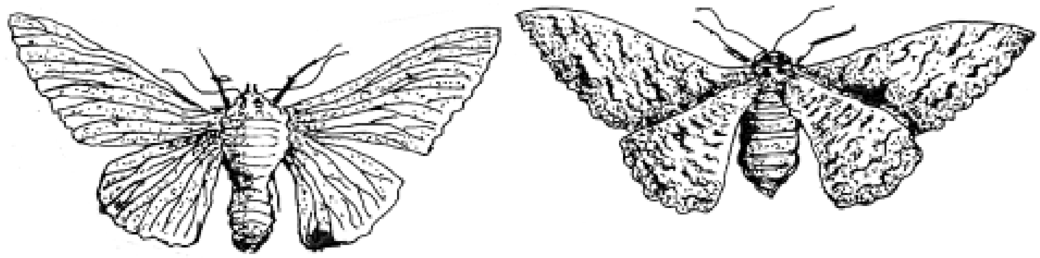


Fig. 1.11 Light and dark forms of *Biston betularia*

(iii) Role of Reproductive Isolation

Once new species arise from the parental species due to the effect of variation and natural selection, reproductive barriers prevent the two species from exchanging genes through reproduction.

Thus two related species cannot mate with each other and remain distinct. Isolation means separation and reproductive isolation simply means that the two species are prevented from successful reproduction and kept genetically distinct from each other. Reproductive isolation operates in the following ways:

Ecological isolation	:	The two species are unable to mate as they live in geographically different areas.
Seasonal isolation	:	Mating is prevented because the reproductive organs mature at different times.
Ethological (Behavioural) isolation	:	The songs in birds of two species or the colouration of two fishes are so different that female of one species is able to recognise only the male of its own species.
Mechanical isolation	:	The male and female organs for mating differ in different species and prevent their union.
Physiological isolation	:	The sperms of one species are not able to survive in the female tract of another species.
Zygotic and developmental Isolation	:	If all the above mechanisms fail and a "hybrid zygote" (zygote from mating of two different species) is formed, it dies after some time. If the hybrid zygote survives it dies during development.

Hybrid sterility	:	Mule, the offspring of a female horse and male donkey is a good example. It leads a normal life but is sterile and cannot reproduce.
F_2 breakdown	:	In rare cases, all the above mechanisms fail and a hybrid (offspring of parents belonging to different species) is fertile, it can reproduce only for one generation.

1.2.4 Speciation

The evolution of new species is termed **speciation.** Speciation occurs in the following ways and is termed accordingly.

Allopatric speciation takes place when a part of the population becomes geographically separated (geographical isolation) from the parental population. For example a group of birds lives at the base of the mountain, some members fly up and get geographically isolated. Variation and natural selection act differently on the two because the environment in which the two live is different. Gradually genetic changes render them to be reproductively isolated.

Sympatric speciation

Sometimes a genetic barrier (reproductive barrier) prevents reproduction between a section of a population of a species with other members. Such a section of population usually arises in plants because of polyploidy. **Polyploidy** is a mutation in which the normal diploid number of chromosomes become doubled or trebled (2n becomes 3n, 4n, 5n etc) in a section of the population of a species due to certain irregularities during cell division. The polyploid section of the population is then unable to interbreed (mate and reproduce) with their diploid ancestors and becomes a new species.

Models of speciation

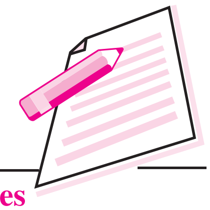
There are two accepted models of speciation that have given rise to the biodiversity

1. Phyletic Gradualism model

Two species from common ancestor gradually become more and more structurally different acquiring adaptations unique to each other (Fig. 1.12a). Darwin also believed that evolution is a slow and gradual process.

2. Punctuated equilibrium

A new species arises through major changes in the beginning and then remain constant for long periods before changing again. (Fig. 1.12b). This model was suggested by palaeontologists (scientists who study fossils), Niles Eldredge and Stephen Jay Gould.



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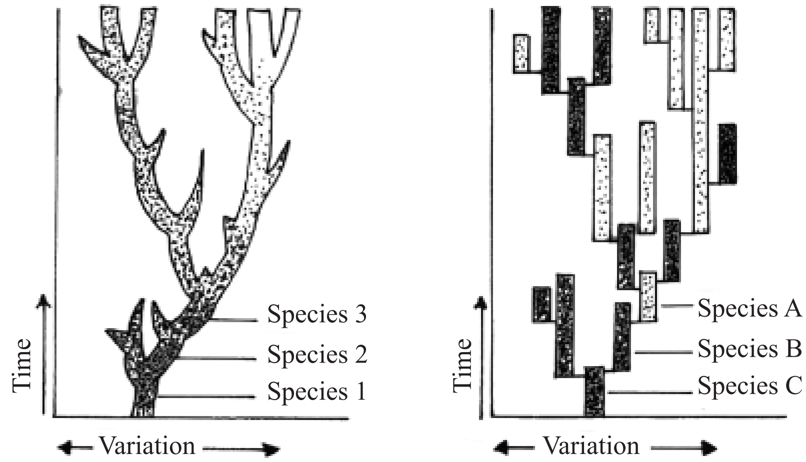


Fig. 1.12 Models of speciation (a) Phyletic gradualism, (b) Punctuated equilibrium

1.2.5 Hardy-Weinberg Equilibrium

This is a concept related to both genetics and evolution and was proposed by G. H. Hardy and W. Weinberg.

A population of sexually reproducing organisms in which genes combine at random due to random mating is called **panmictic**. In other words, a panmictic population is one in which mating partners are not specifically selected. For example, we humans usually do not look for specific blood group when a marriage is arranged so we are panmictic with respect to blood types.

The Hardy Weinberg Principle states that in a panmictic population if there is no pressure of mutation, selection, genetic drift etc. then the relative frequency of any pair of genes remains constant, generation after generation. For example, a gene has two alleles, p and q in the population and no mutation or selection etc. takes place, then the frequency of these two alleles will remain constant generation after generation. This can be mathematically represented as:

$$(p+q)^2 = 1 \text{ or } p^2 + 2pq + q^2 = 1$$

INTEXT QUESTIONS 1.3

1. List the sources of organic variation.

   ....

2. What is 'industrial melanism' about? Answer in one or two sentences.

   ....

3. State one point of difference between (a) allopatric & sympatric speciation (b) Ecological and Ethological Isolation

   ....

4. What is a panmictic population?

   ....

5. According to Hardy Weinberg Principle, $(p + q)^2 = 1$. Explain this mathematical expression.

....

1.3 CLASSIFICATION

1.3.1 Meaning of Classification

Classification means identifying similarities and differences between different kinds of organisms and then placing similar organisms in one group and different kinds of organisms in different groups.

Taxonomy, may thus be defined as the science of classification of organisms into categories, maintaining certain rules. Early taxonomists classified organisms according to **morphological features** only. Once the concept of organic evolution was accepted, taxonomists began to draw evolutionary relationships between different kinds of organisms. This was termed **systematics.** Today taxonomy and systematics are treated as synonymous, since for classification, both morphological and biochemical resemblances and even those between molecules such as DNA and RNA are studied to establish evolutionary relationships.

1.3.2 Taxonomic categories

While classifying an organism, it is assigned to categories which show its evolutionary relationship with other groups of organisms. Each level or category is termed **taxon** (plural-taxa). The lowermost category of classification or taxon is **species**. Other categories are arranged above the species so that there is a hierarchy of categories. The various taxonomic categories are given below :

Species : Group of individuals of one kind which can interbreed to produce fertile offsprings.

Genus : Group of species resembling each other in several features indicating common ancestry.

Family : Group of genera (singular-genus) resembling each other. e.g. *Felis domestica* (the cat) and *Panthera tigris* (the tiger), both belong to the family Felidae.

Order : Includes families showing similar characteristics.

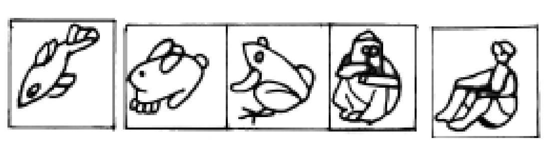
Class : Includes related orders.

Phylum : Includes related classes. (See Fig. 1.13)

The various phyla belong to their respective **kingdoms**. There are **five kingdoms** about which you will learn later. Humans belong to the kingdom Animalae and classification of humans is given as an example to describe the manner in which living organisms are classified.

Kingdom : Animalae (Animals)

Phylum : Chordata (Animals with notochord/ backbone)



Class : Mammalia (Animals that suckle their young ones.)

Order : Primates (Mammals with larger brains and binocular vision)

Family : Hominidae (Humans and human like ancestors)

Genus : *Homo* (Fossilmen and modern man)

Species : *H.sapiens* (Modern man)

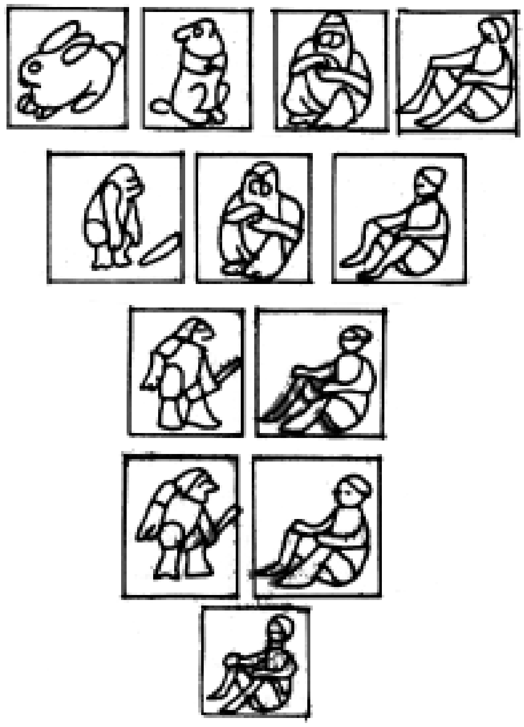


Fig. 1.13 Classification of Human species

1.3.3 Scientific naming of organisms

Different plants and animals have different common names. A cat is called 'billi' in Hindi, 'biral' in Bengali, 'punai' in Tamil and 'manjar' in Marathi. There are different words for cat in French or German. Thus, there arose the need to give organisms names which could be understood throughout the world. Therefore, scientific names which are understood all over the world were given to organisms.

A simplified system of naming organisms called **binomial nomenclature** has been the standard for more than two centuries now. It was proposed by the Swedish biologist, **Carolus Linnaeus (1707-1778)**. Binomial nomenclature simply means **two-name** system of naming. The name of every category of organism has two parts, that of the **genus** followed by that of **species**. The generic name is written with a capital letter and the specific name with a small letter. e.g. ***Homo sapiens*** is the scientific name of modern man, ***Mangifera indica*** is the boctnical name of mango.

Three main features of biological naming are as follows :

1. A scientific name, by convention, is printed in **italics** or **underlined** when hand written.
2. Scientific naming is according to a set of scientific rules of nomenclature.
3. Scientific names are mostly in *Greek* and *Latin*. They are uniformely understood all over the world and have made communication about organisms easier.

1.3.4 Prokaryotes and Eukaryotes

The organisms that are most primitive or the first to evolve on earth are the bacteria. They do not possess a nuclear membrane around their single chromosome. Absence of a well-defined nucleus or in other words a primitive nucleus terms them **prokaryotes** (pro = primitive, karyon = nucleus). **All bacteria including blue-green algae (Cyanobacteria) are prokaryotes**. As a constrast, **organisms other than bacteria** possessing a well-defined nucleus are **eukaryotes** (eu = true; karyon = nucleus). There are other differences between prokaryotes and eukaryotes which are given below in Table 1.1.

Table 1.1 Differences between Prokaryotes and Eukaryotes

Characteristics	Prokaryotes	Eukaryotes
1. Size	0.1-10 µm	10-100 µm (larger volume)
2. Genetic material	Circular DNA, no linear DNA, no histones associated with DNA, nucleoid form, no nuclear membrane	Histones present on which DNA molecule wrapped, well defined linear chromosomes, with free terminal end nuclear membrane present
3. Site of nuclear material	DNA in cytoplasm	DNA inside distinct nucleus
4. Organelles	No membrane bound organelles	Mitochondria, golgi body, lysosomes present in the cell
5. Cell wall	Always present, Contains peptidoglycan	None in (animals) and made of cellulose/chitin in plants and fungi
6. Respiration	By mesosomes	By mitochondria
7. Reproduction	Mostly asexual e.g. bacteria and cyanobacteria (blue-green algae)	Asexual and sexual e.g. Protoctista, fungi, plants Animals

1.3.5 The Five Kingdoms of Organisms

Till recently there were only two kingdoms for classification - **Plantae** and **Animalae**. Such a two kingdom classification had several drawbacks, e.g. bacteria and fungi were kept alongwith plants although they are very different.

R.H. Whittaker in 1969 suggested the five kingdom classification which is based on the following three criteria.

(i) The presence or absence of a well-defined nucleus.

(ii) Unicellular or multicellular

(iii) Mode of nutrition

The five kingdoms are Monera, Protista or Protoctista and Fungi, Plantae and Animalae. Based on the three criteria mentioned above, (Fig. 1.13) the five kingdom classification is explained as under.

Table 1.2 The five kingdom classification of organisms

Names of Kingdoms	Nature of nucleus	Whether unicells or multicells	Kinds of nutrition
1. **MONERA** (Blue green algae and bacteria)	Prokaryotic	Unicellular (except some cyanobacteria that are filamentous or multicellular and sometimes branched.	Diverse types of nutrition
2. **PROTOCTISTA** (some Algae and Protozoa)	Eukaryotic	Unicellular	Diverse kinds of nutrition
3. **FUNGI** (Moulds, etc.)	Eukaryotic	Unicellular or Multicellular	**Saprophytic** (Feed on dead, organic matter)
4. **PLANTAE** (All green plants)	Eukaryotic	Multicellular	**Autotrophic** (Synthesize food by photosynthesis)
5. **ANIMALAE** (Animals)	Eukaryotic	Multicellular	**Heterotrophic** (Depend on other organisms for food)

The five kingdoms are shown below in Fig. 1.14

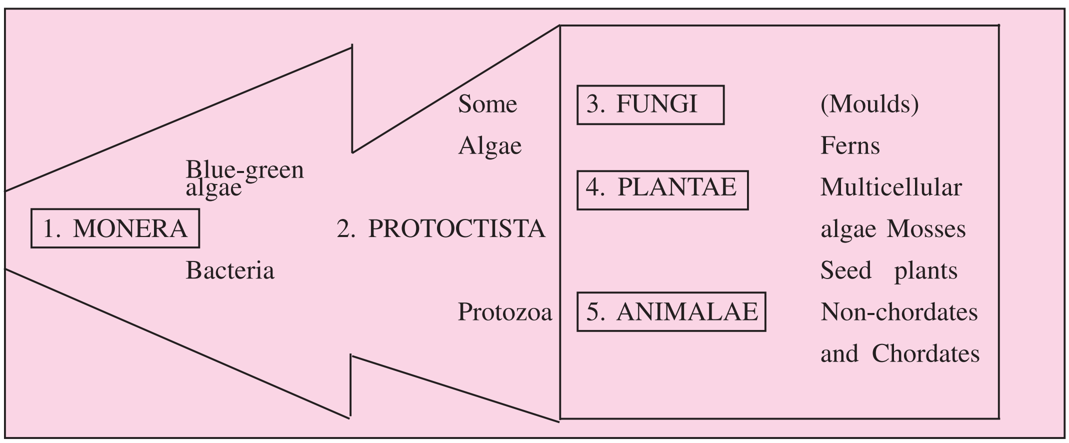


Fig. 1.14 The Five Kingdoms of Life

INTEXT QUESTIONS 1.4

1. Name the scientists who proposed :

   (a) Binomial nomenclature ....

   (b) Five Kingdom Classification ....

2. Which were the first organisms to appear on earth?

   ....

3. Name the taxonomic categories which come before and after family.

   ....

4. Name the categories above order level in a correct sequence.

   ....

5. Rewrite the following in correct form –

   (a) Mangifera Indica ....

   (b) Homo Sapiens ....

   (c) Felis leo ....

6. Place the following in their respective kingdoms

   (a) Bacteria which curdle the milk ....

   (b) Cow ....

   (c) Grass ....

   (d) Amoeba ....

   (e) Bread mould ....

1.4 VIRUSES - AN INTRODUCTION

- You have heard about diseases such as influenza, polio, mumps, rabies, small-pox, AIDS and dengue are caused by viruses.
- They are non-living and made up of DNA or RNA surrounded by a protein coat. They can replicate. However, they cannot reproduce on their own. They reproduce when inside a living cell. Therefore viruses pose a special classification problem.
- Logically, therefore, they cannot be placed in any of the five kingdoms because they can multiply in their host cells, and can mutate – like living organisms but, can be crystallised exhibiting a non-living feature.

Discovery of Viruses

In 1892, the Russian botanist Iwanowsky prepared an extract from tobacco plants suffering from tobacco mosaic disease. The extract was filtered to keep back bacteria in the residue. The filtrate was still infectious. Dutchman Beijerinck gave the term virus in 1898 (Virus - poison in Latin) to these infective particles.

Size

- Viruses are extremely small and can be seen only under the electron microscope.
- They are smaller than the smallest bacteria.
- Can pass through fiters which retain bacteria.
- Their size is indicated in nanometres (nm). Their size ranges from 10 nm to 300 nm in diameter.

> **Nanometre (nm)**
>
> It is a unit of microscopic measurement, equal to 10^{-9} m. It was formerly called millimicron

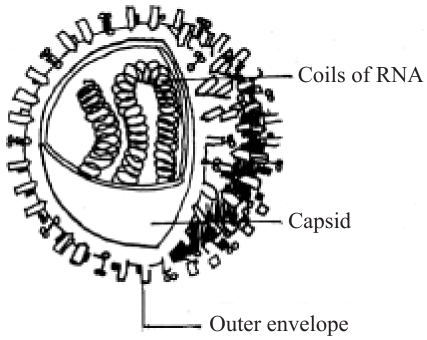


Fig. 1.15(a) Influenza virus

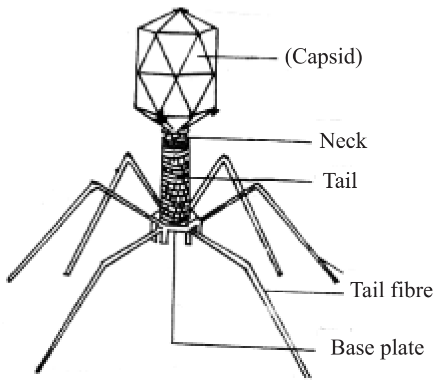


Fig. 1.15(b) T. Bacteriophage

1.4.1 Structure of virus

Virus has a simple structure consisting of a core and a cover. The core particle is the genetic material, either DNA or RNA. The cover is a protein coat called **capsid** (Fig. 1.16).

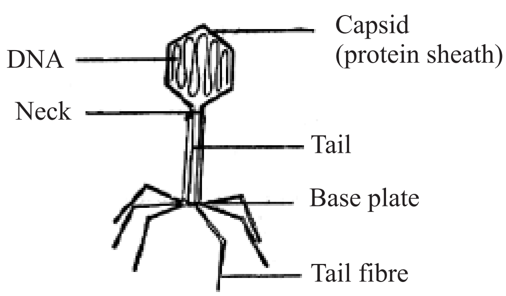


Fig. 1.15 Structure of Virus

Virus can reproduce only when inside the living cells.

A virus cannot reproduce by itself. For its reproduction it needs to enter the cell of some organism. From the host cell, it uses the raw material and enzymes and energy generating machinery of the host cell to produce its own DNA. A number of virus particles are thus formed inside the host cell. The host cell bursts to release the new virus particles.

Virus — living or non-living?

Though viruses possess nucleic acids as genetic material like the living organisms, they cannot make copies of DNA for reproduction on their own. They can make copies of themselves to reproduce only inside a living cell. And because their genetic material is DNA or RNA, they exhibit mutations followed by variations in their infective properties. Further, they are considered non-living because they are non-cellular, they have no enzymes of their own and they can be crystallised

1.4.2 Infective properties of virus

Viruses are known to attack bacteria, plants or animals. Viruses which invade bacteria are called **bacteriophages.**

Viruses are highly specific in their relationship with the host and tissue. For example – Polio virus attacks particular nerves; mumps virus attacks the particular pair of salivary glands (parotid glands) of humans.

Viruses keep on 'mutating'!

Mutation means change in genetic material. For example – Influenza virus which has RNA as its genetic material, mutates and so every year flu is caused by a different virus and scientists find it difficult to find a cure for influenza or flu.

1.4.3 Viruses and diseases

Table 1.3 indicates the names of certain viruses, their hosts and diseases and modes of their transmission

Certain cancers are also known to be caused by viruses. These viruses have RNA as genetic material and are called ***retroviruses***.

Table 1.3 Certain viruses, their hosts, diseases caused by them and mode of transmission.

	Virus	Host	Disease	Mode of Tranmission
Plants	Potato roll virus	Potato	Potato leaf roll	Air borne contact
	Tomato stunt virus	Tomato	Tomato bushy stunt	Air borne, contact
	Tobacco mosaic virus	Tobacco	Mosaic	Air borne, contact
Human	Herpes virus	Humans	Herpes	Air borne,, contact
	Pox virus	Humans	Small Pox	Air borne, contact
	HIV	Humans	AIDS	(i) Sexual contact (ii) Lactating mother to child (iii) Blood transfusion
	Dengue	Humans	Dengue	Bite of infected *Aedes* mosquito
	Hepatitis B	Humans	Hepatitis	Infected water

1.4.4 Viroids

Viroids are circular RNA molecules, consisting of several hundred nucleotides. They infect plants and even kill them. In plants, they use enzymes of the plant cells to replicate like the viruses do. When they infect plants, these RNA molecules cause defects in the regulatory systems controlling plant growth. Hence viroid infected plants show stunted growth and abnormal development.

INTEXT QUESTIONS 1.6

1. With reference to viruses fill in the blanks (1, 2 and 3) in the following table :

1. ...	Tobacco	Tobacco Mosaic Disease
HIV	2. ...	AIDS
Herpes	human	3. ...

2. Give one feature because of which viruses are considered non-livng.

   ....

3. Name one chemical common to viruses and all other organisms.

   ....

4. Complete the following :

   (a) Core particle of virus contains ....

   (b) Coat of virus is made of ....

5. In what way is viroid structurally different from a vrius?

   ....

   (Refer Module 1, Lesson 1 page 22)

6. Why are viroids considered a menace for plants that they attack?

   ....

WHAT YOU HAVE LEARNT

- The most accepted theory about origin of life is the chemosynthetic theory.
- Earth's early environment was favourable for the formation of organic molecules from simple inorganic materials.
- Coacervates are believed to have been membrane–bound molecular aggregates capable of growth and budding.
- It is believed that life originated some 3.5 billion years ago on this earth.
- The environment and the forms of life of the past were quite different from those of today.
- Evolution is the gradual unfolding of living forms from the earlier simpler forms into the complex ones. It was in operation in the past, it is operating at present and will continue do so in the future.
- Chief evidences in favour of organic evolution come from comparative anatomy, embryology, palaeontology and molecular biology.

- Darwin's theory of 'Origin of Species' by natural selection', explains the process of evolution through useful variation and natural selection.
- Neo-Darwinism is the modern interpretation of Darwinism based on natural selection, mutation and reproductive isolation. This is also called the modern synthetic theory.
- Sources of variation are mutation, recombination, geneflow and genetic drift.
- Natural selection acts upon variation through "differential reproduction" which means greater reproduction of favourable genes.
- Isolation helps in formation of new species and also in keeping species distinct.
- The reproductive isolating mechanisms are ecological isolation, seasonal, ethological, mechanical and physiological isolation, zygote inviability, hybrid sterility and F_2 breakdown.
- Evolution of new species is termed speciation.
- Speciation occurs through (a) geographical isolation, or (b) polyploidy.
- Gradualism and punctuated equilibrium are suggested modes of speciation.
- Hardy Weinberg equilibrium relates to genetic variation during evolution. According to this theory, 'in a panmictic population, frequency of two alleles remains same for generations in the absence of Mutation and Natural Selection.
- Classification is essential for studying organisms and communicating about them. Classification means grouping on the basis of similarities and differences.
- There are hierarchical taxonomic categories which reveal evoulutionary relationships of an organism.
- The scientific naming of organisms is according to the Linnaean system of binomial nomenclature.
- The five kingdoms of life are Monera, Protoctista, Fungi, Plantae and Animalae.
- Viruses are nucleoprotein particles which have DNA or RNA molecules present as core particles, surrounded by a protein coat.
- Viruses were discovered by Ivanowsky and named by Beijerinck.
- Viruses are very small and can be observed only through electron microscope.
- Viruses cannot reproduce except when inside living cells.
- Viruses share properties of living and nonliving.
- Viruses infect bacteria, plants and animals.
- Viruses attacking bacteria are called bacteriophages.
- Viruses cause several human diseases like herpes, small pox, AIDS, dengue and influenza.
- Viroids are RNA particles that attack plants.

TERMINAL EXERCISES

1. Explain the most valid theory about origin of life on earth. How did Miller and Urey verify the chemosynthesis theory of evolution?
2. Differentiate between Darwinism and Neo-darwinism.
3. Explain the synthetic theory of evolution.

5. Substantiate the idea of evolution through molecular evidence.
6. Classify the following animals : earthworm, roundworm, frog and human-beings.
7. Write the scientific names of
   (i) Mango (ii) Man (iii) Cat (iv) Tiger
8 How does a virus increase in number? Show only by explanatory diagrams.
9. Give a schematic diagram of the five Kingdom classification.
10. State the criteria on which the five kingdom classification is based.

ANSWERS TO INTEXT QUESTIONS

1.1 1. 5 billion years 2. A.I. Oparin
3. NH_3, CH_4, CO_2, water vapour
4. Lightening/geothermal energy/UV rays (any one)
5. Water
6. aggregates of (life-like) molecules
7. amino acids, fatty acids, sugars (any two)
8. Miller and Urey

1.2 1. The process of slow and gradual change as a result of descent with modification, from a common ancestor.
2. *Archaeopteryx*
3. Fore-limb/arm
4. Functionless organs of the body
5. (i) Lungfish between fish and amphibia
   (ii) Egg laying mammals between reptiles and mammals.
6. See sub-section on evidence of evolution from molecular biology

1.3 1. Mutation, Recombination, gene flow, genetic drift,
2. It is about the evolution of a variety of peppered moth during industrial revolution, through mutation and Natural Selection.
3. Allopatric speciation leads to differences in population of a species due to physical isolating barriers. Reproductive barriers separate sympatric species which may live in the same geographical area.
4. Both are isolating mechanisms, Ecological Isolation by barriers of season or habital and Ethological Isolation by barriers of behavioural differences.
5. Randomly mating population.
6. $(q + q)^2 = 1$ means frequencies of allelic genes p + q remain same for generation after generation if there is no force of evolution like variation, natural selection etc.

1.4 1. Charles Darwin

2. Neo-Darwinism/synthetic theory

3. All organisms are related through ancestry he suggested natural selection as the probable mechanism for evolution.

4. (i) Variation in population forms the basis of evolution

(ii) Differential reproduction

5. Reproduction of favourable genes is greater

1.5 1. (a) Carolus Linnaeus

(b) R.H. Whittaker

2. Bacteria

3. Genus

4. Kingdom, phylum, class, order

5. (i) *Mangifera indica* (ii) *Homo sapiens* (iii) *Felis leo*

6. Kingdom, phylum, class, order, family, genus, species

7. (i) Monera (ii) Animalae (iii) Plantae (iv) Protoctista (v) Fungi

1.6 1. 1. Tobacco mosaic virus, 2. humans, 3. Herpes.

2. They cannot reproduce on their own / they can be crystallised (any one)

3. Nucleic acid/protein (any one)

4. (a) DNA or RNA (b) Protein

5. A virus has a DNA or RNA molecule surrounded by a protein coat, whereas a viroid is only an RNA molecule.

6. They infect plants and when inside the plant cells, use the host plants' enzymes to replicate & increase in number resulting in stunted and abnormal growth of plant.

2

THE KINGDOMS MONERA, PROTOCTISTA AND FUNGI

The Kingdom Monera which includes all the bacteria including blue-green algae (cyanobacteria) and the Protoctista which includes the protozoa, the diatoms and some algae are in a way the simplest among the living world. All bacteria, majority of protoctists and many fungi are microscopic and generally referred to as micro-organisms. You will learn about the three kingdoms in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *state the basis for classifying certain organisms as members of kingdoms Monera, Protoctista and Fungi;*
- *emphasize the fact that Kingdom Monera is the only prokaryotic kingdom and also that it is the most primitive;*
- *describe the generalized structure of a bacterium and cyanobacterium;*
- *describle economic importance of bacteria with examples;*
- *recognize the status of cyanobacteria and justify its inclusion in kingdom Monera;*
- *describe the characteristics of Kingdom Protoctista (protista);*
- *describe the structure of Amoeba, Paramecium, Euglena and Plasmodium;*
- *describe the structure of diatoms;*
- *list the uses of protists to humans and mention the diseases caused by protozoa;*
- *list the general characteristics of fungi with examples;*
- *describe the strucutre and reproduciton of yeast, Rhizopus,* mushroom, *Penicillium and its utility for humans;*
- *explain what are mycorrhizae;*
- *describe the economic importance of fungi.*

2.1 KINGDOM MONERA

- Includes the bacteria and cyanobacteria (commonly called blue-green algae).
- Since only bacteria are prokaryotic (lacking a true nucleus, that is without a nuclear membrane), Monera is the only **prokaryotic** kingdom.
- Bacteria were the first cellular organisms to evolve on the planet earth after life originated around 3.5 billion years ago and were the **only** cellular organisms on earth for almost the next two billion years.
- Most bacteria are single celled or **unicellular** (monere : single) but actinomycetes and some cyanobacteria are multicellular and filamentons wherein filaments may be branched.
- Monerans are also the most numerous of all living cellular organisms.

2.1.1 Structure of a bacterial cell

The single celled bacterium has a cell wall made of the compound peptidoglycan covering the cell membrane; and a single circular (upring-like) chromosome. The cell has ribosomes but no membrane bound organelles. Let us get to know some details of these parts (Fig. 2.1).

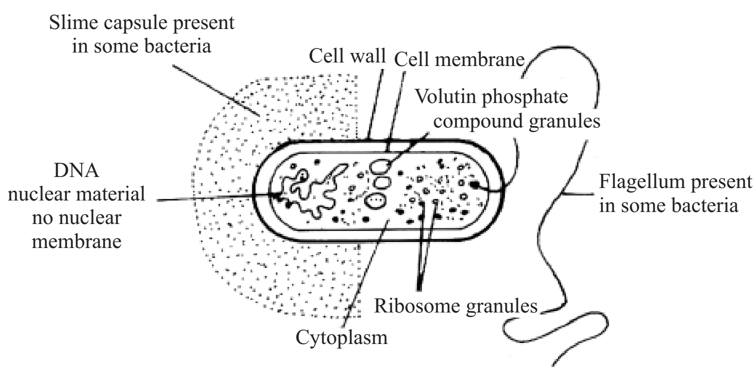


Fig. 2.1 Structure of a bacterium.

Note the following parts of a bacterium in the figure (Fig. 2.1). The outermost covering is the cell wall.

Cell wall

All prokaryotes have a rigid cell wall, which protects and gives shape to the cell. The cell wall is made up of a chemical, **peptidoglycan,** unique to bacteria, lipids, polysaccharides and some proteins.

Pili (Singular : pilus)

Pili are short and thin thread like tubular structures projecting out from the cell wall in some bacteria.

Flagella

Some bacteria move with the help of one or more flagella. Flagella are longer and thicker than pili. Their structure is different from flagella of eukaryotes.

Plasma Membrane

Plasma membrane, present below the cell wall, encloses the cytoplasm and other cell contents. It is made up of lipids and proteins, as in eukaryotes.

Genetic Material

One circular chromosome made of a double helical molecule of DNA is located in a region of the cytoplasm called **nucleoid**. Since the chromosome is not lodged within a true nucleus, bacteria are termed as prokaryotes. Hence Monera is the prokaryotic kingdom. Apart from the chromosome as several species of bacteria possess one or more additional rings of DNA called **plasmids**, which replicate along with bacterial chromosome and bear genes for antibiotic resistance and act as the sex factor or F-factor providing the property of male sex to the cell that bears the sex-factor or the F-factor.

Cell Organelles

Membrane bound organelles like endoplasmic reticulum, mitochondria, chloroplast, and golgi complex are **absent**. Only 70s *ribosomes* are present, which are different from those of eukaryotes (see lesson 1 and 4).

> Prokaryotes have no nuclear membrane around genetic material and no membrane bound cell organelles except mesosomes. They have only the 70s ribosomes.

2.1.2 Monera - General body functions

A. Nutrition

The four nutritional categories found in bacteria are :

(i) Autotrophs - synthesize their own organic food.

(ii) Saprotrophs - feed on dead organic matter.

(iii) Symbionts - use food from other living organisms with which they are associated for mutual benefit.

(iv) Parasites - absorb food from living organisms and cause harm to them

B. Respiration

Respiration in bacteria may be either

(i) aerobic i.e. using oxygen for respiration or

(ii) anaerobic i.e. respiration in the absence of oxygen.

Cellular respiration or breakdown of food to release energy occurs in **mesosomes** which are the inner extensions of the cell membrane.

C. Reproduction

(i) **Asexual Reproduction**

Bacteria reproduce asexually by **binary fission** (Fig. 2.2). Under favourable conditions it takes about 20 minutes for one bacterium cell to divide into two by binary fission.

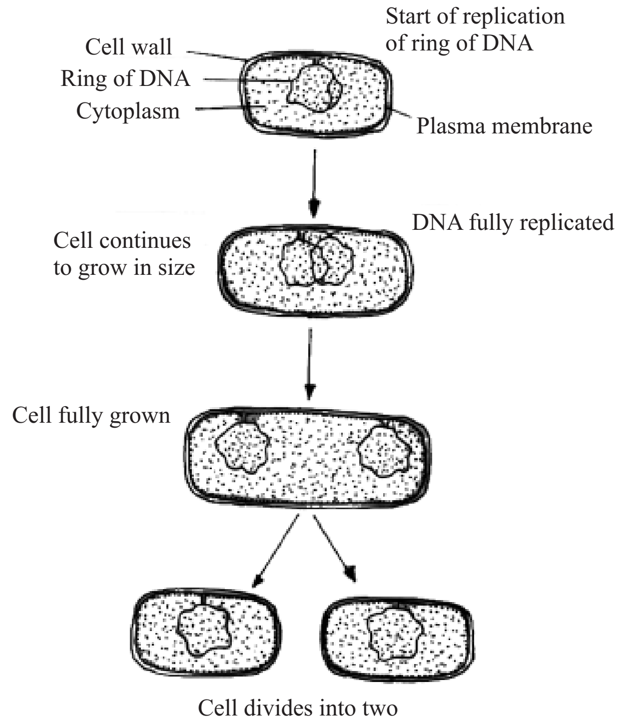


Fig. 2.2 Binary Fission in Bacteria

(ii) **Sexual Recombination (=Genetic Recombination)**

Some bacteria show a primitive mode of sexual reproduction. It is different from sexual reproduction in higher forms. The steps are:

(a) Two conjugating (lie very close for transfer of genes) bacteria are held together by pili.

(b) A segment of DNA strand is transferred from one bacterium to another bacterium. (Fig 2.3) or F-factor = sex-factor (fertilisty factor) is transferred from male donor cell to female (recipient) cell.

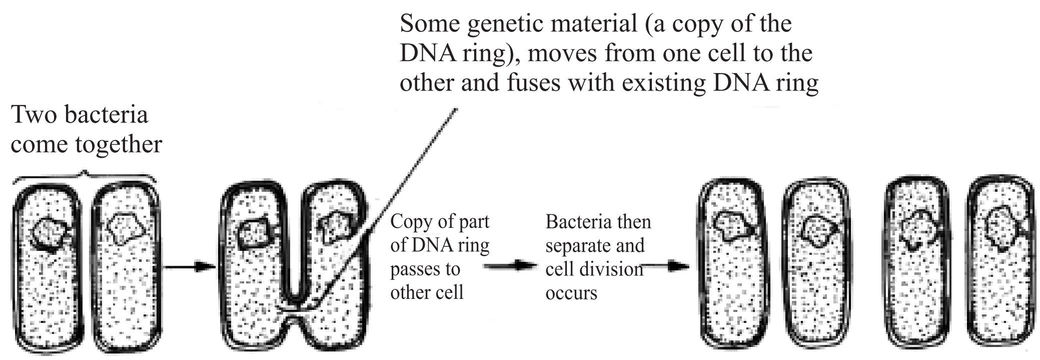


Fig. 2.3 Conjugation in Bacteria

INTEXT QUESTIONS 2.1

1. What is the chemical nature of the circular single chromosome of a bacterium?

   ....

2. Name the special region in the bacterial cell where genetic material lies.

   ....

3. What is the main component of cell wall in prokaryotes?

   ....

4. State one point of difference between flagella and pili.

   ....

5. Give one difference between aerobic and anaerobic bacteria

   ....

6. What is transferred during sexual recombination in a bacterium?

   ....

2.1.3 Beneficial and harmful bacteria

Many bacteria harm us by causing many diseases. On the other hand some bacteria are very useful.

Diseases Caused By Bacteria

	Name of Bacterium	Disease Caused
1.	*Vibrio cholerae*	Cholera
2.	*Salmonella typhi*	Typhoid
3.	*Clostridium tetani*	Tetanus
4.	*Corynebacterium diphtheriae*	Diphtheria
5.	*Mycobacterium tuberculosis*	Tuberculosis

Beneficial Activities of Bacteria

	Name of bacteriun	Activities
1.	*Rhizobium*	Found in roots of legumes, like Peas, grams, Pulses etc, where it fixes atmospheric nitrogen as ammonia, which is then converted into useful amino acid.
2.	*Azotobacter*	Makes the soil fertile. It fixes atmospheric nitrogen in the soil.
3.	*Streptomyces*	Produces Streptomycin antibiotic.
4.	*Lactobacillus*	Ferments lactose (milk sugar) to lactic acid. This helps in setting of milk into curd.
5.	Methanogenic bacteria	Sewage treatment

2.1.4 Cyanobacteria

These were earlier called the blue-green algae. (Fig. 2.4a) A very successful group on primitive earth, they could carry out photosynthesis and the oxygen released during the process changed the earth's atmosphere and gradually the level of oxygen increased in the earth's atmosphere.

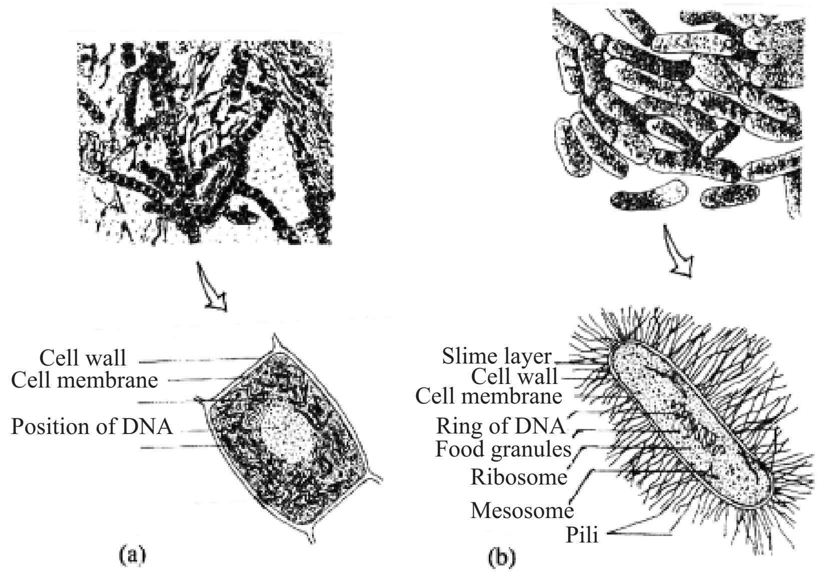


Fig. 2.4a-b Cyanobacteria (blue green algae)

Differences between Bacteria and Cyanobacteria

Bacteria	Cyanobacteria
1. Smaller cells	1. Comparatively larger cells
2. May have flagella	2. Do not have flagella.
3. Some bacteria (green) carry out photosynthesis in a different way and do not release oxygen (anoxygenic)	3. They all carry out photosynthesis in the usual manner as in green plants and release oxygen (oxygenic)
4. Sexual recombination by conjugation in some bacteria	4. Sexual recombination has been observed in some cyanobacteria.

INTEXT QUESTIONS 2.2

1. Name the bacteria that :

   (i) fix atmospheric nitrogen in the soil ....

   (ii) set milk into curd ....

(iii) cause tuberculosis ....

(vi) cause tetanus ....

2. Approximately how many bacteria may be obtained from one bacterium in an hour?

....

3. Give any three differences between bacteria and cyanobacteria.

....

2.1.5 Monera

Kingdom Monera includes three groups, viz.

1. Archaebacteria
2. Eubacteria, and
3. Cyanobacteria

Archaebacteria includes bacteria that live in unusual environments particularly at low levels of oxygen. Main types of Archaebacteria are

- **Methanogenic** bacteria that live in sewage and intestinal tracts of animals
- **Thermoacidophilic** bacteria that live in hot springs.
- **Halophilic** bacteria which live in salty conditions where hot sun concentrates sea water. Eubacteria include all other bacteria excluding cyanobacteria. All cyanobacteria are oxygenic photoautotrophs.

2.2 KINGDOM PROTOCTISTA (UNICELLULAR EUKARYOTES)

- Protoctista are **unicellular eukaryotes**. Protozoa, diatoms and unicellular algae are included in it.
- They have membrane bound organelles such as nucleus with chromosomes enclosed in nuclear membrane, mitochondria, chloroplast (in photosynthetic protoctists only), golgi bodies and endoplasmic reticulum.
- Mitochondria are the respiratory organelles.
- Protoctists are either photosynthetic, parasitic or saprotrophic.
- For locomotion, protoctists may have cilia or flagella (Fig. 2.5) having 9 + 2 microtubules unlike those of bacteria, which consist of only one spirally coiled protein, called flagellin.
- They reproduce both asexually and sexually.
- Some protoctists are beneficial to humans whereas the others are harmful.

2.2.1 Classification of Protoctista

The kingdom protoctista includes –

1. **Phylum Protozoa** which has the following four classes :

   (i) Rhizopoda : Example, *Amoeba*

(ii) Flagellata : Example, *Euglena*

(iii) Ciliata : Example, *Paramecium*

(iv) Sporozoa : Example, *Plasmodium*

The protistan algae belong to

1. Phylum Bacillariophyta : Example diatoms
2. Phylum Chlorophyta : Example *Chlorella*

2.2.2 Some examples of Protoctists

1. *Amoeba*

Amoeba is commonly found in the mud, in freshwater ponds and ditches containing decaying leaves.(Fig. 2.5a)

– It has blunt pseudopodia for locomotion.

– It captures food by pseudopodia to form a food vacuole.

– It has a contractile vacuole for osmoregulation

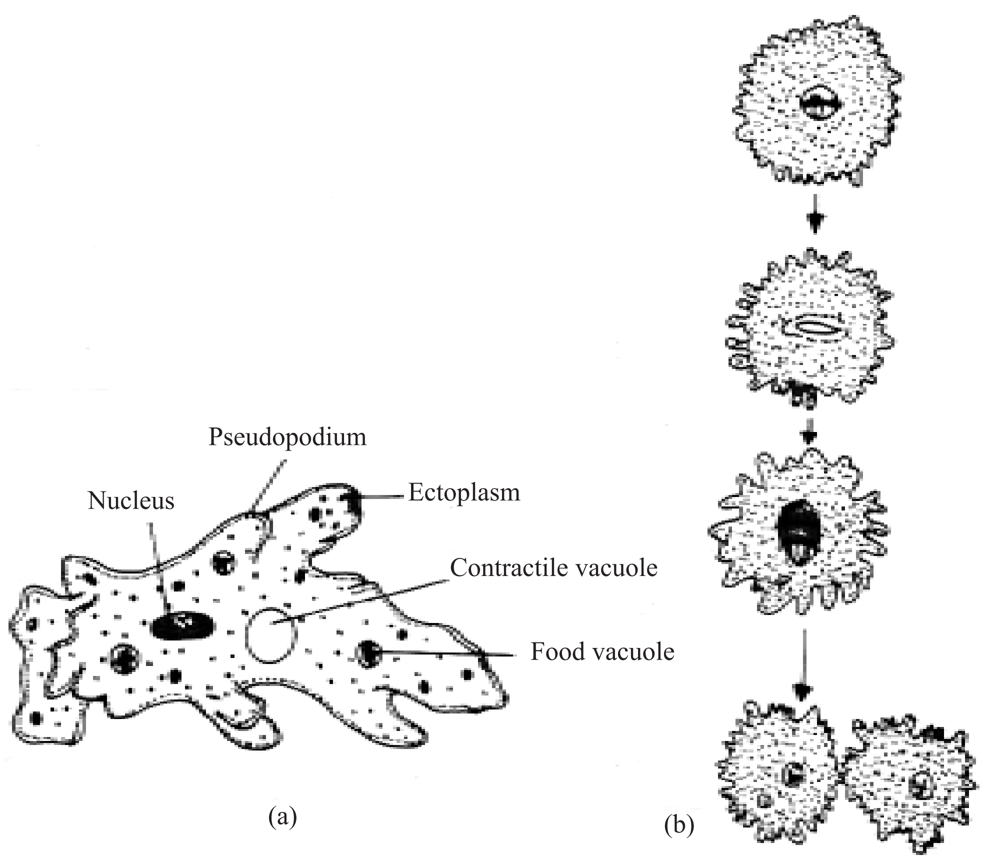


Fig. 2.5 Amoeba : (a) General Structure, (b) Amoeba showing binary fission.

Reproduction : Sexual reproduction is uncommon in *Amoeba*.

Asexual reproduction is by binary fission. (Fig. 2.5b)

2. *Entamoeba*

One common species is *Entamoeba histolytica* which caues amoebic dysentery in humans. It is amoeboid in form. The new host gets infected when the cyst is swallowed along with contaminated food or water. The cyst bursts and releases *Entamoeba* in the intestines where it causes local abscesses (open injury). The symptoms of amoebic dysentery are abdominal pain, nausea and presence of blood and mucus with stool.

3. *Plasmodium* (The malarial parasite)

The life cycle of *Plasmodium* has both asexual and sexual phases.

– The asexual phase is spent in the human blood.

– Sexual phase is spent in the female *Anopheles* mosquito Fig. 2.6.

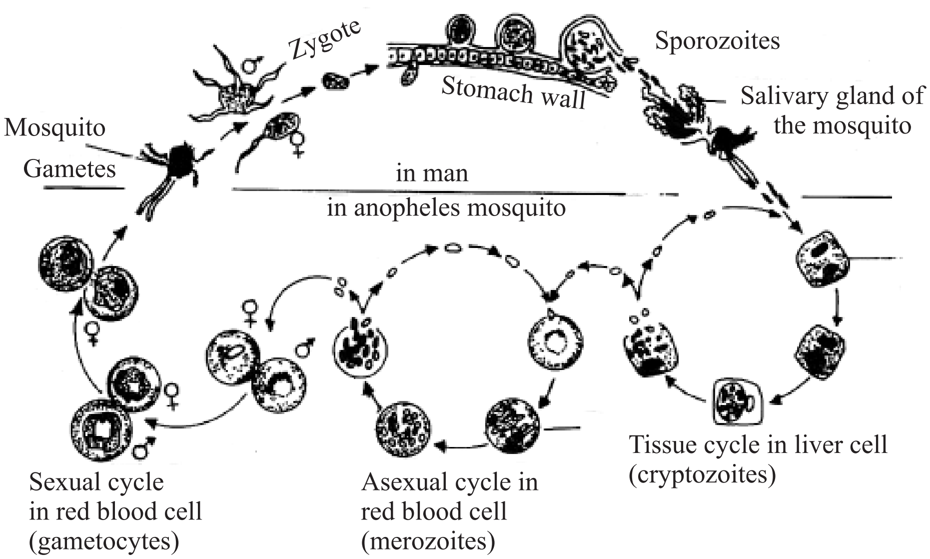


Fig. 2.6 The life cycle of Plasmodium in mosquito and man.

> **Male** *Anopheles* cannot cause malaria as it feeds on plant juices and not the human blood.

4. *Euglena* – A freshwater Flagellate

Euglena is abundantly found in stagnant waters such as pools, ponds and ditches containing decaying organic matter. (Fig. 2.7)

As seen in the Fig. 2.7, the organism has the following parts.

Pellicle - elastic body covering made up of protein.

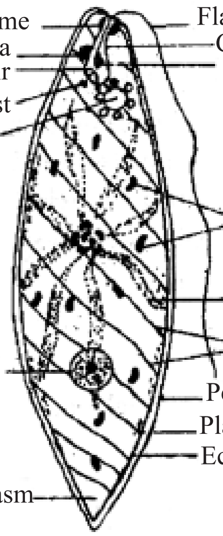


Fig 2.7 *Euglena* - General Structure

Cytostome and Reservoir - the cell mouth leading into a tubular cytopharynx which opens into a vesicle called reservoir.

Stigma or eyespot - a prominent red pigment spot. It is sensitive to light.

Contractile Vacuole - for osmoregulation.

Flagellum - for propulsion in water.

Chloroplast - contain green coloured chlorophyll for photosynthesis.

Reproduction - is by binary fission.

5. The Diatoms

- The diatoms are found in both fresh and salt water and in moist soil.
- Thousands of species of diatoms act as food for aquatic animals.
- Diatoms are either unicellular, colonial or filamentous and occur in a wide variety of shapes (Fig. 2.8).
- Each cell has a single prominent nucleus and plastids. They produce shells (cell walls) containing silica.

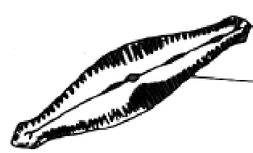


Fig. 2.8 Diatoms

6. Other Algae

- Algae can be unicellular e.g. *Chlamydomonas* (2.9a) or multi-cellular like *Spirogyra* (Fig. 2.9b)

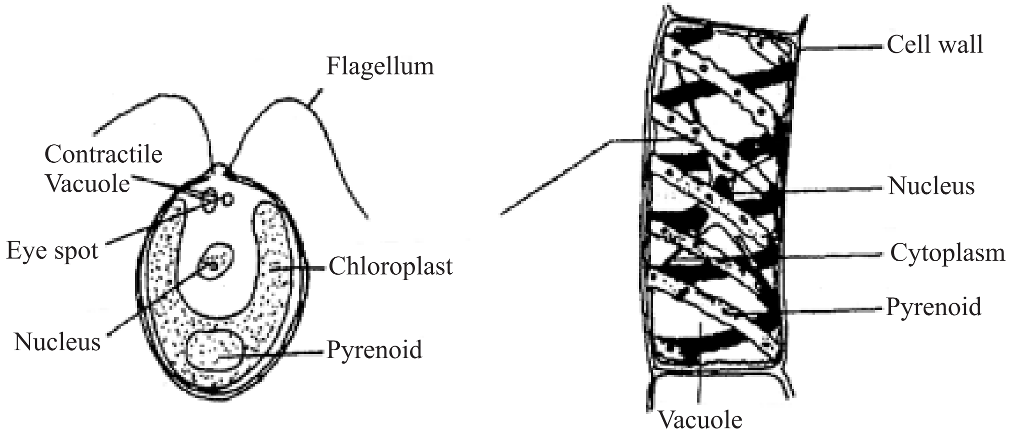


Fig. 2.9 (a) *Chlamydomonas* (b) *Spirogyra*

– Algae can prepare their own food by photosynthesis as they contain chlorophyll. Some algae have other pigments also e.g. blue pigment (Phycocyanin), a brown pigment (Fucoxanthin) or a red pigment (Phycoerythrin). Depending on the pigment present, the algae are called blue, green, brown or red algae.

> Colour of the Red Sea is due to the dominant occurrence of a blue-green alga, *Trichodesmium erythraeus*

– Structurally the algae have a definite cell wall, cell membrane, a nucleus, cytoplasm and choloroplast. The chloroplast is cup-shaped in *Chlamydomonas* and ribbon-shaped in *Spirogyra*. Pyrenoids, the starch containing bodies are integral part of chloroplasts in green algae.

2.2.3 Usefulness of Algae

– Provide food for fish as part of phytoplankton (organisms floating on the water surface)

– These are rich sources of vitamins A and E.

– Many marine forms are important sources of iodine, potassium and other minerals.

– Blue-green algae increase the soil fertility by fixing atmospheric nitrogen.

– Blue-green algae that fix atmospheric nitrogen, are a source of natural fertilizer for the crop plants.

– A group of algae (diatoms) deposit silica in their walls. After their death these algae are preserved as fossils. Their siliceous deposits in large amounts result in the formation of diatomaceous earths that are used as filters, and for lining of furnaces.

INTEXT QUESTIONS 2.3

1. Protoctists are single celled like most of the Monerans. Why have they been put in a separate kingdom? Answer in one short sentence.

   ....

2. Name the protozoan which causes

   (i) Amoebic dysentery ....

   (ii) Malaria ....

3. Which is the kind of asexual reproduction found in Protoctista?

   ....

4. Through which organelle of the protoctists does respiration occur?

   ....

5. Name the organelle responsible for regulating water content (osmoregulation) in amoeba.

   ....

6. Name two kinds of locomotion found in protoctista.

   ....

2.3 KINGDOM FUNGI

2.3.1 Position of Fungi

During warm humid days slices of bread, chapati, leather belts or shoes, develop a powdery layer on them. In lawns and flower beds, mushrooms come out. These are all fungi.

Fungi were earlier classified as plants without chlorophyll and without differentiation of their body into root, stem and leaves. They are now included, in a separate Kingdom called **Fungi.**

2.3.2 Characteristics of Fungi

- Fungi are heterotrophic unicellular or **multicellular eukaryotes**
- Fungi exist as slender thread like filaments called hyphae. Hypha may be one celled or multicelled and has, one or more nuclei. Yeast, however, is single celled, and uninucleate.
- Their cell walls are made of chitin
- A hypha may be divided into cells by partitions called septa.

- Septa have pores through which cytoplasm streams freely.
- A group of hyphae forming a network is called mycelium (mycetos meaning fungus; Fig. 2.10).
- Mycelia spread out on the substrate, or on the ground and even extend upto several kilometers.
- They do not possess chlorophyll as their nutrition is by absorption or feeding on dead organic matter.
- Aquatic fungi have flagellate gametes or flagellate spores
- Higher fungi do not have flagellum at any stage of life cycle.
- Reproduction in fungi is both asexual by means of flagelalte or non-flagellate spores and sexual through conjugation (refer to Fig. 2.13, 2.14).

Fungi are eukaryotic, unicellular or multicellular saprotrophs having filaments which grow through soil, wood and other substrates.

2.3.3 Five main kinds of Fungi

The fungi are of five main kinds

1. Myxomycetes, the **Slime moulds**, which have irregular shape.
2. Phycomycetes, are unicellular, filamentous and branched e.g. *Rhizopus and Phytophthora*.
3. Ascomycetes, are one celled (e.g. yeasts) or multicellular branched e.g. *Aspergillus, Penicillium,* and *Neurospora*.
4. Basidiomycetes, are multicellular, branched, and are represented by rusts, smuts, **Mushrooms** and **toadstools**, which are large enough to be seen by naked eyes.
5. Deuteromycetes, are multicellular filamentous branched fungi which reproduce only by asexual means e.g. *Alternaria*.
6. **Lichens and mycorrhizae** which exist in symbiotic associations.

1. Yeasts

Yeasts are fungi which do not produce any hyphae. These are generally in the form of single oval cells.

Fig. 2.10 shows the general structure of a yeast cell. Note the followmg features in it:

– ovoid cell.
– distinct cell wall and nucleus.
– one or more vacuoles in the cytoplasm.
– cytoplasm is granular and has glycogen and fat (oil) globules.

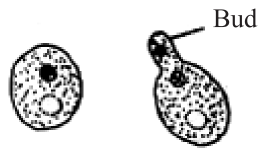


Fig. 2.10 A single cell of yeast

Nutrition

Yeast is saprotrophic. It can directly absorb simple sugar (glucose) but for obtaining sucrose (cane sugar) it gives out the enzyme invertase or sucrase which breaks down sucrose into simple sugars. The simple sugars are then simply absorbed into the cell.

Yeast respires anaerobically to yield energy as follows

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \longrightarrow \underset{\text{(ethyl alcohol)}}{2C_2H_5OH} + 2CO_2 + \underset{\text{(energy)}}{2ATP}$$

Reproduction

Yeast reproduces asexually by budding (Fig. 2.11).

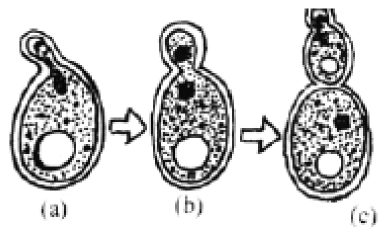


Fig. 2.11 Budding in yeast (a) A bud is forming and the nucleus is dividing; (b) Bud formed and the nucleus gets divided; (c) Further budding forms a chain

Sexual reproduction may also occur by conjugation between two yeast cells. The fused contents divide by one meiosis followed by one mitosis to produce eight cells with a thick wall around each. The 8-celled structure is called **ascus** and each cell is called **ascospore**. The ascospores may be carried by wind and germinate under suitable conditions to produce new yeast cells.

2. Myxomycetes (Slime Moulds)

These consist of a naked, creeping multinucleate mass of protoplasm sometimes covering up to several square metres. The nuclei are diploid

3. Basidiomycetes (Mushrooms and Toadstools)

The vegetative part of the mycelium lies embedded in the substratum (in ground or in wood) When conditions are favourable the umbrella like mushrooms grow out with a stalk and a cap. (Fig. 2.12)

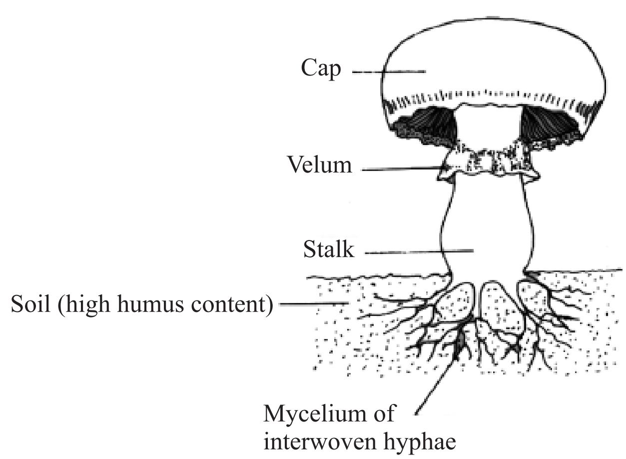


Fig. 2.12 A Mushroom

4. Lichens

These are a combination of a certain fungus and a green or blue green alga which live in a symbiotic (mutually beneficial) association : the green or blue green alga prepares food while the fungus gives protection, and absorbs water and minerals from the surroundings.

INTEXT QUESTIONS 2.4

1. Name the slender filaments that form the body of a fungus.

   ....

2. Which are the types of reproduction found in fungi?

   ....

3. Draw two small figures to show asexual reproduction in yeast.

   ....

4. Which are the four main kinds of fungi?

   1. .... 2. ....

   3. .... 4. ....

2.3.4 Economic importance of Fungi

A. Harmful Fungi

Several agricultural plants like sugarcane, maize, cereals and vegetables suffer from diseases caused by fungi.

1. *Puccinia graminis* (Wheat Rust)

It causes brown patches on leaf and stem of wheat plants. It decreases the yield of wheat and makes it unfit for human consumption.

2. *Rhizopus* or (Bread Mould) grows on bread (Fig. 2.13).

If the bread is exposed to warm and humid conditions a cottony mass develops in few days. This white cotton mass later develops a greyish black colour, because of black coloured spores.

– The whitish network is called mycelium.

– The mycelium contains thread like structures called *hyphae*.

– The root-like sturctures growing out of the hyphae penetrate the bread, and secrete digestive enzymes (extracellular digestion) and absorb the digested food.

– Greyish black colour of the mould develops due to formation of sporangium which after rupturing release dark coloured spores. The spores scatter by wind and germinate after falling on a suitable substractum. **This is asexual reproduction**.

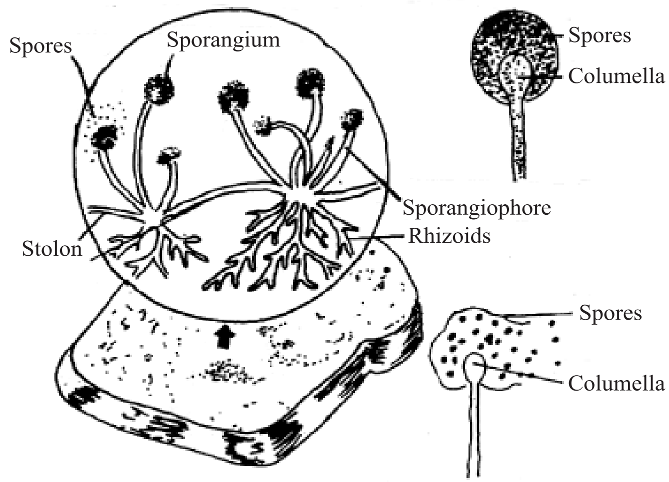


Fig. 2.13 Asexual reproduction in *Rhizopus*

Sexual reproduction (Fig. 2.14) takes place by conjugation between two neighbouring hyphae to produce a zygospore which after a period of rest undergoes meiosis followed by several mitotic cell divisions to produce a germ sporangium having a large number of haploid unicellular spores. The germ sporangium differs from asexual sporangium, as it does not have columella. When mature, the germ sporangium bursts to release spores which germinate on meeting favourable conditions and produce a new mycelium

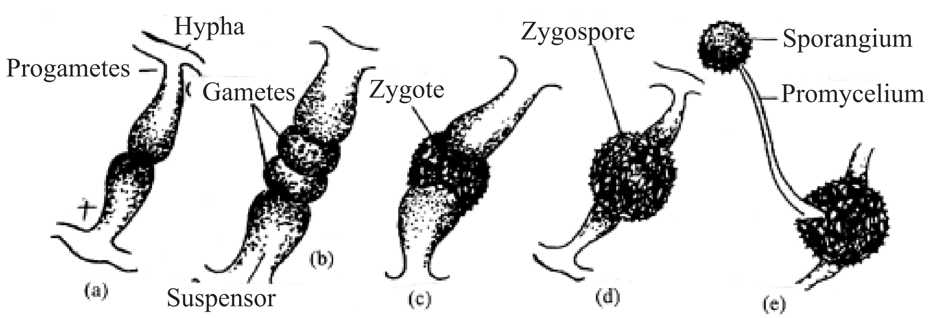


Fig. 2.14 Sexual reproduction in *Rhizopus*

3. In **human,** skin diseases like ringworm and athlete's foot are caused by fungi. Some ear infections are also caused by fungi.

B. Beneficial Fungi

- Certain Mushrooms (such as *Agaricus campestris*) are edible.
  Yeast is used for fermentation during manufacture of bread, beer, soya sauce, cheese and wine.
- **Mycorrhizae** are fungi associated with roots of plants. Roots benefit in getting minerals from the environment while fungi get food from the plant in return through such association.
- *Neurospora* has been a favourite experimental material in Genetics.
- Various antibiotics are derived from fungi. Penicillin is obtained from *Penicillium notatum* (Fig. 2.15). Its antibiotic effect was discovered by chance by Alexander Flemming in 1927.

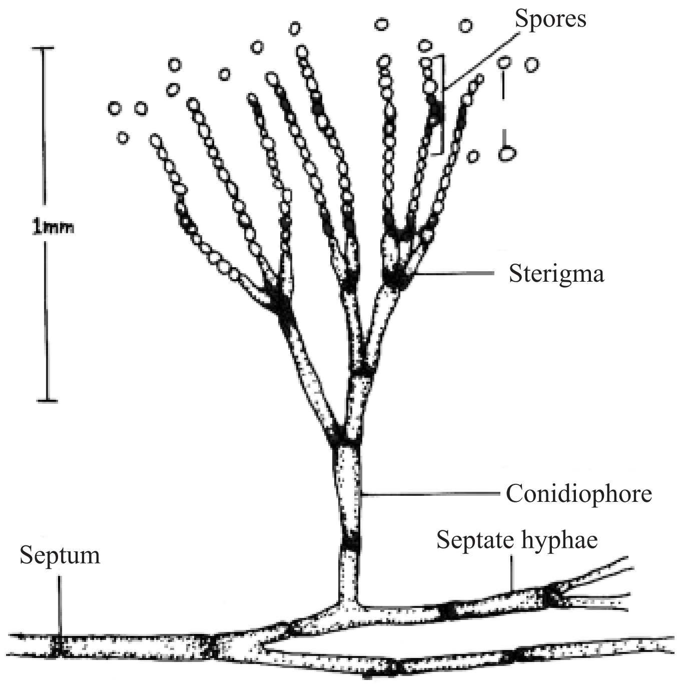


Fig. 2.15 *Penicillium*

INTEXT QUESTONS 2.5

1. Name
   (i) the fungus from which Penicillin is extracted ....
   (ii) a unicellular fungus. ....
   (iii) The fungus which causes wheat rust ....
   (iv) The whitish cottony mass, growing on stale bread. ....
   (v) Two common human diseases caused by fungi ....

2. Who discovered antibiotic properties of *Penicillium*?

   ....

WHAT YOU HAVE LEARNT

- Protoctista includes protozoa, diatoms and other unicellular algae.
- They are unicellular eukaryotes and possess organelles like mitochondria, golgi, bodies, chloroplast, endoplasmic reticulum
- Protoctists ae autotrophic, saprotrophic or parasitic.
- Protozoans may have pseudopodia, cilia and flagella for movement.

- They reproduce asexually as well as sexually.
- Examples of protoctists are *Paramecium*, *Amoeba*, malarial parasite, *Chlorella*, *Euglena*, *Chlamydomonas* and diatoms.
- Some protoza cause diseases. Algae provide food for fish, and are rich sources of some minerals and vitamins. Blue green algae fix atmospheric nitrogen. Walls of diatoms which have silica get deposited to form diatomaceous earths, which is used as filters and for lining the furnaces.
- Diatoms form bulk of plankton in ponds lakes and oceans, and are food for many aquatic organisms.
- Prokaryotes lack true nucleus. Genetic material in Prokaryotes is in the form of single circular DNA.
- DNA is placed in special region in a bacterial cell called nucleoid. A small ring of extra DNA present in some bacteria, is called plasmid or sex factor or F-factor (F = fertility)
- Bacteria exhibit four different kinds of nutrition - autotrophic, saprotrophic, symbiotic and parasitic.
- Cyanobacteria possess chlorophyll that helps in oxygenic photosynthesis.
- Some bacteria fix atmspheric nitrogen to enrich soil, some help in sewage treatment.
- Certain bacteria cause diseases like cholera, typhoid, tetanus and tuberculosis.
- There are bacteria that survive in extreme environments like high temperature, high salinity, and presence of methane.
- Fungi are eukaryotic, unicellular or multicellular saprotrophs.
- Fungi are of several kinds such as yeasts, slime moulds, mushrooms, lichens and mycorrhizae.
- Yeasts are unicellular, which commonly reproduce asexually by budding. Sexual reproduction occurs by conjugation.
- Slime moulds are naked, creeping multinucleate mass of protoplasm.
- Lichens are symbiotic combinations of fungi and algae.
- *Rhizopus* is the common bread mould that produces whitish network (mycelium) on stale bread, in warm humid weather.
- *Rhizopus* reproduces asexually by spores, and sexually by producing zygospore which in turn produces haploid spores after meiosis and repeated mitotic divisions.
- Wheat rust (*Puccinia graminis*) causes brown patches on leaf and stem of wheat plants.
- Ringworm and athelete's foot are two common fungal diseases of humans.
- Certain mushrooms are edible.
- Yeast is used for making bread and beer.

- *Neurospora* is used in experiments on genetics.
- *Penicillium notatum* yields penicillin.
- Various other fungi produce other antibiotics.

TERMINAL EXERCISES

1. Draw a labelled diagram of a typical bacterial cell.
2. List the different nutritional categories of bacteria and protoctists.
3. Draw the labelled diagrams to show binary fission in bacteria.
4. How does amoeba normally reproduce ? Draw diagrams to represent the process.
5. Draw a labelled diagram of *Euglena*.
6. What are the common features of diatoms which justify their inclusion in protoctists?
7. Write a paragraph on economic importance of the protoctists.
8. List any three characteristics of fungi.
9. What are mycorrhizae?
10. Name three harmful fungi mentioning their harmful effects.
11. Write a note on beneficial fungi.
12. Draw labelled diagrams of the following :
    (i) A series of stages in the budding of yeast.
    (ii) Magnified view of the bread mould growing on bread.

ANSWERS TO INTEXT QUESTIONS

2.1
1. DNA
2. Nucleoid
3. Peptidoglycan
4. Flagella are thicker and longer than pili/used in movement, used in conjugation.
5. Aerobic bacteria respires in presence of oxygen/the anaerobic bacteria respires in the absence of oxygen.
6. A fragment of DNA strand.

2.2 1. (i) *Azotobacter*
(ii) *Lactobacillus*
(iii) *Mycobacterium tuberculosis*
(iv) *Clostridium tetani*

2. Eight

3. Bacteria - smaller cells, flagella present, sexual recombination by conjugation. Cyanobacteria - large cells, no flagella, rare sexual recombination.

2.3 1. Protoctista are Eukaryotes/ possess true nucleus.

2. (i) *Entamoeba histolytica*
(ii) Malarial parasite or *Plasmodium*.

3. Binary fission

4. Mitochondria

5. Contractile vacuole

6. Flagellar, Pseudopodial or amoeboid (any two).

2.4 1. (i) mycelium

2. asexually, sexually

3. Refer diagram 2.12

4. (i) Yeast
(ii) Slime moulds
(iii) Mushrooms and Toadstools
(iv) Lichens
(v) *Aspergillus/Penicillium/Neurospora*

2.5 1. (i) *Penicillium notatum*
(ii) Yeast
(iii) *Puccinia graminis*
(iv) mycelium, *Rhizopus*
(v) spores
(vi) Ringworm, Athelete's foot

2. Alexander Flemming

3

KINGDOMS PLANTAE AND ANIMALIA

In the previous lessons you have learnt about the basic aspects of classifying organisms and about the three lower kingdoms: **Monera** (*prokaryotic, unicellular rarely multicellular and filamentous*), **Protoctista** (*eukaryotic, unicellular*), and **Fungi** (*eukaryotic, uni- or multicellular, and heterotrophic*). In this lesson, you will study about the remaining two kingdoms, **Plantae** (*eukaryotic, multicellular and autotrophic*) and **Animalia** (*eukaryotic, multicellular and heterotrophic*).

OBJECTIVES

After completing this lesson you will be able to

- *give the basis of inclusion of certain organisms in Kingdom Plantae;*
- *classify Kingdom Plantae upto divisions;*
- *give the typical characteristics of Algae, Bryophyta, Pteridophyta and Spermatophyta;*
- *classify the division Spermatophyta upto classes- Gymnospermae and Angiospermae;*
- *give the typical features of dicot families such as Malvaceae and Fabaceae;*
- *give the typical features of the monocot families such as Liliaceae and Poaceae;*
- *justify the inclusion of certain organisms in Kingdom Animalia;*
- *classify Kingdom Animalia upto Phyla;*
- *give the characteristics of various animal phyla with examples;*
- *classify Arthropoda and Chordata upto classes with examples;*
- *classify Mammalia upto major orders with examples.*

3.1 MAIN DIVISIONS OF KINGDOM PLANTAE (PLANTS)

Both plant and animal kingdoms include a wide variety of organisms which contribute towards the biodiversity on the planet earth. We shall now learn the classification of plants and animals.

Plants are multicellular, eukaryotic, photosynthetic autotrophs rarely heterotrophs having cellulosic cellwalls. All are embryophytes.

Plantae are classified as follows :

Kingdom Plantae (Embryophyta) is classified into the following divisions:

1. **Bryophyta :** Amphibians of plant kingdom, non-vascular.
2. **Pteridophyta :** True root, stem and leaves, vascular tissue present.
3. **Spermatophyta :** Seed producing, vascular tissues present.

Spermatophyta are further divided into:

(a) Gymnospermae : naked seeded plants. Seeds not enclosed in an ovary.

(b) Angiospermae : seeds enclosed in the ovary wall; are divided into :

(i) Dicotyledons : embryo with two cotyledons.

(ii) Monocotyledons : Single cotyledon in the embryo.

3.2 BRYOPHYTA (BRYOPHYTES)

Bryophytes are amphibians of plant kingdom as they complete their life cycle in both water and on land. These mainly grow in damp, shady places, especially in the hills.

- They are embryophytes that do not have vascular tissues (neither xylem nor phloem), where multicellular sporophytes are always borne on the gametophytes.
- No true leaves and roots, as their independent plant body is gametophytic (haploid).
- Sex organs are jacketed as they are always surrounded by one or several layers of sterile cells.

There are three main types of bryophytes

1. Flat, ribbon-like – Liverworts (*Marchantia*) Fig. 3.1(a)
2. Small, leafy plant body – Mosses (*Funaria*) Fig. 3.1(b)
3. Flat, thalloid plant body bearing a horn-like sporophyte – Hornworts or *Anthoceros*

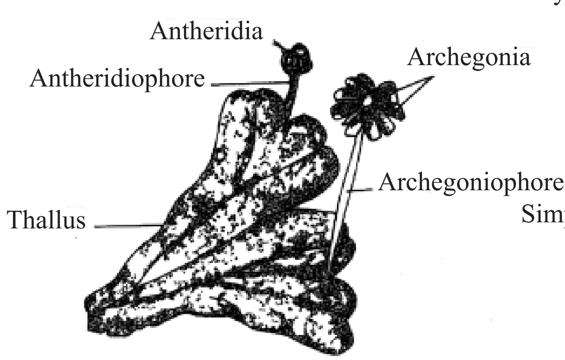


Fig 3.1(a) Liverworts (*Marchantia*)

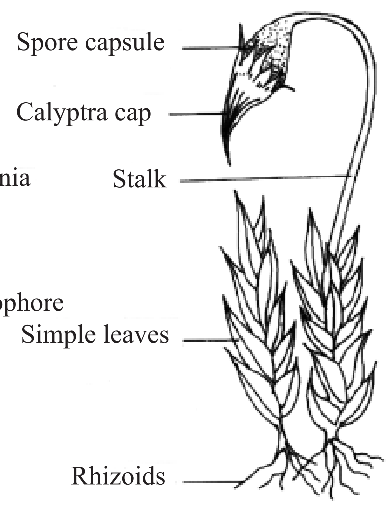


Fig 3.1(b) Moss plant (*Funaria*)

In all types of bryophytes, the main plant body is **gametophyte**, larger and more persistent and photosynthetically active which bears the sex organs. In mosses, the gametophytic plant body is a leafy stem called '**gametophore**' but in liverworts and hornworts the plant body is usually a thallus, that is ribbon-like or heart-shaped and bilaterally symmetrical. The body is without roots, stems and leaves. The plants are anchored to soil by rhizoids, which are unicellular in liverworts and hornworts and multicellullar in mosses. Rhizoids help in anchorage and also in absorption of water and minerals from the substratum. The male sex organs are **antheridia** and female sex organs are **archegonia**. The gametes are produced in the sex organs. Male and female gametes fuse to give rise to a zygote which develops into a **sporophyte**. Sporophyte remains attached to gametophyte and depends on it for food and minerals. The sporogenous tissue in the sporophyte undergoes meiosis to produce haploid spores. The spores, on dispersal, germinate to give rise to a gametophyte again.

Gametophyte (Undergoes Mitosis): Gamete producing phase of plants

Sporophyte (Undergoes Meiosis): Spore producing phase of plants

In all three types of bryophytes, the life cycle shows **Alternation of generations**.

Comparison of gametophytic and sporophytic phases of Bryophytes

Gametophytic phase	Sporophytic phase
1. Haploid phase, generally autotrophic	Diploid phase, heterotrophic or partially autotrophic
2. Has multicellular sex organs called antheridia and archegonia bearing sterile jacket surrounding the gametes	Has spore-producing structure
3. Produces gametes	Produces spores
4. Gametes are produced by mitosis	Spores are produced by meiosis
5. Dominant phase occupies most of the life period	Short-lived phase which remains attached to the gametophyte

- The bryophytes are pioneers of vegetation, i.e. they are the first ones to grow on various habitats like rock, lava, sand, water and act as soil binders.
- The mosses hold water better than the soil thus improve the microhabitat for seeds of other plants to grow.
- These are the sources of food for fish and birds and their dried plant body is used as nesting materials by birds.

INTEXT QUESTIONS 3.1

1. Mention one unique feature of bryophytes.

   ....

2. Define alternation of generations.

   ....

3. Name the male and female sex organs of bryophytes.

   ....

4. List the habitat most suitable for the growth of bryophytes.

3.3 PTERIDOPHYTA (PTERIDOPHYTES)

A fern plant is a pteridophyte. (Fig. 3.2)

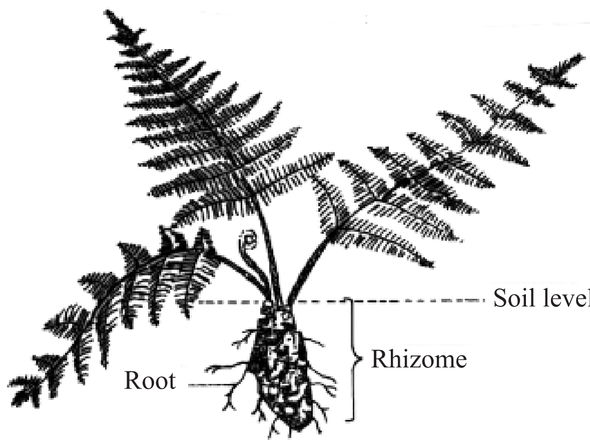


Fig. 3.2 A garden fern plant

1. Ferns are lower vascular plants. They contain vascular tissue. Which is made up of xylem and phloem and helps in conduction of water and nutrients to all parts of the plant body. Pteridophytes are usually found in damp, shady places or in the gardens, and on the hills where temperature is low.
2. The main plant body represents a sporophytic (diploid) generation and has roots which penetrate the soil to absorb water, and minerals.
3. The leaves (**fronds**) of sporophyte grow on thick, horizontal underground stem or **rhizome** which bears adventitious roots. The young leaves and the base of **fronds** are covered by dry brown scales (ramenta).
4. The young leaves and leaflets are characteristically circinately coiled structures (see Fig. 3.2*a*). The axis of the leaves is called **rachis** and leaflets on both sides of rachis are called **pinnae**. The divisions of pinnae are known as pinnules.
5. On the under surface of the leaves, develop spore-producing bodies called **Sporangia** in groups, called **sori** (singular - **sorus**) which may or may not be covered by multicellular structure called **indusium**. The sporogenous tissue in the sporangia undergoes meiosis to produce haploid spores.
6. The spores on dispersal germinate into an independent, small thallus–like body, the gametophyte, called **prothallus**. The prothallus bears antheridia and archegonia which produce male and female gametes respectively. The gametes fuse and the zygote develops into a diploid sporophyte.
7. The young embryo absorbs nutrients and water from the gametophyte until its roots and leaves are formed. The gametophyte then dies.
8. Gametophyte grows independent of sporophyte, and it lives for a short period of time but a new sporophyte is temporarily dependent upon a tiny gametophyte.

The gametophytic and sporophytic phases alternate as in bryophytes

INTEXT QUESTIONS 3.2

1. Name the dominant generation of pteridophytes.

   ....

2. The stage of pteridophytes which produces spores for continuing rest of the life cycle is.

   ....

3. Why do you classify pteridophytes under Trachaeophyta?

   ....

4. Name the male and female reproductive organs in pteridophytes?

   ....

5. Write the name of gametophyte of fern.

   ....

3.4 GYMSOSPERMAE (GYMNOS; NAKED, SPERMA; SEED)

Together with flowering plants Angiosperms, the Gymnosperms form the group Spermatophyta (sperma; seed, phyte; plant) i.e. seed-producing plants.

The gymnospermae bear naked ovules on flat scale leaves called ovuliferous scales which are not enclosed in carpels (ovary). The ovuliferous scales are arranged in cones.

Characteristics of Gymnosperms

1. The adult plant (sporophyte) is a tall, woody, perennial tree or shrub mostly evergreen. The stem is usually branched, but rarely unbranched as in, ***Cycas***.
2. Leaves may be simple (as in ***Pinus***) (Fig. 3.3a) or compound (as in ***Cycas*** Fig. 3.3b).
3. Leaves may be dimorphic or of one kind only. Foliage leaves are large green simple or pinnately compound, needle-like and grow on dwarf shoot as in, *Pinus*, or directly borne on the main trunk as in ***Cycas.*** Scale leaves are brown and simple.
4. Vascular bundles in stem are arranged in a ring and show secondary growth.
5 Gymnosperms bear cones which are usually unisexual (either male or female, Fig. 3.3c), rarely bisexual as in *Gnetum*.
6. Pollen grains are haploid produced in microsporangia of the male cones. In *Pinus*, each pollen grain has two large sacs, called wings to help in the dispersal by wind. Pollen grains produce two male gametes.
7. Ovules are not enclosed in ovary as in Angiosperms, but are borne naked on leafy megasporophylls of female cone, so the term gynmosperms or 'naked seeds' for this group. Ovules are produced side by side, inside which female gamete or egg is produced. The male gamete fuses with female gamete in the ovule. The fertilised ovule then develops into a seed (winged in case of *Pinus*).

Some common Gymnosperms are

Pine (*Pinus*), Redwood (*Sequoia*), Juniper (*Juniperus*), Cedar (*Cedrus*) and sagopalm (Cycas). Many gymnosperms yield timber, resins, turpentine, and several other products like the dry fruit chilgoza. Sago (sabutdana) is obtained from old stems of **Cycas**.

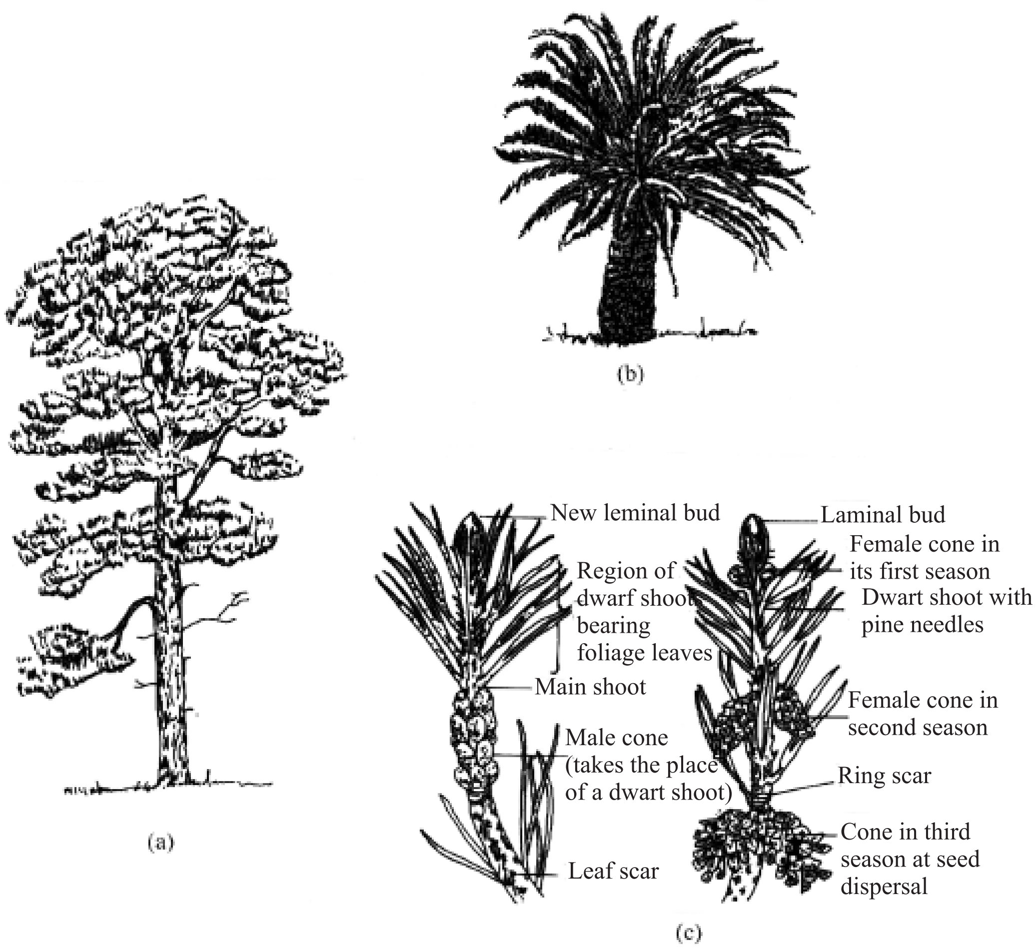


Fig. 3.3 Some examples of phylum Gymnosperm ae (a) *Pinus* tree (b) *Cycas* tree (c) tree with male and female cone

INTEXT QUESTIONS 3.3

1. What does the term gymnosperm mean?

   ....

2. Give any two common examples of gymnosperms.

   ....

3. List two commercial products of gymnosperms.

   ....

3.5 ANGIOSPERMAE

3.5.1 Angiosperms

A typical flowering plant

Our most familiar plants like pea, mango, coconut, wheat and rice come under the group called **Angiosperms**. Their seeds are always enclosed in the fruit. Which is a mature, fertilized ovary.

Look at an angiosperm plant in Fig. 3.4.

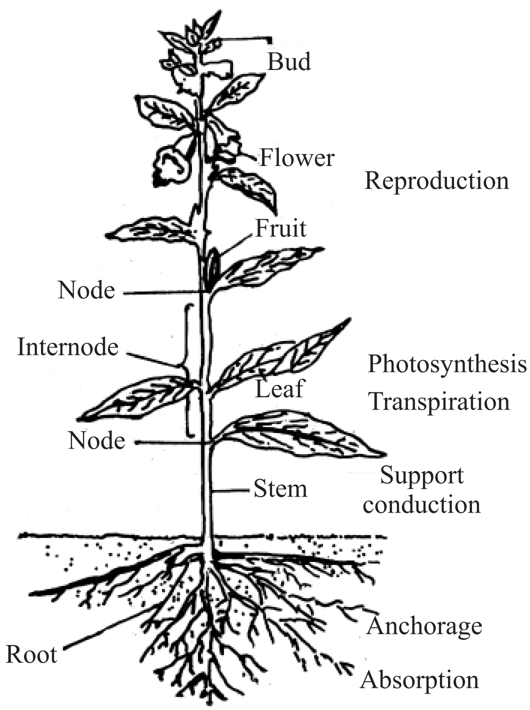


Fig. 3.4 The parts of an angiosperm our plant

The angiosperms are divided into two groups or classes:

1. Dicotyledons. 2. Monocotyledons.

Look at Fig 3.5 to study the differences between the two groups.

Angiosperms bear seeds enclosed in the fruits.

Dicot plants have two cotyledons in seeds whereas **Monocots** have only one cotyledon within the seeds.

Differences between angiosperms and gymnosperms

Gymnosperms	Angiosperms
1. Seeds naked as not enclosed in ovary.	Seeds enclosed in fruit (a mature, fertilized ovary).
2. Independent plants are sporophytes which bear cones where spores develop, that in turn give rise to gametophytes which in turn bear gametes.	Independent plants are sporophytes which bear flowers where reproductive spores develop, which produce gametophytes that in turn, bear gametes.
3. Xylem has mainly tracheids usually absent.	Xylem has both vessels as well as tracheids.

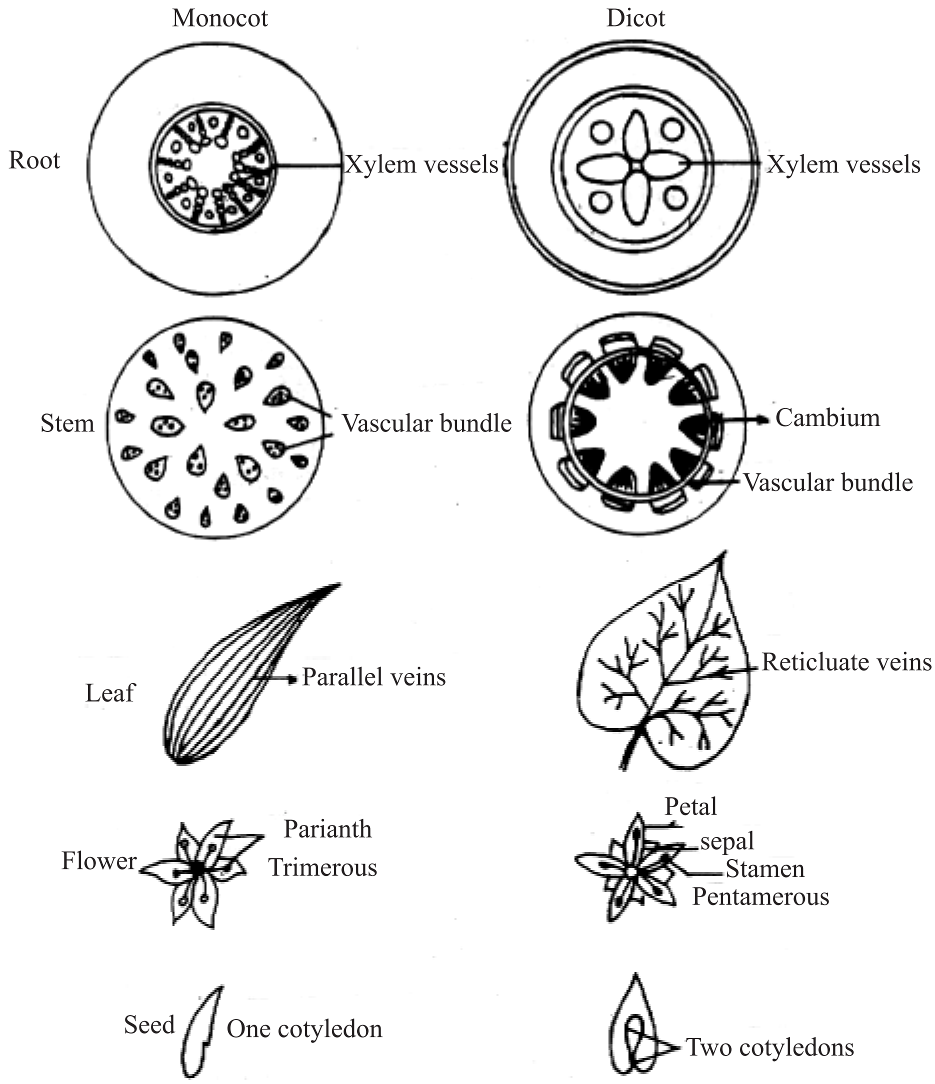


Fig. 3.5 Comparison of Monocots and Dicots

3.5.2 Some families of Angiosperms

Angiosperms include the most diverse and widespread members of the Kingdom Plantae.

Flowers offer a large number of characters which are constant and as such these are used for grouping of angiosperms into different families.

Within each family are included plants which show similarities in organization of various parts of the flower.

We shall study only four families: Two of dicots and two of the monocots

1. Fabaceae – Pea family : includes all the pulses
2. Malvaceae – China rose family
3. Liliaceae – Lily family
4. Poaceae – Grass family : includes cereals

Fabaceae Family (Papilionaceae) : A dicotyledonous family

The plants are herbs or shrubs and rarely trees. Flowers are zygomorphic (means a flower can be cut into two equal halves only through one radius), bisexual, complete, calyx consists of 5 sepals, jointed. Corolla comprise of 5 petals, polypetalous (papilionaceous in shape or butterfly shaped). There is a large petal called standard', two smaller ones called as 'wings and two interior small ones, more or less jointed forming the 'keel'. Androecium gas 10 stamens, arranged in two whorls (9+1) that is diadelphous condition (Fig. 3.6a). Gynoecium is superior, monocarpellary, unilocular with many ovules arranged on a marginal placenta. Fruit is

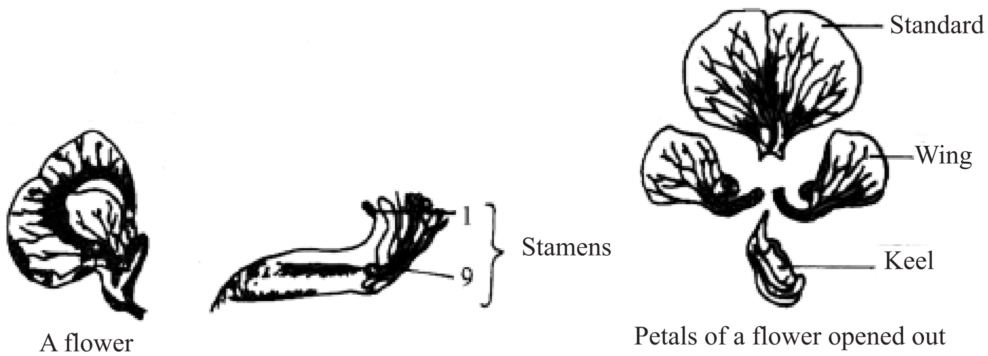


Fig. 3.6a A pea flower

Some examples of useful plants of Fabaceac

Common Names	Botanical Name
Pea (Matar)	*Pisum sativum*
Pigeon pea (Arhar)	*Cajanas cajan*
Green gram (Moong)	*Phaseolus aureus*
Soyabean	*Glycine max*
Lentil (Masoor)	*Lens culinaris*
Groundnut (Moong-phali)	*Arachis hypogea*
Chickpea (Chana)	*Cicer arietinum*

2. Malvaceae

The plants may be herbs, shrubs or trees.

Hibiscus rosa-sinensis (china-rose/shoe flower, vernacular; gurhal) is one of the best examples of this family. The flowers are large and attractive usually solitary axillary (See Fig. 3.6b).

Flowers are pentamerous (all whorls have members that are five or multiples of five), and actinomorphic (means that it can be divided into two equal halves through any radius). Epicalyx is present as an additional whorl of bracteole just below the calyx. Calyx has five sepals that may be free or joined at the base. Corolla has five petals usually free. Androecium consists of indefinite numbers of monadelphous stamens. The lower parts or filaments join together to formtion staminal tube. Gynoceium consists of 5 carpels, syncarpous, and ovary is superior, pentalocular, having axile placenta. Fruit is a capsule.

Cotton, Bhindi, and hollyhock are other examples of members of this family.

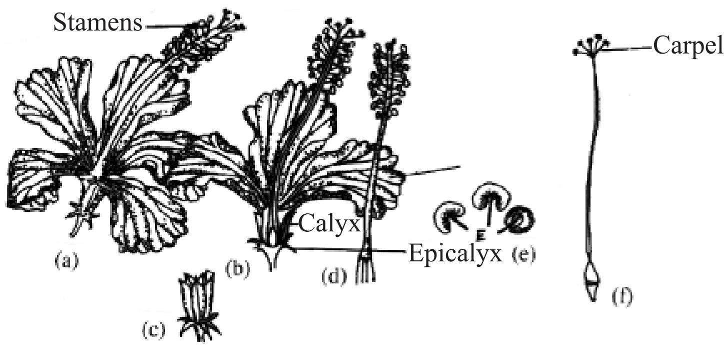


Fig. 3.6b A Chinarose flower

Liliaceae- A monocot family (Lily family)

The plants are mostly perennial herbs. The stem is a rhizome or bulb-like. Leaves may be fleshy, cauline (arising from the underground stem)

Flowers are bisexual, actinomorphic, mostly trimerous (all the whorls have either three units or multiples of three) and hypogynous. Perianth is large, petaloid (corolla-like) usually six, arranged in two whorls of three each, free or united.

Stamens usually six (3+3) in two whorls situated opposite to the perianth lobes. Carpels three, syncarpous, ovary superior, axile placentation. Fruit usually a capsule.

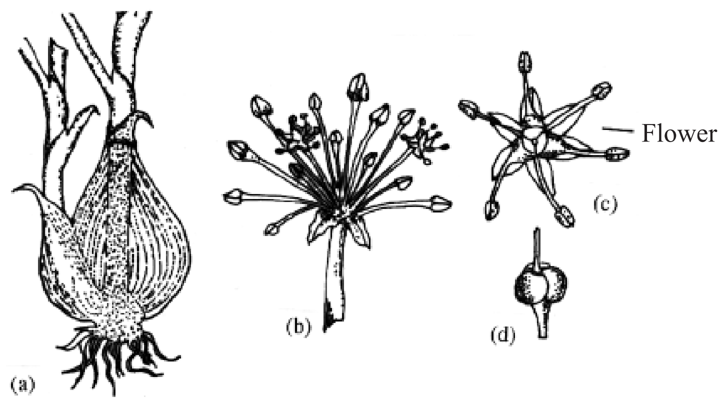


Fig. 3.6c An onion plant.

Some examples of useful plants of Liliaceace

Common names	Botanical names
Ghrit kumari	*Aloe barbadensis*
Shatawar or satmuli	*Asparagus racemosus*
Tulip	*Tulipa tulip*
Kalihari	*Gloriosa superba*
Lily	*Lilium candidum*
Onion	*Allium cepa*

Family Poaceae – A monocotyledonous family

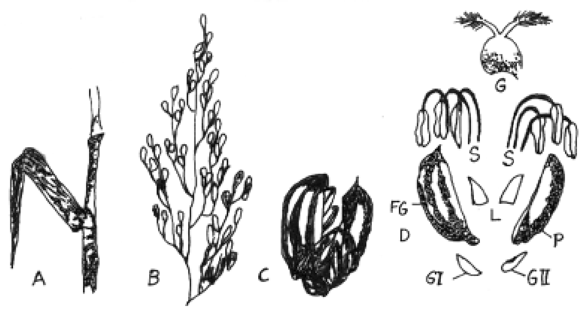
The plants are herbs, rarely woody as in sugarcane. inflorescence, spike of spikelets, For example, wheat. A small spikelet may contain not more than 5 flowers.

Flowers are very small, inconspicuous, with scale-like structures (Fig 3.6d).

Stamens are 3, sometimes 6 as in rice and bamboo, three carpels, syncarpous unilocular, ovary superior bearing a single basal ovule. Fruit is caryopsis (**seed coat and ovary wall inseparably fused**).

Some examples of useful plants of Poaceae

Common Names	Botanical Names
Rice	*Oryza sativa*
Wheat	*Triticum aestivum*
Maize	*Zea mays*
Sugarcane	*Saccharum officinarum*
Sarkanda	*S. spontaneum*
Barley	*Hordeum vulgare*



A. Portion of a branch with sheathing leaves and ligules;
B. A panicle of spikelets;
C. 1-flowered spikelet (note the glumes and stamens)
D. Spikelet dissected out
GI. First empty glume;
G II. Second empty glume;
FG. Flowering glume;
P. Palea;
L. Lodicules;
S. Stamens; and
G. Gynoecium.

Fig. 3.6d Rice plant (*Oryza sativa.*)

INTEXT QUESTIONS 3.4

1. Name one dicotyledonous and one monocotyledonous family.
2. Give the number of stamens in
   (a) Papilionaceae ....
   (b) Malvaceae ....
3. Give botanical names of
   (a) Rice ....
   (b) Arhar ....
   (c) Ghrit kumari ....
4. Where do seeds develop in angiosperms?
   ....

3.6 KINGDOM ANIMALIA

Includes the animals which animalia show a wide variety yet have some common features.

3.6.1 Few general features of kingdom animalia

- These are multicellular eukaryotes
- They have ingestive, heterotrophic nutrition.
- They have the power of locomotion.
- They show increased senstivity through nervous system.

Basis of classification of animals

Organization, symmetry, body cavity, number of embryonic cell layers and presence or absence of notochord are the features used for distinguishing broad categories of animals.

Organization : Bodies of animals are multicellular. although then cells may or may not be organised into tissues and organ systems. Animals such as sponges are aggregates of cells. These are at **cellular level** of organisation. Cnidarians have groups of cells performing specialised functions. They are at **tissue level** of organisation. All other animals have organs and systems for performing body functions. They are at **organ-system** grade.

Symmetry : means *dividing the body into two equal and identical parts*. Sponges are **asymmetrical**. Cnidaria and Echinoderm larvae are radially symmetrical. All other animals are **bilaterally symmetrical or dorsiventral**.

Body Cavity or Coelom : is a cavity between body wall and food canal. It is not present in Acoelomates (a = no, coelom = body cavity) and is present in Eucoelomates (eu = true). Pseudocoelom (pseudo = false) is not a true body cavity. It is found in roundworms.

Embryonic layers : Three layers of cells, ectoderm, mesoderm and endoderm in the embryo (germinal layers) give rise to various parts of the body of the animals. Sponges and Cnidaria do not have mesoderm in their embryos. They have two germinal layers ectoderm and endoderm (diploblastic). Others have three germinal layers (triploblastic).

Notochord : is a solid found in embryonic stage or adults of some animals which are grouped as **phylum Chordata**. All animal groups lacking notochord are termed, **non-chordates**.

Kingdom Animalia
(Multicellular Eukaryotic Heterotrophs)

Sub-Kingdom

	Parazoa		Eumetazoa
	(a) No symmetry		(a) Symmetrical
	(b) No tissues (cellular grade of organisation)		(b) Tissue and organ. grade of organisation
	Phylum Porifera		
Organisation and germinal layers	(a) Tissue grade of organisation		(a) Organ system grade of organisation.
	(b) Two embryonic germ layers. (diploblastic)		(b) Three embryonic germ layers (triploblastic)
	Phylum Cnidaria		All other Phyla
Symmetry	Asymmetrical ↓ **Phylum Porifera**	With Radial Symmetry ↓ **Phylum Cnidaria**	Bilateral Symmetry ↓ **All other phyla**
Body Cavity	Aoelomates (No coelom) ↓ **Phyla Porifera, Cnidaria Platyhelminthes**	Pseudocoelomates (False coelom) ↓ **Phylum Aschelminthes**	Eucoelomates (True coelom) ↓ **All other Phyla**
Notochord	Presence or absence of	no notochord	Notochord at some stage of life
	Notochord	**Non-chordata**	**Chordata**

3.6.2 Major phyla included in Kingdom Animalia

Phylum Porifera (Includes sponges)

Main characters:

- Body with many pores, canals or chambers through which water flows is called the **canal system**.
- large aperture called **osculum** at the upper end.
- Body encloses a large cavity **spongocoel**.
- No organs, movable parts or appendages. Different kinds of cells perform different functions.
- Usually with an internal skeleton of calcareous or siliceous **spicules**, or of **spongin** fibres, or both.
- Reproduction asexual by budding; also sexual.
- Almost all marine.

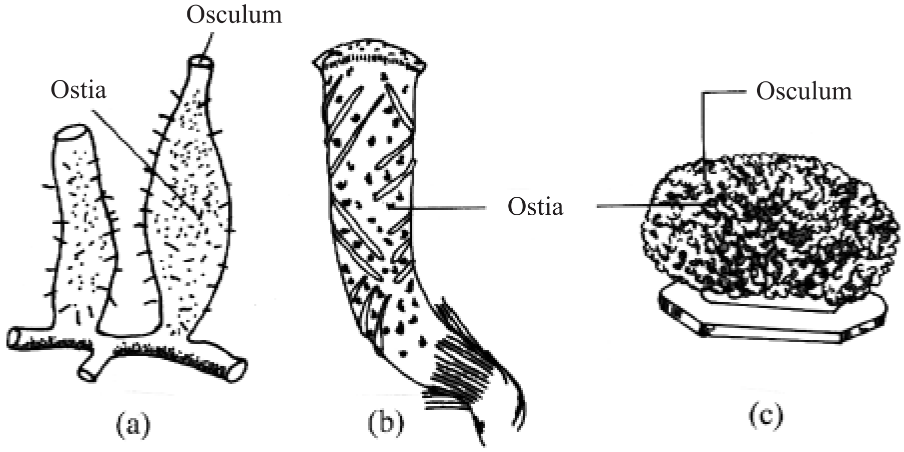


Fig. 3.7 : Phylum Porifera (a) *Sycon;* (b) *Euplectlella;* (c) *Euspongia*

2. Phylum Cnidaria (Includes hydroids, jelly fishes, sea anemone and corals)

Main Characters:

- Body with no head and no segmentation.
- Body wall two layered: external epidermis and inner gastrodermis, jelly-like, non-cellular mesogloea in between.
- Cnidoblasts (stinging cells) present, help to catch prey (carnivorous)
- Skeleton calcareous, horny or none.
- Asexual reproduction by budding in the sessile (polyp) stage, and sexual reproduction in free swimming (medusa) stage.
- Radial symmetry
- All marine, except Hydra (found in fresh water)
- Either fixed like hydra, sea-anemones and corals, or free floating like the jelly fish.

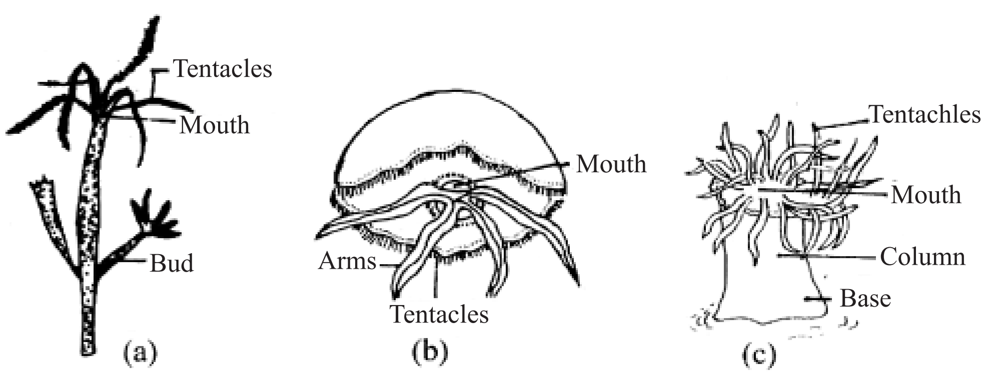


Fig. 3.8 Three common Cnidarians (a) Hydra (b) Jelly fish (c) Sea Anemone

3. Phylum Platyhelminthes (Flat worms)

Main Characters:

- Elongated, soft bodied, dorsoventrally flattened worms, without true segmentation.
- No body cavity

– Suckers or hooks or both for attachment to the body of the host
– Sexes usually united, mostly sexual reproduction, with asexual reproduction in some.
– Alimentary canal has only one opening–the mouth. In some forms (e.g. tapeworms) there is no alimentary canal at all.
– A few are free-living but mostly parasites.

Examples: *Planaria* (free living),
Fasciola (liver-fluke) is a parasite of sheep liver, *Taenia* (tapeworm) is a parasite of the human intestine.

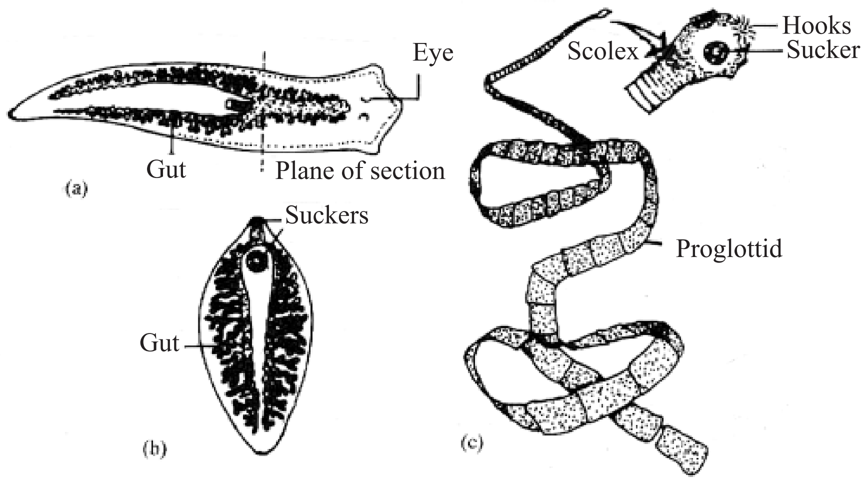


Fig. 3.9 Phylum Platyhelminthes (a) *Planaria* (b) *Fasciola* (c) *Taenia*

3. Phylum Aschehelminthes (Class Nematoda)

(Roundworms, thread worms)

Main characters:

– Elongated cylindrical round body
– Body cavity is a pseudocoelom (false body cavity)
– Alimentary canal opens at the two ends, mouth and anus.
– Sexes separate, males smaller than females (Fig 3.10).
– Mostly parasitic in animals but some live freely in the soil.
– *Ascaris* is a common roundworm, parasitic in the intestine of humans.
– Pinworm and *Wucheria* (Filariaworm) are some other examples.

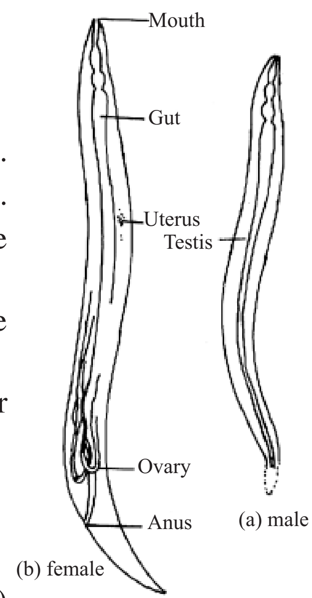


Fig. 3.10 *Ascaris* (a) Female (b) Male

4. Phylum Annelida (Includes earthworms)

Main characters:

– Elongated, segmented, coelomate (true body cavity) worm-like animals.
– Body provided with setae or parapodia for locomotion.

– Well developed digestive system with the alimentary canal open at both the ends.
– Excretory organs called **nephridia**.
– Sexes united (as in earthworm) or separate (as in *Nereis*).
– Regeneration quite frequent.
– Aquatic, some terrestrial animals, some living in tubes and some even parasitic.

Examples: *Nereis*, Earthworms like *Pheretima* (free-living in soil), *Hirudinaria* (leech, a parasitic on cattle, See figure 3.11.

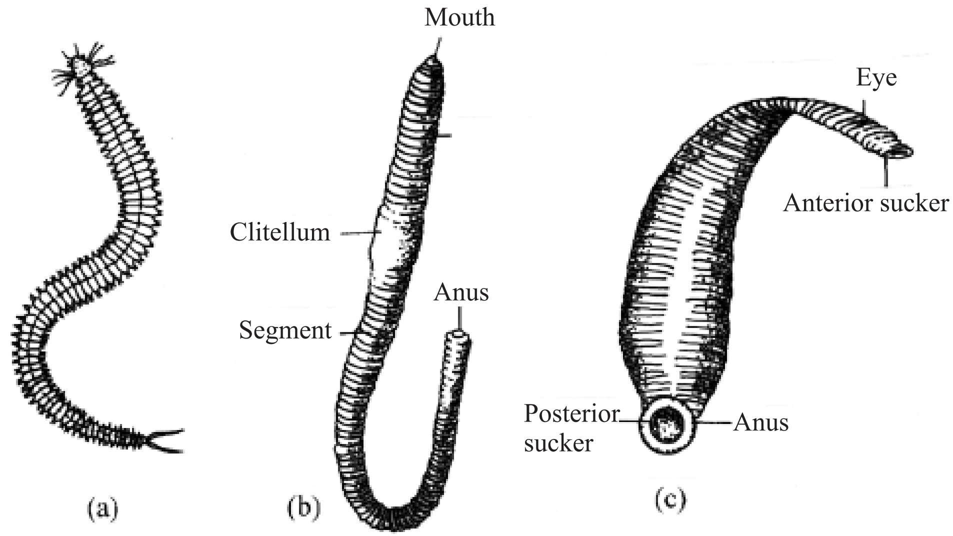


Fig. 3.11 Annelids (a) *Nereis* (b) *Pheretima* (c) *Hirudinaria*

6. Phylum Arthropoda (includes Crab, scorpion, insect, spiders etc.)

Main Characters:

– Segmented body, can be differentiated into head, thorax and abdomen
– Head and thorax often fused to form **cephalothorax**
– Jointed legs for locomotion, one pair each on some or all body segments
– Exoskeleton of chitinous cuticle, shed at intervals (moulting)
– Sexes usually separate.

Arthropods are further divided into classes.

(i) Crustacea (ii) Myriapoda (iii) Insecta (iv) Arachnida

Classification

Phylum Arthropoda

Class 1 Arachnida	Class 2 Crustacea	Class 3 Myriapoda	Class 4 Insecta
(a) Cephalothorax with 2- chelicerae, 3- pedipalpi, and 4 pairs of walking legs	(a) body covered with dorsal covering called carapace	(a) Body with numerous segments	(a) body divisible into head, thorax, and abdomen.

(b) abdomen usually without legs	(b) cephalothorax with 13 pairs of legs in appendages sexes usually separate	(b) each segment bearing 1-2 pairs of legs terrestrial and air-breathing arthropods	(b) thorax 3-segmented with 3 pairs of legs in each segment usually 2 pairs of wings on the last two thoracic segments.
(c) eyes simple	(c) eyes compound	(c) eyes compound	(c) eyes compound
(d) sexes separate	(d) sexes separate	(d) sexes separate	(d) sexes separate
(e) Example scorpion (Fig. 3.12a)	(e) Example Prawn (Fig. 3.12b)	(e) Example (Scolopendra) and Millipede (Fig. 3.12c)	(e) Example: Cockroach (Fig 3.12d)

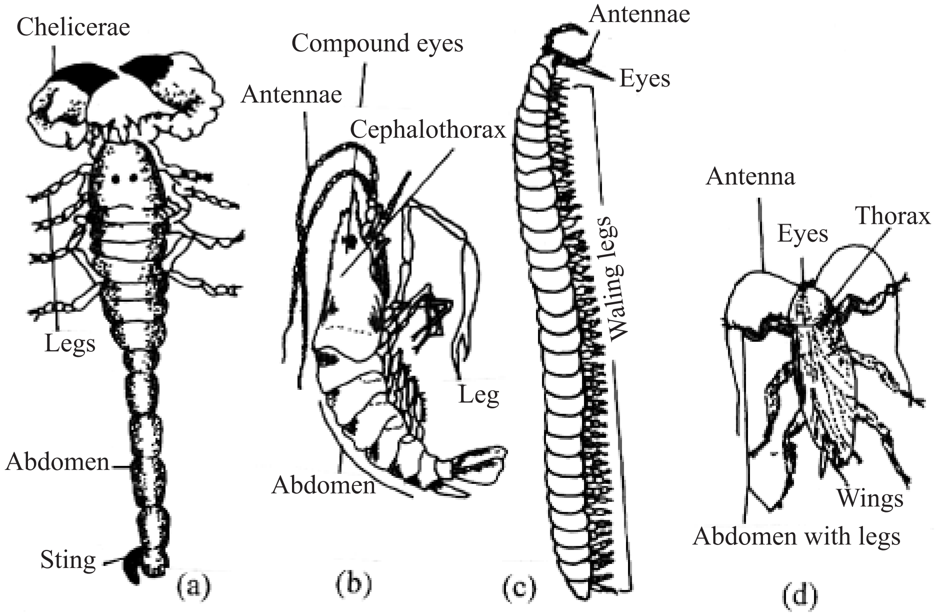


Fig. 3.12 Arthropods (a) Scorpion; (b) Prawn; (c) Millipede; (d) Cockroach

7. Phylum Mollusca (includes squids, snails and oysters)

Mollusca

These animals have a soft, unsegmented body, with a hard, calcareous shell to protect the soft body. They have a muscular foot to help in locomotion and also to act as a weapon in some cases. Examples: snails, slugs, oysters, mussels, clams, squids, and octopuses (Fig. 3.13).

Main Characters.

- Unsegmented soft-bodied animals terrestrial or aquatic,
- Exoskeleton in the form of a shell. When present shell is usually univalved or bivalved; internal shell present in some.
- Sexes separate or united.
- Have a muscular foot for locomotion.

Examples. Apply snail (*Pila*), Freshwater mussel (*Unio*), Cuttlefish (*Sepia*), Slugs, Octopus.

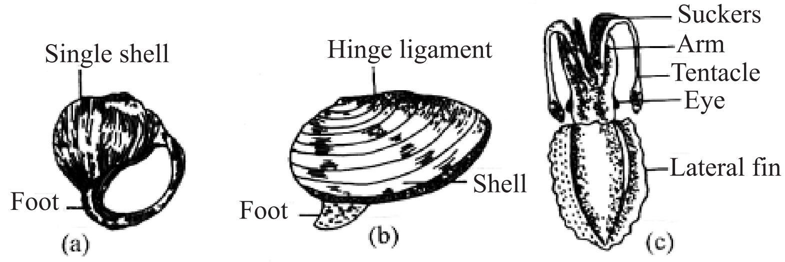


Fig. 3.13 Three molluscs (a) *Pila* (b) *Unio* (c) *Sepia*

8. Phylum Echinodermata (Includes starfishes, brittle stars, sea urchins, sea cucumbers)

Main Characters:

- Marine animals, with unsegmented body.
- Head absent, body surface marked with 5 radiating areas.
- Radial symmetry.
- Endoskeleton of dermal calcareous ossicles with spines.
- Movement by tube feet.
- Sexes usually separate.
- Regeneration of lost parts a peculiarity.
- Adults are radially symmetrical, but the larvae are bilaterally symmetrical.

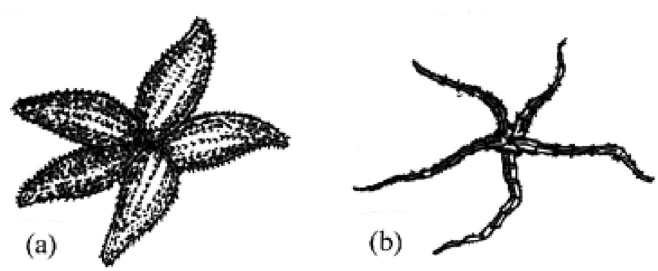


Fig. 3.14 Echinoderms (a) Asterias (b) Ophiara

INTEXT QUESTIONS 3.5

1. Member of which phylum possesses the cnidoblasts?

   ....

2. What do the earthworms possess which help them in locomotion?

   ....

3. Are all the Platyhelminthes parasites?

   ....

4. How many pairs of legs do the following have

   (i) Insects; ....

   (ii) Scorpions; ....

(iii) Spiders ....

5. Name the organs by which the starfish move?

....

6. Give two examples of the Phylum Arthropoda :

....

7. Name the phyla which have the following characteristics :
   (i) Tube feet. ....
   (ii) Cnidoblasts ....
   (iii) Chitinous exoskeleton ....
   (iv) Jointed legs ....
   (v) Nephridia ....
   (vi) Flattened body and a gut without anus. ....

3.9 PHYLUM CHORDATA

Main Characters:

– Notochord present at some stage of life, in most cases replaced by backbone.
– Dorsal tubular nerve cord.
– Gill slits present at some stage of life. (larva or adult)
– Body with a head and trunk and two pairs of appendages.

Classification

Phylum Chordata

1. Subphylum Urochordata	2. Subphylum-Cephalochordata	3. Subphylum Vertebrata
(a) Notochord present only in larval stage. (uro-tail)	(a) Notochord and nerve cord remain present throughout the life and extend through entire length of the body.	(a) Notochord replaced by vertebral column (back bone)
(b) Body bag-shaped, covered by a particular tunic or testa in adult stage.	(b) Body elongated and flattened from sides.	(b) Body with well developed head and paired fins or limbs. Cartilaginous or bony endoskeleton
(c) Limbs absent	(c) Limbs or paired fins absent.	(c) paired limbs present (tetrapoda)
(d) Dorsal tubular nerve cord present in the larval forms and reduced in adult.	(d) Dorsal tubular nerve cord present in adults.	(d) Dorsal tubular nerve cord present which is divided into brain and spinal cord.
(e) Example: *Herdmania* (Fig. 3.15a)	(e) Example: *Amphioxus* (Fig 3.15b)	(e) Examples.: All animals with backbone (Fig. 3.15c)

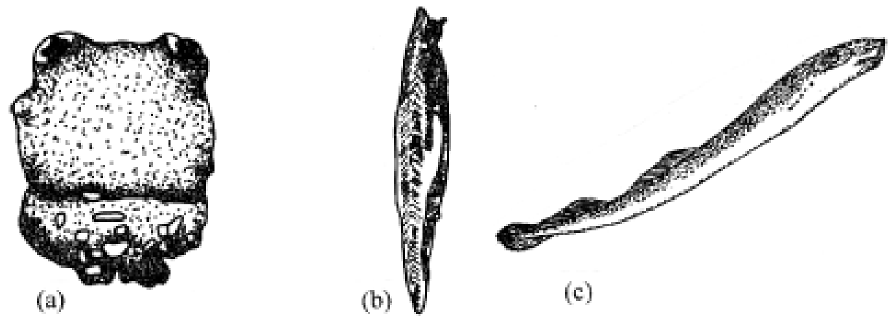


Fig. 3.15 Chordates (a) *Herdmania* (b) *Amphioxus* (c) *Petromyzon*

The subphylum vertebrata has 2 super classes Agnatha (jawless vertebrate) and Gnathostomata (jawed vertebrata)

Super-class Agnatha (A, no ; Gnathos : jaw)	Super-class Gnathostomata
(jawless vertebrates)	(jawed vertebrates)
Class : Cyclostomata	Class (1): Chondrichthyes
(Cyclo = circular, Stoma = mouth)	Class (2): Osteichthyes
– no jaws	Class (3): Amphibia
– 7 pairs of gill-slits	Class (4): Reptilia
– no paired fins	Class (5): Aves
– eg. Petromyzon (Lamprey) (Fig. 3.15)	Class (6): Mammalia

The two classes of fish include the cartilaginous and bony fish. Fishes are aquatic animals, gill breathing and move with the help of scales.

Class 1. Chondrichthyes

(Gk, Chondro = cartilage; ichtyes = fish)

– mouth ventral
– tail heterocercal
– Skeleton cartilaginous
– Five to seven pairs of gills
– Operculum (gill cover) absent

Example: *Scoliodon* (*dog-fish*) (Fig 3.16a)

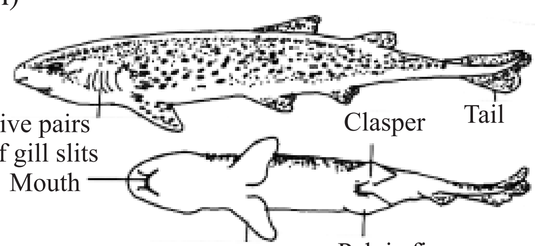


Fig. 3.16a Scoliodon

Class 2. Osteichthyes

(os = bone; ichthyes = fish)

– Mouth terminal
– Tail homocercal
– Skeleton bony
– Four pairs of gills
– Operculum present

Example : *Labeo* (Rohu) (Fig. 3.16b)

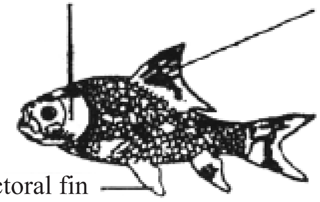


Fig. 3.16b Labeo

INTEXT QUESTIONS 3.6

1. Name the following
   (i) The category of animals possessing backbone.
   ....
   (ii) The group of backboned animals but having no jaws.
   ....
   (iii) Any one cartilaginousfish.
   ....
2. State one difference between cartilaginous and bony fishes.
   ....
3. Name one bony fish.
   ....
4. List the three main characters of the phylum Chordata.
   ....

Class 3 : Amphibia (amphi: double or both, "bios" : life referring to life on land as well as in water)

Main characters:

– The animal partly live in water and partly on land.

– Skin smooth or rough, rich in glands.

– Two pairs of limbs; pentadactyl (five-fingered), digits without claws.

– Body with distinct head and trunk, no neck.

– Two nostrils opening into the buccal cavity.

– Tympanum present on surface of body wall.

– Eggs are laid in water.

– In the early stage of life (larvae), they breathe by means of gills, but adults breathe by lungs.

– Heart three-chambered.

– Larval stage tailed and aquatic.

Some are tailed (salamander) and some are tailless (Frog, Toad)

Examples : *Salamandra*, *Proteus* (Fig. 3.17a), *Rana* (Frog, Bufo Toad (Fig. 3.17b) *Ichthyophis* (Fig. 3.17c)

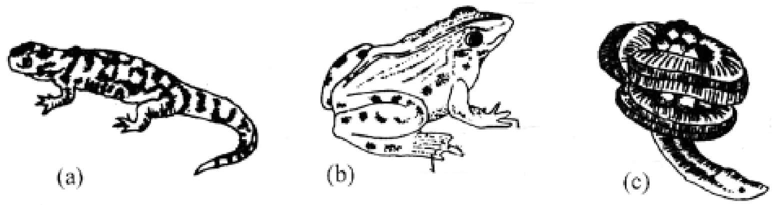


Fig. 3.17 *Amphibian* (a) *Salamandra* (b) Frog (c) *Ichthiophis*

INTEXT QUESTIONS 3.7

1. How many chambers are there in an amphibian heart?

   ....

2. Name one tailless amphibian.

   ....

3. What is the literal meaning of the term "amphibia".?

   ....

Class 4 : Class Reptilia (reptere: to crawl) : are four-legged or legless crawling animals whose body is covered by scales. they lay eggs on land

Characteristic features:

- Terrestrial (live on land), or some are aquatic (live in water).
- Body covered with horny scales.
- Skin is dry.
- Paired pentadactyl limbs (absent in snakes) with clawed digits.
- Tympanum small and depressed (absent in snakes).
- Respiration by lungs.
- Heart three-chambered but with a partially divided ventricle (4- chambered in crocodiles).
- Their eggs have leathery shell.

Examples : Tortoise, turtles, garden lizard (calotes) wall lizard (*Hemidactylus*), cobra (*Naja naja*) and crocodile (*Crocodilus*) and Gharial (*Gravialis*)

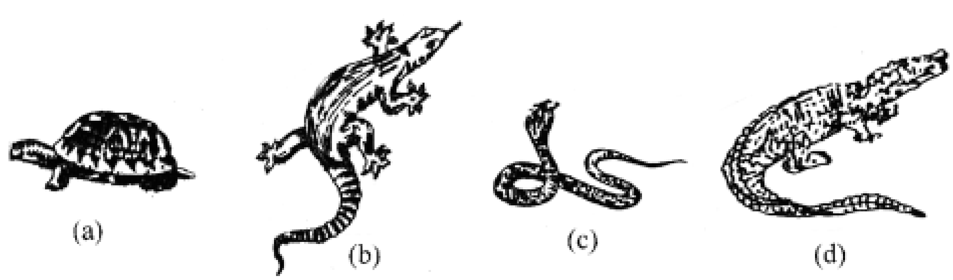


Fig. 3.18 Reptiles (a) Turtle (b) Wall lizard (c) Cobra (d) Crocodile

Class (5) Class : Aves (avis = Bird)

Characteristic features:

- Warm-blooded (homoiothermal, also called endothermal i.e. body temperature remains constant).
- Body covered with feathers, scales are present only on hind-limbs
- Body is divisible into three parts: head, neck and trunk.
- Jaws with horny beak, no teeth.
- Hind-limbs with four digits adapted for perching, walking or swimming
- Bones with air spaces to make the skeleton light (pneumatic bones).
- Forelimbs modified into wings for flight.
- Heart 4-chambered, lungs for respiration connected with air-sacs.
- Voice-box or **syrinx** (present at the junction of trachea and bronchi).
- Only left ovary and oviduct present in the females (economy in body weight.)
- All oviparous (lay eggs), egg with much yolk and calcareous shell.

Example : *Struthio* (Ostrich), *Abteryx* (Kiwi), *Pavo* (Peacock) *Columba*, (Pigeon), Corvus (Crow), etc. (Fig. 3.19).

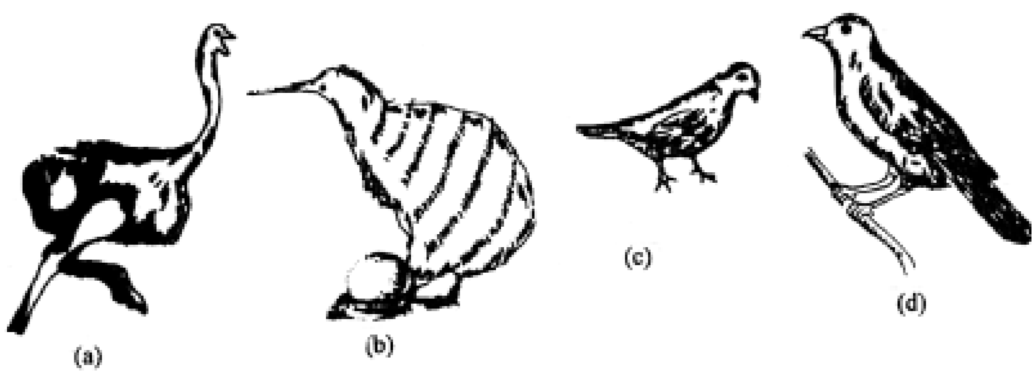


Fig. 3.19 Aves (a) Ostrich (b) Kiwi (c) Pigeon (d) Crow

INTEXT QUESTIONS 3.8

1. Name an aquatic reptile.

   ....

2. How many chambers are there in the heart of a:

   (i) lizard; ....

   (ii) crocodile ....

3. What is the voice box in birds called?

   ....

Class (VI) Mammalia (Mamma : breast)

Characteristic features:

- Body covered with hair.
- Presence of milk (Mammary) glands.
- Sweat and oil glands present in the skin.
- Body divisible into head, neck, trunk and tail; tail absent in some.
- Projecting external ears (pinna) present.
- Digits usually ending in claws, nails or hoofs.
- Dentition thecodont (teeth in sockets of jaw bones) and generally heterodont (four different types).
- Seven neck vertebrae
- Homoiothermal, warm blooded and heart four-chambered.
- Testes are extra-abdominal (not within abdominal cavity) contained in scrotal sacs
- Viviparous, give birth to the young, some primitive mammals are oviparous (lay eggs).
- Foetus is nourished by mother through placenta.

Classification of Class Mammalia

1. Sub-class Prototheria	2. Sub-class Metatheria	3. Sub-class Eutheria
(a) No external ear. (b) Teeth found only in young (c) Placenta absent (d) Mammary glands are devoid of nipples (e) Females are oviparous. Example: Duck-bill platypus (Ornithorhynchus) (Fig. 3.20a)	(a) External ear present. (b) teeth found in both young and adults (c) No placenta for nourishment to the embryo (d) Mammary glands present (e) Immature young ones are born. Marsupium (pouch) is present in females Example: Kangaroo (Macropus) (Fig. 3.20b)	(a) External ear well developed (b) Teeth present in young as well as adults. (c) Placenta is present (d) Mammary glands present (e) Mature young ones are born (For further classification and examples, see below).

Fig. 3.20 (a) Duck-billed Platypus (b) Kangaroo

> **Birds and mammals have a constant body temperature. The are termed homoiothermal.**

Sub-class Eutheria has been divided into a number of orders. Some important ones are as follows:

Order 1 : Rodentia

- Herbivorous and terrestrial.
- Incisors long, sharp and chisel-shaped.
- Forelimbs shorter than the hindlimbs.

Example: Rat, Squirrel (Fig. 3.21).

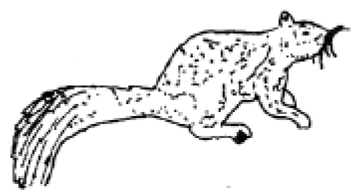


Fig. 3.21 Squirrel

Order 2 : Cheiroptera:

- These are flying mammals.
- Fore-limbs adapted for flight.
- Skin folded i.e. patagium works as wing.
- Hind-limbs thin and short.
- Nocturnal (active at night).
- Bats have poor eyesight. They avoid colliding against objects by **echolocation** in which the bat emits supersonic waves which are reflected back from the objects and the bat can perceive the reflected waves to determine the position of the object. The method is very similar to radar.

Example- Bat (Fig. 3.22)

Fig. 3.22 Bat

Order 3. Carnivora

- Flesh-eating mammals.
- Large pointed and sharp canines to tear the flesh.
- Fingers with sharp claws.

Example: Lion, Tiger, Cat, Dog (Fig. 3.23).

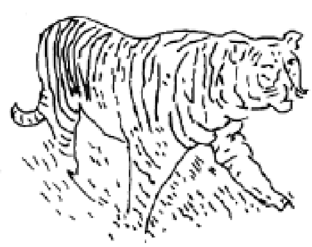


Fig. 3.23 Tiger

Order 4. Primates

- Highly developed brain.
- Eyes are set forward in the head to provide binocular (depth-perception) vision

– The neck is mobile.
– Limbs have five digits with flat nails.
– The thumb of the hand and the greater toe of the feet are opposable (for grasping)
– Two thoracic mammae (breasts) present.

Example: Monkey, Apes, Man (Fig. 3.24).

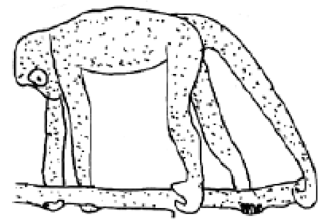


Fig. 3.24 Monkey

Order 5. Cetacea

– Aquatic.
– Fore-limbs are changed into paddles.
– No neck.
– Fish-like shape but respiration by lungs.

Example: whale (Fig. 3.25)

Fig. 3.25 Whale

Order 6. Proboscidea

– Large, herbivorous, terrestrial.
– Fusion of upper lip and nose to form a long mobile trunk.
– Only one pair of incisors in upper jaw which form huge tusks in males.

Example: Elephant (Fig. 3.26).

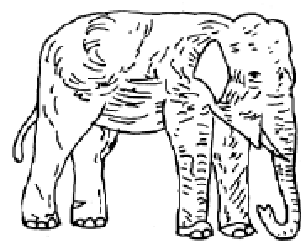


Fig. 3.26 Elephant

Order 7. Ungulata

– Hoofed mammals.
– Herbivorous.
– Usually domesticated by man.
– Mammae are abdominal with teats.

Example: Deer, Cows, Sheep (Fig. 3.27)

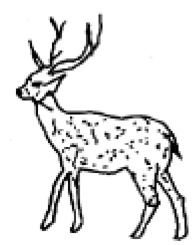


Fig. 3.27 Deer

INTEXT QUESTIONS 3.9

1. Match the items in Column I with those in Column II

Column I		Column II	
(i)	Humans	(a)	Carnivora
(ii)	Platypus	(b)	Ungulata
(iii)	Tiger	(c)	Primates
(iv)	Whale	(d)	Prototheria
(v)	Horse	(e)	Metatheria
(vi)	Kangaroo	(f)	Cetacea

2. Name the Group of Mammals which includes
   (i) Egg-laying mammals ....
   (ii) Pouched mammals ....
   (iii) Flesh-eating mammals ....
   (iv) Aquatic mammals ....
   (v) Flying mammals ....
3. For which characteristic feature are certain animals placed in class mammalia?
   ....
4. Name a mammal which has marsupium.
   ....
5. Which group of chordates possesses hair?
   ....

WHAT YOU HAVE LEARNT

- Animals are multicellular eukaryotes with heterotrophic nutrition, locomotion and sensitivity through nervous system.
- They may be at cellular grade of organisation (Phylum Porifera), tissue grade (Phylum Cnidaria) or organ grade of organisation (other animal phyla).
- Their body may be asymmetrical (Porifera), radially symmetrical (Cnidaria), or bilaterally symmetrical (other animal phyla).
- Kingdom Animalia is divided into two groups: Non-chordates and Chordates.
- Non-chordates are included in three sub phyla Urochordata, Cephalo-chordata and Vertebrata. Vertebrata has super classes-Agnatha (Jawless) and Gnathostomata (possessing jaws).
- Gnathostomata includes six classes – Chondrichthyes (cartilaginous fishes), Osteichthyes (bony fishes), Amphibia (frog), Reptilia (lizard) Aves (birds) and Mammalia (rat)
- Porifera are characterised by ostia, osculum, spongocoel and canal system.
- Cnidaria have cnidoblasts (stinging cells), coelenteron and the polyp and medusoid forms.
- Platyhelminthes (flat worms) include some free-living but mostly parasites like tapeworm and liver fluke.
- Class Nematoda of phylum Aschelminthes includes roundworms.
- Annelida (Earthworms) show metameric segmentation and have nephridia.
- Arthropods have jointed appendages and chitinous cuticle as their exoskeleton.
- Mollusca includes soft-bodied animals covered by a calcareous shell.

- Echinodermata includes spiny-skinned, marine animals which have tube feet for locomotion.
- Chordates have (i) a notochord (ii) a dorsal hollow nerve cord and (iii) gill slits at some stage of the life.
- Amphibians live on land as well as in water. Their limbs have no claws.
- Reptiles have horny scales covering the body. They are mostly terrestrial.
- Class Aves includes birds–the flying vertebrates with forelimbs modified into wings.
- Mammals possess hair and mammary glands which secrete milk to feed the young ones.
- Kingdom Plantae is classified into two divisions i.e. Bryophyta and Trachaeophyta.
- Bryophytes are amphibians of plant kingdom and are non-vascular.
- Main plant body of Bryophytes is a gametophyte; sporophyte remains attached to gametophyte.
- The main plant body of Pteridophytes is a sporophyte.
- All groups of Plantae show alternation of generations
- Gymnosperms and Angiosperms are seed-producing plants.
- In Gymnosperms seeds are naked, whereas in Angiosperms seeds are enclosed in ovary.
- Main difference between dicotyledonous and monocotyledonous plants is number of cotyledons in the embryo.
- Brassicaceae and Fabaceae are dicot families, whereas Poaceae and Liliacea, are monocot families.

TERMINAL EXERCISES

1. List the main groups of Kingdom Plantae.
2. Give the two main types of Bryophytes.
3. Differentiate between gametophyte and sporophyte.
4. Define alternation of generations.
5. Why are Pteridophytes grouped under Trachaeophyta?
6. Differentiate between Angiosperms and Gymnosperms.
7. Give three main differences between dicot and monocot plants.
8. Name three families of Angiosperms giving one character of each family.
9. Define an animal.
10. With examples name (i) the three kinds of symmetry and (ii) the three grades of organisation met within the Kingdom Animalia.

11. Explain the term triploblastic.
12. Name the major non-chordate phyla. Give one characteristic feature and one example of each.
13. Give one major difference between
    (i) Cyclostomes and other fishes
    (ii) Chondrichthyes and Osteichthyes, Cite examples.
14. Why are frogs included in the class Amphibia?
15. Give two characteristic features of reptiles. Cite examples of five reptiles
16. Give three features of birds which adapt them to aerial life and give two examples of flightless birds.
17. Give three features of mammals and one difference between Prototheria, Metatheria and Eutheria.
18. Name any five orders of Mammalia, Give one characteristic feature and one example of each.

ANSWERS TO INTEXT QUESTIONS

3.1
1. They complete their life cycle in water and land.
2. Alternation of gametophytic phase with sporophytic phase.
3. Antheridia and Archegonia
4. Cool and humid place.

3.2
1. Sporophytic 2. Sporophyte 3. They have vascular tissues
4. Antheridia and Archegonia 5. Prothallus

3.3
1. Naked seeds 2. *Cycas* and *Pinus* 3. Timber, resins

3.4
1. Fabaceae, Poaceae. 2. 10, infinite
3. (i) *Oryza sativa* (ii) *Cajanus cajan* (iii) *Aloe barbadumins*
4. In the Ovary after fertilization

3.5
1. Cnidaria 2. Cetae 3. No
4. (i) 3 (ii) 4 (iii) 3
5. Tube feet 6. Prawn, Millipede or any other
7. (i) Echinodermata (ii) Cnidaria
   (iii) Arthropoda (iv) Arthropoda
   (v) Annelida (vi) Platyhelminthes

3.6 1. (i) Vertebrata (ii) Agnatha (iii) Scoliodon

2. Endoskeleton bony in bony fishes and cartilaginous in cartilaginous fishes

or

5 to 7 pairs of gills in cartilaginous fishes and 4 pairs in bony fishes.

3. *Labeo, Catla*.

4. 1. notochrod at some stage of life

2. dorsal tubular nerve cord

3. gill slits at some stage of life.

3.7 1. Three 2. Ichthyophis

3. Can live both, in water and on land.

3.8 1. Turtle, seasnake 2. Three and four

3. Syrinx

3.9 1. (i) and c (ii) and d (iii) and a (iv) and f

(v) and b (vi) and e

2. (i) Prototheria (ii) Metatheria (iii) Carnivora

(iv) Cetacea (v) Cheiroptera

3. Mammary or milk glands 4. Kangaroo

5. Mammalia

4

CELL – STRUCTURE AND FUNCTION

INTRODUCTION

All organisms are composed of structural and functional units of life called 'cells'. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell whereas the body of higher fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.

Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all biological cells. This lesson deals with the structure common to all types of the cells. You will also learn about the kinds of cell division and the processes involved therein in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *justify that cell is the basic structural and functional unit of all organisms;*
- *list the components of the cell and state cell theory;*
- *differentiate between prokaryotic and eukaryotic cells;*
- *differentiate between plant and animal cells;*
- *illustrate the structure of plant and animal cells by drawing labelled diagrams;*
- *describe the structure and functions of plasma membrane, cell wall, endoplasmic reticulum (ER), cilia, flagella, nucleus, ribosomes, mitochondria, chloroplasts, golgi body, peroxisome, glyoxysome and lysosome;*
- *describe the general importance of the cell molecules-water, mineral ions, carbohydrates, lipids, amino acids, proteins, nucleotides, nucleic acids, enzymes, vitamins, hormones, steroids and alkaloids;*
- *justify the need for cell division;*
- *describe various phases of cell cycle;*
- *explain the term karyotype and mention the karyotype analysis and its significance.*

4.1 THE CELL AND CELL THEORY

4.1.1 Landmarks in the study of a cell

Soon after Anton Van Leeuwenhoek invented the microscope, Robert Hooke in 1665 observed a piece of cork under the microscope and found it to be made of small compartments which he called "cells" (Latin cell = small room). In 1672, Leeuwenhoek observed bacteria, sperms and red blood corpuscles, all of which were cells. Much later, in 1831, Robert Brown, an Englishman observed that all cells had a centrally positioned body which he termed the **nucleus**.

4.1.2 The cell theory

In 1838 M.J. Schleiden and Theodore Schwann formulated the "cell theory." Which maintains that:

- all organisms are composed of cells.
- cell is the structural and functional unit of life, and
- cells arise from pre-existing cells.

The cells vary considerably, in shapes and sizes (Fig.4.1). Nerve cells of animals have long extensions. They can be several centimeter in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

4.1.3 The Cell

A cell may be defined as a unit of **protoplasm** bound by a plasma or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and includes the cytoplasm and the nucleus. The cytoplasm has in it **organelles** such as ribosomes, mitochondria, golgi bodies, plastids, lysosomes and endoplasmic reticulum. Plant cells have in their cytoplasm, large vacuoles containing non-living inclusions like crystals, and pigments. The bacteria have neither defined cell organelles nor a well formed nucleus. But every cell has three major components:

- plasma membrane
- cytoplasm
- DNA (naked in bacteria) and enclosed by a nuclear membrane in all other organisms

Two basic types of cells

Cytologists recognize two basic types of cells (Fig. 4.1). Their differences have been tabulated below in Table 4.1. Organisms which do not possess a well formed nucleus are **prokaryotes** such as the bacteria. All others possess a well defined nucleus, covered by a nuclear membrane. They are **eukaryotes**.

Table 4.1 Differences between Eukaryotic and Prokaryotic cells

Eukaryotic cell (eu = true, karyon = nucleus)	**Prokaryotic cell** (Pro = early/primitive)
1. Nucleus distinct, with well formed nuclear membrane.	1. Nucleus not distinct, it is in the form of a nuclear zone 'nucleoid'. Nuclear membrane absent.
2. Double-membraned cell organelles (Chloroplasts, mitochondria, nucleus) and single membraned (Golgi apparatus, lysosomes, vacuole, endoplasm reticulum) are present	2. Single-membraned cell bodies like mesosomes present. Endoplasmic reticulum, plastids, nitochondria microbodies like lysosomes, and Golgi body absent.
3. Ribosomes - 80 S	3. Ribosomes - 70 S
4. Distinct compartments in the cell i.e. the cytoplasm and the nucleus	4. No compartments.
5. Depending upon the species number of chromosomes per nucleus varies from two to many.	5. There is only one chromosome per cell.
6. Each chromosome is linear with its two ends free.	6. The chromosome is circular and remains attached to cell membrane at one point.
7. Each chromosome has one linear double-stranded DNA complexed with histones	7. The chromosome has single double-stranded circular DNA molecule and is not associated with histones.
8. Each chromosome has one centromere that divides a chromosome into two arms. However, if the centromere is terminal, the chromosome would have only one arm	8. The chromosome lacks a centromere.

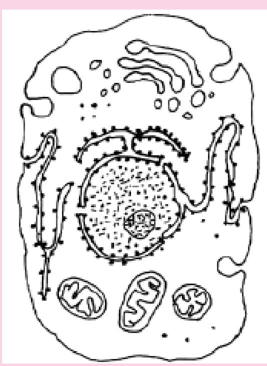


Fig. 4.1a Eukaryotic Cell

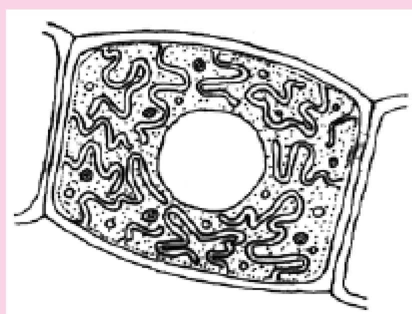


Fig. 4.1b Prokaryotic Cell

(As seen in an electron micrograph.)

Svedberg unit

When the cell is fractionated or broken down into its components by rotating in an ultracentrifuge at different speeds the ribosomes of eukaryotic and prokaryotic cells sediment (settle down) at different speeds. The coefficient of sedimentation is represented in Svedberg unit and is depicted as S.

The plant cell and the animal cell also differ in several respects as given in Table 4.2 and shown in Fig. 4.2.

Table: 4.2 Differences between plant cell and animal cell

Plant cell	Animal cell
1. Cellulose cell wall present external to cell membrane.	1. No cell wall, outermost structure is cell membrane or plasma membrane
2. Vacuoles are usually large.	2. Generally vacuoles are absent and if present, are usually small..
3. Plastids present.	3. Plastids absent.
4. Golgi body present in the form of units known as dictyosomes.	4. Golgi body well developed having 2 cisternae
5. Centriole absent.	5. Centriole present.

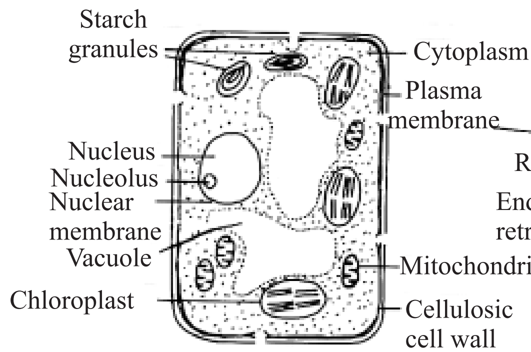


Fig. 4.2a Generalised plant cell

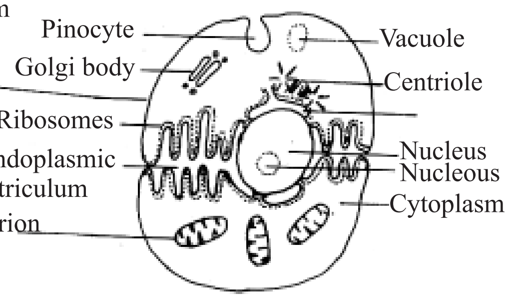


Fig. 4.2b Generalised animal cell

INTEXT QUESTIONS 4.1

1. From where do new cells arise?

   ....

2. Name the scientists who proposed the 'cell theory'.

   ....

3. Name an organelle which a plant cell has but an animal cell does not.

   ....

4. Give two points of difference between a prokaryotic cell and a eukaryotic cell

   ....

4.2 COMPONENTS OF THE CELL

The major components of the cell are (1) cell membrane, (2) cytoplasm, and (3) nucleus.

4.2.1 Cell membrane (Plasma membrane)

Each cell has a limiting boundary, the cell membrane, plasma membrane or plasmalemma. It is a living membrane, outermost in animal cells but internal to cell wall in plant cells.

It is flexible and can fold in (as in food vacuoles of *Amoeba*) or fold out (as in the formation of pseudopodia of *Amoeba*)

The plasma membrane is made of proteins and lipids and several models were proposed regarding the arrangement of proteins and lipids. The **fluid mosaic model** proposed by Singer and Nicholson (1972) is widely accepted. It is represented in Fig 4.3.

According to the fluid mosaic model,

(i) The plasma membrane is composed of a lipid bilayer of phospholipid molecules into which a variety of globular proteins are embedded.

(ii) Each phospholipid molecule has two ends, an outer head hydrophilic i.e. water attracting, and the inner tail pointing centrally hydrophobic, i.e. water repelling

(iii) The protein molecules are arranged in two different ways:

   (a) Peripheral proteins or extrinsic proteins: these proteins are present on the outer and inner surfaces of lipid bilayer.

   (b) Integral proteins or intrinsic proteins: These proteins penetrate the lipid bilayer partially or wholly.

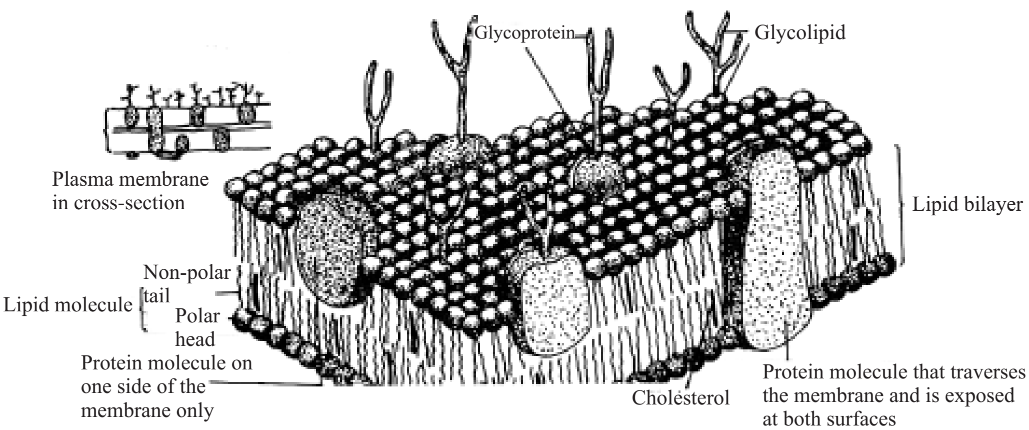


Fig. 4.3 The fluid mosaic model of cell membrane.

Functions

(i) The plasma membrane encloses the cell contents.

(ii) It provides cell shape (in animal cells) e.g. the characteristic shape of red blood cells, nerve cells, and bone cells.

(iii) It allows transport of certain substances into and out of the cell but not all substances so much it is termed '**selectively permeable**'.

Transport of small molecules (such as glucose, amino acids, water, mineral ions etc).

Small molecules can be transported across the plasma membrane by any one of the following three methods:

(i) **Diffusion** : molecules of substances move from their region of higher concentration to the regions of lower concentration. This does not require energy. Example : absorption of glucose in a cell.

(ii) **Osmosis:** movement of water molecules from the region of their higher concentration to the region of their lower concentration through a semipermeable membrane. There is no expenditure of energy in osmosis. This kind of movement is along concentration gradient.

(iii) **Active Transport:** When the direction of movement of a certain molecule is opposite to that of diffusion i.e. from region of their lower concentration towards the region of their higher concentration, it would require an "active effort" by the cell for which energy is needed. This energy is provided by ATP (adenosine triphosphate). The active transport may also be through a carrier molecule.

Transport of large molecules (bulk transport)

During bulk transport the membrane changes its form and shape. It occurs in two ways:

(i) endocytosis (taking the substance in)

(ii) exocytosis (passing the substance out)

Endocytosis is of two types :

Endocytosis

Phagocytosis	Pinocytosis
1. intake of solid particles 2. membrane folds out going round the particle, forming a cavity and thus engulfing the particle (Fig. 4.4a)	1. intake of fluid droplets 2. membrane folds in and forms a cup-like structure and sucks in the droplets (Fig. 4.4b)

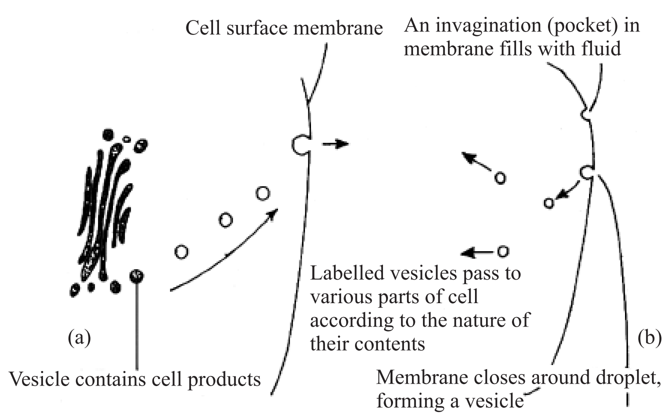


Fig. 4.4 Diagrammatic representation of (a) phagocytosis; (b) pinocytosis

Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally, the cell dies.

Cell wall

In bacteria and plant cells the outermost cell cover, present outside the plasma membrane is the **cell wall** about which we shall study now.

Bacterial cell wall is made up of peptidoglycan. Given below is the structure and function of the plant cell wall.

(a) Structure

- Outermost non-living layer present in all plant cells.
- Secreted by the cell itself.
- In most plants, it is chiefly made up of cellulose but may also contain other chemical substances such as pectin and lignin.
- The substance constituting the cell wall is not simply homogeneous but it consists of fine threads or fibres called microfibrils.
- It may be thin (1 micron) and transparent as in the cells of onion peel. In some cases it is very thick as in the cells of wood.

(b) Functions

- The cell wall protects the delicate inner parts of the cell.
- Being rigid, it gives shape to the cell.
- As it is rigid, it does not allow distension of the cell, thus leading to turgidity of the cell that is useful in many ways
- It freely allows the passage of water and other chemicals into and out of the cells
- There are breaks in the primary wall of the adjacent cells through which cytoplasm of one cell remains connected with the other. These cytoplasmic strands which connect one cell to the other one are known as **plasmodesmata**.
- Walls of two adjacent cells are firmly joined by a cementing material called **middle lamella** made of calcium pectinate.

INTEXT QUESTIONS 4.2

1. Define diffusion and osmosis.

   ....

2. What does active transport mean?

   ....

3. Give one point of difference between phagocytosis and pinocytosis.

   ....

4. Match the following :

(i)	hydrophilic end	(a)	cell wall
(ii)	microfibrils	(b)	inner ends of lipids
(iii)	fluid-mosaic model	(c)	fluid droplets
(iv)	hydrophobic end	(d)	outer ends of lipids
(v)	pinocytosis	(e)	Nicholson and Singer

5. Give two functions of the plant cell wall.

   (i) .... (ii) ....

4.3 THE CYTOPLASM AND THE CELL ORGANELLES

The cytoplasm contains many cell organelles of which we shall learn about :

1. those that trap and release energy e.g. mitochondria and chloroplasts;
2. those that are secretory or involved in synthesis and transport e.g. Golgi, ribosomes and endoplasmic reticulum
3. the organelles for motilily - cilia and flagella
4. the suicidal bags i.e. lysosomes
5. the nucleus which controls all activities of the cell, and carries the hereditary material

4.3.1 Mitochondria and chloroplast - the energy transformers

Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

Mitochondria (Singular = mitochondrion)

Appear as tiny thread like structures under light microscope. Approximately 0.5 - 1.00 μm (micrometer)

Number usually a few hundred to a few thousand per cell (smallest number is just one as in an alga, **Micromonas**.

Structure: The general plan of the internal structure of a mitochondrion observed by means of electron microscope is shown in Fig. 4.5. Note the following parts.

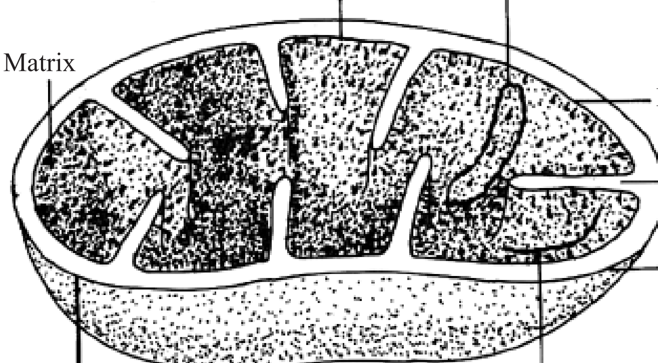


Fig. 4.5 Structure of a mitochondrion

– Wall made up of double membrane
– The inner membrane is folded inside to form projections called '*cristae*' which project into the inner compartment called the 'matrix'.

Function : Oxidises pyruvic acid (breakdown product of glucose) to release energy which gets stored in the from of ATP for ready use. This process is also called **cellular respiration**. That is why mitochondria are called the 'power house' of a cell.

A highly simplified flow-chart of the fate of glucose to release energy is shown below :

In cytoplasm. glucose enters cells (containing 6 atoms of carbon)	Broken into two Pyruvic acid molecules (containing 3 atoms of carbon)	In mitochondria Acetyl-Co-A is Oxidised into CO_2, H_2O and ATP

Plastids

Plastids are found only in a plant cell. These may be colourless or coloured. Based on this fact, there are three types of plastids.

(i) Leucoplast - white or colourless

(ii) Chromoplast – blue, red, yellow etc.

(iii) Chloroplast – green

4.3.2 Chloroplast

- Found in all green plant cells in the cytoplasm.
- Number 1 to 1008 (how so definite)
- Shape: Usually disc-shaped or laminate as in most plants around you. In some ribbon - shaped as in an alga *Spirogyra* or cup-shaped as in another alga *Chlamydomonas*.
- Structure: the general plan of the structure of a single chloroplast has been shown in Fig. 4.6.

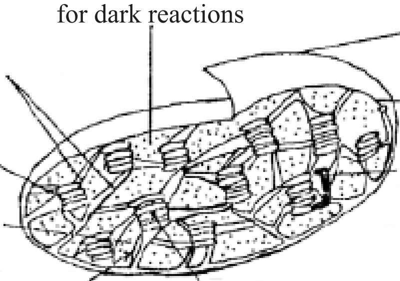


Fig. 4.6 Structure of a single chloroplast

Note the following parts :

- Wall made up of double membrane i.e. outer membrane and inner membrane numerous stack-like (piles) groups or *grana* (singular = granum) are interconnected by *lamellae*.
- Sac-like structures called thylakoids placed one above the other constitute a granum.

- Inside of the chloroplast is filled with a fluid medium called stroma.
- Function: chloroplasts are the site of photosynthesis (production of sugar, from carbon dioxide and water in the presence of sunlight).

Chloroplast versus mitochondria

Can you now visualize how these two organelles are opposite to each other, one traps the solar energy locking it in a complex molecule (by photosynthesis), the other releases the energy by breaking the complex molecule (by respiration).

Similarities between mitochondria and chloroplasts : both contain their own DNA (the genetic material) as well as their own RNA (for protein synthesis). Thus, they can self-duplicate to produce more of their own kind without the help of nucleus.

Thought the chloroplasts and mitochondria contain their own DNA the hereditary molecule and also their own ribosomes, they are termed as semi-autonomous only because they are incapable of independent existence outside the cytoplasm for a long time. Since most of their proteins are synthesised witht he help of the nuclear DNA.

INTEXT QUESTIONS 4.3

1. What is a cell organelle?

   ....

2. Name the chemical which provides energy trapped in its bonds to the cell.

   ....

3. Which part of the chloroplasts is the site of light reaction?

   ....

4. Name the sac like–structure which form the grana?

   ....

5. Why is mitochondrion called the "power house" of the cell?

   ....

6. Which organelle contains enzymes for cellular respiration?

   ....

7. State two similarities between mitochondria and chloroplasts.

   ....

8. Which plastid imparts colour to flower petals?

   ....

9. Which plastid is green in colour?

   ....

10. Why are mitochondria and chloroplast called semi-autonomous?

    ....

4.3.3 Endoplasmic reticulum (ER), golgi body and ribosomes

The Endoplasmic reticulum (ER) and Golgi body are single membrane bound structures. The membrane has the same structure (lipid-protein) as the plasma membrane but ribosomes do not have membranes. Ribosomes are involved in synthesis of proteins in the cell, Golgi bodies in secreting and the ER in transporting and storing the products. These three organelles operate together.

Fig. 4.7 and Fig. 4.8 show the diagram of ER and Golgi body as seen under an electron microscope. Note the ribosomes present in the ER.

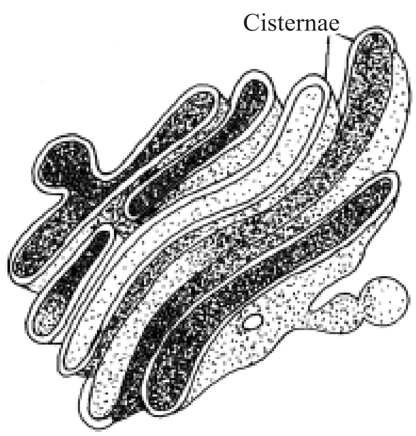


Fig. 4.7 Golgi body

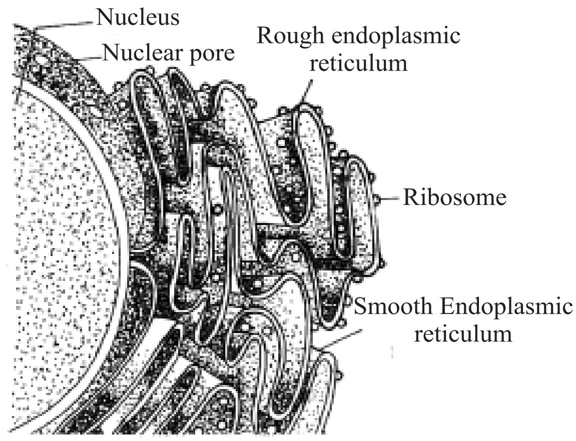


Fig. 4.8 Endoplasmic reticulum

Endoplasmic reticulum (ER)	Golgi body	Ribosomes
Structure		
A network of membranes with thickness between 50 - 60A°. It is of two types– rough endoplasmic reticulum (RER) i.e. when ribosomes are attached to it and Smooth endo-plasmic reticulum (SER) when no ribosomes are present.	Is a stack of membranous sacs of the same thickness as ER. Exhibit great diversity in size and shape.	Spherical about 150 - 250 Å in diameter, made up of large molecules of RNA and proteins (ribonucleo proteins)
Distributed hroughout the cytoplasm and is in contact with the cell membrane as well as the nuclear membrane.	In animal cells present around the nucleus, 3 to 7 in number. In plant cells, many in number of and present scattered throughout the cell called dictyosomes.	Present either as free particles in cytoplasm or attached to ER. Also found stored in nucleolus inside the nucleus. 80S types found in eukaryotes and 70S in prokaryotes (S-svedberg unit of measuring ribosomes).
Function		
Provides internal framework, compartment and reaction surfaces, transports enzymes and other materials through out the cell. RER is the site for protein synthesis and SER for steroid synthesis, stores carbohydrates.	Synthesis and secretion as enzymes, participates in transformation of membranes to give rise to other membrane structure such as lysosome, acrosome, and dictyosomes, synthesize wall element like pectin, mucilage.	Site for protein synthesis.

INTEXT QUESTIONS 4.4

1. Given below is a list of functions, relate them to their respective organelles:
   (a) synthesis of some enzymes ....
   (b) synthesis of steroids ....
   (c) storage of carbohydrates ....
   (d) Intracellular transport ....
   (e) Synthesis of proteins ....
2. Name the equivalent structure of Golgi body in plants. Mention two differences between their structures.
   (i) ……………………….…. (ii) ……….................…………
3. Mention any two advantages of the extensive network of endoplasmic reticulum.
   (i) …………………………….. (ii) ………………...………………
4. What are the three places where ribosomes occur in a cell?
   ....
5. Name the membrane system that connects the nuclear membrane with the cell membrane?
   ....

4.3.4 The microbodies (tiny but important)

These are small sac-like structures bounded by the single membranes. These are of different kinds of which we will take up three, viz. lysosomes, peroxisomes and glyoxysomes.

1. Lysosomes (lysis = breaking down; soma = body)

Lysosomes are present in almost all animal cells and some non-green plant cells (Fig 4.9). They perform intracellular digestion.

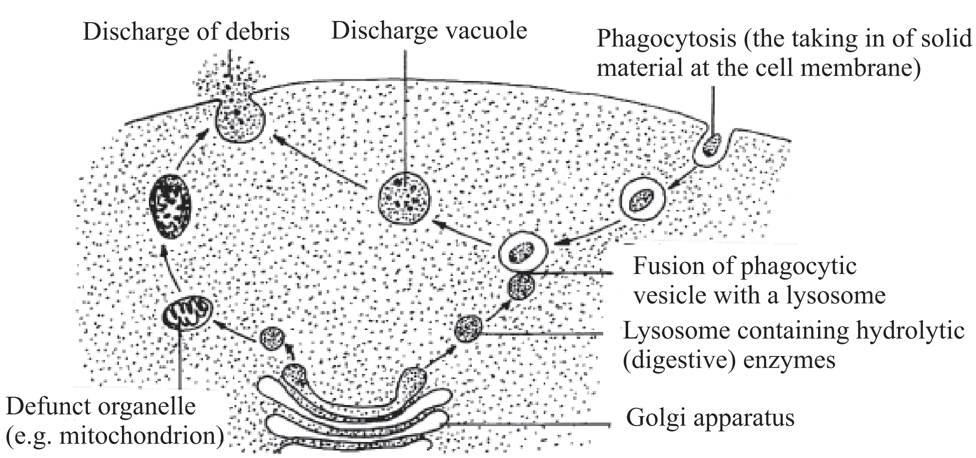


Fig. 4.9 Lysosomes

The main features of lysosomes are as follows :

(i) Membranous sacs budded off from Golgi body.

(ii) May be in hundreds in a single cell.

(iii) Contain several enzymes (about 40 in number)

(iv) Materials to be acted upon by enzymes enter the lysosomes.

(v) Lysosomes are called "suicidal bags" as enzymes contained in them can digest the cell's own material when damaged or dead.

Importance of intracellular digestion by the lysosomes

(i) help in nutrition of the cell by digesting food, as they are rich in various hydrolysing enzymes which enable them to digest almost all major chemical constituents of the living cell.

(ii) Help in defence by digesting germs, as in white blood cells.

(iii) Help in cleaning up the cell by digesting damaged material of the cell.

(iv) Provide energy during cell starvation by digestion of the own parts of the cells (autophagic, auto : self; phagos: eat up).

(v) Help sperm cells in entering the egg by breaking through (digesting) the egg membrane.

(vi) In plant cells, mature xylem cells lose all cellular contents by lysosome activity.

(vii) When cells are old, diseased or injured, lysosomes attack their cell organelles and digest them. In other words lysosomes are autophagic, i.e. self devouring.

2. Peroxisomes

Found both in plant and animal cells. Found in the green leaves of higher plants. They participate in oxidation of substrates resulting in the formation of hydrogen peroxide.

- They often contain a central core of crystalline material called nucleoid composed of urate oxidase crystals.
- These bodies are mostly spherical or ovoid and about the size of mitochondria and lysosomes.
- They are usually closely associated with ER.
- They are involved in photorespiration in plant cells.
- They bring about fat metabolism in cells.

3. Glyoxysomes

- The microbodies present in plant cells and morphologically similar to peroxisomes.
- Found in the cell of yeast and certain fungi and oil rich seeds in plants.
- Functionally they contain enzymes of fatty acid metabolism involved in the conversion of lipids to carbohydrates during germination.

INTEXT QUESTIONS 4.5

1. Why are lysosomes called suicidal bags?

   ....

2. List the usefulness of intracellular digestion by lysosomes

   ....

3. What is the function of peroxisomes in plant cells

   ....

4.3.5 Cilia and flagella (the organelles for motility)

(i) Some unicellular organisms like *Paramecium* and *Euglena* swim in water with the help of cilia and flagella respectively.

(ii) In multicellular organisms some living tissues (epithelial tissues) have cilia. They beat and create a current in the fluid in order to move in a given direction e.g. in the wind pipe (trachea) to push out the mucus and dust particles.

(iii) Cilia beat like tiny oars or pedals (as in a boat) and flagella bring about whiplash like movement.

(iv) Both are made up of contractile protein tubulin in the form of microtubules.

(v) The arrangement of the microtubules is termed as 9 + 2, that is, two central microtubules and nine duplet sets surrounding them.

Cilia	Flagella
shorter (5 to 10 µm)	longer (15 µm)
several 100 per cell structure : protoplasmic projection and membrane bound	usually 1 or 2 in most cells
consist of 9 sets of peripheral duplet microtubules and 1 set of two singlet tubules in the centre	same as in cilia

Centriole

It is present in all the animal cells (but not in *Amoeba*), located just outside the nucleus. It is cylindrical, 0.5 µm in length and without a membrane. It has 9 sets of peripheral triplet tubules but none in the centre (9 + 0). Each set has three tubules arranged at definite angles (Fig. 4.10). It has its own DNA and RNA and therefore it is self duplicating.

Function : Centrioles are involved in cell division. They give orientation to the 'mitotic spindle' which forms during cell division

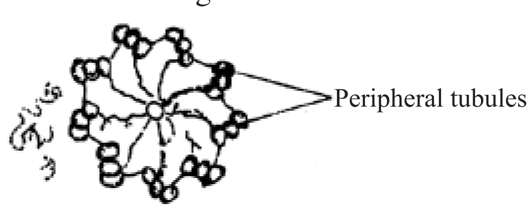


Fig. 4.10 Centriole (showing 9 + 0 structure)

Basal bodies

These are structures similar to centrioles. They have the same nine sets of triplet organization (9 + 0), as in the centrioles. The cilia and flagella appear to arise from the basal bodies.

4.4 NUCLEUS (THE HEREDITARY ORGANELLE)

General structure of the nucleus :

(i) It is the largest organelle seen clearly when the cell is not dividing.

(ii) It stains deeply, is mostly spherical, WBC have lobed nuclei.

(iii) It is mostly one in each cell (uninucleate, some cells have many nuclei; (multinucleate).

(v) Double layered nuclear membrane having fine nuclear pores encloses nucleoplasm which contains chromatin network and a nucleolus.

Functions

- Maintains the cell in a working order.
- Co-ordinates the activities of other cell organelles.
- Takes care of repair work.
- Participates directly in cell division to produce genetically identical daughter cells. This division is called mitotic cell division.
- Participates in production of meio-gametes and meiospores through another type of cell division called meiotic cell divisioin.

The parts of a nucleus are given here :

4.4.1 Nuclear membrane

- Double layered membrane is interrupted by large number of nuclear pores.
- Membrane is made up of lipids and proteins (like plasma membrane) and has ribosomes attached on the outer membrane which make the outer membrane rough.
- The pores allow the transport of large molecules in and out of nucleus, and the membranes keep the hereditary material in contact with the rest of the cell.

4.4.2 Chromatin

- Within the nuclear membrane there is jelly like substance (karyolymph or nucleoplasm) rich in proteins.
- In the karyolymph, fibrillar structures form a network called *chromatin fibrils*, which gets condensed to form distinct bodies called **chromosomes** during cell division. On staining the chromosomes, two regions can be identified in the chromatin material heterochromatin, dark and euchromaticn (light). Heterochromatin has highly coiled DNA and genetically less active than euchromatin which has highly uncoiled DNA and genetically more active.

- The number of chromosomes is fixed in an organism. During mitotic cell division chromosomes divide in a manner that the daughter cells receive identical amounts of hereditary matter.

4.4.3 Nucleolus

- Membraneless, spheroidal bodies present in all eukaryotic cells except in sperms and in some algae.
- Their number varies from one to few, they stain uniformly and deeply.
- It has DNA, RNA and proteins.
- Store house for RNA and proteins; it disappears during early phase of cell cycle and reappears after telophase in the newly formed daughter nuclei.
- Regulates the synthetic activity of the nucleus.
- Thus nucleus and cytoplasm are interdependent, and this process is equal to nucleo–cytopalsmic interaction.

INTEXT QUESTIONS 4.6

1. Why cannot the cell survive without the nucleus?

   ....

2. Explain the following terms:

   (a) chromatin network...... ....

   (b) chromosomes ....

3. What is the function of the nucleolus in the cell?

   ....

4.5 MOLECULES OF THE CELL

The cell and its organelles are made of organic chemicals such as proteins, carbohydrates, nucleic acid and fats. These are aptly termed biomolecules. Inorganic molecules such as water and minerals are also present in a cell.

A. Water

- Water with unique physical and chemical properties has made life possible on earth.
- It is a major constituent of protoplasm.
- It is a medium in which all the metabolic reactions occur.
- It is a universal solvent in which most substances remain dissolved sparingly or completely.
- It is responsible for turgidity of cells.

B. Elements necessary for life

Elements	Functions
Hydrogen, Carbon, Oxygen, Nitrogen, Calcium, Potassium, Sodium, Magnesium, Phosphorous, Sulphur, Chlorine, Iron, Boron, Silicon, Manganese, Copper, Zinc, Cobalt, Molybdenum, Iodine	1. Required for organic compounds of the cell and present as major constituents. (Ca in plant cell wall, C, H, O, N as organic compounds) 2. Act as major cations (Na, K) and anions (Cl) in most physiological processes. 3. As cofactor of enzymes participate in most of the biochemical reactions of a cell (Fe, Cu, Mo, Zn, B) 4. Involved in energy transfer reactions (P in ATP). 5. Green pigment chlorophyll in plants have magnesium in the centre of tetrapyrrole ring.

C. Biomolecules

(i) Carbohydrate

Structure	Functions
1. Composed of C, H and O	1. Most abundant organic substance present in nature which occurs in the form of cellulose in plant cell wall.
2. Simple six carbon sugar (glucose) is called a monosaccharide.	2. In both plants and animals it is used as a source of energy (sugar).
3. Two molecules or units join together to form disaccharide (sucrose).	3. An important storage form in plants is starch and in animals it is glycogen.
4. More than ten units of monosaccharides join in a chain to form a polysaccharide e.g. starch and cellulose.	4. Present in nucleic acids as five carbon sugar (Ribose in RNA, and deoxyribose in DNA).
(ii) Amino acid	
1. Basic amino acid structure shows that the central carbon atom is attached with an amino group ($-NH_2$), a carboxylic acid group ($-COOH$), one hydrogen and one side group (R).	1. Plants have the ability to utilize inorganic nitrogen and synthesize amino acid.
2. There are 20 different side groups which give 20 different amino acids.	2. In an animal, principal source of amino acids is provided by the plants or animals that it consumes in its diet (pulses are rich in protein).
(iii) Proteins	
1. Composed of C, H, O and N.	1. Structurally proteins form integral part of the membranes

2. Amino acids join together by "peptide" bonds to form protein molecules.	2. Functionally in the form of enzymes they play a vital role in metabolic reactions.
3. Twenty different amino acids make numerous simple and complex proteins.	3. Synthesis of DNA is regulated by proteins (enzymes).
4. Based on the complexity of structure the proteins can have primary, secondary, tertiary and quaternary structures.	4. Proteins are so important that nucleic acids directly regulate protein synthesis
5. When proteins exist with other molecules they are known as conjugated proteins e.g. glycoprotein, lipoprotein and chromoprotein.	
(iv) **Nucleic Acids**	
1. They are of two types : Deoxyribose nucleic acid (DNA) and Ribose nucleic acid (RNA)	1. DNA is the main genetic material for almost all organisms except certain viruses.
2. They are long chain polymers composed of units called **nucleotides**. as purines (Adenine and Guanine) and pyrimidines as (Thymine, Cytosine and Uracil)	2. RNA molecules are involved in information transfer and protein synthesis; and RNA acts as genetic material in some viruses e.g. TMV (Tobacco Mosaic Virus)
3. Each nucleotide has pentose sugar, nitrogen base and phosphate group.	
4. DNA has one oxygen less in its sugar molecule.	
(v) **Lipids**	
1. Composed of C, H, O. Amount of oxygen is very less.	1. Due to their low oxygen content, and higher number of C-H bonds they store higher amount of energy and release more energy during their oxidation
2. They are synthesized from fatty acids and glycerol. Simple lipids are called glycerides.	2. A molecule of fat can yield twice as much energy as from carbohydrate.
3. Fats can be saturated or unsaturated.	3. Phospholipids are important components of cell membranes.
4. Fats are solid at room temperature, those that remain liquid at room temperature are called oils.	
(vi) **Vitamins**	
1. Vitamins are organic compounds required in the diet of animals for their healthy growth.	1. Vitamins (from plant) are essential nutrients in animals diet as animals can not synthesise such compounds.
2. Vitamins are classified according to their solubility into two groups : Water soluble e.g. vitamin B and ascorbic acid and fat soluble vitamins (viz. A,D, E, K)	2. Their deficiency causes various diseases in animal, like deficiency of vitamin B causes "beri-beri" and that of vitamin C causes scurvy.

3. Plants have the ability to synthesize vitamins from CO_2, NH_3 and H_2S.	3. Vitamin A present in the carotene pigment of carrot. Vitamin D can be produced by man with the help of sunlight. Vitamin K is produced by bacteria in the human intestine.
(vii) **Hormones**	
1. Hormones are specific organic substances effective in low concentrations, synthesized by cells in one part of the organism and then transported to another part of the organism, where it produces characteristic physiological responses.	1. In animals hormones are produced in ductless glands called endocrine glands which control all the biochemical activities of the organism 2. In animals hormones may be proteins, peptides or steroids. 3. In plants hormones (growth regulators) are generally produced in metabolically active cells and control the vegetitive and reproductive growth of the entire plant. Proteinaceous hormones are not found in plants.
(viii) **Alkaloids**	
1. Alkaloids are complex organic compounds made of C, H, O and N.	1. The active principles of drugs from medicinal plants are generally alkaloids e.g. Quinine from the *Cinchona*. Ephedrine from and Morphine from *Papaver* species
2. Alkaloids in plants are produced from amino acids.	
(ix) **Steroids**	
1. These are fat soluble lipid compounds synthesized from cholesterol.	
2. They are produced by the reproductive organs like ovaries, testes and placenta and also by adrenal glands.	Most of the steroids act as life-saving drugs, and others act as hormones which are effective in performing specific functions in specific organs of animal body.
3. They include testosterone, estrogen, and cortisol	

INTEXT QUESTIONS 4.7

1. What is the importance of water in a living cell.

 ....

2. Which is the basic molecule in starch?

....

3. What is a peptide bond and where will you find it?

....

4. Which is the most energy rich biomolecule in living organisms?

....

5. What are nucleotides?

....

4.7 CELL DIVISION

A single cell divides many times and forms a multicelled organism. Unicellular bacteria and protozoa divide and increase in number. The injured tissues are replaced by new cells through cell division. Thus cell division is one of the most important activities in all organisms. In this lesson you will study about the two kinds of cell division and the processes involved in them.

Majority of cells in a multicellular organism grow and then can divide. However, the cells like the nerve and muscle cells of animals and guard cells of plants do not divide.

The process of cell division is almost same in all organisms. A cell passes through phases of growth after which are able to duplicate their chromosomes before they divide. These phases in the life of a cell constitute the **cell cycle.**

4.7.1 The cell cycle

You can use the term mother or parent cell for the cell that undergoes division and the daughter cells for the ones that are the result of this division. Before each daughter cell undergoes division, it must grow to the same size as its mother cell. We can distinguish two main phases in the life of a cell.

(i) Interphase - Non-dividing period (Growth phase)

(ii) Dividing phase - Also called M-phase (M for mitosis or meiosis)

(i) **Interphase - (Inter = in between)**

The interval between two successive cell divisions is termed interphase (phase at which the cell is not dividing). It is the longest period in the cell cycle (Fig.4.11). The interphase is subdivided into three main periods - G_1, S and G_2.

G_1 (Gap-1) Phase i.e. **First phase of growth** – This is the longest phase. Lot of protein and RNA are synthesised during this phase.

S or synthetic Phase - It comes next. Lot of DNA is (synthesised). A chromosome contains a single double helical strand of DNA molecule. After S-phase each chromosome becomes longitudinally double except at centromere, and thus, it has two molecules of DNA and two chromatids. Thus each chromatid contains one molecule of DNA. The two chromatids are joined by a centromere (which does not divide at this stage) to form a single chromosome.

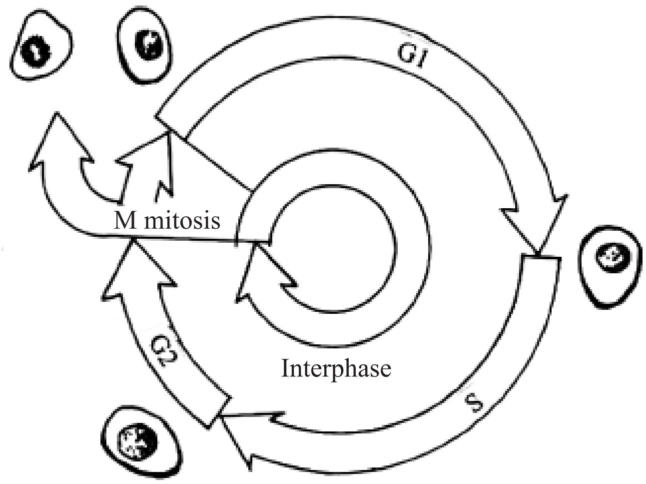


Fig. 4.11 The cell cycle consists of various stages (G_1, S, G_2 and M)

G_2 (GAP 2) phase - More protein including the histones are synthesised in this phase. Cytoplasmic organelles such as mitochondria and golgi bodies get duplicated. Centriole also divides into two centrioles contained in a single centrosome.

(ii) **M-phase or dividing phase** - Represented by the symbol M (Mitosis or meiosis) (Fig. 4.11). Mitosis occurs so that during this period the chromatids separate and form daughter chromosomes. The daughter chromosomes go to daughter nuclei and cytoplasm divides forming two identical daughter cells.

INTEXT QUESTIONS 4.8

1. Explain in one sentence

   (i) Interphase ....

   (ii) Synthetic-phase ....

   (iii) Dividing-phase ....

2. What is the full form of the following in the cell cycle?

   (i) G_1 ....

   (ii) S ....

   (iii) G_2 ....

   (iv) M-Phase ....

4.7.2 Kinds of cell division

There are two kinds of cell division- mitotic cell division and meiotic cell division.

1. Mitotic : Cell division is for growth and replacement of older cells by new cells wherein the two daugher cells are identical and similar to mother cell in all respects. Mitotic cell division occurs in haploid as well as diploid cells.
2. Meiotic cell division occurs in the gonads for sexual reproduction to produce gametes. The resultant cells, egg (in female) and sperms (in male), possess half the chromosome number of that present in the parent cell. Meiotic cell division takes place only in diploid cells responsible for production of haploid spores or gametes.

1. **Mitosis (mitos = thread)** Mitosis is divided into 4 phases or stages termed as

   (i) Prophase (ii) Metaphase

   (iii) Anaphase (iv) Telophase

   These phases refer to the changes taking place in the nucleus (Fig. 4.12).

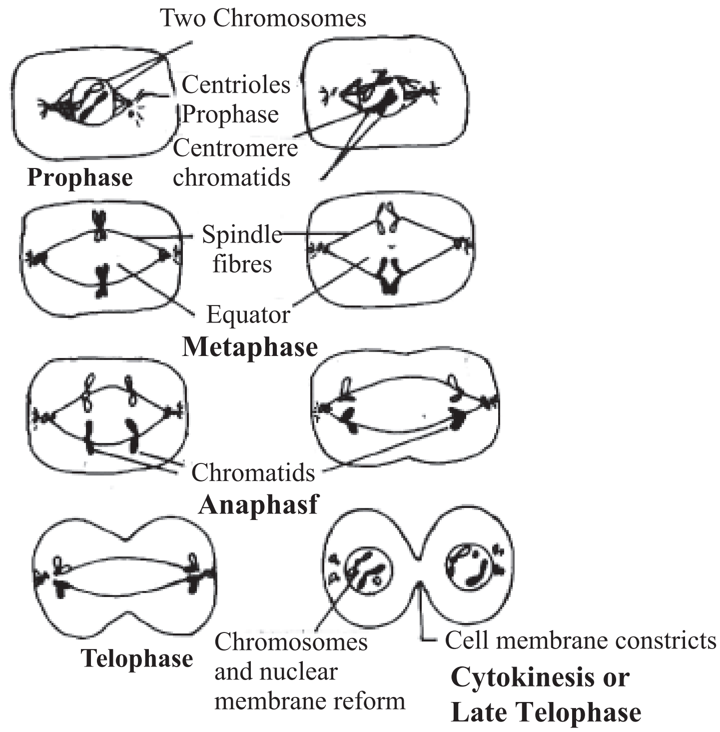
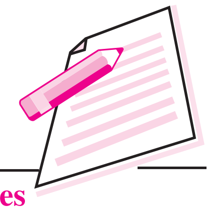


Fig. 4.12 Stages of Mitosis in an animal cell presuming there is just one pair of chromosome in the dividing cell

The nucleus divides first and then the whole cell divides. Division of one nucleus to produce two daughter nuclei a is called (**karyokinesis**). Division of cytoplasm to give two daughter cells is called **cytokinesis**.



Prophase : It shows three subphases :

(i) **Early prophase**

(a) Centriole divides and each of the two centrioles start moving towards opposite poles of the nucleus of the dividing cell.

(b) Chromosomes appear as long threads, and start coiling.

(c) Nucleus enlarges and becomes less distinct (Fig. 4.13a)

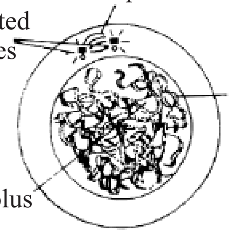


Fig. 4.13a Prophase

(ii) **Middle prophase**

(a) Chromosome condensation is complete and they become short and thick

(b) Each chromosome is made up of two chromatids held together at their centromeres.

(c) Each chromatid contains newly replicated daughter DNA molecule.

(iii) **Late Prophase**

(a) Centrioles reach the opposite poles of the dividing cell.

(b) Some spindle fibres extend from pole to the equator of the dividing cell.

(c) Nuclear membrane disappears

(d) Nucleolus is not visible.

Metaphase

(a) chromosomes are brought towards the equator of the cell, with the help of spindle fibres.

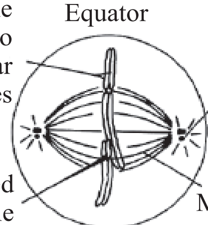


Fig. 4.13b Metaphase

(b) Each chromosome becomes attached to the two spindle fibres by centromere. Whereas each centromere is joined to the opposite poles.

(c) The sister chromatids are not yet separated. (Fig. 4.13b) because the centromere has not divided

Anaphase

(a) Centromeres of all the chromosomes divide and then each chromatid becomes a chromosome.

(b) Spindle fibres contract and pull the centromeres to the opposite poles.

(c) As the chromosomes are pulled by spindle fibres to opposite poles by their centromeres, they acquire various shapes such as V, J or I depending upon the position of centromere.

(d) Half the number of chromosomes move towards one pole and the other half to the opposite pole.

(e) Cytokinesis begins as the cleavage furrow starts from the periphery towards the centre in animal cells, and in plants, cell plate appears in the centre that grows centrifugally towards periphery.

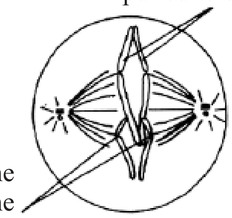


Fig. 4.13c Anaphase

Telophase

(a) Chromosomes uncoil to form a chromatin network as in the parent nucleus.

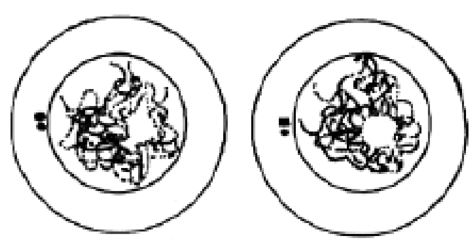


Fig. 4.13d Telophase

(b) New nuclear membrane is formed around each daughter nucleus

(c) Nucleolus reappears again in each newly formed daughter nucleus.

Cytokinesis

It is the process of the division of cytoplasm of a dividing cell into two. It is initiated in the beginning of telophase and is completed by the end of telophase. The mechanism of cytokinesis is different in plant and animal cells. In an animal cell, invagination of plasma membrane proceeds from the periphery of the cell towards the interior. In plant cell phragmoplast (cell plate) begins to form in the centre of cell and then expands towards the periphery (Fig. 4.13e).

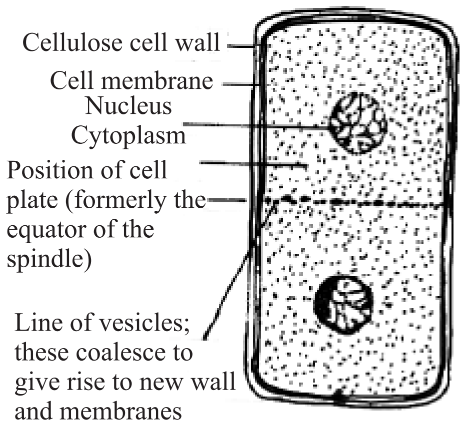


Fig. 4.13e Cytokinesis

Siginificance of Mitosis

It is an equational division, and the two newly formed daughter cells are identical in all respects. They receive the same number and kind of chromosomes as were in the mother cells.

- It is the only mode of reproduction in unicellular organisms.
- It is the process by which growth takes place in multicellular animals and plants by constantly adding more and more cells.
- It also plays a role in repair during growth, for example in wound healing, regeneration of damaged parts (as in the tail of lizard), and replacement of cells lost during normal wear and tear (as the surface cells of the skin or the red blood cells).

Mitotic Cell Division (Limited or unlimited)

Growth by mitosis occurs in a limited or controlled manner to the extent it is required in the body. But at times due to some special cases the number of cells may increase abnormally which may cause **Cancer**.

In plant tissue culture, a cell from a plant can be grown in a nutrient medium, where it divides repeatedly by mitosis to give an undifferentiated cell mass called **callus** capable of differentiating into a plant in the presence of nutrients and specific growth hormones. In animals, stem cell culture is also based on the ability of a cell to divide and give rise to cells of specific type.

INTEXT QUESTIONS 4.9

1. Name the stage of cell cycle during which chromatin material is duplicated.

   ....

2. Is the number of chromosomes reduced in the daughter cells during mitosis? yes/no?

   ....

3. Name the stage in nuclear division described by each of the following sentences:

   (i) disappearance of the nuclear membrane

   ....

   (ii) The nuclear membrane and nucleolus reappear

   ....

   (iii) The centromere divides and the chromatids move to opposite poles due to the shortening of spindle fibres

   ....

   (iv) The chromosomes arrange themselves at the equatorial plane of the spindle with the spindle fibres attached to the centromeres.

   ....

---

2. Meiotic Cell Division (GK meioun = make smaller, sis = action)

This division is also known as '**reduction division**'. But why this name? This is because, in this kind of cell division the normal **chromosome number of the mother cell is reduced to half in daughter cells.** The normal chromosome number in human being is 46 (23 pairs), but as a result of meiosis in ovary and testes this number is halved to 23 in daughter cells (called sperms or the egg).

Where does it occur? It occurs in reproductive cells, e.g. in the testes of male and in the ovaries of female animals; and in plants, in the pollen mother cell of the anthers (male organs) and in the megaspore mother cells of the ovary (female organ) of the flowers.

Why does it occur? In meiosis the chromosome number is reduced to half so that when doubled at fertilisation (zygote formation) during the reproduction it once again becomes ristored to the deploid state.

- The number of chromosomes remains constant in a species generation after generation.
- Cells divide mitotically in the organisms that reproduce vegetatively/ asexually. Thus, there is no change in the number of chromosomes, but sexually reproducing organisms form gametes such as sperms in males and ova in females. The male and female gametes fuse to form the zygote which develops into a new individual. .
- If these gametes were, produced by mitosis, the offspring developing from zygote then would have double the number of chromosomes in the next generation.
- Every living organism has a definite number of chromosomes in its body cells. e.g. onion cell-16; potato-48; horse-64; man-46. Therefore to keep the chromosome number constant the reproductive cells of the parents (ovaries and testis in animals, and pollen mother cells in anthers and megaspore mother cells in the ovules inside the ovary in plants) divide through meiosis.

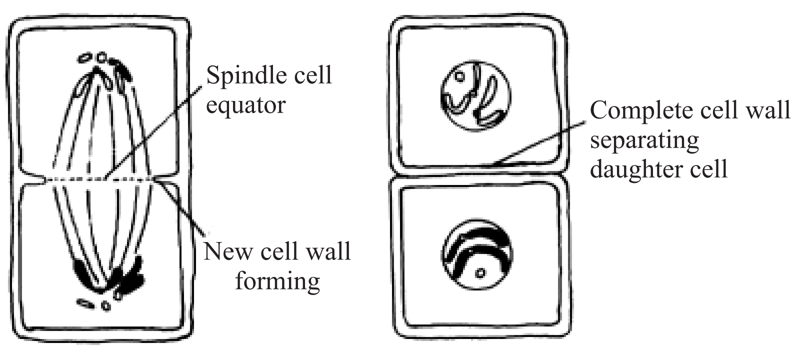
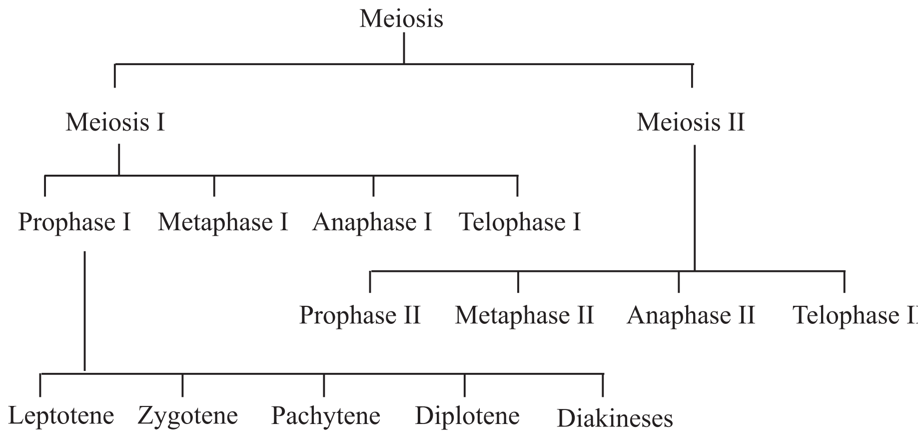


Fig. 4.14 : Cell wall formation after mitosis in a plant cell

How does meiosis occur?

Meiosis is characterized by two successive divisions of the nucleus (meiosis I and II) and cytoplasm, whereas the chromosomes divide only once. The phases of meiotic division are given in the flow-chart drawn here.

– **The interphase** which precedes the onset of meiosis is similar to the interphase which precedes mitosis. At S-phase, the DNA molecule of each chromosome duplicates to give rise to two DNA molecules and hence two chromatids are found in one chromosome attached to a single centromere.



– Meiosis-I and meiosis-II are continuous and have been divided into sub-stages only only for convenience to study the process of nuclear division.

Meiosis-I

Like mitosis, meiosis-I also consists of four stages; prophase-I, metaphase-I, anaphase-I and telophase-I.

Prophase-I

The prophase-I of meiosis-I is much longer as compared to the prophase of mitosis.

- It is further sub-divided into the following five sub-stages :

(i) **Leptotene** (GK 'leptos' - thin; 'tene - thread) (Fig. 4.15a)

- The chromosomes become distinct and appear as long and thin threads bearing fine beads due to condensation (coiling of DNA) at specific points called chromomeres.
- Each chromosome consists of two chromatids held together by a centromere but these are not easily visible.
- Nuclear membrane and nucleolus are distinct.

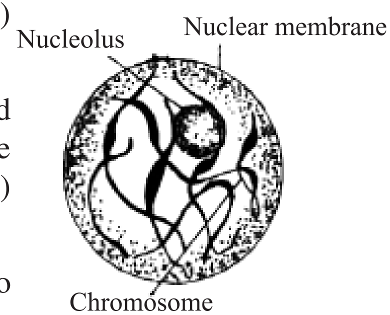


Fig. 4.15a Leptotene

(ii) **Zygotene** (GK. 'Zygos'-pairing) (Fig. 4.15b)

- Chromosomes continue coiling and become shorter and thicker
- Similar or homologous chromosomes start pairing from one end. This pairing is known as **synapsis.**
- Each pair of homologous chromosomes is called a **bivalent**.
- Nuclear membrane and nucleolus are distinct.

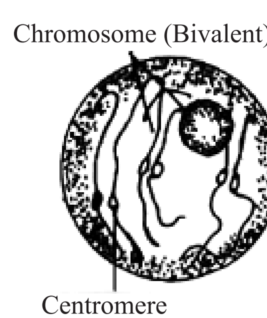
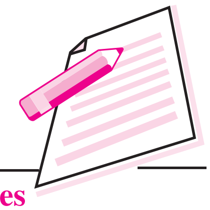


Fig. 4.15b Zygotene



(iii) **Pachytene** (GK. 'pachus' - thick) : (Fig. 4.15c)

- The chromosomes become shorter and thicker due to further coiling.
- Each paired unit called a 'bivalent' shows four chromatids hence bivalents are also known as **tetravalents**.

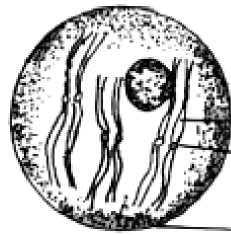


Fig. 4.15c Pachytene

- Crossing-over occurs at the end of pachytene i.e. break and exchange of parts (genes) occurs between non-sister chromatids (chromatids of a homologous pair)

  The point of interchange and rejoining appears X-shaped and is known as chiasma (plural-chiasmata) or the point of **crossing over**.

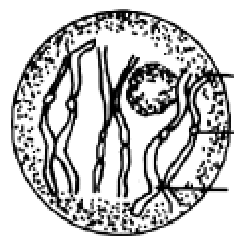


Fig. 4.15d Diplotene

(iv) **Diplotene** ('Diplous'-double) (Fig. 4.15d)

- Chromosomes continue coiling further and become shorter.
- The centromeres of homologous chromosomes start repelling each other
- The two non-sister chromatids of a homologous pair of chromosomes remain, attached at one or two points, the **chiasmata**.
- Nucleolus and nuclear membrane become indistinct.
- It is at the chiasmata that exchange of segments of nonsister chromatids (genes) between homologous chromosomes has taken place. The process of gene exchange is known as **genetic recombination**.

(v) **Diakinesis** (GK dia = through, in different directions, kinesis = motion; Fig. 4.15e)

- The bivalents become the shortest and thickest due to maximum coiling.
- The centromeres and non-homologous parts of homologous chromosomes of a bivalent move apart due to repulsion from each other.

- Consequently, the bivalents acquire various configurations such as O, X or 8, depending upon the number of chiasmata per bivalent.
- Nuclear membrane and nucleolus disappear.
- Spindle formation is completed.

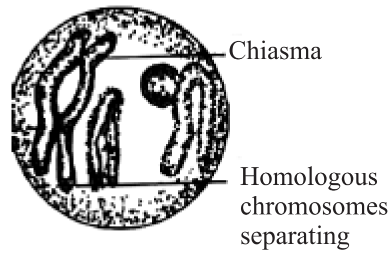


Fig. 4.15e Diakinesis

(vi) **Metaphase-I** (Fig. 4.15f)

- The bivalents arrange themselves at the equatororial plate.
- The homologous chromosomes arrange in such a way that all maternal or all paternal chromosomes do not get attached to same pole. In other words, some maternal and some paternal chromosomes are joined to each pole.
- The spindle fibres are attached at the centromere of the chromosomes.
- One centromere of a bivalent is joined to one pole and second centromere is joined to the opposite pole by the separate spindle fibres.

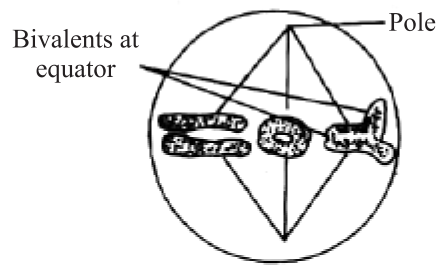


Fig. 4.15f Metaphase

(vii) **Anaphase-I** (Fig. 4.15g)

- The spindle fibres shorten.
- The centromeres of homologous chromosomes are pulled along by the spindle fibres towards the opposite poles (no division of centromere)
- Thus, half of the number chromosomes (each with two chromatids) of the parent cell go to one pole and the remaining half to the opposite pole.
- Each set of chromosomes that moves to one pole consists of a mixture of paternal and maternal chromosome parts (new gene combination). This is the basic reason for mixing of maternal and paternal genes in the products of meiosis.

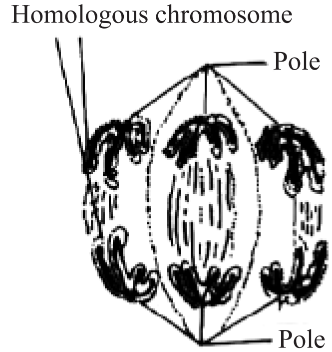


Fig. 4.15g Anaphase

(viii)**Telophase-I** (Fig. 4.15h)

- The separated chromosomes uncoil in the newly formed daughter nuclei.
- The daughter nuclei have half the number of centromeres as compared to that in the parent nucleus. But, since each centromere has two chromatids, amount of DNA at the two poles at telophase-I is same i.e. 2n (diploid as in the parent nucleus wherein the chromosomes had duplicated at S-phase, thus amount of DNA in the dividing cell upto anaphase I was 4n)
- The daughter cells now have half the amount of DNA as compared to that at Anaphase-I, that is 2n.
- The nucleous reappears and nuclear membrane forms
- The daughter nuclei enter into the second meiotic division.,

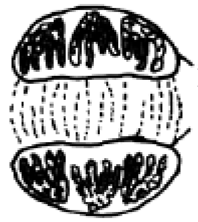


Fig. 4.15h Telophase

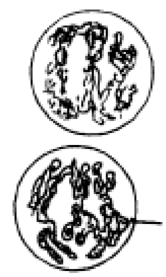


Fig. 4.15i Prophase II

Second Meiotic Division has the same four stages;

(i) Prophase II (ii) Metaphase II
(iii) Anaphase II (iv) Telophase II

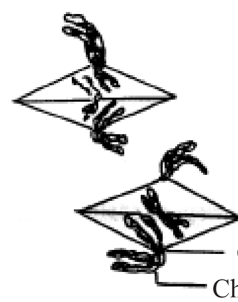


Fig. 4.15j Metaphase II

(i) **Prophase II** (Fig. 4.15i)

- The chromosomes shorten and chromatids become distinct. The two chromatids of each chromosome are attached to the single centromere.
- Formation of spindle starts.
- Nucleolus and nuclear membrane begin to disappear.

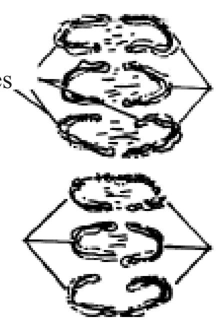


Fig. 4.15k Anaphase II

(ii) **Metaphase II** (Fig. 4.15j)

- The chromosomes arrange themselves along the equator.
- Formation of spindle apparatus is completed.
- The centromere of each chromosome is attached by two spindle fibres to the opposite poles.

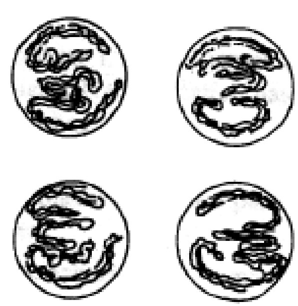


Fig. 4.15l Telophase II

(iii) **Anaphase II** (Fig. 4.15k)

- The centromere in each chromosome divides so that each chromatid has its own centromere and each chromatid is now a complete chromosome.

- The chromatids get their respective centromere and become daughter chromosomes and begin to move towards the opposite poles due to contraction of spindle fibres.

(iv) **Telophase II** (Fig. 4.15l)

- On reaching the poles, the chromosomes organize themselves into haploid daughter nuclei.
- The nucleolus and the nuclear membrane reappear.
- Each of the four daughter nuclei has half the number of chromosomes (n) as well as half the amount of DNA as compared to the parent nucleus (2n).

Cytokinesis

- This may occur in two successive stages, once after meiosis I and then after meiosis II, or in some instances it occurs only after meiosis II.
- Thus after meiotic cell division four haploid cells are formed.

Significance of Meiosis

(i) It helps to maintain constant number of chromosomes in different generations of a species undergoing sexual reproduction.

(ii) Meiosis occurs during gamete formation (gametogenesis) and reduces the number of chromosomes from diploid (2n) to haploid (n) in the gametes. These haploid gametes fuse to form diploid zygote during fertilization. The diploid zygote develops into a normal diploid individual.

(iii) Meiosis establishes new combination of characters due to (i) mixing of paternal and maternal chromosomes and (ii) crossing over during prophase I. As a result the progeny inherits the traits of both the mother and the father in new gene combinations.

Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. Cell divides only once	There are two cell divisions. First meiotic division and the second meiotic division.
2. Takes place in somatic cells as well as in reproductive cells which may be haploid or diploid or polyploid	Takes place only in diploid germ cells.
4. Duration of prophase is short (few hours)	Prophase-I, is compartively longer. (takes many days).
5. Prophase simple.	Prophase I is complicated having five sub-stages namely leptotene, zygotene, pachytene, diplotene and diakinesis.
7. Synapsis does not occur.	Synapsis of homologous chromosomes takes place during prophase-I.
8. No exchange of segments during prophase between two nonsister chromatids of chromosomes.	Exchange of segments during crossing over between non sister chromatids of two homologous chromosomes takes place.
9. Each chromosome consists of two chromatids united by a centromere.	Each bivalent has four chromatids and two centromeres.

10. Chromosomes are duplicated at the beginning of prophase.	In prophase I, chromosomes appear single although DNA replication has taken place in interphase I.
11. In metaphase all the centromeres line up in the same plane.	In metaphase I, the centromeres are lined up in two planes which are parallel to one another.
12. The metaphasic plate is made up of duplicated chromosome.	The metaphasic plate is made up of paired chromosomes.
13. Centromere division takes place during anaphase.	No centromere divisions during Anaphase I, centromeres divide only during Anaphase II.
14. Spindle fibres disappear completely in telophase.	Spindle fibres do not disappear completely during telophase I.
15. Reappearance of nucleoli at telophase.	Nucleoli do not appear in telophase I.
16. The chromosome number does not change at the end of mitosis.	There is reduction in the chromosome number from diploid to haploid.
17. The genetic constitution of chromosomes daughter cells is absolutely identical to that of parent cells.	The genetic constitution of chromosomes in daughter cells is different as compared to the parent cells. The daughter cell chromosomes contain a mixture of maternal and paternal genes.
18. Mitosis is of shorter duration.	Meiosis is of longer duration.
19. It is the basis of growth and repair and reproduction in vegetatively or asexually reproducing organisms.	It is basis of maintaining same chromosome number in different generations of a species reproducting sexually as well as for providing genetic variation in the progeny.

What is a karyotype

Chromosomes can be seen distinctly only at metaphase. They are then photographed, cut and arranged in pairs according to size. Such an arrangement of homologous chromosomes of an individual in descending order according to size, is termed as a karyotype (see human karyotype in lesson 21).

INTEXT QUESTIONS 4.10

1. Name the sub-stage of meiosis-I in which the :

   (i) Homologous chromosomes pair

   ....

   (ii) Tetrads are formed.

   ....

   (iii) Homologous chromosomes begin to move away from each other.

   ....

2. Sites of meiosis in flowering plants, are :

   ....

3. Rearrange the following stages of meiosis I in their proper sequence :

   zygotene, pachytene, leptotene, metaphase-I diakinesis, anaphase-I, telophase-I.

   ....

4. Mention two major points in which meiosis I differs from meiosis II

   ....

WHAT YOU HAVE LEARNT

- A living cell is a self-sufficient unit of the body of a living plant or animal.
- Important cell organelles are mitochondria, Golgi complex, ER, ribosomes, peroxisomes, chloroplast, glyoxisomes, nucleus.
- With the exception of centrioles, ribosomes and nucleolus, all other organelles are membrane-bound.
- Although a cell fails to live, grow and reproduce in the absence of a nucleus, nucleus all by itself without cytoplasm is also ineffective.
- Some organelles like mitochondria and chloroplast have the capacity to duplicate themselves to some extent without the help of the nucleus i.e. they are termed semi-autonomous.
- The living cells divide by mitotic cell division to produce new cells.
- Growth in body occurs due to increase in the number of cells.
- The continuity of the chromosomal set is maintained by cell division.
- The life cycle of a cell includes interphase (G_1, S & G_2) and M-phase (mitosis or meiosis)
- Mitotic cell division occurs in somatic cells or reproductive cells that results in the formation of identical cells, both qualitatively and quantitively.
- Meiosis occurs in germ cells only i.e. testis and ovary. This is a reduction division where the chromosome number becomes half.
- The significance of mitosis is growth, and reproduction where the product of reproduction is identical.
- The Significance of meiosis is in sexual reproduction where ova and sperm both have half the number of chromosomes i.e. 23 each in human gametes (but normal number of chromosome of human is 46 or 23 pair) and on fertilization the chromosome number becomes normal.
- Meiosis also helps in mixing the paternal and maternal characters.

TERMINAL EXERCISES

1. Justify the statement that cell wall although a dead material, influences living processes inside the cell.
2. Differentiate between cell wall and cell membrane.
3. Draw Singer and Nicholson's model of cell membrane.
4. Why is cell membrane vital for the cell?
5. Draw structure of mitochondria and chloroplast as seen by electron microscope.
6. List functions of mitochondria and chloroplast.
7. Name the self–duplicating cell organelles? Why are they called so?
8. Differentiate between functions of ER, ribosomes and Golgi bodies.
9. Most organelles are membrane – bound. What is the advantage of such arrangement.
10. Differentiate between the structure and function of centriole and cilia/flagella.
11. Why are lysosomes known as "suicidal bags"?
12. What are the functions of nucleus?
13. List the cell organelles. Write in one line each, about their functions and explain the division of labour.
14. Give the points of difference between
    (i) prokaryotic and eukaryotic cell.
    (ii) plant and animal cell.
15. Why is the cell termed the structural and functional unit of living organisms?
16. Name the following :
    (i) The condition in which a cell has the normal paired chromosomes.
    (ii) The condition in which a cell contains only one member of each pair of chromosomes.
    (iii) The pairing of maternal and paternal chromosomes during meiosis.
    (v) The exchange of parts in homologous (maternal and paternal) chromosomes during prophase-I of meiosis.
    (vi) The point by which a chromosome is attached to the spindle fibre.
    (vii) The type of cell division that results in growth.
17. What are the sites of meiosis in a flowering plant and in a sexually reproducing animal?

18. List the sub-stages of prophase-I.
19. What is the significance of meiosis?
20. Draw a schematic diagram of various stages of the life-cycle of a cell.
21. Draw labelled diagrams of various stages of mitosis.
22. Tabulate the main differences between mitosis and meiosis.
23. Why is prophase of meiosis so prolonged and elaborate?
24. What is the difference between cytokinesis in animal cell and cytokinesis in plant cell?

ANSWERS TO INTEXT QUESTIONS

4.1
1. Pre-existing cells
2. Schleiden and Schwann
3. Chloroplast/plastid
4. Prokaryote - naked nucleus, no membrane bound cell organelles

   Eukaryote - distinct nucleus with a cell membrane, membrane bound cell organelles present

4.2
1. Diffusion : Movement of molecules from region of their higher concentration to region of their lower concentration.

   Osmosis : Movement of water molecules across a semipermeable membrane from region of their higher concentration to the region of their lower concentration.
2. Movement of molecules against concentration gradient that is region of lower to higher concentration by expending energy.
3. Intake of solid particles (phagocytosis)

   Intake of fluid droplets (pinocytosis)
4. (i) – d (ii) – a (iii) – e

   (iv) – b (v) – c
5. (i) Protection/shape

   (ii) Provide communication between cells through plasmodesmata

4.3
1. Membrane bound bodies in the cytoplasm
2. ATP
3. Grana
4. Thylakoids
5. Because energy as ATP is generated and stored in mitochondria
6. Mitochondria

7. (i) both are semiautonomous
   (ii) both contain DNA or both contain ribosomes
8. Chromoplasts
9. Chloroplast
10. They have their own DNA for production of more copies of themselves by self duplication but cannot lead independent life, outside the cell/ cytoplasm.

4.4
1. (a) Golgi body (b) ER, (c) amyloplasts (d) ER, (e) ribosomes
2. refer text
3. (i) internal framework, (ii) transport of cellular substances
4. cytoplasm, ER, Nucleolus; chloroplasts, mitochondria
5. ER

4.5
1. Because the lysosome can devour organelles of the same cell
2. They help in cleaning up the cell by digesting useless matter
3. Fat metabolism

4.6
1. Nucleus controls all the functions of the cell as it has the hereditary information
2. (a) Chromosomes are present as a network when not dividing, that is, at early interphase or Go-stage (Differentiation stage during development)
   (b) Bearers of hereditary information as genes on them
3. Site of RNA synthesis

4.7
1. (i) It is a universal solvent and most chemical reactions of the cell occur in aqueous medium
   (ii) It is a constituent of protoplasm
2. glucose
3. –NHCO–, between amino acids in a polypeptide, found in proteins
4. ATP
5. building blocks of nucleic acids, each containing a pentose sugar, nitrogenous base and phosphate

4.8
1. (i) Interphase - stage between two successive cell divisions;
   (ii) Synthetic phase - DNA is synthesised;
   (iii) Dividing phase - Mitosis in somatic cells or meiosis in the germ cells takes place.

2. (i) First growth phase; (ii) Synthetic phase;
   (iii) Second growth phase; (iv) Mitosis/meiotic phase.

4.9 1. S-shape of Interphase;
2. No;
3. (i) Late Prophase; (ii) Late Telophase; (iii) Anaphase; (iv) Metaphase

4.10 1. (i) zygotene (prophase I); (ii) Pachytene; (iii) Diplotene
2. Microspore/pollen mother cell in anthers and megaspore mother cell in the ovule.
3. Leptotene, zygotene, pachytene, diplotene, diakinesis, metaphase I, telophase I.
4. Reduction in chromosome number to half in Meiosis-II; exchange of genetic material in meiosis I.

5

TISSUES AND OTHER LEVELS OF ORGANIZATION

You have just learnt that cell is the fundamental structural and functional unit of organisms and that bodies of organisms are made up of cells of various shapes and sizes. Groups of similar cells aggregate to collectively perform a particular function. Such groups of cells are termed "tissues". This lesson deals with the various kinds of tissues of plants and animals.

OBJECTIVES

After completing this lesson, you will be able to :

- *define tissues;*
- *classify plant tissues;*
- *name the various kinds of plant tissues;*
- *enunciate the tunica corpus theory and histogen theory;*
- *classify animal tissues;*
- *describe the structure and function of various kinds of epithelial tissues;*
- *describe the structure and function of various kinds of connective tissues;*
- *describe the structure and function of muscular tissue;*
- *describe the structure and function of nervous tissue.*

5.1 WHAT IS A TISSUE

Organs such as stem, and roots in plants, and stomach, heart and lungs in animals are made up of different kinds of tissues. **A tissue is a group of cells with a common origin, structure and function.** Their common origin means they are derived from the same layer (details in lesson No. 20) of cells in the embryo. Being of a common origin, there are similar in structure and hence perform the same function. Several types of tissues organise to form an **organ**.

Example : Blood, bone, and cartilage are some examples of animal tissues whereas parenchyma, collenchyma, xylem and phloem are different tissues present in the plants. The study of tissues is called **histology**.

A group of cells with similar origin, structure and function is called **tissue**. e.g. bone, and muscle in animals and meristem in tips of root and shoot in plants

5.2 THE PLANT TISSUES

The plant tissues are mainly of two catagories:

1. Meristematic (Gk. meristos : dividing)
2. Permanent (non-dividing)

1. **Meristematic tissues**
   - Composed of immature or undifferentiated cells without intercellular spaces.
   - The cells may be rounded, oval or polygonal; always living and thin-walled.
   - Each cell has abundant cytoplasm and a prominent nucleus in it.
   - Vacuoles may be small or absent.

Table 5.1 Types of meristematic tissue

Types	Location	Function
Apical Meristem	Root tip and shoot tip.	Growth in length of plants and their branches.
Intercalary Meristem	At the bases of leaves or at the bases of internodes.	Internodal growth, in monocots growth of leaf lamina in grasses.
Lateral Meristem	Cambium between xylem and phloem and cork. cambium in the cortex of dicot plants.	Growth in thickness of the plant body (secondary growth).

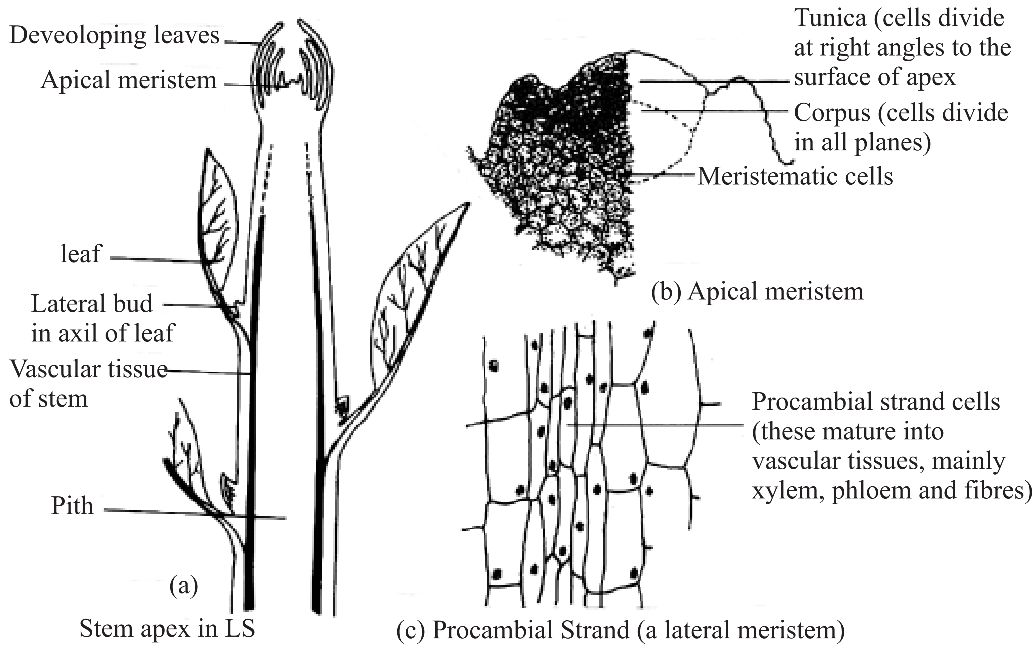


Fig. 5.1 Location of the meristematic tissues in an angiospermous plant

2. **Permanent tissues**
   - Permanent tissues are those in which growth has stopped either completely or for the time being.
   - Cells of these tissues may be living or dead; and thin-walled or thick-walled.
   - Thin-walled permanent tissues are generally living whereas the thick-walled tissues may be living or dead.

Types of permanent tissues

(i) **Simple tissues :** A simple tissue is made up of only one type of cells. Common simple tissues are parenchyma, collenchyma and sclerenchyma (Fig. 5.2, 5.3 and 5.4).

(ii) **Complex tissues :** A complex tissue is made up of more than one type of cells working together as a unit. Common examples are xylem and phloem (Fig. 5.5 and 5.6).

The structure, function and distribution of simple plant tissues is given in Table 5.2.

INTEXT QUESTIONS 5.1

1. Define a tissue.

   ....

2. Give one word equivalent for the following :
   (i) A plant tissue that consists of cells which continue to divide to produce more cells.

   ....

   (ii) The meristematic tissue responsible for the increase in thickness of the stem of a tree.

   ....

   (iii) The kind of plant tissues which consists of all similar cells.

   ....

   (iv) The category of plant tissues in which the cells do not divide.

   ....

3. What do you mean by "cells of a tissue have similar origin"?

   ....

4. Name that branch of Biology in which tissues are studied?

   ....

5. What is a complex tissue?

   ....

6. Mention any **two** special features of the meristematic cells.

   ....

5.2.1 Simple Plant Tissues

There are three types of simple plant tissues (Fig. 5.2, 5.3 and 5.4)

1. Parenchyma (Chlorenchyma and Aerenchyma)
2. Collenchyma
3. Sclerenchyma

Table 5.2 Structure, Function and Distribution of simple tissues

Tissue	Living or Dead	Structure	Function	Distribution
1. Parenchyma	Living	(i) Oval or round, thin-walled with sufficient cytoplasm. (ii) Has prominent nucleus and intercellular spaces (iii) Wall made up of cellulose	(a) They make large parts of various organs in most plants. (b) Act as storage cells. (c) Chlorenchyma carries out photosynthesis. (d) Turgid, parenchyma gives rigidity to the plant body.	1. Pith and cortex of stem and root. 2. Mesophyll of leaves. 3. Endosperm of seed. 4. Xylem and phloem parenchyma in vascular tissue.
(a) Chloren-chyma	Living	Parenchyma containing chloroplasts.		
(b) Aeren-chyma	Living	Parenchyma with large air spaces or intercellular spaces.		5. Occur in leaves and stems of aquatic plants
2. Collenchyma (Gk. collen : glue)	Living	(i) Elongated cells with thick primary walls. Thickenings more in the corners of the cells. (ii) Wall material is cellulose and pectin (iii) Intercellular sapces present.	Gives mechanical support to the plant body. Specially in many dicot leaves and green stems	Occurs in the peripheral regions of stems and leaves.
3. Sclerenchyma (Gk. scleros = hard)	Dead	Sclerenchyma consists of thick walled cells, walls uniformly thick with lignin.	Sclerenchyma is mainly a supporting tissue, which can withstand strains and protect the inner thin-walled cells from damage.	• Fibres occur in patches or continuous bands in various parts of stem in many plants.
(a) Fibres	Dead	Elongated cells with pointed ends. Walls are thick with lignin.		• Sclereids occur commonly in fruits and seeds.
(b) Sclereids	Dead	Irregular in shape. Cell wall very thick making the cell cavity very small.		Present in some leaves in large numbers.

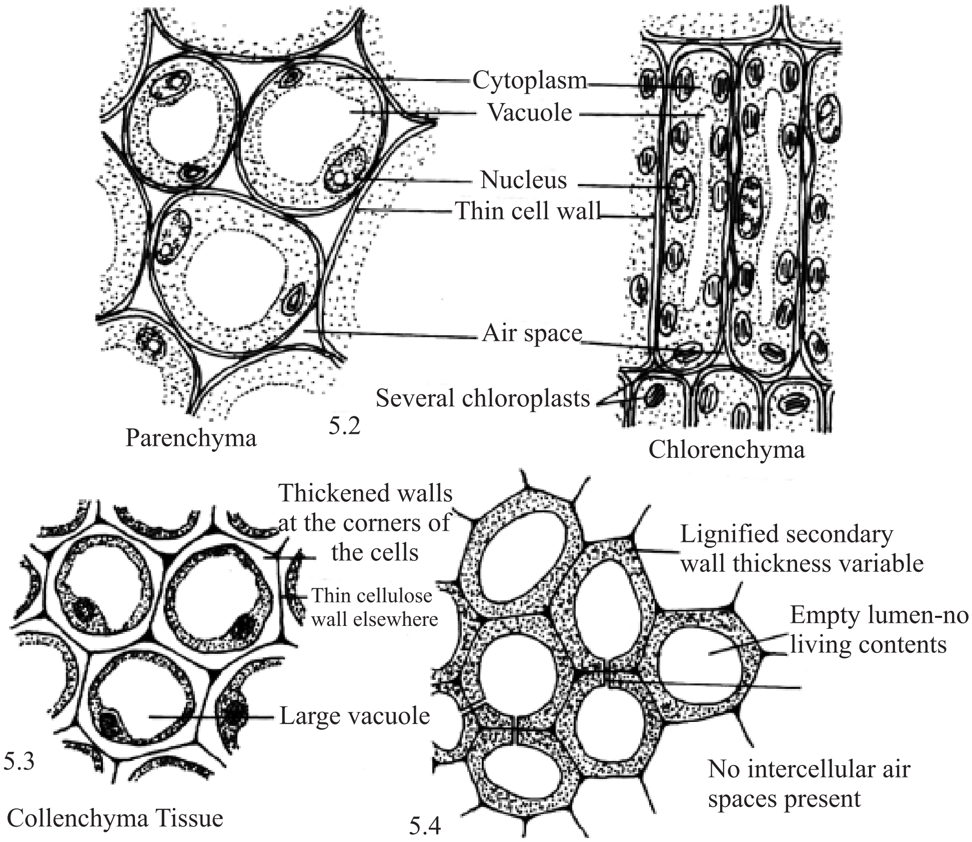


Fig. 5.2, 5.3, 5.4 Various types of simple tissues

5.2.2. Complex tissues

Complex tissues are mainly of two types :

(i) Xylem

(ii) Phloem

– Xylem and phloem form a continuous system inside the plants, that is from the roots through the stem and leaves.

– They are known as vascular tissues and form vasular bundles in roots and stems.

Xylem (Greek xylo = wood)

– Xylem is a conducting tissue which conducts water and salts upward from roots to leaves.

– Xylem is composed of (a) Tracheids, (b) Vessels (c) Fibres and (d) Xylem Parenchyma (Fig. 5.5)

Phloem

– Phloem too is a conducting tissue which conducts the metabolites (food) food synthesised in the leaves to different parts of the plant.

– Phloem is composed of (a) Sieve tube element (b) Companion cells (c) Phloem fibre and (d) Phloem Parenchyma (Fig. 5.6)

The structure, and function of the complex plant tissues is given in Table 5.3.

Table 5.3 Structure and function of the components of xylem and phloem

Tissues	Living or Dead	Structure	Function
Xylem			
1. Tracheids	Dead	Long cells with pointed ends. Walls thick with lignin. Have pores on the walls	All of them function as a unit to conduct water and minerals upward from root to leaves.
2. Vessels	Dead	Cells shorter and broader than tracheids. Walls thick with lignin and have pores. End walls open and the cells join to form a long tube.	
3. Xylem Fibres	Dead	Long cells with very thick lignin deposition on the walls, no pores on the walls.	
4. Xylem Parenchyma	Living	Small thin walled cells with cellulose walls.	
Phloem			
1. Sieve tube	Living	Elongated sieve elements join to form sieve tubes; cell wall of cellulose. End walls of the cells have perforations on them, which give them the name (sieve).	All of them function as a unit to translocate food assimilated in the leaves by photosynthesis to different parts of the plant.
2. Companion cell	Living	Long, rectangular cells associated with seive cells. Cell wall made of cellulose.	
3. Phloem fibre	Dead	Very long cells with thick lignified walls	
4. Phloem parenchyma	Living	Elongated cells. Cell walls thin and made of cellulose.	

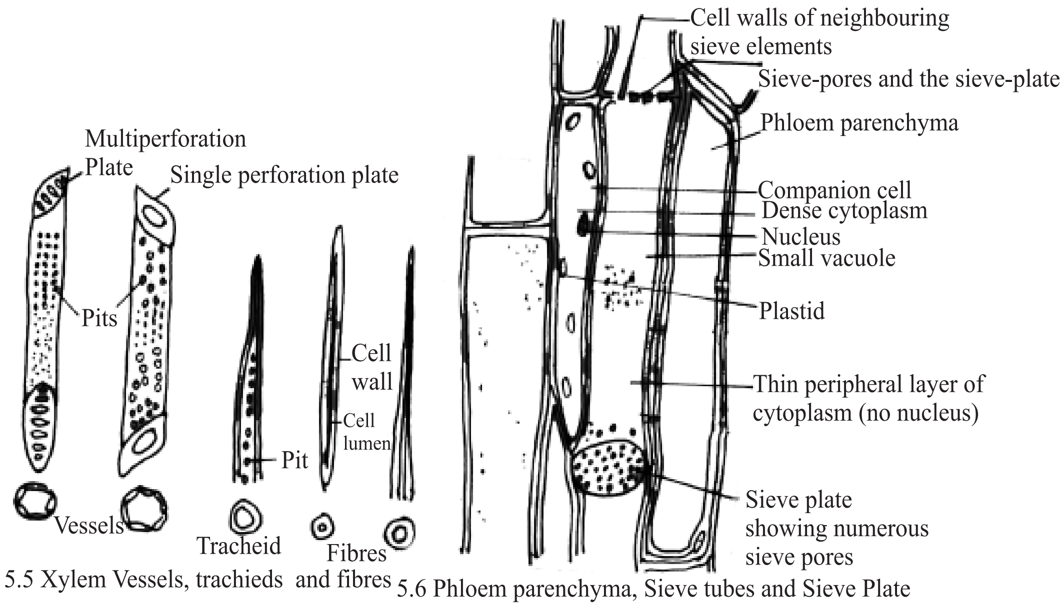


Fig. 5.5, 5.6 Various types of complex tissues

5.2.3 Theories explaining growth of the plant at its shoot apex and root tip

There are two important theories that explain the growth of a plant at the extremities of shoot and root. These are (i) the Tunica corpus theory and (2) the Histogen theory.

Tunica Corpus Theory :

- Tunica corpus theory was developed for vegetative shoot apex.
- According to this theory, there are **two** zones of tissues in the apical meristems **the tunica** (Tunic = cover) consisting of one or more layers of peripheral layers of cells, and the **corpus** (corpus = body) a mass of cells enclosed by the tunica.
- According to the theory, different planes and rates of cell division and methods of growth in the apex set apart two regions.
- The layers of tunica show anticlinal (perpendicular to periphery) divisions and bring about surface growth.
- In the corpus, cell division is irregular and at various planes resulting in grwoth in volume of the mass.
- Tunica gives rise to the epidermis and cortex. Corpus gives rise to endodermis, pericycle, pith and vascular tissue.

Histogen Theory

- According to this theory, the apical meristem of stem and root are composed of small mass of cells which are all alike and divide fast (meristematic)
- These meristematic cells form promeristem, which differentiates into three zones **dermatogen, periblem** and **plerome**.
- Each every zone consists of a group of initials called a **histogen** (tissue builder).
  (i) The dermatogen gives rise to epidermis of stems and epiblema of roots.
  (ii) Periblem (middle layer) gives rise to cortex of stems and roots.
  (iii) Plerome gives rise to the central meristematic region – pericycle, pith and vascular tissue.

Classification of plant tissues-at a glance

Plant Tissue
- Meristematic
  - Apical
  - Intercalary
  - Lateral
- Permanent
  - Simple
    - Parenchyma
    - Collenchyma
    - Sclerenchyma
  - Complex
    - Xylem
    - Phloem

INTEXT QUESTIONS 5.2

1. Give Two characteristics and one example of the location of the given tissues in plants in the following table:

S.No.	Tissue	Characteristics	Example of location
(i)	Parenchyma	....	....
(ii)	Collenchyma	....	....
(iii)	Sclerenchyma	....	....

2. Name the plant tissues which
   (i) conduct water ....
   (ii) conduct food metabolites. ....

5.3 ANIMAL TISSUES

As in plants, tissues in animals are also of various types which perform different functions. See the flow-chart given below

Animal Tissues

- **Epithelial tissue** (Protection by covering, secretion, and absoption)
- **Connective Tissue** (Binding, support, transport)
- **Muscular tissue** (Movement and Locomotion)
- **Nervous Tissue** (Control and co-ordination)

5.3.1 Epithelial Tissue

Structural Characteristics : The cells forming epithelial tissue –

(i) are closely packed with no intercellular spaces in between.

(ii) arise from a non-cellular basement membrane.

(iii) are not supplied with blood vessels.

Function : Epithelian tissues line the surfaces, help in absorption, secretion, and also bear protoplasmic projections such as the cilia. (See Table 5.4 and Fig. 5.7)

Table 5.4 : Types of epithelial tissue

Type	Structure	Location	Function
1. Squamous Epithelium	Flattened cells with a centrally placed nucleus. Have irregular margins.	Lining of air sacs in the lungs. Lining of Kidney tubules. Lining of blood capillaries.	For exchange of O_2 and CO_2. For absorption. For exchange of materials.

2. Cubodial Epithelium	Cube like cells with a centrally placed nucleus, Cells appear polygonal.	Lining of salivary and pancreatic ducts.	For absorption.
		In sweat and salivary glands.	For secretion
3. Ciliated Epithelium	Have cilia at free ends.	Lining of kidney tubules.	For flow of nephric filtrate.
4. Columnar epithelium	Long column-like cells, each with nucleus at the basal end	Lining of stomach, instestine	Secretion and absorption
5. Ciliated Columnar Epithelium	Cilia at free ends	Lining of trachea	Flow of fluids in a particular direction
6. Brush bordered Columnar Epithelium	Numerous folds at free ends—folds looking like bristles of a brush.	Lining of intestine	Increasing the surface area for absorption

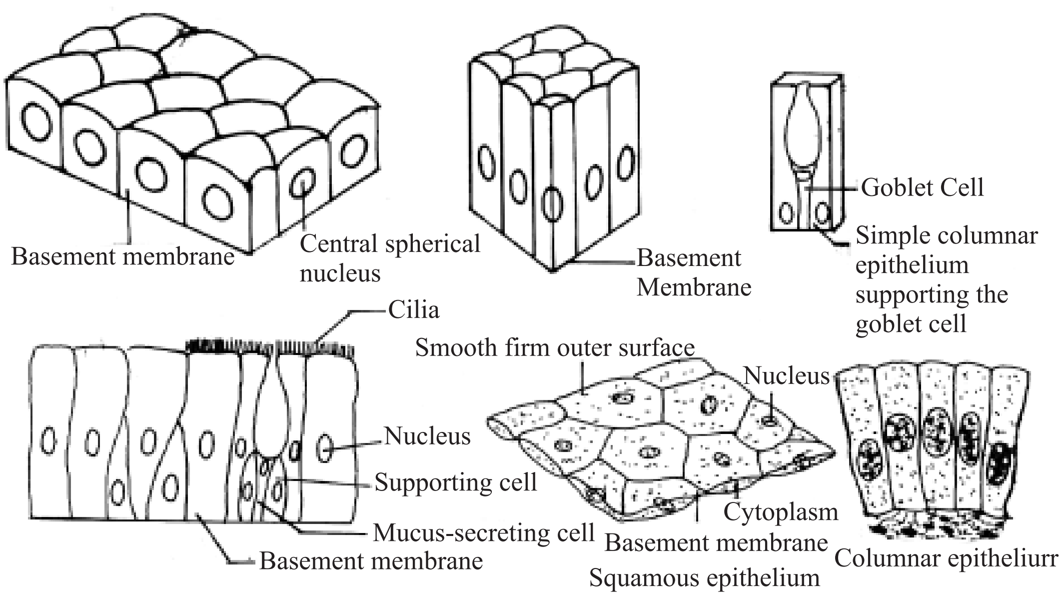


Fig. 5.7 The structure of different kinds of epithelial tissues

If the epithelial cells are in a single layer, they form simple eptihelium. If the epithelial cells are arranged in many layers, they form compound epithelium or stratified epithelium (many layers). Stratified eptihelium is present in the body, where there is lot of wear and tear. For example the skin and inner lining of cheeks.

INTEXT QUESTIONS 5.3

1. List the different types of animal tissues

   ....

2. Match the items in Column I with those in Column II by writing the corresponding serial number within brackets.

	Column I		Column II
(a)	Compound Epithelium	( )	(i) Epithelial tissue
(b)	Basement membrane	( )	(ii) For increasing the surface area
(c)	Brush-bordered epithelium	( )	(iii) Lining of trachea
(d)	Salivary gland	( )	(iv) Skin
(e)	Ciliated Epithelium	( )	(v) Cuboidal epithelium

5.3.2 Connecitve tissue

The connective tissue has two components :

(a) matrix, the ground substance and (b) cells

The matrix and cells are different in different connective tissues (Fig. 5.8).

Types of connective tissue

- Proper
  - Areolar
  - Adipose
  - Fibrous
- Supporting
  - Cartilage
  - Bone
- Fluid
  - Blood
  - Lymph

A. Proper Connective Tissue

1. Areolar : Most widely spread connective tissue.

The cells forming the tissue are :

(i) **Fibroblasts**-which form the yellow (elastin) and white (collagen) fibres in the matrix.

(ii) **Macrophages**-which help in engulfing bacteria and micro-pathogens.

(iii) **Mast cell**-which secretes heparin, that helps in clotting of blood.

2. Adipose tissue : It has specialized cells which store fat and provide help in forming paddings.

3. Fibrous : It is mainly made up of fibroblasts. It forms tendons and ligaments.

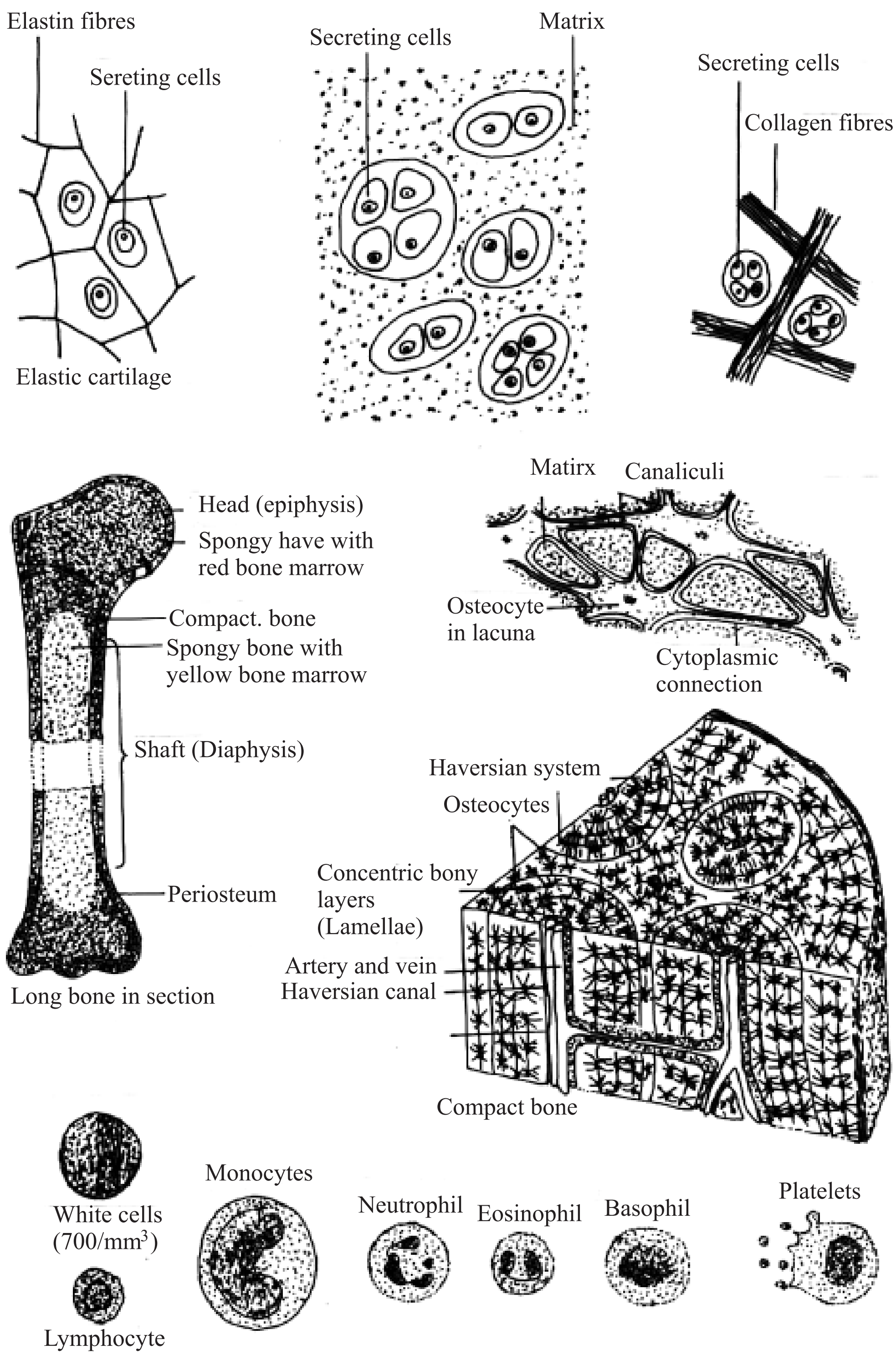


Fig. 5.8 Some representative types of connective tissues.

B. Supporting Connective Tissue

Supporting Connective Tissue

Cartilage	Bone
1. Matrix is composed of **chondrin.** The cells lie in the matrix singly or in groups of two or four surrounded by fluid-filled spaces. The cartilage may be elastic whose matrix has yellow fibres as in the pinna of the ear.	1. Matrix is composed of **ossein.** Matrix also contains salts of calcium, phosphorus and magnesium. Matrix in mammalian long bones (such as the thigh bone) is arranged in concentric rings. The **osteocyte**s (bone cells) lie on the lamellae (concentric rings in the matrix.) Osteocytes give out branched processes which join with those of the adjoining cells. Some bones have a central cavity which contains a tissue that produces blood cells. The substance contained in the bone cavity is called **bone marrow.**
2. The cartilage is a flexible and strong type of connective tissue in most of the vertebrates usually occurring as part of their endoskeleton.	2. Bones are of two types : **Spongy** and **Compact**. In a spongy bone, the bone cells are irregularly arranged. Such bones are found at the ends of the of long bones.
3. The cartilage can be calcified where calcium salts are deposited in the as in head of long bones.	3. In the compact bones, cells are arranged in circles or lamellae around a central canal- the Haversian canal.

C. Fluid connective tissue

Blood and Lymph are the two forms of fluid connective tissue.

Blood : It is a complex of blood cells and plasma. Plasma forms the matrix.

The blood cells are :
1. Red Blood Cells (Erythrocytes)-Transport O_2 and CO_2
2. White blood cells (Leucocytes)-Function in defence against bacteria, viruses and other invaders.
3. Platelets (Thrombocytes)-help in the clotting of blood.

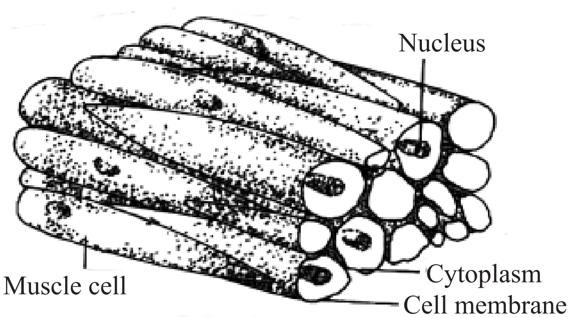
Plasma is the extracellular fluid matrix in the ground substance. It contains a large number of proteins such as Fibrinogen, Albumin, and Globulin to be transported to various parts of the animal body for various purposes.

5.3.3 Muscle tissue

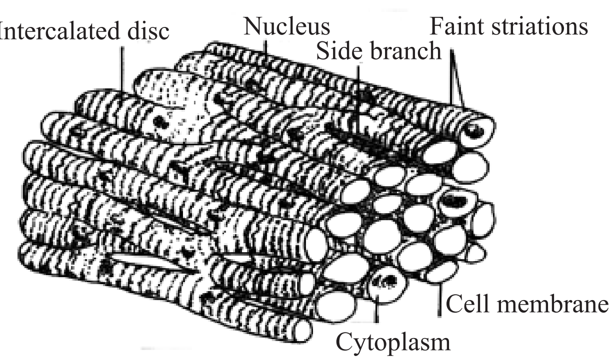
This is composed of long excitable cells containing parallel microfilaments of contractile proteins, as in actin, myosin, troponin and tropomysin. Because of its elongated shape, muscle cell is called a muscle fibre. The muscle fibres of vertebrates are of three different types (i) Striated (ii) Unstriated and (iii) Cardiac (Fig. 5.9) according to the shape and functions as mentioned in Table 5.5 and Fig. 5.9.

Table 5.5 Types of Muscle Fibres

Striated/Voluntary/Skeletal	Unstriated/ Involuntary	Cardiac
Location		
1. Attached to the skeleton like head, limbs, face etc.	In the walls of body organs like stomach, intestines.	Walls of heart.
Shape		
Elongated, cylindrical, unbranched fibres	Spindle shaped, tapering.	Elongated, cylindrical, branched.
Myofibrils so arranged in the cytoplasm, that there are striations seen.	No such striations seen as myofibrils are not uniformly arranged .	Striations (stripes) seen.
Sarcolemma		
Thin and tough membrane sarcolemma of the fibre (cell).	Thin cell membrane, no sarcolemma.	Thin
Nucleus		
Multi nucleated, Peripheral nuclei.	Uninucleated, centrally placed.	One nucleus in each unit, centrally placed.
Blood Supply		
Rich	Poor	Rich
Intercalate Discs		
Absent	Absent	Present
Voluntary (Contracts at will)	Involuntary	Involuntary



Smooth muscle fibres



Cardiac muscle fibres

Fig. 5.9 Types of Vertebrate Muscle Tissue

The muscle fibres have the following characteristics:

(i) Excitability, (respond to stimulus)
(ii) Extensibility, (stretch)
(iii) Contractility, (contract)
(iv) Elasticity, (move back to the original position)

INTEXT QUESTIONS 5.4

1. Name the different types of cells found in the different types of connective tissue.

   ....

2. Match the item in Column I with those in Column II, by writing the corresponding serial number within brackets:

	Column I			Column II
a.	Unstripped muscles	( )	(i)	multinucleate
b.	Myofibrils	( )	(ii)	run parallel to each other in a striped muscle
c.	Sarcolemma	( )	(iii)	cardiac muscles
d.	Striped muscle	( )	(iv)	outer tough membrane of a striped muscle fibre
e.	Branched myofibrils	( )	(v)	involuntary

5.3.4 Nervous Tissues

Nervous tissues has two kinds of cells i.e. **neurons and neuroglia cells**

Neurons

Neuron is the functional unit of nervous tissue. Neurons are also called nerve cells. Nervous tissues constitute the brain, spinal cord, nerves and the sensory cells and sense organs.

A single neuron has a generalised appearance as shown in the Fig. 5.10.

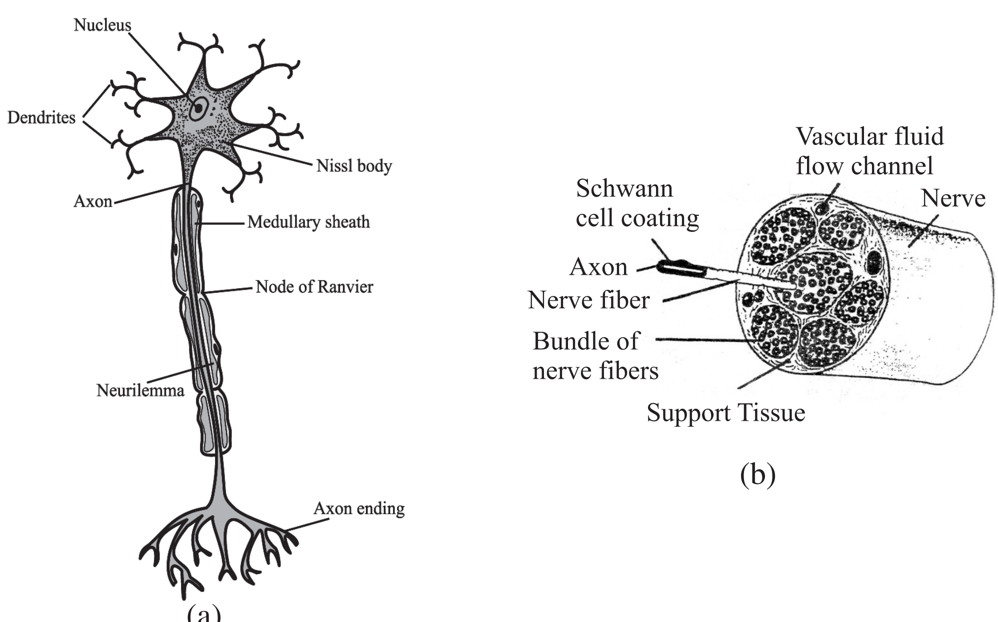


Fig. 5.10 Nerve cell and nerve fibre.

Like any other cell of the body, the nerve cell or neuron has the main cell body called **cyton** from which project out a varying number of processes –one of which is usually very long. This long fibre is called the **axon**.

The smaller branching processes of the cyton are called the **dendrites** (GK dendros = tree). The cells bounded by plasma membrane, possess a nucleus and other organelles like mitochondria.

The cyton also contains dark granules called **Nissi** bodies. These are made of RNA and Protein.

Transmission of nerve impulse – The branching dendrites receive the stimulus and transmit it through the cyton to the axon, which finally transmits it through its variously branched ends into either a muscle (to order it to contract) or to a gland (to order it to secrete). The axon constitutes the nerve fibre. The nerve fibre may or may not be covered by an extra sheath called **medullary sheath** secreted by sheath cells. It is made of **myelin** a lipid like substance. Accordingly, the nerve fibre is termed **medullated** and **non-medullated.** The medullary sheath is not continuous and is broken at **nodes of Ranvier** (Fig. 5.10).

INTEXT QUESTIONS 5.5

1. What is the function of the nervous tissue?

   ....

2. What is the direction of the "flow of impulse" within a nerve cell from its dendrites to its axon end or from its axon end toward its dendrites?

   ....

3. What are the following parts in a nerve cell?
   (i) Cyton ....
   (ii) Dendrite ....
   (iii) Axon ....
   (iv) Medullary sheath ....
   (v) Node of Ranvier ....

5.4 LEVELS OF ORGANISATION – CELL TO ORGANISM

We started the lesson by talking about the smallest unit of life in any living organism i.e. the cell. The cell has a very complex system of its organelles, each organelle concerned with a particular task or activity, and each activity contributing to the total performance of the cell. Thus there is a division of labour at the cellular level. As evolution progressed and larger and larger organisms appeared with enormous number of cells in the body, it became necessary that the bodily functions are distributed among different groups of cells or tissues even among groups of tissues. Such higher and higher stages or groupings are known as the levels of organization. These levels are as follows:

(i) **Cellular Levels of Organization–** The organization of the activities by different organelles in a single cell. Example, white blood cells or a green cells of a leaf.

(ii) **Tissue Level–** The aggregates of cells of same origin and having same function, example, the surface epithelium of our skin or the dividing cells at the root cap of a plant.

(iii) **Tissue System–** Generally seen in plants where two or more different cell types combine to perform a particular activity. Example – Vascular tissue e.g. veins of a leaf, consisting of xylem and phloem, for transport of water and food materials.

(iv) **Organ Level–** A distinct recognizable part of the body, composed of a variety of tissues and performing one or more special functions which contribute to the well being of the organism. Example : Liver in animals and leaf in plants.

(v) **Organ System-** Combination of a set of organs all of which are usually devoted to one general function. Example : respiratory system (consisting of lungs, trachea, and diaphragm) in man or the shoot system (consisting of leaves, stem and branches) in a plant.

(vi) **Organism–** The complete individual made of different organ systems. Examples: man, monkey, or a mustard plant.

INTEXT QUESTIONS 5.6

1. Rearrange the following levels of organizations in their correct sequences:- tissue, cell, organ, organism, organ system.

   ....

2. Complete the following Table by giving one example of each of the following in an animal and plant.

Level of	**Examples**	
Organisation	**Animal**	**Plant**
Cell	....	....
Tissue	....	....
Organ	....	....
Organ system	....	....
Organism	....	....

WHAT YOU HAVE LEARNT

- A tissue is a group of cells which are essentially of the same kind and of the same origin and performing similar function.

- In plants there are, first of all two major categories of tissues- meristematic (dividing and undifferentiated) and permanent (specialized) tissues.
- Meristematic tissue is located at all growth points.
- Permanent tissue consists of the simple tissue (parenchyma, collenchyma and sclerenchyma) and complex tissue (xylem and phloem).
- The animal tissues consist of epithelium (closely packed cells usually on surfaces,) connective tissue which primarily support, connect or bind the body parts together (bones blood etc.), the contractile muscular tissue (different muscles,) and nervous tissue consisting of nerve cells adapted for conducting the message (brain cells,)
- The various tissues in both plants and animals are grouped together to form an organ. The different organs together form the organ system and the various organs systems together constitute the organism or the individual. Thus there are different levels of organization with increasing complexity and specialization from cell to organism.

TERMINAL EXERCISES

1. What is a tissue?
2. State one main structural characteristic and the special activity of the following tissue:

   meristem, sclerenchyma, xylem, phloem, epithelium, muscle, nervous tissue.
3. In what way do the following tissues differ from the one stated:-
   (i) Connective tissue from epithelial tissue
   (ii) Bone from blood
   (iii) Phloem from xylem
   (iv) Squamous epithelium from columnar epithelium
   (v) Tracheids from wood fibres
4. Name the different levels of organizations in animals (such as humans) giving one example of each.

ANSWERS TO INTEXT QUESTIONS

5.1 1. a group of cells with similar origin, structure and function

2. (i) Merisematic;
   (ii) Lateral meristem
   (iii) Simple
   (iv) Permanent

3. arising from same embryonic layer of cells

4. histology

5. composed of more than one type of cells all cooperating in performing common function

5.2 1.

S.No.	Tissue	Characteristics	Example of location
1.	Parenchyma	1. Round cells 2. Living	1. Root, stem and leaves
2.	Collenchyma	1. Polygonal cells with thickening at corners 2. Living	1. Petiole and Mid-rib of leaves
3.	Sclerenchyma	1. Elongated or irregular in shape 2. Dead and thick walled	1. Woody Stems

2. xylem, phloem

5.3 1. Epithelial, connective, muscular, nervous

2. a-iv, b-i, c-ii, e-iii

5.4 1. Firbroblasts - areolar

Macrophages - areolar

Mast cells - areolar

Cartilage cells/chondrocyte - chondrocyte-cartilage

Bone cells/osteocyte - bone

Blood cells/WBC RBC - blood

2. a (v); (b) (ii); c (iv); d (i); e. (iii)

5.5 1. sensory

2. Dendrite to the axon

3. (i) cell-body (ii) thin processes of cyton (iii) sensory fibre (iv) medullary layer (v) interruptions in medullary sheath

5.6 1. Cell, tissue, organ, organ system, organism

2. refer to text subsection 5.4

MODULE - II
FORMS AND FUNCTIONS OF PLANTS AND ANIMALS

06 Root system

07 Shoot system

08 Absorption, Transport and Water Loss in Plants

09 Nutrition in plants - Mineral Nutrition

10 Nitrogen Metabolism

11 Photosynthesis

12 Respiration in Plants

13 Nutrition and Digestion

14 Respiration and Elimination of Nitrogenous Wastes

15 Circulation of Body Fluids

16 Locomotion and Movement

17 Coordination and Control - The Nervous and Endocrine Systems

18 Homeostasis: The Steady State

6

ROOT SYSTEM

The root system is the **descending** (growing downwards) portion of the plant axis. When a seed germinates, **radicle** is the first organ to come out of it. It elongates to form **primary** or the **tap root**. It gives off lateral branches (**secondary** and **tertiary** roots) and thus forms the root system. Its branches penetrate through large and deep areas in the soil and anchor the plant very firmly. It also plays another vital role of absorbing water and mineral salts from the soil and transporting them upwards. How is the root suited in structure to carry out such functions? You shall learn in this lesson.

OBJECTIVES

After studying this lesson, you will be able to :

- *define and identify root;*
- *distinguish between different types of root systems;*
- *describe and illustrate different regions of a root apex;*
- *describe various modifications and functions of roots;*
- *describe and distinguish between primary structure of dicot and monocot root;*
- *illustrate and explain the mode of secondary growth in a dicot root;*
- *describe the deep-seated (endogenous) origin of lateral roots.*

6.1. CHARACTERISTICS OF ROOTS

The main features of roots by which you can recognize them are :

- Non-green due to absence of chlorophyll;
- Not divided into nodes and internodes;
- Absence of leaves and buds;
- Positively geotropic (**grow towards gravity**);
- Positively hydrotropic (**grow towards water**);
- Negatively phototropic (**grow away from light**).

6.2. TYPES OF ROOT SYSTEMS

Root systems are mainly of two types:

(i) **Tap root system —** It is the root system that develops from the radicle and continues as the primary root (tap root) which gives off lateral roots. These provide very strong anchorage as they are able to reach very deep into the soil. It is the main root system of dicots e.g. gram, chinarose, neem (Fig. 6.1a).

(ii) **Fibrous root system** — In this root system, the primary root is short-lived. A cluster of slender, fiber-like roots arises from the base of the radicle and plumule which constitute the fibrous root system. They do not branch profusely, are shallow and spread horizontally, hence cannot provide strong anchorage. Fibrous root system is the main root system of monocots, e.g. maize, grasses, wheat (Fig. 6.1b).

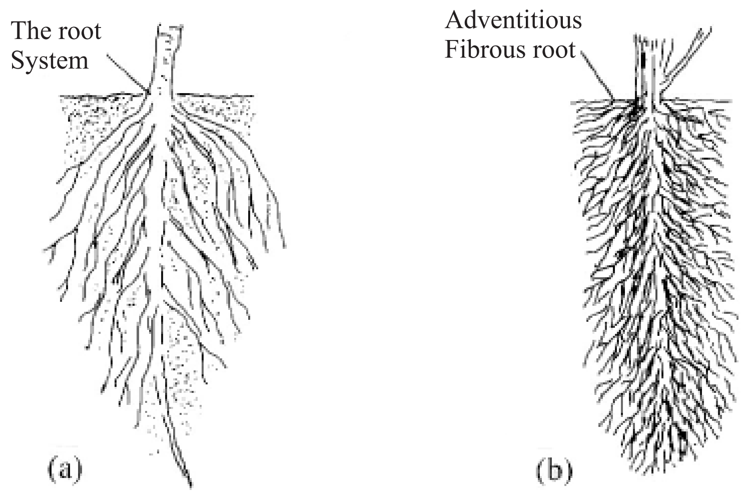


Fig. 6.1 Types of root systems (a) Tap root system (b) Fibrous root system

6.3 TYPES OF ROOTS

(i) **Tap root** – It is the **primary** and the main root that develops from the radicle, bears numerous branches and remains underground. It is usually found in dicots e.g. sunflower, mustard, carrot, mango (Fig. 6.1a).

(ii) **Adventitious root** – These are roots that develop from any part of the plant except the radicle. They may be aerial or underground (Fig. 6.1b). They may grow from node (money plant, bamboo), stem cutting (rose), tree branch (banyan) or stem base (fibrous roots in monocots).

INTEXT QUESTIONS 6.1

1. Name the plant organ which grows towards gravity and water but away from light?

....

2. From which part of the germinating seed does the root develop?

   ....

3. Which root system gives better anchorage and why?

   ....

4. Give two examples each of plants having fibrous and tap root system?

   ....

5. Mention three characters by which you can say that carrot which you eat is a root.

   ....

6.4 REGIONS OF ROOT

The apical region of roots of any root system shows the same zones or regions as can be seen in Fig.6.2a. A longitudinal section of root apex (Fig.6.2b) shows the following structures:

1. **Root cap region** — It is a thimble-like structure produced by meristematic (rapidly dividing) zone and protects the tender apex (apical meristem) from harsh soil particles. As the root grows further down in soil, root cap wears out but it is constantly renewed . In aquatic plants (*Pistia* and water hyacinth) root cap is like a loose thimble, called **root *pocket***.

2. **Region of meristematic cells** — is a small region of actively dividing cells called the apical meristem. It consists of :

   (i) Dermatogen (outermost layer whose cells mature into epiblema and root cap);

   (ii) Periblem (inner to dermatogen whose cells mature into cortex) and

   (iii) Plerome (central region whose cells mature into stele). In monocots, cap is formed by independent group of cells known as *Calyptrogen.*

3. **Region of elongation** — This is situated next to the meristematic region, wherein, the cells elongate and enlarge to make the root grow in length.

4. **Region of maturation** — This is next to the region of elongation, wherein the cells mature and differentiate into various tissues constituting (i) **Root hair** or **piliferous region** having unicellular hairs which absorb water and mineral salts from the soil and (ii) **Permanent region** which lies behind the root hair zone and is without hairs. It produces lateral roots, anchors the plant in soil and conducts water and minerals upwards.

In the maize root tip, Clowes (1958) discovered a central cup-like reservoir of inactive cells, lying between the root cap and the active meristematic region, called the **Quiescent Centre**. These cells become active whenever the previously active meristematic cells are damaged.

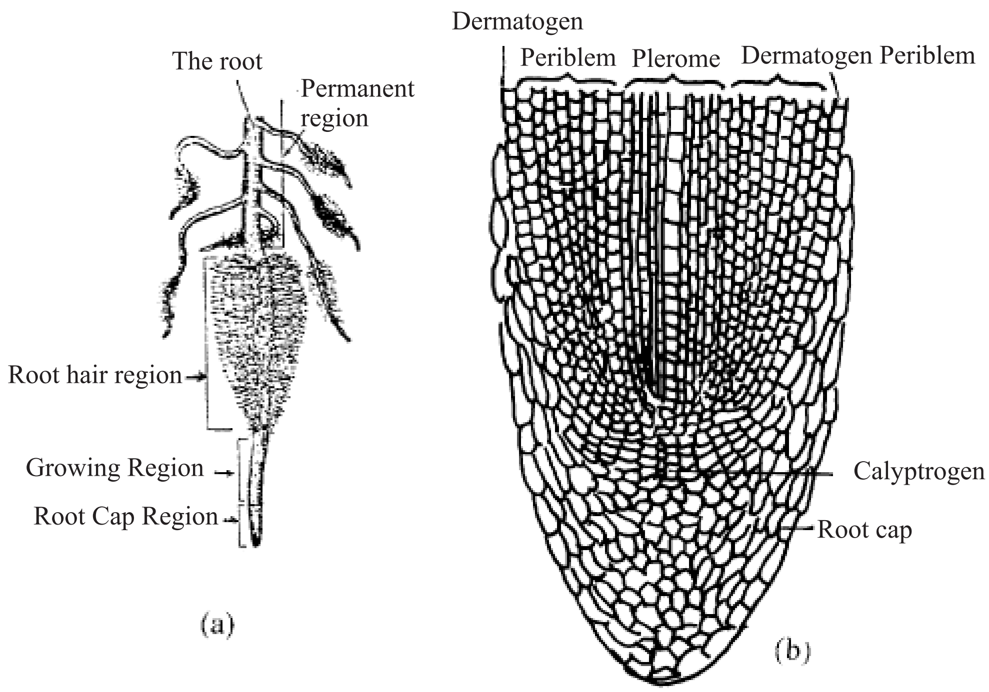


Fig. 6.2 (a) Apical part of a root showing four different regions; (b) LS through root apex

INTEXT QUESTIONS 6.2

1. Name the structure which protects the root apical meristem.

   ....

2. Give in a sequence, the various regions of root from its tip towards its base.

   ....

3. Into which tissues do dermatogen and plerome differentiate?

   ....

4. Which region of root absorbs water and mineral salts?

   ....

6.5 MODIFICATIONS OF ROOTS

Tap roots and adventitious roots can get modified into a variety of forms to perform various functions as can be seen from the following chart and Tables 6.1 and 6.2.

Modifications of roots

Tap root modification

(i) Conical root

(ii) Fusiform root

(iii) Napiform root

(iv) Tuberous root

Adventitious root modification

(i) Tuberous root

(ii) Fasciculated root

(iii) Nodulose roots

(iv) Moniliform roots

(v) Annulated roots

(vi) Assimilatory roots

(vii) Epiphytic roots

(viii) Pneumatophores/Respiratory roots

(ix) Sucking roots or haustoria

(x) Prop roots

(xi) Stilt roots

(xii) Climbing roots

(xiii) Clinging roots

(xiv) Floating roots

A. Tap root modifications

Tap roots become fleshy for storage of food (Table 6.1)

Table 6.1 – Tap root modifications for food storage

Type	Characters	Example
1. Conical (Fig. 6.3a)	Base is broad and tapers gradually towards apex	Carrot
2. Fusiform (Fig. 6.3b)	Swollen in middle, tapering towards both ends	Radish
3. Napiform (Fig. 6.3c)	Spherical at base tapering sharply towards the tip	Turnip
4. Tuberous (Fig. 6.3d)	Thick and fleshy with no definite shape	4 O'clock plant

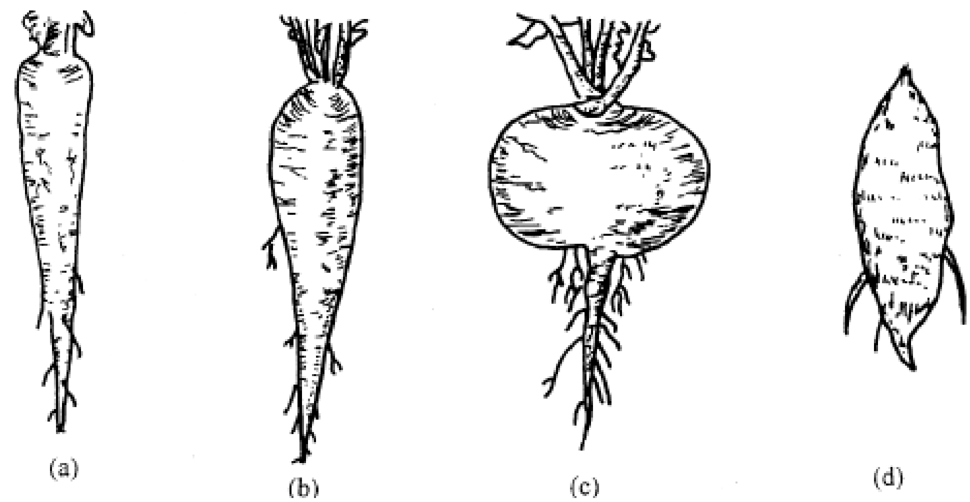


Fig.6.3 Modifications of tap root (a) Conical (carrot); (b) Fusiform (radish); (c) Napiform (turnip); (d) Tuberous (4 o'clock plant)

B. Adventitious root modifications

Adventitious roots get modified for various functions (Table 6.2)

Table 6.2 – Adventitious root modifications

Type	Characters	Example
(i) Modifications for food storage		
1. Tuberous (Fig 6.4a)	Swollen roots developing from nodes of prostrate stem	Sweet Potato
2. Fasciculated (Fig. 6.4b)	Swollen roots developing in a cluster from the stem	*Dahlia*
3. Nodulose (Fig. 6.4c)	Only apices of roots become swollen like single beads	Mango-ginger
4. Moniliform (Fig.6.4d)	Roots alternately swollen and constricted presenting a beaded or moniliform appearance	Grasses, Sedges
5. Annulated (Fig.6.4e)	Looks as if formed by a number of discs placed one above the other	Ipecac
(ii) Modification for photosynthesis		
Assimilatory roots (Fig6.4f)	Roots which when exposed to sun develop chlorophyll, turn green and manufacture food	*Tinospora* (aerial root), orchid

(iii) Modification for absorbing atmospheric moisture		
Epiphytic roots (Fig.6.4f)	Aerial roots of epiphytes are greenish and covered with spongy tissue (Velamen) with which they absorb atmospheric moisture	orchids (*Vanda*)

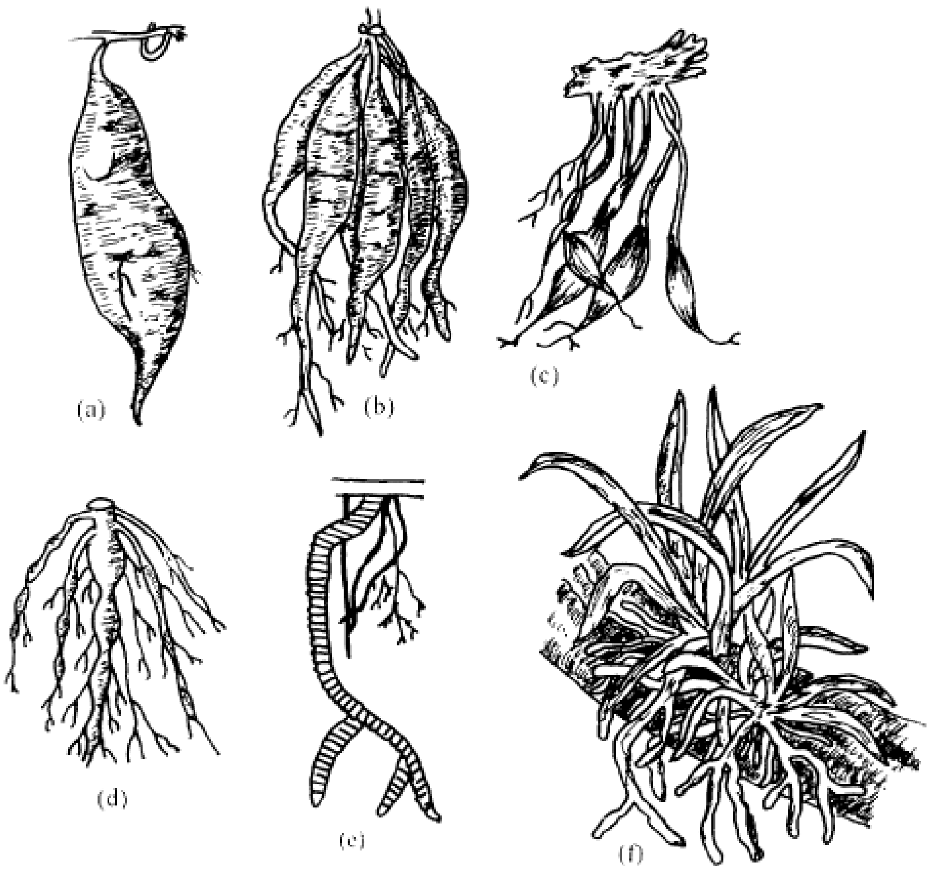


Fig. 6.4 Adventitious root modifications (a) Tuberous root (sweet potato); (b) Fasciculated roots (*Dahlia*); (c) Nodulose roots (mango ginger); (d) Moniliform roots (grass); (e) Annulated roots (*Ipecac*); (f) Assimilatory and epiphytic roots (orchid)

(iv) Modification for better gaseous exchange

Pneumatophores or respiratory roots (Fig.6.5a)	Some roots grow vertically up (negatively geotropic) into air. Exposed root tips possess minute pores through which roots respire, appear like conical spikes coming out of water	Mangroves (marshy plants) *Rhizophora*

(v) Modification for sucking nutrition from host

Sucking roots or haustoria (Fig.6.5 bi,bii)	Parasitic plants give out sucking roots or haustoria which penetrate living host plant and suck food from phloem.	*Cuscuta*

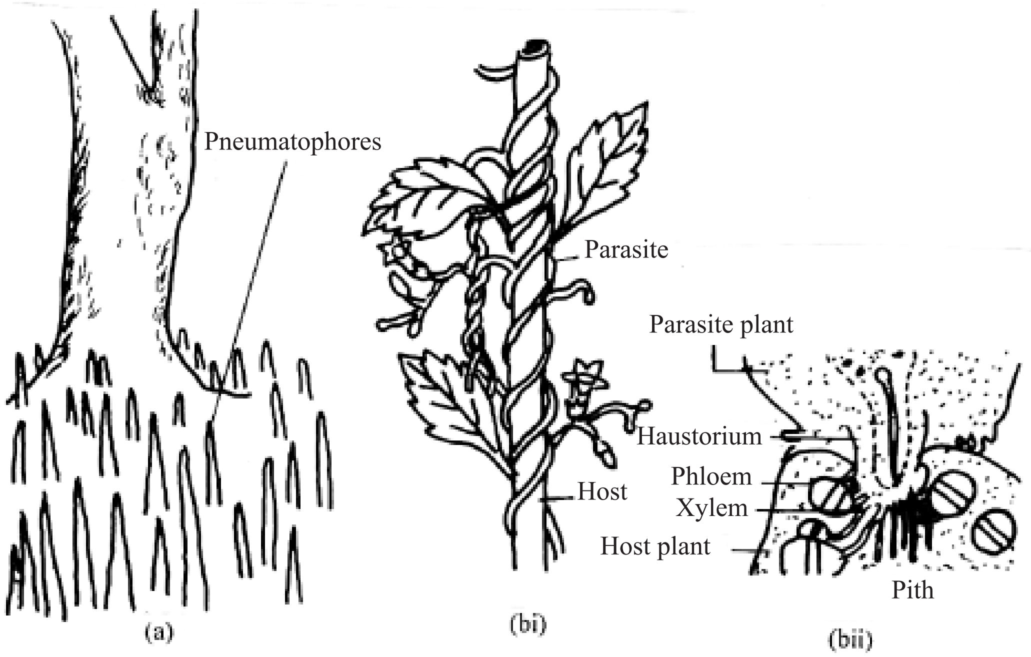


Fig. 6.5 Adventitious root modifications (a) Pneumatophores of a mangrove plant; (bi) *Cuscuta* (parasite) on host; (bii) Section showing sucking root or haustorium penetrating the host plant

(vi) Modification for strong support

1. **Prop roots** (Fig.6.6a)	Roots develop from tree branches, hang downwards and ultimately penetrate the ground, thus provide support to heavy branches	Banyan
2. **Stilt roots** (Fig.6.6b)	Extra roots developing from nodes near the base of stem, grow obliquely downwards and penetrate the soil giving strong anchorage	Sugarcane, Screwpine
3. **Climbing roots** (Fig.6.6c)	Weak climbers twine around and clasp the support with the help of climbing roots arising from their nodes	money plant betel
4. **Clinging roots** (Fig.6.4f)	Special clinging roots arise, enter the crevices of support and fix the epiphyte	epiphytes orchids

(vii) Modification for buoyancy and respiration

Floating roots (Fig.6.6d)	Spongy, floating roots filled with air, arise from nodes of some aquatic plants, and help in floating and respiration	*Jussiaea*

The great Banyan tree in Sibpur, Kolkata is more than 200 years old, forming a crown of over 404 meters in circumference and has about 1600 prop roots.

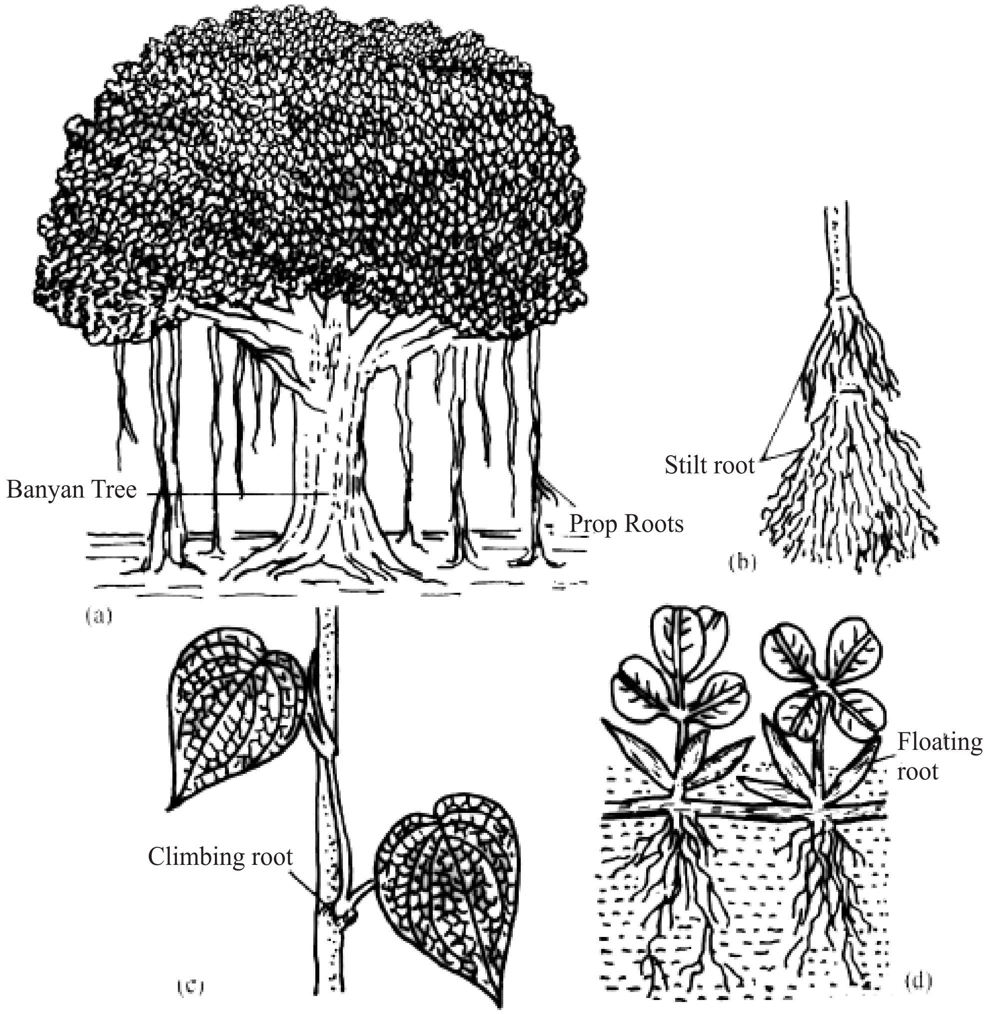


Fig.6.6 Adventitious root modifications – (a) Prop roots in banyan; (b) Stilt roots of sugarcane; (c) Climbing roots of betel; (d) Floating roots of *Jussiaea.*

6.6 FUNCTIONS OF ROOTS

(i) **Anchorage –** Roots anchor the plant firmly to the soil (mechanical function).

(ii) **Absorption –** Roots absorb water and mineral salts and conduct them upwards (physiological function).

(iii) **Special functions –** By undergoing modifications in their structure, roots perform special physiological functions like food storage, assimilation, absorption of atmospheric moisture, sucking food from host, better gaseous exchange and mechanical functions like floating (buoyancy), stronger anchorage and climbing.

INTEXT QUESTIONS 6.3

1. Are carrot, radish and turnip roots? Justify. Why have they become fleshy?

   ....

2. Name the type of root modification found in plants growing in marshy areas. What is their function?

   ....

3. What is the tissue in aerial roots of epiphytes known as which helps in absorption of moisture from the atmosphere?

   ....

4. What are the two main functions of roots?

   ....

5. Match the items of column A with those in column B

	A		B
(a)	Prop roots	(i)	Storage
(b)	Haustorium	(ii)	*Jussiaea*
(c)	Sweet potato	(iii)	Banyan
(d)	Floating roots	(iv)	*Cuscuta*

You would enjoy doing the following activity.

ACTIVITY 6.1

AIM : To study the characteristics of roots, type of root and modification of root in given plants.

Material required: Carrot, radish, turnip, sweet potato, sugarcane, money plant, uprooted grass, mustard/coriander plant.

Method: Observe the roots carefully and tabulate your answers to the following questions–

1. Is the root green?
2. Does it have nodes and internodes?
3. Are leaves present on the roots?
4. Are any buds present on the roots?
5. Is it a tap or adventitious root?
6. Name the type of modification, if present.

6.7 PRIMARY STRUCTURE OF ROOTS

A. DICOT ROOT (e.g. gram)

A thin transverse section of dicot root (Fig. 6.7) shows the following structures —

(i) **Epiblema :** Single, outermost layer of thin-walled cells. Some cells are prolonged to form unicellular root hairs. It protects and absorbs water.

(ii) **Cortex :** Large zone, many layered, cells thin-walled parenchymatous with intercellular spaces, stores food and water.

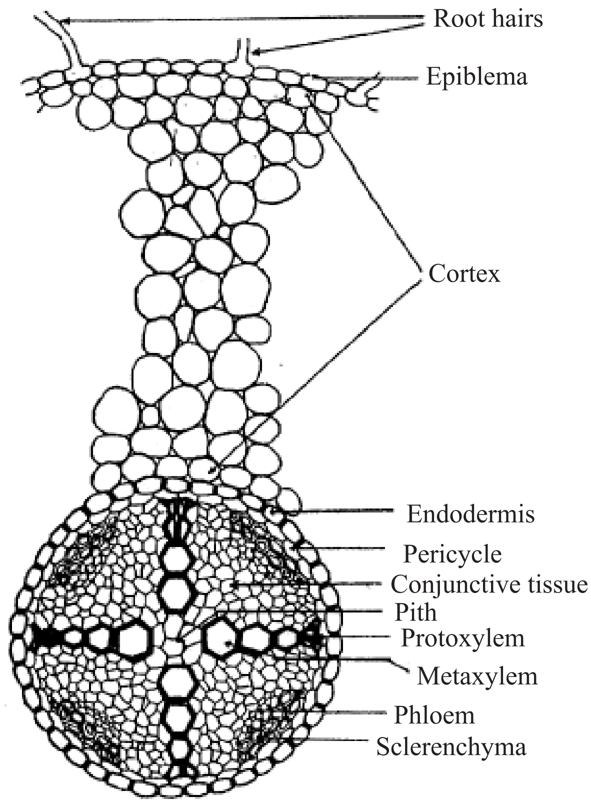


Fig. 6.7 A portion of dicot root in transverse section

(iii) **Endodermis :** Innermost layer of cortex, cells barrel-shaped, closely packed, that show band like thickenings on their radial walls called *casparian strips.* Some cells (opposite the protoxylem) which lack these strips are called *passage cells.* They help in the movement of water and dissolved salts from cortex directly into xylem.

Stele : All tissues inner to endodermis comprise stele.

(iv) **Pericycle :** Inner to endodermis lies a single layer of pericycle. It is the seat of origin of lateral roots and vascular cambium and cork cambium during secondary growth.

(v) **Vascular bundle :** It consists of xylem and phloem patches lying on alternate radii i.e., it is *radial*. Xylem is *exarch* where *protoxylem* (first formed , having narrow vessels and tracheids) lies towards the periphery and metaxylem (differentiates later, has wider vessels and tracheids) lies towards the center. Depending upon the number of xylem patches a root may be *diarch* (di-2 patches) to hexarch (hexa- 6 patches).

(vi) **Pith :** Sometimes the metaxylem of all xylem patches meet in the centre, and in that case pith is absent or is small and parenchymatous.

(vii) **Conjunctive parenchyma**: Parenchyma which separates xylem and phloem lying on different radii.

B. MONOCOT ROOT (e.g. maize root)

A thin transverse section of monocot root (Fig. 6.8) shows the following structures

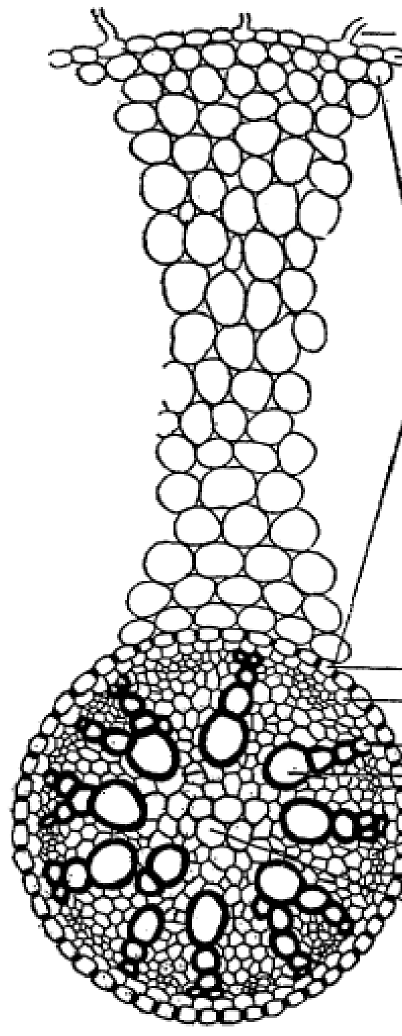


Fig. 6.8 A portion of monocot root in transverse section.

(i) **Epiblema :** Outermost, single layer of thin-walled, closely packed cells. Some cells are prolonged into unicellular root hairs.

(ii) **Cortex :** Large zone, multilayered, composed of parenchymatous cells with intercellular spaces, stores water and food material.

(iii) Endodermis : Innermost layer of cortex with characteristic *casparian strips* and *passage cells.*

Stele : All the tissues inner to endodermis constitute stele

(iv) Pericycle : Single layered, having polygonal thin walled cells. The lateral roots originate from this layer.

(v) Vascular bundle : It consists of many patches of xylem and phloem arranged radially. The xylem is exarch and polyarch (poly-many).

(vi) Pith : Is situated in the center, large, well developed, parenchymatous or sclerenchyamatous , stores food.

(vii) Conjunctive Parenchyma : Is located in between the strands of xylem and phloem.

The anatomical differences between Dicot and Monocot roots can be studied from Table 6.3

Table 6.3 Differences between a Dicot and Monocot root

Characters	Dicot root	Monocot root
1.Number of vascular bundles	2-6 (*di-hexarch*)	Many (*polyarch*)
2. Pericycle	Seat of origin of lateral roots, vascular and cork cambium	Seat of origin of lateral roots only
3. Cambium	Present	Absent
4. Secondary growth	Present	Absent
5. Pith	Very small or absent	Large

6.8 ORIGIN OF LATERAL ROOTS

- The origin of lateral roots is endogenous i.e. from a deeper layers.
- The seat of its origin is pericycle where cells opposite the protoxylem divide and form a hump in the endodermis (Fig. 6.9 a-b).
- The hump penetrates into the cortex (Fig. 6.9 c-d), and emerges as a lateral branch.

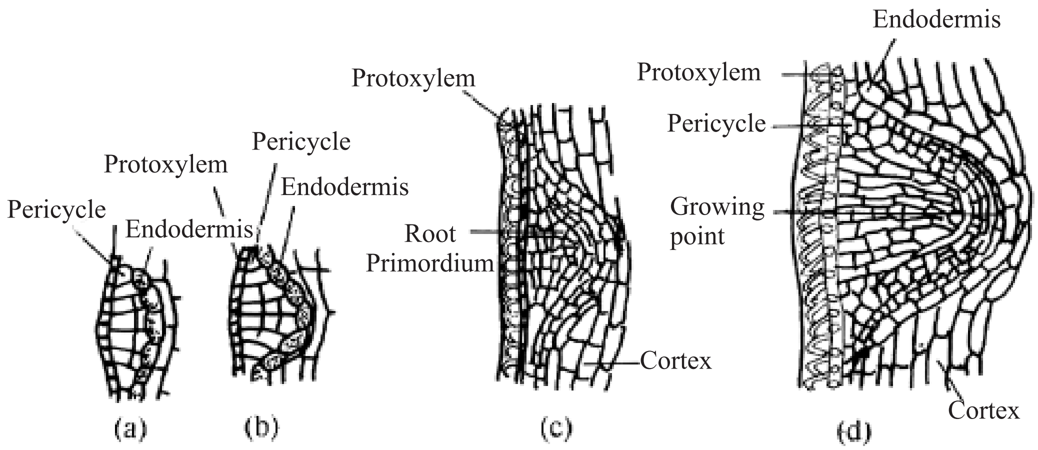


Fig. 6.9 a-d Formation of lateral root (Endogenous origin)- Stages as seen in longitudinal sections of root.

- Later, the hump differentiates into 3 regions of the root apex i.e. *dermatogen, periblem* and *plerome*.
- Finally the lateral root comes out.
- The number of lateral roots corresponds to the number of xylem bundles.

INTEXT QUESTIONS 6.4

1. Name the condition where protoxylem lies towards the periphery and metaxylem towards centre.

   ....

2. Why is it difficult to pluck lateral roots from carrot?

   ....

3. What is the seat of origin of lateral roots and cambium?

   ....

4. Name the endodermal cells which do not possess casparian strips and help in the movement of water?

   ....

5. Give two major differences between a dicot and monocot root.

   ....

6. If the number of xylem bundles is 4 (tetrarch), how many lateral roots will be formed in that area?

   ....

6.9 SECONDARY GROWTH IN DICOT ROOTS

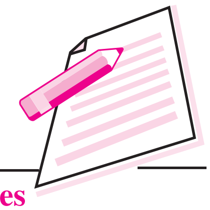
The roots grow in length with the help of apical meristem. It is called **primary growth**. Apart from primary growth, roots grow in width i.e., they increase in girth. This increase is called **secondary growth**. It is found only in dicot roots.

The tissues involved in secondary growth are *lateral meristems* i.e., *vascular cambium* and *cork cambium*.

It is important to remember that the vascular cambium and cork cambium are secondary in origin and arise from the pericycle.

Secondary growth is as follows-

- Pericycle cells outside the protoxylem divide to form a strip of cambium (Fig 6.10b).
- Another strip of vascular cambium appears in the conjunctive tissue on the inner side of phloem bundle (Fig. 6.10 a, b).



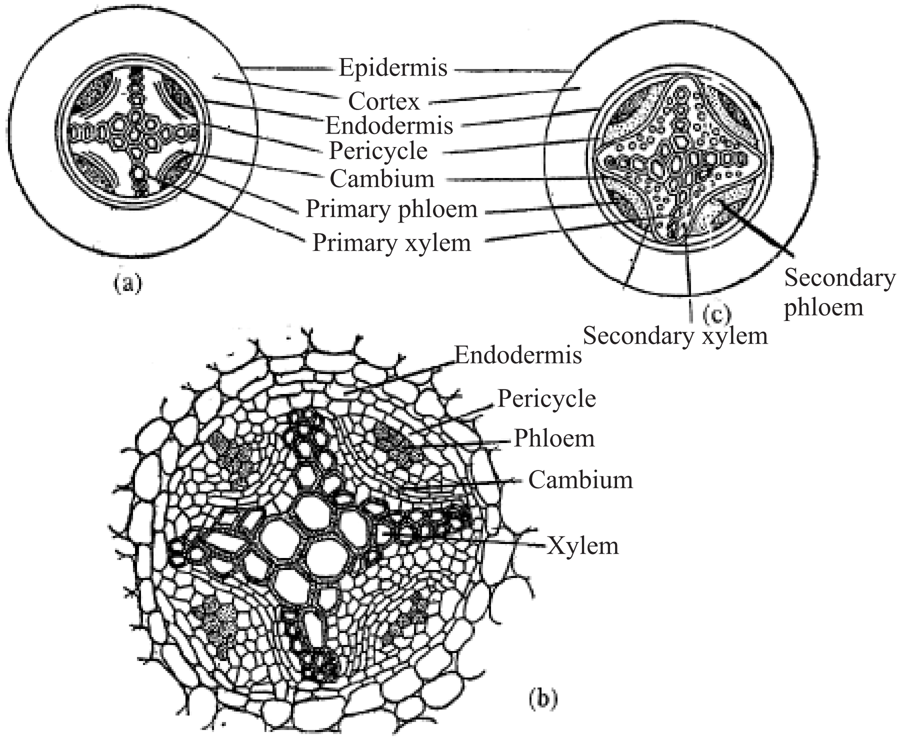


Fig. 6.10 T. S. Dicot Root – (a) and (c) (diagrammatic) – Early stages in secondary growth (b) Stele enlarged (cellular)

- These two vascular cambium strips join laterally to form a ring which may initially be wavy (Fig. 6.10c) but later becomes circular due to over production of secondary xylem tissue inner to primary phloem (Fig. 6.11a).
- Cambium cells consist of brick shaped cells which divide and add cells on its either side i.e. towards periphery and towards center. Those added towards the periphery differentiate into *secondary phloem* and the ones formed towards the center differentiate into *secondary xylem*.

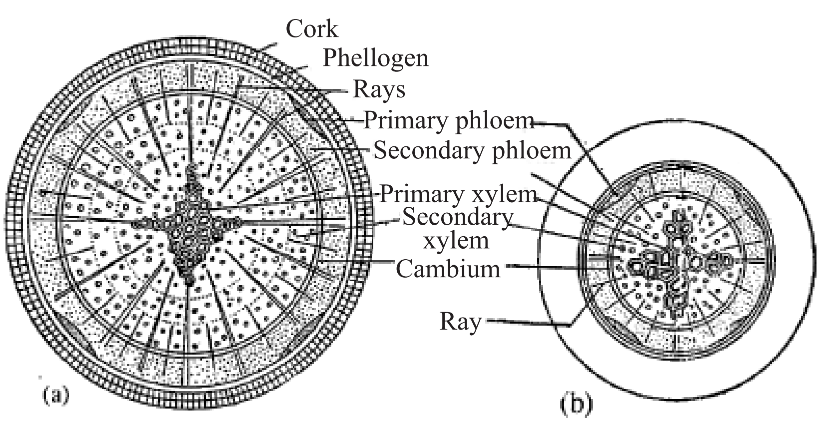


Fig. 6.11 T. S. Dicot root (Diagrammatic) a,b. Later stages in secondary growth.

- Secondary tissue formed outer to the protoxylem bundle differentiates into prominent *primary medullary ray* thus, protoxylem does not get crushed (Fig. 6.11a).

- Later, cork cambium (**Phellogen**) also differentiates in the pericycle (Fig. 6.11b).
- The cork cambium divides and gives rise to cork (**Phellem**) towards outside and secondary cortex (**Phelloderm**) towards inside.
- All the three layers i.e. *Phellogen*, *Phellem* and *Phelloderm* together form the **Periderm** of the root and have protective function.
- Finally all the primary tissues outside the developing cork (i.e. endodermis, cortex and epiblema) are sloughed off.

INTEXT QUESTIONS 6.5

1. Name the lateral meristems found in old dicot roots? What is their function?

   ....

2. From which layer does the vascular cambium originate?

   ....

3. What is the conjunctive tissue?

   ....

4. Define periderm. What role does it play in a root?

   ....

5. Do primary roots of dicot plant possess cambium?

   ....

WHAT YOU HAVE LEARNT

- The radicle elongates to form the primary or tap root.
- Roots are non-green due to the absence of chlorophyll, lack nodes and internodes, leaves and buds.
- These grow towards gravity (positively geotropic) and water (positively hydrotropic) but grow away from light (negatively phototropic).
- Root systems are of two types – Tap root system (in dicots) and Fibrous root system (in monocots).
- Tap root develops from the radicle while adventitious roots develop from any part of the plant except the radicle.
- Apical region of root has 4 regions namely root cap region, region of meristematic cells, region of elongation and region of maturation.
- Main functions of root are anchorage and absorption of water and ninerals.
- In some plants, roots undergo modifications in their structure to perform special physiological functions (food storage, assimilation, respiration, absorption of

atmospheric moisture and sucking nutrients from host plants) and mechanical functions (stronger anchorage, climbing, buoyancy).

- Internal structure of root shows unicellular hairs, single-layered epiblema, large multilayered cortex, prominent one-layered endodermis with casparian strips and some passage cells. The stele consists of single layered pericycle, radial vascular bundles, exarch xylem and pith.
- Dicot root differs from monocot root in having lesser number of vascular bundles (2-6), very small pith and presence of cambium (secondarily formed).
- Origin of lateral roots is endogenous.
- Number of lateral roots corresponds to the number of xylem bundles.
- Lateral roots , vascular cambium and cork cambium originate from pericycle in dicot roots.
- Due to the presence of cambium dicot roots undergo secondary growth.
- Because of apical meristem roots undergo primary growth and increase in length.
- The dicot roots grow in girth by undergoing secondary growth due to the involvement of lateral meristems (vascular cambium and cork cambium).
- Vascular cambium originates as a strip in pericycle cells lying outside the protoxylem and in conjunctive tissue inner to each phloem bundle.
- Initially the cambium is wavy but later becomes circular.
- The vascular cambium gives rise to secondary phloem towards periphery and secondary xylem towards centre.
- Primary medullary rays differentiate outer to protoxylem.
- Cork cambium (phellogen) also differentiates in the pericycle and gives rise to cork (phellem) towards periphery and secondary cortex (phelloderm) towards inside.
- Phellem, Phellogen and Phelloderm together form the periderm which is protective in function.

TERMINAL EXERCISES

1. Describe any four adventitious root modifications.
2. Give one point of difference between:
   (i) Tap root and adventitious root
   (ii) Prop and stilt roots
   (iii) Protoxylem and metaxylem
   (iv) Phelloderm and periderm
   (v) Vascular cambium and cork cambium

3. Describe the various types of edible roots which you have studied.
4. What are pneumatophores? Where are they found and what is their function?
5. Describe secondary growth in dicot roots.
6. Why is it difficult to break the lateral roots from the main root?
7. What is periderm ? How is it formed?
8. Give four characteristics by which you can identify a root.
9. What is the function of region of maturation?
10. Give one example each of plants having pneumatophores, climbing roots, floating roots and haustoria.
11. A cross section of plant organ when seen under the microscope shows—radial vascular bundles, exarch xylem, single layered pericycle and unicellular hair. What organ is it?
12. Name the meristematic tissues which help the dicot roots to grow in length and girth.
13. Name the modification of root which supports tree branches.
14. If a transverse section of root shows polyarch condition of vascular bundles, large pith and no cambium, which type of root will it be?
15. Differentiate between stele of dicot and monocot root.

ANSWERS TO INTEXT QUESTIONS

6.1 1. Root

2. Radicle

3. Tap root system gives better anchorage because it is very deep seated, and branches profusely which ramify through large areas in soil.

4. Fibrous root system in maize, sugarcane and tap root system in sunflower, mango.

5. Absence of nodes and internodes, buds and leaves.

6.2 1. Root cap

2. Root cap region, region of meristematic cells, region of elongation, region of maturation.

3. Dermatogen differentiates into epiblema and cap, whereas plerome differentiates into stele.

4. Root hair or piliferous region /Region of maturation.

6.3 1. Yes, they are roots since they do not have nodes and internodes, buds or leaves; they become fleshy for storage of food.

2. Pneumatophore, respiration
3. Velamen
4. Anchorage and absorption of water and mineral salts
5. (a) – (iii); (b) – (iv); (c) – (i); (d) – (ii)

6.4
1. Exarch
2. Because these arise from the inner layer i.e.pericycle/ endogenous origin
3. Pericycle
4. Passage cells
5. In dicot root 2-6 vascular bundles and cambium is present but in monocot root many vascular bundles are present while cambium is absent.
6. Four

6.5
1. Vascular cambium and cork cambium; Vascular cambium forms secondary vascular tissue while cork cambium forms cork and secondary cortex.
2. Pericycle and conjunctive tissue.
3. Conjunctive tissue is the parenchyma tissue lying between xylem and phloem patches that are arranged radially in roots.
4. Periderm is a tissue which is formed during secondary growth and consists of phellem, phellogen and phelloderm; protection.
5. No, cambium is absent in the primary dicot root.

7

SHOOT SYSTEM

Shoot system is an aerial and erect part of plant body which grows upwards. It is usually above the soil and develops from **plumule** of the embryo. It consists of stem, branches, leaves, flowers, fruits and seeds. In this lesson you will study about the structure, types, modifications and functions of stem, leaf, flower and fruit.

OBJECTIVES

After studying this lesson, you will be able to -

- *list the general characteristics of stems and distinguish them from those of root;*
- *describe the shoot apex and explain the origin of lateral branches;*
- *explain the types, modifications and functions of stem;*
- *describe the primary structure of dicot and monocot stems with the help of diagrams and distinguish between them;*
- *describe secondary growth in a dicot stem;*
- *define wood and its types;*
- *describe the general morphology of leaf and explain phyllotaxy;*
- *describe and illustrate various modifications of leaf highlighting their functions;*
- *describe and compare the internal structure of a typical dicot and monocot leaf;*
- *define inflorescence and describe it's major types;*
- *define a flower and describe it's structure and functions;*
- *define placentation and describe different kinds of placentation;*
- *define and explain the structure of fruit and enlist it's major categories with examples.*

7.1 STEM

7.1.1 Characteristics of Stem

(i) Arises as a prolongation of plumule (one end of an embryo).

(ii) Grows and bends towards light **(positively phototropic)** and away from gravity **(negatively geotropic).**

(iii) Divided into **nodes** (point of attachment of leaf) and **internodes** (regions between two nodes).

(iv) Bears leaves, branches and flowers on nodes.

(v) Bears **vegetative buds** which could be terminal (apical bud) for plant to grow upwards or axillary (bud in the axil of leaf) which give rise to lateral branches.

(vi) Bears **floral buds** (terminal or axillary) that grow into flowers.

7.1.2 Differences between stem and root

Table 7.1 gives the difference in morphology between stem and root.

Table 7.1 Morphological differences between stem and root

Stem	Root
1. Develops from plumule.	Develops from radicle.
2. Young stem is green because of chlorophyll.	Non green because chlorophyll is absent.
3. Divided into nodes and internodes.	Not divided into nodes and internodes.
4. Bears leaves, vegetative and floral buds.	Absent.
5. No cap present at the apex.	Root cap is present at the apex.
6. Positively phototropic and negatively geotropic.	Negatively phototropic but positively geotropic.
7. Origin of lateral branches is exogenous (originating from outer layers i.e. endodermis).	Origin of lateral roots is endogenous (originating from inner layers i.e. pericycle).

INTEXT QUESTIONS 7.1

1. Name the part of plant which bears nodes, leaves and flowers.

....

2. Lateral branch develops from which bud?

....

3. Why is it difficult to break lateral roots and not lateral branches on stem?

....

4. Roots are negatively phototropic and positively geotropic, what pattern of growth does the stem show?

....

7.1.3 The Shoot Apex

Shoot apex is the terminal, dome shaped part of shoot, formed of meristem called **apical shoot meristem** responsible for the development and differentiation of primary permanent tissue and mainly causes growth in length. It is divided into two regions - **Tunica** and **Corpus** (Fig. 7.1)

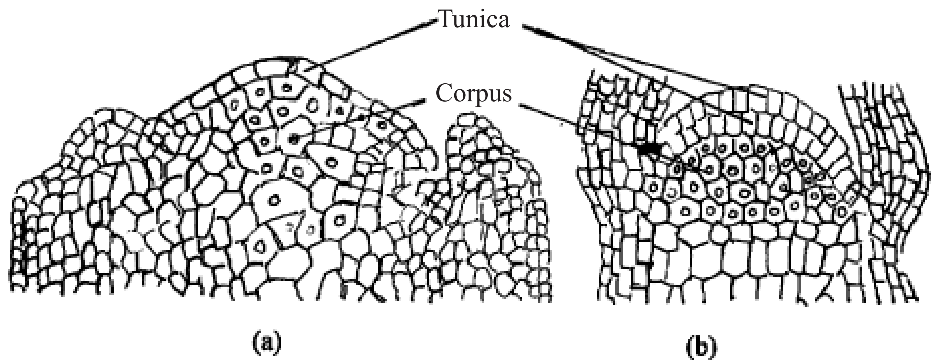


Fig.7.1 a-b L.S. of shoot apex to show tunica and corpus

(i) **Tunica** (covering)- An outer zone of shoot apex, 1-3 layers in thickness. It gives rise to epidermis and is responsible for surface growth, and its cells divide only anticlinally.

(ii) **Corpus** (body)- Inner multi-layered zone of cells which divide in all directions. They finally give rise to *procambium* (forms vascular tissue) and *ground meristem* (forms ground tissue). These cells also form leaf primordia (a newly developing leaf).

7.1.4 Origin of Lateral branches

Branches arise from axillary buds present in the axil of leaves (Fig 7.1). Each axillary bud is a small, compact, underdeveloped shoot covered with a large number of overlapping leaf primordia. Internodes of this bud enlarge and develop into a branch. Therefore the development of branches is **exogenous** (exo = outside).

INTEXT QUESTIONS 7.2

1. Name the meristematic zone in which cells divide in all planes.

   ....

2. From which meristematic layer does the vascular tissue develops?

   ....

3. Which structure gives rise to a lateral branch? Name the type of its origin.

   ....

4. What is the structure known as which covers the apical meristem of root but is absent in stem?

   ....

7.1.5 Types of stem

The stem may be (i) **aerial** (erect, rigid, strong and upright as in herbs, shrubs and trees) (ii) **sub aerial** (weak, unable to stay upright and trail on ground as **creepers** or climb up as **climbers)** or (iii) **underground** (buried in soil and produces aerial branches under favourable conditions only).

7.1.6 Modifications of Stem

Stems are variously modified into underground, sub aerial and aerial stems for performing functions like manufacturing and storing food, perennation (overcoming unfavourable climatic conditions), providing mechanical support and protection and for propagating vegetatively

Types of stem and modifications

Underground	Subaerial	Aerial
Rhizome	Runner	Tendrils
Corm	Stolon	Thorns
Bulb	Offset	Phylloclade
Tuber	Sucker	Cladode

Underground modified stems – Since underground, they may seem like roots but you can recognise them as stem due to the presence of :

(i) Nodes and internodes, (ii) scaly non green leaves, (iii) buds.

They serve two functions -

- Act as perennating structures by remaining leafless and dormant in winter but giving off aerial shoots under favourable conditions (next season)
- Store food and become thick and fleshy.

The various types of underground modified stems are given in Table 7.2.

Table 7.2 Underground Modified Stems

Type	Characters	Examples
1. **Rhizome** (Fig.7.2a)	Thick, fleshy, flattened horizontally growing stem near the soil surface. Bears scale leaves on nodes, terminal and axillary buds, adventitious roots.	Ginger (Adrak) Turmeric ('haldi')
2. **Corm** (Fig.7.2b)	Fleshy, spherical stem with flattened base, grows vertically; bears many scale leaves, distinct nodes and internodes, buds and adventitious roots.	Saffron ('kesar') Yam ('zimikand') Gladiolus

3. Bulb (Fig.7.2ci,ii)	Reduced, flattened discoid stem with crowded nodes bearing overlapping fleshy (inner) and dry (outer) scale leaves. Terminal bud (in centre) forms foliage (green) leaves. Adventitious roots grow from discoid base.	Onion
4. Tuber (Fig.7.2d)	Swollen tips of underground lateral branches of stem, store food as starch, bear "eyes". Each eye is a node which bears bud and scar of scale leaves.	Potato

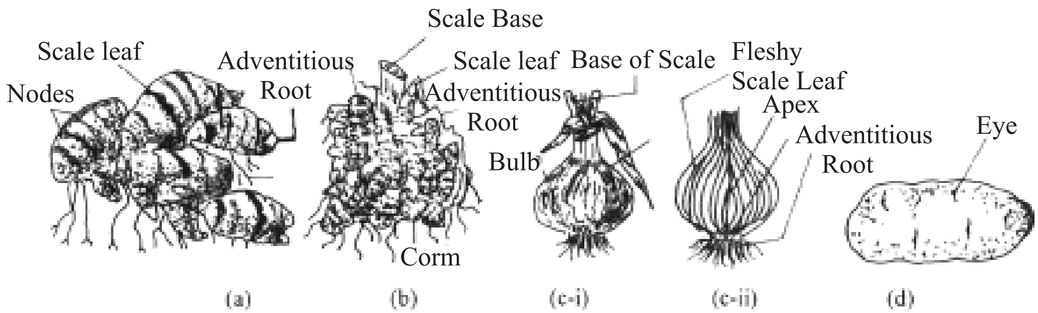
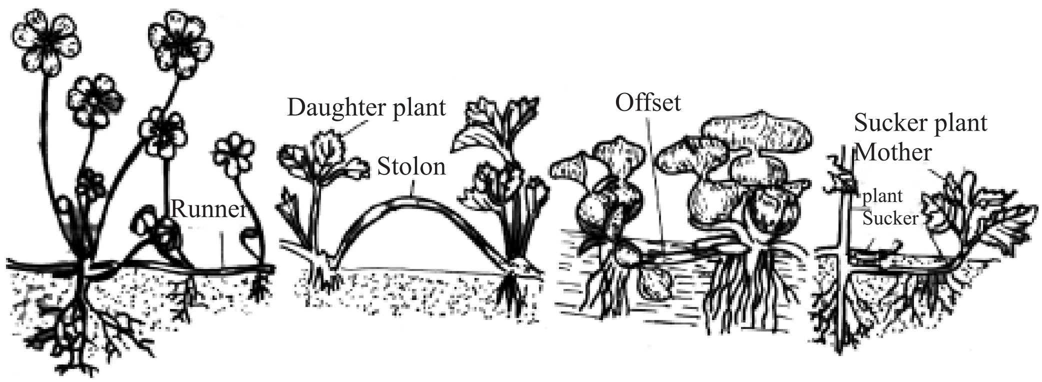


Fig.7.2 Underground modifications of stem – **(a)** Rhizome of Ginger, **(b)** Corm of Yam, **(ci)** Bulb of Onion **(cii)** V.S. bulb, **(d)** Tuber of potato.

Sub aerial modifications Of stem- Stems are weak, therefore lie prostrate on the ground or may get partially buried in the top soil. The plants bearing such stems are called creepers. Their stems serve the function of vegetative propagation.

Table 7.3 Modifications of Sub aerial stems

Type	Characters	Examples
1. **Runner** (Fig.7.3a)	Long, weak, slender branch with long internodes. Runs horizontally on soil surface giving off adventitious roots at nodes	Grass, *Oxalis*
2. **Stolon** (Fig. 7.3b)	Weak lateral branch which grows upwards then arches down to meet the soil, strike roots and produce daughter plants.	Mint ('Pudina'), Jasmine
3. **Offset** (Fig.7.3c)	Like runner but thicker and shorter, grow for a short distance then produce cluster (rosette) of leaves above and adventitious roots below; generally in aquatic plants	Water hyacinth, water lettuce
4. **Sucker** (Fig.7.3d)	Underground runner which grows horizontally for a distance under soil then emerges obliquely upwards, strikes roots and forms daughter plants	Chrysanthemum



(a) (b) (c) (d)

Fig.7.3 Sub-aerial modification of stem : (a) Runner; (b) Stolon; (c) Offset; (d) Sucker.

Aerial stem modifications - Whole stem or its part (axillary or terminal bud) gets modified to perform definite functions. You can recognise them as stems by following features :

(i) Arise in the axil of leaf (ii) Bear nodes and internodes (iii) may bear leaves, buds, flowers.

Table 7.4 Types of aerial stem modifications

Type	Characters	Examples
1. **Stem tendrils** (Fig.7.4a)	Thread like, spirally coiled, leafless structures (tendrils) which twine around neighbouring objects and help weak plants to climb	Grape vine
2. **Thorns** (Fig.7.4b)	Straight, pointed, hard structures; modifications of axillary *(Citrus)* or terminal *(Carissa)* bud; act as defence organs or as climbing organs	*Citrus*, Duranta *Carissa* *('Karonda')*
3. **Phylloclade** (Fig.7.4c)	Green, flattened or cylindrical fleshy stem, with nodes and internodes; bears spines (modified leaves to check evaporation); carries out photosynthesis, stores water. Found in plants growing in dry regions	*Opuntia* (prickly pear)
4. **Cladode** (Fig.7.4 di,dii)	It is a phylloclade with limited growth i.e. with only one or two internodes; help in photosynthesis	*Asparagus*

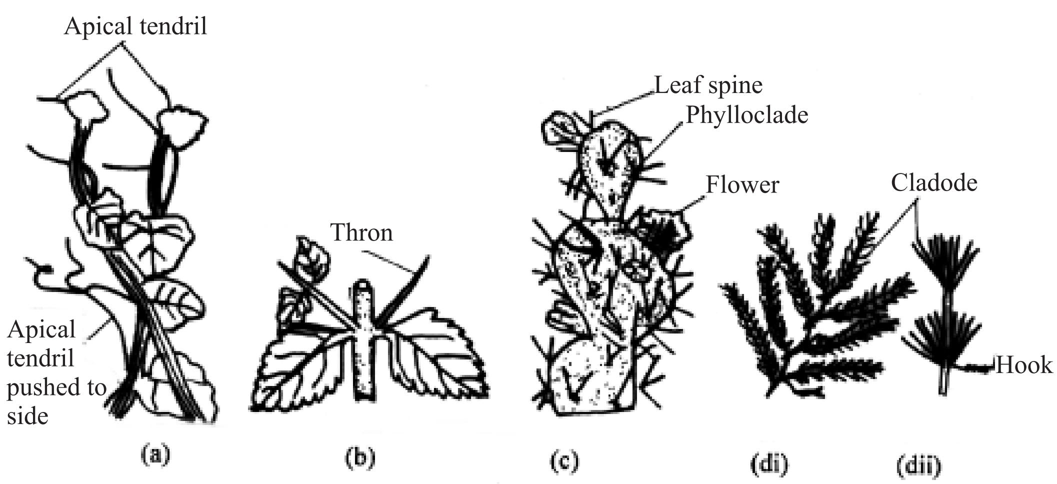


Fig. 7.4 Aerial stem modifications— (a) Stem Tendril; (b) Thorns; (c) Phylloclade of *Opunlia;* di, dii-Cladode *of Asparagus* and part enlarged

INTEXT QUESTIONS 7.3

1. What are plants with weak stem trailing on the ground known as?

   ....

2. Name the modification to which Runner, Stolon, Offset and Sucker belong.

   ....

3. What is a phylloclade with one or two internodes called?

   ....

4. 'Haldi' and onion belong to which category of stem modification respectively?

   ....

5. Match the items of column A with those of column B

A		B	
(a)	Tendril	(i)	Protection
(b)	Sucker	(ii)	Perennation
(c)	Thorns	(iii)	Reproduction
(d)	Bulb	(iv)	Photosynthesis
(e)	Phylloclade	(v)	Climbing

7.1.7 Functions of stem

A. Primary functions

1. **Support and orient the leaves** in a manner that they are exposed to maximum sunlight and for efficient gaseous exchange during photosynthesis and respiration.

2. **Conduct water and minerals** from roots to leaves and manufactured **food** from leaves to different parts of the plant.
3. **Bear flowers and fruits**

B. Secondary Functions

1. **Storage -** Stems store food and water in some plants e.g. potato
2. **Perennation -** The underground stems help tide over the unfavourable growing periods e.g. ginger.
3. **Vegetative propagation -** Stem can be a means of vegetative propagation e.g. rose, and sugarcane.
4. **Photosynthesis-** in certain plants like xerophytes (desert plants) where leaves are reduced, the stem takes up the function of photosynthesis. These stems possess chlorophyll e.g. *Opuntia*
5. **Protection-** In some plants the axillary bud modifies into thorn and protects the plants from grazing animals e.g. citrus, *Duranta.*
6. **Climbing -** Tendrils or hooks are modified branches or buds. They coil around the support and help the plant to climb e.g. grape vine

INTEXT QUESTIONS 7.4

1. Give one primary function of stem.

   ....

2. How does sugarcane plant multiply?

   ....

3. Match the following in column A with column B

A		B	
(a)	*Opuntia*	(i)	Conduction
(b)	*Duranta*	(ii)	Storage of food
(c)	Ginger	(iii)	Photosynthesis
(d)	Potato	(iv)	Perennation
(e)	Stem	(v)	Protection

7.1.8 Internal (anatomical) structure of stem

The internal structure can be studied if you cut the stem transversely and observe it under a compound microscope.

A. Internal structure of dicot stem (e.g., Sunflower)

In a transverse section of a young dicot stem you will see the following structures (Fig. 7.5a and 7.5b)

1. **Epidermis -** Outermost single layered, covered with cuticle, bears multicellular hairs, protective function.

2. **Cortex** - Inner to epidermis, there are three regions.

- **Hypodermis -** 4-6 layers of collenchyma for mechanical support.
- **Middle layers -** Few layers of parenchyma.
- **Endodermis -** Innermost layer of cortex, has barrel shaped cells. As cells contain starch grains, it is also called **starch sheath.**

3. **Stele -** All the tissues lying internal to endodermis constitute the stele.

(i) **Pericycle -** Inner to endodermis, multilayered, parenchymatous with patches of sclerenchyma.

(ii) **Vascular bundles -** Arranged in a ring (Fig. 7.5a); each vascular bundle is **(a)conjoint** (xylem and phloem together in one bundle), (b) **collateral** (xylem and phloem on the same radius with phloem towards the periphery) and (c) open (cambium present in between xylem and phloem). Xylem is **endarch** (protoxylem towards centre and metaxylem towards periphery).

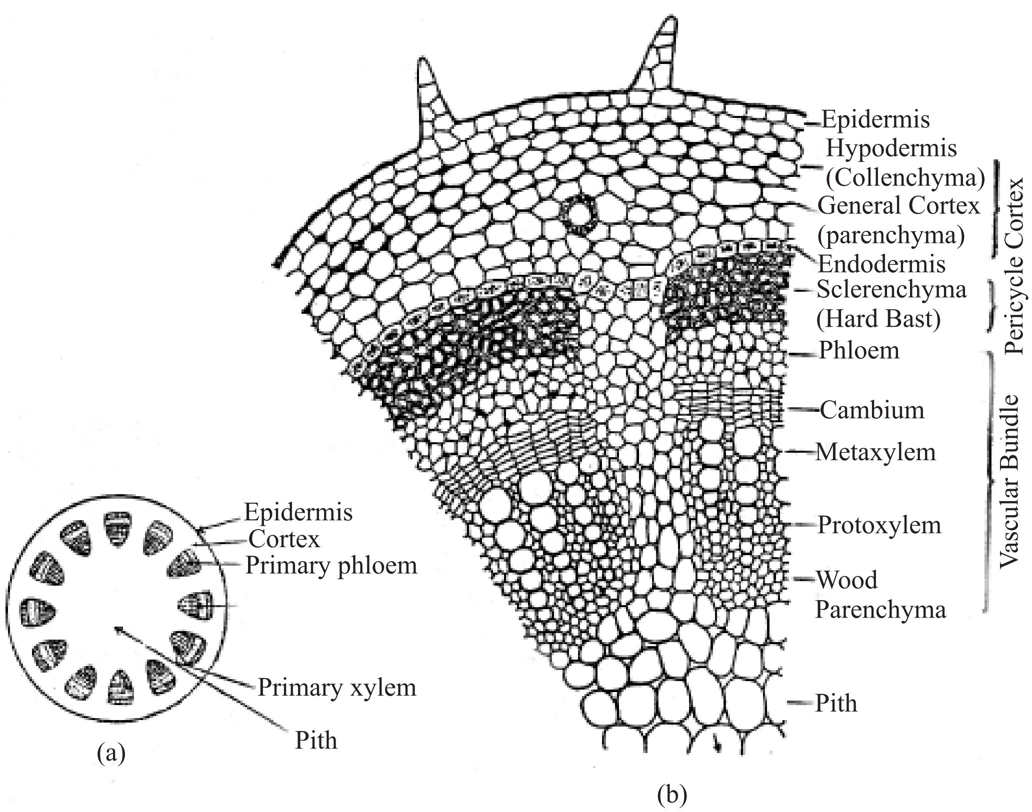


Fig. 7.5 T.S. Dicot stem. a-Diagrammatic b-A portion enlarged.

(iii) **Medullary rays -** Narrow regions of parenchymatous cells in between the vascular bundles.

(iv) **Pith -** The central parenchymatous zone with intercellular spaces.

B. Internal structure of monocot stem (e.g., maize)

A transverse section of monocot stem reveals the following structures (7.6a and b)

1. **Epidermis -** Single layered, covered with cuticle, stem hairs absent.
2. **Ground tissue-** A mass of parenchymatous tissue. Only a few peripheral layers below epidermis are sclerenchymatous called **hypodermis.**
    1. **Vascular bundle-** Numerous, scattered in the ground tissue each enclosed by sclerenchymatous bundle sheath. Each bundle is **(a) collateral** and **(b) closed** (no cambium strip between xylem and phloem) with **(c) endarch** xylem. Xylem occurs in the form of letter 'Y 'and innermost protoxylem disintegrates to form a water cavity.

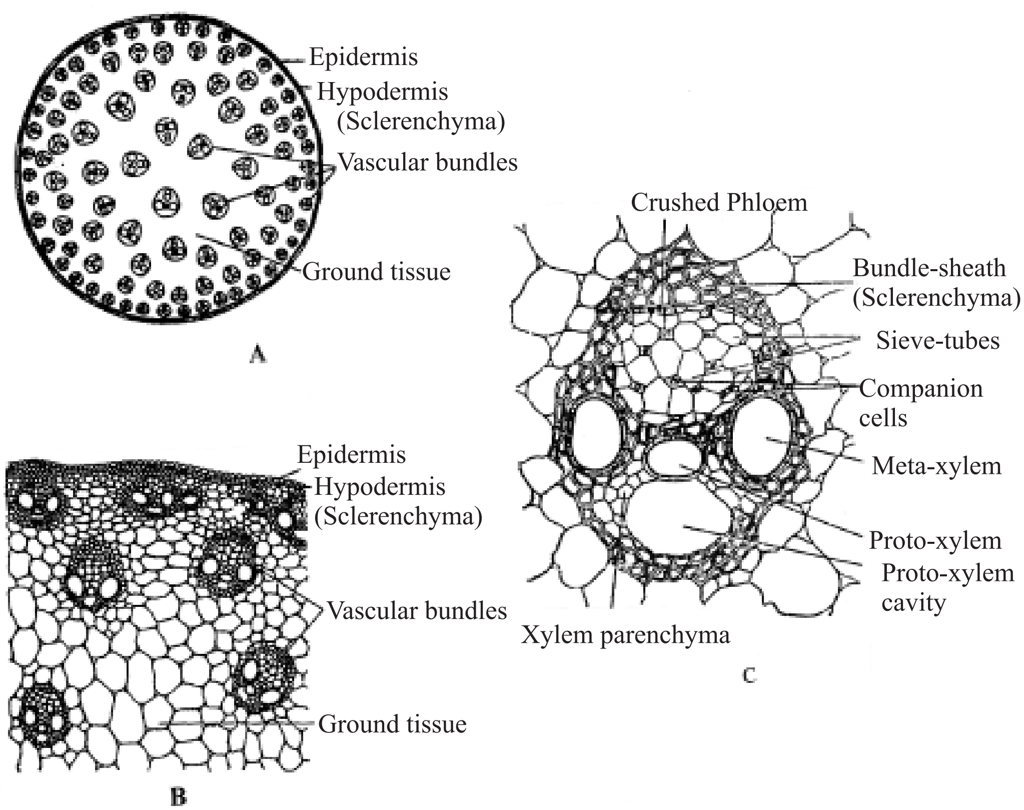


Fig. 7.6 T.S. Monocot stem. (a) Diagrammatic (b) A portion enlarged (c) A vascular bundle magnified.

Anatomical differences between dicot and monocot stem, and anatomical differences between root and stem are given in Tables 7.5 and 7.6

Table 7.5 Differences between monocot stem and dicot stem

Characters	Dicot stem	Monocot stem
1. Epidermal hairs	Present	Absent
2. Hypodermis	Collenchymatous	Sclerenchymatous
3. Ground tissue	Differentiated into cortex, endodermis, pericycle, pith and medullary rays	Undifferentiated
4. Vascular bundles	(i) Number not very large (ii) Uniform in size (iii) arranged in a ring (iv) open (v) bundle sheath absent (vi) xylem vessels arranged in a radial row (vii) water cavity absent	(i) Numerous (ii) smaller near periphery, bigger in the centre (iii) scattered (iv) closed (v) bundle sheath present (vi) xylem vessels arranged in shape of letter "Y" (vii) water cavity present
5. Secondary growth	Present	Mostly absent

Table 7.6 Anatomical differences between stem and root

Characters	Stem	Root
1. Cuticle	Present	Absent
2. Hair	Multicellular	Unicellular
3. Ground Tissue	Differentiated	Differentiated
4. Cortex	Narrow (dicot) or undifferentiated (monocot)	Wide
5. Pericycle	Many layered, of sclerenchymatous and parenchymatous cells	Single layered, of parenchymatous cells only
6. Vascular bundles	Many, conjoint and collateral	Fixed number, radial
7. Xylem	Endarch	Exarch

INTEXT QUESTIONS 7.5

1. Differentiate between conjoint and collateral vascular bundle.

   ....

2. What is the region between two vascular bundles in a dicot stem known as?

   ....

3. Where will you find radially arranged vascular bundles with exarch xylem?

   ....

4. If you want to study the internal structure of a monocot and a dicot stem, name the plants you would select for the study.

....

7.1.9 Secondary growth in stem

You have learnt in lesson 6 about the secondary growth in dicot roots and its importance, let us study it in stem. It occurs only in dicot stem a little away from the shoot apex and helps the plant to (a) grow in girth (thickness) and (b) makes it very strong to stand upright for many years. That is why you see that very tall trees can withstand strong winds, and lashing rains without falling down but monocot plants like wheat, rice, maize, and grasses bend easily due to absence of secondary growth in their stems.

Growth in thickness in dicot stem becomes possible due to the formation of new tissues entirely by the activity of two lateral meristems -(i) Vascular cambium and (ii) Cork cambium (Fig.7.7 a-d).These tissues thus formed are known as secondary tissues and growth in girth is referred as secondary growth.

(i) Activity of vascular cambium -Forms secondary vascular tissues as follows

- The strip of cambium present in the vascular bundle is called **Fascicular Cambium** (Fig 7.7a)
- The cells of medullary rays adjoining the strip of vascular (Fascicular) cambium become meristematic and form **interfascicular cambium**(Fig. 7.7b).
- Both fascicular and inter-fascicular cambium join to form a continuous cambium ring (Fig. 7.7b,c)

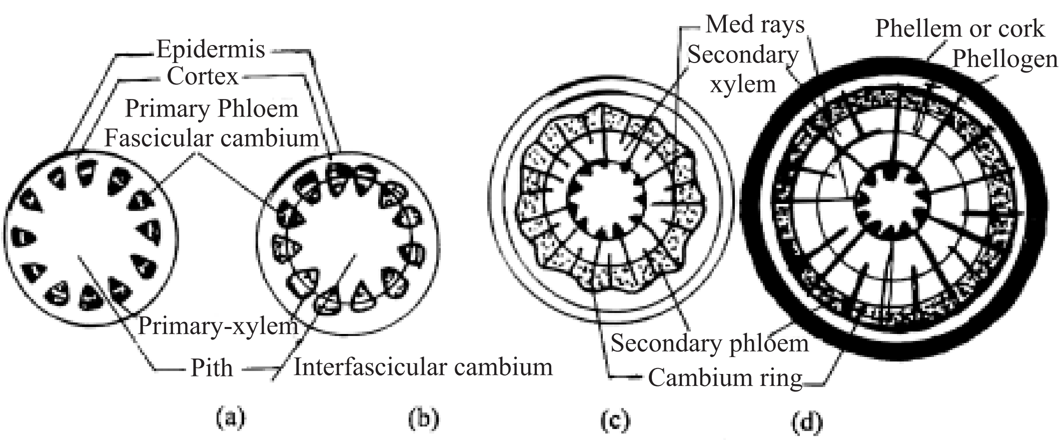


Fig. 7.7 (a-d) T. S. Dicot Stem- Various stages in secondary growth (Diagrammatic)

- Cambium divides and adds cells on internal side (towards pith) which mature into **secondary xylem** and cells added towards external side (periphery) mature into secondary phloem (Fig 7.7c).
- Amount of secondary xylem produced is comparatively comparatively more than secondary phloem (Fig7.7d)

(ii) Activity of cork cambium-Forms periderm as follows :

- Cork cambium or **phellogen** develops in the cortex.

- **Phellogen** divides and adds cells on both the inner and the outer side.
- The inner cells differentiate into **phelloderm** or **secondary cortex** while outer cells into **phellem** or **cork** (Fig.7.7d).
- Cork cells are compactly arranged and become dead and suberized (deposition of suberin) except in regions of **lenticels** (Fig. 7.8) where cells are loosely arranged **(complimentary cells)** and non-suberized. It is through the lenticels that woody branches and tree trunks can undergo gaseous exchange.
- Phellogen, phelloderm and phellem together constitute the **periderm** (Fig7.8).Due to internal increase in thickness, periderm replaces the epidermis, becomes protective in function.
- All the dead cells lying outside the active phellogen constitute the **bark.**

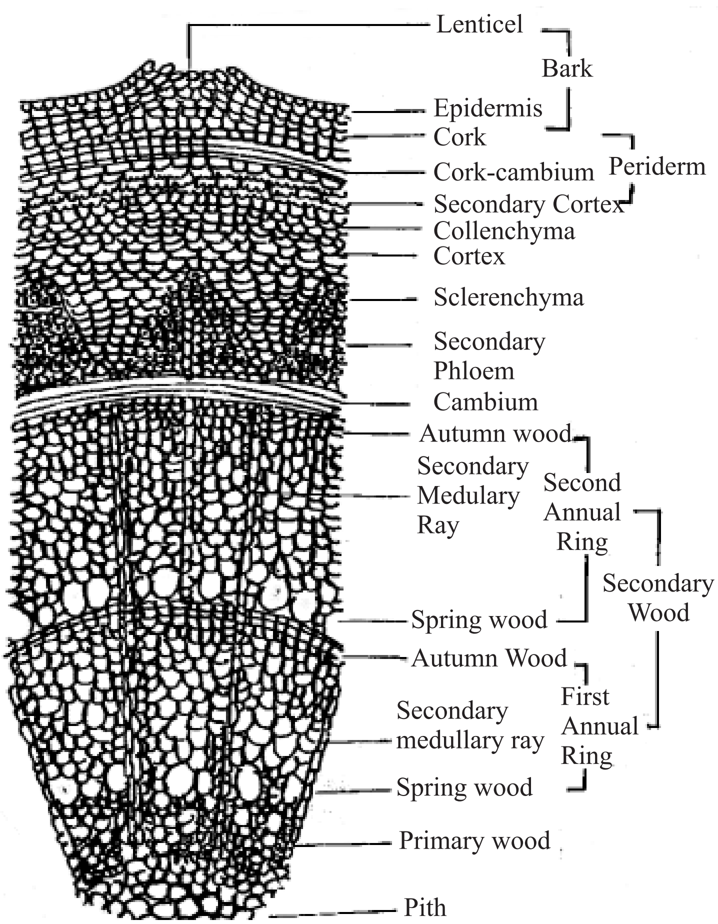


Fig. 7.8 T.S. of old stem, A Portion enlarged

In *Betula bhojpatra* bark peels off like sheets of paper. Ancient manuscripts are still preserved on them. Cork tissue becomes very thick in Cork tree *(Quercus suber)* and is used commercially as, bottle-stoppers, insulators, and shoe soles.

INTEXT QUESTIONS 7.6

1. Name the two lateral meristems which 'are responsible for increase in girth of stem.

   ....

2. From which region does the interfascicular cambium develop?

   ....

3. Define bark.

   ....

4. Why are lenticels, non suberized?

   ....

5. The stems of grasses, and rice, remain weak and thin, why?

   ....

6. Which layers constitute the periderm? What is it's function?

   ....

7.1.10 Wood

Wood is the secondary xylem produced by the activity of vascular cambium in dicot stem.

Annual Rings (A secret to know the age of tree)

In temperate regions, the climatic conditions show pronounced seasonal variations. The activity of vascular cambium also becomes periodical as a result, distinct growth layers are formed in xylem. In spring season cambium is very active and produces a greater number of vessels with wider cavities. The wood formed during spring is called **early wood** (or **spring wood).** In summer, cambium is less active and forms narrow vessels, this wood is called **late wood** (or **summer wood).** These two kinds of woods in a transverse view appear as alternate concentric rings together forming an **annual ring** (Fig 7.8). By counting the number of these annual growth rings we can know the age of a tree. Science dealing with predicting the age of a tree by counting the annual growth rings is called as **Dendrochronology.**

Sap Wood and Heart Wood

Outer part of wood which is functional and consists of recently formed secondary xylem having some living cells is called **sap wood.** As the plant ages in the central part of stem, the inner cells of sap wood that become non-functional and dark in colour constitute, **heart wood** (Fig 7.9)

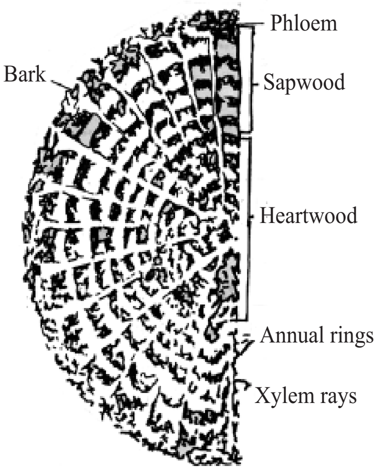


Fig. 7.9 T.S. old stem showing Heart wood and Sap wood.

Table 7.7 enlists the main differences between sap wood and heart wood.

Table 7.7 Differences between sap-wood and heart wood

SAP WOOD	HEART WOOD
1. It is the outer light coloured wood of an old stem	It is the central dark colured wood of an old stem
2. Light coloured	Dark coloured due to presence of gums, resins, oils, tannin etc.
3. Contains living cells	Living cells are absent
4. Vessels not plugged and help in upward movement of water and minerals	Vessels are plugged with tyloses
5. Wood is lighter in weight	Heavier in weight
6. Less durable because of susceptibility to attack of pathogens	More durable, resistant to attack of the pathogens
7. Commercially less valuable	Commercially more valuable

Mechanical tissues in stem -The stem of a tall tree needs to i) resist against pulling forces of wind and ii) to stand erect against gravity. Stem gets this strength from - Sclerenchyma in hypodermis and it's patches in the pericycle and secondary phloem, abundant lignified vessels, tracheids and fibres in secondary xylem i.e. wood and sclereids in pith.

INTEXT QUESTIONS 7.7

1. Which type of wood is formed when the cambium is less active?

   ....

2. How can you determine the age of a tree?

   ....

3. Why is heart wood commercially more valuable?

   ....

4. Why does a tall tree stand erect even in strong wind and lashing rain?

....

5. Define wood.

....

7.2 LEAF

Leaf is a flattened and expanded lateral appendage of stem or branch developing from its node. It originates from leaf primordium formed by the shoot meristem and bears a bud in its axil called **axillary bud.** It is the seat of very important physiological processes like photosynthesis, transpiration and respiration. Besides protecting axillary buds ,leaf can get modified into structures for storing food and water, climbing, and vegetative propagation.

7.2.1 Structure of Leaf

A typical leaf has three parts (Fig. 7.9)

(i) **Leaf base -** Lower most part of leaf by which it is attached to the stem node. It may be expanded as sheath (in monocots) or bear lateral outgrowths (stipules) as in dicots.

(ii) **Petiole -** Is the stalk of leaf. Leaf can be **petiolate** (with petiole) as in many dicots or **sessile** (without petiole) as in most monocots. Petiole may get modified and swell (e.g. water hyacinth) or develop wings (e.g. orange) or become flat like a leaf (e.g. Australian Acacia)

(iii) **Lamina or leaf blade-** It is a green, thin, flattened and expanded part of leaf with veins and veinlets traversing through its surface. The most prominent vein running from base to apex and present in the middle of leaf blade is called **mid rib.** Veins provide support and conduct water, minerals and prepared food.

Leaf shows a lot of variation in -

(i) Shapes of lamina (Fig.7. 10) (ii) Leaf apices (Fig. 7.11), and

(iii) Leaf margins (Fig.7.12)

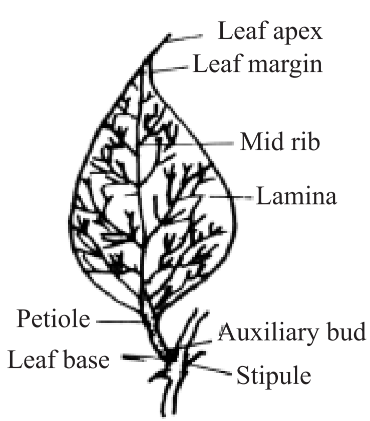


Fig. 7.9 Leaf and its parts

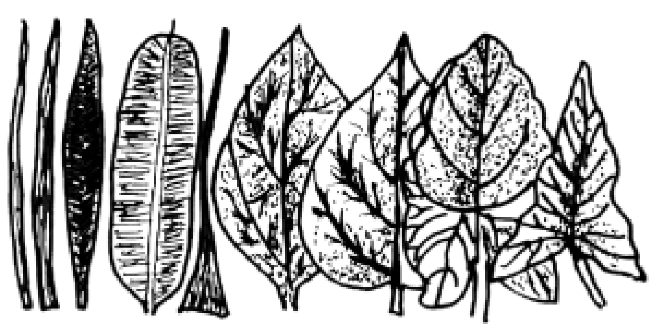


Fig. 7.10 Variations in leaf shape.

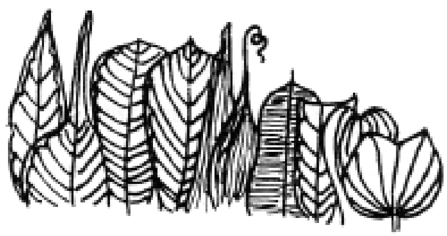


Fig. 7.11 Variations in Leaf apices

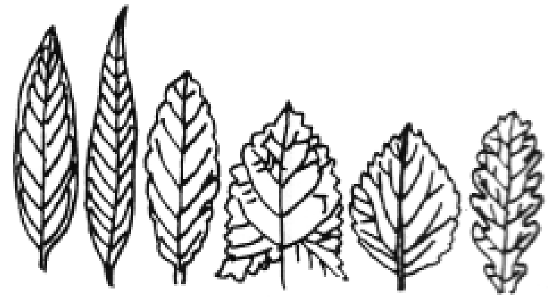
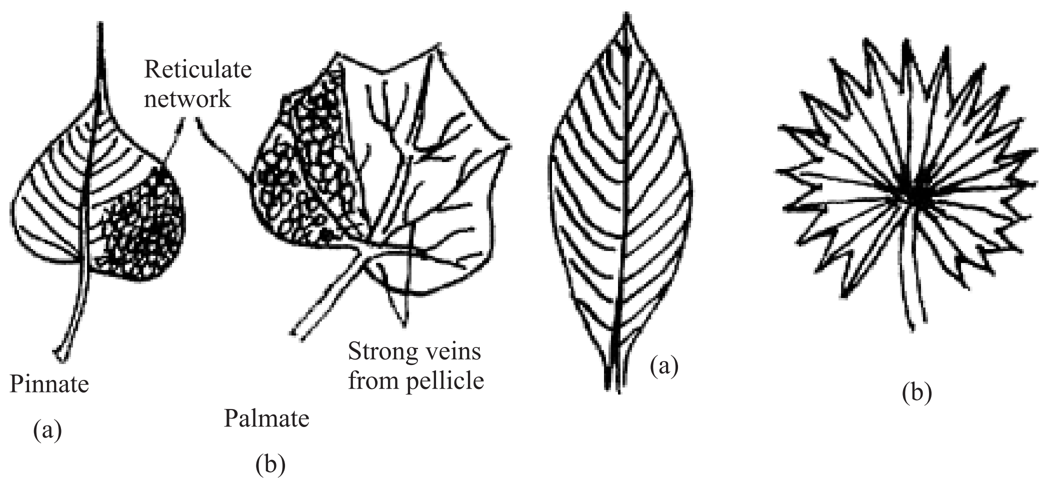


Fig. 7.12 Variations in Leaf margins

7.2.2 Venation in leaves

Arrangement of veins and veinlets in the lamina is known as **Venation.** It is of two types

- **Reticulate venation** -veins forming a network e.g. dicots (Fig.7.13A-a,b)
- **Parallel venation** -veins arranged in parallel rows e.g. monocots (Fig.7.13B c,d).
- Reticulate and parallel venation may be **unicostate** (Fig. 7.13 a,c) with one mid rib, giving out secondary veins like in feather, hence **pinnate** or, **multicostate** (Fig. 7.13 b, d) having many strong veins spreading out from a common point like fingers from palm, hence **palmate as seen** in Fig.7.13.



(A) Reticulate Venation
(a) Unicostate (Peepal)
(b) Multicostate(Grape vine)

(B) Parallel Venation
(a) Unicostate (Canna)
(b) Multicostate(Palm)

Fig. 7.13 Types of Leaf venation

INTEXT QUESTIONS 7.8

1. Define venation.

   ....

2. Differentiate between unicostate and multicostate venation.

   ....

3. What is the type of venation found in peepal and palm leaves?

   ....

4. Name the structure which arises in the axil of leaf

   ....

5. What is the prominent vein called which is present in the middle of lamina and runs from base to apex?

   ....

7.2.3 Types of leaves

There are two types of leaves **Simple** and **Compound.** Since a leaf bears a bud in its axil, you can recognize a compound leaf from a simple one by locating the axillary bud. A bud is present in the axil of both simple and a compound leaf but not in th axil of leaflets. The differences between the two types of leaves are given in table 7.7

Table 7.7 Differences between Simple and Compound leaf

Simple leaf	Compound leaf
1. The leaf has a single undivided lamina (Fig. 7.9)	The lamina is divided into many segments called **leaflets** (Fig. 7.14)
2. If divided, the incisions do not touch the mid rib (Fig. 7.13d)	Incisions touch the mid rib (Fig. 7.15)

Types of Compound leaves - They are of two types as shown in table 7.8

Table 7.8 Types of compound leaf

Pinnate	Palmate
1. Leaflets are attached to mid rib or rachis and are arranged laterally (Fig 7.15)	Leaflets radiate from the end of petiole like fingers of a palm (Fig. 7.14)
2. Leaflets and mid rib may get further divided to form compound leaves that are unipinnate, bipinnate, tripinnate and decompound (Fig. 7.15)	Depending upon the number of leaflets compound leaves are bifoliate, trifoliate, quadrifoliate and multifoliate (Fig.7.14)

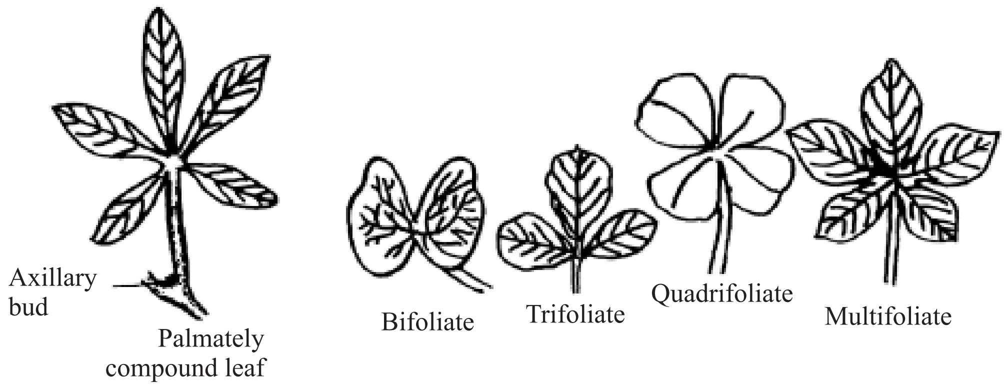


Fig. 7.14 Palmately compound leaf and its types

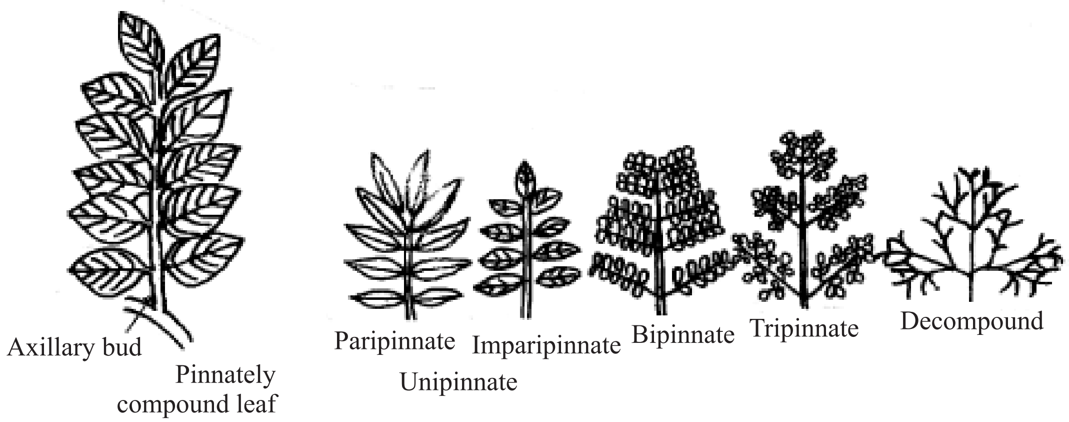


Fig. 7.15 Pinnately compound leaves and its types

INTEXT QUESTIONS 7.9

1. Name the structure to which the leaflets are attached in a compound leaf.

   ....

2. What is the structure which helps you differentiate a leaf from a leaflet?

   ....

3. What are the two types of compound leaves known as ?

   ....

You will enjoy doing the following activity

ACTIVITY 7.1

Aim - To collect and study a few leaves.

Material required — Collect leaves of peepal, neem, banana, palm, rose, grass, imli and tulsi.

Method - Observe the following features in the collected material

(i) Simple or compound leaf

(ii) Reticulate or Parallel venation.

On the basis of the type of venation, group the leaves into monocot and dicot leaves.

7.2.4 Phyllotaxy

It is the arrangement of leaves on stem or branch. The orientation and arrangement of leaves is such that they get appropriate amount of sunlight for photosynthesis. It is of three types

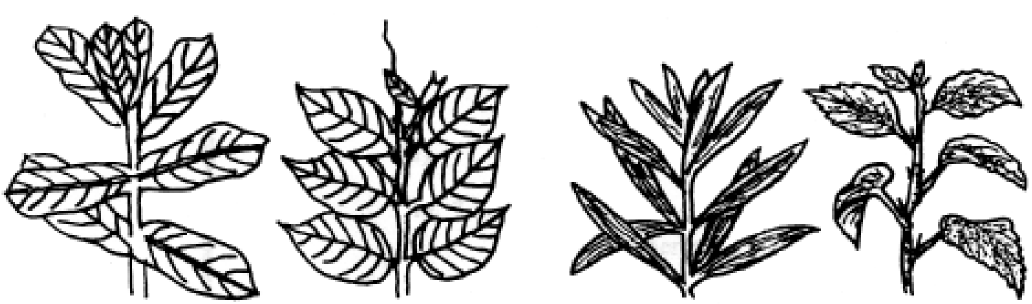
(i) **Alternate** (Fig. 7.16d) - a single leaf arising at each node e.g. china rose, mango.

(ii) **Opposite** (Fig. 7.16a-b) - Leaves occur in pairs at each node. This arrangement may be

  (a) **Decussate** (Fig. 7.16a) - When the successive pairs of leaves at upper and lower nodes are at right angles e. g .,"Tulsi", *Calotropis*

  (b) **Superposed** (Fig. 7.16b) - when the successive leaf pairs at upper and lower nodes are exactly in the same plane e.g. guava

(iii) **Whorled** (Fig. 7.16c) - When there are more than two leaves at each node arranged in a circle or whorl e.g. *Nerium.*



(a) (b) (c) (d)

Fig. 7.16 (a-d) Phyllotaxy- (a) Opposite-Decussate; (b) Opposite-Superposed; (c) Whorled; (d) Alternate

7.2.5 Modifications of leaves

Although the function of leaves is to synthesize food, in some cases they get modified into distinct structures to perform special functions like support and protection to plant, storage of food and water or to catch insects as in case of insectivorous plants (Table 7.9).

Table 7.9 Modifications of leaves

Type	Characters	Examples
1. Leaf Tendril (Fig.7.17a)	Here leaves or leaflets get modified to form thin wiry, closely coiled sensitive structure called the **tendril** that helps the plant to climb the support.	Pea, Glory lily
2. Spines (Fig 7.17b)	The leaves are modified into sharp and pointed structures which protect the plant and help in reducing transpiration.	Prickly poppy *(Argemone)* *Opuntia,* Aloe
3. Phyllode (Fig. 7.17c)	The petiole of compound leaf becomes flattened leaf like and helps in photosynthesis; the leaflets gradually disappear	Australian acacia
4. Leaves of Insectivorous plants (Fig. 7. 17d, e)	In pitcher plant the whole leaf gets modified into pitcher while in bladderwort some segmented leaves get modified into bladders. They help in trapping insects	Pitcher plant *(Nepenthes)* Bladderwort *(Utricularia)*

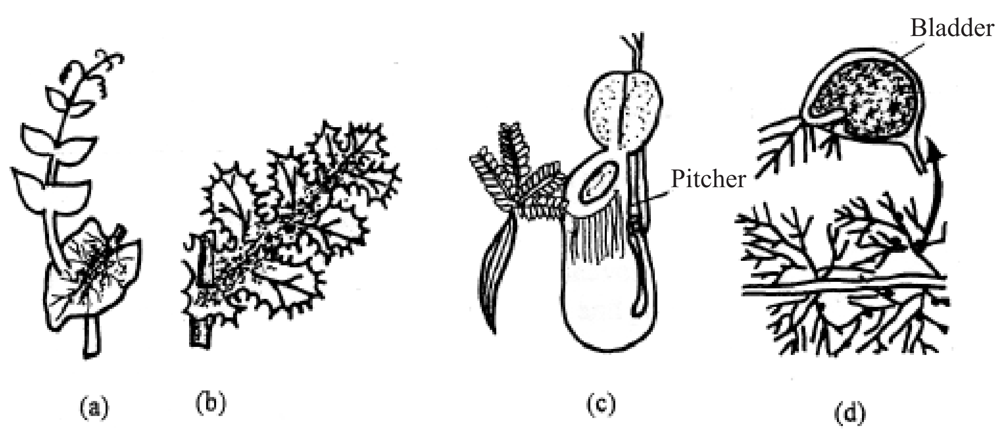


Fig. 7.17 Modifications of Leaf a-d (a) Leaf tendril; (b) Spines; (c) Pitcher plant; (d) Bladderwort

Heterophylly (heteros = different)- Some plants show more than one type of leaves in the same plant , this phenomenon is called heterophylly. It is found in some plants which remain partly submerged in water e.g. Water chestnut, and *Limnophila*

INTEXT QUESTIONS 7.10

1. What is the type of phyllotaxy found in mango, 'tulsi' and guava plants?

....

2. Match the following items of column A with those of column B

A		B	
(a)	Pitcher	(i)	Photosynthesis
(b)	Spines	(ii)	Climbing
(c)	Phyllode	(iii)	Trapping insects
(d)	Tendril	(iv)	Protection

3. Give two examples of insectivorous plants.

   ....

4. Water chestnut shows two different types of leaves on the same plant, what is such a condition known as?

   ....

7.2 6 Functions of Leaf

Leaf performs following functions :

(i) **Photosynthesis** - Leaves manufacture food in the presence of sunlight.

(ii) **Exchange of gases -** Stomata help in exchange of gases which are important for respiration and photosynthesis.

(iii) **Transpiration** - Evaporation of excess of water in vapour form takes place through stomata which helps in ascent of sap and cooling of leaf surface.

(iv) **Guttation -** Exudation of excess of water containing salts takes place in liquid form from leaf margins in plants growing in humid climate.

(v) **Modifications for special functions -** In certain plants leaves perform functions like manufacturing and storing food, providing support and protection, vegetative propagation and trapping insects.

7.2.6. Internal structure of leaf (Figs. 7.18-19)

A General features

- Leaves of most dicot plants are dorsiventral (oriented horizontally, with differentiated mesophyll) where as those of monocots are isobilateral (oriented vertically, mesophyll undifferentiated).
- V.S. of leaf shows three main parts (i) **Epidermis** (ii) **Mesophyll** (iii) **Vascular system.**

  (i) **Epidermis -** Present on **both** upper and lower surface of leaf. Some epidermal cells give rise to guard cells that get arranged to form openings called stomata which help in exchange of gases for photosynthesis, respiration and evaporation of water vapour during transpiration. In some monocot leaves, some epidermal cells in upper epidermis become enlarged to form bulliform cells which lose water so that leaves become tubular to reduce transpiration on hot sunny days.

  (ii) **Mesophyll -** Consists of chloroplast - containing parenchyma **(chlorenchyma)** and is responsible for carrying out photosynthesis. It is differentiated into **palisade** and **spongy** cells in dicot leaves. In monocot leaves, palisade tissue is lacking, thus, mesophyll has only spongy tissue.

- **Palisade cells -** occur below upper epidermis in dicot leaf.
  - Cells are radially elongated, compactly arranged.
  - Possess abundant chloroplasts
- **Spongy cells -** Occur below the palisade cells in a dicot leaf.
  - Cells irregular and loosely arranged - Contain fewer chloroplasts
  - Store gases in the inter cellular spaces

(iii) **Vascular Bundles -** They are **conjoint, collateral** and **closed**

- In each bundle, xylem is located on upper side (ventral) and phloem on lower side (dorsal)
- Most vascular bundles are surrounded by colourless parenchyma called **bundle sheath or border parenchyma.**

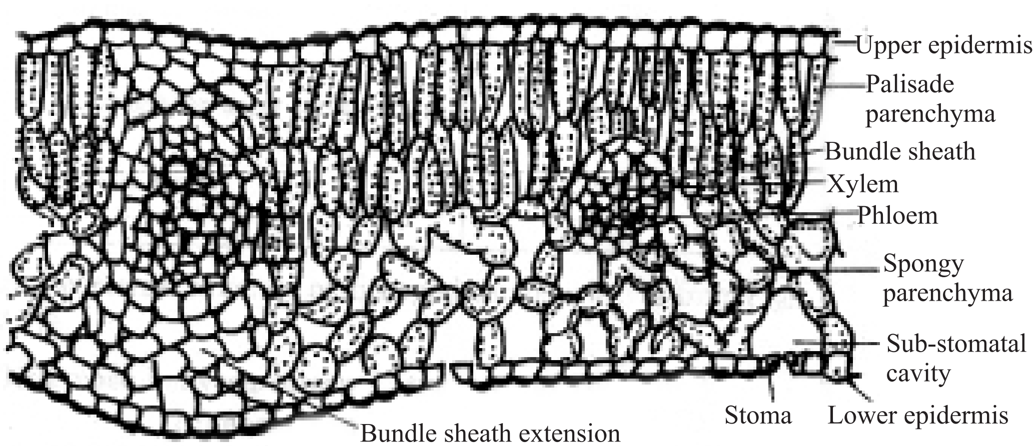


Fig. 7.18 V.S. of a dicot (Dorsiventral) Leaf

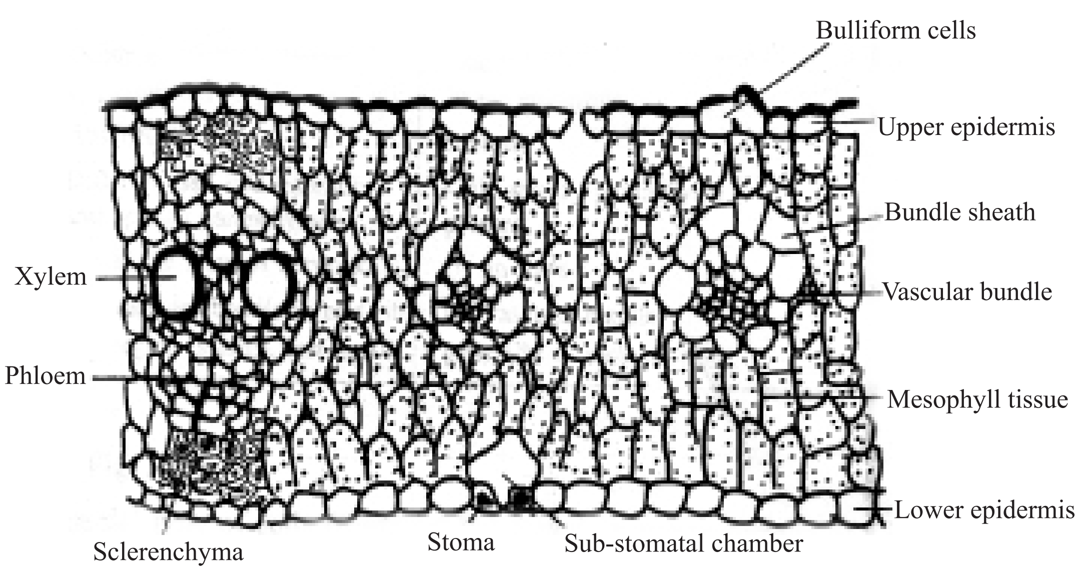


Fig. 7.19 V.S. of a Monocot (Isobilateral) Leaf

Structure of stomatal apparatus : In dicot leaves, stomatal apparatus is made up of two semi circular guard cells surrounding a pore-stoma (Fig. 7.21) The guard cells contain chloroplasts and regulate the opening and closing of stomata. Stomatal pore opens into the inter cellular spaces (substomatal cavity) of mesophyll (Fig. 7.19). The number, shape and distribution of stomata vary (Table 7.10) depending upon the plant whether it is xerophyte or mesophyte.

Table 7.10 Distribution of stomata.

Plants	Stomatal characters	Examples
1. Dicots	Guard cells semicircular reniform occur generally on lower surface	Mango, neem
2. Monocots	Guard cells dumbbell shaped, occur on both the surfaces	Maize
3. Xerophytes	To reduce transpiration- (i) occur only on lower surface, (ii) are absent or less in number on the upper surface (iii) may be sunken	*Nerium*
4. Hydrophytes		
– with floating leaves	Occur only on upper surface	Lotus
– with submerged leaves	Stomata absent	*Hydrilla*

Now you can compare the internal structures of dicot and monocot leaves from Figs. 7.18-19 and Table 7.11

Table 7.11 Difference between internal structure of Dicot and Monocot Leaf

Tissue	Dicot leaf (Dorsiventral leaf)	Monocot leaf (Isobilateral leaf)
1. Epidermis		
(i) Stomata	Occur generally in lower epidermis	Occur both in upper and lower epidermis
(ii) Bulliform cells	Absent	Present in upper epidermus
2. Mesophyll	Differentiated into palisade and spongy parenchyma	Only spongy parenchyma present
3. Vascular system	(i) in the form of network (ii) vascular bundle in mid rib region is large, rest of the vascular bundles decrease in size towards the leaf-margin.	(i) in rows (ii) vascular bundle of midrib is large, but other vascular bundles are small generally of same size.

B. Special features

(i) **Bulliform Cells** (Fig 7.19)

- These are special type of cells **(motor cells)** found on upper leaf surface of some monocots (e.g. maize, bajra, jowar).

- They help the leaf to roll and unroll due to change in their turgidity.
- Leaf rolls when these cells lose water due to high rate of transpiration especially at Mid-day on hot sunny days.
- Thus, under dry conditions they help in reducing the loss of water vapour through stomata.

(ii) **Hairs**

- Hairs are present especially on leaves of plants growing in dry conditions. They check the rate of transpiration.
- They protect the leaf from bright sunlight, high temperature and air pollution.

(iii) **Hydathodes (water stomata)**

- These are specialised structures (Fig.7.20) present in leaves of angiosperms (garden nasturtium) occurring in humid climate.
- Through these openings excretion of water and minerals plus simple organic compounds in liquid form **(guttation)** takes place. When water absorption by a plant is more and transpiration is less.

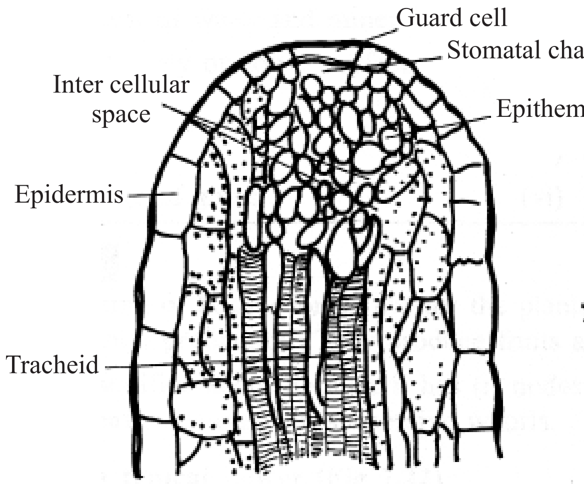


Fig. 7.20 Hydathode

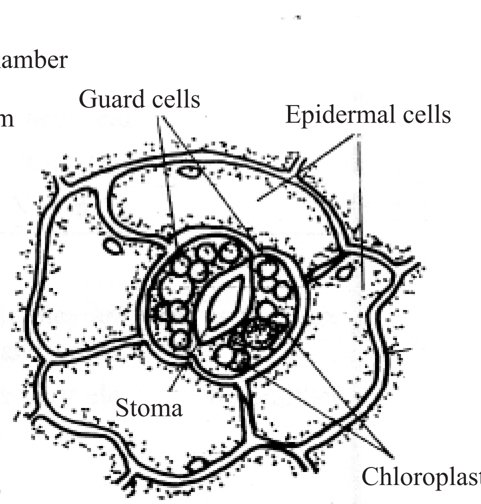


Fig. 7.21 Stomatal apparatus from a dicot leaf

Table 7.12 Difference between Stomata and Hydathode

Characters	Hydathode	Stomata
1. Size	Large	Small
2. Location	Located at vein endings near leaf margins only	Present throughout the leaf surface
3. Structure	Always remain open	They open and close depending upon light intensity
4. Loss of water	Water comes out in liquid form and contains dissolved salts & sugars	Water loss is in vapour form
5. Occurrence	Found in plants of humid areas	In plants occurring in all climates
6. Physiological process	Guttation	Transpiration

INTEXT QUESTIONS 7.11

1. How is the mesophyll tissue of dicot leaf different from that of monocot leaf? What is it's function?

   ....

2. Where are stomata located in a grass leaf?

   ....

3. Name the structure through which plants growing in humid areas get rid of excess of water in liquid form.

   ....

4. Match the following item of column A with that of column B

	A		B
(a)	Bulliform cells	(i)	Protection
(b)	Transport of water and mineral salts	(ii)	Guttation
(c)	Stomata only on lower surface	(iii)	Monocot leaf
(d)	Hydathode	(iv)	Dicot leaf
(e)	Hair	(v)	Stomata
(f)	Exchange of gases	(vi)	Xylem

7.3 FLOWER

Flowers are a thing of beauty for us but for the plants they are vital as they are the seat of sexual reproduction. They produce fruits and seeds.

A flower is a modified shoot because it has (i) nodes very close to one another and (ii) floral leaves arranged in successive whorls.

7.3.1 Parts of a typical flower (Fig 7.22)

Take a flower of any colour or size growing in your area, you'll find it's basic plan to be the same i.e. the flower is borne on a stalk called **pedicel.** The pedicel has a swollen tip known as **thalamus** or **receptacle** on which are borne four whorls successively in definite order as given below :

Accessory whorls

1. **Calyx** (collection of sepals) - The outer most whorl of green sepals whose main function is protection.
2. **Corolla** (collection of petals) - The next whorl of variously coloured petals. They help in attracting insects for pollination.

Reproductive whorls

3. **Androecium** (male reproductive part) consists of collection of stamens. Each stamen has a long slender **filament** with a bilobed **anther** at it's tip with a **connective.** Anthers produce pollen grains for pollination.

4. **Gynoecium** (female reproductive part) - centrally located. It consists of a collection of one or more **carpels** which organise to form one or more **pistils.** Each pistil has three parts -
   - **Ovary -** It is the swollen basal part, one to many chambered (called **locules)** containing ovules which get fertilized to form seeds and the, fertilized ovary forms the fruit.

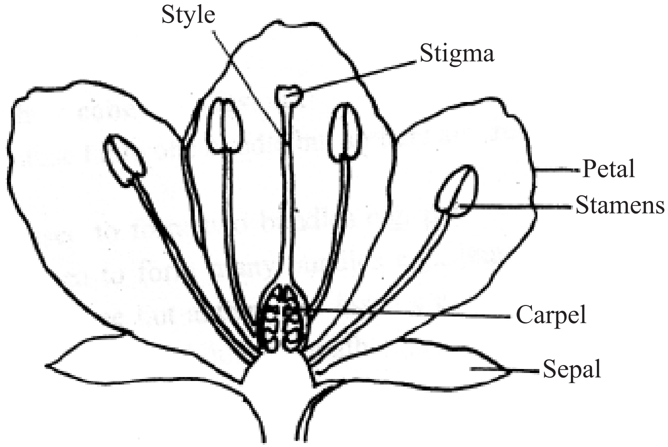


Fig.7.22 A typical flower

   - **Style-** It is the elongated tube connecting the upper part of ovary to stigma.
   - **Stigma-** It is the receptive surface for pollen.

Common variations in flower and its floral parts -Flowers show a lot of variation, some of which you can study from the Table 7.13

Table 7.13 Variations in flower

Variation	Characters
1. **Complete/Perfect** flower	All 4 floral whorls present
2. **Incomplete/Imperfect** flower	Any one or more of floral whorls are absent
3. **Bisexual** (Hermaphrodite)	Both reproductive organs i.e. stamens and carpels present
4. **Unisexual**	Only one reproductive organ present
(i) **Staminate** or male flower	Only stamens present
(ii) **Pistillate** or female flower	Only pistil present
(iii) **On** the basis of occurrence of unisexual flowers, plant is	
(a) **Monoecious**	Both male and female flower occur on same plant e.g., cucumber
(b) **Dioecious**	Male and female flower occur on different plants e.g., papaya
5. **Neuter** flower	Both stamens and carpels are absent
6. **Actinomorphic (Regular)** flower	If it can be divided into two equal halves through any vertical plane e.g., mustard
7. **Zygomorphic** (irregular bilateral)	If it can be divided into two similar halves only through one particular plane e.g., pea
8. **Asymmetrical (Irregular)**	It cannot be divided into two similar halves in any vertical plane *e.g., Canna*

A. Variations in sepals and petals

(i) **Polysepalous** and **Polypetalous** (poly - free)- sepals or petals are free respectively.

(ii) **Gamosepalous** and **Gamopetalous** (gamo - united)- all sepals or petals are fused, respectively.

(iii) **Perianth -** Sepals and petals not distinguishable e.g. onion

B. Variations in Stamens (Fig. 7.23)

The stamens show variation in their **cohesion** (fusion).

(i) **Monadelphous -** filaments fused into one bundle but anthers are free e.g. china rose

(ii) **Diadelphous** – filaments fused to form two bundles e.g. pea

(iii) **Polyadelphous**–filaments fused to form many bundles e.g., lemon

(iv) **Syngenecious** – filaments are free but anthers are fused e.g. sunflower

(v) **Synandrous** – stamens are fused throughout the length e.g., cocks-comb.

Other variations in stamens are as follows

(vi) **Epipetalous** – stamens are attached to petals by their filaments but anthers are free e.g., brinjal

(vii) **Didynamous** – four stamens, two short and two long e.g. tulsi

(viii) **Tetradynamous** – six stamens, inner four are long and outer two are short e.g., mustard

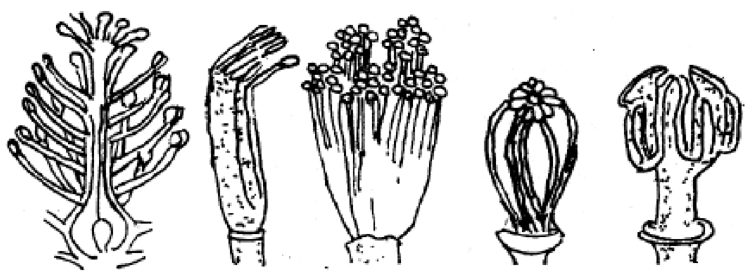


Fig. 7.23 Cohesion (fusion) of stamens.

C. Variation in Carpel

On the basis of number of carpels in a pistil, flowers may be

(i) **Monocarpellary** – If in a Gynoecium pistil has only one carpel e.g. pea.

(ii) **Polycarpellary** – If the Gynoecium has many carpels (e.g. china rose). It may be

(a) **syncarpous** - two or more carpels are fused to form a pistil. e.g. tomato, mustard

(b) **apocarpous** – carpels are free e.g. *Ranunculus*, lotus.

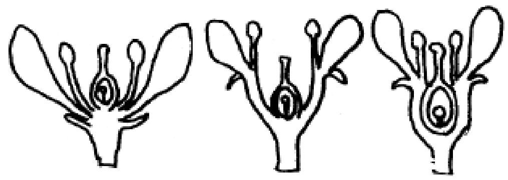
7.3.1a Position of floral whorls on thalamus with respect to ovary

Flower could be of three kinds (Fig, 7.24)

(i) **Hypogynous** - ovary occupies the highest position on thalamus, other three whorls are sucessively below it. Ovary is said to be superior e.g. china rose, and mustard.

(ii) **Perigynous** - The thalamus is disc-like on which the ovary is borne in the centre and rest of floral whorls are located on rim of thalamus. Ovary is said to be half inferior e.g. peach, and plum.

(iii) **Epigynous** -thalamus forms a cup- shaped structure; and encloses the ovary completely and fuses with it. The other whorls are positioned above the ovary. The position of ovary is now inferior e.g. sunflower, cucumber.



(a) Hypogynous (b) Periogynous (c) Epigynous

Fig. 7.24 Position of floral parts on thalamus

> **Do you know**
> Some plants like cashew nuts and mango have neuter, bisexual and unisexual flowers on the same tree.

7.3.2 Placentation

It is the manner in which placentae are distributed in the ovary. Placenta is the point of attachment of ovules (or future seed) in the ovary.

Types of placentation (Fig. 7.26)

(i) **Marginal** - The ovary is monocarpellary and one chambered and ovules are arranged along the fused margins of the single carpel. e.g. pea, gram.

(ii) **Axile** - Ovary is polycarpellary syncarpous, having many chambers and ovules present on the placenta develop from the central axis formed by the fusion of the margins of two or more carpels e.g. China rose, tomato, bhindi,

(iii) **Parietal** - Ovary is polycarpellary and syncarpous, having one chamber and ovules are attached on its inner wall where margins of adjoining carpels meet e.g, mustard, cucumber,

(iv) **Basal** – Ovary is bi-or polycarpellary, syncarpous, having one chamber and placenta develops at the base of ovary and bears a single ovule e.g. sunflower.

(v) **Free central** – Ovary is syncarpous and polycarpellary but unilocular as septae are absent. In the central part of the ovary the placenta bears many groups of ovules e.g. *Dianthus*, *Primula*.

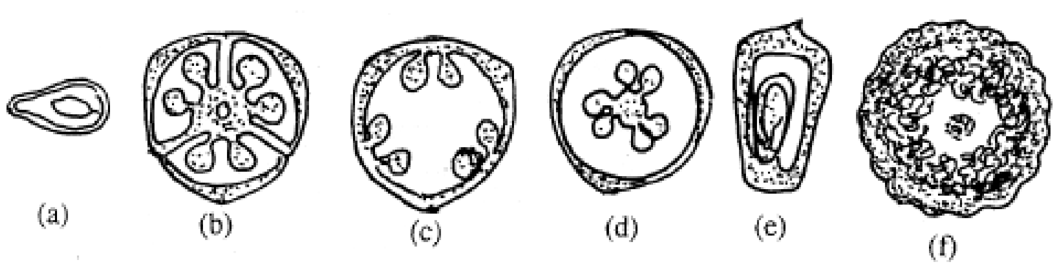


Fig. 7.25 Types of placentation (a) Marginal, (b) Axile, (c) Parietal, (d) Free central, (e) Basal, (f) Superficial

(vi) **Superficial** - Ovary is polycarpellary syncarpous and multilocular in which entire inner walls of chambers are lined with placental tissue so that ovules develop all around e.g.,water lily (*Nymphaea*)

INTEXT QUESTIONS 7.12

1. What is the collection of sepals and petals respectively known as?

   ....

2. Match the following items of column A with those of column B

	A		B
(a)	Flower	(i)	China rose
(b)	Polycarpellary	(ii)	Pollination
(c)	Petals	(iii)	Reproductive organ
(d)	Monodelphous	(iv)	Many carpels
(e)	Carpel	(v)	Modified shoot

3. Define placentation.

   ....

4. Name the type of placentstion where ovary is many chambered and ovules are arranged on the central axis.

   ....

7.4 INFLORESCENCE

Inflorescence is the arrangement of flowers on the floral axis called peduncle. :Inflorescence could be terminal or axillary.

7.4.1 Types of inflorescence

The various types of inflorescence depend upon the type of branching of peduncle and arrangement of flowers. There are two major types of inflorescence

(i) **Racemose.** The main axis does not end in a -flower but continues to grow.

(ii) **Cymose.** The main axis ends in a flower and the growth is limited.

The major differences between the two are given in table 7.14

Table 7.14 Differences between Racemose and Cymose inflorescence

Racemose	cymose
1. Main axis shows unlimited growth	Growth is limited
2. Axis does not terminate in a flower	Axis ends in at flower
3. Flowers occur in acropetal order (oldest flower below and youngest near the apex)	Flowers in basipetal order (terminal flower is older)

Table 7.15 Types of Racemose Inflorescence (Fig. 7.20)

A. With main axis elongated

Type	Characters	Examples
1. Raceme	Flowers present on the floral axis are stalked and arranged acropetally.	Mustard
2. Spike	Like raceme but the flowers are sessile	*Achyranthes* ('Latzira')
3. Spikelet	Cluster of one or more flowers (florets' and their associated bracts	Wheat
4. Catkin	Like spike but the axis is pendulous bearing unisexual flowers	Mulberry
5. Spadix	Like spike but the axis is fleshy and enclosed by a large showy bract (Spathe)	Colocassia, banana

B With main axis shortened

Type	Characters	Examples
6. Corymb	Lower (older) flowers have longer stalks than the upper younger ones, thus all flowers come to lie at same level	Candytuft
7. Umbel	Flower with stalks of equal length arising from the same, point	Coriander

C. With main axis flattened

Type	Characters	Examples
8. Head or capitulum	Main axis is flattened into convex receptacle on which sessile flowers (florets) are arranged in centripetal order (older towards periphery). Whole inflorescence is surrounded by involucre of bracts	Sunflower

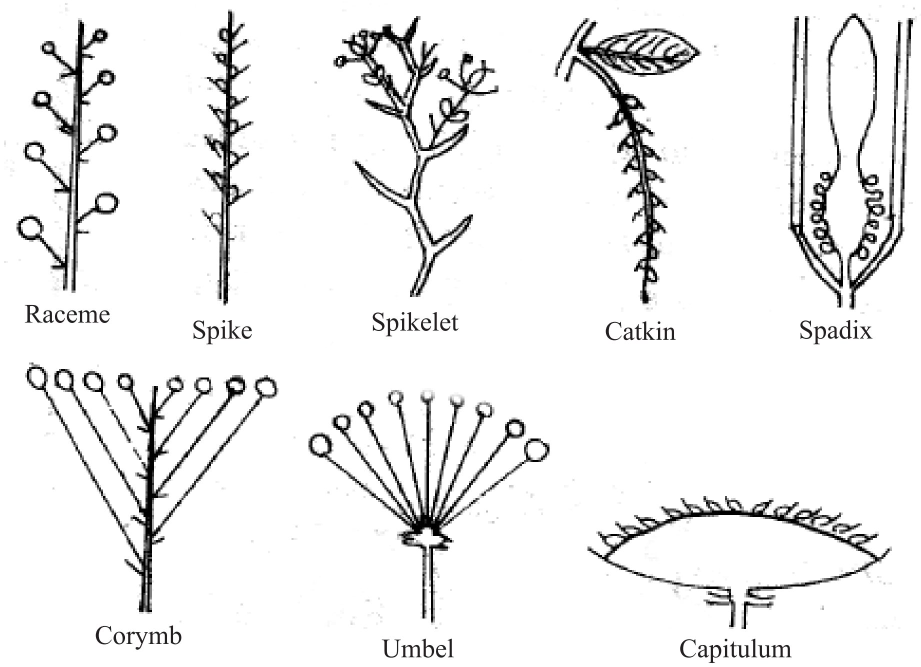


Fig. 7.26 Types of Racemose Inflorescence

Table 7.16 Types of cymose inflorescence (Fig. 7.27)

Type	Characters	Examples
1. Monochasial cyme (Fig. 7.27a)	Main axis ends in a flower. A lateral branch comes from one side and ends in a flower	Cotton
2. Dichasial cyme (Fig. 7.27b)	Two lateral branches develop form either side of terminal flower and each branch ends in a flower	*Dianthus, jasmine*
3. Multichasial cyme (Fig. 7.27c)	Number of lateral branches come from the sides of terminal flower, each lateral branch ends in a flower.	*Calotropis*

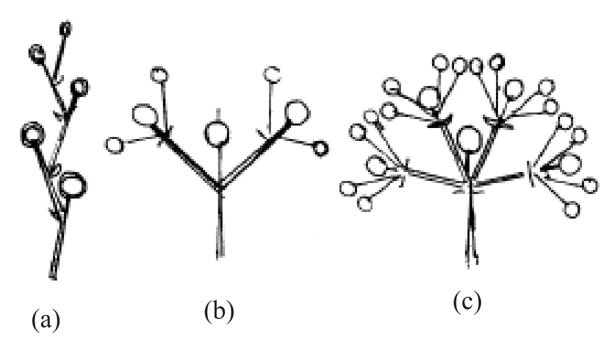


Fig. 7.27 Types of Cymose inflorescence (a) Monochasial, (b) Dichasial, (c) Polychasial

7.4.2 Special types of inflorescence

1. **Hypanthodium** (Fig.7.28a) - The fleshy receptacle forms a cup like cavity and has an apical opening. The male and female flowers are borne on the inner wall of the cavity e.g. Fig, Peepal
2. **Cyathium** (Fig. 7.28b) - A type of inflorescence characteristic of Euphorbia, in which a cup shaped involucre encloses a single female flower surrounded by a number of male flowers. A nectary is present at the rim of involucre,
3. **Verticillaster** (Fig. 7.28c)- It is a series of condensed dichasial cyme at each node with a cluster of sessile flowers in the axil of leaves e.g. *Ocimum* (Tulsa), *Salvia*,

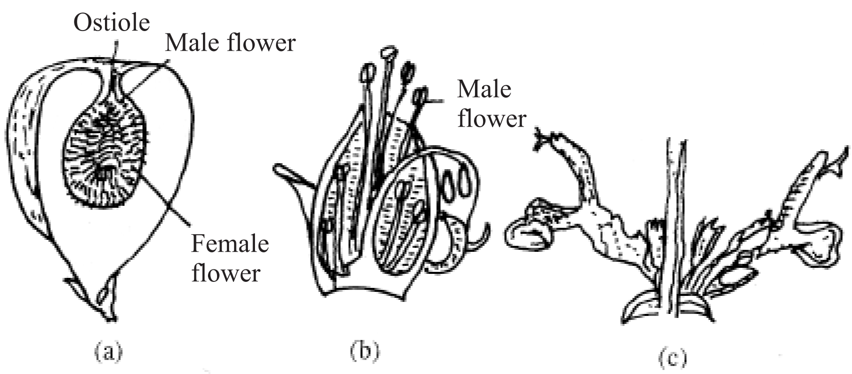


Fig.7.28 Special type of Inflorescence- (a) Hypanthodium, (b) Cyathium, (c) Verticillaster

INTEXT QUESTIONS 7.13

1. What is a cyamose inflorescence?

   ....

2. Give one difference between Raceme and Spike.

   ....

3. Define inflorescence.

   ....

4. Name the type of inflorescence found in sunflower and Fig.

   ....

7.5 FRUIT

A true fruit is a ripened ovary that develops after fertilization. Ovules develop into seeds and the ovary wall matures into fruit wall which is now called pericarp. The pericarp may be thick or thin. In fleshy fruits like mango, pericarp is thick and differentiated into three regions-(a) **epicarp** forms the skin of the fruit (b) **mesocarp**, middle pulpy and (c) **endocarp** inner hard and stony (coconut, mango) or often thin membranes (orange). In **dry fruits** pericarp, is thin, dry, papery or thick and woody but not divided into three regions.

Sometimes along with ovary other floral parts like thalamus, receptacle or calyx may develop as part of fruit, such fruits are-called false fruits. e.g. apple, pear (thalamus), fig (receptacle).

Parthenocarpic fruit -It is a fruit that develops without fertilization. It is seedless or has non-viable seeds e.g, banana, grapes. Horticulturists are producing such fruits artificially.

7.5.1 Kinds of fruits - There are three basic types

1. **Simple fruit** - Develops from single mono-to polycarpellary, syncarpous (fused) ovary e.g, pea, tomato.
2. **Aggregate fruit** - Collection (etaerio) of simple fruits or fruitlets on same thalamus developing from polycarpellary, apocarpous (free carpels) ovary e.g. *Calotropis* and *Ranunculus*.
3. **Composite or multiple fruit** - Fruit develops from a number of flowers juxtaposed together or from inflorescence e.g. mulberry, pineapple.

Table7.17 Major categories of fruits

1. Simple	Dry	Dehiscent	(i) Legume - pea, bean, groundnut
			(ii) Siliqua - mustard
			(iii) Follicle - *Calotropis*
			(iv) Capsule - cotton, poppy, 'bhindi'
		Indehiscent	(i) Caryopsis - wheat, rice
			(ii) Nut - almond, cashewnut
			(iii) Cypsella - sunflower, marigold
			(iv) Samara - yam, hiptage
	Fleshy		(i) Drupe - mango, coconut
			(ii) Berry - tomato, banana, date palm
			(iii) Pepo - cucumber, watermelon
			(iv) Hesperidium - lemon, orange
			(v) Pome - apple, pear
2. Aggregate			(i) Etaerio (cluster) of drupes - Raspberry
			(ii) Etaerio of achenes - Strawberry, rose
			(iii) Etaerio of berries - Custardapple
			(iv) Etaerio of follicles - periwinkle, larkspur
3. Multiple or composite			(i) Sorosis - pineapple, mulberry, jackfruit
			(ii) Syconus - Fig, peepal

Table 7.18 Common Fruits and their edible parts.

Names	Types	Edible Parts
1. Banana	Berry – simple, fleshy	Mesocarp and endocarp
2. Apple	Pome – simple, fleshy	Fleshy thalamus
3. Coconut	Fibrous Drupe – simple, fleshy	Endosperm
4. Custard Apple	Etaerio of Berries – aggregate	Pericarp
5. Date Palm	Berry – simple, fleshy	Pericarp
6. Cashew Nut	Nut – simple, dry indehiscent	Peduncle and Cotyledons
7. Mango	Drupe – simple, fleshy	Mesocarp
B. Orange	Hesperidium – simple, fleshy	Juicy hairs from endocarp,
9. Tomato	Berry – simple, fleshy	Pericarp and Placentae
10. Pear	Pome – simple, fleshy	Fleshy thalamus
11. Pineapple	Sorosis – composite	Outer portion of receptacle, bracts and perianth
12. Fig	Syconous – composite	Fleshy receptacle
13. Litchi	Nut – simple	Juicy aril
14. Wheat	Caryopsis – simple dry indehiscent	Starchy endosperm
15. Strawberry	Etaerio of achenes- aggregate	Succulent thalamus

INTEXT QUESTIONS 7.14

1. Define Fruit.

   ....

2. Give two examples of false fruits.

   ....

3. What is the fruit wall known as which is formed by the ovary wall?

   ....

4. Give the names of three layers of pericarp of a fleshy fruit.

   ....

5. Match the following of column A with that of column B

A		B	
(a)	Apple	(i)	Berry
(b)	Hesperidium	(ii)	Mesocarp
(c)	Mango-edible part	(iii)	Endosperm
(d)	Coconut -edible Part	(iv)	Orange
(e)	Tomato	(v)	False Fruit

WHAT YOU HAVE LEARNT

- Stem is aerial, upright, positively phototropic part of plant and bears nodes, internodes leaves and buds.
- It has a terminal apical meristem which gives rise to leaves and axillary buds
- The stems are variously modified into underground, subaerial and aerial stems for performing special functions.
- Dicot and monocot stems are different anatomically.
- The internal structure of dicot stem shows epidermis, differentiated ground tissue, multilayered pericycle and vascular bundles arranged in a ring. Each vascular bundle is conjoint, collateral and open with endarch xylem.
- Monocot stem differs in having undifferentiated ground tissue, scattered vascular bundles which are closed.
- Secondary growth takes place only in dicot stem.
- Wood is of two types- heartwood (dark and non functional) and sap wood (light and functional)
- The differential activity of vascular cambium during secondary growth forms annual growth rings.
- Origin of lateral stem branches is exogenous.
- The primary function of stem is conduction of water and minerals through xylem and food through phloem; support and orient leaves towards sunlight for better photosynthesis ; bear flowers and fruits.
- Stem undergoes modifications for various special functions like food storage, perennation, protection, climbing, photosynthesis and vegetative propagation.
- Leaf is a specialised organ for photosynthesis.
- It has three parts -leaf base, petiole and lamina traversed by parallel or reticulate venation. The arrangement of leaves on stem is called phyllotaxy
- Leaves can be simple or compound.
- Leaves are modified into tendrils, spines, phyllode, pitcher or bladder to perform special functions.
- Internal structure of leaf shows three main tissues - epidermis with stomata, mesophyll differentiated into spongy and palisade tissue in dicot leaf but only spongy tissue in monocot leaf and vascular system.
- In dicot leaves each stomatal apparatus consists of kindney shaped guard cells surrounding a pore. In monocot leaves stoma is surrounded by two dumbbell shaped guard cells. Guard cells regulate the opening and closing of stomata, depending upon the presence or absence of sunlight.

- Stomata help in gaseous exchange and allow loss of water vapour during transpiration.
- Special structures like bulliform cells, hydathodes and hairs occur in leaves of some plants.
- Flower is a modified shoot.
- A typical flower has accessory whorls i.e., calyx and corolla and reproductive or essential whorls i.e., androecium (male) and gynoecium (female).
- Flowers may be bisexual, unisexual or neuter; actinomorphic or zygomorphic; hypogynous, perigynous or epigynous.
- Variations occur in floral parts.
- Placentation is the manner in which placentae bearing ovules are distributed in the ovary. It is of many types.
- Inflorescence is the arrangement of flowers on the floral axis.
- It has two major types - racemose and cymose.
- Hypanthodium, verticillaster and cyathium are special types of inflorescence.
- Fruit is a ripened ovary that develops after fertilization
- Ovules develop into seeds and the ovary wall matures into fruit wall called the pericarp which may be thin or differentiated into epicarp, mesocarp and endocarp.
- Fruits may be true or false and categorized into simple, aggregate or composite types.
- Simple fruits may be dry (dehiscent or indehiscent) or fleshy.
- A fruit that develops without fertilization is called parthenocarpic fruit.

TERMENAL EXERCISES

1. Differentiate between
   (i) Dicot stem and monocot stem
   (ii) Root and stem
   (iii) Racemose and cymose inflorescence
   (iv) Stoma and hydathode
   (v) True fruit and false fruit
   (vi) Dicot and monocot leaf
2. Explain the different types of underground modified stem?
3. Explain the process of secondary growth in dicot stem.
4. Draw and label the vertical section of dicot leaf.
5. Define the following

(a) Flower (b) Actinomorphic (c) Heterophylly
(d) Phyllotaxy (e) Hypogynous (f) Parthenocarpic fruit
(g) Venation.

6. What is cork cambium? State its functions.

7 Draw labelled diagrams of the following
   (a) Raceme and corymb inflorescence
   (b) Axile and parietal placentation

8. What is a fruit? Enlist the various types of simple- fleshy fruits giving one example of each type.

9. What are the edible parts of the following fruits
   (a) Mango (b) Orange (c) Apple
   (d) Banana (e) Coconut (f) Cashew nut

10. Match the following of column A with that of column B

	A		B
(a)	Tendril	(i)	Protection
(b)	Stolon	(ii)	Food, storage
(c)	Thorn	(iii)	Reproduction
(d)	Tuber	(iv)	Photosynthesis
(e)	Capitulum	(v)	Climbing
(f)	Phylloclade	(vi)	Sunflower

11. Name the type of modification of an underground, non-green structure bearing nodes and internodes and ‘eyes’.

12. If a section of stem shows scattered vascular bundles which are closed, have ‘Y’ shaped xylem and are surrounded by bundle sheath; what group of plant is it?

13. What is the region ouside the phellogen known as?

14. When the cambium is less active which type of wood does it produce?

ANSWERS TO INTEXT QUESTIONS

7.1
1. Stem, 2. Axillary bud
3. Because lateral roots originate from inner layer, that is, pericycle (endogenous origin)
4. Stem is positively phototropic and negatively geotropic

7.2
1. Corpus 2. Procambium
3. Axillary bud, exogenous 4. Root cap

7.3
1. Creeper 2. Sub-aerial
3. Cladode 4. Rhizome, Bulb
5. (a) - (v) (b) - (iii) (c) - (i) (d) - (ii) (e) - (iv)

7.4 1. Conduction of water and minerals from root to leaf and manufactured food from leaf to other parts of plant

2. Stem cuttings

3. (a) - (iii) (b) - (v) (c) - (iv) (d) - (ii) (e) - (i)

7.5 1. Conjoint is when xylem and phloem are together in one bundle, collateral is when xylem and phloem are on the same radius

2. Medullary ray (3) Root

4. Maize stem for monocot and sunflower for dicot stem

7.6 1. Cork cambium (phellogen) and vascular cambium

2. Medullary ray parenchyma

3. All the tissues outside the functional cork cambium is called bark

4. For gaseous exchange in branches

5. Phellem, Phellogen, Phelloderm, Protection

7.7 1. Late or summer wood

2. By counting the annual rings

3. Durable, resistant to attack of pathogen

4. Presence of abundant mechanical tissue like sclerenchyma and secondary xylem

5. Wood is secondary xylem produced by the activity of vascular cambium in dicot stem

7.8 1. Venation is the arrangement of veins and veinlets in lamina of leaf

2. Unicostate has one strong midrib while multicostate has many strong veins

3. Reticulate, parallel 4. Axillary bud 5. Midrib

7.9 1. Rachis

2. Presence of axillary bud in leaf but not in leaflet

3. Pinnately and palmately compound leaf

7.10 1. Alternate, opposite-decussate; opposite-superposed;

2. (a) - (iii) (b) - (iv) (c) - (i) (d) - (ii)

3. Pitcher plant; bladderwort 4. Heterophylly

7.11 1. Mesophyll differentiated into palisade and spongy tissue in dicot leaf but composed of only spongy tissue in monocot leaf; photosynthesis

2. In both surfaces of leaf 3. Hydathodes

4. (a) - (iii) (b) - (vi) (c) - (iv) (d) - (ii) (e) - (i) (f) - (v)

7.12 1. Calyx, Corolla

2. (a) - (v) (b) - (iv) (c) - (ii) (d) - (i) (e) - (iii)

3. Placentation is the manner in which placentae are distributed in the ovary

4. Axile

7.13 1. When the main axis ends in a flower and the growth is limited

2. Flowers are stalked in raceme but sessile in spike

3. Arrangement of flowers on floral axis

4. Capitulum, Hypanthodium

7.14 1. Fruit is a ripened ovary that develops after fertilization

2. Apple, pear 3. Pericarp 4. Epicarp, mesocarp, endocarp

5. (a) - (v) (b) - (iv) (c) - (ii) (d) - (iii) (e) - (i)

8

ABSORPTION, TRANSPORT AND WATER LOSS (TRANSPIRATION) IN PLANTS

Water is the most important component of living cells. It enters the plants through roots and then moves to other parts. It is also lost by transpiration through the aerial parts of plants, mainly through the leaves. There are several phenomena involved in the movement of water about which you will study in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *define the terms permeability, diffusion, osmosis and plasmolysis;*
- *define and differentiate between the active and passive absorption;*
- *explain imbibition, water potential, turgor pressure and wall pressure, wilting;*
- *describe the pathways of water from root hair up to leaf;*
- *describe the mechanism of translocation of solutes in plants;*
- *explain the process and significance of transpiration;*
- *list the factors affecting the rate of transpiration;*
- *explain the opening and closing mechanism of stomata (potassium ions theory) and list the factors affecting stomatal movement;*
- *explain the process of guttation and list the factors affecting rate of guttation.*

8.1 FOUR BASIC PHENOMENA-PERMEABILITY, DIFFUSION, OSMOSIS AND PLASMOLYSIS

8.1.1 Permeability

Permeability is the property of a membrane to allow the passage of the substances through it. The plant cell wall is **permeable** because it allows both solvent and solute molecules to pass through it. Cuticle layer is impermeable. All biological membranes (cell membrane, mitochondrial membrane, nuclear membrane etc.) are **selectively permeable** as they allow penetration of only solvent molecules but not the solute molecules.

8.1.2 Diffusion

If a can containing volatile substance, such as ethyl ether, is opened in a room, their molecules will soon be distributed in the room until their concentration is the same throughout the room. In other words, ether molecules diffuse into the air in the room. Similarly the fragrance of incense sticks or agarbatti spreads from one corner of the room to the other due to diffusion. Another example is placing a small crystal of a water soluble dye (copper sulphate) at the bottom of a test tube and then pouring water carefully over the crystal. Dye molecules will dissolve and the colour will spread slowly throughout water, partly because of the movement of dye molecules through the water and partly because of the movement of water molecules into a region close to the crystal.

Thus diffusion is the intermingling of molecules of the same or different substances as a result of their random movement. It is dependent on the difference in concentration of molecules of different substances in the adjacent areas and this difference is called **diffusion gradient**.

Diffusion is an effective method of transport of matter over short distances. For diffusion to take place no membrane is required. If a membrane is present, it should be fully permeable. The cell membranes are permeable to both gases CO_2 and O_2 and hence the two gases are able to diffuse freely (Fig. 8.1).

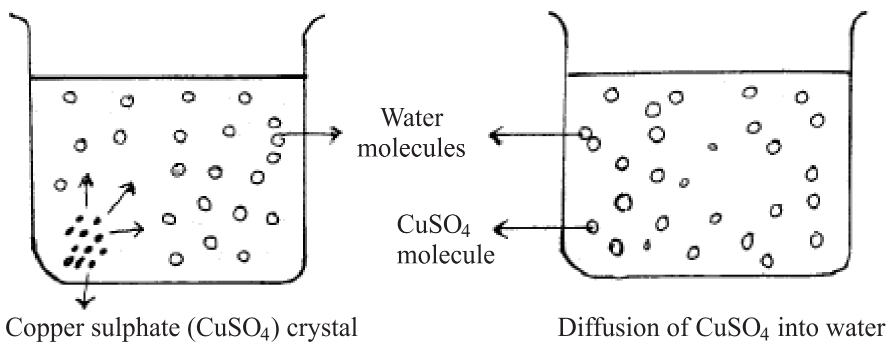


Fig. 8.1 Diffusion of copper sulphate (CuSO4) in water.

8.1.3 Osmosis

Osmosis can be regarded as a special kind of **diffusion of water molecules** from a region of their high concentration to their region of low concentration through a semipermeable membrane (Fig. 8.2). In osmosis, the water molecules move, and the presence of a semipermeable membrane is essential.

Experiment to demonstrate Osmosis

Experiment : To demonstrate the phenomenon of osmosis through plant membrane with the help of potato osmoscope (Fig. 8.3)

Requirements. A large potato tuber, 10% sugar solution, beaker, water, scalpel, pin.

Method. Take a large potato tuber and peel off its outer skin with the help of scalpel. Cut its one end to make the base flat. Now make a deep hollow cavity on the opposite side. Pour some sugar solution to fill half of the cavity and mark the level by inserting a pin in the wall of the tuber. Put the potato in the beaker containing a small amount of water and allow the apparatus to stand for some time. Make sure that the level of water in the beaker is below the level of sugar solution in the cavity of potato osmoscope. (Fig. 8.3)

Observation and Conclusion. The level of sugar solution in the cavity rises. It is because of the movement of water molecules into the cavity from pure water in the beaker. This experiment shows the phenomenon of osmosis.

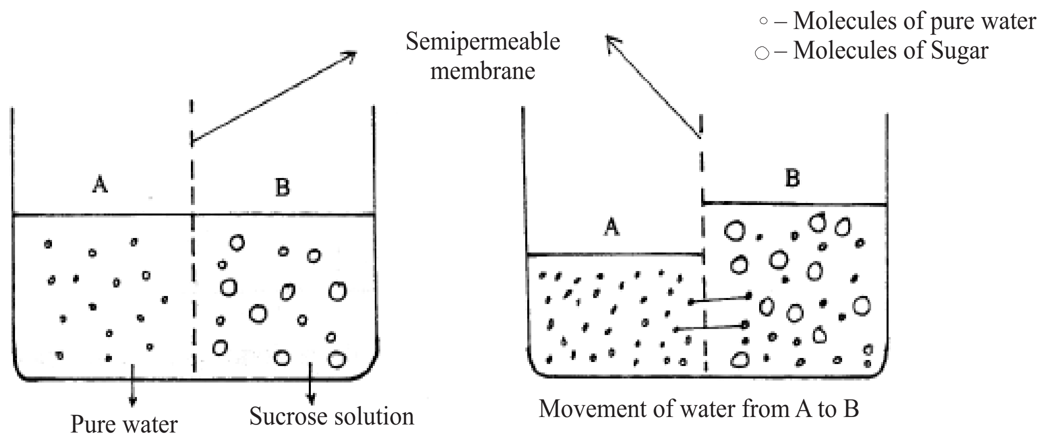


Fig. 8.2 Osmosis - Movement of water molecules through a semipermeable membrane.

Explanation. The living cells of potato tuber collectively act as differentially permeable membrane (membrane which permits movement of certain molecules only through it). The two solutions i.e. pure water in the beaker and sugar solution in the cavity are separated by living cells of potato. Water molecules continue to move through the cell-membranes, into the sugar solution till the concentration of water molecules in the beaker becomes equal to that in the cavity of the osmoscope. If sugar solution is taken in the beaker and pure water in the cavity, the result will be reversed. The movement of water will not occur if the skin of potato is not removed because the skin, being waxy, is impermeable to water.

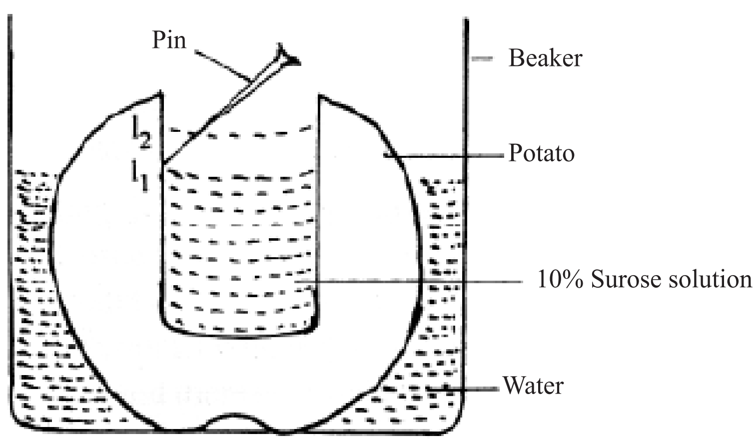


Fig. 8.3 Experiment to demonstrate osmosis by using potato osmoscope.

Difference between Diffusion and Osmosis

Diffusion	Osmosis
1. Diffusion is the movement of a given substance from the place of its higher concentration to an area of its lesser concentration, irrespective of whether separated or not separated by a semipermeable membrane.	**1.** Osmosis is a special type of diffusion of solvent molecules such as water from lower concentration of solution to higher concentration of solution when the two are separated by a semi permeable membrane.
2. The diffusion may occur in any medium. The moving particles may be solid, liquid or gas.	**2.** It occurs in liquid medium and only the solvent molecules such as water move from one place to another.

If you place a cell in a solution, it may shrink, swell or remain unchanged on the basis of relative concentration of water and solutes with respect to their concentration in the cell. On the basis of which solution can be of 3 types:

- **Isotonic** **solution** has the same concentration of water and solutes as inside a cell. Cell remains stable in isotonic solution or there is no entry or exit of water from the cell.
- **Hypotonic** **solution** outside has lower solute concentration than inside the cell. The cell swells as water enters the cell, through the process called **endosmosis**.
- **Hypertonic** **solution** outside has higher solute concentration than inside the cell. Water from cell moves out so the protoplasm of the cell shrinks and collects in the centre of the cell, through the process called **exosmosis**.

Osmotic Pressure and Osmotic Potential

When pure water is separated from a solution by a semipermeable membrane, pure water tends to enter the solution by osmosis. Now the maximum pressure required to prevent the osmotic entry of water in a solution even though the concentration of water in the solution is low as compared to that in pure water, is called **osmotic pressure**.

Imbibition

Before cooking chick pea or gram, it is soaked in water overnight. Next morning the dry chick pea looks well swollen as it has imbibed water.

Imbibition in plant cells refers to the absorption and **adsorption** of water by protoplasmic and cell wall constituents. Water is absorbed as a result of both diffusion and capillary action. Imbibition is a process that accounts for only when solid plant material (dry wood, dead or living air dried seeds) comes in contact with water. In case of living dry seeds water is initially adsorbed by imbibition and thereafter water entering into the inner tissues, is absorbed by osmosis.

Imbibition produces a large pressure, so much so that dry wood can even break a piece of rock in the presence of water. Because of imbibition, the wooden doors, during rainy season, swell up and it becomes difficult to close the door.

Importance of Imbibition

- Imbibition is the initial step in the germination of seeds.
- It causes swelling of seeds and breaking of seed coat.

8.1.4 Plasmolysis

When a cell is placed in a solution, it will either shrink, swell or will remain unchanged depending upon the concentration of the bathing solution or the solution in which the cell is placed.

(i) When a cell is placed in a **hypertonic** solution i.e. when the concentration of the outer solution is higher than the cell sap, water from the cell move out resulting in shrinkage of the protoplasm in the centre of the cell. This phenomenon is known as **plasmolysis.** The space between the cell wall and the protoplast is occupied by the bathing solution as the cell wall being dead, is permeable to the outer solution.

(ii) When such a plasmolysed cell is placed in a **hypotonic** or dilute solution or pure water, water moves into the cell causing the protoplasm to stretch and get back to its original shape. This phenomenon is known as deplasmolysis. The cell after deplasmo-lysis, becomes fully turgid.

(iii) When a cell is placed in an **isotonic** solution or a solution with similar concentration as that of the cell sap, there is no change in the shape of the protoplasm or the cell.

Plasmolysis is a physical phenomenon. A cell can become plasmolysed and deplasmolysed depending upon the concntration of the outer solution in which the cell is placed. No chemical change is caused to the cell. Plasmolysis is a kind of defense mechanism against adverse (stress) conditions such as hypertonic soil solution.

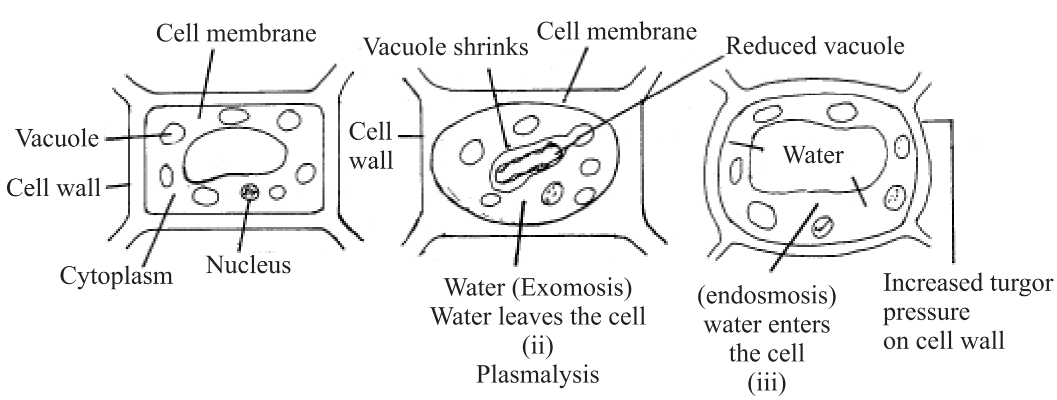


Fig. 8.4 Changes in a plant cell when placed in hypertonic isotonic (i), (ii) and hypotonic solution (iii).

INTEXT QUESTIONS 8.1

1. Define diffusion.

   ....

2. Give one point of difference between osmosis and diffusion.

   ....

3. Name the process because of which crystals of $KMnO_4$ added to water makes it purple.

   ....

4. If blood cells are placed in salt water what will happen to them ? Based on your answer state if salt solution is isotonic, hypotonic or hypertonic?

   ....

5. When does plasmolysis occur in plant cells?

   ....

6. Name the phenomenon which makes it difficult to close a wooden door after monsoon?

   ....

8.2 WATER POTENTIAL

Water-Potential or chemical potential of water is the energy of water molecules or tendency of water to leave a system or the ability of free water molecules to do work or move. Water moves from a region of high water potential to a region of low water potential.

Water-Potential of pure water is taken as zero. When solutes are dissolved in pure water or in a solution some water molecules are used in dissolving the solutes thus less number of the water molecules are available to do the work. Hence a solution has less energy or potential as compared to pure water. The water potential of a dilute solution is more than that of a concentrated solution. The value of water potential of a solution is less than that of pure water or zero i.e. a negative number. Water potential is designated by a Greek letter ψ (psi). Pure water has highest water potential or $\psi = 0$ for pure water.

Water potential determines the water status in plant cells and tissues. The lower the water potential in a plant cell or tissue, the greater is its ability to absorb water. Conversely, the higher the water potential, the greater is the ability of the tissue to supply water to other more desiccated cells or tissues.

8.3 TURGOR PRESSURE

Turgor Pressure is the pressure exerted by the protoplasm against the cell wall.

In a turgid cell, the turgor pressure is equal to the back pressure exerted by the cell wall against the protoplasm. This back pressure exerted by the cell wall onto the protoplasm or the cell contents, is called as **wall pressure (WP).** These two pressures are equal and opposite in direction (Fig. 8.5). When TP becomes more than the WP the cell or will burst.

Turgor pressure is maximum when the cell wall cannot stretch any more. Such a cell is said to be fully turgid. At this point a dynamic equilibrium reaches i.e. the amount of water entering the cell is equal to amount of water leaving the cell.

Turgor pressure develops in the plant cells only because of the presence of cell wall which is able to resist the pressure generated by the protoplasm due to entry of water. It is a real pressure not a potential one and can occur to a great extent. In case of animal cells, where the cell wall is lacking, the plasma membrane bursts if the turgor pressure increases.

Turgor pressure plays a very important role in plants:

- Turgor pressure helps in maintaining the shape and form of the plant.
- The stems of herbaceous plants and the ones with non-woody tissues like maize, sugarcane and banana are held straight by fully turgid cells packed tightly together.
- Turgor pressure holds the leaves in a flat and horizontal position by keeping the mesophyll cells turgid.
- Turgor pressure helps in cell enlargement and consequently in stretching of the stems.
- Opening and closing of stomata is governed by turgidity and flaccidity of the guard cells.
- Certain plants like bean and Touch Me Not plant- *Mimosa pudica* show quick response of leaves due to change in light intensity or by touch stimulus followed by changes in the turgidity of cells present at the bases of leaves and leaflets.

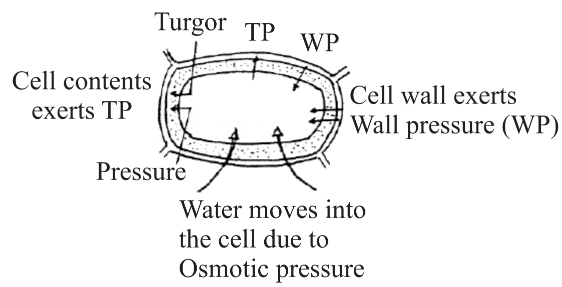


Fig. 8.5 A turgid cell showing osmotic pressure, turgor pressure and wall pressure.

Availability of water in the soil

The plants absorb water through the root hairs from the soil. The soil contains water in three forms (Fig. 8.6)

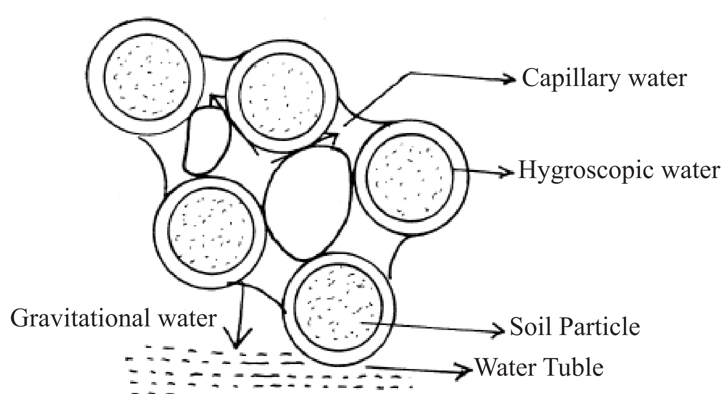


Fig. 8.6 Types of soil water.

(i) **Gravitational Water.** It is the water that drains downwards through the soil. The level to which it drains is called the water table. The water table of a place differs in depth due to rainfall.

The gravitational water lies far below and is generally not available to plant roots. It is of extreme importance as it causes washing out of minerals and nutrients from the soil through the process called leaching.

Part of water that is retained by soil could be hygroscopic water and/or capillary water.

(ii) **Hygroscopic Water.** It is the water that is retained as a thin film around the individual soil particles. Strong adhesive forces between the soil particles and the water molecules hold this water tightly. This is the water least available to the plant and is generally the water left in the dry soils. In the clay soils, it amounts to about 15% and in the sandy soils, it amounts to about 0.5%.

(iii) **Capillary Water.** The soil particles always have very fine pores in between, forming a very fine capillary system As the water spreads, it fills the finer pores and is held round the soil particles by capillary forces against the force of gravity, due to high surface tension of water. It is this water, which is readily available and is easily utilized by the plant roots. The clay soil being very fine textured holds much more water than sandy soil. When a soil rich in organic matter, is watered, it retains good amount of capillary water and this condition is known as **field capacity.**

8.4 ABSORPTION OF WATER BY PLANTS

- Major portion of water required by plants is absorbed by roots but in some cases water may be absorbed by leaves and stems also.
- Root hair is a specially modified epidermal cell meant for absorption of capillary water of the soil.
- The plasma membrane and the vacuolar membrane (tonoplast) act as semipermeable membranes and water is absorbed by osmosis.
- Soil solution should have a higher water potential as compared to root hair cell, then only water will enter the root hair cell. Once into the root hair, water will pass into cortical cells, endodermis, pericycle and into the xylem vessel. The movement of water is purely dependent on water potential gradient.
- Water movement into the plant follows two pathways – **symplast** and **apoplast** (Fig. 8.7a).
- Cytoplasm of the entire plant is connected through plasmodesmata which are the protoplasmic strands forming the **symplast system**. Water movement through the cells take this symplast pathway by osmosis.

  The cell wall and the intercellular spaces form the apoplast pathway which allows water movement inside the plant by the phenomenon of capillarity and adsorption.
- The water absorbed through the roots is transferred radially to the xylem, from where it reaches to all the other parts of the plant body by vertical conduction of water through the xylem vessels (Fig. 8.7b).

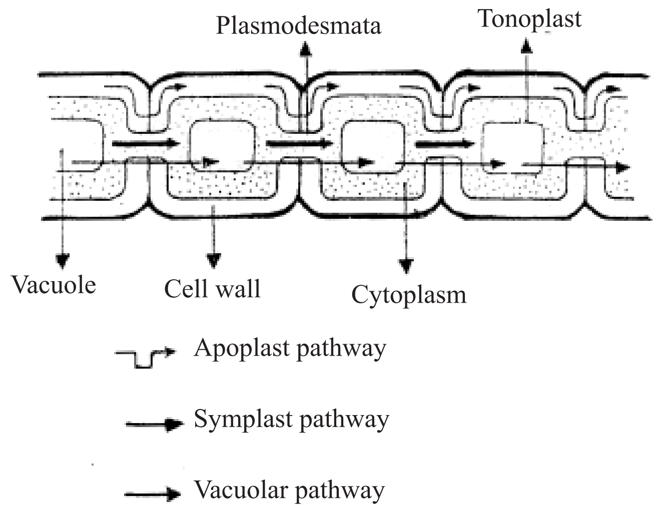


Fig. 8.7a various pathways of water movement

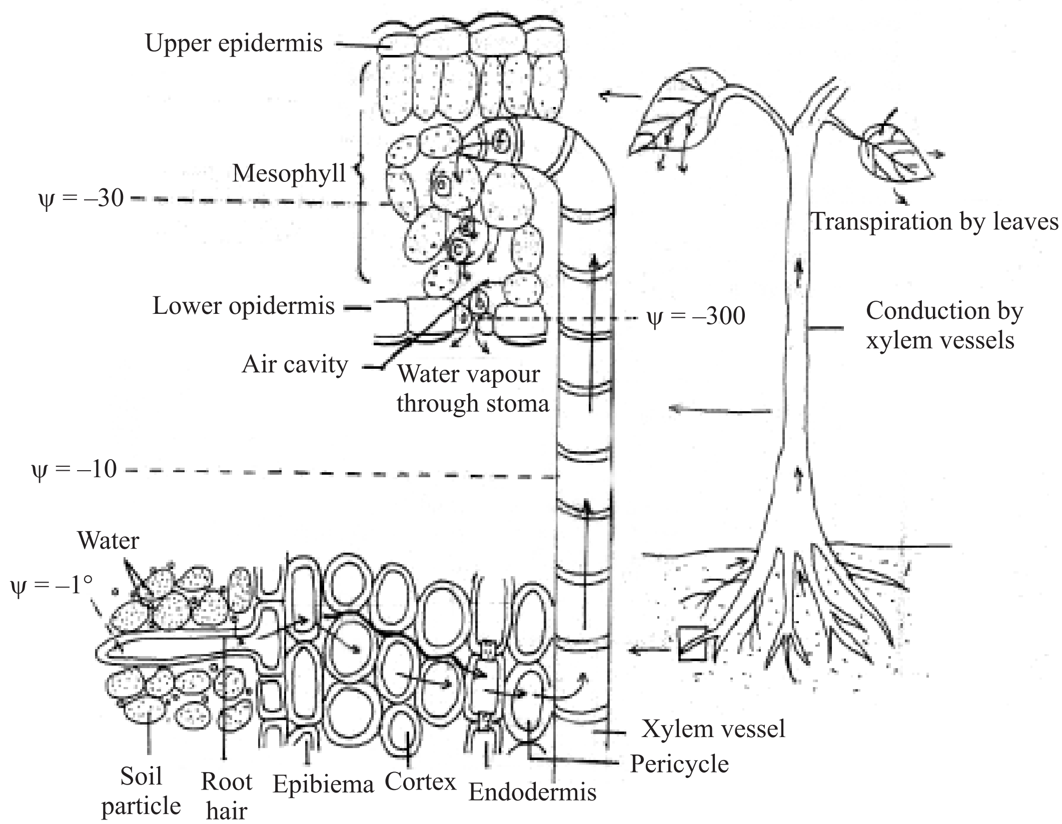


Fig. 8.7b Diagram to show absorption of water bvy root hair, its radial transport to cortex, and upward transport to leaves through xylem

Conduction of water through the xylem

The content of xylem vessels is known as xylem sap. Various theories have been postulated to describe the lifting of the xylem sap or ascent of sap in the xylem.

Root Pressure Theory

If a stem is cut few inches above from the ground with a sharp knife, xylem sap is seen flowing out through the cut end. This phenomenon is known as **exudation** and this is due to the positive pressure developed within the root system due to continuous absorption of water by osmosis which develops a positive pressure known as root pressure. This pressure can be measured and ranges from 3 to 5 atmospheres. But this pressure is enough to raise water to small heights in herbaceous plants, but it does not explain rise of water in stems of tall trees that are taller measuring 10 to 100 meters.

Physical Force Theory or Cohesion Theory

This theory takes into account the physical forces which explain uplift of water to great heights in very tall trees. The three forces that act together are force of cohesion (attraction between water molecules), force of adhesion (attraction between water and lignocellulose walls of xylem) and transpiration pull which lifts the water column by creating a tension inside the xylem vessel. Water forms an unbroken column starting from the intercellular space of the leaf mesophyll to the xylem of the leaf, through stem and root to the water in the soil. A water potential gradient exists between the leaf to the root and transpiration causes a pull of the entire water column. So long as the column is an unbroken one from the outer atmosphere, through the plant upto the soil, water is lifted up by the force of **transpiration pull.**

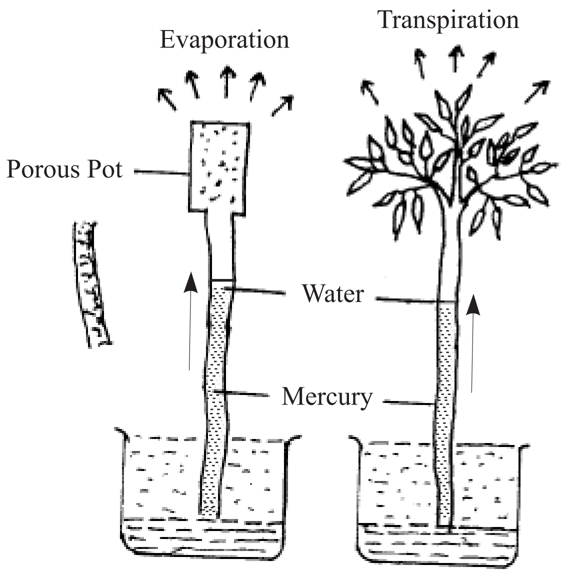


Fig. 8.8 Effect of evaporation and transpiration on absorption of water

8.5 TRANSLOCATION OF ORGANIC SOLUTES

Movement of organic and inorganic solutes from one part of the plant to another is known as translocation, e.g. transport of sugar in sieve tubes of leaves to stem or fruit.

There are experimental evidences to suggest that phloem is the tissue involved in translocation of products of photosynthesis i.e. sugars.

Sugar is produced in photosynthesis in the leaves and then sent to all part of the plants for the growth and development of the plant. Leaf is known as the "source", where the food is produced and all other parts of the plant which receive this food is known as the "sink". Sink can be root, stem, fruits and storage organs like tuber, bulbs and, rhizomes. Thus unlike conduction of water in xylem which takes place in one direction from the root to upwards in the aerial parts of the plant, phloem translocation from a leaf takes place in all directions.

Mechanism of translocation

Sugar solution in the phloem sieve tube moves along the water potential gradient created between the source (leaf) and sink (storage) cells

Here we find a mass movement of sugar solution from the leaf mesophyll to sieve tubes of leaf, and then, to all parts of the plant.

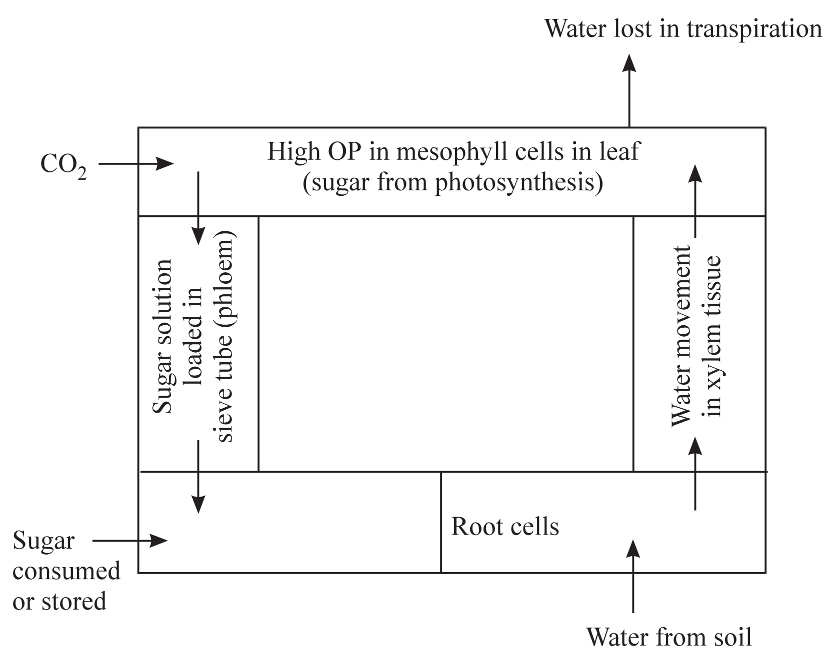


Fig. 8.9 Mechanism of translocation

This model known as Munch hypothesis or Mass flow theory is most acceptable model for phloem translocation.

INTEXT QUESTIONS 8.2

1. Which part of the plant absorbs water and minerals?
   ....
2. What are plasmodesmata?
   ....
3. How does translocation occur in plants?
   ....
4. What is the process of ascent of sap?
   ....
5. Which are three different forms in which water is present in the soil?
   ....

8.6 TRANSPIRATION

8.6.1 What is transpiration

The loss of water from aerial parts of the plant in the form of water vapour is termed **transpiration** and, when transpiration is low and absorption of water by roots is high, loss of water from leaves in the form of liquid is termed **guttation**.

Transpiration may occur through three main sites in the plant : 1. cuticle 2. lenticels and, 3. stomata.

(i) **Cuticle :** Cuticle is the waxy covering of the epidermis of leaves and green herbaceous stems. Though it is meant to check transpiration, still about 10% of the total transpiration may take place through fine cuticular pores, and he process is known as cuticular transpiration.

(ii) **Lenticels :** Lenticels are areas in the bark of stems, branches and fleshy fruits which are made up of loosely arranged cells that account for about 0.1 percent of water loss. It is known as lenticular transpiration.

(iii) **Stomata :** Stomata are minute pores on the epidermis of leaves, or tender green stems, whose opening and closing are controlled by guard cells. About 90 percent of water loss from plants takes place through stomata by the process known as stomatal transpiration.

8.6.2 Mechanism of transpiration

Transpiration occurs in two stages :

(i) Evaporation of water from the cell walls of mesophyll cells into the intercellular spaces.

(ii) Diffusion of this water vapour of the inter cellular spaces into the outside atmosphere, through cuticles, lenticels and stomata, when the outside atmosphere is drier.

8.6.3 Factors affecting transpiration

There are many external and internal factors that affect the process :

(i) Temperature : The increase in temperature increases the rate of transpiration by increasing the rate of evaporation of water from cell surface and decreasing the humidity of the atmosphere.

(ii) Wind velocity : The increase in wind velocity increases the rate of transpiration by removing the water vapour of the atmosphere and lowering the relative humidity, around the aerial parts of a plant.

(iii) Light : Light has got no direct effect on the rate of transpiration but indirectly it affects the rate in two ways, firstly by controlling the stomatal opening and secondly by affecting the temperature. With increase in intensity of light rate of transpiration increases because stomata get opened and the temperature increases.

(iv) Water supply : Deficiency of water supply in the soil decreases the rate of transpiration by decreasing the rate of absorption. When the deficiency of water in the soil becomes too much then the plants wilt and do not recover from wilting unless water is supplied in the soils. This is known as **permanent wilting**. When in a hot and dry summer day the plant transpires more causing higher water loss by the leaves than the roots are able to absorb, even though there is enough water in the soil, the plants wilt exhibiting **temporary wilting** as the plant recovers from such wilting in the late afternoon or at night.

(v) Atmospheric pressure : Reduction of atmospheric pressure reduces the density of external atmosphere thus permitting more rapid diffusion of water. Plants growing on high altitudes will show higher rate of transpiration hence they develop xerophytic characters.

(vi) Atmospheric humidity : Humidity means the amount of water vapour present in the atmosphere. The diffusion and evaporation of water depends on the vapour pressure gradient or the difference of water potential gradient between the atmosphere and the inside of the leaf. More the difference more will be the rate of transpiration.

Internal plant factors

Certain plant adaptations reduce transpiration

– Reduced size of the leaves, thereby reducing transpiring surface. Some xerophytic plants have needle like or spine like leaves (*Pinus* and *Opnuntia*)
– thick deposition of cutin (wax like substance) on the leaf surface.
– stomata found sunken in the cavities surrounded by epidermal hairs as in *Nerium* and *Cycas*.
– root shoot ratio, when there is more root and less of shoot system or leaves, there will be more of transpiration. Root is the water absorbing surface and shoot or leaves represent the transpiring surface; high root shoot ratio will cause more transpiration.

8.6.4 Role of Stomata in Transpiration

Since most of the water is lost through stomata, plants regulate the degree of stomatal opening and closing to reduce the water loss, with the help of guard-cells.

It has been seen that stomata show periodic opening and closing during the day (diurnal variation) depending upon the heat and light, water content of the cell and humidity. The stomata are generally closed during the night, and remain open during the day in the presence of sunlight.

From early morning till midday, the stomata are open and hence the transpiration increases till midday.

During the sunny mid-day, the stomata are closed and leaves get wilted to transpiration. From late afternoon till evening, the stomata are open again and hence the transpiration increases. At night, the stomata are closed and hence the transpiration is very low.

8.6.5 Stomatal-Apparatus

Structure of Stomatal-Apparatus

Each stoma represents a minute pore surrounded by two **guard cells**. Which in turn, are closely surrounded by two or more subsidiary cells. The stoma acts as a *turgor-operated valve,* which closes and opens according to alternate change in the flaccidity and the turgidity of guard cells and subsidiary cells. The guard cells have unevenly thickened walls. The cell wall **around stoma is tough and flexible** and the one away from stoma is thinner. The shape of guard cells differs in dicots and monocots, though the mechanism remains the same.

Mechanism of Stomatal action

The opening and closing of stomata depends upon the turgidity and flaccidity alternately in the guard cells and subsidiary cells. When the **guard cells are turgid, and subsidiary cells are flaccid, the stoma opens,** and, when **guard cells lose water** into subsidiary cells so that guard cells become flaccid and subsidiary cells become turgid, the **stoma closes.** The mechanism of opening and closing of stomata in dicots and monocots is as give below:

(a) The **dicotyledonous** plants have kidney shaped guard cells. The inner walls around the stoma are thicker than the outer walls.

A. When guard cells get distended by turgor pressure → Guard cells expand → Tough inner walls become convex → Stomata open

B When the turgor pressure in guard cells decreases → Guard cells sag → Inner cell walls come closer. → Stomata close

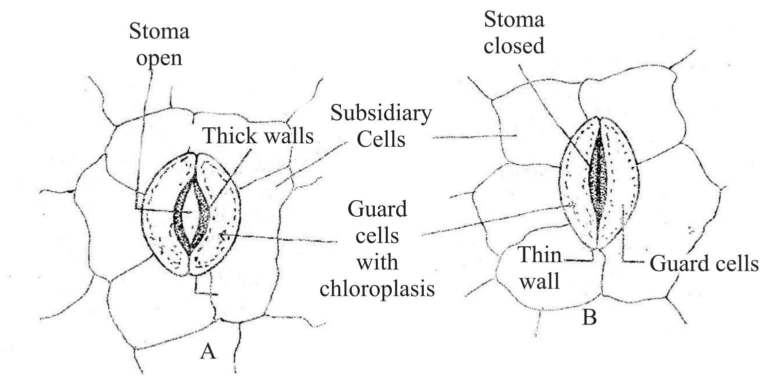


Fig. 8.10 Stomatal action in Dicots.

(b) In **monocotyledonous** plants, the guard cells are **dumb bell shaped** with thickened walls towards and nearest the stoma and thinner walls towards the inflated region.

A. When the guard cells become turgid → The region with thin walls bulges and gets inflated → The thick walls move apart → Stoma opens

B. When the guard cells lose water → The inflated part sags → The thick walls collapse → Stoma close

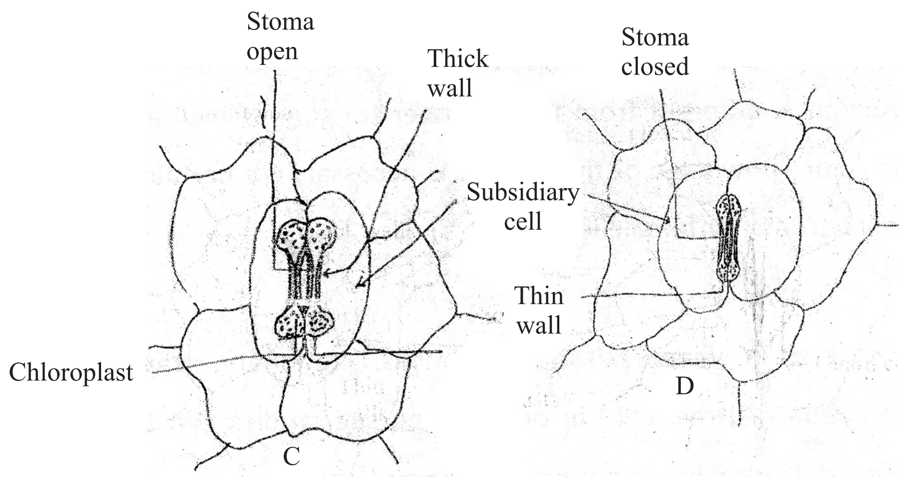


Fig. 8.11 Stomatal action in monocot.

Changes in turgidity and flaccidity, alternately involving guard cells and subsidiary cells, in bringing about opening and closing of stomata has been known for a long time but the mechanism that leads to turgidity needs to be explained.

(i) Starch- Sugar Hypothesis

This hypothesis goes by the basis that the increase in sugar concentration due to photosynthesis in guard-cells and hence endosmosis of water during the day leads to turgidity of guard cells leading to opening of stomata and the reverse i.e. decrease in sugar concentration followed by exosmosis leads to closing of the stomata at night. The changes in guard cells during the day i.e. in light and at night in the dark are as given below.

Reaction in Light

Utilization of CO_2 during photosynthesis in guard cells
↓
Drop in CO_2 leads to increase in pH or protoplasm becoming alkaline
↓
Conversion of starch into sugar
↓
Increased concentration of solute
↓
Endosmosis of water from subsidiary cells to the guard cells
↓
Increased turgor pressure of the guard cells leads to turgidity of guard cells accompanied by flaccidity of subsidiary cells
↓
Stoma opens
↓
A. Stoma opens during light

Reaction in Dark

Accumulation of CO_2 due to absence of photosynthesis in guard cells
↓
Increased acidity or decrease in pH due to formation of carbonic acid
↓
Conversion of sugar into starch
↓
Decreased concentration of solutes in guard cells
↓
Exosmosis of water from guard cells to subsidiary cells
↓
Decreased turgor pressure in guard cells leads to flaccidity of guard cells, accompanied by increased T.P. and turgidity of subsidiary cells.
↓
Stoma closed
↓
B. Stoma closed at dark

This theory can not explain stomatal movement where starch is absent in the guard cells or guard cells lack chloroplasts and opening of stomata at night and closing by the day in some plants like succulents (e.g. cacti).

(ii) Effect of potassium ions (K^+) on stomatal opening and closing

It has been convincingly proved that the accumulation of K^+ ions in guard cells brings about the opening of stomata and loss of K^+ ions from guard cells into subsidiary cells brings about, the closing of stomata.

During Day Light	**During Night/Dark**
Accumulation of K^+ ions by the guard cells	Loss of K^+ ions by the guard cells
↓	↓
Increased solute concentration	Decreased solute concentration
↓	↓
Endosmosis of water	Exosmosis of water
↓	↓
Increased turgidity	Decreased turgidity
↓	↓
Stoma opens	Stoma closes

The uptake of K^+ ions is balanced by one of the following.

(a) **Uptake of chloride (Cl^-) ions** as anions. The subsidiary cells lack chloroplast and take up Cl^- ions as anions to balance the influx of K^+ ions.

(b) **Transport of H^+ ions released from organic acids.** In some plants the guard cells contain starch, There is accumulation of organic acid like malate by conversion of starch into malic acid in light. The organic acid dissociates into malate and H^+. Potassium reacts with malate to form potassium malate which increases the solute concentration.

(c) Entry of K^+ is balanced by exit of protons (H^+).

(iii) Role of Abscisic Acid (ABA)

It has been observed that during water shortage in the soil or by intense solar radiation, a plant hormone abscisic acid accumulates in the leaves leading to closing of stomata, thus preventing an excessive water loss. Under experimental conditions also, when abscisic acid is applied to the leaves, stomata get closed and check water loss.

8.6.6 Significance of transpiration

(i) **Absorption of water.** Transpiration pull influences the rate of absorption of water from the soil.

(ii) **Water movement.** By transpiration, water moves upwards and as it passes into the cell vacuoles, it makes the cells turgid. This gives a form and shape to the cells and to the plants as a whole.

(iii) **Mineral salt transport.** The water stream moving upwards also carries the dissolved minerals required for the development of the plant. Transpiration also helps in distributing these minerals through out the plant body.

(iv) Cooling. The evaporation of water during transpiration cools the leaves.

(v) Protection from heat injury. Some plants like Cacti retain water by reducing transpiration. This saves the plants from high temperatures and strong sunlight.

Transpiration is a necessary evil

Stomata remain open during day time for the absorption of carbon dioxide and release of oxygen for a very important process of photosynthesis. When the stomata remain open for this important gaseous exchange, escape of water vapour cannot be controlled. Thus loss of water is a wasteful process which cannot be avoided because stomata must remain open to do some thing more important that is absorption of carbondioxide during day time for photosynthesis. It is for this reason that Curtis in 1926 has referred transpiration as a necessary evil.

Factor affecting stomatal movement : Any condition which causes turgidity of the guard cell will cause stomatal movement.

1. Increased Solute concentration of the guard cells, which will allow endosmosis of water into the guard cells making them turgid.
2. Light causes photosynthesis in guard cell by the chloroplasts and hence accumulation of sugar in the guard cells would increase concentration of solutes in guard cells.
3. Entry of potassium ions from subsidiary cells into guard cells would further increase solute concentration in guard cells.

8.6.7 Anti-transpirants

Many crop plants give poor yield in dry seasons, as the water lost by transpiration is much more than the water uptake by the roots. The rate of transpiration can be reduced by the application of certain chemicals known as anti transpirants. These chemicals however, should not affect the CO_2 uptake. The reduction in transpiration is achieved by two means.

(i) Chemicals like phenyl mercuric acetate – PMA and abscisic acid –ABA cause partial closure of stomata checking transpiration to some extent.

(ii) Some waxy substances like silicon emulsions form a thin film over the leaf and cover the stomata without affecting the uptake of CO_2.

Guttation. It is seen in early morning in the form of water-drops at the margins or tips of leaves of herbaceous plants (Fig.8.12a). The plants in which transpiration is low and the root pressure is high, the liquid water droplets are seen at the vein ending.

– It occurs through specialized pores called hydathodes present near the vein endings (Fig. 8.12b).

– It is quite common in young grass seedlings and in the tropical rain forests due to warm and humid nights. Tomato and *Nasturtium* are some common examples.

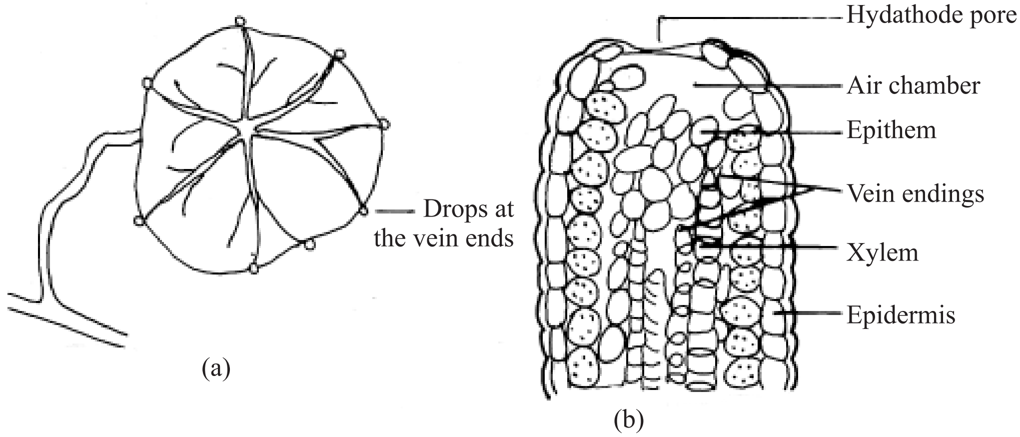


Fig. 8.12 (a) *Nasturtium* leaf showing guttation at the margin of leaf (b) A vertical section of a leaf showing hydathode.

8.6.8 Difference between Transpiration and Guttation

Transpiration	Guttation
(i) Water is lost in the form of water vapor.	(i) Water is lost in the form of water drops.
(ii) Occurs through stomata, cuticle and lenticels.	(ii) Occurs through special pores, called hydathodes.
(iii) Occurs during day time and at high temperature.	(iii) Occurs at night and early in the mornings at low temperature.
(iv) Water vapour lost is pure water and does not contain minerals.	(iv) Water lost has substances dissolved in water. It contains sugars, salts and amino acids.
(v) Increased transpiration is physical process (see cohesion physical force theory)	(v) It is due to increased root pressure that develops in the aerial shoot system when water absorption by roots is more and transpiration by aerial plant parts is low.

INTEXT QUESTIONS 8.3

1. Name the pressure in guard cells responsible for opening and closing of stomata.

   ....

2. Mention the shape of guard cells in monocots and dicots.

   ....

3. Give a point of difference between a stoma and a hydathode

   ....

WHAT YOU HAVE LEARNT

- The movement of water from one cell to another depends upon the water potential of the cells.
- Water always moves from a region of lower solute concentration (higher water potential) to the region of higher solute concentration (lower water potential) i.e. along the water potential gradient.
- A more concentrated solution has a higher osmotic potential (earlier termed osmotic pressure).
- Osmotic pressure is expressed in terms of energy. Water always moves from a region of higher free energy to a region of lower free energy.
- Water potential is the capacity of a solution to give out water. It is represented by the word Psi ψ. It is affected by the solute concentration and external pressure.
  - ψ of pure water = zero.
  - More solute means low water potential.
  - A solution has lower water potential than pure water.
  - Water potential of a solution is a negative number i.e. less than zero.
- Plants absorb water by their roots (mainly by root hair) from the soil through osmosis. The increased water content inside the protoplasm exerts a turgor pressure on the cell wall.
- The equal and opposite force exerted by the cell wall onto the cell contents is termed as wall pressure.
- Water is present in the soil as gravitational water, hygroscopic water (least available to the plant) and capillary water (most readily available to the plant).
- The water absorbed by root hairs flows to the xylem vessels mainly by the apoplast pathway.
- The water moves up through the xylem vessels to the leaf along the water potential gradient as explained by the cohesion- tension theory (most acceptable). Transpiration or evaporation of water from the plant through stomata, causes a pull and water moves up like a water column due to the force of cohesion and tension created by transpiration.
- Certain plants show guttation due to high root pressure and low transpiration.
- Turgidity of guard cells is explained by the increased conversion of starch into sugar and by the accumulation of K^+ ions.

- Various environment factors like temperature, light, wind, humidity and internal factors like structure of leaf and root-shoot ratio affect the transpiration.
- Transpiration not only brings about ascent of sap but also has a cooling effect and saves the plant from heat injury.
- When the transpiration rate exceeds the water absorption rate, it leads to **temporary wilting** of the plant.
- When a plant undergoes wilting due to water deficit in the soil, it is called **Permanent Wilting.**

TERMINAL EXERCISES

1. Name two types of passive absorption in plants.
2. In what ways diffusion is important to a plant ?
3. Name various factors that affect osmosis in plants.
4. Differentiate between turgor pressure and wall pressure.
5. Discuss the mechanism of stomatal opening in dicot plants.
6. Explain any four factors that affect transpiration in plants.
7. Describe an experiment to demonstrate osmosis by potato osmometer.
8. Discuss the cohesion tension theory for uptake of water in plants.
9. Describe the mechanism of translocation of solutes. Name the most appropriate theory for the translocation of solutes in plants. Who proposed this theory ?
10. Differentiate between symplast and apoplast pathway of water movement in plants.
11. Define transpiration.
12. Name the holes in the bark through which transpiration in the bark of old trees takes place ?
13. Why is transpiration considered to be a necessary evil ?
14. Give one way by which desert plants prevent transpiration.
15. State one point of difference between transpiration and guttation.

ANSWERS TO INTEXT QUESTIONS

8.1

1. Movement of molecules from their region of higher concentration to the region of lower concentration.
2. A semipermeable membrane is required for osmosis and not necessarily for diffusion.
3. Diffusion

4. Water will move out from the blood cells and they will shrink.
5. When the cell is placed in a hypertonic solution.
6. Imbibition

8.2
1. Root
2. Cytoplasmic connections between plant cells
3. Through the phloem
4. Movement of water and minerals from roots to leaves, that is from the ground to tip of plant.
5. Gravitational, Hygroscopic and capillary

8.3
1. Turgor pressure
2. Dicot : Kidney shaped

   Monocots : Dumb bell shaped
3. Stomata – are pores on the leaf surface through which water diffuses as vapour

   Hydathodes – special pores in leaf margins through which water is lost as water droplets.

9

NUTRITION IN PLANTS – MINERAL NUTRITION

Sometimes you may observe that a potted plant kept in sunlight and provided with sufficient water does not grow. Its leaves look pale and weak. Plant may not even flower properly. Such a situation is an indication, that the plant may not be getting all that is required for normal growth and development.

In most of such situations one or more minerals required may be lacking in the soil. You might have seen farmers adding some extra manure (khad) to the soil. In this lesson you will learn the importance of mineral nutrition in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define the terms mineral nutrition, macro and micro nutrients;*
- *explain the functions of minerals with reference to the techniques of hydroponics and aeroponics;*
- *list the role of macro and micro nutrients;*
- *mention the deficiency symptoms of macro and micro nutrients;*
- *differentiate between autotrophic and heterotrophic nutrition in plant;*
- *describe the saprophytic and parasitic modes of nutrition in plant.*

9.1 WHAT IS PLANT NUTRITION

As you know that all living organisms require food to survive, grow and reproduce so every organism takes in food and utilizes the food constituents for its requirements of growth. A series of processes are involved in the synthesis of food by plants, breaking down the food into simpler substances and utilization of these simpler substances for life processes. **Nutrition** in plants may thus be defined as a process of synthesis of food, its breakdown and utilisation for various functions in the body.

The chemical substances in food are called nutrients e.g. CO_2, water, minerals, carbohydrate, protein, fats etc. Green plants can make their own organic food from simple substances like water and carbon dioxide through the process of photosynthesis and are called autotrophs (auto : self; trophos : feeding). But the non-green plants and other organisms which cannot prepare their own food and obtain nutrition from green plants are called **heterotrophs** (heteros : different).

9.2 MINERAL NUTRITION

Now we will discuss how plants get the nutrients. You already know that carbohydrates are synthesised by the process of photosynthesis. What are the elements present in these carbohydrates?

Carbon, hydrogen and oxygen are the main elements in carbohydrates, fats and proteins. In addition to these three elements, plants need a variety of elements for their survival. These are generally referred to as mineral elements. They are absorbed by the root system of plants in the form of their salts.

The study of how plants get mineral elements and utilize them for their growth and development is called **mineral nutrition.**

If the minerals are not available to plants, specific symptoms appear due to the deficiency of a particular element. There are methods to determine the requirement of minerals by plants. Some such methods are given below.

9.3 METHODS TO DETERMINE THE REQUIREMENT OF MINERALS FOR PLANT

Minerals are absorbed by plants in **solution form.** So it is possible to grow plants in water containing the desired amount of mineral salts taking care that the aerial parts are exposed to air and light.

> This technique of growing plants in a nutrient solution in complete absence of soil is known as **Hydroponics/water culture.**
>
> It was demonstrated for the first time by a German Botanist Julius Von Sachs in the year 1980.

In water culture experiments, seedlings are made to grow in water containing the known nutrients in a particular proportion. Vigorous bubbling of the air is routinely done to provide sufficient oxygen to the root system. The culture solutions may contain all essential nutrients except the one whose importance is to be identified. Then the plant growing in it is compared to the one growing with all essential nutrients (**control experiment**).

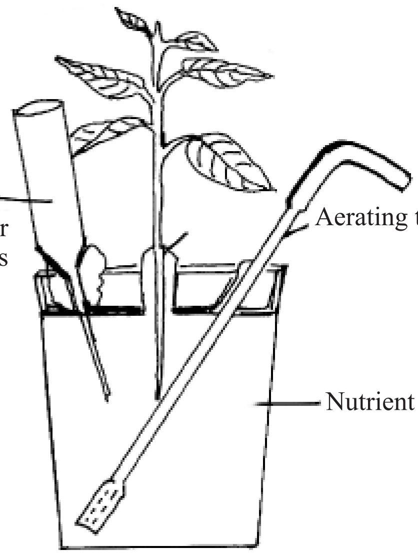


Fig. 9.1 Experimental set up for nutrient solution culture of plants.

Water culture experiments help us to understand :

(i) which element is essential for normal growth of the plant.

(ii) which element is not essential and is absorbed along with other nutrients.

(iii) how much quantity of each mineral is essential.

Hydroponics has been successfully employed for the commercial production of seedless cucumber, tomato and lettuce.

Aeroponics : Like hydroponics, aeroponics is another technique of growing plants in an air/mist environment without the use of soil.

Aeroponics is a technique of growing plants with their roots supplied with moisture present in the air. Rooted plants are placed in a special type of box. The shoots of the rooted plants are exposed to air and the roots are inside the box having computer controlled humid atmosphere. The roots are sprayed/misted for short durations with a hydro-atomized pure water/nutrient solution. This method has been developed recently. Since plants cultured by this technique get a very good growth of root hairs, it is very useful method for research purposes. Citrus plants and olives have been successfully grown through aeroponics.

INTEXT QUESTIONS 9.1

1. What are nutrients ?

   ....

2. Define aeroponics.

   ....

3. Why is it necessary to aerate nutrient solution in water culture?

   ....

9.4 ESSENTIAL MINERAL ELEMENTS

You know that 112 elements have been discovered until now. So you might be wondering whether plants require all 112 elements for their mineral nutrition. Most of the mineral elements present in soil are absorbed by roots of the plant. But all are not essential. Only **17 elements** are considered as essential for the plants. Let us now discuss the criteria for the essentiality of an element for normal plant growth.

9.4.1 Criteria for Essentiality of Elements

The nutrients or elements which are essential for the healthy growth of the plant are called **essential nutrients or essential elements.** The roots absorb about 60 elements from the soil. To determine which one is an essential element, the following criteria are used :

(i) An essential element is absolutely **necessary for normal growth** and **reproduction** of the plant, and should be a part of essential metabolite for plant growth.

(ii) The requirement of the element is very specific and it **cannot be replaced** by another element.

(iii) The element is **directly** or indirectly **involved** in the metabolism of a plant.

(iv) In the deficiency of an essential element, the plant would exhibit specific symptoms of deficiency, and the plant would recover from its symptoms, if supplied with the deficient element.

Example : Magnesium is said to be an essential element because it is essential for the formation of chlorophyll molecule. Its deficiency causes yellowing of leaves.

9.4.2 Types of Essential Elements

Essential elements may be required in small amounts or large amounts. Accordingly they have been grouped into two categories

Essential Elements

Micro elements/Micronutrients	Macro elements/Macro nutrients
Required in minute quantities like 0.1 mg per gram of dry matter or less than that. Also called as **trace elements.**	Required in relatively large quantities like one to 10 milligram per gram of dry matter
Examples : Manganese, Boron, cobatt Copper, Molybdenum, Iron, Zinc and Chlorine are required in very small quantities	**Examples :** Carbon, Hydrogen, Oxygen Phosphorous, Potassium, Calcium and magnesium, Nitrogen, Sulphur

9.4.3 Sources of Essential Elements for Plants

After studying the types of essential elements we will now discuss about their sources. Most of the essential elements are taken from soil, and some from the atmosphere. The table given below focuses on the sources of different essential elements.

Table 9.1 Sources of Essential Elements

Elements	Sources of the elements
Carbon	Taken as CO_2 from the atmosphere (air)
Oxygen	Absorbed in the molecular form from air or from water. It is also generated within a green plant during photosynthesis.
Hydrogen	Released from water during photosynthesis in the green plant
Nitrogen	Absorbed by the plants as nitrate ion (NO_3^-) or as ammonium ion (NH_4^+) from the soil. Some organisms like bacteria and cynobacteria can fix nitrogen from air directly.
Potassium, calcium iron, phosphorus, sulphur magnesium	absorbed from the soil (are actually derived from the weathering of rocks. So they are called mineral elements). They are absorbed in the ionic forms e.g. K^+, Ca^{2+}, Fe^{3+}, $H_2PO_4^-$/ HPO_4^{2-} etc.

INTEXT QUESTIONS 9.2

1. In which form do plants get oxygen?

   ....

2. Molybdenum is a micronutrient. Give reason.

   ....

3. Why are carbon, oxygen, potassium and sulphur called macronutrients?

   ....

9.5 ROLE OF MACRO AND MICRO NUTRIENTS

Essential elements perform various functions. They carry out several metabolic processes in the plant cells like the maintenance of turgidity of cell, transportation of electrons, membrane permeability and enzyme activity. Essential elements also act as important constituents of the biomolecules and co-enzymes. Various functions of the macro and micro nutrients are given in the following table.

The forms in which the elements are taken in and their functions are described in the table given below -

Table 9.2 Essential Elements and their Functions

Element	Form in which the element is taken in	Region of the plant that requires the element	Function
Nitrogen, N	NO_2^-, NO_3^- or NH_4^+ ions	All tissues, particularly in meristematic tissues	Required for the synthesis of amino acids, proteins nucleic acids, vitamins, hormones, coenzymes, ATP and chlorophyll.
Phosphorus, P	$H_2PO_4^-$ or HPO_4^{2-}	Young tissues from the older metabolically less active cells	Required for the synthesis of nucleic acids phospho-lipids, ATP, NAD and NADP. Constituent of cell membrane and some proteins.
Potassium, K	K^+	Meristematic tissues buds, leaves and root tips.	Activates enzymes, associated with K^+/Na^+ pump in active transport, anion-cation balance in the cells. Brings about opening and closing of stomata. Common in cell sap in plant cell vacuole and helps in turgidity of cells.
Calcium, Ca	Ca^{2+}	Meristematic and differentiating tissues Accumulates in older leaves	Present as calcium pectate in the middle lamella of cell walls that joins the adjacent cells together. Activates enzymes needed for the growth of root and shoot tip. Needed for normal cell wall development. Required for cell division, cell enlargement.
Magnesium, Mg	Mg^{2+}	Leaves of the plant	Forms part of the chlorophyll molecule. Activates enzymes of phosphate metabolism. Important for synthesis of DNA and RNA. Essential for binding of ribosome subunits.
Sulphur, S	SO_4^{2-}	Stem and root tips young leaves of the plant	As a constituent of amino acids cysteine and methionine and of some proteins. Present in co-enzyme A, vitamin thiamine, biotin and ferredoxin. Increases root development. Increases the nodule formation in legumes.

Iron, Fe	Fe^{3+}	Leaves and seeds	Needed for the synthesis of chlorophyll. As a constituent of ferredoxin and cytochromes. Activates the enzymes catalase.
Manganese Mn	Mn^{2+}	All tissues. Collects along the leaf veins.	Activates many enzymes of photosynthesis, respiration and N_2 metabolism. Acts as electron donor for chlorophyll b. Involved in decarboxylation reactions during respiration.
Molybdenum Mo	MoO_2^{2+}	All tissues particularly in roots	Required for nitrogen fixation. Activates the enzyme nitrate reductase.
Boron, B	BO_3^{3-} or $B_4O_7^{2-}$	Leaves and seeds	Increases the uptake of water and calcium. Essential for meristem activity and growth of pollen tube. Involved in translocation of carbohydrates
Copper, Cu	Cu^{2+}	All tissues	Component of oxidase enzymes and plastocyanin. Involved in electron transport in photosynthesis.
Zinc, Zn	Zn^{2+}	All tissues	Component of indoleacetic acid – a plant hormone. Activates dehydrogenases and carboxylases. Present in enzyme carbonic anhydrase
Chlorine, Cl	Cl^-	All tissues	Essential for oxygen evolution in photosynthesis. Anion-cation balance in cells.

INTEXT QUESTIONS 9.3

1. State any two metabolic processes for which mineral nutrition is required.

   ....

2. Which element is provided by NO_2 and NH_4 when taken up by plants?

   ....

3. State any two functions of Ca^{2+} in plants?

   ....

9.6 SYMPTOMS OF MINERAL DEFICIENCY IN PLANTS

The absence or deficiency (not present in the required amount) of any of the essential elements leads to **deficiency symptoms.** The symptoms can be studied by hydroponics. Under natural conditions, these symptoms can be taken as indicators of the mineral deficiencies in the soil.

Some common deficiency symptoms are :

- **Chlorosis** - It is the loss of chlorophyll leading to yellowing in leaves. It is caused by the deficiency of elements like K, Mg, N, S, Fe, Mn, Zn and Mo.
- **Necrosis** or death of tissues, particularly leaf tissue is caused by deficiency of K, Ca, Mg
- **Inhibition of cell division** is caused due to lack or deficiency of N, K, B, S and Mo.
- Stunted/Retarded plant growth caused by the deficiency of N, P, K, Zn, Ca
- Premature fall of leaves and buds is caused by deficiency of K, P.
- Delay in flowering is caused due to deficiency of N, S, Mo.

9.7 UPTAKE OF MINERAL ELEMENTS

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be **passive** or **active**.

(a) **Passive Absorption** : It is the initial and rapid phase wherein ions are absorbed into the "outer space" of the cells, through the apoplast (Recall from lesson No. 08) pathway. It does not require use of any metabolic energy.

(b) **Active Absorption :** It is the second phase of ion uptake. The ions are taken in slowly into the 'inner space' the symplast of cells (Lesson No. 08). It needs the expenditure of metabolic energy.

The movement of ions is called **flux.** When the ions move into the cells, it is called **influx** and the outward movement of ions is called **efflux**.

The mineral ions absorbed by the root system are translocated through the xylem vessels to other parts of the plant.

INTEXT QUESTIONS 9.4

1. What is meant by 'passive absorption' of minerals by plants.

   ....

2. Name the minerals whose deficiency affects normal cell division.

   ....

3. "Deficiency of K, Ca and Mg causes necrosis of leaves". What does this statement mean ?

   ....

9.8 MODE OF NUTRITION IN PLANTS

Nutrition is plants is classified into two main categories : autotrophic and heterotrophic. Heterotrophic plants are further classified into saprophytes, parasite and insectivores.

Nutrition in Plants

- Autotrophic Nutrition (Auto = self; trophos = feeder)
- Heterotrophic Nutrition (Hetero = other; trophos = feeder Heterotrophic plant)
    - Saprophytic plants/ Saprophytes (Sapros = rotten; Phyton = plant
    - Parasitic plants/Parasites (Para = beside; sites = food)
    - Insectivorous plants/ Insectivores (eat insects)

1. Autotrophic Nutrition

It is a type of nutrition in which the living organisms manufacture their own organic food from simple inorganic raw materials. The green plants exhibit autotrophic mode of nutrition and hence called the autotrophs. The autotrophs require external energy source for the manufacture of organic substances. Green plants obtain energy from sunlight and therefore are called **photoautotrophs**. The process of synthesizing food in plant in the presence of sunlight is called **photosynthesis**. The insectivores are autotrophic but they develop specific structures to trap insects to overcome N_2 deficiency because they grow in soils having acute N_2-deficiency.

2. Heterotrophic nutrition

Certain non green organisms like fungi and many bacteria fail to synthesize their own organic nutrients from inorganic substances. These organisms are thus dependent on some other external sources for their organic nutrition. Such plants are called **heterotrophic plants** and the mode of nutrition is called **heterotrophic nutrition.**

The heterotrophic plants are broadly categorised into two main groups depending upon the source from which they get their nourishment. Saprophytes, and parasites.

(a) **Saprophytes** are those plants which grow and live on dead organic matter including animal and plant remains. Most of these plants secrete some extracellular enzymes (enzymes secreted and poured out on food) which break down the complex organic compounds into simple forms. The simple form are then absorbed by the plants. Saprophytes include mainly fungi and bacteria. Also among higher plants the Indian pipe plant *Monotropa* found in khasi hills of our country (Fig. 9.2) is a saprophyte.

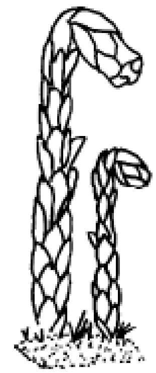


Fig. 9.2 A Monotropa, a saprophyte.

(b) **Parasitic Plants** : *Dodder* (*Cuscuta*) known locally as Amarbel/Akashbel is a parasitic plant that lacks both chlorophyll and leaves. It is a yellow colour climber that attaches itself to the host. It gives out haustoria or the suckers that get attached to the phloem of the host and derive nutrition. *Cuscuta* does not have roots in the mature condition. It produces bunches of whitish or yellowish bell shaped flowers.

Insectivorous Plants : These are plants which are autotrophic but develop adaptations to trap insects in order to **supplement the deficiency of Nitrogen in the soil**. They feed on insects. They are generally found in nitrogen deficient habitats and hence to compensate the loss, they use insects as a source of nitrogen. Some examples are given below :

(i) Pitcher plant : *Nepenthes* (ii) Sundew : *Drosera*

(iii) Venus flytrap : *Dionaea* (iv) Bladderwort : *Utricularia*

Fig. 9.3 Heterotrophic plants : (a) *Monotropa* (Indian pipe plant (b) *Cuscuta* (dodder) and (c) *Nepenthes* (pitcher plant)

Pitcher plant (Nepenthes) : It is found in north eastern India, Borneo and in many regions of North America.

These plants grow well in wet soils. The leaves are modified in the form of pitchers. The pitcher has nectar producing glands below its rim. Shiny surface of the pitcher and nectar secreted by nectar glands attract the insects. Insects once trapped can not escape due to the presence of numerous downward pointing hairs in the pitcher. The digestive glands present at the base of pitcher secrete enzymes. The insects are digested by the enzymes and the products which are mainly aminoacids are absorbed by the inner surface of leaves (pitcher).

INTEXT QUESTIONS 9.5

1. Give one point of difference between autotrophic and heterotrophic nutrition.

   ....

2. Name a plant which exhibits parasitic mode of nutrition.

   ....

3. Why does pitcher plant eat insects when it is capable of carrying out photosynthesis?

   ....

WHAT YOU HAVE LEARNT

- Plants have the nutritional requirement of various inorganic and organic raw materials for building their structure and maintaining body functions.
- Nutrition is the sum total of processes involving intake or synthesis of food and its utilisation.
- Plants generally derive their inorganic nutrients from soil, water and atmosphere.
- The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition.
- Plants require 17 essential elements. They are C, H, O, N, P, K, S, Mg, Ca, Fe, B, Mn, Cu, Zn, Mo, Cl and Co.
- The essentiality of minerals may be determined by employing the technique of hydroponics and aeroponics.
- Inorganic nutrients are broadly classified into two categories-micronutrients and macronutrients on the basis of the amount required by plant.
- Absence of any one element may cause deficiency symptoms in plants. These symptoms include reduction in growth, delaying of flowering, chlorosis, necrosis, early leaf fall, wilting etc.

- The minerals are taken by the roots through passive or active absorption.
- Basically, there are two modes of nutritioin autotrophic and heterotrophic.
- In autotrophic nutrition the organisms (plants) manufacture their own food from inorganic raw materials by photosynthesis or chemosynthesis.
- In heterotrophic nutrition the organism is dependent on other external sources for its organic nutrition.
- Heterotrophic plants are broadly categorised into two main groups: saprophytes, and parasites.
- Insectivorous plants are special type of autotrophic plants which grow in N_2-deficient soils and develop adaptations to trap insects to overcome N_2-deficiency.

TERMINAL EXERCISES

1. Which element can be obtained from both mineral and non-mineral sources.
2. Deficiency of which essential element causes yellowing of leaves in certain plants and why?
3. Why is magnesium included among essential elements?
4. What are the criteria of essentiality of elements?
5. Differentiate between micro and macro nutrients.
6. Why do biologists grow plants by hydroponics technique?
7. Explain the uptake of mineral nutrients by the plants.
8. Give the deficiency symptoms of nitrogen, phosphorus and potassium.
9. Differentiate between the different modes of heterotrophic nutrition in plants.
10. Write notes on :
    (i) Aeroponics
    (ii) Insectivorous plants
    (iii) Active absorption of minerals by plants

ANSWERS TO INTEXT QUESTIONS

9.1 1. Nutrients are the chemical substances in food

2. A technique of growing plants with roots supplied with moisture present in the atmosphere.

3. To supply oxygen in sufficient quantity

9.2 1. Molecular form from air or water

2. Required by plant in very small quantity. 0.1 mg per gram of dry matter or less.

3. They are required in large quantities 1-10 mg per gram of dry matter.

9.3 1 Membrane permeability, turgidity of cell, transport of electrons, enzyme activity (any two)

2. Nitrogen

3. See table 9.2

9.4 1. Without expenditure of energy

2. N, K, S, Mo (any two)

3. The deficiency causes death of leaf tissues

9.5 1. Autotrophs synthesize their own food, heterotrophs depend on others for food

2. *Cuscuta* (dodder)

3. Because it grows in a nitrogen deficient habitat.

10

NITROGEN METABOLISM

All the living organisms are basically composed of carbon, hydrogen, oxygen, nitrogen and many other forms of chemical elements. These elements contribute to finally organize various biomolecules present in a cell. Nitrogen is next to carbon in importance in living organisms. In a living cell, nitrogen is an important constituent of amino acids, proteins, enzymes, vitamins, alkaloids and some growth hormones. Therefore, study of nitrogen metabolism is absolutely essential because the entire life process is dependent on these nitrogen-containing molecules. In this lesson, you will learn about various aspects of nitrogen metabolism including nitrogen fixation and nitrogen assimilation in plants.

OBJECTIVES

After completing this lesson, you will be able to:

- *describe the modes of nitrogen fixation (both biological and abiological);*
- *explain the steps involved in nitrogen fixation by free living organisms;*
- *explain the mode of symbiotic nitrogen fixation in leguminous plants;*
- *describe the assimilation of nitrate and ammonia by plants;*
- *describe amino acid synthesis in plants.*

10.1 MOLECULAR NITROGEN

Nitrogen is primarily present in the atmosphere freely as dinitrogen or nitrogen gas. It is present in the combined form as Chile saltpetre or sodium nitrate and Chile in South America is the major source of this nitrate nitrogen.

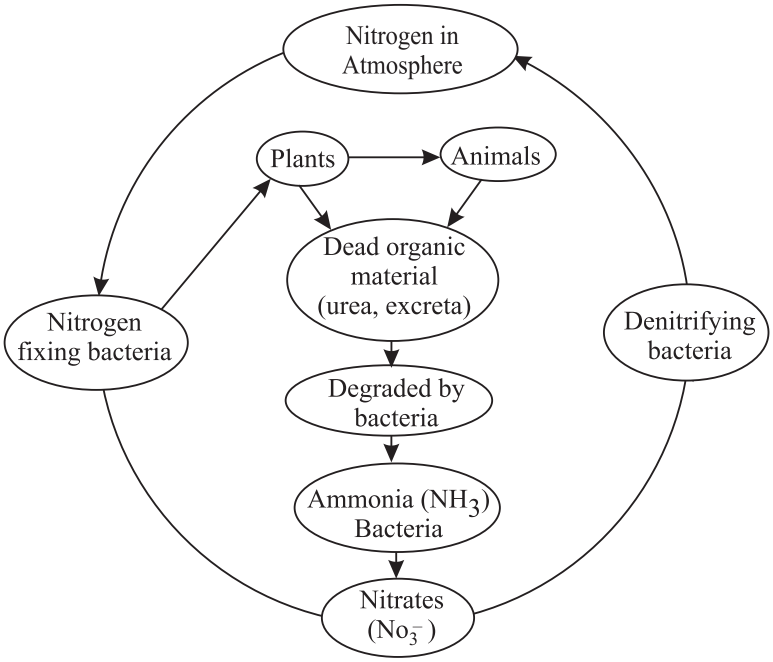
Molecular Nitrogen or diatomic nitrogen (N_2) is highly stable as it is triple bonded ($N \equiv N$). Because of this stability, molecular nitrogen as such is not very reactive in the atmosphere under normal conditions. In the atmosphere molecular nitrogen is 78.03% by volume and it has a very low boiling point (-195.8^oC) which is even lower than that of oxygen. Proteins present in living organisms contain about 16% nitrogen.

10.1.1 Nitrogen Cycle

Nitrogen is an essential constituent of living beings. Nitrogenous bases are part of nucleic acids and proteins are made up of amino acids of which Nitrogen is an important consituent. You already know about the importance of these two biomolecules.

Air has 78% N_2 but most of the living beings cannot utilize this atmospheric Nitrogen. Nitrogen cycle converts this nitrogen into a usable form. Lightning fixes Nitrogen to NH_3, and nitrogen fixing bacteria like *Rhizobium* (which live in roots of leguminous plants like pea, rajma, beans, pulses etc.) also convert N_2 into NH_3. Most plants absorb nitrates from soil and reduce it to NH_3 in the cells for further metabolic reactions. Dead organisms and their excreta like urea are decomposed by bacteria into NH_3 and by a different set of bacteria into nitrates. These are left in the soil for use by plants. In this way Nitrogen cycle is self regulated but human activities have caused steady loss of soil Nitrogen.

NITROGEN CYCLE



INTEXT QUESTIONS 10.1

1. What is the percent by volume of nitrogen gas in the atmosphere?

   ....

2. Name two biomolecules that contain nitrogen in plants.

   ....

3. Why nitrogen is a stable molecule?

   ....

4. What is the percentage of nitrogen in protein?

 ....

5. What is the boiling point of nitrogen?

 ....

6. Choose the correct option:

 Nitrogen fixation is the conversion of :

 (a) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Nitrates

 (b) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Ammonia

 (c) atmospheric Nitrogen $\xrightarrow{\text{into}}$ Amino acids

 (d) both (a) and (b)

7. Nitrogen content of biosphere remains constant because of :

 (a) Nitrogen cycle

 (b) Nitrogen fixation

 (c) Industrial pollution

 (d) Absorption of nitrogen

8. Nitrates are converted into nitrogen by microbes called ....

10.2 NITROGEN FIXATION (BIOLOGICAL AND ABIOLOGICAL)

The conversion of molecular nitrogen into compounds of nitrogen especially ammonia is called **nitrogen fixation**. Nitrogen fixation, is a reductive process i.e., nitrogen fixation will stop if there is no reducing condition or if oxygen is present. This nitrogen fixation may take place by two different methods – abiological and biological.

10.2.1 Abiological nitrogen fixation

In abiological nitrogen fixation the nitrogen is reduced to ammonia without involving any living cell. Abiological fixation can be of two types : industrial and natural. For example, in the Haber's process, synthetic ammonia is produced by passing a mixture of nitrogen and hydrogen through a bed of catalyst (iron oxides) at a very high temperature and pressure.

$$N_2 + 3H_2 \xrightarrow[\text{1000 atmosphere}]{\text{500°C}} 2NH_3$$

This is industrial fixation wherein nitrogen gets reduced to ammonia.

In natural process nitrogen can be fixed especially during electrical discharges in the atmosphere. It may occur during lightning storms when nitrogen in the atmosphere can combine with oxygen to form oxides of nitrogen

$$N_2 + O_2 \longrightarrow 2NO \xrightarrow{O_2} 2NO_2$$

These oxides of nitrogen may be hydrated and trickle down to earth as combined nitrite and nitrate.

10.2.2 Biological nitrogen fixation

Chemically, this process is same as abiological. Biological nitrogen fixation is reduction of molecular nitrogen to ammonia by a living cell in the presence of enzymes called nitrogenases.

INTEXT QUESTIONS 10.2

1. Define nitrogen fixation.

   ....

2. Which industrial process is utilized for converting nitrogen to ammonia?

   ....

3. Distinguish between biological and abiological nitrogen fixation.

   ....

4. Name the enzyme that helps in nitrogen fixation in living cells.

   ....

5. Which gas prevents nitrogen fixation?

   ....

10.3 NITROGEN FIXATION BY FREE LIVING ORGANISMS AND SYMBIOTIC NITROGEN FIXATION

Nitrogen fixation is a distinctive property possessed by a select group of organisms, because of the presence of the enzyme nitrogenase in them.

The process of nitrogen fixation is primarily confined to microbial cells like bacteria and cyanobacteria. These microorganisms may be independent and free living (Table 10.1).

Table 10.1 : Some free living microbes which fix nitrogen

Organisms	Status
Clostridium	Anaerobic bacteria (Non-photosynthetic)
Klebsiella	Facultative bacteria (Non-photosynthetic)
Azotobacter	Aerobic bacteria (Non-photosynthetic)
Rhodospirillum	Purple, non-sulphur bacteria (Photosynthetic)
Anabaena	Cyanobacteria (Photosynthetic)

Some microbes may become associated with other oragnisms and fix nitrogen. The host organism may be a lower plant or higher plant. The host organism and the nitrogen fixing microbes establish a special relationship called **symbiosis** and this results in symbiotic nitrogen fixation (Table 10.2).

Table 10.2 : Some symbiotic nitrogen fixing organisms

System	Symbionts
Lichens	Cyanobacteria and Fungus.
Bryophyte	Cyanobacteria and *Anthoceros*.
Pteridophyte	Cyanobacteria and *Azolla.*
Gymnosperm	Cyanobacteria and *Cycas.*
Angiosperms	Legumes and *Rhizobium.*
Angiosperms	Non leguminous plants and actinomycete (Such as *Alnus*, *Myrica*, *Purshia*).
Angiosperm	Brazilian grass (*Digitaria*), Corn and *Azospirillum*.

10.3.1 Mechanism of Biological Fixation of Nitrogen

Nitrogen fixation requires

(i) the molecular nitrogen

(ii) a strong reducing power to reduce nitrogen like reduced FAD (Flavin adenine dinucleotide) and reduced NAD (Nicotinamide Adenine Dinucleotide)

(iii) a source of energy (ATP) to transfer hydrogen atoms from $NADH_2$ or $FADH_2$ to dinitrogen and

(iv) enzyme nitrogenase

(v) compound for trapping the ammonia formed since it is toxic to cells.

The reducing agent ($NADH_2$ and $FADH_2$) and ATP are provided by photosynthesis and respiration.

The overall **biochemical process** involves stepwise reduction of nitrogen to ammonia. The enzyme nitrogenase is a Mo-Fe containing protein and binds with molecule of nitrogen (N_2) at its binding site. This molecule of nitrogen is then acted upon by hydrogen (from the reduced coenzymes) and reduced in a stepwise manner. It first produces diamide (N_2H_2) then hydrazime (N_2H_4) and finally ammonia ($2NH_3$).

NH_3 is not liberated by the nitrogen fixers. It is toxic to the cells and therefore these fixers combine NH_3 with organic acids in the cell and form amino acids.

The general equation for nitrogen fixation may be described as follows:

$$N_2 + 16ATP + 8H^+ + 8e^- \longrightarrow 2NH_3 + 16ADP + 16Pi +$$

Molecular nitrogen is a very stable molecule. Therefore, sufficient amount of cell energy in the form of ATP is required for stepwise reduction of nitrogen to ammonia.

In legumes, nitrogen fixation occurs in specialized bodies called **root nodules**. The nodules develop due to interaction between the bacteria *Rhizobium* and the legume roots (see diagram 6.4c). The biochemical steps for nitrogen fixation are same. However, legume nodules possess special protein called LEGHEMOGLOBIN. The synthesis of leghemoglobin is the result of symbiosis because neither bacteria alone nor legume plant alone possess the protein. Recently it has been shown that a number of host genes are involved to achieve this. In addition to leghemoglobin, a group of proteins called **nodulins** are also synthesized which help in establishing symbiosis and maintaining nodule functioning.

Leghemoglobin is produced as a result of interaction between the bacterium and legume roots. Apparently, Rhizobium gene codes for Heme part and legume root cell gene codes for Globin moiety. Both the coded products together consitute the final protein leghemoglobin. During N_2-fixaion, function of Leghemoglobin is to act as Oxygen-scavenger so that the enzymes, Nitrogenages then, convert N_2 to NH_3 under anaerobic condition.

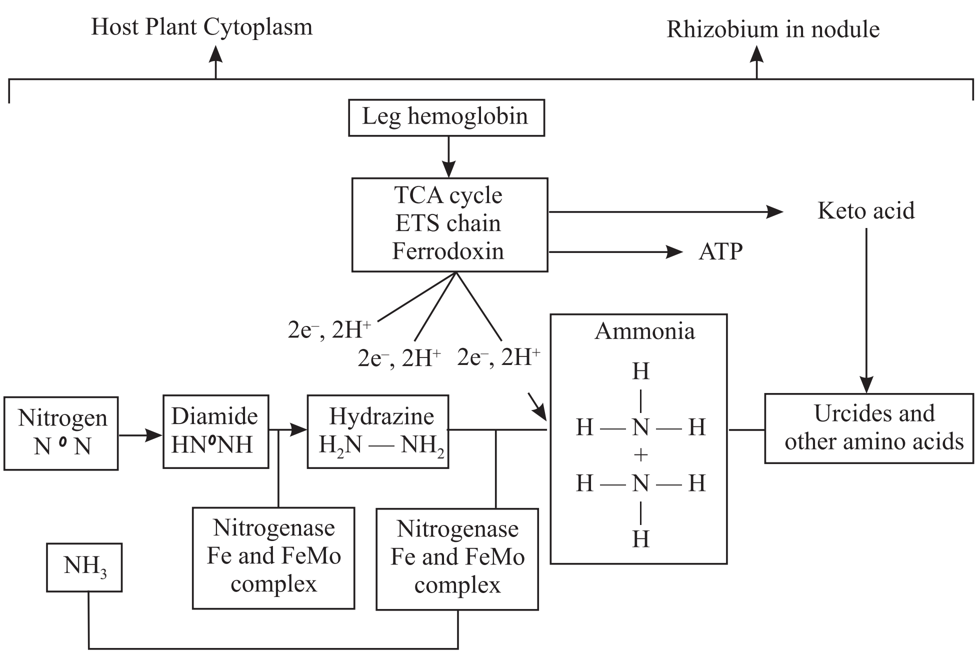


Fig. 10.1 Simplified flowsheet of biochemical steps for nitrogen fixation

Leghemoglobin is considered to lower down the partial pressure of oxygen and helps in nitrogen fixation. However, this function is specific for legumes only because free living microbes do not possess nitrogen fixing leghemoglobin. Moreover, it has also not been found in cyanobacterial symbiosis with other plants, which fix N_2 under aerobic condition.

Notes

INTEXT QUESTIONS 10.3

1. Match the following:

	A		B
(i)	*Azotobacter*	(a)	anaerobic nitrogen fixer.
(ii)	*Clostridium*	(b)	aerobic nitrogen fixer
(iii)	*Lichens*	(c)	aerobic nitrogen fixing cyanobacterium
(iv)	*Anabaena*	(d)	symbiotic nitrogen fixer.

2. Which Gymnospermous plant fixes nitrogen?

   ....

3. Is there any other gas evovled during nitrogen fixation? If yes, name the gas evolved.

   ....

4. How many ATP molecules are required to reduce a single molecule of nitrogen?

   ....

5. What is the major source of electrons for reduction of nitrogen?

   ....

6. Match the following:

	A		B
(i)	Leghemoglobin	(a)	cyanobacterium
(ii)	*Anabaena*	(b)	Legumes
(iii)	Reductive process	(c)	nitrogen fixation

7. Name the proteins that help in establishing symbiosis and maintain root nodule functioning in legumes.

   ....

10.4 NITRATE AND AMMONIA ASSIMILATION BY PLANTS

As pointed out in the previous section, nitrogen fixation is confined to selected microbes and plants. But all plants require nitrogen because it has a role to play in the general metabolism. Therefore, plants which do not fix nitrogen, use other combined nitrogen sources such as nitrate and ammonia for carrying on metabolic activity.

Nitrate is absorbed by most plants and reduced to ammonia with the help of two different enzymes. The first step conversion of nitrate to nitrite is catalyzed by an enzyme called nitrate reductase. This enzyme has several other important constituents including FAD, cytochrome, NADPH or NADH and molybdenum.

$$NO_3^- + NADH + H^+ \xrightarrow{\text{Nitrate reductase}} NO_2^- + NAD^+ + H_2O$$

The overall process of nitrate reduction take place in the cytosol and is an energy dependent reaction.

The enzyme nitrate reductase has been studied in many plants and it is observed that the enzyme is continuously synthesized and degraded. The enzyme nitrate reductase is inducible. This means that increase in nitrate concentration in the cytosol induces more of nitrate redutase to be synthesized. However, when excess NH_4^+ is produced then it has a negative effect on the synthesis of nitrate reductase. In plants, it has also been observed that light also increases nitrate reductase when nitrate is available.

In the second step the nitrite so formed is further reduced to ammonia and this is catalyzed by the enzyme nitrite reductase. Nitrite present in the cytosol is transported into chloroplast or plastids where it is reduced to ammonia.

$$NO_2^- + 3NADPH + 3H^+ \xrightarrow{\text{Nitrite reductase}} NH_3 + 3NADP^+$$

The enzyme nitrite reductase is able to accept electrons from sources such as NADH, NADPH or $FADH_2$. Besides, reduced ferredoxin has also been shown to provide electrons to nitrite reductase for reducing nitrite to ammonia. Ammonia so formed has to be utilized quickly by plants because accumulation of ammonia has a toxic effect. Some plants including algae leach out excess ammonia which can further be oxidized to nitrite and nitrate by microorganisms in the soil or water.

INTEXT QUESTIONS 10.4

1. Which is the most reduced form of inorganic nitrogen?

   ....

2. Match the following:

	A		B
(*i*)	Nitrate reductase	(a)	nitrogen fixation
(*ii*)	Nitrite reductase	b)	nitrate reduction
(*iii*)	Nitrogenase	c)	nitrite reduction

3. In which part of the cell, reduction of nitrate to nitrite occurs?

   ....

4 Which is the most oxidized form of inorganic nitrogen?

   ....

5 In which plant organelle reduction of nitrite to ammonia is catlyzed by the enzyme nitrite reductase?

   ....

10.5 AMINO ACID SYNTHESIS BY PLANTS

As you have noticed that ammonia formation is achieved by plants either by (i.) nitrogen fixation or (ii) by reduction of nitrate to nitrite. Ammonium (NH_4^+) is the

Notes

most reduced form of inorganic combined nitrogen. This ammonium now becomes the major source for the production of amino acids, which are the building blocks of enzymes and proteins. Amino acids have two important chemical groups. (i) amino group (NH_2) and (ii) carboxy1 group (-COOH).

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ R & — & C & — & COOH \\ & & | & & \\ & & NH_2 & & \end{array}$$

Fig. 10.2 A typical amino acid with functional groups. R represents alkyl group.

Ammonium so produced is the major source of amino group. However, the carboxyl group has to be provided by other organic molecule synthesized by the plants. There are two major reactions for amino acid biosynthesis in plants:

10.5.1 Reductive amination reaction:

In this reaction, ammonia combines with a keto acid. The most important keto acid is the alpha ketoglutaric acid produced during the operation of Krebs cycle (see lesson 12 Plant Respiration). The keto acid then undergoes enzymatic reductive amination to produce an amino acid.

$$\underset{\text{(keto acid)}}{\alpha\text{-ketoglutaric acid}} + NH_3 \xrightarrow{\text{glutamate dehydrogenase}} \underset{\text{(amino acid)}}{\text{Glutamic}}$$

Similarly another amino acid called aspartic acid is produced by reductive amination of oxaloacetic acid.

> It has been noted that reductive amination respresents the major 'port of entry' for ammonia into the metabolic stream in plants. This initiates synthesis of glutamic acid followed by other amino acids.

10.5.2 Transamination reaction

This is another very important reaction for amino acid biosynthesis. The reaction involves transfer of amino group, from already synthesized amino acid, to the keto acid.

$$\underset{\text{(Keto acid)}}{\alpha\text{-Ketoglutaric acid}} + \underset{\text{(Amino acid)}}{\text{Aspartic acid}} \xrightarrow{\text{Transaminase}} \underset{\text{(Amino acid)}}{\text{Glutamic acid}} + \underset{\text{(Keto acid)}}{\text{Oxaloacetic acid}}$$

In the above reaction, aspartic acid has transferred its amino group (NH_2) to the α-ketoglutaric acid to synthesize glutamic acid and release keto acid. The reaction is catalyzed by enzymes called **transaminases**. A large number of amino acids are synthesized by this transamination reaction. Amino acids are organic molecules containing nitorgen. The incorporation of amino group, from ammonium, into keto acids represents the major step for synthesis of nitrogenous organic biomolecules.

INTEXT QUESTIONS 10.5

1. Match the following:

	A	B
(i)	Amino acid	(a) keto acid
(ii)	Glutamic acid	(b) amino group and carboxyl group
(iii)	α-ketoglutaric acid	(c) amino acid

2. Name two biochemical reactions for biosynthesis of amino acids in plants.

   ....

3. Which group of enzymes catalyzes transamination reaction?

   ....

4. What is the source of amino group for amino acid synthesis in reductive amination reaction?

   ....

5. Which keto acid is the source for synthesis of glutamic acid?

   ....

WHAT YOU HAVE LEARNT

- Nitrogen is an important constituent of several biomolecules such as amino acids, proteins and enzymes.
- Molecules such as vitamins, alkaloids, nucleic acids, pigments and some growth hormones also contain nitrogen.
- Molecular nitrogen is triple bonded and stable.
- Nitrogen fixation is the reduction of nitrogen to ammonia.
- Abiological nitrogen fixation is an industrial process (Haber's process)
- Biological nitrogen fixation takes place in a living cell.
- The enzyme that catalyzes nitrogen fixation is Nitrogenase.
- Nitrogen fixation may take place in free living organisms or in symbiotic systems.
- There are many symbiotic nitrogen fixation systems such as Lichens, Pteridophytes, Bryophytes, Gymnosperms and Legumes.
- Cyanobacteria is the symbiotic component in Lichens, Bryophytes, Pteridophytes and Gymnosperms.
- In Legumes, the symbiont is a species of bacterium *Rhizobium*.
- Source of electrons and energy for nitrogen fixation is generally pyruvic acid after it enters Krebs' cycle during cell-respiration.
- Hydrogen gas evolution may also accompany nitrogen fixation process.

- Nitrate is the most oxidized form and ammonium is the most reduced form of nitrogen.
- Nitrate is reduced to nitrite by an enzyme nitrate reductase.
- Amino acids have two functional groups, namely, amino group and carboxyl group.
- Amino acids may be produced by reductive amination of keto acids.
- Amino acids may be produced by transamination reaction.
- Reductive amination reactions are catalyzed by dehydrogenases.
- Transamination reactions are catalyzed by transaminases.

TERMINAL EXERCISES

1. Define nitrogen fixation.
2. Which form of combined nitrogen may be formed during lightening storms?
3. Name three biomolecules other than enzymes and proteins, which contain nitrogen.
4. Name one aerobic and one anaerobic bacterium, which fixes nitrogen.
5. Which amino acid is synthesized due to reductive amination of α-ketoglutaric acid?
6. Differentiate between biological and abiological nitrogen fixation.
7. What is required for biological nitrogen fixation?
8. How does human hemoglobin differ from leghemoglobin?
9. What is the function of leghemoglobin?
10. What are the functional differences between nitrate reductase and nitrite reductase?
11. What is the difference between nitrogen fixation and nitrogen assimilation? Describe in brief the process of abiological nitrogen fixation.
12. Describe in brief various steps involved in biological nitrogen fixation.
13. Enumerate various free living and symbiotic nitrogen fixing systems with suitable examples.
14. What are the major differences between free living and leguminous nitrogen fixing organisms?
15. Describe in brief nitrate and nitrite reduction in plants..
17. Describe in brief the reductive amination reactions for synthesis of amino acids in plants.
18. Describe the transamination reaction for synthesis of amino acids in plants. How does this differ from reductive amination?

ANSWERS TO INTEXT QUESTIONS

10.1 1. 78.03 percent 2. proteins and enzymes.
3. Because it is triple bonded. 4. 16 percent.
5. –195.8°C. 6. (b)
7. (a) 8. Denitrifying Bacteria

10.2 1. Conversion of molecular nitrogen to ammonia.
2. Haber's process.
3. Biological nitrogen fixation takes place in a living cell and abiological fixation without a living cell.
4. Nitrogenase. 5. Oxygen.

10.3 1. (i) b (ii) a (iii) d (iv) c
2. Cycas. 3. Yes, Hydrogen gas.
4. 16 ATP 5. Reduced coenzymes such as Ferrodoxin
6. (i) b (ii) a (iii) c 7. Nodulins.

10.4 1. NH_4
2. (i) b (ii) c (iii) a
3. Cytosol. 4. Nitrate. 5. Chloroplast.

10.5 1. (i) b (ii) c (iii) a
2. Reductive amination and transamination.
3. Transaminases. 4. Ammonia.
5. Alpha ketoglutaric acid.

11

PHOTOSYNTHESIS

Photosynthesis (Photo = light; synthesis = to join) is the single most important process on earth on which depends the existence of human beings and almost all other living organisms. It is a process by which green plants, algae and chlorophyll containing bacteria utilize the energy of sunlight to synthesize their own food (organic matter) from simple inorganic molecules. Innumerable number of organic molecules which compose the living world are derived directly or indirectly from the photosynthetic organic matter. The oxidation of organic compounds releases stored energy to be utilized by the living organisms to carry out essential metabolic processes. It is important to note that photosynthesis is the only natural process which liberates oxygen to be used by all living forms for the process of aerobic respiration.

You have studied in lesson 4, that chloroplasts are the organelles that carry out photosynthesis or in other words they act as solar cells producing carbohydrates. In this lesson you will learn how green plants carry out photosynthesis.

OBJECTIVES

After completing this lesson, you will be able to :

- *define photosynthesis;*
- *name the different pigments found in chloroplasts;*
- *explain the main aspects of the process of photosynthesis;*
- *enumerate the steps involved in the light and dark reactions of photosynthesis;*
- *define the terms absorption spectrum, action spectrum, electron acceptor and photophosphorylation;*
- *distinguish between, absorption spectrum and action spectrum; light and dark reactions, cyclic and non-cyclic photo-phosphorylation,* C_3 *and* C_4 *photosynthesis;*
- *list the environmental variables and internal factors affecting photosynthesis;*
- *describe the principle of limiting factor giving suitable graphs.*

11.1 PHOTOSYNTHESIS

11.1 Let us look into the significance of the process

Significance

1. Green plants possess the green pigment, chlorophyll which can capture, transform, translocate and store energy which is readily available for all forms of life on this planet.
2. Photosynthesis is a process in which light energy is converted into chemical energy.
3. Except green plants, no other organism can directly utilise solar energy to synthesize food, hence they are dependent on green plants for their survival.
4. Green plants which can prepare organic food from simple inorganic elements are called autotrophic while all other organisms which cannot prepare their own food are called heterotrophic.
5. During photosynthesis, oxygen liberated into the atmosphere makes the environment livable for all aerobic organisms.
6. Simple carbohydrates produced in photosynthesis are transformed into lipids, proteins, nucleic acids and other organic molecules.
7. Plants and plant products are the major food sources of almost all organisms on the earth.
8. Fossil fuels like coal, gas, and oil represent the photosynthetic products of the plants belonging to early geological periods.

11.1.1 What is photosynthesis?

Photosynthesis is the process by which green plants, in the presence of light combine water and carbon dioxide to form carbohydrates. Oxygen is released as a by product of photosynthesis. Current knowledge of photosynthesis has resulted from discoveries made over 300 years of work. Some landmark experiments are given in the box below.

- Joseph Priestley (1772) and later Jan Ingenhousz (1779) showed that plants have the ability to take up CO_2 from the atmosphere and release O_2.
- Ingenhousz also discovered that release of O_2 by plants was possible only in presence of sunlight and by the green parts of the plant.
- Robert Hill (1939) demonstrated that isolated chloroplasts evolve O_2 when they are illuminated in the presence of electron acceptor which gets reduced. This reaction called Hill reaction accounts for the use of water as a source of electrons and protons for CO_2 fixation and release of O_2 as bye-product.

Photosynthesis is represented by the following overall chemical equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

In photosynthesis, CO_2 is fixed (or reduced) to carbohydrates (glucose $C_6H_{12}O_6$). Water is split in the presence of light (called photolysis of water) to release O_2. Note that O_2 released comes from the water molecule and not from CO_2.

11.1.2 Where does photosynthesis occur?

Photosynthesis occurs in green parts of the plant, mostly the leaves, sometimes the green stems and floral buds. The leaves contain specialised cells called mesophyll cells which contain the chloroplast– the pigment containing organelle. These are the actual sites for photosynthesis.

Look at the figure 11.1 that shows leaf Cell Structure and Function.

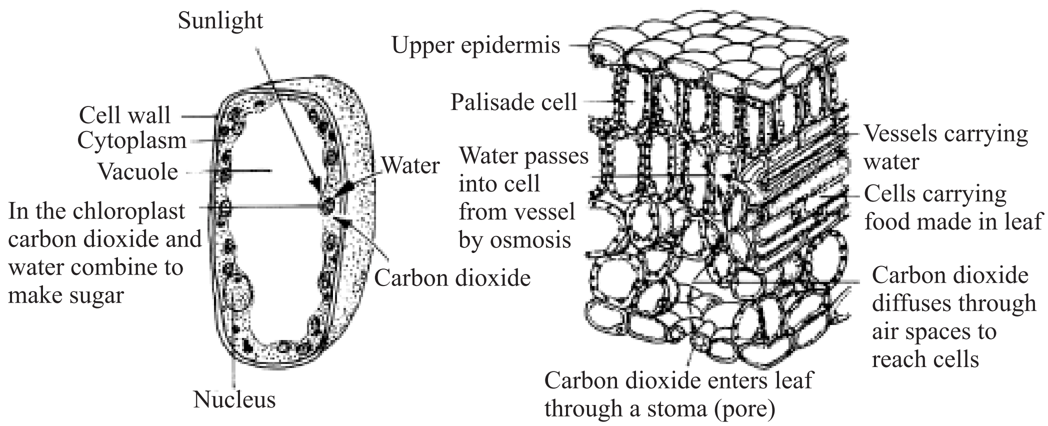


Fig. 11.1 Diagram to show structure of leaf cells

11.2 PHOTOSYNTHETIC PIGMENTS

The thylakoids of the chloroplast contain the pigments which absorb light of different wavelengths and carry out the photochemical reaction of photosynthesis.

The role of the pigments is to absorb light energy, thereby converting it to chemical energy. These pigments are located on the thylakoid membranes and the chloroplasts are usually so arranged within the cells that the membranes are at right angles to the light source for maximum absorption. The photosynthetic pigments of higher plants fall into two classes the chlorophyll and carotenoids.

The photosynthetic pigment **chlorophyll** is the principle pigment involved in photosynthesis. It is a large molecule and absorbs light maximally in the violet blue and in the red region of the visible spectrum and reflects green light and thus leaves appear green in colour. **Carotenoids** (carotene and xanthophyll) absorb light in the regions of the spectrum not absorbed by the chlorophylls and transfer that energy to chlorophyll to be used in photosynthesis.

Chlorophyll-a (a special type of chlorophyll) is the main pigment that traps solar energy and converts it into chemical energy. Chlorophyll-a is present in all autotrophic plants except photosynthetic bacteria. Thus Chl-a is called the essential photosynthetic pigment responsible for representing the **reaction centre.**

All other pigments such as chlorophyll b and carotenoids are collectively called accessory pigments since they pass on the absorbed light energy to chlorophyll a (Chl-a) molecule to be utilized for photosynthesis. These pigments, that is the reaction centres (Chl-a) and the accessory pigments (**harvesting centre**) are packed into functional clusters called **photosystems**. Photosystems are of two types **PSI** and **PSII**.

About 250-400 Chl-a molecules constitute a single photosystem. Two different photosystems contain different forms of chlorophyll a in their reaction centres. In photosystem I (PSI), chlorophyll– a with maximum absorption at 700 nm (P_{700}) and in photosystem II (PSII), chlorophyll– a with peak absorption at 680 nm (P_{680}), act as reaction centres. (P stands for pigment). The primary function of the two photosystems, which interact with each other is to trap the solar energy and convert it into the chemical energy also called **assimilatory power** (ATP and $NADPH_2$). The differences between them are given in the following Table 11.1.

Table 11.1 Differences between Photosystem I and Photosystem II

Photosystem I	Photosystem II
• PS I has a reaction centre of chlorophyll 'a' molecule with maximum light absorption at 700 nm wavelength. This reaction centre is referred to as P_{700}.	• PS II has a reaction centre of chlorophyll 'a' molecule with maximum light absorption at 680 nm. This reaction centre is also referred to to as P_{680}.
• Primary electron acceptor is an iron protein (Fe-S-protein)	• Primary electron acceptor, pheophytin, is a modified chlorophyll-a molecule with 2 hydrogen atoms in place of magnesium ion.
• A set of electron carriers are plastocyanin, ferredoxin and cytochrome	• A set of electron carriers are pheophytin plastoquinone, cytochromes.

11.3 ROLE OF SUNLIGHT IN PHOTOSYNTHESIS

Light consists of small particles or packages of energy called "photons". A single photon is also called **quantum.** What does the chlorophyll do? It absorbs light energy.

> Chlorophyll molecules absorb light energy and get into an excited state and lose an electron to the outer orbit. No substance can remain in an excited state for long, so the energised and excited chlorophyll molecule comes down to a low energy state known as **ground state** and releases the extra amount of energy. This energy can be lost as heat, or as light (fluorescence) or can do some work. In photosynthesis, it works by splitting water moelcule to produce H^+ and OH^- ions.

Carotene is orange-yellow pigment present along with chlorophylls in the thylakoid membrane. A carotene molecule breaks down into the vitamin A molecules. It is this pigment which gives carrot its colour.

Absorption and Action Spectra

For investigating a process such as photosynthesis that is activated by light, it is important to establish the action spectrum for the process and to use this to identify the pigments involved. An **action spectrum** is a graph showing the effectiveness of different wavelengths (VIBGYOR) of light in stimulating the process of photosynthesis, where the response could be measured in terms of oxygen produced at different wavelengths of light. An **absorption spectrum** is a graph representing the relative absorbance of different wavelengths of light by a pigment. An action spectrum for photosynthesis is shown in Fig. 11.2 together with an absorption spectrum for the combined photosynthetic pigments. Note the close similarity, which indicates that the pigments, chlorophyll-a in particular, are responsible for absorption of light used in photosynthesis.

All wavelengths of light are not equally effective in photosynthesis i.e. the rate of photosynthesis is more in some and less in others.

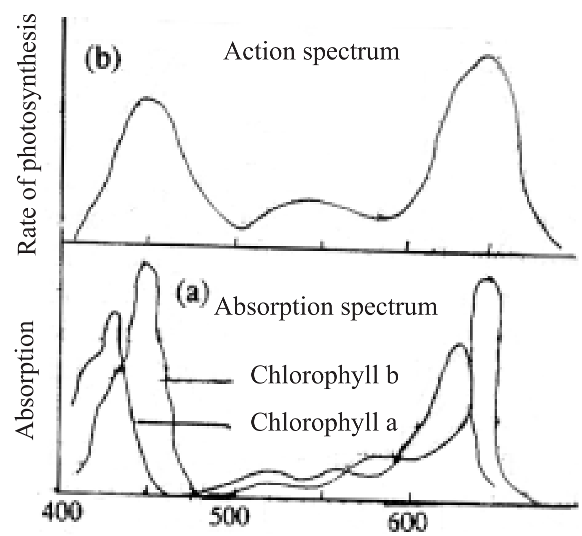


Fig. 11.2 Absorption Spectra of electromagnetic radiation B. Action Spectrum

Photosynthesis occurs maximum in blue and red region of spectra. Photosynthesis is very little in green and yellow light, because these rays are reflected back from the leaf.

INTEXT QUESTIONS 11.1

1. (i) Define photosynthesis

....

(ii) Give the overall general chemical equation of photosynthesis.

....

2. (i) List the two categories of photosynthetic pigments.

....

(ii) Which pigments are known as accessory pigments?

....

3. (i) What does chlorophyll do to the light falling on it?

....

(ii) Which pigment system absorbs maximally the red wavelength of light?

....

4. Answer the following

(i) In which colour of light, rate of photosynthesis is minimum and in which colour of light it is maximum?

....

(ii) Name the type of energy that is used in the process of photosynthesis. In which form does this energy get stored in plant body?

....

5. Which molecule is the source of evolution of oxygen in photosyntheisis— CO_2 or H_2O?

....

11.4 PHOTOCHEMICAL AND BIOSYNTHETIC PHASE

- The entire process of photosynthesis takes place inside the chloroplast. The structure of chloroplast is such that the light dependent (**light reaction**) and light independent (**Dark reaction**) reactions take place at different sites in the same organelle.
- The thylakoids have the pigments and other necessary components to absorb light and transfer electrons to carry out the light reaction or Electron Transport Chain (ETC). In ETC upon absorption of light, the electrons from PSII and PSI are excited to a higher energy level i.e. the electrons acquire excitation energy. As the electrons gain this energy, they are accepted by the electron acceptor which in turn is reduced, leaving the reaction centres of PSII and PSI i.e. P_{680} and P_{700} molecules in an oxidised state. This represents the conversion of light energy into chemical energy. The electrons then travel downhill in energy terms, from one electron acceptor to another in a series of oxidation-reduction reaction. This electron flow is ‘coupled’ to the formation of ATP. In addition, NADP is reduced to $NADPH_2$. The product of light reaction is called the reducing power or assimilatory power (ATP and $NADPH_2$) which move out of the thylakoid into the stroma of the chloroplast.
- In the stroma, the second step called as **dark reaction or biosynthetic pathway** occurs, where CO_2 is reduced by the reducing power generated in the first step and carbohydrates are produced.

Let us study these two steps in some more detail in the next part of the lesson.

11.4.1 Electron transport chain in photosynthesis

After receiving light PSII absorbs light energy and passes it on to its reaction centre, P_{680}. When P_{680} absorbs light, it is excited and its electrons are transferred to an electron acceptor molecule (Primary electron acceptor i.e. pheophytin) and it itself comes to the ground state. However by losing an electron P_{680} is oxidised and in turn it splits water molecule to release O_2. This light dependent spliting of water is called **photolysis**. With the breakdown of water electrons are generated, which are then passed on to the electron deficient P_{680} (which had transferred its electrons earlier). Thus the oxidised P_{680} regains its lost electrons from water molecules.

The reduced primary acceptor now donates electrons to the down stream components of the electron transport chain. The electrons are finally passed onto the reaction centre P_{700} or PSI. During this process, energy is released and stored in the form of ATP.

Similarly, PSI also gets excited when it absorbs light and P_{700} (Reaction centre of PSI) gets oxidised as it transfers its electrons to another primary acceptor molecule. While the oxidised P_{700} draws its electrons from PSII, the reduced primary acceptors molecule of PSI transfers its electrons via other electron carrier to NADP (Nicotinamide Adenine Dinucleotide Phosphate) to produce $NADPH_2$ a strong reducing agent. Thus we see that there is a continuous flow of electrons from the H_2O molecules to PSII to PSI, and finally to the NADP molecule which is reduced to $NADPH_2$. $NADPH_2$ is then utilised in reduction of CO_2 to carbohydrates in the biosynthetic pathway.

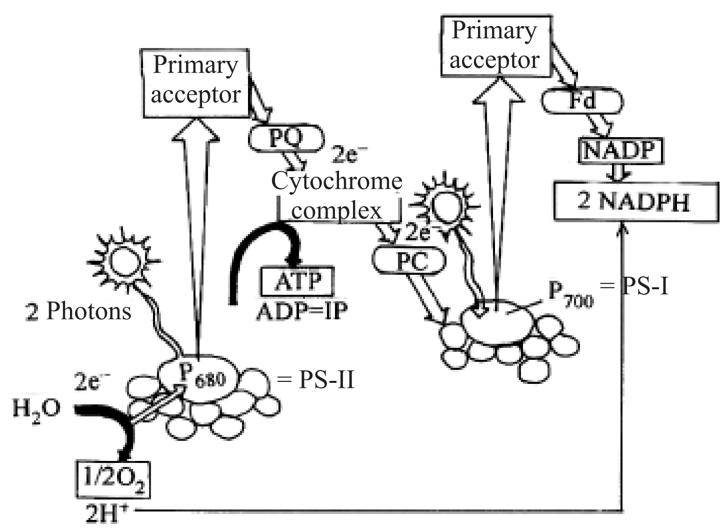


Fig. 11.3 Non-cyclic (z-scheme) photophosphorylation PQ = Plastoquinine, PC-Plastocyanin Fd = Ferredoxin

- Reduction of CO_2 to carbohydrate also requires ATP, which too are generated via electron transport chain. As the energy rich electrons pass down the electron transport system, it releases energy which is sufficient to bind inorganic phosphate (Pi) with ADP to form ATP. This process is called photophosphorylation. Since this takes place in presence of light it is called **Photo-phosphorylation.** It occurs in chloroplast in two ways:

(a) Non-cyclic photophosphorylation where electrons flow from water molecule to PSII and then to PSI and ultimately reduce NADP to $NADPH_2$. Since the electron flow is unidirectional and the electrons released from one molecule do not return to the same molecule, it is called non-cyclic photosphorylation (Fig. 11.3).

(b) Cyclic photophosphorylation occurs in photosynthetic bacteria which lack PS-II, and it involves PSI only. During this process electrons from PSI are not passed on to NADP. Instead the same electrons are returned to the oxidised P_{700} molecule. During this downhill movement of electrons ATP formation takes place. Thus this is termed as cyclic photophosphorylation (Fig. 11.4).

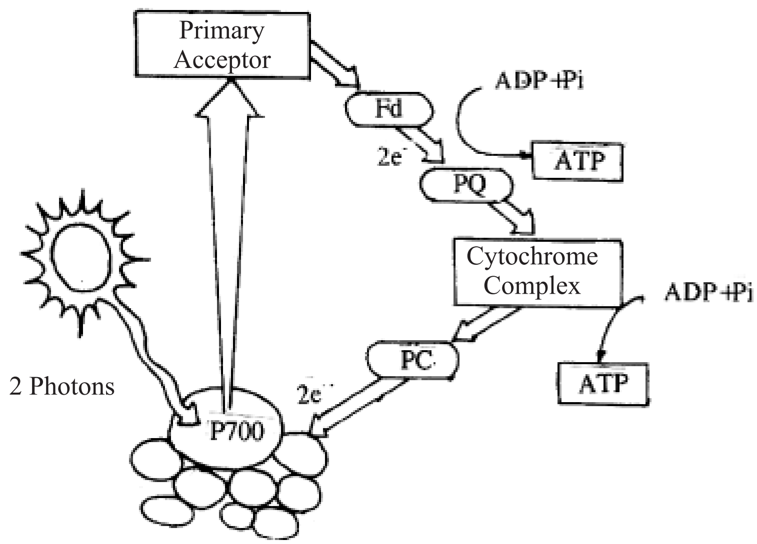


Fig. 11.4 Cyclic photophosphorylation

Table 11.2 Differences between cyclic and non-cyclic photophosphorylation

Cyclic photophosphorylation	Non-cyclic photophosphorylation
1. Only PSI is functional.	1. Both PSI and PSII are functional.
2. Electron comes from the chlorophyll P_{700} molecule and returns to the same chlorophyll P_{700}	2. Water is the primary source of the electrons and H^+. It gets photolysed through the process called **Photolysis;** NADP is the final acceptor of the electrons and H^+ ions.
4. Oxygen is not evolved because there is no photolysis of water	4. Oxygen is evolved as a bye product.
5. This process is found mainly in photosynthetic eubacteria e.g. purple sulphur bacteria.	5. This mainly takes place in all green plants, and cyanobacteria except photosynthetic eubacteria.

In higher photosynthetic plants, extra ATP can be made via cyclic photophosphorylation if cyclic and non-cyclic photophosphorylaiton occur side by side. The efficiency of energy conversion in the light reactions of photosynthesis is high and estimated at about 39%.

11.5 BIOSYNTHETIC PATHWAY (DARK REACTION)

- Both $NADPH_2$ and ATP produced during light reaction are essential requirements for synthesis of carbohydrates.
- These series of reactions which catalyse the reduction of CO_2 to carbohydrates (also called fixation of CO_2) take place in the **stroma** of the chloroplast.
- These reactions are independent of light i.e. light is not necessary but can continue in light as well if products of the light reaciton are available. Thus it is also called **dark reaction**.
- The carbon fixation reactions produce sugar in the leaves of the plant from where it is exported to other tissues of the plant as source of both organic molecule and energy for growth and metabolism.
- There are **two** major pathways by which CO_2 fixation (Dark reaction) takes place.

11.5.1 C_3 cycle (also called Calvin cycle after the name of its discoverer, Melvin Calvin)

In this cycle, initially the atmospheric CO_2 is accepted by a 5-carbon sugar ribulose bisphosphate (RuBP) resulting in the generation of two molecules of 3-carbon compound, 3-phosphoglyceric acid (PGA). This 3-carbon molecule is the first stable product of this pathway and hence the name C_3 cycle is given. Formation of PGA is called **carboxylation**. This reaction is catalysed by an enzyme called **ribulose bisphosphate carboxylase/oxygenase or Rubisco.** This enzyme is probably the most abundant protein on earth.

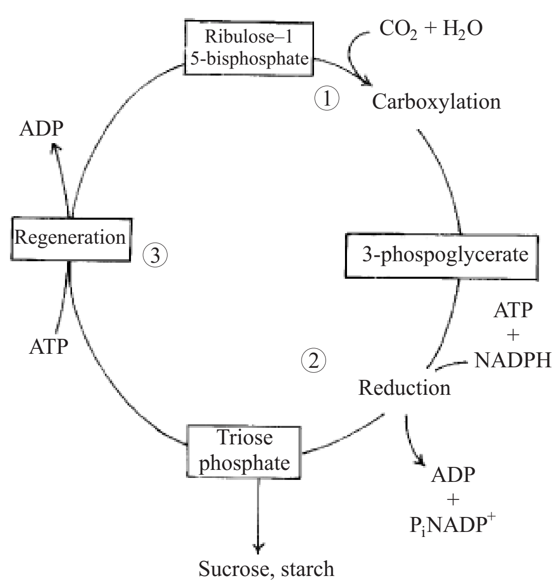


Fig. 11.5 The Calvin cycle

- In the next step, PGA is reduced to 3-carbon carbohydrate called **triose phosphate** using $NADPH_2$ and ATP (from light reaction). Much of these molecules are then diverted from the C_3 cycle and used for synthesis of other carbohydrates such as glucose and sucrose.
- To complete the cycle, the initial 5-carbon acceptor molecule, RuBP is regenerated from the triose phosphates using ATP molecule thus the C_3 cycle continues to regenerate the CO_2-acceptor (RuBP).

11.5.2 C_4 Cycle (or Hatch Slack Cycle)

- The C_4 cycle seems to be an adaptation for plants growing under dry hot environment. Such plants can photosynthesise even in the conditions of very low CO_2 concentration and under partial closure of stomata.
- Such plants can thus grow at low water content, high temperature and high light intensity. Sugarcane, and maize are some examples.
- Photorespiration (oxidation of RuBP in presence of O_2) is absent in these plants. So the photosynthetic rate is high. (For detail of photorespiration refer to lesson-12 Plant Respiration Section No. 12.5)
- The leaves of C_4 plants show presence of dimorphic chloroplasts, called **Kranz anatomy**.
  - (a) In these plants, the vascular bundles have a sheath of large parenchyma cells around them in the form of a wreath, thus the name Kranz anatomy (Kranz : wreath)
  - (b) Leaves possess two types of chloroplasts (dimorphic chloroplasts)
  - (c) Chloroplasts in the mesophyll cells are smaller and have well developed grana (granal chloroplasts) but do not accumulate starch.
  - (d) Chloroplasts in the bundle sheath cells are larger and lack grana (**agranal chloroplasts**) but contain numerous starch grains. (See Fig. 11.6).

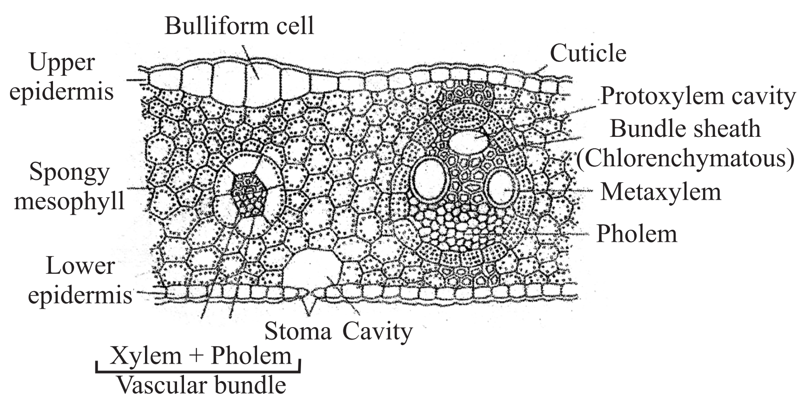


Fig. 11.6 Transverse section of maize leaf showing Kranz' anatomy

- In C_4 plants, the initial acceptor of CO_2 is **phosphoenol pyruvic acid or PEP**, a 3-carbon compound. It combines with CO_2 in presence of an enzyme **Phosphoenol pyruvate carboxylase (PEP carboxylase)** and forms a C_4 acid, oxaloacetic acid (OAA). This fixation of CO_2 occurs in the cytosol of the mesophyll cells of the leaf. OAA is the first stable product of this cycle which is 4 carbon compound and hence the name C_4 pathway is given.

- OAA then travels from mesophyll cells to the chloroplasts of bundle sheath cell where it releases the fixed CO_2. C_3 cycle operates within these cells and this CO_2 immediately combines with RuBP in C_3 cycle producing sugars. (See Fig. 11.7).

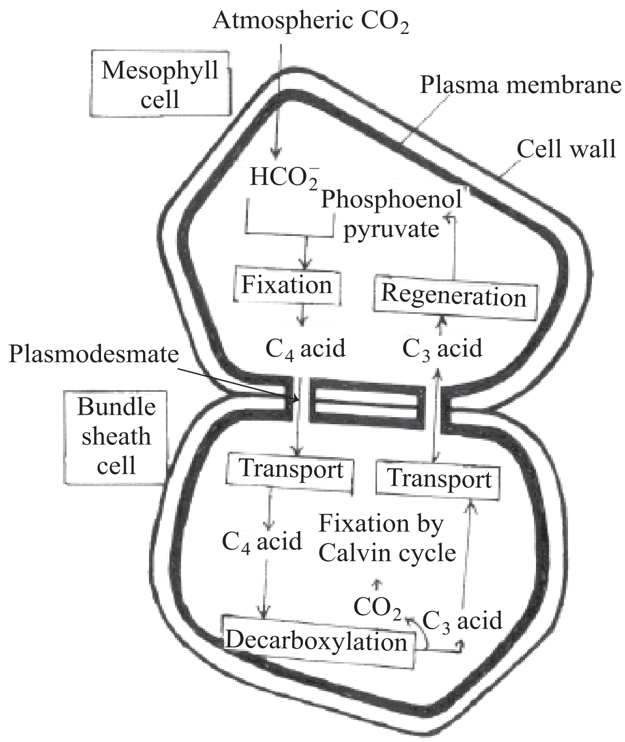


Fig. 11.7 The C4 photosynthetic carbon cycle

- Thus in C_4 pathway of dark reaction, there are two carboxylase enzymes that take part. PEP carboxylase (PEPCo) in the mesophyll cells and RUBP carboxylase (Rubisco) in the bundle sheath cells.
- The differences between C_3 and C_4 plants are tabulated below.

Table 11.3 Difference between C_3 and C_4 Plants

	C_3 Plants	C_4 Plants
Carbon dioxide fixation	Occurs once	Occurs twice, first in mesophyll cells, then in bundle sheath cells.
Carbon dioxide acceptor	Only one acceptor, RuBP which occurs in all green cells of the plant	In Mesophyll cells, PEP (Phosphoenol Pyruvic acid), 3-C, compound is CO_2 acceptor, but in the bundle sheath cells-RuBP, 5C, compound, is the CO_2^- acceptor
Carbon dioxide fixing enzymes	RuBP carboxylase, which is not efficient when CO_2 conc is low	PEP caboxylase which is very efficient, even if CO_2 conc. is low RuBP carboxylase, works efficiently because carbon dioxide concentration is high.
First product of photosynthesis	The first stable product is 3-C compound phosphoglyceric acid	The first product is 4-C compound oxaloacetic acid

Concentration of CO_2	Higher CO_2 conc. promotes photosynth]esis	Photosynthetic efficiency is high even if CO_2 conc. is low
Leaf anatomy	Only one type of chloroplast Kranz' anatomy is absent	Two types of chloroplasts (dimorphic) or Kranz' anatomy, i.e., two types of cells. each with its own type of chloroplasts are present.
Photorespiration	Occurs; excess of oxygen is an inhibitor of photosynthesis	Photorespiration is absent. The photo synthetic efficiency is further increased
Efficiency	Less efficient plotosynthesis than C_4 plants. Yields usually much lower.	More efficient photosynthesis as compared to that of the C_3 plants. Yields usually much higher.

INTEXT QUESTIONS 11.2

1. What is the role of NADP?

   ....

2. Why is dark reaction called so?

   ....

3. What is the role of the enzymes (i) rubisco and (ii) PEPCo and where are they present?

   ....

4. Explain Kranz anatomy.

   ....

5. Differentiate between the chloroplasts present in the mesophyll cells and in the bundle sheath cells of the leaf of a C_4 plant.

   ....

6. Why are C_4 plants more efficient than C_3 plants?

   ....

7. Name the two sets of reactions in photosynthesis in which light energy is required.

   ....

11.6 FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

11.6.1 Factors affecting Photosynthesis

Factors affecting photosynthesis can be divided into two broad categories, the internal and external (environmental) factors.

(i) Internal Factors

1. **Chlorophyll :** The amount of chlorophyll present has a direct relationship with the rate of photosynthesis because this pigment is directly involved in trapping light energy responsible for the light reactions.
2. **Leaf age and anatomy :** Newly expanding leaves show gradual increase in rate of photosynthesis and the maximum is reached when the leaves achieve full size. Chloroplast functions decline as the leaves age. Rate of photosynthesis is influenced by variation in (i) number, structure and distribution of stomata, (ii) size and distribution of intercellular spaces (iii) relative proportion of palisade and spongy tissues and (iv) thickness of cuticle.
3. **Demand for photosynthate :** Rapidly growing plants show increased rate of photosynthesis in comparison to mature plants. When demand for photosynthesis is lowered due to poor meristematic activity, the photosynthetic rate declines.

(ii) External Factors

The major external factors which affect the rate of photosynthesis are temperature, light, carbondioxide, water, and mineral elements.

Concept of limiting factors : When a process is affected by various factors, the rate of the process depends upon the pace of the slowest factor. Let us consider three factors like light, carbon dioxide and temperature. It is seen that when all three factors are optimum, the rate of photosynthesis is maximum. However, of the three factors even if one of the factors becomes suboptimal and the other factors remain optimal, the rate of the photosynthetic process declines substantially. This is known as law of limiting factors shown by Blackman in 1905. It is defined as when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor which is known as the **limiting factor**.

Light : The rate of photosynthesis increases with increase of intensity of light within physiological limits or rate of photosynthesis is directly proportional to light intensity. Except on a cloudy day and at nights, light is never a limiting factor in photosynthesis in nature.

At a certain light intensity the amount of CO_2 used in photosynthesis and the amount of CO_2 produced in respiration are the same. This point of light intensity is known as **compensation point**.

Wavelength of light absorbed by photosynthetic pigments affects rate of photosynthesis. Red light and to some extent blue light has an enhancing influence on photosynthesis (See action spectrum).

The proportion of the total incident sunlight on earth, absorbed by green plants is generally a limiting factor. As per the estimates of the total incident light reaching the green plants, only about 1-2% is actually absorbed, because 70% is transmitted, and 28-29% is reflected back into the atmosphere.

Temperature : Very high and very low temperature affect the rate of photosynthesis adversely. Rate of photosynthesis will rise with temperature from 5°-37°C beyond which there is a rapid fall, as the enzymes involved in the process of the dark reaction are denatured at high temperature. Between 5°-35°C, with every 10°C rise in temperature rate of photosynthesis doubles or Q_{10} is 2 (Q = quotient), or slightly less than two.

Carbon dioxide : Since carbon dioxide being one of the raw materials for photosynthesis, its concentration affects the rate of photosynthesis markedly. Because of its very low concentration (0.03%) in the atmosphere, it acts as limiting factor in natural photosynthesis. At optimum temperature and light intensity, if carbon dioxide supply is increased the rate of photosynthesis increases markedly until CO_2 conc. is as high as 3.0%. Thus, CO_2 conc. in the atmosphere is always a limiting factor for photosynthesis.

Water : Water has an indirect effect on the rate of photosynthesis. Loss of water in the soil is immediately felt by the leaves, which get wilted and their stomata close down thus hampering the absorption of CO_2 from the atmosphere. This causes decline in photosynthesis.

Oxygen : Concentration of oxygen as an external factor, is never a limiting factor for photosynthesis because it is a by-product of photosynthesis, and it easily diffuses into the atmosphere from the photosynthesizng organ, **the leaf**. However, excesss of O_2 surrounding a green plant, reduces photosynthetic rate by promoting the rate of aerobic respiraiton.

Mineral elements : Some mineral elements like magnesium, copper, manganese and chloride ions, which are components of photosynthetic enzymes, and magnesium as a component of chlorophylls are important, and their deficiency would affect the rate of photosynthesis indirectly by affecting the synthesis of photosynthetic enzymes and chlorophyll, respectively.

11.7 CHEMOSYNTHESIS

Chemosynthesis

When plants utilise light energy to reduce carbon dioxide to carbohydrates, they are called photosynthetic autotrophs. There are some bacteria which can utilise chemical energy released during biological oxidation of certain inorganic substances to reduce carbon dioxide to carbohydrate. These bacteria are called **chemosynthetic autotrophs.**

This is found in many colourless bacteria and because they use chemical energy to reduce carbon dioxide, this process of carbohydrate synthesis is known as **chemosynthesis**.

Chemosynthesis may be defined as "the method of carbon assimilation when the reduction of CO_2 is carried out in darkness, utilising the energy obtained from oxidation of inorganic substances, such as H_2S and NH_3.

The common chemosynthetic forms are :

(i) Nitrifying bacteria. *Nitrosomonas* and *Nitrobactor* oxidise NH_3 to NO_2

(ii) Sulphur bacteria

(iii) Iron bacteria

(iv) Hydrogen and methane producing bacteria

Differences between photosynthesis and chemosynthesis

Chemosynthesis	Photosynthesis
1. It occurs only in colourless anaerobic bacteria	1. This process occurs in all green plants including green bacteria.
2. During this process CO_2 is reduced to carbohydrates without light and chlorophyll.	2. CO_2 and H_2O are converted into carbohydrates in the presence of light and chlorophyll.
3. Here chemical energy released during oxidation of inorganic substances is used up to synthesise carbohydrates.	3. Light energy is converted into chemical energy and stored in the form of carbohydrates.
4. No pigment molecule is involved and oxygen is not evolved.	4. Several pigments are involved and oxygen is evolved as a by-product.
5. No photophosphorylation takes place.	5. Photophosphorytion takes place i.e. ATP is produced.

11.8 CHEMIOSMOTIC SYNTHESIS

This is a process in which energy stored as a hydrogen ion gradient across a membrane is used to synthesise ATP from ADP and Pi. The enzyme which uses the energy is ATP synthase and the energy or power source is the difference in the concentration of H^+ ions on opposite sides of the membrane. The membrane is the inner membrane of the mitochondrion or the chloroplast. The word 'osmosis' in Greek means 'push' and here the flow of H^+ ions across the membrane provides the energy or push to ATP synthase enzyme which then catalyses the synthesis of ATP.

Chloroplasts use chemiosmosis to generate ATP during photosynthesis. The prokaryotes lack the organelles mitochondria and chloroplast to generate H^+ gradients across plasma membranes and cannot use it for ATP synthesis. Peter Mitchell won the Nobel prize in 1978 for proposing the chemiosmotic model for syntheis of ATP.

INTEXT QUESTIONS 11.3

1. List the internal factors that influence the rate of photosynthesis?

   ....

2. State the principle of limiting factor.

   ....

3. Give an example of chemosynthetic bacteria.

   ....

4. Why are prokaryotes not able to produce ATP by chemiosmosis?

   ....

WHAT YOU HAVE LEARNT

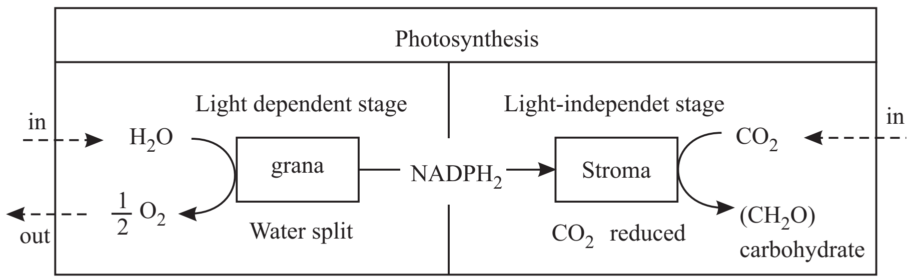
- Green plants are capable of synthesizing carbohydrates from CO_2 and H_2O in the presence of light, by the process of photosynthesis.
- During photosynthesis 'light energy', which is captured by the photosynthetic pigments (chlorophyll, carotenoids and xanthophylls) present in the chloroplasts, is converted into chemical energy.
- Photosynthesis in general is expressed by the following equation:

$$6CO_2 + 12H_2O \xrightarrow[\text{Light}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

- Photosynthesis comprises two sets of reactions:
- Light reactions: which take place in grana or thylakoids of chloroplasts only in the presence of light.
- Dark reactions: Which occur in the stroma of chloroplast and are independent of light, if products of light reaction are provided.
- Light energy is used for splitting of water, and production of ATP and $NADPH_2$ and actual reduction of CO_2 takes place in the dark reaction.
- Light reaction occurs with the help of two functional units, photosystem-I and photosystem-II.
- During light reaction phosphorylation of ADP to ATP may occur in two ways, cyclic and non-cyclic.
- During dark reactions CO_2 is accepted by Ribulose biphosphate (RuBP) and the first stable product. 3-PGA (3 phosphoglyceric acid) is formed, which by further cyclic reactions (Calvin Cycle) leads to the formation of carbohydrates as well as in regeneration of RuBP.

- In C_4 plants like maize, jawar, bajra, the primary acceptor of CO_2 is in mesophyll cells and the first detectable product of dark reaction is oxaloacetic acid (OAA), whereas in the bundle sheath cells CO_2 fixation occurs through. Calvin cycle.
- Occurrence of dimorphic chloroplasts in C_4 plants is known as "Kranz anatomy" and is characterized by the presence of a sheath of parenchyma cells around a vascular bundle (bundle sheath). Cells of this sheath have larger chloroplasts which lack grana and are filled with starch grains. In contrast mesophyll cells contain chloroplasts which are smaller but have well developed grana.
- Rate of photosynthesis is influenced by (i) environmental factors such as light, temperature, carbon dioxide concentration and water, and (ii) internal factors which include age of leaf, chlorophyll content and leaf anatomy.

A SUMMARY OF PHOTOSYNTHESIS



Light-dependent stage	Light independent stage
• occurs in the thylakoid membranes of the grana	• occurs in the stroma
• largely a photochemical change, requiring light energy	• a series of biochemical changes, each reaction catalysed by an enzyme
• light energy is converted to chemical energy in the form of ATP and $NADPH_2$; water is split into hydrogen and oxygen; hydrogen is combined in $NADPH_2$; oxygen gas is released as a byproduct	• carbon dioxide is converted to compounds such as carbohydrates (with the help of chemical energy of ATP and $NADPH_2$); the reactions of the light-independent stage are known as the Calvin cycle and C_4-pathway
• chlorophylls are grouped together in units of about 300 molecules (known as photosystems); two types exist, photosystems I and II	• carbon dioxide is combined with ribulose bisphosphate (the acceptor substance) and the product splits instantly into two molecules of glycerate 3-phosphate (GP, the first product of photosynthesis) in C_3-plants
• light energy absorbed by the photo-systems causes electrons from chlorophyll to be raised to a high energy level and to pass to $NADPH_2$; ATP is generated; water is split and provides the electrons	• CO_2 is reduced with the help of RuBP and Rubisco to a three-carbon sugar, triose phosphate; then, in a series of reactions, the acceptor molecule is regenerated and sugars, starch and other substances are formed from

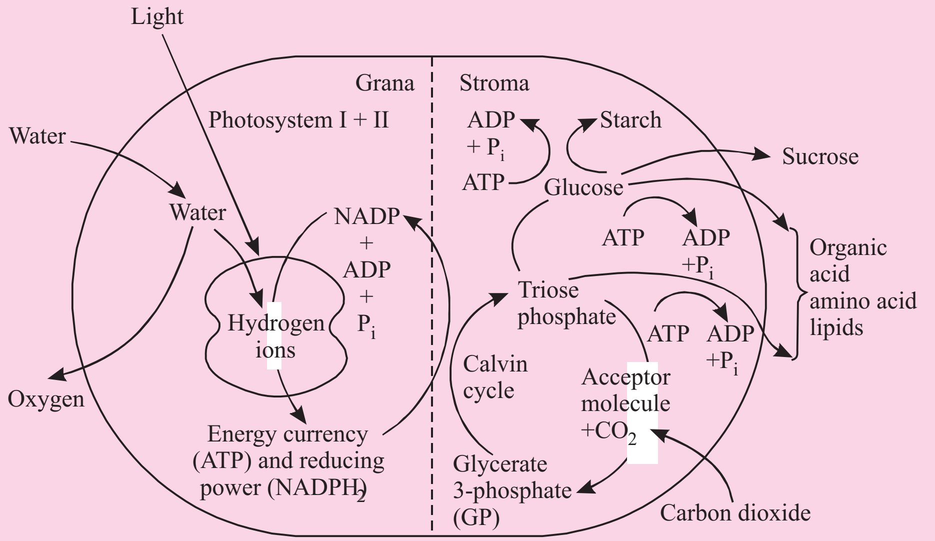
to the photosystem and the hydrogen for $NADPH_2$ production:

$$2H_2O + 2NADP \xrightarrow[\text{Chlorophyll}]{\text{Light}} O_2 + 2NADPH_2$$

$$ADP + P_i \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{ATP (considerable, but variable amount)}$$

triose phosphate:

$$3ATP + CO_2 + 2NADPH_2 \longrightarrow (CH_2O) + H_2O + 3ADP + 3P_i + 2NADP$$



TERMINAL EXERCISES

1. Describe briefly the process of photosynthesis.
2. Write short notes on (i) Ultrastructure of chloroplast and (ii) Pigments involved in photosynthesis.
3. What are accessory pigments? Why they are called so?
4. Mention path of electrons in the light reaction of photosynthesis.
5. What do you understand by photophosphorylation.
6. Discuss photolysis of water and its significance.
7. Describe the reactions occurring during dark reaction of photosynthesis.
8. Differentiate between C_3 and C_4 plants.
9. Differentiate between PSI and PSII.
10. What are the products of light reactions. What is the fate of these products?

11. Why is cyclic photophosphorylation called so?

12. What is Kranz anatomy?

13. Name the two carboxylase enzymes in C_4 cycle.

14. What are chemosynthetic autotrophs?

15. How does CO_2 concentration affect the rate of photosynthesis?

16. What is the effect of excess of oxyygen on the rate of photosynthesis?

17. Whether light absorbed by green plants, on global basis is limiting factor for photosynthesis or not! Explain

ANSWERS TO INTEXT QUESTIONS

11.1 1. (i) It is the process by which green plants produce food (carbohydrates) from simple substances like CO_2 and water in presence of sun light and chlorophyll.

(ii) $6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6H_2O + 6O_2$

2. (i) Chlorophylls and carotenoids.

(ii) Carotenoids and chlorophyll b

3. (i) Absorb it and then convert it into chemical energy.

(ii) Chlorophyll a and b

4. (i) Minimum in green and yellow light and maximum in blue and red light.

(ii) light energy; chemical energy

5. From photolysis of water in PSII

11.2 1. NADP acts as an electron acceptor and H^+ acceptor and finally, it gets reduced to $NADPH_2$.

2. It is called dark reaction because it can occur independent of light i.e. can occur both in light and in dark.

3. (i) Rubisco is a part of C_3 cycle and combines with CO_2 to produce a C_3 compound called PGA.

(ii) PEPCo is a part of C_4 path way and combines with CO_2 to form a C_4 compound called OAA.

Rubisco is present in the mesophyll cells of C_3 plants and in the bundle sheath cells of C_4 plants.

PEPCo is found only in mesophyll cells of C_4 plants.

4. See text
5. See text
6. C_4 plants have no photorespiration and thus there is no loss of additional carbon dioxide, due to breakdown of RuBP to Glycolate and CO_2.
7. (i) Photolysis of water

11.3

1. leaf age, chlorophyll content, leaf anatomy (size, internal structure, stomatal distribution)
2. See text
3. *Nitrosomonass* and *Nitrobacter*.
4. Because they are not able to maintain H^+ gradient across a membrane in the absence of membrane bound organelles in their cytoplasm.

12

RESPIRATION IN PLANTS

Two most important prerequisites of life are continuous supply of materials for growth of body and energy for carrying out various life processes. All systems, from a single cell to ecosystem, require energy to work. As you have already studied, light energy is converted into chemical energy by plants during photosynthesis and this energy is then stored in the bonds of complex molecules such as glucose, and starch. It is these complex molecules which are given the name 'food'.

However, the energy in the food has to be made available to the cells in a usable form. This is the role of respiration. Respiration is the process by which fats and protein's the energy stored in organic molecules is released by oxidation. This energy is thus made available to the living cells in the form of ATP (Adenosine Tri-Phosphate). The O_2 required for respiration is obtained from the atmosphere. ATP is the energy currency of the cell. This lesson covers various aspects of respiration in plants.

OBJECTIVES

After completing this lesson, you will be able to :

- *define respiration, fermentation, photorespiration and Respiratory Quotient;*
- *list the basic events of anaerobic respiration and write the chemical equation representing it;*
- *state the role of fermentation in industry;*
- *compare aerobic and anaerobic respiration;*
- *draw the flow-chart to show the basic steps in Kreb's Cycle;*
- *explain how energy is actually released and stored in the form of ATP in the cell;*
- *account for 38 ATP molecules that are released during aerobic respiration;*
- *list the factors that influence the rate of respiration and appreciate the usefulness of RQ value of different food items.*
- *to understand the Pentose Phosphate Pathway (PPP) which is the special feature of the microbes (bacteria and funagi) as well as the cells of the highly active tissues of the animals.*

12.1 RESPIRATION

Respiration is the stepwise oxidation of complex organic molecules and release of energy as ATP for various cellular metabolic activities. It involves exchange of gases between the organism and the external environment. The green as well as non-green plants obtain oxygen from their environment and return carbon dioxide and water vapour into it. This mere exchange of gases is known as **external respiration** or breathing in case of animals. It is a physical process.

The biochemical process, which occurs within cells and oxidises food to obtain energy, is known as **cellular respiration**. Various enzymes (biocatalysts) catalyze this process. The process by which cells obtain energy from complex food molecules depends upon whether or not oxygen is present in their environment and utilised. Respiration is termed **aerobic** when oxygen is utilized and **anaerobic** when oxygen is not utilized. In anaerobic respiration, organic molecules are incompletely broken down in the **cytosol** of the cell and only a small fraction of energy is captured as ATP for use by the cell. In aerobic respiration the reactions of anaerobic respiration are followed by an oxygen requiring process that releases much larger quantity of energy in the form of ATP. This occurs in the **mitochondria** of the eukaryotes and in the folded plasma membrane (mesosome) of the prokaryotes.

It is important for you to note that several common processes occur in both, anaerobic and aerobic respiration, such as,

- Oxidation reaction to release chemical energy from complex food.
- Use of coenzyme as carriers of hydrogen to remove the hydrogen from the organic molecule leading to reduction of the coenzyme and oxidation of the substrate. Most of the hydrogen carriers are NAD (nicotinamide adenine dinucleotide) and FAD (flavin adenine dinucleotide).These are later reoxidised, releasing energy for ATP synthesis
- Use of high-energy phosphate compounds like ATP for energy transfer.

The basic differences between the two forms of respiration are given in the Table 12.1.

Table 12.1 Differences between aerobic and anaerobic respiration.

Aerobic (Aero = Air)	Anaerobic (Anaero = No Air)
1. Takes place in the presece of oxygen.	1. Takes place in the complete absence of oxygen.
2. Leads to complete oxidation of organic substrate.	2. Incomplete oxidation of organic substrate takes place.
3. It is most common in higher organisms (both plants and animals).	3. Takes place in lower organisms such as bacteria, fungi, and in higher animals under limiting conditions of oxygen (e.g. in muscles when oxygen present is insufficient).

4. $C_6H_{12}O_6 \longrightarrow 6CO_2 + 6H_2O$ $+ 6O_2$ $+38$ ATP	4. $C_6H_{12}O_6 \longrightarrow$ 2Ethyl alcohol + $2CO_2$ +2 ATP (as in yeast) OR $C_6H_{12}O_6 \longrightarrow$ 2 Lactic acid + 2 ATP (as in muscles)
5. Takes place in the cytoplasm, and mitochondria in eukaryotes and plasma membrane in prokaryotes.	5. Takes place in the cytoplasm.

Coenzyme is a complex non-protein molecule which is temporarily bound to an enzyme and acts as a link between metabolic pathways, (series of biochemical reactions).

INTEXT QUESTIONS 12.1

1. How do plant and other organisms obtain energy for various activites such as growth?

   ....

2. Name the energy-rich molecule formed during respiration from food.

   ....

3. Give two differences between aerobic and anaerobic respiration.

   ....

12.2 EXTERNAL RESPIRATION/GASEOUS EXCHANGE

- In plants, the atmospheric air moves in and out by simple diffusion that takes place through,
  (a) the general body surface of the plant (stems, roots, fruits and seeds);
  (b) lenticels (openings in the bark of the tree trunk (Fig. 12.1);
  (c) stomata present in the leaves and young, green parts of the stems.

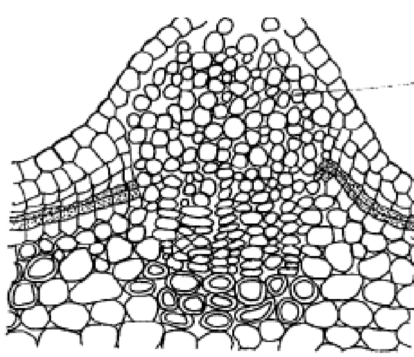


Fig. 12.1 Lenticels on the bark of a tree

- Plants do not need O_2 carrier (in contrast to animals) where O_2 is carried by blood). This is because O_2 requirement is less in plants than in animals since the plants have a large surface area (leaves) to absorb the required amount of O_2 through diffusion.
- From the atmosphere, gases enter the intercellular spaces inside the plants. As O_2 is utilized, more of it diffuses into the plant. Since CO_2 is being continuously formed, its concentration in tissue spaces becomes higher than in the surrounding air. As a result, it diffuses out of the plant, specially when it is not being used for photosynthesis.
- Can you explain as to why during the day, plants give out O_2 instead of taking it up for respiration?

In plants, O_2 released during photosynthesis in day time is made available for respiration. However, the rate of photosynthesis is higher than that of respiratin. Thus, plants give out excess O_2 in the daytime. However, these release only CO_2 at night as photosynthesis stops in the absence of sunlight. Animals give out CO_2 at all times.

INTEXT QUESTIONS 12.2

1. Name the surfaces that help plants in taking up oxygen from the atmosphere.

   ....

2. Name the process by which oxygen is taken up by the plants from the atmosphere.

   ....

3. Name the gases given out by plants during daytime and night.

   ....

4. Why do plants not have any special respiratory organs like animals? Give two reasons.

   ....

12.3 CELLULAR RESPRIATION

Oxygen that is absorbed in the body, is used to oxidize the nutrients, viz., glucose, amino acids and fatty acids completely producing CO_2, water and energy. It occurs within the cells and tissues. Observe Fig. 12.2 and identify the steps of cellular (aerobic and anaerobic) respiration. Note that the first stage in all these pathways is **glycolysis**.

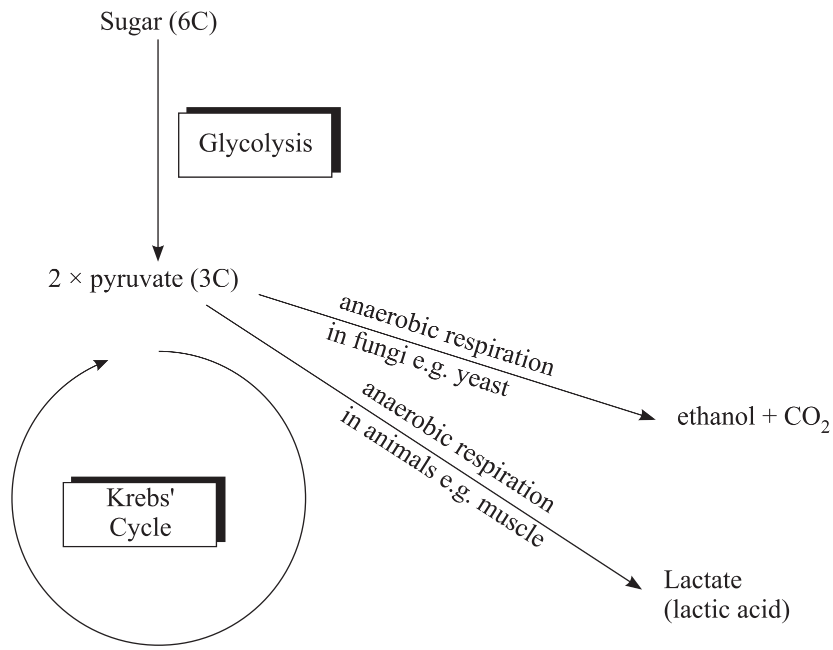


Fig. 12.2 Pathways in cellular respiration

12.3.1 Glycolysis (Also known as-Embden-Meyerhof-Parnas Pathway)

Whether or not the oxygen is available in the cells, the breakdown of glucose is initially always anaerobic. It is common to both aerobic and anaerobic respirations.

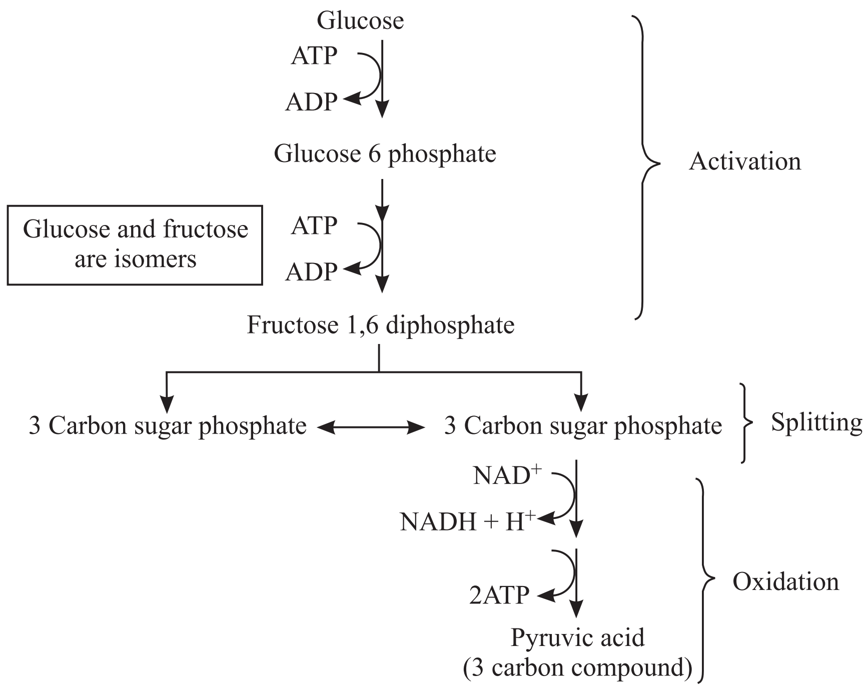
It involves oxidising **glucose** (6-carbon compound) to two molecules of **pyruvic acid** through a series of enzymatically controlled reactions occurring in the cytosol. Initial substrate is glucose (either from photosynthesis as in plants or from carbohydrate digestion as in animals).

Glycolysis may be subdivided into **3 major phases:**

1. Phosphorylation of glucose to fructose 1,6 diphosphate. This is activation of glucose and 2ATPs are used.
2. Splitting of this compound into two 3- carbon sugar phosphates, which are interconvertible. Note that this is the origin of the term **glycolysis** meaning splitting of glucose.
3. Oxidation by dehydrogenation. Each 3-C sugar phosphate is oxidized by removal of hydrogen, making a reduced NAD that is NADH and production of 2ATPs.

> This group of reactions is believed to be one of the first energy capturing reactions which evolved about three billion years ago in ancient bacteria and today it occurs in virtually all cells of all forms of life.
>
> $$ATP \longrightarrow ADP + Pi + 30.6\ kJ$$

The balanced equation is:



- Glucose + 4ADP + 4Pi + 2NAD $\longrightarrow$ 2Pyruvic acid + 4ATP + 2NADH
- Two molecules of ATP were used up in the initial steps of glycolysis. Thus, the net gain of ATP during glycolysis is 4 – 2 = 2 ATP. Also, 2NADH + H^+ are produced.
- Thus, we see that only a small amount of energy is released at the end of glycolsis.

12.3.2 Fermentation

Further oxidation of Pyruvic acid requires O_2 (as you will study soon). It then enters mitochondria for aerobic respiration.

Under anaerobic conditions (or insufficient supply of O_2) microbes, plants and animals carry out fermentation.

Fermentation involves **reduction** of pyruvic acid to **ethyl alcohol** and $\mathbf{CO_2}$ (as in yeast) or to **lactic acid** (as in muscle cells of animals) and oxidation of NADH to NAD^+. Thus, NAD is regenerated which can be used in glycolytic pathway and production of 2 ATPs can continue under anaerobic conditions. (Refer to the figure 12.3). Note that there is no further release of ATP during fermentation.

> Although you are more familiar with the term fermentation in the context of alcoholic fermentation it is now being used for the anaerobic pathway after the production of pyruvic acid, in glycolysis in cytosol.

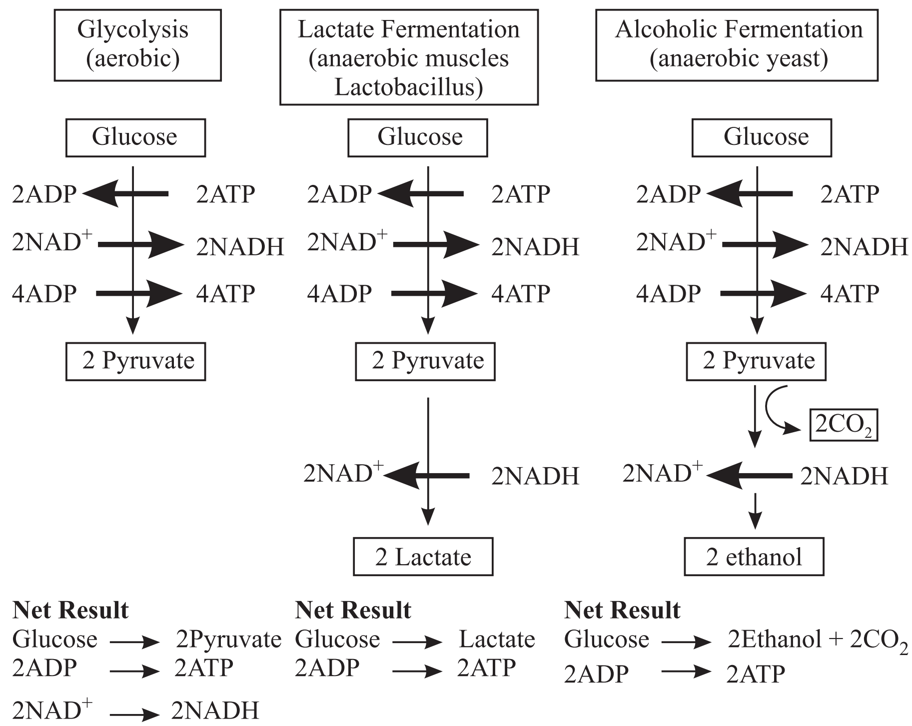


Fig. 12.3 Pathways of anaerobic respiration

Significance of fermentation

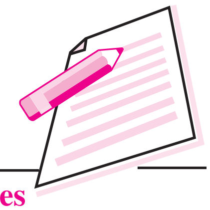
Fermentation has a number of industrial applications. It is made use of on a large scale in certain industries. Micro-organisms like the different strains of bacteria and yeast are cultured in very large numbers and used for various purposes.

1. In bakeries for preparing bread, cakes and biscuits.
2. In breweries for preparing wine and other alcoholic drinks.
3. In producing vinegar and in the tanning and curing of leather.
4. Ethanol is used to make gasohol, a fuel that is used for cars in Brazil.
5. In everyday life, fermentation is used while making *idli*, *dosa, bhatura* and *dhokla*. The kneaded flour or *maida* left for some hours in warm environment becomes somewhat spongy (leavening). This is because of fermentation by the bacteria that begin to grow in it. As carbon dioxide escapes, it causes leavening. Fermentation products give a typical flavour and taste to these items.

Do you know why muscles pain during prolonged exercise? This is due to accumulation of lactic acid under anaerobic condition.

12.3.3 Fate of pyruvic acid in aerobic respiration

- You have already learnt how glucose is converted into 2 molecules of pyruvic acid in the cytoplasm of a cell during glycolysis.



- In the presence of oxygen, pyruvic acid enters the mitochondria and is decarboxylated (removal of CO_2) and dehydrogenated (removal of H) to acetyl CoA. **Acetyl CoA** is thus the connecting link between glycolysis and the next series of reactions that yield more energy in the form of ATP. Acetyl CoA can also be generated from fats and proteins.

Krebs' Cycle or the citric acid cycle

- Acetyl CoA is the molecule entering the Krebs' Cycle taking place in the matrix of the mitochondria.
- Details of this cycle were worked out by Sir Hans Krebs in the 1930s. It is also known as tricarboxylic acid cycle or TCA cycle.
- Steps of the Krebs' Cycle are as follows, (*See* Fig. 12.4)

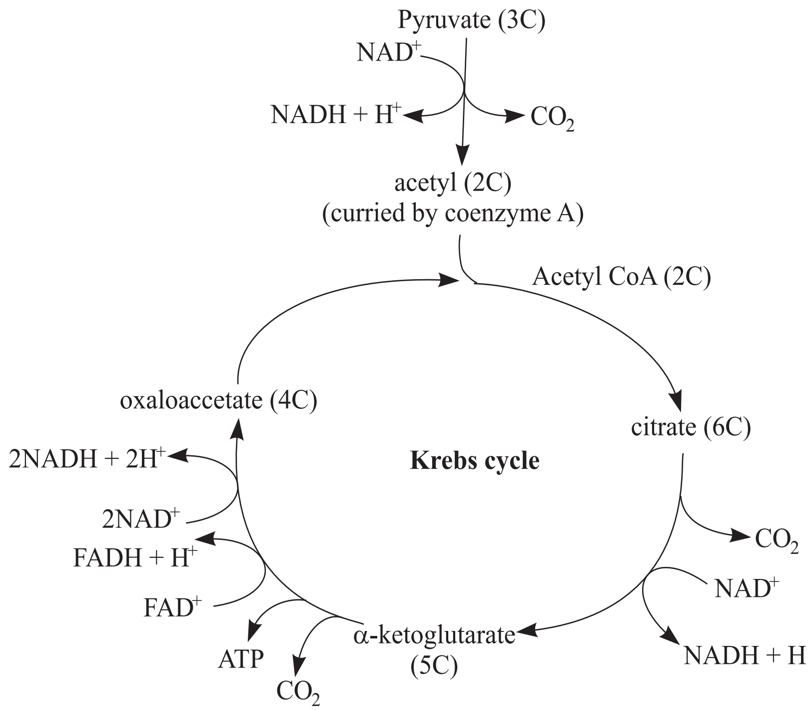


Fig. 12.4 Kreb's Cycle (simplified)

Summary of this phase in respiration is

$$2\text{Pyruvic acid} + 8NAD + 2FAD + 2ADP \longrightarrow 6CO_2 + 8NADH + 2FADH_2 + 2ATP$$

H-carrier NAD and FAD are derived from vitamin B complex and are known as coenzymes

- Acetyl group (2 carbon) enters the cycle by combining with **oxaloacetate** (4 carbon), to form **citrate** (6 carbon). This initiates citric acid cycle.
- As acetyl group passes round the cycle, the 2 carbon atoms are lost in CO_2 in two decarboxylation reactions, and hydrogen is added to hydrogen carriers in four dehydrogenation reactions, resulting in a total of 3 $NADH_2$ and 1 $FADH_2$ molecules.

- One molecule of ATP is also made directly for every turn of the cycle. (Remember that two acetyl groups were made from one glucose molecule. As such two turns of the cycle occur per glucose molecule used). Oxaloacetate is regenerated at the end of the cycle ready to accept another acetyl group.
- Thus, at the end of the Citric Acid Cycle, there are a total of 10NADH and $2FADH_2$ (2NADH from glycolysis).
- Note that all the hydrogen atoms from the original glucose are now on hydrogen carriers, NAD and FAD.

These hydrogen carriers enter the next phase known as the respiratory chain or Electron-Transport-Chain (E.T.C.) for further release of energy.

The Respiratory Chain or Electron Transport Chain (E.T.C.) or Oxidaive-Phosphorylation

- The hydrogen carriers now move to the inner membrane of the mitochondrion. This membrane has folds called *cristae*, which increase its surface area.
- The hydrogen ions carried to the cristae undergo stepwise oxidation using molecular oxygen and energy is released in a series of small steps. Some of this energy is used to make ATP from ADP and inorganic Phosphate (P_i). This is called *oxidative phosphorylation*.
- During these reactions, the hydrogen is split into H^+ and electrons (e^{-1}), which are accepted by a series of hydrogen or electron carriers ending with oxygen. This series of carriers constitute the **respiratory chain** (Fig. 12.5).

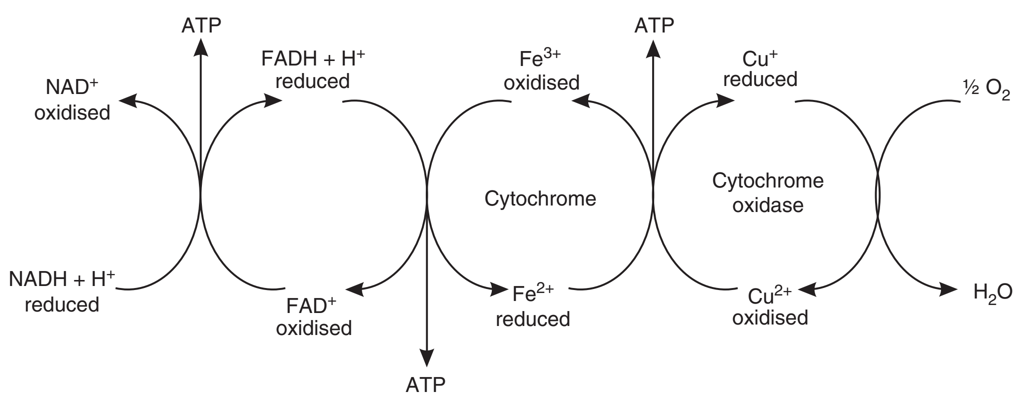


Fig 12.5 Respiratory Chain (Oxidative Phosphorylation)

- Hydrogen or electrons at a higher energy level are passed from one carrier to the next, moving downhill in energy terms, until they reach oxygen, the final acceptor of electrons which as a result is reduced to water.
- At each transfer level, some energy is released as heat and in some of the transfers this is used for the formation of ATP.
- The final step involves cytochrome oxidase enzyme, which hands over the electrons to the H^+ before being accepted by oxygen to form water.
- For each $NADH_2$ that enters the respiratory chain, 3 ATP can be made but for each $FADH_2$, only 2 ATP can be made. Can you guess why? This is owing to the facts that $FADH_2$ enters the respiratory chain at a lower energy level in the chain of reactions.

Substances like carbon monoxide and H_2S act as poisons since they block the H-transfer system and stop ATP generation.

Overall budget for aerobic respiration of one glucose molecule

See table no: 12.2

	CO_2	ATP	$NADH+H^+$	$FADH_2$
Glucolysis	-	2	2	-
Pyruvate-> Acetyl coA	2	-	2	-
Krebs cycle	4	2	6	2
Total	$6CO_2$	4ATP	10 $NADH+H^+$ 10×3=30 ATP	2 $FADH_2$ 2×2=4 ATP

Total No. of ATP mols = 38

* Remember that two turns of the Krebs' Cycle take place per glucose molecule as at the end of glycolysis two pyruvic acid molecules are formed each of which separately enters the Krebs' Cycle.

* According to some biologists, the total numbr of ATP molecules produced in cell respiration after oxidatrion of one glucose molecule is 36 and not 38 because two $NADH_2$ molecules produced in glycolysis in cytoplasm, are theoretically oxidised through electron-transport system in mitochondrion. In the mitochondrion, on the other hand, the matrix is already having higher concentration of $NADH_2$ molecules. Thus, two $NADH_2$ molecules produced in glycolysis, have to enter the mitochondrion against the Concetration Gradient, for oxidation, and for this process, two ATP-molecules would be consumed. For this reason, the net amount of ATP molecules per glucose oxidation by aerobic respiration, should be 36. However, since bacteria do not have mitochondria; the number of ATP molecules produced per glucose molecule oxidised by prokaryotes,

should be considered as 38.

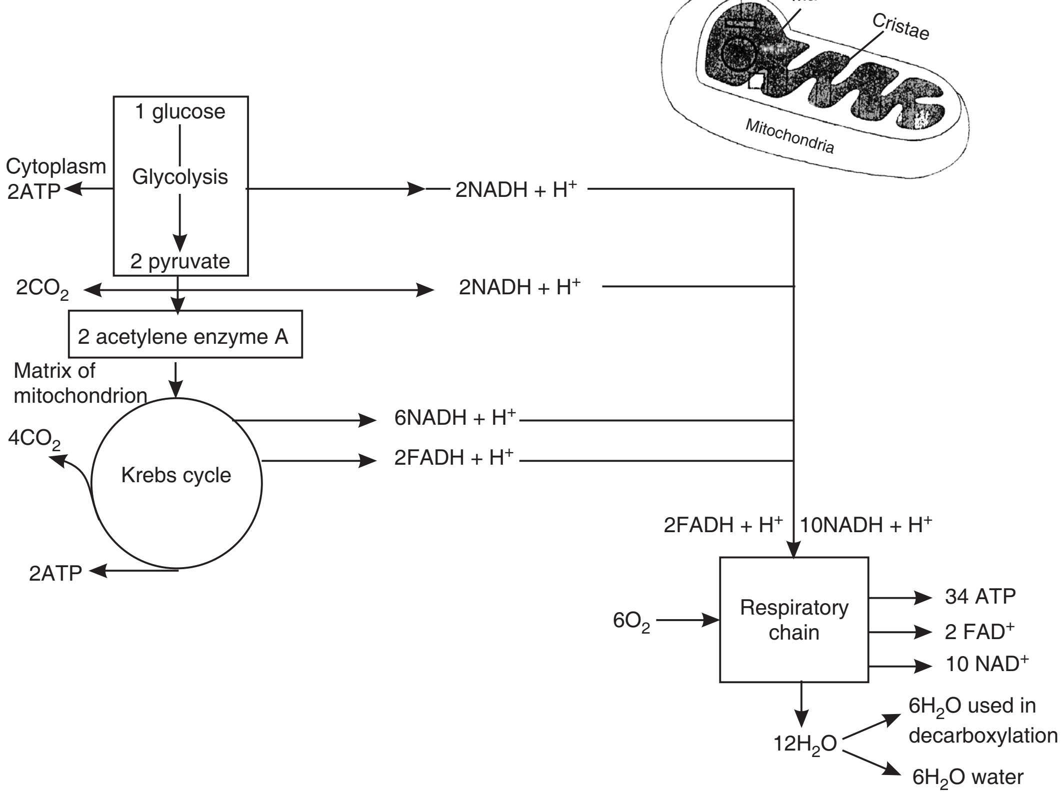


Fig 12.6 Summary of Aerobic respiration.

12.3.4. Significance of Krebs' Cycle and Acetyl CoA

1. It is the major pathway to release reduced coenzymes and energy, in a controlled manner.
2. It is the common pathway for oxidative breakdown of glucose, (carbohydrates), fatty acids and amino acids. The fatty acids undergo β oxidation to produce acetyl CoA and amino acids from proteins enter Krebs' Cycle after deamination (removal of $-NH_2$ group) of amino acids.
3. Krebs' Cycle provides series of intermediate compounds needed for the synthesis of other biomolecules like amino acids, nucleotides, chlorophyll, and fats.

12.3.5 Amphibolic Pathway

Respiration is necessary for the survival of all living beings. In respiration, oxygen is utilised and carbon dioxide given out. The green plants carry out photosynthesis during which CO_2 and H_2O are utilised in the presence of sunlight to synthesize starch and energy. As such, photosynthesis is the building up or anabolic pathway whereas respiration is a breaking down or catabolic process in which glucose is oxidised to yield CO_2, H_2O and energy. The two pathways occurring together constitute the amphibolic pathway (amphi = two).

The light intensity at which photosynthesis just compensates for respiration is called **Compensation Point**. In other words, in a green plant at the compensation point, amount of CO_2 consumed during photosynthesis is equal to the amount of CO_2 generated through respiration.

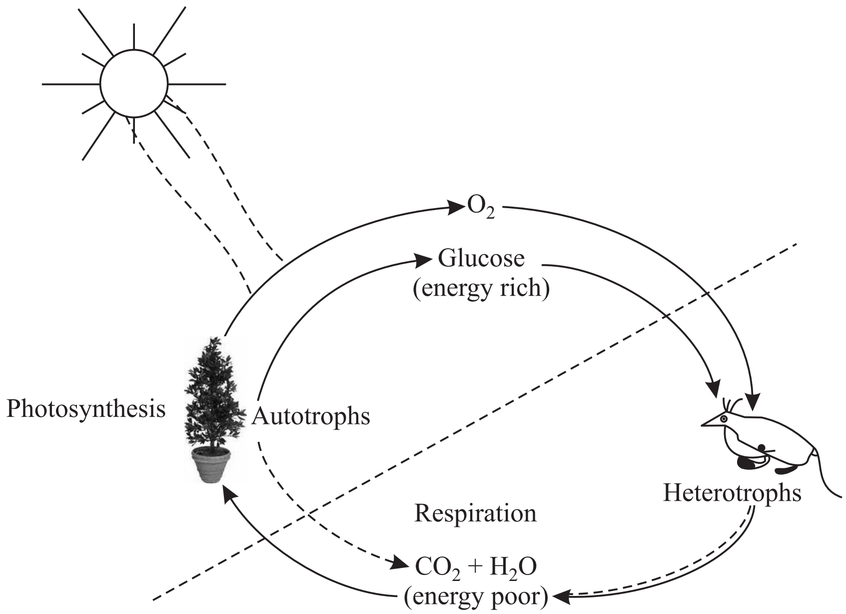


Fig. 12.7 Anaerobic respiration in germinating seeds

INTEXT QUESTIONS 12.3

1. Why is pyruvic acid converted into alcohol or lactic acid during fermentation?

   ....

2. Why is there less release of energy during anaerobic respiration?

   ....

3. List the three phases of aerobic respiration of glucose. Where in the cell do these reactions take place?

   ....

4. What is the role of O_2 in aerobic respiration?

   ....

5. Name the substrate and products of Krebs' Cycle.

   ....

6. How do fatty acids enter Krebs' Cycle?

   ....

7. When the amount of CO_2 uptake during photosysthesis is equal to the amount of CO_2 generated through respiration, it is called ....
8. What is amphibolic pathway?

   ....

12.4 RATE OF RESPIRATION AND FACTORS AFFECTING IT

The rate of respiration can be measured by the amount of CO_2 released per unit time. As expected, it varies in different organs and with age.

In general the factors which affect respiration include **internal factors** such as minerals, structure of respiratory tissue or organ, the activity of the respiratory enzymes and the type of substrate; and **external factors** such as oxygen, water, and temperature.

(a) **Type of substrate**-Respiratory substrate may be carbohydrate, protein or fats. The kind of substrate being oxidized can be determined by measuring the **Respiratory Quotient** of the respiratory tissue or oxygen. What is respiratory quotient or R.Q?

$$\text{R.Q} = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ consumed}}$$

> For carbohydrates, $CO_2/O_2 = 1$ as in the stem and roots.
>
> For protein, $CO_2/O_2 < 1$ as in protein-rich seeds like pulses.
>
> For fat and oils $CO_2/O_2 > 1$ as in the oil-containing seeds e.g. mustard.
>
> As for fats RQ > 1 since more energy is released per mol of fat than per mol of glucose.

(b) **Temperature -** The temperature between 30-35°C is most suitable for respiration. Can you guess why? This is because the enzymes can work best in this range. Respiration is reduced beyond 50°C and also at very low temperatures (0-10°C).

(c) **Oxygen**-the rate of respiration increases with rise in oxygen concentration. As O_2 concentration increases from zero, the rate of respiration increases. However, beyond a limit the rate of increase falls.

(d) **Carbon dioxide**–rate of respiration decreases if CO_2 is allowed to accumulate surrounding the respiratory tissue.

(e) **Water**–respiration is very slow if the water content of the protoplasm is low as in dry, matured seeds. Dormant seeds show very low rate of respiration. It water is supplied to dry seeds, respiration starts immediately.

INTEXT QUESTIONS 12.4

1. What is the R.Q. for carbohydrates and fats?

   ....

2. What is the effect of high concentration of O_2 on respiration?

....

3. What is the ideal temperature for the process of respiration ?

....

4. Define R.Q.

....

5. What is the limiting factor of respiration in dry seeds?

....

12.5 PHOTORESPIRATION

- Your have aready studied that during dark reaction of photosynthesis, the enzyme RUBISCO catalyses the carboxylation of RUBP :

$$\text{RUBP} + CO_2 \xrightarrow{\text{RUBISCO}} \text{2PGA (Phosphoglyceraldehyde)} \longrightarrow \text{Calvin Cycle}$$

- This enzyme also has very high affinity for O_2. It can therefore, catalyze the reaction of O_2 with RUBP (oxygenation).

- The respiration that is initiated in chloroplast and occurs in the presence of light and high concentration of O_2 (and low CO_2) is called photorespiration :

$$\text{RUBP} + O_2 \xrightarrow{\text{RUBISCO}} \underset{\substack{\downarrow \\ \text{Calvin Cycle}}}{\text{2PGA}} + \text{1 Phosphoglycolate}$$

Thereafter, the phosphoglycolate undergoes series of reactions in **mitochondria and peroxisomes.** 2 molecules of phosphoglycolate ultimately produce 1 molecule of PGA and 1 molecule of CO_2. Note that there is no ATP production here, unlike respiration.

- This occurs because RUBISCO anzyme has the same active site for both CO_2 and O_2.

- Oxygenation of RUBP in presence of oxygen leads to a loss of about 25% carbon fixed by plants during the dark reaction.

- Use: Protects the plants from photo-oxidative damage by utilising part of the solar energy which would otherwise damage the plant pigments.

INTEXT QUESTIONS 12.5

1. Name the products that are formed when RUBP combines with O_2. Name the enzyme that is responsible for this reaction.

   ....

2. Give one point of difference between respiration and photorespiration.?

   ....

3. State the conditions under which photorespiration occurs?

   ....

12.6. PENTOSE PHOSPHATE PATHWAY OR HMP-PATHWAY

In microbes (bacteria and some fungi) used for Industrial production of commercial products such as antibiotics and in highly metabolically active tissues of animals, most efficient respiratory pathway has been discovered. It is called **PPP or Pentose Phosphate Pathway or Hexose-Monophosphate Shunt Pathway** or **Direct Oxidation of Glucose-pathway**. The site of this respiratory pathway is cytosol and it does not require ETC (electron transport chain) or the mitochondrion.

It this pathway, when a molecule of glucose enters the respiratory process, it is phosphorylated to Glucose-6-Phosphate by consumption of one ATP-molecule. This Glucose-6-P molecule, meets a group of 5 glucose-6-P molecules in the cytoplasm, which in the presence of dehydrogenase and 6 NADP get oxidized to 6 Phosphoglucomutase molecules, producing 6 $NADPH_2$ molecules. In the next reaction catalyzed by dehydrogenase and decarboxylase, six-phosphogluconate molecules, get oxidised to six molecules of pentose sugar, Ribulose-5P; producing $6CO_2$ (that diffuse in air) and 6 more NADP get reduced to 6 $NADPH_2$. Thus, in this respiratory pathway a glucose molecule is broken down to 6 CO_2 + $12H_2$ (as part of 12 $NADPH_2$), side by side producing 6 molecules of pentose sugar (Ribulose-5 phosphate) which is utilized for regeneration of 5 molecules of Glucose-6-P through a long chain of intermediate compounds produced in Calvin Cycle of photosynthesis to restart another cycle of glucose-oxidation.

You would observe that in this pathway if 12 $NADPH_2$ molecules produced within two steps of glucose-oxidation, are allowed to enter oxidative phosphorylation (ETC), 36 ATP molecules would be produced. If we deduct one ATP, consumed in first step of conversion of Glucose to Glucose-6P, a net amount of 35ATP molecules would be available as respiratory energy produced by complete oxidation of one glucose molecule within two chemical reactions to $12H_2$ and $6CO_2\uparrow$

PPP is so-called because after complete oxidation of one glucose molecule to $6CO_2$ + $12NADPH_2$; a side product is a pentose phosphate sugar i.e., ribulose-5-Phosphate. If glucose molecules keep entering this pathway, a large number of pentose sugars would be formed. This sugar, on conversion to ribose-5-P, would act as raw material for RNA synthesis. If ribose-5-P loses one O-atom, it would change to deoxyribose-5P, that can act as raw material for DNA-synthesis. However, in general, 6 molecules of ribulose-5P, through large number of intermediate compounds (such as erythrose, sedoheptulose, and hexoses), regenerate 5 molecules of Glucose-6-P, responsible for new cycle of Pentose Phosphate Pathway.

PPP is also called HMP-pathway because the raw material for glucose oxidation is Glucose-6-P which is a hexose sugar produced after consuming only one ATP in contrast to Glycolytic pathway, where two ATP-molecules are consumed during the respiratory-oxidation of Glucose under aerobic condition.

ACTIVITY I

To demonstrate anaerobic respiration in germinating seeds

Take eight or ten water-soaked pea seeds with the seed coats removed and push them into the mouth of a test tube filled with mercury and invert it in a beaker of mercury. The pea seeds float on the top and are completely surrounded by mercury. After about two days there is a fall in the level of the mercury because of gas liberation. If potassium hydroxide (KOH) is introduced into the test tube then it is found that KOH floats up through the mercury and on coming in contact with the gas, makes the level of mercury to rise up again. Now can you say why does this happen? KOH absorbs the carbon dioxide gas liberated by the seeds. Therefore this experiment demonstrates the anaerobic respiration (See Fig. 12.8) wherein, CO_2 is process of evolved due to anaerobic respiration of seeds soaked in water.

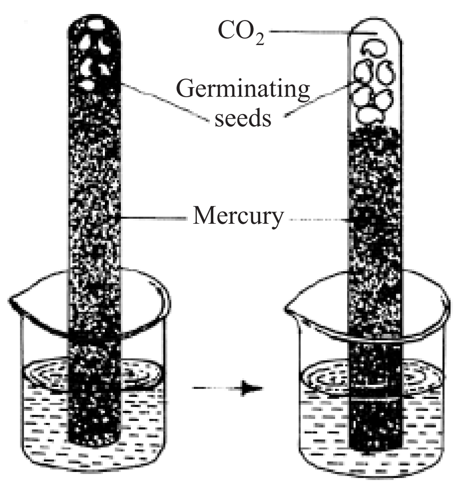


Fig. 12.8 Anaerobic respiration in germinating seeds

ACTIVITY II

Anaerobic respiration in yeast

Procedure : Take a pinch of dry baker's yeast (in water) or few ml of yeast suspension used in a bakery. Add this to 10 ml of 10% glucose solution in test tube A. Cover the surface of the liquid in the tube with oil to prevent contact with air. Close the test-tube tightly with a cork. Take a double bent glass delivery tube with one end small and other end long (See Fig. 12.9).

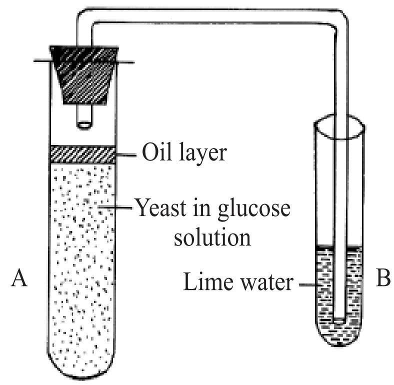


Fig. 12.9 Anaerobic respiration in yeast.

Insert the short end of the glass tube through the rubber-cork stopper so that it remains exposed to the air inside the tube A. Insert the other end of the tube into the limewater containing test tube B, as shown in the figure.

Place test tube A in warm water 37-38°C in a beaker. Observe that lime water gradually turns milky indicating evolution of CO_2 from yeast preparation. Also note that the level of the limewater in the delivery tube does not rise, showing that there is no fall in volume of gas in test tube A and therefore no utilization of O_2 by yeast. Keep the experimental set up for one day. Open the stopper of tube A and smell. Do you notice the smell of alcohol? Can you name the alcohol and write the equation for the alcoholic fermentation

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 2ATP$$

ACTIVITY I

You can use similar set-up as in activity II to demonstrate aerobic respiration in yeast. Make the following changes :

1. Replace the test tube A with a large conical flask so that it has sufficient space left above the glucose solution with yeast.
2. The surface of the solution should not be covered with oil to permit easy contact with air.

3. Observe that lime water turns milky in this experiment too, indicating evolution of CO_2. Also note that the level of H_2O in the delivery tube B also rises indicating a fall in gas volume in tube A. How do you explain this? Oxygen is utilized by the yeast, and you will not smell alcohol after the reaction in the test tube A

Note that the yeast grows both in aerobic and anaerobic conditions but better under aerobic conditions. The secret of brewing is to regulate the conditions very strictly.

WHAT YOU HAVE LEARNT

- All living organisms require energy. Oxidation of food molecules provides this energy.
- Respiration involves (i) external respiration or gaseous exchange, and (ii) cellular respiration.
- Anaerobic respiration is the process of incomplete oxidation and produces only 2 molecules of ATP whereas the aerobic respiration is a process of complete oxidatin with production of 38 molecules of ATP, per molecule of glucose-oxidised.
- Aerobic respiration occurs in three main steps viz. Glycolsis; Krebs' Cycle; and electron trasport chains (or oxidative phosphorylation).
- Steps of glycolysis are common between aerobic and anaerobic respiration.
- Glycolysis occurs in cytoplasm and Krebs' Cycle and ETC in mitochondria.
- Alcoholic fermentation has many industrial applications.
- Young parts of the plants show higher rate of respiration.
- Factors like type of substrate, temperature, oxygen and amount of available water influence the rate of respiration.
- RQ value is important in identifying the kind of substrate used in respiration.
- Photorespiration occurs in plants during intense light and low level of carbon dioxide. There is no net gain of ATP. It protects the chlorophyll pigments from photo-oxidation, when light intensity is very high.

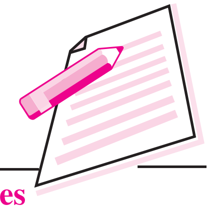
TERMINAL EXERCISES

1. Define respiration
2. What is the role of O_2 in electron transport chain (ETC)?
3. How many molecules of ATP are released when a molecule of glucose is oxidised to
   (a) CO_2 and H_2O?
   (b) Ethyl alcohol and CO_2?

4. Write the equation for aerobic respiration.
5. Name the end products of electron transport chains.
6. Respiration is a continuous process in green plants. Then why is it that they give out O_2 and not CO_2 during the day?
7. What is the site for
   (a) Glycolysis,
   (b) Krebs Cycle,
   (c) ATP generation by oxidative phosphorylation?
8. What is the fate of pyruvic acid in the (a) presence, and (b) absence of oxygen? Write the equations representing the processes, that take place in (a) & (b).
9. What is the significance of stepwise oxidation of organic molecules instead of one step reaction?
10. What is the significance of photorespiration?
11. List the substrates that enter and the products produced in
    (a) Glycolysis
    (b) Krebs Cycle
12. How is yeast useful in industry? Give any three examples.
13. How does exchange of respiratory gases take place in plants
14. Define RQ. What is its significance?
15. Mention the significance of TCA cycle.
16. Why does fermentation yield less energy than aerobic respiration?
17. List any 2 important contributions of PPP in a cell.
18. What are the three major phases of glycolysis?
19. What is the importance of Krebs' Cycle?
20. Differentiate between aerobic and anaerobic respiration
21. Why is photorespiration a wasteful reaction?
22. What is respiratory chain or ETC? What is its significance?
23. Discuss the site of Pentose Phosphate Pathway in a cell.

ANSWERS TO INTEXT QUESTIONS

12.1 1. The green Plants convert solar energy to chemical energy and store it in the form of complex organic molecules. During respiration, they are oxidised and large amount of energy is released. This is stored as ATP. Plants use this ATP for metabolic activities.



Notes

2. In the form of ATP

3. Please see text.

12.2 1. Gaseous exchange takes place through the general body surface of the plants; through the stomata; and the lenticels.

2. Diffusion

3. Oxygen; carbon dioxide

4. (a) They have a large surface area to allow exchange of gases from and (b) their requirement of oxygen is much less.

12.3 1. In the presence of O_2, it is completely broken down to simple forms such as CO_2 and H_2O.

$$2\text{Pyruvic acid} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 30\text{ATP}$$

(8ATP are obtained from glycolysis)

In the absence of O_2 they carry out alcoholic fermentation.

$$2\text{Pyruvic acid} \longrightarrow 2\text{Ethyl alcohol} + 2CO_2$$

2. This is becausse organic molecules are only partially oxidised in anaerobic respiration and much of the energy remains in the end products such as alcohol or lactic acid.

3. Glycolysis-in cytosol

Krebs' Cycle-matrix of mitochondria

E.T.C.-inner membrane of mitochondria

4. O_2 acts as the terminal acceptor of electrons and H_2, removed from the glucose molecule and gets reduced to H_2O.

5. Substrate- Acetyl CoA

Product-2 CO_2, 3 $NADH_2$, 1 $FADH_2$, 1 ATP

6. Fatty Acid undergoes β oxidation and produces acetyl CoA. This can enter the Kreb's Cycle

12.4 1. R.Q. is 1

2. Rate of respiration increases up to a point and beyond this point its rate of increase falls.

3. 30-35°C

4. It is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration. It gives us an idea of the kind of substrate used for respiration.

5. Water for hydration of respiratory enzymes.

12.5 1. Products are1 P.G.A. and 1 Phosphoglycolate

2.

Respiration	Photorespiration
1. Occurs in cytoplasm and mitochondria	1. It involves 3 organelles chloroplast, mitochondria peroxisome
2. Substrate is glucose	2. Substrate is RUBP
3. ATP, CO_2 and H_2O are given out as products	3. The products are only CO_2 and P.G.A. and no ATP is generated
4. Takes place in C_3 as well as C_4-plants	4. Takes place in green plants (C_3-plants)
5. Occurs at both day and night	5. Takes place under high O_2 and low CO_2 and high temperature. Therefore occurs only during the day.
6. Makes energy available for metabolic activities.	6. It is a wasteful reaction. Its only use is that it prevents photo-oxidative damage of photosynthetic pigments in the green-C_3-plants. (any one)

3. (a) Light
   (b) High concentration of O_2
   (c) Low concentration of CO_2

13

NUTRITION AND DIGESTION

Plants manufacture their own food by photosynthesis, but animals including humans have to take in ready made food. Most part of such food consists of complex organic molecules (carbohydrates, proteins and fats) which have to be broken down into simpler forms before they can be absorbed into the body. Such breaking down of the food and subsequent absorption of food constituents occurs inside the digestive tract (alimentary canal). The digestive tract together with the associated glands constitute the digestive system.

OBJECTIVES

After studying this lesson, you will be able to :

- *define the term nutrition and mention types of nutrition;*
- *draw a labelled diagram of the alimentary canal of cockroach and of humans;*
- *describe the steps involved in the nutrition of humans viz., ingestion, digestion, absorption, assimilation and egestion;*
- *differentiate between intracellular and intercellular digestion;*
- *tabulate the organs of digestion, the enzymes they secrete, the substrates acted upon by enzymes and the end products formed.*
- *explain the process of food absorption in certain regions of digestive tract;*
- *explain briefly the role of hormones in digestion.*
- *list some digestive disorders and mention their cause, symptoms and remedies.*

13.1 NUTRITION AND DIGESTION

Our food contains a number of organic and inorganic constituents to meet the requirements of our body. These food constituents must be digested to be utilized by our body. The process by which organisms obtain and utilize food for their growth, development and maintenance is called **nutrition** and the chemical constituents present in the food are called **nutrients**. On the other hand, **digestion** is the breaking down of complex constituents of food by enzymes into simpler soluble forms that can be absorbed and utilised by the cells of the body.

In this lesson you will study the various modes of nutrition, types of digestion, the process of digestion of food, and its absorption and assimilation in humans. The nutritional role of food constituents will be discussed in lesson 27.

Types of nutrition

There are mainly two types of nutrition **autotrophic nutrition** and **heterotrophic nutrition**.

Nutrition

- Autotrophic nutrition
  (Auto : self, trophos : food)
  Green plants and certain bacteria manufacture their own food (organic substances) from inorganic substances (CO_2 and H_2O) using energy from sunlight.
- Heterotrophic nutrition
  (Hetero : different, trophos : food)
  Food (organic and inorganic substances) obtained by feeding on other organisms.
  - Holozoic
    Organisms engulf the food into the body, digest it and absorb the soluble products of digestion, eg., humans.
  - Saprotrophic
    Ogranisms secrete digestive enzymes on to dead organic material and absorb the products of digestion, eg., certain bacteria and fungi.
  - Parasitic
    Food is derived from other living organisms by living on or inside their body eg., certain bacteria,roundworm, tapeworm, *Cuscuta*, etc.

There are Five Major Steps in Animal Nutrition (Holozoic nutrition)

The food we take contains highly complex nutrients like **protein, carbohydrates** and **fats**. These substances cannot be utilized as such by our body. These have to be broken down into simpler and smaller molecules before they can enter into the cells. Proteins must be broken down into amino acids, carbohydrates into glucose, fats into fatty acids and glycerol. Amino acids, glucose, fatty acids and glycerol are simpler substances, and can be directly utilised by our body. This breakdown of complex food constituents and their absorption is accomplished by the **digestive system**. The processes involved in nutrition are :

(i) **Ingestion :** Taking in food, chewing or sucking it and swallowing.

(ii) **Digestion :** Conversion of complex food into simpler absorbable form.

(iii) **Absorption :** Absorbing digested food from the gut to reach the body tissues.

(iv) **Assimilation :** Utilization of digested food nutrients by the body tissues.

(v) **Egestion :** Removal of undigested and unabsorbed food from the body.

13.2 TWO TYPES OF DIGESTION (Intracellular and extracellular)

Generally two types of digestion are seen in heterotrophs :

(a) Intracellular (b) Extracellular

13.2.1 Intracellular Digestion (Intra = inside)

All the five steps of nutrition occur inside the cell itself, as in *Amoeba*, *Paramecium* and other unicellular animals.

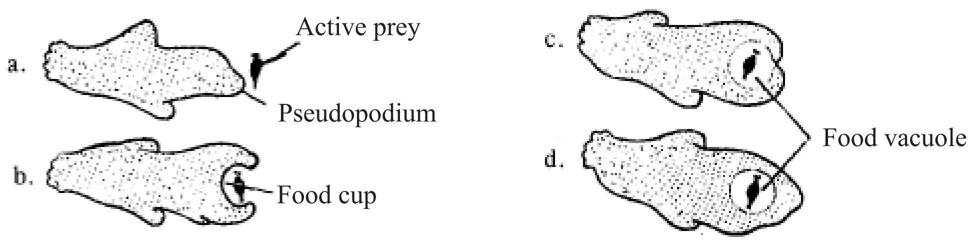


Fig. 13.1 Intracellular digestion in Amoeba

- Food particles such as minute bacteria are enclosed (caught) by pseudopodia (pseudo = false, podia = feet) to form a *food vacuole (Ingestion).*
- Enzymes from cytoplasm are secreted into the food vacuole to break down complex food. *(Digestion)*
- Digested food is absorbed into the cytoplasm. *(Absorption)*
- The absorbed food is used up wherever required in the cell. *(Assimilation)*
- The undigested unabsorbed food is expelled, when the food vacuole comes near the cell surface and bursts open. *(Egestion)*

Food vacuoles are temporary structures and every time the Amoeba feeds, a new food vacuole is produced. All free-living *unicellular* animals carry out intracellular digestion, as mentioined above.

13.2.2 Extracellular digestion (extra = outside)

Digestion occurs outside the cell. All animals (excluding sponges) carry out extracellular digestion. They have either a cavity, a tube, or a food canal which receives the ingested food. Digestive enzymes are poured over the food, and the products of digestion are absorbed back into the cells. The undigested, unabsorbed food is thrown out of the digestive cavity. For example, Fig.13.2 shows digestive organs of cockroach where extracellular digestion occurs.

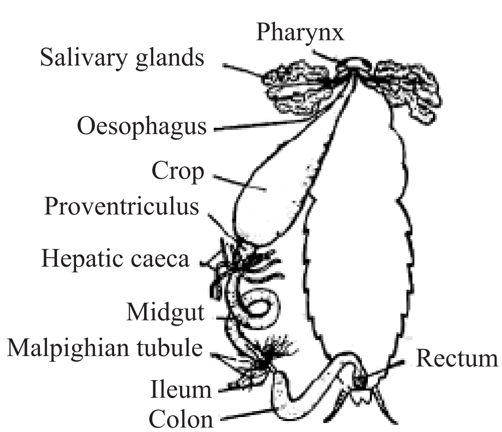


Fig. 13.2 Digestive organs of a cockroach for extracellular digestion.

13.2.3 Joint Intracellular and Extracellular digestion

In Hydra and other Cnidarians, the food (tiny prey) is caught by the tentacles and ingested through the mouth into the single large digestive cavity, called gastro-vascular cavity (Fig. 13.3). Enzymes are secreted from the cells bordering this cavity and poured on the food for **extracellular digestion**. Small particles of the partially digested food are engulfed into the vacuoles of the digestive cells lining gastrovascular canal for intracellular digestion. Any undigested and unabsorbed food is finally thrown out of the mouth.

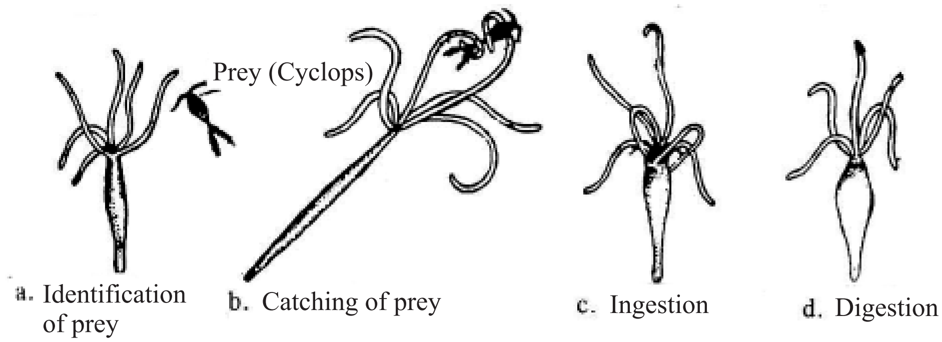


Fig. 13.3 Hydra catching its prey

INTEXT QUESTIONS 13.1

1. List the five major steps in animal nutrition
   (i) ....
   (ii) ....
   (iii) ....
   (iv) ....
2. What is intracellular digestion? Give example of an organism showing intracellular digestion.
   ....

13.5 THE HUMAN DIGESTIVE SYSTEM

The digestive system in humans consists of an alimentary canal and associated digestive glands. The human alimentary canal (aliment: nourish) is a continuous muscular digestive tube that runs through the body. It is open at two ends with the openings, which are **mouth** at anterior end and **anus** at posterior end. It digests the food, breaks it down into smaller substances, and absorbs the digested food. The alimentary canal has the following parts (Fig. 13.4).

1. **Mouth** and associated organs (teeth, tongue)
2. **Pharynx (or throat) :** A cavity at the back of the mouth. It is a common passage for the inhaled air and the swallowed food.
3. **Oesophagus :** A narrow tube arising from pharynx, continuing through the thorax and ending in the stomach.
4. **Stomach :** An elastic bag with highly muscular walls, located below the diaphragm.

5. **Small intestine :** Longest part of alimentary canal, a tube about 7 meters long and about 2.5 cm wide. Much coiled and folded, it is contained in the abdomen. Its three subdivisions are:
   (i) **Duodenum–**Short upper part, next to stomach
   (ii) **Jejunum–**Slightly longer part, about 2 meters long.
   (iii) **Ileum–**Longest, about 4 meters long, coiled and twisted.

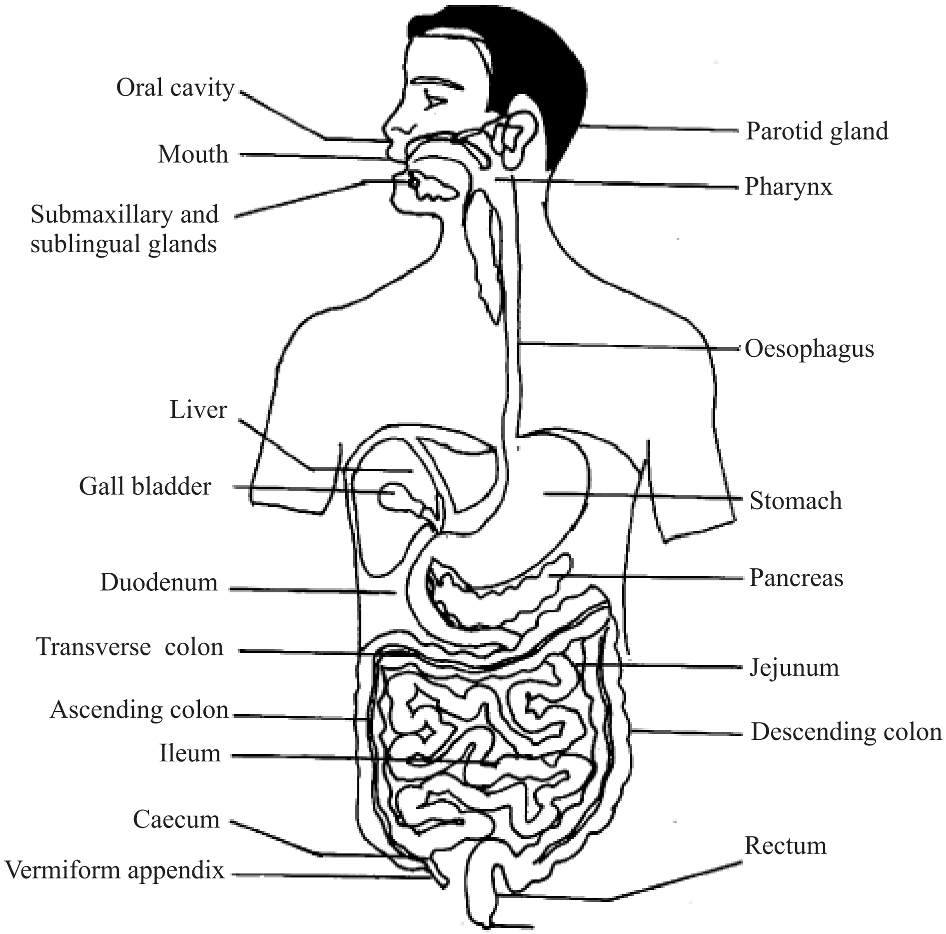


Fig. 13.4 Human Alimentary canal and the associated glands.

6. **Large Intestine :** About 1.5 meters long and has three parts.
   (i) **Caecum–**Small blind pouch at the junction of small and large intestine. A narrow worm-shaped tube (vermiform appendix) projects from the caecum.
   (ii) **Colon :** A little over 1 meter long, it has three parts termed ascending, transverse and descending limbs of the colon.
   (iii) **Rectum :** Last part, about 15 cm. long. It has two parts, the rectum proper and anal canal. Anus is the external opening surrounded by circular muscles (sphincters).

The vermiform appendix is a vestigial (functionless) organ in humans, but is large and functional in herbivorous mammals.

(a) Digestive Glands (Sources of digestive enzymes)

There are two sources of digestive enzymes :

1. The glandular cells of the lining of stomach and intestine, which directly pour their secretion into the lumen of the gut or the alimentary canal.
2. Special glands such as the **salivary glands**, the **liver** and the **pancreas** which pour their secretions into the gut through their ducts.

Our mouth is always moist, even on a hot summer day. How does this happen? This happens because there is a watery fluid called saliva which is secreted by salivary glands into the mouth cavity. It is this saliva, that keeps the mouth moist all the time.

(b) Salivary Glands

There are three pairs of Salivary glands in our mouth cavity (Fig. 13.4).

1. **Parotid glands** located in front of and below each ear, produces watery saliva rich in amylase (Starch digesting enzyme)

2. **Submaxillary glands** close to inner side of lower jaw, produce water and mucus.

3. **Sublingual glands** below the tongue, produce water and mucus.

These glands continuously pour saliva into the mouth cavity. Do you know that the amount of saliva secreted is about 1000 to 1200 ml per day.

(c) Functions of Saliva

1. It cleans the mouth cavity and tends to destroy germs with its lysozymes that cause teeth decay.
2. It moistens and lubricates food which helps in swallowing.
3. It acts as solvent, dissolving some food particles to stimulate taste buds of the tongue.
4. Saliva helps in the digestion of food as it contains an enzyme salivary amylase which digests starch converting it into sucrose. That is why starch when chewed leaves a sweet taste in the mouth.

(d) Liver

Liver is the largest gland, located in the upper right side of the abdomen below the diaphragm. It secretes bile, which gets collected in gall bladder and is finally poured into the duodenum through the common bile duct (Fig. 13.4). Besides secreting bile, which helps in digestion, the liver has numerous other functions.

(e) Pancreas

Pancreas is a reddish brown gland located in the bend of the duodenum. Its digestive secretion (pancreatic juice) is poured into the duodenum by the pancreatic duct. (Pancreas also produces certain hormones, which will be taken up in details in lesson no 16)

INTEXT QUESTIONS 13.2

1. Match the characteristics in column A with the parts of digestive system given in column B

Column A Characteristics	Column B Part
(1) Common passage for air breathed in and the food swallowed.	(a) Small intestine
(2) Elastic bag like structure	(b) Pancreas
(3) Has three limbs-ascending, transverse and descending	(c) Duodenum
(4) Longest part of the food canal	(d) Pharynx
(5) Receives bile and pancreatic juice	(e) Appendix
(6) Narrow worm-shaped projection	(f) Stomach
(7) Largest gland in body	(g) Colon
(8) Gland located in the bend of duodenum	(h) Liver

2. Name the **three** salivary glands and mention their location in the mouth cavity.

....

13.6 THE DIGESTIVE PROCESS

Digestion involves two kinds of processes :

(a) ***Mechanical process*** which includes cutting and, grinding thus breaking the food into small particles; swallowing the food and then pushing the food along the food canal. **Smaller particles expose greater surface area for action by enzymes.**

(b) ***Chemical process*** which includes the enzymatic breakdown of complex food constituents (nutrients) into simpler absorbable form.

Digestion involves hydrolysis, i.e. spliting by addition of water (H^+ and OH^- ions) to a molecule resulting in its break down into two or more simpler molecules. The enzymes act only as catalysts to accelerate the reaction.

For example $\underset{\text{(sucrose)}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{Sucrase}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$

(a) Mechanical Process in Digestion

- The lips hold the food within the mouth and help in sucking it in and sipping liquids.
- The teeth cut, tear and grind the food.

- The tongue manipulates food while chewing, mixes saliva in it, rolls it into a ball termed as **bolus** and helps in swallowing.
- The oesophagus conducts the food (bolus) down into the stomach by a wave of contraction of the circular muscles in the wall of alimentary canal (Fig. 13.5). This wave of contraction is called **peristalsis**.

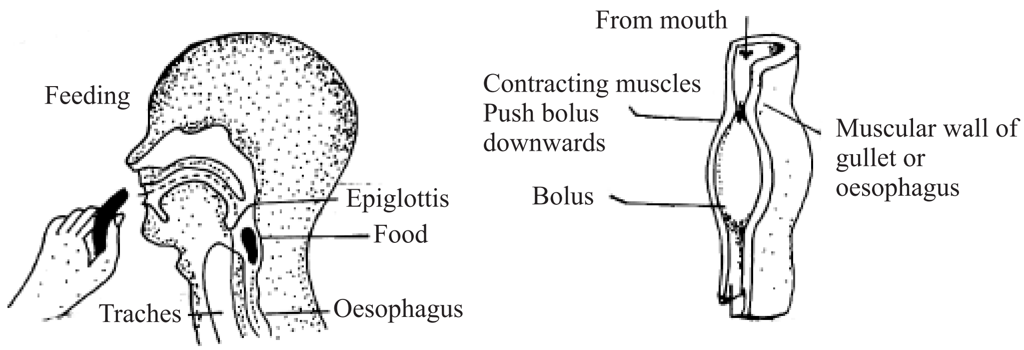


Fig. 13.5 **A**-During swallowing, the epiglottis closes the opening of the trachea, leading to momentary stoppage of breathing, and the food is pushed down the oesophagus, **B**-Peristalsis is a wave of contraction of muscles of alimentary canal which pushes food down through the alimentary canal.

- The stomach churns the food mixing it with gastric juice and thus produces a creamy **chyme** (partially digested food).
- The peristaltic movements keep pushing the food from stomach to the intestine and finally pushing it into the rectum.

(b) Chemical Processes in Digestion

1. In Mouth

Saliva contains only a single enzyme Amylase (old name Ptyalin) which acts on starch in two ways :

(i) Raw *uncooked* starch $\xrightarrow{\text{Amylase}}$ Dextrins (soluble, partially hydrolysed starch)

(ii) Cooked starch $\xrightarrow{\text{Amylase}}$ Maltose (a sweet-tasting disaccharide)

2. In Oesophagus

Food as bolus moves through obsophagus into the stomach by peristalsis. Salivary amylase continues digesting starch.

3. In Stomach

Initial digestion of starch by salivary amylase continues till the contents of stomach become acidic by presence of HCl. The gastric juice produced from the lining of the stomach is a colourless highly acidic liquid (pH 1-2). It contains *Water* (98%), some salts, ***hydrochloric acid*** (0.5%), the lubricant mucin and two enzymes ***pepsin*** and ***lipase***.

Hydrochloric acid is secreted by ***Oxyntic (parietal)*** cells of the stomach wall. It performs the following function :

(i) kills bacteria entering along with food,

(ii) loosens fibrous material in food,

(iii) activates the inactive pepsinogen to its active form pepsin,

(iv) maintains acidic medium for action by pepsin,

(v) curdles milk so that it does not flow out and stays for action by pepsin.

Pepsin is secreted in its inactive form or the proenzyme called pepsinogen secreted from the chief cells of the stomach wall. In the presence of HCl it turns into the active pepsin which acts on proteins and breaks them down into proteoses and peptones.

$$\text{Protein} \xrightarrow{\text{Pepsin}} \text{Proteoses and peptones}$$

4. Small Intestine

In the small intestine the food which is partially digested in the stomach, and called **chyme** is acted upon by three main digestive juices.

(i) Bile juice from the liver

(ii) Pancreatic juice from the pancreas

(iii) Intestinal juice secreted from special cells in the intestinal epithelium at the base of intestinal villi. (Fig. 13.6)

The bile juice and pancreatic juice are poured into the duodenum by their respective ducts which join together to form a common hepato pancreatic duct. The intestinal juice directly mixes with the food.

(i) Bile Juice

Bile is a yellowish, green, alkaline liquid (pH about 8). It consists of (i) *water* (98%), (ii) *sodium carbonate* in large quantity which neutralizes the acid of the **chyme** (semi digested food) received from stomach; makes it alkaline, and (iii) *bile salts* (sodium glycocholate and sodium taurocholate) which emulsify fats.

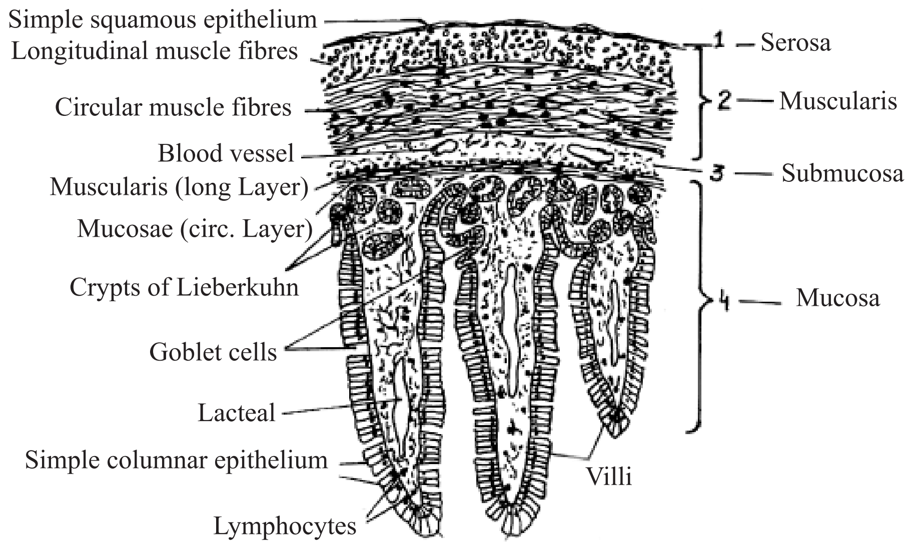


Fig. 13.6 Portion of intestinal wall showing villi and the associated structures.

Emulsification is the breaking up of large lipid (fat) droplets into small droplets, which provides greater surface for enzyme action.

The yellowish green colour of the bile is due to the pigments ***biliverdin*** and ***bilirubin*** produced by the breakdown of the dead and worn out RBCs (Red Blood corpuscles). These pigments are excreted in faeces (solid or semi-solid waste and undigested food) that is thrown out through the anus.

Bile has no digestive enzymes. It simply emulsifies fats.

(ii) Pancreatic Juice

The pancreatic juice contains *six* major categories of enzymes, which act in an **alkaline medium**.

(a) **Amylase –** completes conversion of starch (polysaccharide) into maltose (disaccharide).

(b) **Lipase –** also called *steapsin*, acts on emulsified fats to produce *fatty acids* and *glycerol*.

(c) **Nucleases –** digest nucleic acids, i.e. DNA and RNA content of the food.

(d) **Trypsinogen –** the inactive precursor (proenzyme) of trypsin. It is activated into *trypsin* by the enzyme *enterokinase* secreted by the lining of duodenum. Trypsin acts on remaining proteins (not digested by pepsin) and the proteoses and peptones to produce *peptides* and *amino acids*.

(e) **Chymotrypsin –** acts on milk protein casein to produce *paracasein* (curd), and also converts other proteins into *peptides*.

(f) **Carboxypeptidases –** act on peptides to produce small *peptides* and *amino acids*.

(iii) Intestinal Juice or Succus Entericus

It contains the following categories of enzymes :

(i) **Glycosidases** (including maltase, sucrase and lactase). These hydrolyse the disaccharide maltose (malt sugar), sucrose (cane sugar) and lactose (milk sugar) into the simpler absorbable monosaccharides (glucose, fructose and galactose).

$$\text{Disaccharides}\left\{\begin{array}{l} 1.\ \text{Maltose} \xrightarrow{\text{Maltase}} \text{gluscose} + \text{glucose} \\ 2.\ \text{Sucrose} \xrightarrow{\text{Sucrase}} \text{gluscose} + \text{Fructose} \\ 3.\ \text{Lactose} \xrightarrow{\text{Lactase}} \text{gluscose} + \text{galactose} \end{array}\right\}\text{Monosaccharides}$$

(ii) **Lipase** completes the digestion of any lipid (fat) not digested by pancreatic juice.

(ii) **Peptidases** (aminopeptidase and dipeptidase) act on peptides and dipeptides to produce smaller peptides and amino acids.

(iii) **Nucleases** breakdown nucleotides into phosphate, sugar and different nitrogenous bases.

Summary of digestion in various parts of human alimentary canal is shown in table 13.1

Table 13.1 : Various digestive enzymes secreted and their role in the digestion of food in humans

Site of Secretion	Digestive juice	Enzyme	Mode of action
Mouth	Saliva	Salivary amylase (ptyalin)	Converts starch into maltose
Stomach	Gastric juice	Pepsin	Converts proteins into peptones and proteoses
Duodenum	Bile juice	No Enzyme	Emulsification of fats
	Pancreatic juice	Trypsin	Converts peptones and small peptides into amino acids.
Small intestine	Intestinal juice	Erepsin	Converts peptones and small peptides into amino acids.
		Sucrase	Converts sucrose into glucose and frutose.
		Maltase	Converts maltose into glucose
		Lactase	Converts lactose into glucose and galactose.
		Lipase	Converts fats into fatty acids and glycerols.

INTEXT QUESTIONS 13.3

1. How is grinding of food in the mouth helpful in digestion?

   ....

2. Name the source gland for following enzymes.

   (i) amylase ....

   (ii) pepsin ....

   (iii) lipase ....

3. List at least **four** enzymes that contribute towards digesting proteins.

   (i) …………… (ii) …………… (iii) ………… (iii) ……..…....

13.7 ABSORPTION OF NUTRIENTS

Some absorption occurs in the mouth itself, some in the stomach but most absorption occurs in the intestine. The summary of absorption of nutrients is given below.

1. In Mouth

Minute quantities of water, water-soluble vitamins and simple sugars like glucose (as in honey) are absorbed in the mouth.

2. In Stomach

Water, glucose, ethanol (alcohol), certain minerals, vitamins and certain drugs may be absorbed into the cells lining the stomach. This absorption occurs by osmosis, diffusion (down the concentration gradient) and active transport (against concentration gradient).

3. Small Intestine

Most absorption of digested food occurs in small intestine. For this, the small intestine is adapted in many ways :

(i) It is very long and therefore provides more surface area for absorption.

(ii) Many folds in its wall called *villi* (singular, *villus*) further increase the surface area of absorption. (Fig. 13.6).

(iii) Single cell epithelial lining further reduces the distance between the food and underlying blood vessels.

(iv) The epithelial cells have **microvilli** which are projections of plasma membrane to further increase the absorptive surface.

(v) It is narrow for slow movement of nutrients allowing absorption.

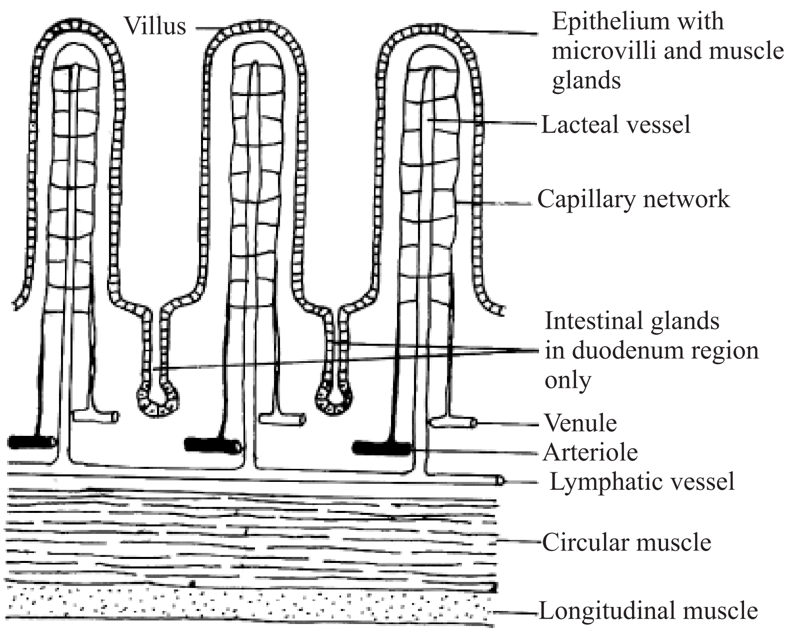


Fig. 13.7 Magnified details of Microscopic structure of a part of the wall of small intestine.

- Products absorbed *into the blood capillaries* of the villi are amino acids and monosaccharides (glucose, fructose, galactose).

- Products absorbed into the lacteals (lymph vessels) of the villi are fatty acids and glycerol.
- Nutrients absorbed into the blood is carried by veins into the liver, and the nutrients absorbed by the **lacteals** (small lymph vessels) enters the lymphatic system.

4. Large Inestine

Most of the water present in the food is absorbed in the *colon* by diffusion. Some mineral ions are absorbed by the colon through active transport.

13.8 ASSIMILATION

The final conversion of the absorbed nutrients into the living substance, i.e. their utilization by the cells is called **assimilation**.

After absorption from the food canal the digested food is assimilated by the body in the following ways.

(i) Fatty acids and glycerol are again converted into fats, that may be used or stored in adipose tissue.

(ii) Simple sugars (monosaccharides) which are in excess are converted into complex polysaccharides like glycogen in liver.

(iii) Amino acids are utilized in the synthesis of proteins for building up the body tissues and enzymes.

(iv) Excess amino acids are deaminated (removal of nitrogenous part) to produce simple sugar. (*Amino acids* cannot be stored).

13.9 EGESTION (DEFAECATION)

The undigested part (plant fibers) and the unabsorbed digested substances pass into the *rectum*. Such food remnants are temporarily stored in rectum. More water is absorbed and the remnants become semisolid to form *faeces*.

A special reflex called defaecation reflex causes emptying of the rectum and the faeces are passed out via the anus by the relaxation of *sphincter* muscle (A ring shaped muscle which contracts and relaxes to close and open the anus or anal opening.

INTEXT QUESTIONS 13.4

1. In which part of the alimentary canal does maximum absorption of water occur?

   ....

2. List any three ways in which the intestine increases the surface area for absorption?

   (i) ....

   (ii) ....

   (iii) ....

3. Which end products of digestion are absorbed by
   (i) blood capillaries of intestinal villi? ....
   (ii) Lacteals? ....

13.10 NEURAL AND HORMONAL CONTROL OF DIGESTIVE SYSTEM

Do digestive juices flow into the alimentary canal all the time? If it were so, it would mean terrible wastage of enzymes when there is no food in the alimentary canal. So, everything must be so timed that there is neither wastage, nor shortage. How is it possible? Let us see how this happens.

Think of the following situations:

1. When we see or smell good food or even think or talk about it, our mouth begins to “water” (salivation). This happens through stimulation by nerves coming from the brain. The secretion of thicker saliva is stimulated by chewing action (even if you chew wax instead of food, you will salivate).
2. On reaching the stomach, the presence of food stimulates the stomach lining to secrete gastric juice. Secondly, the mechanical stimulation of stomach wall produces a hormone, **gastrin** which again stimulates the secretion of gastric juice.
3. As the food enters duodenum, the duodenal epithelium secretes four hormones- **Secretin, Pancreozymin, Cholecystokinin, and Enterogastrone**.
   (i) **Secretin** stimulates the flow of pancreatic juice, which is rich in bicarbonates (to neutralize acid).
   (ii) **Pancreozymin** helps in the flow of pancreatic enzymes.
   (iii) **Cholecystokinin** stimulates flow of bile from gall bladder.
   (iv) **Enterogastrone** stops secretion of gastric juice, because stomach becomes empty as food now passes from stomach to duodenum.

Several nerves (from sympathetic and parasympathetic nervous system) stimulate and control the gut to accelerate or slow down the movements of alimentary canal as termed peristalsis.

INTEXT QUESTIONS 13.5

1. Mention the source of secretion and the effect of the following:
   (i) Gastrin ....
   (ii) Enterogastrone ....

13.11 ROLE OF LIVER IN METABOLISM

Liver is the largest gland associated with the alimentary canal. It is reddish brown in colour and is located on the upper side of the abdomen just below the diaphragm. Its numerous functions can be grouped under five major categories :

Blood related functions :

(i) Produces *red blood cells* in the embryo. (In adults, RBCs are produced in bone marrow).

(ii) Produces *prothrombin* and *fibrinogen* required for blood clotting.

(iii) Produces *heparin* which prevents unnecessary coagulation of blood.

(iv) Destroys dead and worn out red blood cells.

(v) Removes toxic and metallic poisons from the blood (protective function).

Storage functions :

(i) Storage of iron and some other metallic ions.

(ii) Storage of vitamins A, D and B_{12}.

(iii) Converts extra blood glucose into glycogen and stores it.

Metabolic functions

(i) **Regulation of blood** sugar level by retaining excess *glucose* received as product of carbohydrate digestion from the intestines, and storing it as insoluble *glycogen* to release it again as soluble glucose when the blood sugar level falls.

(ii) **Breaking down of excess amino acids.** Amino acids are the end products of protein digestion. Liver breaks down excess amino acids into urea and sugar. Urea is excreted out in urine and sugar is stored for use.

(iii) **Synthesizes fatty acids** from carbohydrates, which can be used or stored as fat.

INTEXT QUESTIONS 13.6

1. Name any three substances related to the blood, produced by liver.

   (i) ……………...... (ii) ……………...... (iii) ……………......

2. List any three substances which the liver stores.

   (i) ……………...... (ii) ……………...... (iii) ……………......

3. What happens to excess amino acids absorbed from gut ?

   ....

13.12 SOME DIGESTIVE DISORDERS (VOMITING, DIARRHOEA, CONSTIPATION, INDIGESTION AND JAUNDICE)

13.12.1 Vomiting

Vomiting is the forcible voluntary or involuntary emptying (throwing up) of stomach contents through the mouth. Vomiting is not a disease but a symptom of many conditions such as motion sickness, emotional stress, overeating, reaction to certain smells and odours, food poisoning, and infections. The most common cause of vomiting is **gastroenteritis**. This is an infection of the gut usually caused by virus or bacteria. Prolonged and excessive vomiting can dehydrate the body and may alter the electrolyte balance. Repeated or excessive vomiting may cause injury to the oesophagus or may corrode the oesophageal mucosa (inner lining of oesophagus). In such a case, fresh blood may be seen in the vomit. However, in most cases vomiting does not last for more than one or two days and is not very serious.

A person who is vomiting should be given lot of fluids. ORS (**Oral Rehydration Solution**) may be given frequently. ORS is a special powder which contains sugar and salts in specific amounts. This powder can be converted into a liquid form by following the instructions written on the packet. Person who is vomiting should sip this fluid at regular intervals. A home made sugar solution with a pinch of salt can substitute for ORS.

Vomiting should not be taken very lightly. Persistent vomiting can sometime be due to a severe infection. A doctor must definitely be consulted if vomiting continues for more than a day.

13.12.2 Diarrhoea

Passing loose stool or liquid stool three or more times in a day is termed Diarrhoea. It is usually a symptom of gastrointestinal infection which can be caused by bacteria, virus or a parasitic protozoan. It begins as an irritation in the colon wall, then peristalsis increases and absorption of water by the colon becomes very slow.

Infection is spread through contaminated food or by drinking contaminated water or from person to person because of poor hygiene. *Rotavirus* and *Escherichia coli* (colon bacteria) are two most common causative agents of diarrhoea in developing countries. Severe diarrhoea leads to fluid and electrolyte imbalance particularly in children and people who are malnourished and have impaired immunity.

The most serious threat posed by diarrhoea is **dehydration**. Water and electrolytes (sodium, chloride, potassium and bicarbonate) are lost through liquid stools, vomiting, sweat, urine and with breathing. If these are not replaced then the person suffers from dehydration and if proper treatment is not given then the person may even die because of severe dehydration and fluid loss.

A person suffering from diarrhoea should be given ORS at regular intervals and doctor should be consulted if diarrhoea persists for more than a day or two.

In order to prevent diarrhoea one should always observe good personal hygiene and prevent food from contamination. Some of the precautions for preventing diarrhoea are:

- washing hands with soap before taking food
- fruits and vegetables thoroughly washed with water before eating or cooking
- keeping food covered and unexposed to flies or dust and dirt
- drinking safe and clean uncontaminated water

13.12.3 Constipation

Constipation is a term which is used when bowel movement becomes difficult or less frequent. The faeces become excessively dry and hard. This happens when the undigested food passes slowly through the colon and large amount of water is absorbed in the large intestine. It is basically a disorder of the bowel function caused mainly due to inadequate fibre in the diet, irregular diet, inadequate activity or exercise, and stress or due to resisting the urge to have a bowel movement. Medicines (especially strong pain killers, antidepressants), or hypothyroidism may also be a cause of constipation. One can easily prevent constipation by eating a well balanced diet with plenty of fibre, drinking lot of water/fluids, regular exercises and passing stool whenever one feels the urge.

13.12.4 Indigestion

Indigestion, also called **dyspepsia** is another name for an upset stomach. Indigestion is a feeling of discomfort in the upper abdomen during or immediately after eating (commonly called stomach ache). There is a recurrent pain and burning sensation in the upper abdomen. Indigestion may be triggered by overeating, eating spicy, greasy or fatty foods, emotional stress, consuming too much of high fibre foods, caffeine or tobacco and smoking or drinking too much of alcohol. Frequent consumption of medicines like antibiotics and pain killers, stomach or intestinal ulcers, and gastritis (inflammation of stomach lining and gall stones) are some other causes of indigestion.

Indigestion is common in all age groups and is not a sign of serious health problem unless there are other accompanying symptoms like an unexplained weight loss or severe abdominal pain. It can easily be prevented by life style changes. Some of these are:

- Cutting down on fatty foods, tea, coffee, alcohol
- Not eating too much food or too quickly
- Eating at least two or three hours before going to bed
- Reducing stress
- Giving up smoking

13.12.5 Jaundice

In jaundice, there is a yellow discoloration of the skin and the eyes due to a high level of bilirubin (bile pigment) in the blood. This happens when not much of it gets excreted. The high levels of bilirubin may be because of inflammation or other abnormalities of the liver cells, or blockage of the bile ducts. Sometimes jaundice is caused by the breakdown of a large number of red blood cells, which can occur in newborn babies. Jaundice is usually the first sign, and sometimes the only sign, of liver disease. Jaundice may also be caused by viral infection transmitted through infected water.

Jaundice is related to the function of the liver so it is necessary to keep the liver healthy by eating a balanced diet and doing regular exercises.

INTEXT QUESTIONS 13.7

1. (a) A doctor advises a person to sip ORS at regular intervals because he/she was suffering from diarrheoa. What is this ORS?

   ....

   (b) Name any one causative agent of diarrhoea in developing countires.

   ....

   (c) During the rainy season there is a rise in diarrhoea cases. What piece of advice will you give to your younger brother/sister to prevent oneself from getting diarrhoea?

   ....

2. A little girl/boy had a problem in passing stool. The faeces were dry and hard. The doctor said that this was because the child was not taking adequate amount of fibres in the diet and was not taking proper diet at proper time. What is this child suffering from?

   ....

3. What is dyspepsia? What are its symptoms?

   ....

4. Which organ of the body is involved in jaundice and how can you make out that a person is suffering from jaundice.

   ....

WHAT YOU HAVE LEARNT

- Digestion is the breakdown of complex food, and nutrition include taking in and utilization of food.
- All animals are heterotrophic or phagotrophic or holozoic (ingesting bulk food) while the green plants are autotrophic (or holophytic)
- Animal nutrition involves five steps-ingestion, digestion, absorption, assimilation and egestion (defecation).

- Digestion can be either intracellular or extracellular.
- The human alimentary canal consists of mouth, pharynx, oesophagus, stomach, small intestine, large intestine and anus.
- The digestive enzymes poured into the gut, are secreted from two kinds of sources; gut epithelium of stomach and intestine, and special glands (salivary glands, liver and pancreas).
- Starch is digested in the mouth by salivary amylase, and in the duodenum by pancreatic amylase. Other carbohydrates like maltose, sucrose and lactose are digested by the respective enzymes in the intestine.
- Fats are emulsified by bile, and are hydrolysed by lipases in stomach and intestine.
- Proteins are digested by pepsin in the stomach and by trypsin in the intestine and the peptidases break them into amino acids.
- Absorption of digested food mainly occurs in the small intestine – simple sugars and amino acids are absorbed into the blood capillaries of the intestinal villi and the fatty acids and glycerol into lacteals.
- Most water from the digested food is absorbed in colon and rectum.
- Defaeaction is the expulsion of semi-solid faeces.
- Several hormones regulate the secretion of digestive juices from different parts, at the right time and in right quantity.
- Besides playing an important digestive role, the liver has numerous other functions in connection with blood and general metabolism.
- Common digestive disorders are vomiting, diarrhoea, constipation, indigestion and jaundice
- Intake of ORS or oral Rehydration solution is a must when suffering from digestive disorders like vomiting and diarshoea in order to prevent dehydration.

TERMINAL EXERCISES

1. Explain the term "autotrophs". How are animals different from plants with regard to their mode of nutrition?
2. Enlist at least ten organs of the alimentary canal of man.
3. Define the term "digestion". List the digestive processes occurring in the small intestine.
4. How does digestion of carbohydrates and proteins take place in humans?
5. Explain the role of the following in the digestive process in humans :
   (a) Gastrin (b) Hydrochloric acid (c) Secretin
6. Write short notes on
   (a) absorption of the digested food (b) assimilation
   (c) defaecation (d) role of liver in metabolism.

7. Name the enzymes concerned with the digestion of various carbohydrates, the region of the gut where they act and their products in the table given below:

Carbohydrate	Enzyme	Region of gut	Product
1. Starch	....	....	....
2. Dextrin	....	....	....
3. Maltose	....	....	....
4. Sucrose	....	....	....
5. Lactose	....	....	....

8. Bile has no digestive enzyme yet it plays a key role in digestion. What is its role?

9. Draw a well labelled diagram of alimentary canal in humans.

10. List common digestive disorders. Add a note on ORS.

ANSWERS TO INTEXT QUESTIONS

13.1 1. Ingestion, digestion, absorption, assimilation, egestion

2. All the five steps of digestion occur inside the cell itself. Paramecium, Amoeba etc.

13.2 1. 1. d, 2. f, 3. g, 4. a, 5. c, 6. e, 7. h, 8. b

2. Parotid – in front of and below ear

Submaxillary – inner side of lower jaw.

Sublingual – below the tongue

13.3 1. Smaller particles provide larger surface area for digestive action.

2. (i) Salivary glands (ii) Stomach (iii) Pancreas

3. 1. Pepsin 2. Trypsin, 3. Chymotrypsin, 4. Carboxypeptidase.

13.4 1. Colon/large intestine.

2. (i) very long (ii) villi (iii) microvilli

3. (i) Amino acids and simple sugars, (ii) fatty acids and glycerol.

13.5 1. (i) Gastrin-stomach, stimulates secretion of gastric juice

(ii) Enterogastrone-Duodenum, stops secretion of gastric juice.

13.6 1. Fibrinogen, prothrombin, heparin

2. Sugar/glycogen, iron, vitamin A/D/B_{12}

3. Broken down to produce sugar and urea, sugar is used and urea is excreted.

13.7 1. (a) Oral Rehydration Solution which is drinking water containing a pinch of sugar and salt. Its consumption prevents dehydration.

(b) Rota virus / E.coli

(c) Wash hands with soap and water before eating/wash raw vegetables well before cooking or consuming / cover food so that flies cannot sit on it / consume clear uncontaminated water.

2. Constipation

3. Indigestion or upset stomach. Symptoms–Stomach pain

4. Lever; urine and eyes look yellow.

14

RESPIRATION AND ELIMINATION OF NITROGENOUS WASTES

Every living organism needs energy to perform various life activities, and the process of respiration fulfils this energy requirement. You have already learnt in the lesson on food and nutrition that animals take in high energy organic molecules in the form of food. During respiration, this food is broken down in the presence of oxygen and energy is released during respiration. Respiration also produces carbon dioxide, a toxic substance which is eliminated from the body. Thus, uptake of oxygen and removal of carbon dioxide is an essential requirement of all animals.

At the same time numerous other toxic wastes such as ammonia, and urea are also produced in the tissues during various cellular activities. Such toxic wastes need to be removed from the body. In this lesson you will learn about removal of nitrogenous wastes and maintenance of water and salt balance in the body.

OBJECTIVES

After completing this lesson you will be able to :

- *define respiration, breathing, inspiration, expiration and vital capacity;*
- *describe briefly the gaseous exchange in earthworm and cockroach;*
- *describe the parts of respiratory system in the human body and mention their functions;*
- *draw a labeled diagram of human respiratory system;*
- *differentiate between breathing and respiration; and inspiration and expiration;*
- *describe the mechanism of breathing and its regulation;*
- *describe the exchange of respiratory gases in the lungs and their transport to and from tissues;*

- *name some common ailments of respiratory system and suggest their prevention;*
- *define excretion and mention its importance;*
- *explain the terms such as ammonotelism, ureotelism and uricotelism;*
- *list the organs of excretion in cockroach;*
- *list the parts of human excretory system and mention their functions;*
- *explain ultrafiltration and describe how urine is formed in humans;*
- *draw the microscopic structure of the human kidney;*
- *list the normal and abnormal components of urine;*
- *explain the mechanism of osmoregulation and its regulation by ADH;*
- *explain the role renin-angiotensin system in regulating blood volume and blood pressure.*
- *explain the role of dialysis and kidney transplantation in case of kidney failure;*
- *explain the role of liver in excretion.*

14.1 RESPIRATION

Respiration is the stepwise oxidation of glucose (and other nutrients) which results in the release of energy that is stored in the cytosol in the form of ATP (adenosine triphosphate). Whenever energy is required by our body, ATP is broken down and large amount of energy is released.

Respiration is completed in following steps :

Step-1 Gaseous exchange

It involves exchange of gases between the cell and its surrounding medium. The cells obtain oxygen from the environment and return carbon dioxide and water vapour to it. In most higher animals this exchange of gases takes place in two phases :

(a) exchange of gases between the animal body and its external environment, also called **ventilation** or **breathing.**

(b) transport of gases O_2 and CO_2 between the respiratory surface and the cells.

Oxygen obtained from the atmosphere is used up in the second step i.e. during **cellular respiration**, which occurs inside the cell.

Step 2 Cellular Respiration

It is a complex and elaborate process which occurs in the cytoplasm and the mitochondria. It involves :

(i) the uptake of oxygen by tissues,

(ii) stepwise oxidation of glucose molecules and other nutrients, and

(iii) release of carbon dioxide and energy.

Thus ultimate goal of respiratory system is to provide oxygen to the tissues for oxidation of food and removal of carbon dioxide from them.

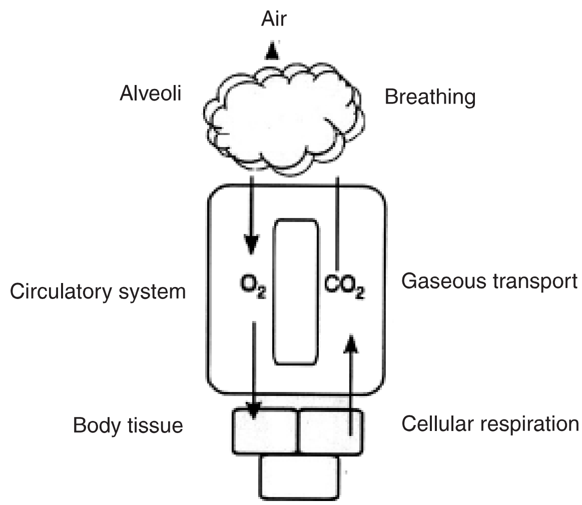


Fig. 14.1 General features of respiration

14.1.1. Respiratory Exchange in Different Animals

- All animals exchange gases with their surroundings by the mechanism of diffusion.
- A gas diffuses across a membrane from outside where its concentration (partial pressure) is higher than inside where its concentration is lower.
- Thus oxygen is taken up and carbon dioxide is released from the respiratory surface.
- For efficient gas exchange the respiratory surface should be large, moist, highly vascular, thin and easily permeable to oxygen and carbon dioxide.
- To fulfill this requirement complex respiratory systems have evolved in the animal world. You will study a few of them in this lesson.

14.1.2 Gas exchange through the general body surface in earthworm – cutaneous respiration

- Earthworm has no respiratory organs. The entire skin on the body of earthworm functions as the respiratory surface.
- The skin of earthworm is thin, moist and has a rich supply of blood capillaries. Thus, it is very suitable for respiration.
- The body surface is covered with a moist film consisting of secretions of mucous glands, coelomic fluids and excretory wastes.
- The capillaries on the skin take up O_2 dissolved in the water (in the moisture) on the surface of skin and release CO_2 into the atmosphere.
- Earthworms have a closed circulatory system which means that blood flows within blood vessels. The respiratory pigment haemoglobin remains dissolved in blood plasma and not in any cell. In human beings and other vertebrates, Haemoglobin is inside RBC
- There is regular rhythmic contraction of blood vessels which helps in the circulation of blood and hence in the transport of dissolved gases in the body.

Even frogs show cutaneous respiration (respiration through skin) across their moist skin, particularly during hibernation when they become inactive during the winter to avoid cold. However, frogs are mainly lung breathing animals.

14.1.3 Tracheal System in Cockroach

You must have noticed that the insects keep expanding and contracting their abdomen. This is to allow gaseous exchange.

- Like majority of insects, cockroach respires by means of internal tubes called **tracheae**.
- These tubes branch out extensively inside the body and carry air directly to the tissues from the atmosphere.
- In cockroach, respiration does not involve blood as shown in the flow chart given below and therefore it is very fast and very efficient. Tracheae open up to the exterior by paired slit like apertures called **spiracles**. Spiracles are found on the sides in the thorax and abdomen.
- The fine branches of tracheal trunks called **tracheoles** finally penetrate the cells of the body and allow diffusion of respiratory gases directly into and from the cells.
- The ends of the tracheoles are thin and filled with fluid in which respiratory gases dissolve. The inflow and outflow of air is affected by alternate contraction and expansion of the abdomen.

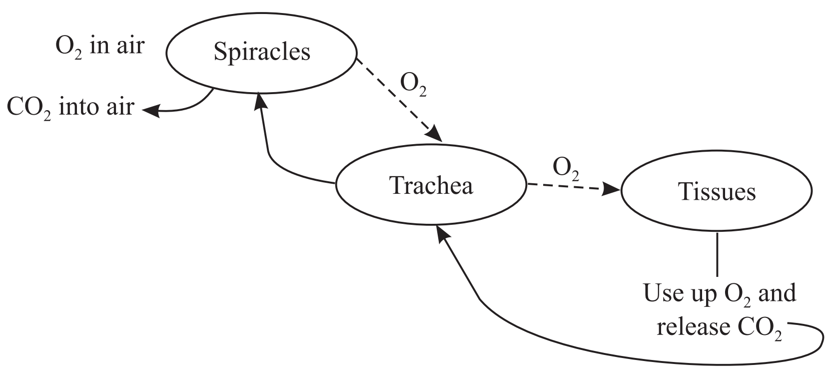


Fig. 14.2 Tracheal system in a cockroach

14.1.4 Respiratory system in humans (pulmonary respiration)

- Humans have a well developed respiratory system suitable for meeting the higher requirement of oxygen in their bodies.
- The respiratory system consists of nostrils, nasal cavity, pharynx, larynx, trachea, and bronchi.
- The two bronchi branch extensively into bronchioles, terminal bronchioles and ultimately end in the air sacs called alveoli. The bronchioles, their branches and air sacs are enclosed in a double membrane called pleural membrane to form the lungs. The lungs are the main respiratory organs.

- Air passes through nostrils into bronchi, to bronchioles and into air sacs which are thin walled sacs with a single layer of cells and heavily covered with blood capillaries. O_2 from alveoli passes into capillaries and CO_2 from other capillaries diffuses into alveoli for being removed. Alveoli are the organs where the actual gaseous exchange occurs.
- The double layer pleural membrane covers the lungs for its protection. It contains pleural fluid, which makes the movement of the lungs easy.
- Each lung consists of a tree like system of branched bronchial tubes.
- The finest of them terminate into millions of tiny sac like structures called alveoli.
- Alveolar membrane is very thin, moist and richly supplied with blood capillaries.
- The walls of both the capillaries and alveoli consist of a single layer of flattened epithelial cells.

Refer to the following table 14.1 to get an idea of the structure and functions of different parts of the human respiratory system.

Table 14.1 Respiratory organs of human body

Organ	Structure	Function
Nostril Nasal Cavity	Opening of Nose Covered with mucous membrane and cilia	Filtration of unwanted particles. Traps dust, bacteria; warms and moistens the air in the pharynx.
Pharynx (Throat)	Muscular Tube	The common passage for both respiratory gases and food moving into digestive passage, separated by epiglottis Epiglottis is a flap like structure that closes the tracheal opening (opening of the wind pipe) called glottis when food is swallowed.
Larynx /Voice Box)	A small cartilaginous organ with vocal cords : lined by ciliated epithelium	Connects pharynx to the trachea; helps in sound production.
Trachea (Wind pipe)	Supported by C-shaped cartilaginous rings to prevent it from collapsing. Trachea divides into two bronchi and enters the two lungs	Passage for air upto bronchi.
Bronchus (Plural : Bronchi)	Elastic, ciliated and covered with mucous epithelium	Enters the lungs and divides to form secondary bronchi, tertiary bronchioles and ultimately terminal bronchioles. Together they form the bronchial tree.

Bronchioles	Small terminal branches of bronchus leading to alveoli	Convey air into alveoli.
Alveoli (Air sacs)	Supplied with blood capillaries, thin moist	Exchange of Gases.

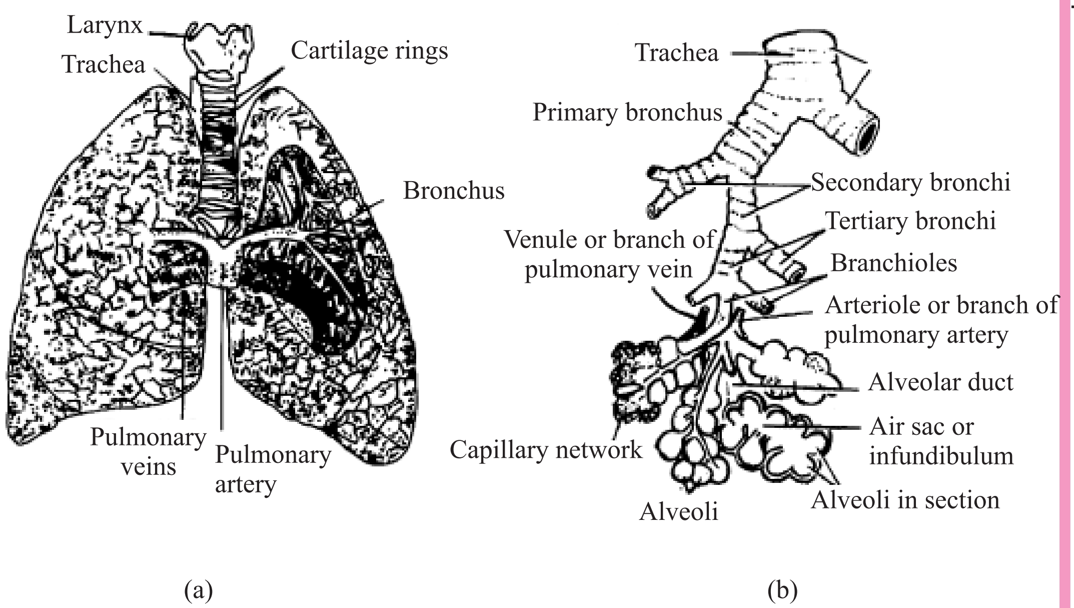


Fig. 14.3 (a) Human lungs (b) branching of bronchi upto terminal alveoli

Table 14.2 : Differences between breathing and respiration

Breathing	Respiration
1. Physical process	1. Bio-chemical process involving enzymes
2. Takes place only in reptiles, birds and mammals	2. Occurs in all organisms
3. It is a rhythmic process	3. It is a continuous process
4. It is an extracellular process	4. It is an intracellular process
5. It involves gaseous exchange between the animal and its external environment	5. It involves enzymatic breakdown of glucose in the presence or absence of Oxygen to release energy

INTEXT QUESTIONS 14.1

1. Define respiration

   ....

2. Name the two gases that are exchanged during respiration.

   ....

3. What is cutaneous respiration? Name one animal that undertakes cutaneous respiration.

   ....

4. What is the colour of the blood of the earthworm? Name the pigment responsible for the colour.

   ....

5. How is oxygen transported to the cells in the cockroach?

   ....

6. Name the group of animals in which blood is not involved in gaseous exchange.

   ....

7. How does trachea communicate with the exterior in cockroach?

   ....

8. Trace the path of air from the nostrils to the lungs in the human body.

   ....

9. Name the part of the respiratory system where air is filtered, moistened and warmed in humans

   ....

10. What is the function of the epiglottis in humans?

    ....

14.2 MECHANISM OF PULMONARY RESPIRATION

The main purpose of respiratory system is to provide oxygen to the tissues and to remove carbon dioxide from them. This entire process is achieved through the following steps:

(i) Breathing or pulmonary ventilation leading to exchange of oxygen and carbon dioxide between the atmospheric air and the lungs.

(ii) Exchange of gases at the alveolar surface.

(iii) Transport and exchange of gases in the tissues.

(iv) Cellular respiration.

14.2.1 Breathing or pulmonary ventilation

It is a mechanical process of taking in atmospheric air into the lungs and giving out carbon dioxide. Breathing is an involuntary process but under special conditions it can become voluntary also. It consists of two steps during which lungs are contracted and expanded alternately.

1. Inspiration or taking air in, and
2. Expiration or forcing air out (refer to Fig. 14.4).

1. **Inspiration (The intake of air) :** A muscular dome shaped diaphragm is present at the base of the lungs. On contraction it becomes flattened and lowered. The lower surface of lungs is pulled downwards and the volume of lungs increases.

External intercostal muscles present between the ribs contract, the rib cage moves outwards and upwards. These contractions together increase the volume of the chest cavity, lower the air pressure within the lungs and the atmospheric air rushes in filling the lungs with fresh air. Thus, inspiration is an active phase of breathing.

2. **Expiration (releasing air) :** This step involves the relaxation of external intercostal muscles and contraction of internal intercostal muscles. As a result the rib cage lowers and moves inwards. The diaphragm also relaxes and rises again into its original dome shaped condition. The abdominal organs press up against the diaphragm. This change decreases the volume of the chest cavity, thus, increasing the air pressure within the lungs and the air, which is laden with CO_2 and is forced out.

Forced breathing. It is possible that during forced breathing both inspiration and expiration are active processes because some more intercostal muscles and the abdominal muscles are brought into action for deeper breathing movements

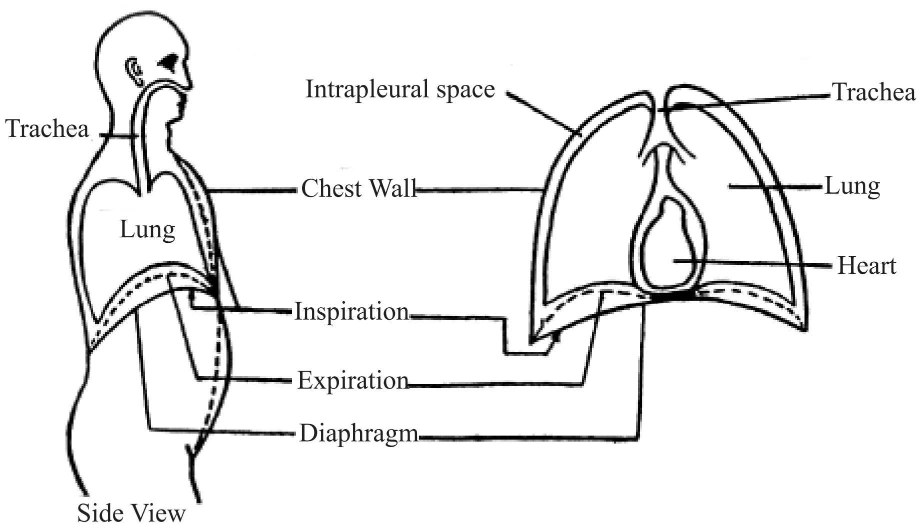


Fig. 14.4 Breathing movements

14.2.2 Exchange of gases at the alveolar surface

- Blood is the medium for the transport of oxygen from the lungs to the different tissues and carbon dioxide from tissues to the lungs.
- The deoxygenated blood is brought to the lungs by pulmonary artery which divides into fine capillaries that surround alveoli.
- Both alveoli and capillaries are made up of thin walled single layer of epithelial cells and therefore allow gaseous exchange easily.
- There is more oxygen in alveolar air and more carbon dioxide in the capillaries. Due to the pressure difference of oxygen and carbon dioxide between the alveoli and blood capillaries, the oxygen diffuses from alveolar air into the blood

capillaries. At the same time carbon dioxide diffuses from blood capillaries into the alveolar air.

- Oxygenated blood is taken from the lungs to the heart by pulmonary vein.

Volumes exchanged

Following table 14.3 shows the air volumes exchanged during breathing in a normal adult human being.

Table 14.3 : Air volume exchanged during breathing

Tidal volume (TV)	Volume of air inhaled and exhaled without any noticeable effort (normal breathing).	500mL
Vital capacity (VC)	Volume of air that can be maximally breathed out after a maximum inspiration (VC = IRV+TV+ERV).	3400-4800mL
Inspiratory reserve volume (IRV)	Volume of air that can be taken in by forced inspiration over and above the normal inspiration.	2000-3000 mL
Expiratory reserve volume (ERV)	Volume of air that can be expelled by forced expiration over and above the normal expiration.	1000 mL
Residual volume (RV)	Volume of air that cannot be forced out even on forced expiration. This is the air that remains in the lungs and in the air passage.	1000-1500mL
Total lung capacity	Sum of all lung volumes (maximum air that remains in the lungs after a maximum inhalation).	5500-6000mL

> Vital capacity may be highly reduced in smokers and people suffering from tuberculosis. Athletes and singers on the other hand have higher vital capacity.

14.2.3 Transport of oxygen by blood from lungs to tissues

Efficient transport of oxygen is by a complex blood protein called haemoglobin. This iron rich protein is packed in Red Blood Corpuscles (R.B.Cs) giving blood a red colour. About 97 percent of the total oxygen is transported from lungs to the tissues in combination with haemoglobin. Only 3% of oxygen is transported in dissolved form by plasma. Oxygenation of blood takes place in lungs. Four molecules of oxygen form a reversible bond with haemoglobin forming the compound oxyhaemoglobin.

$$\text{Hb} + 4O_2 \xrightleftharpoons[\text{Active Tissue}]{\text{Lung alveoli}} \text{Hb}(4O_2)$$

(Haemoglobin) (Oxyhaemoglobin)

When the oxygenated blood reaches the tissue surface there is high concentration of CO_2 in the tissues, oxygen having been used up and low concentration of O_2. As a result the bonds holding oxygen and haemoglobin in Hb $(4O_2)$ becomes unstable and blood releases oxygen and takes up CO_2.

14.2.4 Transport of carbon dioxide (from tissues to lungs)

Blood transports carbon dioxide with comparative ease because of its high solubility. Active tissues constantly produce CO_2. This CO_2 is transported to the lungs in three ways:

(i) CO_2 is physically dissolved in blood plasma (only 5-7% of the total CO_2 is transported).

(ii) CO_2 directly combines with haemoglobin of RBCs to form carbaminohaemoglobin (about 21-23% only).

(iii) As bicarbonate it is dissolved in plasma but produced in RBCs catalysed by the enzyme carbonic anhydrase and then diffuses into plasma (largest fraction of CO_2, about 75% to 80%) to be transported in this manner.

$$CO_2 + H_2O \underset{\text{Carbonic anhydrase}}{\overset{\text{Enzyme}}{\rightleftharpoons}} \underset{\text{(Carbonic acid)}}{H_2CO_3}$$

$$\underset{\text{Carbonic acid}}{H_2CO_3} \longrightarrow \underset{\text{(Bicarbonate ion)}}{HCO_3^- + H^+}$$

Bicarbonate is extremely soluble and dissolves in blood plasma. It again passes into RBC and breaks into CO_2 and H_2O in the alveoli. Inside the lungs the CO_2 is transported to lungs from tissues in the three ways mentioned above and is released into the alveolar air and finally breathed out (Fig. 14.5).

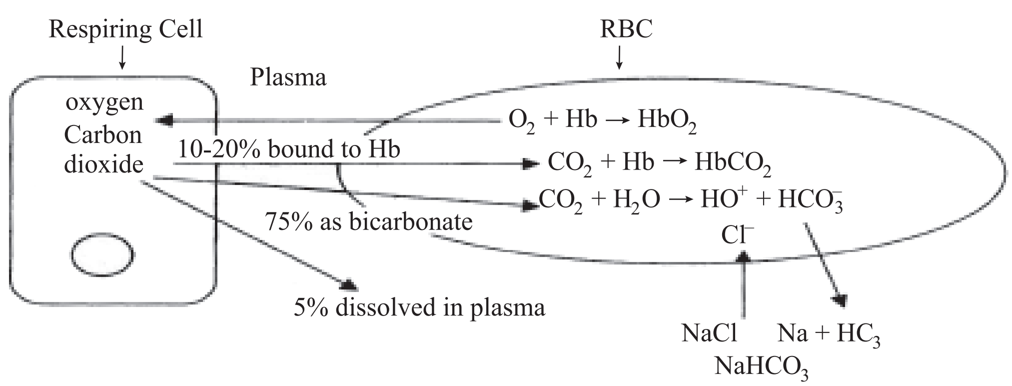


Fig. 14.5 Transport of carbon dioxide in the blood.

14.2.5 Regulation of respiration

Count the number of times you breathe during normal resting condition and when climbing up the stairs. How is the change in the breathing rate brought about? You will now study about regulation of respiration.

The regulation of respiration is under nervous control. There are three groups of neurons called respiratory centres present in the medulla oblongata and pons the brain. These are:

(a) **Dorsal respiratory group** – generates basic respiratory rhythm. It stimulates the external intercostal muscles, the diaphragm contracts and inspiration occurs. When the stimulation ceases, these muscles relax and expiration takes place.

(b) **Ventral respiratory group** sends signals under enhanced respiratory needs. It controls both inspiration and expiration.

(c) **Pneumotaxis center** in the pons controls switch off point of inspiration and thereby smoothens the transition between inspiration and expiration.

Increase in blood carbon dioxide and hydrogen ions increase the rate of respiration.

> If we try to hold our breath, we are not able to hold it for long time. This is because the respiratory centres of the medulla automatically reinstate breathing when the concentration of CO_2 in blood reaches a critical level.

14.2.6 Cellular respiration

Oxygen taken in the blood is utilised in all the living cells during cellular respiration. It is a complex process that is completed in the mitochondria. During cellular respiration, glucose is oxidized to release energy. Energy released is stored in ATP (Adenosine Triphosphate) molecules and is readily available for cell use. The process can be summed up as follows:

$$C_6H_{12}O_6 + 6CO_2 \xrightarrow[\text{Cell Respiration}]{\text{Mitochondria}} 6CO_2 + H_2O + ATP \text{ (e}$$

Respiration that takes place in the presence of O_2 is called **aerobic respiration**. It is more efficient as 38 molecules of ATP are released on the oxidation of one glucose molecule.

Absence of oxygen for sometime may lead to **anaerobic respiration**. It is inefficient as only 2 molecules of ATP are produced from one glucose molecule (Refer lesson 12 for details).

Respiration
Breakdown of glucose to release energy

Aerobic (Respiration when O_2 is available)
↓
Glucose
↓
2 Pyruvic acid
↓ ← O_2
$6CO_2 + 6H_2O + 38ATP$

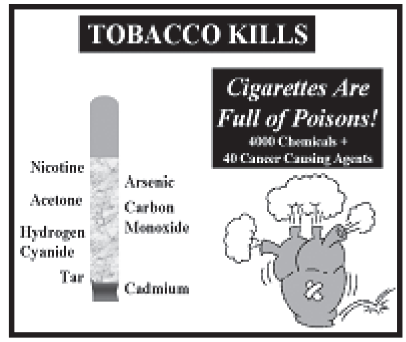
Anaerobic (respiration in the absence of O_2)
↓
Glucose
↓
2 Pyruvic acid → 2 Lactic acid + 2ATP
↓
$2CO_2$ + Alcohol + 2ATP

14.3 Common respiratory disorders and their prevention

Disease	Cause	Symptoms	Prevention
Bronchial asthma	It is an allergic disease caused due to certain foreign substance in the air.	Causes difficulty in breathing and coughing because excess mucous secretion may narrow down (clog) the bronchioles.	Avoiding exposure to the foreign substance is the best preventive measure.
Bronchitis	Inflammation of bronchi caused by infection. It can also be caused by smoking and by exposure to air pollution.	Regular coughing with greenish blue sputum	Avoiding exposure to smoke and dust prevents bronchitis.
Pneumonia	Acute inflammation caused by diplococcus infection in the alveoli of the lung.	It causes fever, pain and severe cough. Most of the air space is occupied by fluid and dead W.B.C.	Avoid crowded places where infection is prevalent.
Tuberculosis	It is a bacterial infection that spreads through droplets of infected persons	It can affect many other organs but pulmonary T.B. is most common. Weight loss and cough are common symptoms. It is accompanied by low fever. In extreme cases blood may come out while coughing.	BCG vaccine can prevent T.B. Well – ventilated dwellings and protein rich diet is also essential for T.B. patients.
Occupational lung hazards	Caused due to exposure to harmful substance like silica, asbestos, dust etc. present in the environment where a person works.	It is expressed after exposure of 10-15 years or more. It causes fibrosis of the lungs.	Such diseases can be prevented by minimizing the exposure to such substances by using protective masks and clothing. Regular health check – up is necessary.

The suffix ‘itis’ means inflammation of an organ. Bronchitis, pharyngitis or tonsillitis affects different respiratory tissues. Can you tell the specific organ affected?

Some Basic Facts



Why is cigarette smoking harmful?

Cigarette smoking is harmful because it leads to:

- diminished or extinguished sense of smell and taste
- smoker's cough
- gastric ulcers
- chronic bronchitis
- increase in heart rate and blood pressure
- premature and more abundant face wrinkles
- heart disease
- stroke
- cancer of the mouth, larynx, pharynx, oesophagus, lungs, pancreas, cervix, uterus, and bladder

14.2.7 Emphysema

Emphysema is a respiratory disorder caused by excessive cigarette smoking and chronic bronchitis. Either the bronchioles or the alveolar sacs get distended abnormally in Emphysema resulting in loss of elasticity of these parts. Gradually due to continuous distention, lung increases in size and air remains in lungs even after expiration.

Emphysema can be prevented by giving up smoking before damage is done to alveoli. Cure is difficult as elasticity is lost irreversibly.

INTEXT QUESTIONS 14.2

1. What is breathing?

   ....

2. What is the position of the diaphragm at the time of expiration?

   ....

3. What is the capacity of tidal volume?

   ....

4. What is the maximum number of oxygen molecules with which haemoglobin can combine?

   ....

5. Name the blood vessel that takes oxygenated blood from the lungs to the heart.

   ....

6. What are the three forms in which carbon dioxide is transported by the blood?

   ....

7. Name the vaccine used for prevention of TB.

   ....

8. What is an occupational hazard.

   ....

9. What is the difference between bronchitis and asthma?

   ....

10. The alveoli of a heavy smoker were damaged, their surface area was reduced and elasticity was lost. What is the technical term for this condition.

    ....

14.3 EXCRETION

All animals possess some mechanism of getting rid of the waste substances produced in their body during metabolic activities. These waste substances include CO_2, water, urea, uric acid and ammonia. Such substances can be harmful if retained in the body.

Besides metabolic wastes, excess salt (eg. NaCl taken in food), H_2O and even excess of some vitamins needs to be eliminated. Certain medicines (antibiotics) too are removed from the blood in the urine. **Removal of all harmful, unwanted products (specially nitrogenous wastes) from the body is called excretion**. Excretory system is primarily associated with removal of nitrogenous wastes.

Urea is the main nitrogenous waste in our body. It is formed by the breakdown of surplus amino acids and nucleic acids in the liver. Blood transports urea to the kidneys for filtration and removal in the form of urine.

14.3.1 Modes of removal of nitrogenous wastes

Depending upon the nitrogenous wastes excreted, animals can be classified as **ammonotelic, ureotelic** and **uricotelic**. Table 14.4 gives categories of animals on the basis of nitrogenous waste produced.

Table 14.4 **Categories of animals on the basis of nitrogenous waste produced**

Category	Product formed	Solubility in water	Examples
Ammonotelic	Ammonia (highly toxic)	Highly soluble, therefore needs plenty of water for its excretion.	Fresh water aquatic animals e.g. bony fish, *Amoeba*
Ureotelic	Urea (less toxic)	Less soluble, thus needs less water for excretion	Mammals like humans, dog etc, marine fishes and amphibians like frog and toad
Uricotelic	Uric acid (least toxic)	Insoluble solids or semi solid. Needs very little water just to flush out the uric acid	Birds, reptiles and insects.

Importance of excretion

(a) Excretion is necessary for the elimination of nitrogenous wastes formed during metabolism of proteins (amino acids) and nucleic acids.

(b) Elimination of excess salts like NaCl, vitamins, bile pigments (from the breakdown of old RBCs) and certain medicines and drugs, and

(c) Removal of excess of water or its retention in case of shortage of water. This is to maintain the required quantity of water (osmoregulation) in the body.

INTEXT QUESTIONS 14.3

1. Name the organ where urea is produced and the organ from where urea is excreted.

   ....

2. Which is the most toxic form of nitrogenous waste? Name an organism that excretes it.

   ....

14.3.2 Excretory organs in cockroach

- Cockroaches are adapted for terrestrial life and possess excretory organs called **Malpighian tubules** (Refer Fig. 14.6). They excrete uric acid, which is almost insoluble in water.
- The malpighian tubules are long, blind ended tubules attached to the alimentary canal at the junction of mid and hindgut.
- They lie in the abdomen and are bathed in haemolymph (blood of insects).

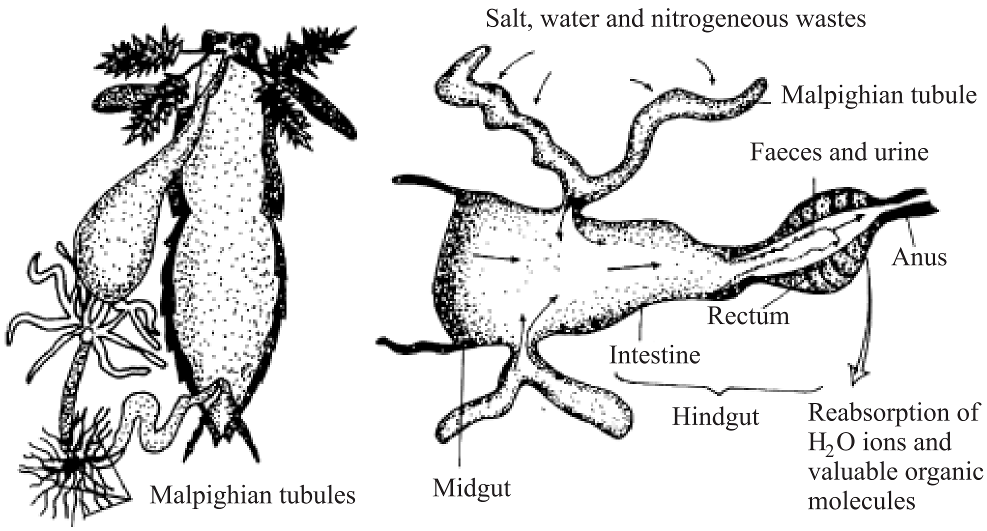


Fig. 14.6 Excretory organs of cockroach.

- The cells of tubules remove nitrogenous waste and certain salts from the haemolymph and then pump them into the lumen of the tubule.
- Fluid passes to the hindgut and in the process gets concentrated.
- This concentrated fluid then moves into the rectum and is excreted as concentrated urine along with faeces.
- Most of the salt and water is pumped back into the haemolymph by Malpighian tubules and in this way the nitrogenous wastes are eliminated as almost dry matter.

14.3.3 Excretary organs in humans

The human excretory system comprises of a pair of kidneys, a pair of ureters, a urinary bladder and urethra (Fig. 14.7)

- Kidneys are bean shaped organs located on either side of the vertebral column in the lower abdominal cavity.
- On the concave median margin of each kidney there is a notch called **hilum** which leads into funnel shaped space called **renal pelvis**.
- The renal pelvis is surrounded by an outer layer of tissue called **renal cortex** and an inner layer of tissue called the **renal medulla**.
- Kidneys filter metabolic wastes from the blood and excrete them as a liquid called urine. As kidneys form the urine, they also maintain the normal composition of blood, fluid and salt balance throughout the body tissues.
- Urine formed in the kidney is brought to the urinary bladder by two hollow muscular tubes called ureters.

- Urethra is the small tube that leads urine to the outside of the body.
- From urinary bladder urine is passed outside via urethra during urination voiding of urinary bladder is called micturition.

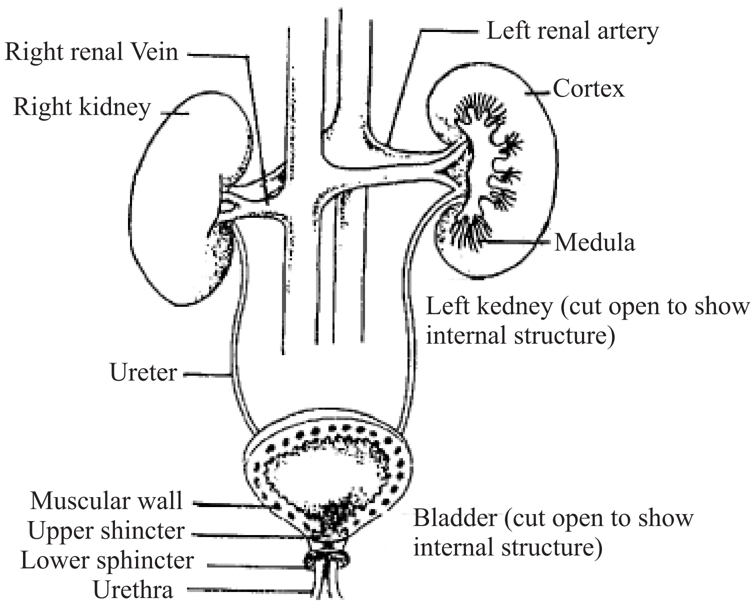


Fig. 14.7 Excretary organs of humans.

Structure of Kidney

Microscopic structure of kidney (Fig. 14.8)

- Kidney contains a large number of minute tubular structures called **nephrons** that are located partly in the renal cortex and partly in the renal medulla. They form urine and drain it ultimately into the pelvis of the kidney from where the ureters transport the urine to the urinary bladder.
- Nephrons are the structural and functional units of kidney associated with blood vessels and capillaries. There are about 1 million nephrons in each kidney which filter out about 180 litres of fluid per day most of which is reabsorbed. Each nephron can be divided into two regions (i) proximal nephron and (ii) loop of Henle. Further structural and functional components of a nephron are as follows:

  1. Renal corpuscle (is composed of cup-shaped Bowman's capsule and a tuft of capillaries (called glomerulus). Glomerulus receives the blood from a branch of renal artery.
  2. Proximal convoluted tubule (PCT)
  3. Descending limb of loop of Henle
  4. Ascending limb of loop of Henle

5. Distal convoluted tubule (DCT)
6. Collecting duct
7. Collecting ducts of all the nephrons join and ultimately form the renal pelvis from where the ureters arise.
8. Peritubular blood capillaries passing over the tubules join, and form the renal vein.

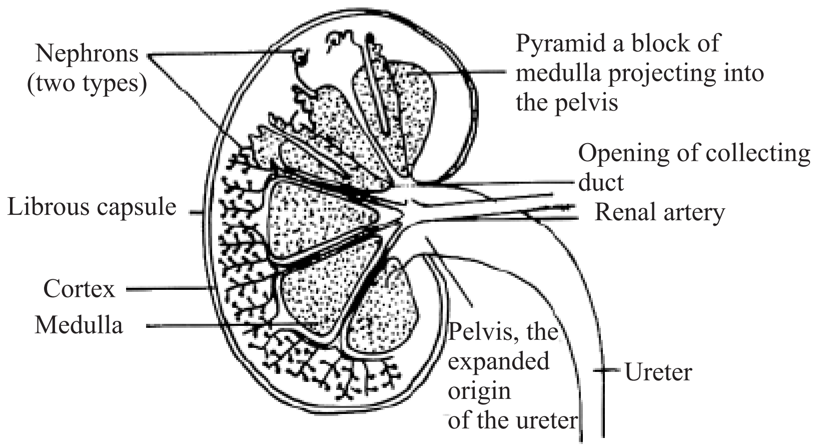


Fig. 14.8 Microscopic structure of human kidney

14.3.4 Formation of urine

Nephrons carry out excretory and osmoregulatory functions in the following steps-

1. Ultrafiltration
2. Selective reabsorption
3. Tubular secretion

1. Ultra-filtration

Each glomerular capillary receives blood flowing under high pressure through a branch of renal artery. There is continuous process of ultra filtration (filtration under pressure).

All small molecules like water, glucose, minerals, amino acids, urea and uric acid are filtered out of the blood plasma into the Bowman's capsule through the capillary walls. Proteins remain in the glomerular blood. Thus a protein free filtrate is collected in the lumen of the Bowman's capsule. The hydrostatic pressure of the circulating blood provides the pressure for filtration.

2. Selective reabsorption or tubular reabsorption

As the glomerular filtrate flows through the tubules several substances useful to the body such as glucose and animoacids and mineral ions needed to maintain the water and salt balance are reabsorbed through the walls of the renal tubule. The blood capillary passing over the nephrons absorb these substances.

(a) About 65%- 85% of filtrate is reabsorbed in Proximal Convoluted tubule (PCT). It includes water, glucose, amino acids, and salts.

(b) About 5% of water is reabsorbed in the descending limb.

(c) Ascending limb is impermeable to water; hence only salts are reabsorbed here.

(d) In Distal convoluted tubule (DCT) and collecting duct Na^+ is reabsorbed under the influence of the hormone **aldosterone** (secreted by adrenal cortex) . Water is absorbed under the influence of **ADH** (Anti diuretic Hormone) secreted by posterior pituitary.

3. Tubular Secretion

Cells of the renal tubule also directly serecte certain unwanted substances from the blood into the filtrate. These include uric acid, K^+ ions and ammonia. The filtrate is now known as urine.

Storage of Urine

The urine passes into urinary bladder via ureters and is stored there. The bladder can hold 400-500 cm^3 of urine. When about 200 cm^3 or more urine gets collected in urinary bladder, stretch receptors are stimulated leading to the desire to discharge urine.

14.3.5 Composition of urine (Table 14.5)

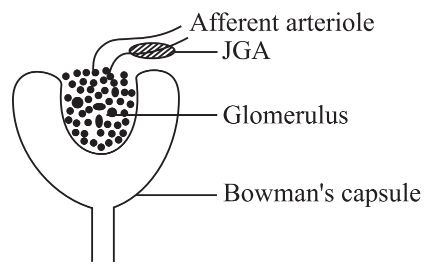
Table 14.5 Composition of urine

Normal components		Abnormal components	
Components	**Amount/Day**	**Component**	**Cause**
Water	1200-1500ml	Glucose	Diabetes mellitus
Urea	25-30 gms	Proteins	Kidney disease
Uric acid	0.7 gms	Acetones	Diabetes mellitus, starvation
Creatine	1.2 gms	Erythrocytes	Infection in urinary system
Ammonia	0.6 gms	Leucocytes	Large numbers indicate infection in urinary system
NaCl	10-15 gms	Uric acid crystals	Gout
KCl	2.5 gms		
Magnesium	0.2 gms		
Phosphate	1.7 gms		
Sulphate	2.0 gms		
Minute amounts of fatty acids, amino acids, pigments, mucin, enzymes, hormones, vitamins.			

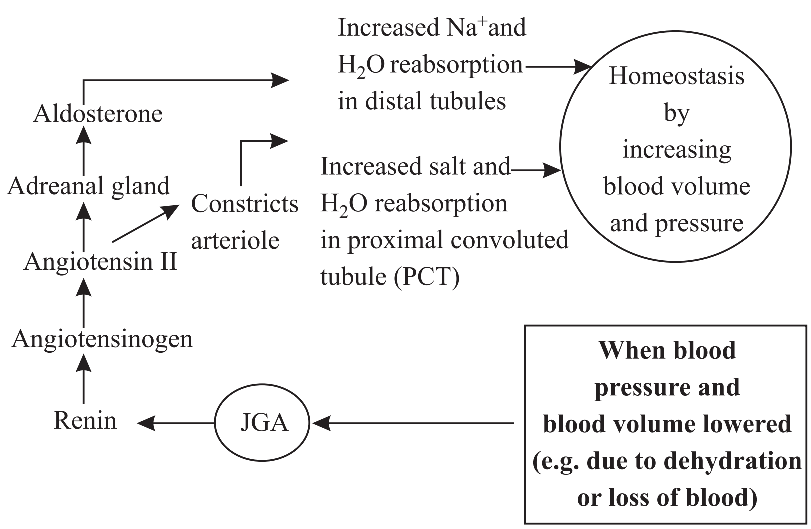
14.3.6 Renin-angiotensin and Atrial Natriuretic Factor

Renin-angiotensin is part of a feedback circuit which helps to regulate blood pressure and blood volume.

You know that nephron, the structural and functional unit of the human kidney has a cluster of capillaries called **glomerulus**. Recall its location from the Module 2, Unit 14 submit 14.3.3. Near the arteriole supplying the glomerulus lies a specialised tissue called **juxtaglomerular apparatus** (JGA)



When blood pressure or blood volume in the afferent arteriole drops, JGA secretes as enzyme called **renin.** Renin converts a plasma protein called **angiotensinogen** into **angiotensin II** which acts like a hormone, constricts the arteriole, which in turn elevates the blood pressure. Angiotensin II also stimulates the proximal convoluted tubules (PCT) of nephron (again, recall structure of nephron) to reabsorb more salt and water so that salt and water excreted in the urine are reduced. As a consequence, blood volume and blood pressure both increase. Angiotensin II also stimulates adrenal gland to release the hormone **Aldosterone** which makes distal tubules of nephron to reabsorb sodium and water. This also increases blood volume and blood pressure.



Renin angiotensin system for regulating blood volume and blood pressure

Antinatriuretic factor

Antinatriuretic factor is a powerful vasodilator and is a polypeptide hormone secreted by the cells of heart muscles (myocytes or muscle cells). It is released in the atria of the heart in response to the high blood pressure and is involved in the homeostatic control of water, sodium, potassium and fat in the body.

INTEXT QUESTIONS 14.4

1. In what form the cockroaches excrete their nitrogenous waste? What is its advantage for cockroach?

2. Where do Malpighian tubules of cockroach open?

3. List the parts of human excretory system and their functions.

4. Name the functional unit of kidney and its parts.

5. List the substances that are filtered out during ultrafiltration

6. What are the substances reabsorbed by the nephron?

7. What is the importance of tubular secretion?

8. Under which situation are the following present?

   (a) Glucose in the urine

   (b) Uric acid crystals

9. What is the normal volume of urine excreted per day?

10. What will happen if JGA (juxtaglomerular apparatus) stops secreting the enzyme renin?

11. Name a hormone, which is a polypeptide in nature and secreted by the heart muscles and is also a vasodilator.

14.4 OSMOREGULATION BY KIDNEY

Maintaining the solute concentration of the body fluids is called osmoregulation. Fine control of the precise amount of water and salt reabsorbed into blood is an important function of the distal convoluted tubules and collecting ducts. Depending on the need of the water in the body, kidneys excrete hypotonic (dilute) or hypertonic (concentrated) urine. Osmoregulation is controlled by the hormones ADH and aldosterone. Feedback circuits regulate their secretion.

(a) When the water content of the body is more, leading to low osmotic pressure, less ADH (anti diuretic hormone) is released. Hence the wall of the DCT and collecting tubules remain less permeable and as a result plenty of dilute urine (hypotonic urine) is excreted.

(b) When water content of the body is low, the posterior pituitary secretes more of ADH. The permeability of the tubules is increased. As a result more water is reabsorbed into the blood and reduced volume of concentrated urine is excreted (hypertonic urine). **Diuresis** means the production of increased amount of urine, so anti diuresis means reduction of urine volume and hence the name antidiuretic hormone or ADH.

(c) Urine is also concentrated by the counter current system of the descending and ascending limbs of Henle's loop. About 5% of the water from the filtrate is absorbed in this part.

(d) In response to low sodium ion concentration (or low blood pressure) another hormone, **aldosterone** is released by the adrenal cortex. It stimulates the kidney tubules to absorb sodium ions in exchange of potassium ions. This leads to reabsorption of water by osmosis. As a result of increased blood volume the blood pressure is increased. Similarly high sodium concentration will inhibit aldosterone release and as a result in would lead to lower sodium ion concentration in blood.

You will learn more about hormones in lesson 16.

14.5 HAEMODIALYSIS AND KIDNEY TRANSPLANTATION

Haemodialysis

1. The blood urea level rises abnormally (uraemia) in patients suffering from kidney failures. In such patients, an artificial kidney is used for removing excess urea from the blood by a process called **haemodialysis**. It is carried out in the following steps :
2. Blood is taken out from the artery of the patient and cooled to 0°C.
3. This blood is then passed through cellophane tubes of the artificial kidney. Cellphane is permeable to micro molecules such as urea, uric acid and mineral ions. It is not permeable to macromolecules such as plasma proteins.
4. Outside the cellophane tube is the dialyzing fluid, which has some solutes like those in blood plasma but no nitrogenous molecules like urea, and uric acid.
5. Hence the nitrogenous compounds from within the cellophane tubes flow into the dialyzing fluid by diffusion.
6. Blood coming out of the artificial kidney is warmed to the body temperature and returned to the vein of the patient.

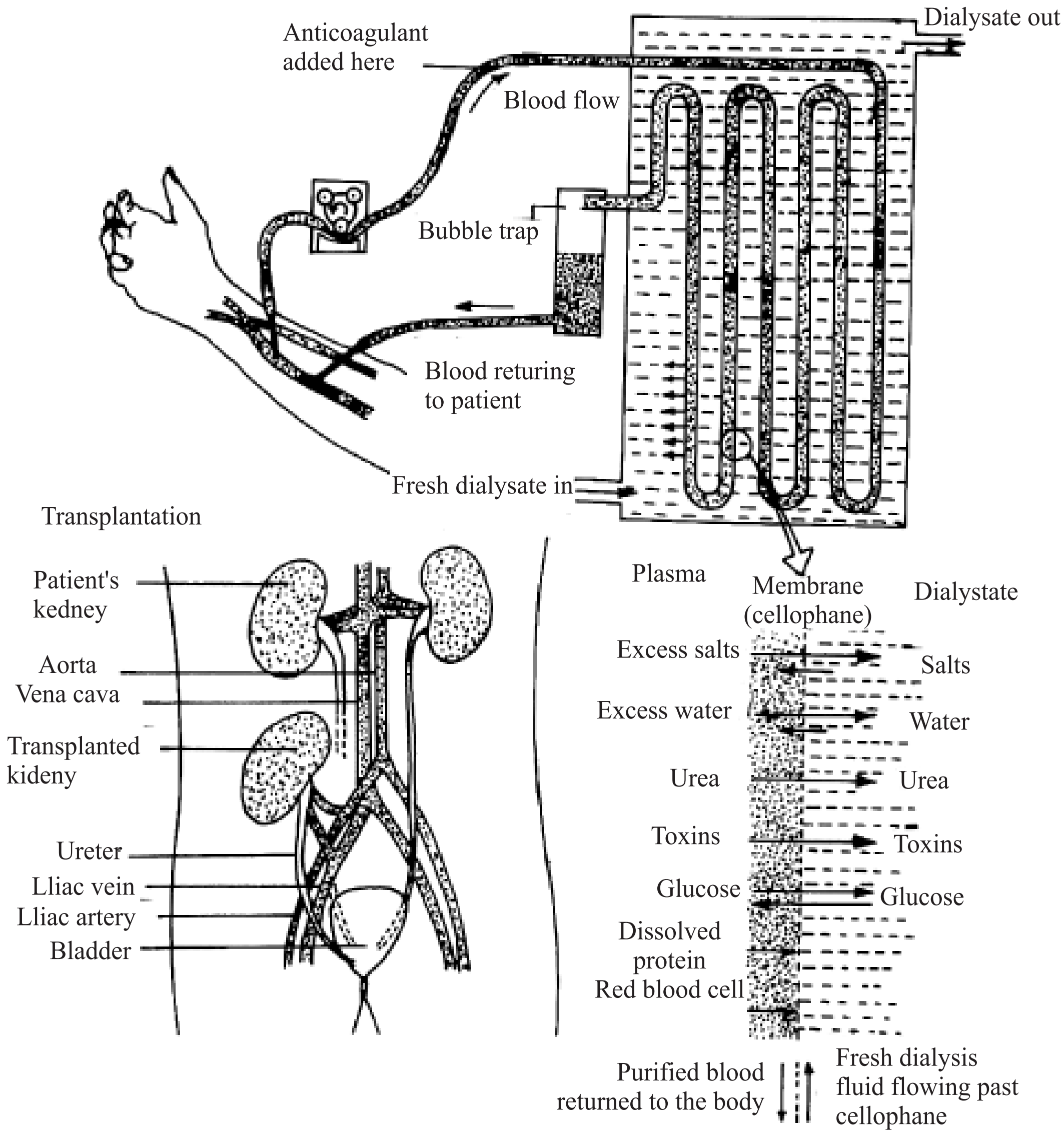


Fig. 14.9 Artificial kidney (haemodialysis)

Kidney transplantation

If kidney failure cannot be treated by other available means, kidney transplantation is advised.

- Donated kidney may come from a living person or a donor who has recently died.
- The genetic make up of the donor should be as close to the patient as possible, that is, if it is donated by a close relation, it reduces the chances of rejection.
- Drugs are, however, used to prevent rejection of the transplanted kidney by the body.

14.6 ROLE OF LIVER IN EXCRETION

- It excretes bile pigments, cholesterol, drugs and some vitamins.
- It excretes all the above mentioned substances in bile, which flows into the small intestine and from there these get removed with the faeces.
- Formation of urea and uric acid (from ammonia) also takes place in liver. These are removed from the body by the kidneys.

INTEXT QUESTIONS 14.5

1. Name the organ where urea is formed.

   ....

2. Why is cellophane used in haemodialysis?

   ....

3. What is the composition of dialyzing fluid?

   ....

4. From which type of blood vessel artery or vein, is the blood taken out for dialysis?

   ....

5. When is kidney transplantation advised?

   ....

6. How is bile pigment removed from our body?

   ....

WHAT YOU HAVE LEARNT

- Metabolic activities produce a number of waste products that need removal from the body.
- Breathing is a mechanical process of inhaling air (inspiration) and giving out of CO_2 rich air (expiration).
- Skin acts as the breathing organ for earthworm. It is thin, moist and richly supplied with blood capillaries.
- Cockroaches have air tubes called trachea for respiration. Air reaches directly to the tissues for gaseous exchange. Blood does not participate in gaseous transport.
- In humans, air passes through respiratory passage as follows-

  Nostrils→Pharynx→Trachea→Bronchi→Bronchioles→Alveoli in lungs

- Cellular respiration is a chemical process which takes place within the cell and is associated with release of energy.
- Haemoglobin is an iron containing pigment that can easily combine with oxygen and transport it to different parts of the body.
- Carbon dioxide in blood is transported in three ways: (a) dissolved in plasma, (b) as carbaminohaemoglobin, and (c) as bicarbonates
- Aerobic respiration takes place in the presence of oxygen. 38 molecules of ATP, carbon dioxide and water are released during this process.
- Anaerobic respiration takes place in the absence of oxygen. 2 molecules of ATP, carbon dioxide and alcohol or lactic acid are produced during this process.
- Excretion is the removal of nitrogenous wastes from the body.
- Human excretory system consists of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra.
- Nephrons are the filtering units of kidney.
- Urine formation by nephrons has three steps : ultrafiltration, reabsorption and tubular secretion.
- Urine consists of water, urea, unwanted salts and some drugs.
- Depending upon the kind of excretory product, animals may be classified as ammonotelic ureotelic, or uricotelic.
- An artificial kidney or dialysis machine may be needed in case of kidney failure.
- Malpighian tubules in cockroach remove uric acid from the body cavity into the digestive tract for removal.
- Cigarette smoking is injurious to health and causes emphysema in which alveoli lose their elasticity.
- JGA or Jux taglomerular apparatus in the nephron helps to restore blood volume and blood pressure when it falls by secreting an enzyme renin.
- Heart secretes a hormone called antinatriuretic factor which helps in maintaining homeostasis, related to control of water, sodium, potassium and fat in the body.

TERMINAL EXERCISES

1. List the major steps that are involved with respiration in humans.
2. How is oxygen transported in earthworm?
3. Name the respiratory pigment in earthworm.
4. What is the role of carbonic anhydrase in the transport of carbon dioxide in our body?
5. Which part of our respiratory system is known as the voice box?
6. Where are respiratory centres situated in our brain?

7. Name one nitrogenous waste removed by the kidney.
8. Name the hormone the absence of which will result in excretion of hypotonic urine.
9. What is the role of cellophane in dialysis?
10. Why is inspiration said to be an active phase and expiration as passive phase?
11. Differentiate between
    (a) Breathing and respiration
    (b) Inspiration and expiration
12. List the special features of alveoli that enable easy gaseous exchange.
13. What is vital capacity, tidal volume and residual volume?
14. Give reasons for the following :
    (a) Exchange of gases at the alveolar surface continues even during expiration.
    (b) Trachea and bronchi do not collapse when air pressure decreases inside them.
15. Draw the excretory system of human and label the parts.
16. Draw the structure of a nephron and label the parts.
17. What is the cause and symptoms of pneumonia and TB?
18. What is the role of liver in excretion?
19. Explain how nitrogenous wastes are removed from the body of cockroach.
20. How does ultrafiltration and reabsorption occur in nephrons?
21. Explain how gaseous exchange takes place in the lungs.
22. How is oxygen transported from the lungs to the tissues and carbon dioxide from tissues to the lungs?
23. How is (a)Water balance, and (b) Salt balance maintained by kidney?
24. List the parts of human respiratory system in correct sequence and state their functions.
25. List three characteristics of our lungs which make them suitable as respiratory surface.

ANSWERS TO INTEXT QUESTIONS

14.1
1. Stepwise oxidation of glucose resulting in release of energy.
2. O_2, CO_2
3. Respiration by the skin; frog
4. Red, haemoglobin
5. Directly through tracheoles

6. Insects
7. Through spiracles
8. Nostrils → pharynx → bronchi → bronchioles → lungs
9. Nasal cavity
10. Prevent food from entering the trachea or food pipe

14.2 1. mechanism of taking in air and then giving it out
2. relaxed and dome shaped
3. 500 mL 4. 4 molecules 5. Pulmonary vein
6. (a) dissolved in plasma as carbon dioxide – 5%
(b) as carboxy carbamino haemoglobin in RBC – 20%
(c) as bicarbonate ions in RBC or plasma – 75%
7. Bacillus Calmette Guerin (BCG)
8. Silicosis or asbestosis
9. Bronchitis is an infection of the bronchi and antibiotics can cure it whereas bronchial asthma is an allergic reaction.
10. Emphysema

14.3 1. (a) Liver (b) Kidney
2. Ammonia; amoeba and fresh water fishes

14.4 1. Uric acid; this is to prevent water loss as these animals need to conserve water
2. Malpighian tubules open at the junction of mid and hind gut
3. Kidney-filters nitrogenous wastes, excess of water and salt
Ureters-transport urine to the bladder
Urinary bladder-temporary storage of urine
Urethra-drains urine outside the body
4. Nephron, consisting of renal corpuscles made up of Bowman's capsules and glomerulus, PCT, loop of Henle, DCT, collecting duct
5. Water, amino acid, glucose, urea, uric acid, minerals, vitamins.
6. Water, glucose, some salts, amino acid and small quantity of urea and uric acid.
7. Direct elimination of certain minerals can take place such as ammonia and potassium.
8. (a) Diabetes mellitus (b) Gout
9. 1200 to 1500 mL
10. Blood Pressure will remain abnormally low.
11. Antinatriuretic factor.

14.5 1. Liver

2. Cellophane is impermeable to macromolecules like plasma proteins and blood corpuscles

3. It contains some minerals and solutes like those in plasma but no urea and uric acid is present.

4. Artery

5. When kidney failure cannot be treated.

6. Bile pigments are removed along with bile via the digestive tract.

15

CIRCULATION OF BODY FLUIDS

The body of almost all the animals, has some form of fluid circulating in the body. Such fluids constitute the distributing system (to supply substances) as well as collecting system (to pick up substances) from the various parts of the body (including the remotest cell). What are these fluids? How are these circulated and in what way do they function in our body? These and many more questions will be answered in this lesson.

OBJECTIVES

After studying this lesson, you will be able to :

- *explain the importance of the circulatory system in human body;*
- *differentiate between open and closed systems of circulation;*
- *list and draw the organs of circulatory system of cockroach;*
- *list and draw the organs of circulatory system in humans*
- *describe the histology, functions and composition of blood in humans*
- *compare the structure and functions of an artery, a vein and a capillary;*
- *explain the process of blood coagulation in humans*
- *name the blood groups and describe modalities of blood transfusion;*
- *explain blood pressure;*
- *describe lymphatic system and mention its components;*
- *define immunity and describe its different types;*
- *explain various immuno-deficiency disorders;*
- *name and describe some blood related disorders such as hypertension; atheroma and arteriosclerosis;*
- *explain the importance of ECG and role of pacemaker in treating heart beat related disorders.*

15.1 CIRCULATORY SYSTEM

Our body is made of cells. Cells need nutrients and oxygen to survive, and wastes need to be removed from them. Hormones are also needed to be transported from the endocrine glands which secrete them to their respective target cells. This work of transportation of nutrients, gases, wastes and other substances from one part of our body to the other part, is carried out by blood, and termed **circulation**.

> The organs responsible for the flow of blood and lymph through various parts of the body constitute the circulatory system

1. Functions of circulatory system

(i) Transport of nutrients to the tissues for their utilization

(ii) Transport of respiratory gases (O_2 and CO_2) to and from the cells.

(iii) Collection of metabolic wastes from different tissues and transporting them to excretory organs for their removal.

(iv) Transport of hormones from endocrine glands to target organs.

(v) Protection of body by destroying pathogens.

(vi) Uniform distribution of heat in the body.

2. Types of Circulatory System

Depending upon the mode of circulation, the circulatory system may be open or closed type.

(i) Open circulatory system

(a) Blood does not flow in closed vessels rather it flows through parts of the body cavity. It remains mixed with the body fluid.

(b) Sufficient high pressure for circulation is not maintained.

Organisms like prawns, and insects have open circulatory system.

(ii) Closed circulatory system

(a) Blood flows in well-defined tube-like vessels.

(b) Sufficient high pressure is maintained .

(c) System is more efficient than open type.

Closed system is found in all vertebrates.

15.2 CIRCULATORY SYSTEM OF COCKROACH

The circulatory system of cockroach is of open type. It consists of a pulsatile heart (dorsal blood vessel) and sinuses through which the blood flows. The blood is colourless and fills the entire body cavity which is rightly called **haemocoel**. Thus the blood is called haemolymph. Haemocoel is divided into three sinuses (chambers) by two horizontal septa called **dorsal diaphragm** and **ventral diaphragm**. The three sinuses are dorsal sinus or **pericardial sinus** enclosing the heart, middle **perivisceral sinus** lodging the various visceral organs and the ventral **perineual**

sinus enclosing the ventral nerve cord. Both the diaphragms are perforated such that the three sinues remain in communication with each other.

The heart is an elongated, tubular structure, closed behind and open in front, running all along the middle line through thorax and abdomen. It consists of thirteen segmentedly arranged funnel shaped chambers. At the lateral side of each chamber is a pair of ostia one on each side, which are guarded by **valves**. Through these ostia, the heart communicates with the pericardial sinus. Anteriorly, the heart continues into the head as anterior aorta which opens into the haemocoel of head. Attached to each segment, is a pair of triangular **alary muscles** present on either side of the heart.

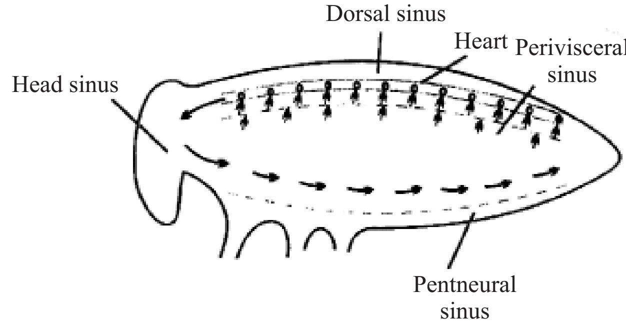


Fig. 15.1 Circulatory system of cockroach

The blood is a colourless fluid, made up of plasma and cells termed haemocytes. Since the blood of cockroach lacks any respiratory pigment, it is not involved with the transportation of respiratory gases. It serves only for (i) the transportation of the nutrients (ii) maintenance of hydrostatic pressure and (iii) acts as a reservoir of water. The blood of cockroach circulates due to contraction and relaxation of the heart and the alary muscles.

15.3 ORGANS OF HUMAN CIRCULATORY SYSTEM

The circulatory system consists of the following parts :

1. Heart – the central pumping organ.
2. Blood vessels – the connecting tubes – arteries, veins and capillaries.

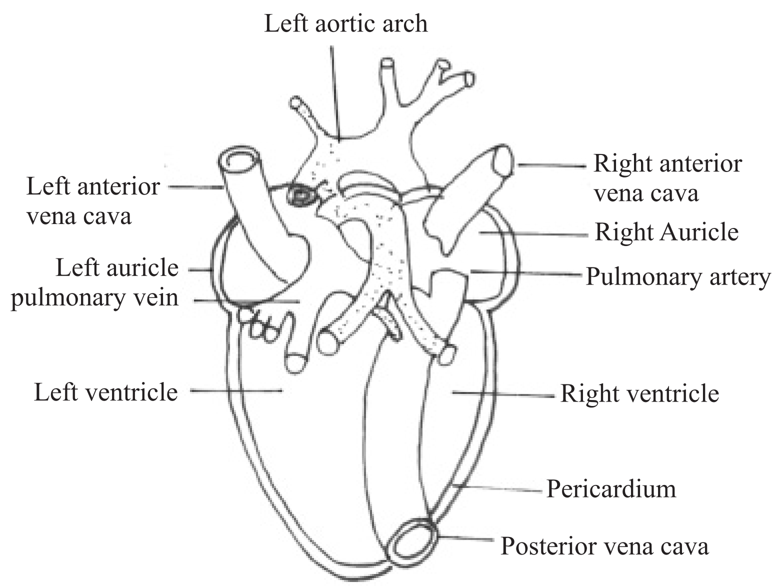


Fig. 15.2 (a) External structure of humnan heart (Front view)

3. Blood – is the circulating fluid, a connective tissue made of a fluid matrix and cells.
4. Lymphatic system comprises of lymph nodes and lymph vessels.

1. The human heart

It is a muscular organ made of cardiac muscle fibres (Fig. 15.2). It is able to perform its function by coordinating contraction and, relaxation and opening and closing of a number of valves present inside the heart. This fist sized organ consists of 4 chambers, the two upper chambers – the **atria** and two lower chambers – the **ventricles**. Ventricles have thick muscular walls for pumping blood to longer distances. Heart is covered by a membrane – the **pericardium**.

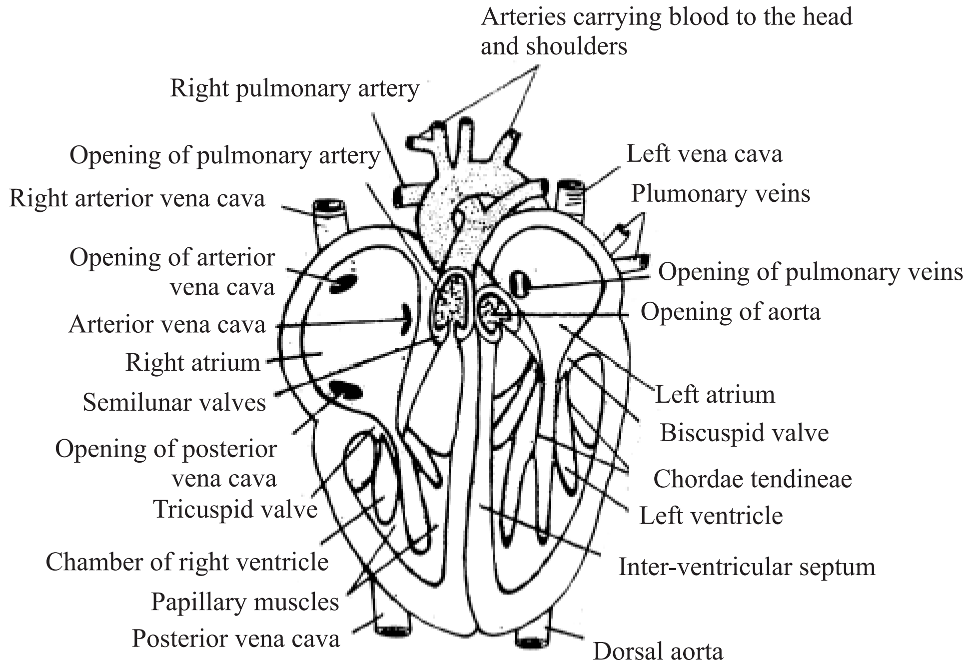


Fig. 15.2 (b) Internal structure of human heart.

(i) Valves inside the heart

Locate the following valves in figure 15.3. The atrio-ventricular valves are between Atria and Ventricles.

(a) Right **atrio-ventricular valve** or **tricuspid valve**

(b) Left **atrio-ventricular valve** or **bicuspid valve**

Semilunar valves at the origin of aorta and pulmonary artery.

Valves open only on one side like a door. They regulate the flow of blood by opening on one side to let blood flow out in one direction only and prevent the back flow of blood.

(ii) Heart beat and cardiac cycle

The **beating of heart** goes on by itself as long as one is alive. Each heartbeat consists of the steps mentioned below and makes two sounds – **Lubb** and **Dubb** during each beat.

(a) The heart beat starts with contraction or **systole** of atria, followed by relaxation or **diastole**. The lubb sound or 1st heart sound occurs due to closure of atrioventricular valves, the atrial systole.

(b) Contraction of ventricles followed by relaxation accompanied by the dubb sound or the 2nd heart sound occurs due to closure of semi lunar valves. At the beginning of every heart beat the four chambers of the heart are in the relaxed state (**Joint diastole**). At this stage the venae cavae pour deoxygenated blood into right atrium and the pulmonary vein pours oxygenated blood into left atrium.

Heart beat originates at the **Sinu-Atrial Node or S.A Node** which is a modified part of the muscular wall in the upper corner of the right atrium (Fig. 15.3).

As a result right atrium contracts, tricuspid valve is pushed open and deoxygenated blood enters the right ventricle. At the same time, the bicuspid valve is pushed open and oxygenated blood flows into left ventricle.

Atrio-Ventricular Node (A.V. Node), modified muscle is located in the interatrial septum. When impulse comes from SA node to AV node, the contracted atria begin to relax and impulse passes to **Bundle of HIS** lying in the interventricular septum and then passes to **Purkinje Fibers** lying in the walls of ventricles. As a result ventricles contract (Ventricular systole)

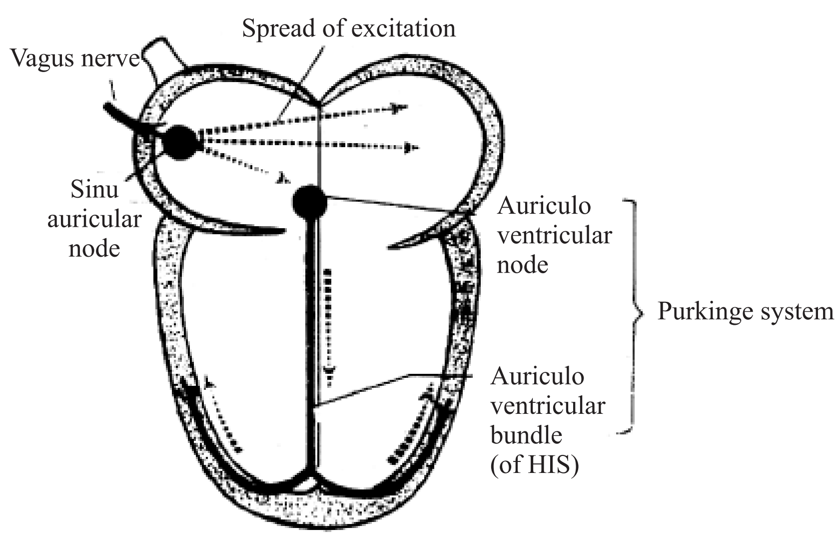


Fig. 15.3 Position of the Sino-atrial and atrio-ventricular nodes and the bundle of HIS and conduction of impulse for heart beat.

Since Sinu-atrial Node initiates and regularizes the heartbeat, it is also called the **pacemaker**. The pacemaker is influenced by nerves, hormones, CO_2 and O_2 content of blood, and heat.

Do You Know?

Sometimes the S.A. (Sino-Atrial) Node may become defective or damaged. A person may need to have an artificial pacemaker grafted in the chest. This regularizes the heartbeat.

Electro Cardiogram (ECG) is the instrument that records the conduction of heartbeat .

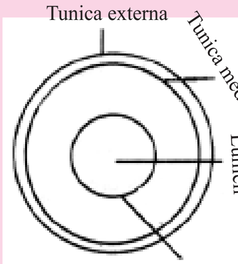
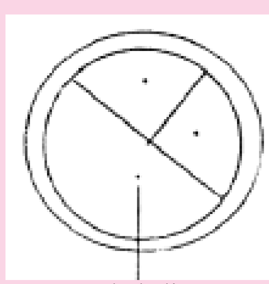
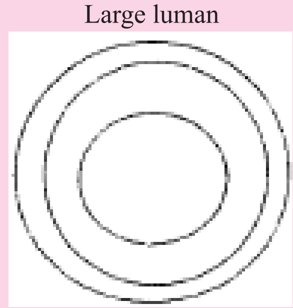
This helps in detecting heart beat disorders.

15.3.2. Blood vessels

The tubes transporting blood are called **Blood Vessels**. The wall of a blood vessel has three layers, tunica externa, tunica media and tunica interna. There are 3 kinds of blood vessels:

(i) Artery (ii) Capillary and, (iii) Vein. These three vessels differ in structure and speed of blood flow, as shown below.

Table 15.1 Comparison in structure and function of an artery, the capillary and the vein.

Artery	Capillary	Vein
• Transports blood away from the heart.	• Capillaries link arteries to . veins for exchange of material between blood and tissues which also have capillaries	• Site of Transport of blood towards the heart.
• Tunica media is thick and composed of elastic, muscular tissue.	• No tunica media. Only single layer of cells forming **endothelium**. No elastic fibers	• Tunica media is relatively thin and only slightly muscular. Few elastic fibers.
• No semi-lunar valves. along arteries	• A semi-lunar valve present.	• Semi-lunar valves are present all along the length of vein at intervals to prevent back flow of blood
• Pressure of blood is high and arteries are pulsatile.	• Pressure of blood falling and non-pulsatile.	• Pressure of blood low and non-pulsatile.
• Blood flow rapid	• Blood flow slow	• Blood flow slow
• Low blood volume Blood is oxygenated except in pulmonary artery	• High blood volume Mixed oxygenated and deoxygenated blood.	• Increased blood volume • Blood deoxygenated except in pulmonary vein
• Small lumen	• Extremely narrow lumen	• Large lumen
		

Arteries divide into **Arterioles** and then into **Capillaries**. This way they come in contact with all the tissues and bathe the cells with blood plasma. Diagram 15.4 shows the possible route that blood may take between arteriole, capillary bed and venule. Capillaries join to form venule. Venules are thin blood vessels that join to form veins.

(i) Major Arteries and Veins

Blood that has been circulated through the body has lost much of the O_2, it carried. This de-oxygenated blood returns to the heart by two major veins.

1. **Superior vena cava**-brings deoxygenaled blood from head and shoulder region.
2. **Inferior vena cava**-brings deoxygenated blood from lower parts of the body.

These venae cavae open in the right atrium (refer to diagram 15.2). Contraction of right atrium forces this blood into the right ventricle.

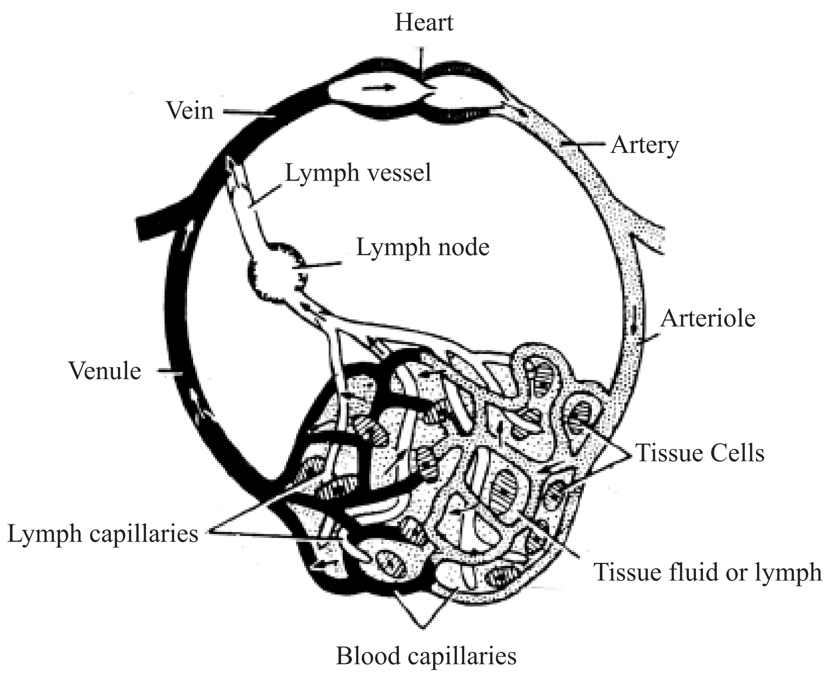


Fig. 15.4 The route that blood takes between arteriole, capillary bed, and venule.

Contraction of right ventricle pumps blood into **pulmonary artery** which transports blood to the lungs. Blood gets oxygenated in the lungs and returns to the left atrium through the **pulmonary vein**.

Blood then passes from the atrium into the left ventricle. Left ventricle pumps blood into aorta. The aorta distributes blood throughout the body.

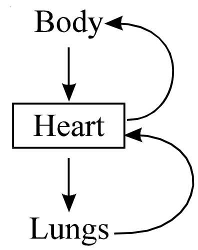
See the flow diagram given below which summarizes the **path of blood** through the entire circulatory system.

Double circulation

Since blood passes twice through the heart, it is termed **Double circulation**

(i) First Deoxygenated blood passes from the body to heart and oxygenated blood from heart to the body.

(ii) Then Deoxygenated blood flows from heart to lungs and oxygenated blood from lungs <u>again to heart</u>, from lungs.



In one circulation, the blood passes through the heart twice. Once from body to heart to lungs and second time from lungs to heart to body.

Path of circulation

First from body to heart
(Venae cavae carry blood from tissues with very little oxygen and lot of CO_2 to Right atrium)
↓
Tricuspid valve opens
↓
Right ventricle
↓
Pulmonary arteries
↓
(Pulmonary arteries carry blood to lungs to give up CO_2 and to collect O_2 from lungs)
Pulmonary veins
↓
(Pulmanary veins carry oxygenated blood back to left atrium of heart)
↓
Left atrium
↓
Bicuspid valve
↓
Left ventricle
↓
Aorta
(carries blood with a lot of oxygen and distributes this oxygenated blood to different parts of the body)

Pulmonary artery is the only artery that carries the de-oxygenated (**blood poor in O_2**) blood. It is called artery as it carries blood away from heart.

Pulmonary vein is the only vein that carries oxygenated blood (blood rich in O_2). It is called vein as it carries blood into heart.

INTEXT QUESTIONS 15.1

1. Give one example each of animals with open and closed circulatory system.
   (i) Open circulation ....
   (ii) Closed circulation ....
2. Where in the heart are the following valves located?
   (i) Bicuspid ....
   (ii) Tricuspid ....
3. Name the following
   (i) Structure where the wave of contraction originates in heart to begin heart beat
   ....
   (ii) Structure connecting arteries with the veins
   ....
   (iii) Blood vessel that brings oxygenated blood from the lungs to the heart
   ....
   (iv) The blood vessel which collects and brings deoxygenated blood from brain and shoulder region to the heart ....

(ii) Components and functions of blood

Blood is a red coloured, thick and slightly alkaline, fluid which keeps circulating in our body through the blood vessels. Why is blood so important? It is important because

1. it transports substances in the body such as Oxygen, nutrients, and hormones. It also carries waste to the kidney.
2. it protects body against disease.
3. it maintains normal body temperature.

The components of blood

Blood is a fluid connective tissue made of plasma and blood cells.

Blood

- **Plasma** 55% (liquid)
  - Water 90%
  - Proteins (little less than 10%)
- **Cellular Components** (45%)
  - Red blood Corpuscles (RBC)
  - White Blood Corpuscles (WBC)
  - Platelets (pieces of cells without nuclei)

A. Plasma

It is a pale yellow liquid consisting of **blood proteins** like **albumin, globulin and fibrinogen.**

Functions : Plasma has the following functions :-

1. Transport of products of digestion from small intestine to various tissues.
2. Transport of waste products from tissues to excretory organs.
3. Transport of hormones from endocrine glands to target organs.
4. Maintenance of temperature by distribution of heat all over the body.
5. Provides factors for clotting of blood (Fibrinogen).
6. Retention of fluids in blood (through plasma proteins).
7. Maintenance of acid-base equilibrium in the blood.
8. Provides body immunity through antibodies (Immunoglobulins) which are made by one kind of WBC and then released into the plasma.

B. Blood Cells

The cells of blood are **Red Blood Corpuscles (RBC)** and **White Blood Corpuscles (WBC)** and cell fragments, the **Platelets**. Blood cells are formed in the bone marrow. Their formation is termed **haemopoiesis**. Table 15.2 gives the idea of the cellular components, their origin, function and structure.

Table 15.2 Cellular components of blood

Component	Origin of cells/mm	Number	Function
Erythrocytes (Red Blood corpuscle)	Bone marrow	5.000,000	transport of • oxygen to tissues and a large amount of • carbon dioxide back to lungs
Leucocytes (White Blood Corpuscles)	Bone marrow	4,000 8,000	
(a) Granulocytes (72% of total white blood cell count)		4900	• engulf bacteria
neutrophils (70%)	Bone marrow	105	• anti-histamine properties
eosinophils (1.5%)		35	• Produce histamine and heparin
basophils (0.5%)			
(b) Agranulocytes (28%)			
monocytes (4%)	Bone marrow	280	• engulf bacteria (Phagocytosis)
lymphocytes (24%)	Bone marrow, lymphoid tissue, spleen	1680	production of antibodies to provide immunity
Platelets	Bone marrow	250,000	initiate blood-clotting

> Do you know about the following blood disorders ?
> 1. Increase in R.B.C (More than normal) POLYCYTHEMIA
> 2. Decrease in R.B.C (less than normal) ANAEMIA
> 3. Increase in W.B.C.(more than normal) LEUKAEMIA
> 4. Decrease in W.B.C (less than normal) LEUKOPENIA

Coagulation of Blood (Blood Clotting). You must have, sometime or the other, got a cut on your finger and seen blood flowing out of it . You would have noticed that after a few minutes, the blood flow stops, as the blood thickens and forms a lump. This lump is called **clot**. The process of thickening of blood is called **coagulation or clotting of blood**. We are lucky that the blood clots and the bleeding stops. If it did not, a person with a very small wound would lose a lot of blood and die. When blood vessels are injured, a sequence of reactions takes place to prevent loss of blood. Steps involved are as follows :

Thromboplastin (from blood platelets) + Prothrombin (Plasma protein)

$\downarrow$ Ca^{++}ions

Fibrinogen (Plasma protein) $\xrightarrow{\text{Thrombin}}$ Fibrin (Insoluble fibres)

FIBRIN + R.B.C $\longrightarrow$ CLOT (Scab) Prevents blood loss

> **Haemophilia** – A genetic disease that results in a condition where blood fails to clot

Blood group

The blood of an individual may belong to any one of the four blood groups, A, B, AB, and O. Blood group remains constant throughout lifetime as it is genetically controlled and is inherited from parents. These blood groups are due to the presence of special proteins present on the membrane of RBCs termed as antigens. Antigens present could be A, B both A and B or no **Antigen** may be present in the cell membranes of RBC of a particular blood group. Blood plasma, on the other hand, contains **antibodies** a, b, or both a and b, or neither of the two. Antigen A reacts with antibody b and antigen B with antibody a causing clumping of blood.

Blood Group	Antigen	Antibody
A	A	b
B	B	a
AB	A, B	–
O	–	a, b

Blood transfusion

When excessive blood is lost from the body either due to an accident, hemorrhage or during surgery (operation), doctors transfer blood from a healthy person (Donor) to the patient (Recipient). This is called **Blood Transfusion.** When blood transfusion is needed, the red blood cells selected must belong to a group which will not be affected by any antibody in the patient's plasma.

Clumping of donor's blood (Agglutination) may take place upon transfusion if the blood group of donor does not match with that of the recipient. Table 15.3 shows blood groups and possibility of their transfusion.

> **Clumping** is a condition where the antibodies present in the plasma of recipient link donor's blood cells with each other to form a clump
>
> **Agglutination** is the process by which red blood cells clump together when the antigens on their surface react with complementary antibodies.

Table 15.3 Matching of Blood Group, Safe and Unsafe After Transfusion of Blood.

Those who can safely receive blood of donor type	Donor	Blood group types who cannot
O, A, B, AB	O	
A, AB	A	O, B
B, AB	B	O, A
AB	AB	O, A, B,

The above table indicates that :

Blood group of recipient	Donor's blood group				
	Group O	Group A	Group B	Group AB	√ Safe transfusion
Group O	√	×	×	×	
Group A	√	√	×	×	×
Group B	√	×	√	×	
Group AB	√	√	√	√	Dangerous transfusion

The above table indicates that :

1. Blood group of O type can be given to all groups. It is thus the **Universal Donor**. This is because there are no antigens in the blood of Group O.
2. Blood groups AB can receive blood from all other groups and is thus called **Universal Recipient**. No Antibodies present in the blood of Group AB, so no reaction with antigens of other blood groups.

Rh Factor

Presence or absence of another blood protein in addition of ABO antigens makes a person Rh^+ or Rh^-.

> Rh factor in expectant mothers can sometimes cause problems. The blood of an Rh^+ embryo whose mother is Rh^- is in danger of severe clumping.

Antibodies are produced in the mother against the Rh^+ blood cells of the embryo and whenever there is even the slightest mixing of foetal blood mothers blood.

15.3.5 Blood Pressure

You have already learnt that during systole, the ventricles contract and force the blood into the arteries, which carry it to all parts of the body. The flow of the blood in the arteries exerts a pressure on their elastic walls. This pressure is called **blood pressure**.

The pressure of blood at the time of ventricular contraction is higher and is called **systolic pressure**. When ventricles are relaxed and are being filled by blood, there is a drop in pressure. This lower pressure is called **diastolic pressure**. These two pressures can be measured in the arteries of the arms. The device used for measuring blood pressure is called **Sphygmomanometer**.

A reading of 120/75 means that the person's systolic pressure is 120 mm of mercury and diastolic pressure is 75 mm of mercury. A typical reading for a healthy adult is 120 ± 570 ± 5 mm of mercury.

The difference between diastolic and systolic pressure can be felt as a throb in the arteries of the wrist. This throb at the wrist is called **Pulse**. The number of throbs felt at a particular point on the wrist (due to systole) per minute is called **Pulse Rate**. It is equal to the number of heart beats i.e. around 70 beats per minute for a normal adult.

INTEXT QUESTIONS 15.2

1. Name the following
   (i) The term given to the production of blood cells ……….........……….
   (ii) The three proteins present in the plasma
   (i) ……………. (ii) ……………. (iii) …………….
   (iii) Cell fragments of blood involved in the clotting of the blood
   ………………………………......................................…………………….
2. Fill in the blanks
   (i) Transfer of blood from donor to recipient is called ….................………
   (ii) Antigens are present on ………………, and antibodies in the ……………..
   (iii) People from blood group O can receive blood from blood group /groups ………………………
   (iv) Blood pressure is measured by an instrument called………………. The reading for a person with normal blood pressure will be around ….....…………………….....

4. Lymphatic system

Our body has the presence of two kinds of circulating fluids – blood and lymph. Of these you have seen and felt the first (i.e. blood) in your own body, but lymph remains unnoticed even if it oozes out at any point of injury because it is colourless.

This system consists of a series of branching vessels and a collection of lymphatic organs. Let us understand. A continuous exchange of materials between the blood capillary and the intercellular fluid (fluid present between cells of tissues) goes on. Some important components like proteins that could not be sent back to blood capillaries from intercellular fluid, are taken up by the lymph capillaries as lymph and drained into veins in the lower neck portion of the body (subclavian vein). Lymph should be regarded as **modified tissue fluid**.

The clear, colourless liquid moving out of the capillary wall is called Lymph. Lymph comes into direct contact with body cells. (Fig. 15.5)

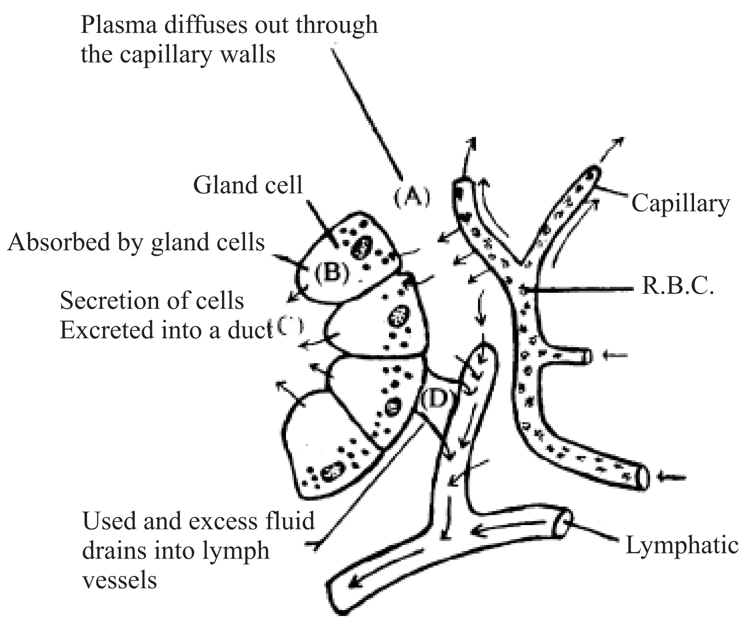


Fig. 15.5 Flow of lymph between capillaries and lymph vessel

(a) Functions of lymph

(i) Supplies nutrition and oxygen to those parts of body where blood cannot reach

(ii) Drains away, excess tissue fluid from extra-cellular spaces and pours back into the blood.

(iii) Absorbs and transports fats absorbed from small intestine (lacteals)

(iv) Collects nitrogenous waste

(v) Lymphocytes and antibodies present in lymph help in removing bacteria

(b) Differences between blood and lymph

Blood differs from lymph in a number of ways as shown in table 15.4

Table 15.4 Differences between Blood and Lymph

Blood	Lymph
1. Red in colour due to presence of haemoglobin	1. Colourless fluid
2. Flows rapidly	2. Flow is very slow
3. Contains RBC, WBC, Platelets and Plasma	3. Contains plasma and WBC
4. Route of blood flow Heart ↓ Arteries ↓ Capillaries ↓ Veins ↓ Heart	4. Route of lymph flow Tissue Spaces ↓ Lymph Capillaries ↓ Lymph Vessels ↓ Subclavian Vein ↓ Heart

The clear, colourless fluid that collects in a blister to provide protection to the underlying tissue is **lymph**.

The lymphatic system consists of a large number of **lymph ducts, lymph nodes and lymph vessels** (Fig. 15.6). It lacks a pumping mechanism. Fluid is pushed by muscle movement.

The lymph nodes are scattered throughout the body. They are more concentrated in the neck, armpits and groins

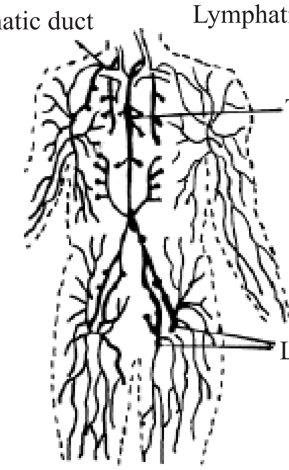


Fig. 15.6 Lymph vessels and lymph glands

Lymph nodes

Each node is a clump of tissue housing a number of lymphocytes. These nodes act as filters for bacteria, viral particles and cancerous cells. These resident lymphocytes then immediately attack the disease causing germs or pathogens.

The spleen and tonsils are lymphoid organs.

Spleen

It is the largest lymphoid organ and has the following functions

(i) Haemopoiesis – Formation of Blood cells in the foetus

(ii) Destruction of old and worn out blood cells and hence termed as 'grave yard' of RBC.

(iii) Blood reservoir

(iv) Defensive action by engulfing bacteria

15.5 IMMUNITY

The body's ability to resist or protect itself from the harmful effects of disease producing substance or organisms is called Immunity.

Any substance that causes production of antibodies in response of the body metabolism, is known as **antigen**. Antigen may be bacteria, viruses, or allergens (such as pollen grains) which cause allergy.

Antigens enable the body to protect itself with the help of antibodies produced by lymphocytes (WBC)

Immunity could be **natural or acquired**. Natural immunity is by birth. Acquired immunity develops during lifetime. It develops due to exposure to a disease or by vaccination.

Acquired immunity is of two types

(a) Active Immunity : Develops during exposure to disease causing germs. The body produces antibodies that remain in the blood to prevent further infection by that particular pathogen or disease causing organism. Vaccine containing weakened germs is administered to provide active immunity e.g DPT vaccine is given for developing immunity against diphtheria, pertusis (whooping cough) and tetanus and BCG vaccine is given for immunity against tuberculosis

People also develop immunity against chicken pox, small pox and measles after suffering from these diseases. This form of immunity is usually a life long immunity.

(b) Passive Immunity : This form of immunity is shortlived. It is developed by injecting readymade antibodies (collected from other animals). **Anti tetanus serum (ATS vaccine)** provides temporary immunity against tetanus.

A vaccine is a sample of an antigen, too small to cause a disease, but enough to produce antibodies. Vaccines have been developed for a number of diseases like polio, mumps, measles, tetanus, diphtheria, and cholera.

Cells Of Immune System

Lymphocytes are cells of the immune system. There are two major types of lymphocytes, T-cells and B-cells, both develop in the **Bone Marrow.**

T-Cells	B-Cells
1. Mature in thymus glands	Mature in lymphoid tissues like tonsils and appendix
2. T-cells identify antigens and destroy them	Recognise antigen with the help of surface receptors
3. Attack directly	Produce a large number of antibodies for attack
4. Life span is upto 3-4 years	Anitbodies are short lived

A person may lack T-cells or B-cells, or both. Such persons are highly prone to infections

Immuno Deficiency Disorders

Hereditary, congenital (by birth) or acquired defects in immune response are called **Immuno Deficiency Disorders.**

SCID and **AIDS** are two common examples of such disorders.

SCID (Severe Combined Immuno-Deficiency Syndrome) is caused due to the absence of both T-cells and B-cells. This defect is present from birth.

AIDS (Acquired Immuno Deficiency Syndrome) causes considerable reduction in T-cells and ultimate destruction of the Immune System. It is caused by HIV (Human Immuno Virus).

You should know

AIDS may be caused by

1. Sexual contact with a person infected with HIV
2. Blood transfusion from HIV infected person
3. Sharing of contaminated needles with HIV sufferers or Drug addicts
4. From infected mother to foetus through the placenta

15.6 DISORDERS RELATED TO BLOOD AND HEART

You must have heard of people suffering from high blood pressure. In these people, the blood pressure is more than the normal (120/75). The state of having high blood pressure is called **hypertension**. Hypertension is usually related to stress, overweight, age or faulty diet.

Other heart related disorders are **atherosclerosis** and **arteriosclerosis.** Sometimes, especially if too much of fatty food is taken over a long period, there is a tendency for fat to deposit on the inner wall of the arteries. Such a deposit is called **atheroma** and the disorder **atherosclerosis**. This narrows the lumen of the arteries supplying the heart and consequently interfere in the functioning of the heart.

Also with age the wall of the arteries harden and lose their flexibility. Further, there may be deposits on the inner side of the walls of the arteries supplying the heart.

This condition is **arteriosclerosis** and interferes with normal functioning of the heart. To remedy the situation, the lumen of the arteries of the heart have to be widened by placing a small piece of tube (stent). This is called **ballooning angioplasty**. Sometimes the artery may have to be replaced and this treatment is called 'heart by-pass'.

ECG

Electrocardiograph is a machine which can record the heartbeat like a graph which is called **eletrocardiogram (ECG)**. From the ECG, the doctor can make out which chamber of the heart is not contracting or relaxing properly and suggests treatment accordingly.

INTEXT QUESTIONS 15.3

1. Fill in the blanks :
   (i) The clear colourless liquid flowing out of the blood capillary walls is called ……………….
   (ii) Lymphatic system consists of ………………. lymph nodes and ……………….
   (iii) A number of ………………. are present in lymph nodes and attack bacteria
2. Give one example of lymphoid organ in your body ……………………………
3. Give **two** examples of Immuno Deficiency Syndrome ………………………
4. Name the **two** kinds of lymphocytes of your immune system ……………….
5. Name **two** heart related disorders
   (i) .... (ii) ....

WHAT YOU HAVE LEARNT

- Circulatory system is of two kinds; closed and open type.
- Circulatory system consists of muscular pump (heart), tube like vessels (blood vessels) and circulating fluids (blood, lymph).
- Blood helps in transport of gases, collection of wastes, maintenance of body temperature and protection from diseases.
- Wave of contraction in the heart is conducted from S.A. node to A.V. node to bundle of HIS, to Purkinje fibers.

- Blood vessels are arteries, capillaries and veins
- Superior and inferior venae cavae bring deoxygenated blood to the heart. Pulmonary vein brings pure (oxygenated) blood to the aorta and aorta supplies it to the body.
- Production of blood is called haemopoiesis which takes place in the bone marrow
- Blood consists of plasma and cell components viz., RBC, WBC and Platelets
- In the A, B, O Blood group system, a person with blood group O is a universal donor and person with blood group AB is universal recipient.
- Rh factor is important in matching blood groups for transfusion as well as in the case of expectant mothers.
- Normal blood pressure for healthy person is 120 ± 5/75 ±5 mm of mercury and is measured by Sphygmomanometer.
- The colourless fluid moving out of capillary wall is called lymph
- Spleen and tonsils are examples of lymphoid organs and house lymphocytes (T-cells and B-cells)
- Body's ability to protect itself from harmful substances is called immunity
- Disorder of the immune system diminishes resistance to diseases. SCID is an immunodeficiency disorder from birth; AIDS is another one caused by HIV virus.

TERMINAL EXERCISES

1. Give one function of each of the following :
   (i) R.B.C.
   (ii) Platelets
   (iii) Plasma
2. With the help of a flow chart describe the steps involved in the coagulation of blood
3. Why is a person with blood group AB called universal recipient?
4. Differentiate between the systolic and diastolic pressures. What are the values of these pressures for a normal human adult?
5. Give **three** differences between lymph and blood.
6. What is immunity? Differentiate between active and passive immunity.
7. What are (i) hypertension and (ii) atherosclerosis?
8. What is an ECG and what is its function?

ANSWERS TO INTEXT QUESTIONS

15.1
1. Name the following
   (i) Prawn, insects etc
   (ii) Vertebrates like human, fish, birds
2. (i) Between left atrium and left ventricle
   (ii) Between right atrium and right ventricle
3. (i) Sino-atrial node (ii) capillaries (iii) pulmonary vein
4. Superior vena cava

15.2
1. (i) Haemopoiesis
   (ii) Ablumin, globulin and fibrinogen
   (iii) Platelets
2. (i) Blood transfusion
   (ii) Cell membrane of RBC; plasma
   (iii) Only from blood group O
   (iv) Sphygmomanometer, $120 \neq 5 / 75 \pm 5$ mercury

15.3
1. (i) Lymph
   (ii) Lymph ducts and lymph vessels
   (iii) Lymphocytes
2. Spleen or tonsils
3. SCID and AIDS
4. T-cells, B-cells
5. Hypertension, atherosclerosis, arteriosclerosis (any 2)

16

LOCOMOTION AND MOVEMENT

Movement is the temporary or permanent displacement of a body or its parts from its original position. Living beings and parts thereof move in response to stimulus from outside or from within the body. Locomotion, on the other hand, is the displacement of the entire body from one place to another. It is a characteristic feature of all animals, Protoctista and zoospores and zoogametes of lower plants.

OBJECTIVES

After studying this lesson, the learner will be able to

- assert that movement is an important feature of all living beings.
- emphasize that locomotion is a characteristic of the Protoctista, gametes and spores of some lower plants, and animals.
- differentiate between movement and locomotion with the help of examples.
- explain the functions of cilia and flagella as organelles for movement and locomotion in Protoctista and animals.
- recognise skeleton and muscles as organs which help in locomotion in animals.
- describe the structure and working of muscles.
- describe the types of contractile proteins and their role in muscle contraction.
- explain the mechanism of muscle contraction.
- provide an outline of human skeletal system and mention functions of its parts.
- give a brief account of disorders related to muscular and skeletal systems such as Myaesthenia Gravis, Tetany, Muscular Dystrophy, Arthritis, Osteoporosis and Gout.

16.1 MOVEMENT AND LOCOMOTION

Consider the following examples

(i) Your arm stretches to pick up an apple or flexes to scratch the face.

(ii) Your tongue is in motion when you sing, the dog wags its tail, the frog's tongue is shot out to catch insects.

(iii) The gill cover of the fish flips up and down to draw in a current of water.

(iv) Cytoplasm streams within cells

The above examples signify movement, not locomotion. In locomotion, the entire body of an animal or a protozoan or an alga moves away from its original position. In the unicellular organisms like bacteria and Protoctists specific organelles like flagella and cilia cause locomotion. Recall the microscopic structure of these organelles from lesson 4 of your text book entitled Cell Structure and Function. Sperms, the male gametes have a flagellar tail by which they move about. Among the multicelled animals, molluscs locomote with a muscular foot and the starfish with the help of tube feet. Birds fly using muscles and other animals use muscles to walk or run.

INTEXT QUESTIONS

What would you call the following as – movement (M) or locomotion (L) ?

- The elephant uses its trunks to pick up sticks ( )
- The cow uses its tail to drive away flies ( )
- A mouse runs into a hole. ( )
- The bees leave their hive in search of pollen ( )
- Johan kicks the football into the goal ( )
- The cat jumps on to the window ( )

16.2 TYPES OF MOVEMENTS FOR LOCOMOTION

16.2.1 Ciliary Movements

Cilia are minute hair like processes which are motile and extend from cell surfaces. In smaller organisms like the ciliate protozoa, cilia help in locomotion from one place to another. In animals, the cilia help to propel fluids and materials.

Cilia beat in a pattern which is different from that of the flagellum although their internal structure is the same. Ciliary beat begins with fast stroke ahead in one direction called effective stroke and then it bends back and returns to its original position. This second stroke is called recovery stroke. (Fig 15a.1a & b). During ciliary beat, water is propelled parallel to ciliated surface.

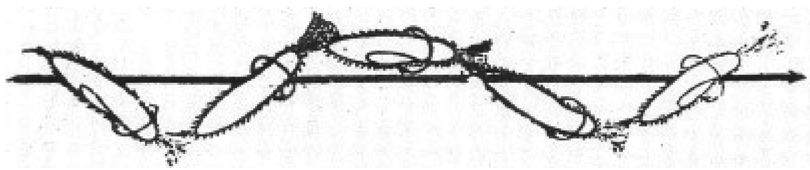
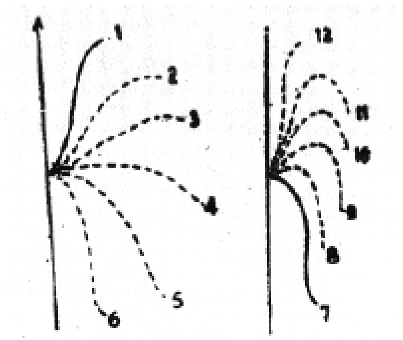


Fig. 16.1(a) Locomotion in *Paramecium*. Solid line represents the general direction;



A B

Fig. 16.1(b) A – Effective stroke of a cilium, B – Recovery stroke of a cilium, C – Metachronous wavy movement of a row of cilia.

16.2.2 Flagellar movement

A flagellum is a long, whip like structure. While cilia cover the entire surface, flagellum is mostly present singly or in a small number at one end of a cell. Flagella occur in flagellate protozoan like *Euglena* or an alga like *Chlamydomonas* and in animal sperms. A flagellum beats symmetrically in a snake like manner and propels the water parallel to long axis of flagellum. See figure of flagellum of *Euglena* and *Chlamydomonas* in Module 1, lesson 2, unit 2.2.2 of your text book.

INTEXT QUESTIONS

1. State the similarity in internal structure between a cilium and a flagellum as learnt in lesson 4 of your text book?
2. What is an effective stroke ? Which stroke is called the recovery stroke as depicted during ciliary movement ?
3. State the difference between flagella and cilia with regard to location and number.

16.3 MUSCULAR MOVEMENT IN ANIMALS

16.3.1 Structure of muscle

You have already learnt about muscular tissue in lesson 5, Module 1, unit 5.3.3. Go back to the lesson and revise the structure of striated muscle fibres. Stuated muscles are also called skeletal muscles as they are attached to bones and are responsible for movements of the limbs.

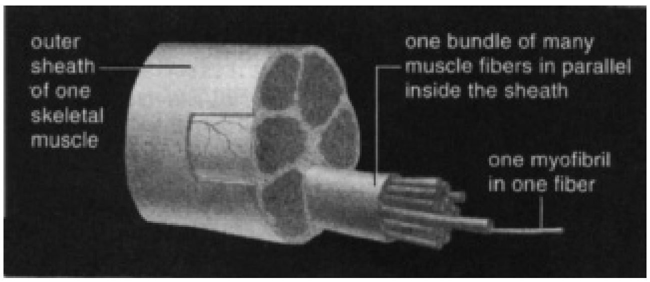


Fig. 16.2 The skeletal muscle

Striated muscle fibres are packed into bundles enclosed in a tough connective tissue. These bundles are grouped to form a muscle. Every skeletal muscle is also enclosed in a thin connective tissue as shown in the above figure.

The ends of muscles connect to bones through another kind of connective tissue called **tendon**. So, tendon joins a bone to a muscle.

16.3.2 Myofilaments

The muscle cell, also called muscle fibre because of its long shape, is multinucleated and contains myofibrils made of myofilaments. Myofilaments are proteins which are of two types:

(i) thick filaments made of myosin protein and

(ii) thin filaments made of actin protein.

Myosin and actin proteins are contractile proteins and responsible for muscular contraction.

The functional unit of the myofibril is called sarcomere. It lies between two successive dense linear structure called Z lines.

The thin filaments also contain two other proteins, tropomyosin and troponin Troponin is the switch, which in the presence of calcium ions controls muscle contraction.

Study the figure below to understand the structure of myofilaments:

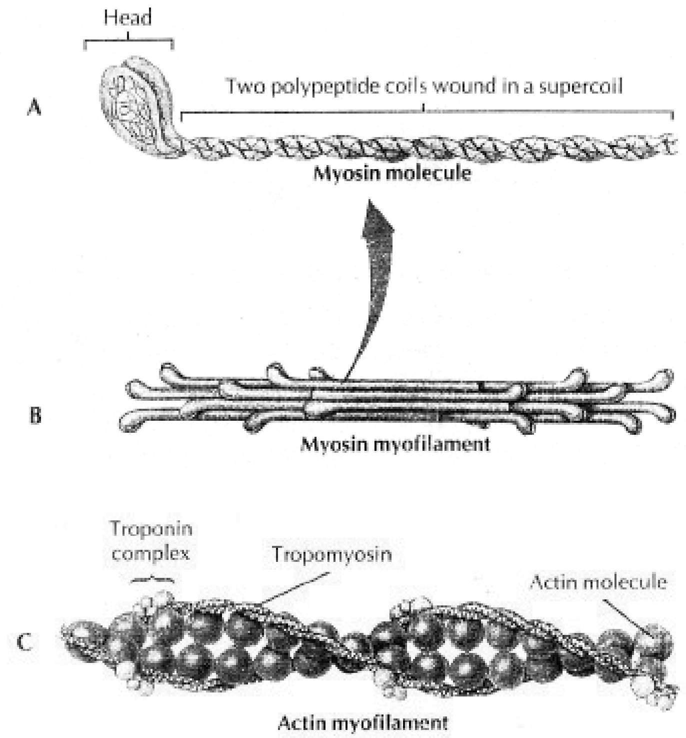


Fig. 16.3 Molecular structure of thick and thin myofilaments of a skeletal muscle. A. the myosin molecule is with coiled expanded ends forming a globular head. B. The thick myofilament is composed of a bundle of myosin molecules with their globular heads extended outward. C. The thin myofilament consists of a double strand of actin surrounded by two tropomysoin strands. A globular protein complex, troponin, occurs in pairs on actin.

16.3.3 The sliding model of muscle contraction

Striated muscle contraction is explained by **Sliding Filament Theory**. This theory can be explained through the following steps:

(i) The thick and thin filaments myosin and actin are linked by crossbridges of troponin and tropomyosin.

(ii) These crossbridges, on contraction, pull the thin filaments back over thick filaments.

(iii) As a result, the thin filaments slide over the thick filaments. Calcium and ATP are required for attaching and releasing Troponin.

(iv) Because of this sliding action, Z lines come closer (Fig 16.4) and sarcomere shortens.

(v) All sarcomeres shorten together so the entire muscle contracts.

(vi) The muscle relaxes when crossbridges relax and sarcomere regains original position.

See figure given below

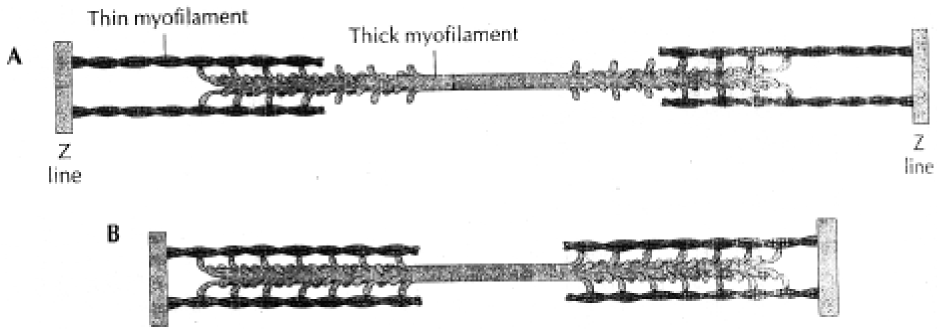


Fig. 16.4 Sliding myofilament model, showing how thick and thin myofilaments interact during contraction, A. Muscle relaxed. B. Muscle contracted.

Stimulation of muscle contraction

Muscles cannot contract on their own unless stimulated by a nerve. The nerve branches on a muscle and this area of the muscle fibre is called **myoneural junction** (myo: muscle; neuro: nerve).

Summary of events of muscle contraction

Impulse at nerve ending of muscle fibre

Muscle fibre stimulated

Ca^{++} released from muscle fibre

Binding sites of actin filaments released

ATP releases energy → Crossbridges flex & reattach to new sites

Actin & Myosin slide over each other

Muscle cells shorten

As a result the muscle contracts

INTEXT QUESTION 16.3

1. Name the structure that connects (i) a bone to another bone (ii) muscle to bone. Which type of tissue are these ?
2. Why is the muscle cell also called muscle fibre ?
3. Why is the mechanism of muscle contraction called 'sliding movement'?
4. What is the chemical composition of myofilaments.
5. In a muscle, where can you find the following ? myofilaments, muscle fibres.

16.3.4 Energy for muscle contraction

The biological energy, ATP or Adenosine triphosphate is required for muscle contraction. Muscle also has a reservoir of high energy phosphate called creatine phosphate which can be converted to ATP.

16.4 THE SKELETAL SYSTEM

16.4.1 The types of skeleton.

Skeleton supports the body, gives rigidity to body, provides surface for attachment of muscles, and protects soft internal organs like the brain, heart, lungs etc.

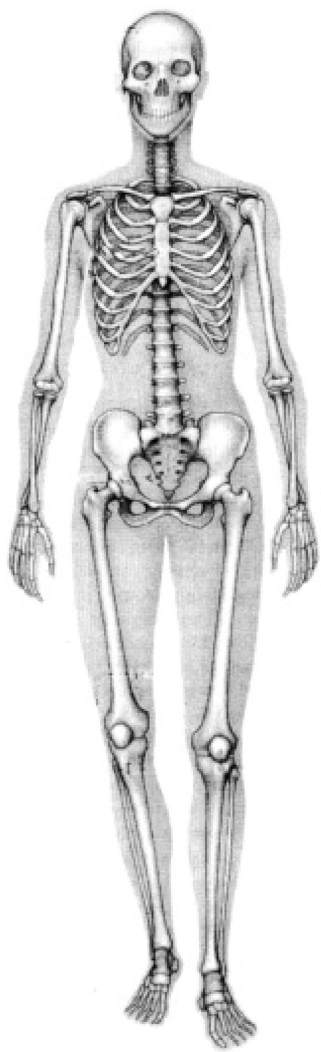
In the vertebrates, skeleton is made of bone and cartilage about which you have studied in the lesson on tissues. It is located inside the body and hence termed endoskeleton. Another rigid skeleton is the exoskeleton in the form of hard, calcareous shells in molluscs and the covering of chitin (a carbohydrate) in insects and other arthropods. Many invertebrates, such as the earthworm use their muscles, which are not attached to any rigid skeletal elements, by contracting against fluid in their body cavity. Coelomic (Coelom = body cavity) fluid within limited space acts as skeleton for muscle movement and is hence termed hydrostatic skeleton.

16.4.2 The human skeleton

The human skeleton is divided into following parts:

- Human Skeleton
  - Axial Skeleton
    - Skull and jaws
    - Vertebral column
  - Appendicular Skeleton
    - Girdles
      - Pectoral
      - Pelvic
    - Limbs
      - Arms
      - Legs

See the figure given below and locate the rib cage, the skull and the girdles.



16.5 MUSCULAR AND SKELETAL DISORDERS

You have all seen some people who are wheel chair bound. They are unable to move on their own. You have just learnt that muscle contracts only when stimulated by nerves. If nerve supply to muscle get severed, muscle gradually weakens or **atrophies**.

The old may limp because of calcium deficiency or deficiency of vitamin D_3 which is responsible for calcium absorption.

Injury to limb or girdle bones also hamper locomotion. But, these apart, some muscular and skeletal disorders are **hereditary** e.g. **Myaesthenia gravis** and **Muscular dystrophy**. **Arthritis** and **Rheumatoid arthritis** may or may not be hereditary. **Osteoporosis** and **Gout** are due to nutritional deficiency and **metabolic errors**. Let us learn a little about them.

Myaesthenia gravis is because of a gene on X chromosome and so is hereditary. The muscles slowly waste away and the patient gradually becomes immobile and in the last stages even the jaw muscles do not work and patient is unable to eat.

Muscular dystrophy is an autosomal dominant disorder. In this hereditary disorder, muscles waste away and person becomes immobile.

Arthritis and Rheumatoid arthritis are disorders of bones especially joints. There is constant joint pain in Rheumatoid arthritis which is a crippling disease. Hands and feet become crooked due to inflammation in the joints.

Osteoporosis is the softening of bones due to calcium deficiency. You know that calcium absorption is dependent on availability of Vitamin D. So it is important to expose oneself to the sun every day for atleast half an hour. You have aleady learnt that sunlight helps to generate Vitamin D. Women, post menopause are prone to osteoporosis. Estrogen, the female hormone mobilises calcium and sends it to bones. In the absence of estrogen, bones tend to crack and break.

Gout results in painful inflammation of joints due to elevated level of uric acid in blood. Uric acid is a product of protein metabolism. Gout can be cured.

INTEXT QUESTION 16.4

1. Name an animal with endoskeleton and one with exoskeleton.
2. Name main parts of skeleton and mention their functions.
3. Name any two disorders of the musculo–skeletal system which are hereditary.

4. What causes osteoporesis and gout ?
5. Which limbs are supported by which girdles and which kind of muscles are attached to the limb skeleton ?

16.6 MOVEMENTS IN PLANTS

Plants are rooted to the soil, hence they are unable to undertake locomotion. But plants show movements in response to external stimuli like light, water, gravity, called TROPIC MOVEMENTS. When a plant part, such as the root or stem, move towards the source of stimulus, it is termed positively tropic e.g. shoot moves and grows towards sunlight, it is positively phototropic. Root moves away from light, it is negatively phototropic. Similarly there are movements in response to stimuli which are given in the table below.

Stimulus	Term for Response
Touch/Contact	Thigmotropism
Gravity	Geotropism
Water	Hydrotropism

In tropic movements, plants are fixed but their parts e.g. a branch or a flower move in the direction of stimulus. Turgor movements are due to difference in water potential in different parts of plant. Examples are given below

- Leaf closes in the insectivorous plant Venus fly trap when an insect enters.
- *Mimosa pudica* called 'chhui mui ' in Hindi, droops when touched.
- Guard cells cause opening and closing of stomata due to changes in tugor pressure.

NASTIC MOVEMENTS are induced by certain stimuli like contact, change in day length, temperature etc. Unlike tropic movements in nastic movements the plant parts do not move in the direction of stimulus e.g. flowers of *Portulaca*, bloom in the day. But when light fails at sunset, the petals close in response to darkness and lowered temperature. In other words, direction of movement of an organ is fixed but the stimulus may come from any direction.

WHAT YOU HAVE LEARNT

- Movement is an important feature of all living beings and locomotion is characteristic of protoctista and animalia.
- While in movement, an organ or organelle may shift from its original position and come back to it, in locomotion, the entire body of the animal or the protoctist moves away and is displaced from its original location
- Ciliate protozoa or alga carry out locomotion by means of cilia, organelles made of microtubules. Ciliary beating begins with fast stroke and ends in a recovery stroke.
- Flagellum is long and whip like organelle made of microtubules. While cilia are many, flagella may be one or two.
- Muscles and bones help the vertebrates to locomote from one place to another, muscles are joined to bone by ligaments and one muscle is joined to the other by a tendon.
- Muscles are a tissue made of muscle cells, also called muscle fibres. Muscle fibres are made of thick and thin myofilaments made of myosin and actin protein molecules respectively.
- Muscles contract and relax to cause movement. Muscle contraction is explained by sliding filament theory of muscle contraction.
- Ca and ATP are required for muscle contraction.
- Vertebrate skeleton is made of bone and cartilage
- Axial skeleton is made of skull and vertebral column and appendicular skeleton is made of girdles and limbs.
- Hereditary muscular and skeletal disorders are myaesthenia gravis and muscular dystrophy. Arthitis and Rheumatism are bone disorders. Osteoporosis to softening is the bones due to Ca and Vitamin D deficiency. Gout results from increase in level of uric acid in blood.

  Plant movements may be tropic movements or nastic movements.
- Movement is a characteristic of living beings. It means a temporary or permanent displacements of the body or its parts.
- Locomotion is the displacement of the entire body from one place to another. It is a characteristic of protoctists and animals.
- Cilia and flagella are organslles which help in movement. Ciliary protozoa Locomote with the help of cilia. Human sperms, certain algae like *Chlamydomonas* move from one place to another with the help of flagella.

- Cilia are many and move together causing a wavy motion. Flagella may be one or two and with whip like strokes help in Locomotion.
- Most animals carry out Locomotion with the help of muscles.
- Muscles are made of muscle fibres. Muscle fibres have protein filaments called myofilaments.
- Actin and myosin filaments in a muscle fibre (muscle cell) slide over each other to cause Locomotion.
- Hence the muscle is said to contract through sliding of these two kinds of myofilaments and this is termed sliding model of muscle contraction.
- Apart from actin and myosin protein molecules, two other protein molecules named Troponin and Tropomyosin participate in muscle movement.
- The unit of contraction is termed a sarcomere and it contains both the myofilaments which slide between Z lines.
- Nerve impulse stimulates muscle movement.
- Human skeleton is divided into axial skeleton which includes skull and vertebral column and appendicular skeleton comprised of bones of girdles and limbs.
- Bones are connective tissues made of ossein and cartilage which are also part of human skeleton. Bones are joined to each other by ligaments & to muscles by tendons.
- Muscular & Skeletal disorders include Muscular dystrophy, arthritis, Myaesthenia graive, Osteoporosis and gout.

TERMINAL EXERCISES

1. Distinguish between the following pairs of terms:
   (i) movement and locomotion
   (ii) thick and thin myofilaments
   (iii) tendon and ligament
   (iv) cilia and flagella
   (v) tropic and nastic movement
2. Enlist the steps in muscle contraction as explained by sliding filament theory.
3. How does *Paramecium* swim in water?
4. Answer in one word or sentence

(i) What is the shape of actin molecule?

(ii) What is the chemical nature of troponin and tropomyosin?

(iii) What is meant by recovery stroke of cilia?

(iv) Give an example each of geotropism and phototropism.

(v) Why do we say that vertebrate muscle contraction is energy dependent?

ANSWER TO INTEXT QUESTIONS

16.1

M, M, L, L, M, L

16.2

1. Both made of microtubules arranged in a similar manner.
2. Fast stroke – cilium beats to move ahead

   Recovery stroke – cilium bends back to original position
3. Location – cilia all over body, flagella at anterior or posterior end

   Number – cilia many, flagella 1 or 2

16.3

1. Ligament; tendon; connective tissue
2. because of its elongated structure
3. because thick and thin myofilaments slide over each other to cause muscle contraction.
4. Protein
5. myofilaments in muscle fibre

   muscle fibres in muscle tissue

16.4

1. any vertebrate named

   any insect/mollusc named
2. axial, appendicular

   support, protection to interanl organs; locomotion and movement; blood cells manufactured in bone marrow gives shape to body

3. Myaesthenia gravis; muscular dystrophy
4. Osteoporosis – lack of Ca

   Gout – High level of uric acid in blood
5. Pectoral – fore limbs; Pelvic – hind limb; Striped or striated

17

COORDINATION AND CONTROL : THE NERVOUS AND ENDOCRINE SYSTEMS

Every organism performs movements and a number of other tasks for its survival. Besides, several other actions are continuously occurring inside the body that need to be properly timed and coordinated. All this is the outcome of two organ systems – the nervous and the endocrine (hormonal) systems.

OBJECTIVES

After completing this lesson, you will be able to :

- *describe the functions of the nervous system and list its subdivisions;*
- *list, draw and label the major parts of the human brain and spinal cord and explain their functions;*
- *describe the nervous system of cockroach*
- *explain the structure of a neuron, a nerve and describe the conduction of impulse through a nerve fibre and across the synapse;*
- *define reflex action and draw the components of the reflex arc;*
- *list various sensory receptors in human body and describe the structure and functioning of the sense organs–eye, ear, nose, tongue and skin;*
- *distinguish between exocrine and endocrine glands;*
- *list various endocrine glands and locate their position in human body;*
- *identify properties of hormones and mention their nature and manner of functioning;*
- *differentiate between hormones and pheromones;*
- *name the various hormones secreted by pituitary, thyroid, parathyroid, thymus, adrenals, pancreas and reproductive organs in humans and mention their functions;*
- *relate the hormonal imbalance with hormone related disorders in humans;*
- *state the effects of over functioning (hyperactivity) and hypoactivity (underfunctioning) of pituitary and thyroid;*
- *explain the feedback mechanism of hormonal control.*

17.1 FUNCTIONS OF THE NERVOUS SYSTEM

The major functions of the nervous system in humans are as follows:

(i) It keeps us informed about the outside world through the sense organs.

(ii) It enables us to remember, think and to reason out.

(iii) It controls all voluntary muscular activities like running, speaking etc.

(iv) It regulates several involuntary activities such as breathing, beating of the heart, movement of food through the food canal, etc.

Thus, the nervous system makes our body parts work together in proper coordination, as one single integrated unit.

Some basic terms

Before you learn about the various aspects of the nervous system, get familiar with the following related terms.

Stimulus : an agent or a sudden change of the external or the internal environment that results in a change in the activities of the organism.

Impulse : a wave of electrical disturbance that travels accross the nerve cell and its fibre.

Response : a change in the activity of the organism caused due to stimulus.

Receptors : The nerve cells which on receiving the stimulus, set up wave of impulses towards the central nervous system (brain and spinal cord).

Effectors : muscles or glands, which on receiving the impulse from the brain or spinal cord contract or secrete substances.

Nerve : A bundle of axons (nerve fibres) of separate neurons connecting the central nervous system with other parts of the body.

Sensory (afferent) nerve or the cell : bringing the impulse from the receptor (sensory organ) to the main nervous system.

Motor (efferent) nerve or the cell : Carrying the impulse from the main nervous system towards a muscle or a gland.

17.1.1 Nervous System in Animals

Various activities of an animal's body are controlled and coordinated through two systems viz. the nervous system and the endocrine system. We will discuss the nervous system of cockroach here. A detailed account of the nervous system in humans is given in your text book lesson 16: module 2: Book l. Recall that the nervous system basically consists of two parts:

(i) Central nervous system

(ii) Peripheral nervous system

The nervous system of cockroach also follows the same basic plan and consists of:

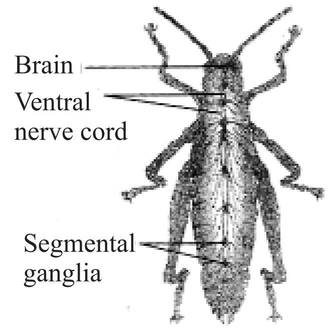
(i) Central nervous system

(ii) Peripheral nervous system

(iii) Sympathetic or visceral nervous system

Central Nervous System

It consists of **brain** or **supra-oesophageal ganglion** that lies above the oesophagus in the head. A **sub-oesophageal ganglion** lies below the oesophagus and is formed. The brain gives off a pair of short and stout **circumoesophageal connectives** that meet the sub-oesophageal ganglion. A double ventral **nerve cord** extends from the sub-oesophageal ganglion. It bears three thoracic and six abdominal ganglia (See figure below).



Nervous System of Cockroach

Peripheral Nervous System

It consists of nerves which are given off from the ganglia so as to innervate all the parts of the body (See the figure).

Sympathetic Nervous System

It consists of frontal ganglion and a visceral ganglion. Various nerves are given are given off from the visceral ganglion.

(a) **Central Nervous System (CNS),** consisting of brain and spinal cord. It is the site of information processing (receiving information and responding to it).

(b) **Peripheral Nervous System (PNS),** consisting of all the nerves entering and leaving the brain and the spinal cord.

Further division of these two components is shown in Fig. 17.1.

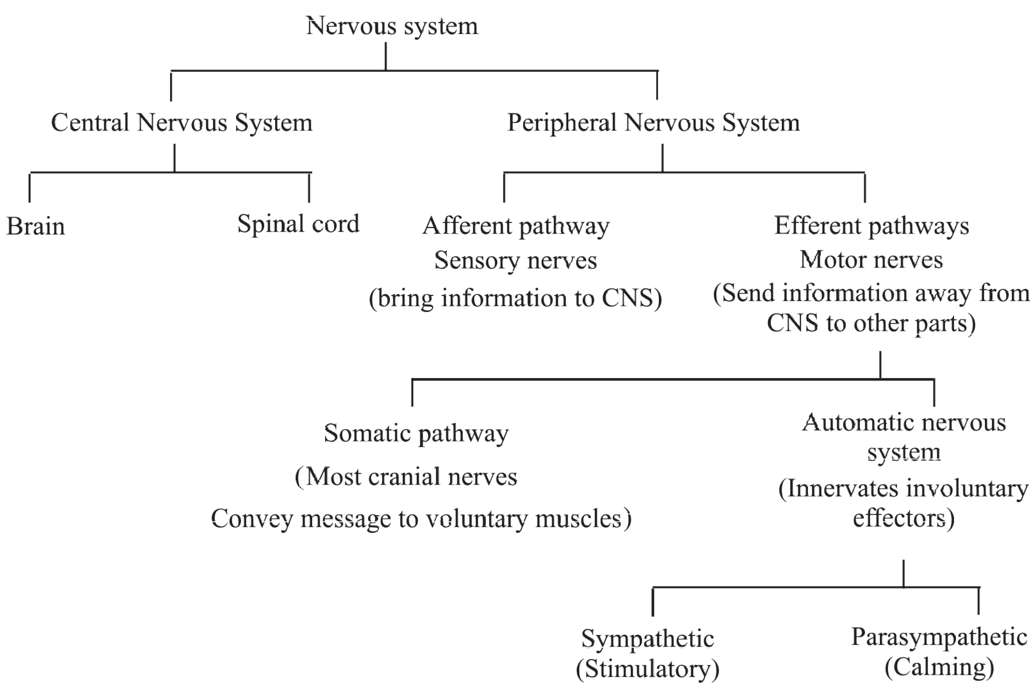


Fig 17.1 The basic components of nervous system

17.2 NERVOUS SYSTEM OF HUMANS

The central nervous system of humans includes a highly developed brains and spinal coad (Fig. 17.2). Peripheral Nervous system is made of nervous as shown in Fig. 17.1.

17.2.1 The Brain

The brain is a very delicate organ lodged inside the cranium of the skull (Fig.17.1a) It is protected by three coverings, the **meninges** (meninx: membrane): an outer tough **duramater** (dura: tough; mater: mother), a thin delicate web-like middle **arachnoid** (arachne: spider), and the innermost highly vascular **piamater** (pia: tender) richly supplied with blood vessels. The space between the membranes is filled with a fluid called **cerebrospinal fluid**. There are cavities inside the brain, which are also filled with the same fluid.

The brain consists of three main regions:

(i) ***forebrain*** consisting of cerebrum and diencephalon,

(ii) ***midbrain*** a small tubular part between the fore and the hindbrain,

(iii) ***hindbrain*** consists of cerebellum, pons, and medulla oblongata.

The individual parts of the brain are described below:

(a) **Cerebrum.** This is the largest part of the brain, divided into two (the right and the left) parts called **cerebral hemispheres**. Their outer surface is highly convoluted with ridges and grooves. Each hemisphere is hollow internally and the walls have two (an inner and an outer) regions. The outer region (cerebral cortex) contains cell bodies of the nerve cells and being grayish in colour it is called ***gray matter***. The inner region is composed of whitish axon fibres and is called the ***white matte***r. **Corpus callosum** is a sheet of cris-cross nerve fibres connecting the two cerebral hemispheres (Fig. 17.2b). Left side of the cerebrum controls the right side of the body and vice-versa.

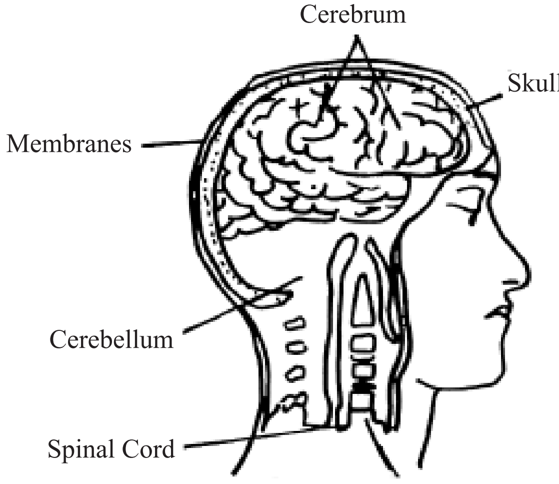


Fig. 17.1 (a) Brain lodged inside cranium

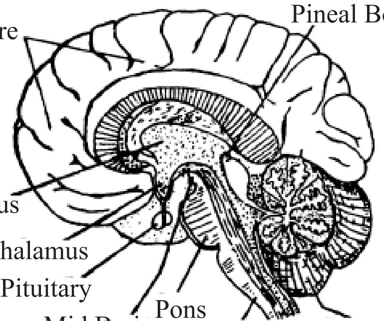


Fig. 17.2 (b) brain in median section.

The **cerebral cortex** has three main functions:

(i) It controls and initiates voluntary muscle contractions.

(ii) It receives and processes information form the sense organs, like eyes, ear, nose etc.

(iii) It carries out mental activities of thinking, reasoning, planning, memorizing etc.

(b) **Diencephalon.** This is the part of the forebrain lying below the cerebrum. It consists of the following two parts;

1. **Thalamus.** This is an egg shaped mass of gray matter, located in the centre below the cerebrum. It is the relay centre for sensory impulses (e.g. pain and pleasure) going to the cerebrum.

2. **Hypothalamus.** This is a region of the brain located below thalamus. It controls motivated behavior such as eating, drinking and sex. It controls the secretions of pituitary gland hanging below it. It also serves as the regulation centre of body temperature and body fluids (see lesson 17).

(c) **Cerebellum.** The cerebellum is a smaller region of the brain located at the base and under the cerebrum. It has numerous furrows. It also has a cortex of gray matter. Its two main functions are.

(i) to maintain the balance of the body, and

(ii) to coordinate muscular activities.

(d) **Medulla oblongata.** This is the last part of the brain, which is connected to the spinal cord. Its functions are as follows:

(i) It is the cente for breathing, coughing, swallowing, etc.

(ii) It controls heartbeat, the movement of alimentary canal and many other involuntary actions.

In all, **12 pairs of nerves** (cranial nerves) come out of the brain, some of these are sensory, some motor and some are of mixed type.

17.3.2 The Spinal cord

The spinal cord extends form the medulla of the brain downward almost the whole length of the backbone. It is also wrapped in the same three meninges as the brain and the space between them contains the same cerebrospinal fluid. The arrangement of the white and gray mater is reversed in it i.e. white matter is outside and the gray matter inside.

Fig. 17.6 shows the general structure of the spinal cord as seen in its cross section. It also shows the manner in which the spinal nerves originate from it.

Functions of spinal cord.

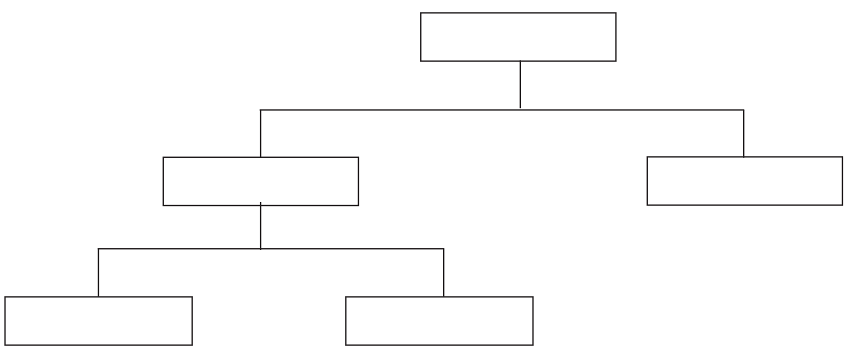
(i) Carry out reflexes below the neck,

(ii) Conducts sensory impulses from the skin and muscles to the brain,

(iii) Conducts motor responses from the brain to the trunk and limbs.

INTEXT QUESTIONS 17.1

1. With the help of a flow chart write down the basic components of the nervous system in the space given below.



2. Name the ganglia which
   (a) forms the brain
   (b) lies below the oesophagus and is joined to brain.
3. Which part of nervous system of cockroach can be compared to our spinal cord though our spinal cord is dorsal and this part of nervous system of cockroach is ventral?

4. Name the main parts of the brain.

   ....

5. Mention the one functions each of :

   (i) Cerebrum..

   (ii) Cerebellum ....

   (iii) Medulla oblongata ....

   (iv) Hypothalamus...

6. What are the

   (i) gray matter, and...

   (ii) white matter made of? ....

7. Name the fluid in the cavities of the brain.

   ....

17.4 PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system consists of all nerves arising from the brain and the spinal cord. Overall, it consists of two kinds of pathways: the afferent (receiving) sensory pathways and efferent (carrying aways) motor pathways.

A. The **afferent (receiving/sensory) pathways** are included in two kinds of nerves.

- Purely sensory nerves, for example the cranial nerves received from the eyes, ears, nose, etc.
- Mixed cranial nerves like the fifth (facial nerve) which contains sensory fibres bringing sensations from the face but it also contains motor fibres which carry impulses away to the jaw muscles.

B. The **efferent (sending) pathway** may be subdivided into somatic and autonomic nervous systems.

(i) **The somatic nervous system** controls the voluntary muscles. It includes most **cranial nerves** as well as the motor nerve fibres of the **spinal nerves**. Both these convey message from the CNS to the **voluntary muscles**.

(ii) **Autonomic nervous system** (ANS). This innervates the involuntary muscles and the glands. It consists of a pair of chains of ganglia and nerves on either sides of the backbone (Fig. 17.3) This system is essentially a motor system, which regulates the involuntary actions of the internal organs. It consists of two parts: (a) Sympathetic nervous system and (b) parasympathetic nervous system. (Fig. 17.3).

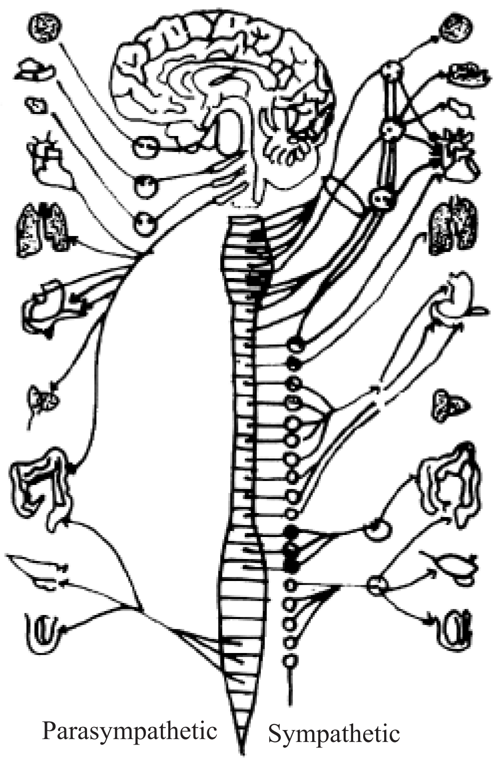


Fig. 17.3 Autonomic nervous system - sympathetic and parasympathetic

Sympathetic nervous system prepares the body for facing emergency situations and the **parasympathetic nervous system** reestablishes the normal conditions once the emergency is over.

The opposite effects of the two subdivisions of the autonomic nervous system on the different organs are listed below in the table 17.1.

Table 17.1 Effects of autonomic nervous system

Organ	Effect of Sympathetic Activity	Effect of Parasympathetic activity
1. Eye pupil	Dilated	Constricted
2. Heart beat	Speeded up	Slowed down
3. Blood vessels		
a. on skin	Constricted	Dilated
b. on muscles	Dilated	No effect
4. Bronchioles	Dilated	Constricted
5. Urinary bladder	Muscles relaxed	Muscles contract (feeling of urination)
	Sphincter contracted	Sphincter relaxed
6. Sweat secretion	Increased	No effect

7. Blood sugar	Increased	No effect
8. Salivary secretion	Stops	Increased
9. Tear glands	Activated	Slowed down
10. Erector muscles of skin hair	Stimulated (hair raised)	Relaxed (hair flattened)
11. Adrenal glands	Increased secretion of Adrenalin	No effect
12. Intestine	Peristalsis decreased	Peristalsis increased
13. Stomach glands	Decreased secretion	Increased secretion

The autonomic nervous system is strongly influenced by emotions such as grief, anger, fear, sexual stimulation, etc.

INTEXT QUESTIONS 17.2

1. What are the two subdivisions of the autonomic nervous system?

   ....

2. Name the specific subdivisions of the autonomic nervous system concerned with the following:
   - (i) Slowing down heart beat ....
   - (ii) Increasing salivary secretion ....
   - (iii) Dilatation of the pupil ....
   - (iv) Increasing intestinal peristalsis ....
   - (v) Muscle contraction of the urinary bladder giving the feeling the need for urination. ....

3. Why is the peripheral nervous system called so?

   ....

4. State the alternative terms for sensory and motor nerves.

   ....

17.5 NEURON – THE STRUCTURAL AND FUNCTIONAL UNIT OF NERVOUS SYSTEM (FIG. 17.4)

You have already studied about the nerve cell. This is to refresh your memory for relating the structure of the neuron with the conduction of nerve impulse.

- The **cell body** contains nucleus and cell organelles in the cytoplasm.

- **Dendrites** (short branching processes) extend out from the cell body. They bring signals (impulses) from the receptor or from the axon endings of another neuron. There may be as many as 200 dendrites in a single neuron allowing as many connections with the axon endings of other neurons.
- A long **nerve fibre or axon** carries the impulse from the cell body towards its terminal branches which may either pass on the impulse to another neuron, or into a muscle or gland to bring about the required action. Synapse is the point of communication between one nerve cell and another or between nerve cell and a muscle.
- A sheath of fatty material (myelin) often covers the axon, and such nerve fibres are called medullated or myelinated fibres.

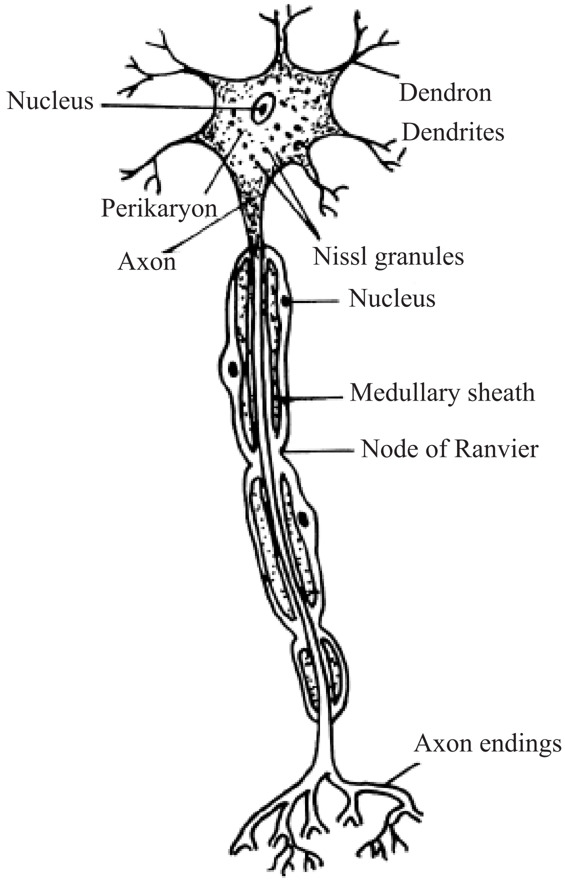


Fig. 17.4 The nerve cell

17.6 CONDUCTION OF NERVE IMPULSE ALONG THE NEURON AND OVER THE SYNAPSE

The conduction of nerve impulse through the nerve fibre is electrical in nature and the one through the synapse is chemical in nature.

A. Along the neuron–Electrical Signalling

The transmission (moving from one end to another) of the nerve impulse through the nerve fibre is electrochemical. It is not simply a flow of electrons through an electric wire but it travels as a wave of **depolarization** (Fig. 17.5). Read the following to understand depolasis atom.

In normal resting condition the outside of the nerve fibre carries positive (+) charge. In this condition nerve fibre is said to be polarized. The polarization is due to the presence of more Na^+ ions outside the cell membrane. Such state is maintained due to the sodium ions being continuously pumped out by means of the **sodium potassium pump** and operated by **active transport** using ATP for energy.

> **Sodium potassium pump** is a carrier protein on the plasma membrane which transports sodium and potassium ions across the membrane. Normally ions move from the region of their high concentration to the region of their low concentration.

The changes when a stimulus arrives at the nerve fibre are as follows:

- The axon membrane at that spot becomes more permeable to Na^+ ions, which move inward and bring about **depolarization** or localised change of charge from positive to negative (see diagram) on that spot.
- This point of depolarization itself becomes the stimulus for the adjoining area of the membrane, which in turn becomes depolarized.
- Meanwhile the previous area becomes repolarized due to active movement of the sodium ions to the outside of the membrane by means of what is called 'sodium pump'.
- And now the fibre is ready for the next wave of depolarization.

Thus a nerve impulse is a self- propagating wave of depolarization and repolarization

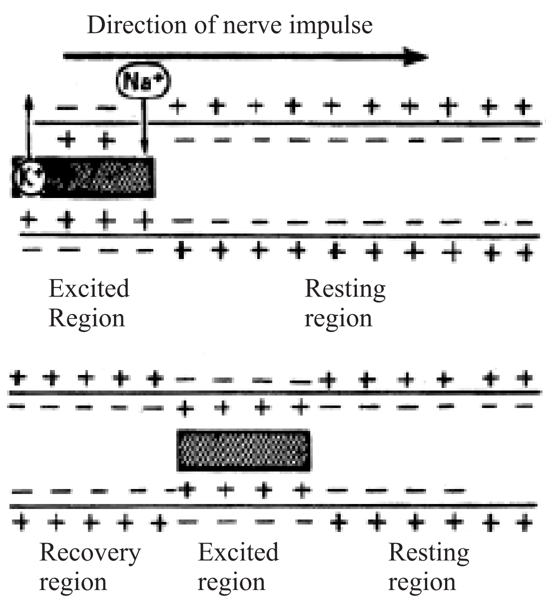


Fig. 17.5 Conduction of nerve impulse.

B. Over the Synapse – Chemical Signalling

The impulse travelling through a nerve fibre may reach either its destination. (muscle or gland) for action or the dendrites of another neuron for further transmission. The meeting place is called **synapse**. The transmission over a synapse is a chemical process. As the impulse reaches the terminal end of the axon, the following events occur :

- a chemical acetylcholine is released by the end of the axon.
- acetylcholine stimulates the next neuron to start the new impulse.
- acteylcholine is soon broken down there to make the synapse ready for the next transmission.

In case the axon endings are branched and in contact with the dendrites of other neurons the impulse will travel through all of them.

'All or none' principle. If the stimulus is strong enough (with a minimum threshold) to produce the impulse, the impulse will set up and travel at its own speed. Threshold is the minimum strength of a stimulus that can initiate an impulse. ***Increasing the intensity of the stimulus cannot raise the speed of transmission***.

17.7 REFLEX ACTION

Reflex action is an automatic, quick and involuntary action in the body brought about by a stimulus. For example,

- You instantaneously withdraw your hand on accidentally touching a hot plate or a sharp thorn.
- Watering (salivation) of the mouth takes place on seeing or just smelling a familiar tasty food.

Two types of reflexes – simple and conditioned

The two examples of reflex action given above are basically different. The first one is inborn or natural, which did not require previous learning. Such reflexes are called **simple reflexes**.

The other example is the outcome of repeated experience. Here the brain actually remembers the taste of food and works in an unconscious manner- such reflexes are called **conditioned reflexes**.

Some other examples of reflexes are as follows:

(A) Simple Reflex

- **Quick closing of eyelids** on noticing an object suddenly approaching the eye.
- **Coughing** when the food swallowed enters the windpipe instead of the food pipe.
- **Narrowing of the eye pupil** in strong light.
- If the foot of sleeping person is tickled, it is **jerked away.**

(B) Conditioned Reflexes

- **Applying brakes** in your vehicle (car or bicycle) on noticing someone suddenly coming in front of it.

- **Tying shoe laces** while talking to someone, not knowing whether you are first putting the left lace over the right or the vice versa.
- **A dog runs away** if it notices you kneeling down as if you are picking up a stone for striking.
- **Standing up on** seeing the teacher entering the classroom.

Mechanism of Reflex Action

Some reflexes are brought about through the brain (cerebral reflexes) such as the closing of the eyelids due to approaching objects while other are brought about through the spinal cord (spinal reflexes). The pathway in a simple spinal reflex action is represented in the diagram below (Fig.17.6).

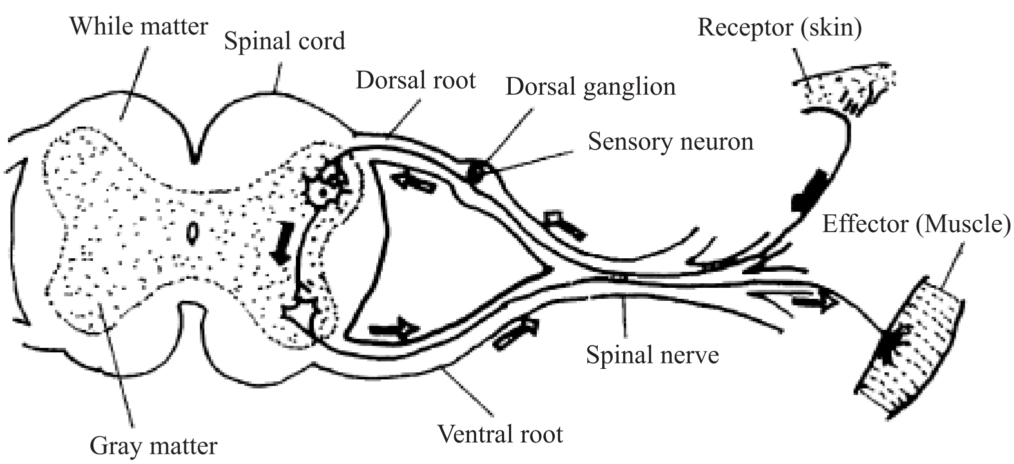


Fig. 17.6 Nerve pathways in a simple reflex action

In this, there are five necessary parts:

The stimulus (prick, heat etc.) → receptor in the sensory organ → the afferent (sensory) nerve fibre running through the dorsal root of the spinal nerve bringing the impulse into the spinal cord → a (motor) neuron sending out the command through its efferent fibre in the ventral root of the spinal nerve → a muscle or the gland.

Mostly there occur an **intermediate neuron** between the axon ending of the afferent fibre and the motor neuron inside the spinal cord.

INTEXT QUESTIONS 17.3

1. Given below are a few examples of reflexes. Write against each, the category of reflex, whether simple or conditioned.

   (i) Knee jerk..

(ii) Salivation on seeing a favorite dish ....

(iii) Tying of shoe laces while talking ....

(iv) Closing of eyelids if a strong beam of light is flashed across ....

(vi) Mistaking a coiled rope as snake if you happen to step on it in darkness ....

17.8 SENSORY RECEPTORS (THE SENSE ORGANS)

Sense organs are the organs through which we sense or detect changes in the external environment. Each sense organ has special sensory cells, which receive the stimuli and transmit the impulses produced through the concerned nerve to the brain or the spinal cord. The brain sorts out the impulses, interprets them and transmits message for the required response. In human there are typically five sense receptors, eyes for seeing, ears for hearing, nose for smelling, tongue for taste and skin for sensing touch, pain, heat, etc.

17.8.1 The Eye (the sense of vision)

The eye is nearly spherical in shape, bulging a little in front, and is able to rotate freely in the bony socket. It is a hollow ball containing several structures inside (Fig.17.7).

The wall of the eyeball is made up of three layers: the sclera, choroid and retina.

- **Sclera** is the outermost tough white layer. In front it is continued as the transparent **cornea**.
- **Choroid** is the middle layer. It is composed of connective tissue having a dense network of blood vessels. Its inner surface is dark brown or black. This prevents reflection, which would otherwise interfere with the clarity of the image.

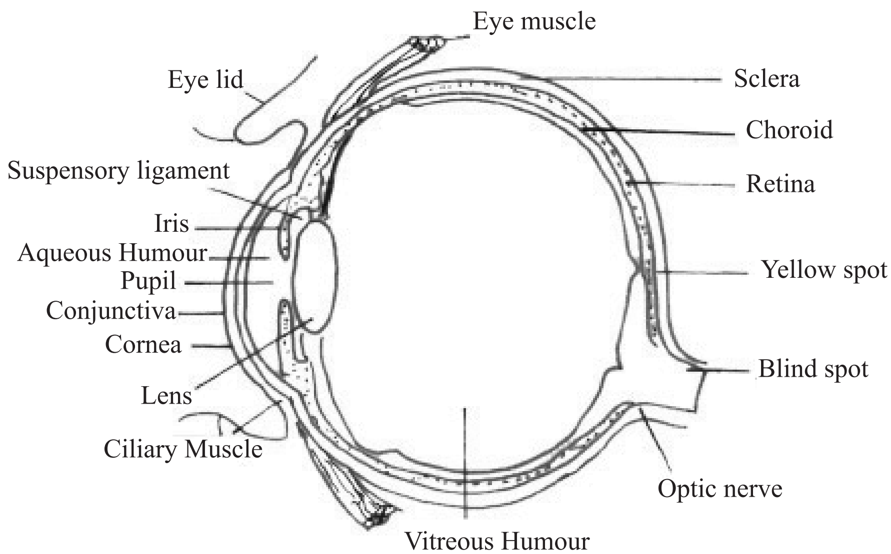


Fig. 17.7 Vertical section of the human eye

- **Retina** is the innermost sensitive layer. It contains two kinds of sensory cells– the **rods** (sensitive to dim light) and **cones** (sensitive to bright light and colours).
  - **Yellow spot** lying at the visual axis is the place of best vision in the normal eye. It contains maximum number of sensory cells and particularly the cone. The rest of the retina has fewer cones and more rods.
  - **Blind spot** is the point where the nerve fibres (axons) from all the sensitive cells of the retina converge to form the optic nerve which connects the eye to the brain. There are no sensory cells at the blind spot and any image formed here is not perceived.

The parts of the eye

Internally the eye is divided into two main chambers separated by the lens.

- **Aqueous chamber** is the front part containing a watery fluid (**aqueous humour**) and **vitreous chamber** is the back part containing a thick jelly like glassy substance (**vitreous humour**, *vitro* : glass). The aqueous humour keeps the lens moist and protects it from physical shocks. The vitreous humour helps in maintaining the shape of the eyeball and protects the retina.
- The **lens** is biconvex in shape and semi-solid. It is composed of soft gelatinous tissue. It is held in position by suspensory ligament, which attaches it to the muscular **ciliary body**. The shape of the lens is influenced by the amount of tension in the suspensory ligament.
- **Iris** is a sort of circular curtain in front of the lens. It is black, brown or blue. The colour of the eye is the colour of its iris. It contains two kinds of muscles : **circular muscles** for narrowing the pupil, and **radiating muscles** for dilating it. The size of the pupil is adjusted involuntarily to control the amount of light entering the eye. Can you think of the situations when the pupil gets narrower and when it becomes wider?

How Do We See

- **Transmission of light :** Reflected light rays from the object enter the eyes through the transparent structures of the eye i.e. conjucativa, cornea, aqueous humour, lens and vitreous humour.
- **Formation of image**. The curvature of the cornea bends the rays to some extent and the lens bends them further to form an image on the retina.
- **Nature of image**. The image is inverted and real.
- **Production of nerve impulse and its transmission**. The light energy of the image produces chemical changes in the sensory cells (rods and cones). These changes produce nerve impulses, which travel through the optic nerve and reach the brain.
- **Perception.** The brain interprets the image in many ways; e.g. it sees the object vertical although the actual image formed is inverted.

- **Accomodation (focusing)**. Focusing the image on retina is called **accommodation**. Changing the curvature of the elastic lens brings about accommodation.
  - **For distant vision :** The lens is more flattened or thinner; this is the normal condition of the lens, which is kept stretched by the suspensory ligaments.
  - **For near vision :** The ciliary muscles which are circular, contract and tend to reduce the circumference of the eyeball there. This releases the tension on the suspensory ligament and the lens becomes thicker (more rounded) on account of its own elasticity.

> A normal eye is constantly accommodating while walking, playing or just looking around.

- **Binocular vision**. In all primates including humans, both eyes are placed forward. Each eye views at a slightly different angle. The images from the two eyes are perceived overlapped inside the brain giving the impression of depth (3-dimensional/stereoscopic vision).

Three Common defects of the eye

1. **Near sightedness (Myopia).** Nearby objects are clearly seen but not the distant ones by those suffering from myopia because the image of the object is formed in front of the retina. This can be corrected by using concave lens (worn in frames (spectacles) or as contact lenses).
2. **Long sightedness (Hypermetropia).** Distant objects are clearly seen but not the nearby because the image of the object is formed behind the retina. This can be corrected by convex lens (worn in frames as spectacles or as contact lenses).
3. **Cataract (opacity of the lens).** The lens usually loses its transparency and turns opaque with age. Such a lens can be surgically removed and replaced by an intra-ocular lens.

INTEXT QUESTIONS 17.4

1. State the function of the following parts of the eye:
   (i) Iris ....
   (ii) Ciliary muscles ....
   (iii) Pupil ....
   (iv) Vitreous humour ....
   (v) Retina ....

2. Name the following:
   (i) Area of sharp vision in the eye ....
   (ii) The kind of lens used for correcting near-sightedness ....
   (iii) The condition in which the lens of the eye turns opaque ....
   (iv) The capacity of eye to focus objects at different distances ....

17.8.2 The Ear-Sense of Hearing and Balance

The ear serves two sensory functions: hearing and maintaining balance of the body. The ear has three main parts – external ear, middle ear, and internal ear (Fig. 17.8)

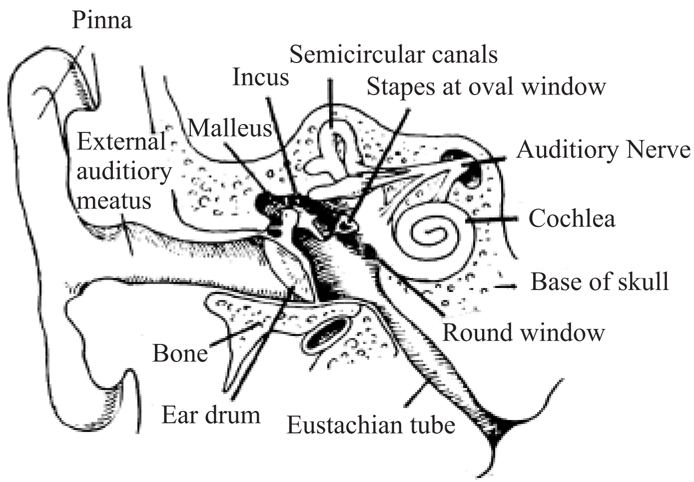


Fig. 17.8 The human ear.

The **external ear** consists of the following :

– an outwardly projecting ear to be called **pinna** supported by cartilage. It directs the sound waves inwards.

– The **auditory canal** through which the sound waves travel up to the ear drum (tympanic membrane)

The **middle ear** consists of the following:

- An air-filled tympanic cavity
- The **tympanum** or ear drum
- Three tiny bones-**malleus** (hammer) connected to the ear drum, incus (anvil) in between and **stapes** (stirrup) forming a contact with the oval window of the internal ear.
- **Eustachian tube** connects the tympanic cavity with pharynx. It equalizes the pressure on both sides of the eardrum or tympanum :

The **internal ear** contains two main parts:

(a) **Cochlea** – It is a long coiled structure which looks like the coils of the shell of a snail. It has two and a half turns. The inner winding cavity of the cochlea is divided into three parallel tubes of canals separated by membranes. The canals are filled with a fluid called endolymph. The middle canal possesses sensory cells (organ of corti) for hearing.

(b) **Vestibule** – is concerned with physical balance of the body. It consists of three **semicircular canals** arranged at right angles to each other and a part joining the cochlea and differentiated into a **utriculus** and a **sacculus**. One end of each semicircular canal is widened to form an **ampulla,** which contains sensory cells, and the nerve fibres from them continue into auditory nerve.

Mechanism of hearing

- The sound waves enter the auditory canal and cause the eardrum to vibrate
- The vibrations of the eardrum are transferred to malleus, to incus, and then to stapes. Stapes transfers the vibrations through oval window into the cochlea.
- These vibrations move the fluid in the cochlea. The organ of corti catches the movement of the fluid and transfers it to the auditory nerve that carries the impulses to the brain

Perception of body balance

Static balance due to gravity – Any bending or change in the body posture causes the fluid inside the semicircular canals to move. The semi circular canals are arranged in different planes. The sensory hairs in the ampulla of the canal pick up these movements and the impulses are transmitted through the auditory nerve.

Balance during motion – Utriculus and sacculus perceive dynamic equilibrium (while the body is in motion). Fine particles of calcium carbonate present in the endolymph press on the sensory hairs whenever the body is in some motion. The impulses are carried through the auditory nerve.

17.8.3 Tongue and Nose (Sense of taste and smell)

The tongue perceives the taste and the nose perceives the smell. The perception depend upon the nature of chemical substance coming in contact with the sensory cells. For taste there is a direct contact of the substance with the sensory cells located in the taste buds on the tongue. For smell, the molecules of the chemical are carried inward by the air inhaled and they stimulate the sensory epithelium of the nose.

17.8.4 Skin (Touch and some other miscellaneous senses)

There are a variety of nerve endings in the skin. Some of these are concerned with touch (gentle pressure), some with deep pressure and others with cold, heat and pain.

The sense of hunger is due to receptors in the stomach wall. The sense of thirst is due to stimulation of nerves in the pharynx. And the sense of fatigue is located in the muscles.

INTEXT QUESTIONS 17.5

1. Which part of the ear is involved when:

   (i) a gymnast performs various balancing feats. ....

   (ii) you hear a song. ....

2. Name the following :

 (i) The part into which the sound waves are directed by the ear pinna.

 ....

 (ii) The kind of balance with which the semi-circular canals are concerned.

 ....

 (iii) Any two sensations felt through free nerve endings in the skin.

 ....

17.9 COORDINATION THROUGH HORMONES—THE ENDOCRINE SYSTEM

Hormones are secretions from specific cells or glands in the body called endoerine glands Harmones are carried by blood to target organs. Their effect is produced in one or more specific parts only. Most hormones are secreted by special glands called the endocrine glands. These are also called ductless glands because their secretions are poured directly into the blood and not through ducts. Certain hormones are produced by other glands or body parts also, for example, the stomach and the duodenum.

17.9.1 Nature and Function of Hormones

- Hormones are secreted from their source directly into the blood.
- Blood carries the hormone to the **target cells** which respond to it.
- Hormones **regulate** the physiological processes.
- They are produced in **very small quantities** and are **biologically very active**. For example, adrenaline is active even at a concentration of 1 in 300 million parts.
- Their **excess** and **deficiency**, both, cause serious disorders.
- Chemically, the hormones may be water-soluble **proteins (peptides), glycoproteins** and **amines** or lipid-soluble **steroids**.
- The extra hormones are not stored in the body and are excreted out.

17.9.2 Hormone Secretors — the Endocrine Glands

In humans there are more than a dozen tissues and organs that produce hormones. Most of these are shown in Fig. 17.8. These can be listed under two categories

(a) **Exclusively endocrine** : the **pituitary,** the **thyroid,** the **parathyroid, thymus** and the **adrenals.**

(b) **Partially endocrine** : The **pancreas, gastric and duodenal epithelium,** the **gonads** (testis in males and ovary in females) and **placenta** in females.

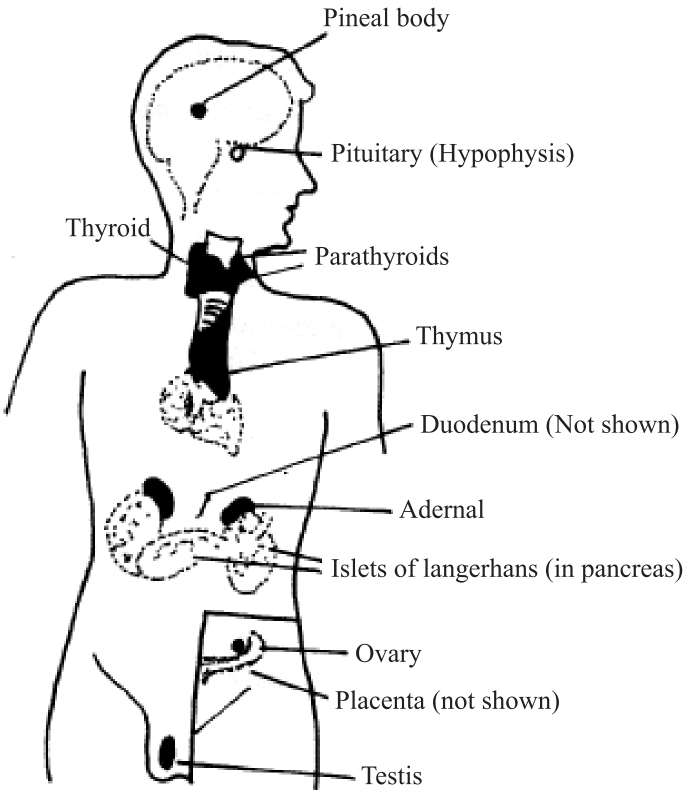


Fig. 17.8 Location of principal endocrine glands in the human body

1. Pituitary — the master gland

The pituitary gland (also called hypophysis) (Fig. 17.9) is a small projection (about the size of a pea) which hangs from the base of the mid-brain. It is connected to the hypothalamus of the brain by the pituitary stalk. The hypothalamus, although a part of the brain, also secretes some hormones.

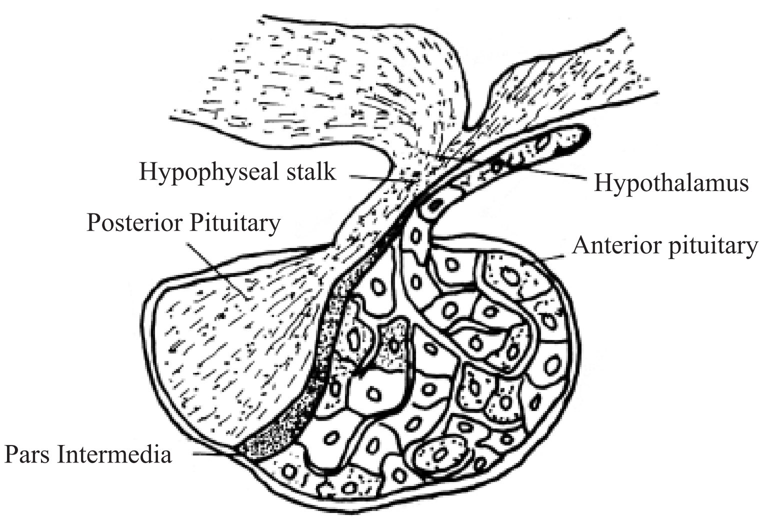


Fig. 17.9 Pitutary gland

The pituitary controls most other endocrine glands. It has two distinct parts: the **anterior pituitary** and the **posterior pituitary**. Various hormones produced from these two parts and their actions are listed below in Table 17.2.

Table 17.2 Pituitary hormones, their action and abnormalities due to its oversecretion or undersecretion

Source	Hormones	Action and abnormalities produced
Anterior lobe of pituitary	Growth hormone (GH), also known as somatotropic hormone (STH)	Promotes growth of whole body, particularly of the skeleton. Undersecretion in childhood lead to Dwarfism; oversecretion in childhood causes gigantism and in adult, acromegaly.
	Tropic hormones (stimulate other endocrine glands)	1. Thyroid stimulating hormone (TSH) stimulates thyroid. 2. Adrenocorticotropic hormone (ACTH) stimulates adrenal cortex.
	Gonadotropic hormones	3. Follicle stimulating hormone (FSH) stimulates egg formation in females and sperm formation in males. 4. Luteinizing hormone (LH) stimulates ovulation and the formation of corpus luteum which produces the female hormone progesterone and LH stimulates testis to produce the male hormone testosterone. 5. Prolactin stimulates milk production.
Posterior lobe of pituitary	Antidiuretic hormone (ADH) or vasopressin	Increases absorption of water from the kidney tubules (osmoregulation). Its deficiency causes **diabetes insipidus**.
	Oxytocin	Stimulates contractions of the uterus during childbirth.

2. Thyroid

Thyroid is a bilobed structure situated in the front region of the neck (Fig. 17.10). It secretes two hormones—**thyroxine** and **calcitonin.**

Thyroxine regulates basal metabolism i.e. the rate of cellular oxidation resulting in heat production. Controls growth and development, ossification of the bones, body temperature, mental development, etc.

Undersecretion of thyroxine (hypothyroidism) produces three conditions

- Simple **goitre.** Enlargement of thyroid visible as a swelling in the neck. It is caused due to iodine deficiency in food as iodine is needed for production of thyroid hormones.
- **Cretinism.** Poor body growth (dwarfism) and mental retardation
- **Myxoedema.** Swelling of the face and hands. General sluggishness.

Oversecretion of thyroxine (hyperthyroidism) produces exophthalmic goitre. This condition causes marked increase in the metabolic rate, rapid heart beat, shortness of breath and the eyes protrude out together with goitre in the neck.

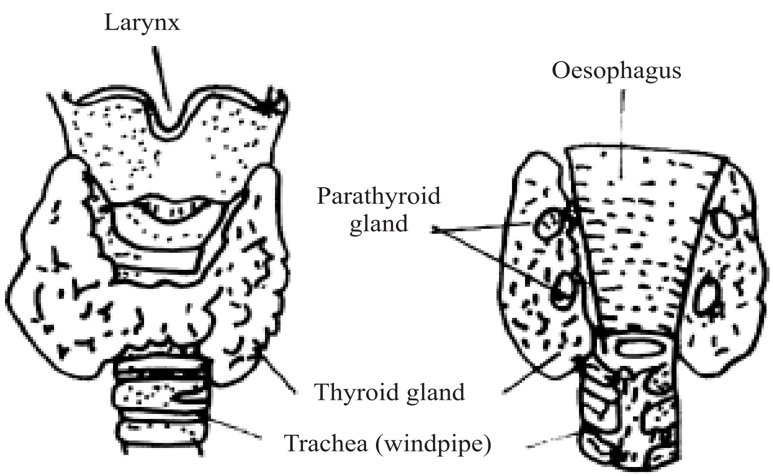


Fig. 17.10 The thyroid gland

Calcitonin. It regulates the calcium and phosphate levels in the blood. If the calcium level in blood is high more calcitonin is secreted and the calcium ions are moved from the blood to the bones making them harder. The reverse happens when the calcium level in the blood is low making the bones soft.

3. Parathyroids

These are two small pairs of glands wholly or partially embedded in the thyroid gland. Their secretion **parathormone** raises blood calcium level by stimulating release of calcium from bones.

4. Thymus

It is located at the base of neck. It produces some hormones involved in maturation of T lymphocytes. It begins to atrophy after puberty.

5. Adrenals

The adrenals (ad: adjacent, renal; kidney) are a pair of glands situated like caps one above each kidney. Each adrenal consists of two parts: a central **medulla** and a peripheral **cortex**.

The **adrenal medulla** secretes adrenaline which,

- increases heart beat accompanied by an increase in the blood pressure.
- increases blood supply to the muscles while decreasing blood supply to the visceral organs.
- releases more glucose into the blood from the liver.

The **adrenal cortex** secretes two categories of hormones: **glucocorticoids** and **mineralocorticoids**.

(a) **Glucocorticoids** e.g. **cortisone**

- In response to stress it raises blood glucose through action of the liver including deamination of amino acids. During starvation and prolonged fasting the required glucose is partly provided through this hormone.
- It adapts the body to stresses such as extreme heat or cold, burns, infections, etc.
- Some of the cortical hormones behave like sex hormones.
  - **Overgrowth of adrenal cortex in young children** causes premature sexual maturity.
  - **Overgrowth of adrenal cortex in mature females** results in the development of male characters such as beard and deep voice.
  - **Overgrowth of adrenal cortex in mature males** results in the development of some feminine characters such as enlargement of breasts.

(b) **Mineralocorticoids** e.g. **aldosterone**

This hormone is concerned with water retention. It increases reabsorption of sodium and chloride ions in kidneys. Read the role of aldosteronl in increasing blood volume and blood pressure in increasing blood volume and blood pressure in lesson 14 (14.3.6)

6. Pancreas

Pancreas is an endocrine as well as an exocrine gland. It has special groups of cells called **Islets of Langerhans**, which consists of three kinds of cells – *alpha cells* producing the harmone glucagon, *beta cells* producing harmone *insulin* and *gamma* cells producing harmone **somatostatin**.

(i) **Glucagon.** It stimulates breakdown of glycogen to glucose in the liver, leading to rise in the blood sugar level.

(ii) **Insulin**. It performs two principal tasks;

- Promotes glucose utilization by the body cells.
- Stimulates deposition of extra glucose in the blood as glycogen in the liver.

Gluccagon and insulin have oppsite functions.

Non-secretion or under secretion of insulin causes **diabetes mellitus** (***hyperglycemia***, meaning 'more than normal sugar in blood'.

A diabetic person,

- has higher glucose in blood;
- excretes a great deal of urine loaded with sugar;
- feels thirsty because of loss of water through too much urination;
- loses weight and becomes weak. In some cases, the patient even loses the eyesight.

Oversecretion of insulin causes **hypoglycemia** or low blood sugar. The brain may enter a state of coma if the level of sugar in blood becomes too low.

(iii) **Somatostatin** also called Growth Hormone-Inhibiting Hormone (GHIH) inhibits secretion of insulin as well as glucagon.

7. Gonads (testis and ovary)

Testes in males possess two kinds of cells : the sperm-producing germinal cells and the hormone-producing interstitial cells. The hormones produced are called androgens and the commonest one among them is **testosterone**.

The **testosterone** stimulates the development of the male characters during which the body at **puberty** starts developing facial hair**,** and their voice cracks and deepens.

Ovaries in females produce two kinds of hormones—**estrogen** and **progesterone**. **Estrogen** is secreted from the follicles of the ovary and stimulates the development of breasts and fat deposition on the hip in a mature woman. Estrogen prepares the wall of the uterus for receiving the fertilized egg.

Progesterone is secreted by the corpus luteum (follicle left after the release of ovum). It brings about the final changes in the uterus for the retention and growth of the foetus during pregnancy.

8. Placenta

Placenta of a pregnant woman produces certain hormones. One such hormone is **human chorionic gonadotropin** (HCG), which maintains the activity of corpus luteum in secreting progesterone continuously, when a women becomes pregnant.

9. Hormones from stomach and intestine

(i) **Gastrin** is the hormone secreted by the mucus membrane of the pyloric end of the stomach. It stimulates the gastric glands to secrete gastric juice.

(ii) **Secretin** is the hormone secreted by the inner lining of the duodenum. It stimulates the production of pancreatic juice while the hormone **cholecystokinin** stimulates release of bile from gall bladder.

17.10 THE FEEDBACK MECHANISM (CONTROL OF HORMONAL SECRETION)

The amount of hormone released by an endocrine gland is determined by the body's need for the particular hormone at any given time. The product of the target tissue exerts an effect on the respective endocrine gland. This effect may be positive ('*secrete more*') or negative ('*secrete no more*' or '*slow down*'). This can be explained by taking the example of thyroid gland.

Feed back mechanism of thyroid activity (Fig. 17.11). Hypothalamus releases a hormone TSH-RH (TSH- Releasing Hormone) which instructs the anterior pituitary to release TSH (thyroid stimulating hormone). The TSH stimulates thyroid to release thyroxine. If the level of thyroxine in blood increases, the pituitary stops the release of TSH. When the level of thyroxine falls in the blood, the thyroid gets stimulated to secrete more of it. In feedback mechanism the starting point of an activity receives back the information whether to continue or increase, or to slow down or even stop.

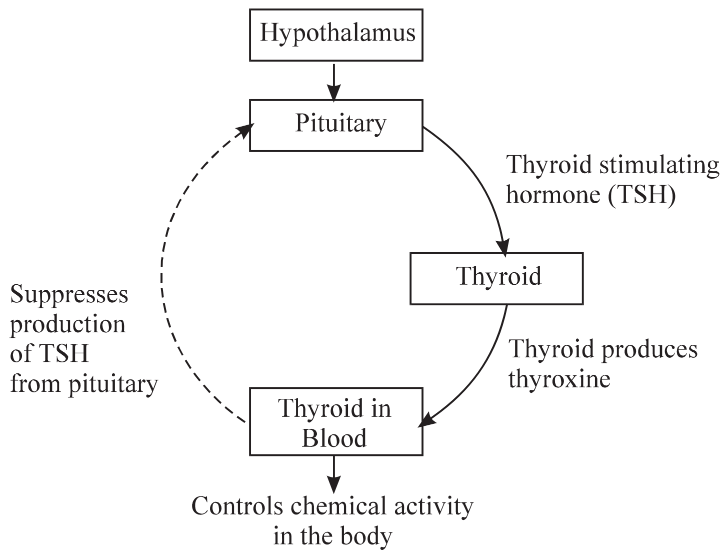


Fig. 17.11 Feed back mechanism in hormone action
(solid line = stimulation; broken line = suppression/inhibition)

17.11 COMPARISON OF HORMONAL AND NERVOUS COORDINATION

The table 17.2 below lists a few major differences between these two different kinds of control and regulating mechanisms.

Table 17.2 difference between hormonal and nervous control

Property	Hormonal control	Nervous control
1. Nature of signal	All hormones are chemical signal	Nerve impulses are electrical signals. Chemical signalling takes place at synapses
2. Speed of signal	Slow	Rapid. Between 0.7 metres per second and 120 metres per second
3. Effect in the body	General effect. The hormones can influence cells in many different parts of the body.	Localized effect – affects only the particular muscle or the gland

4. Effect on growth	Can affect growth	Cannot affect growth
5. Capacity for modification	Cannot be modified by learning from previous experience	Can be modified by learning from previous experiences
6. Duration of effect	Short term or long lasting.	Short – lived

17.12 PHEROMONES—THE CHEMICAL MESSENGERS AT SOCIAL LEVEL

Pheromones are the secretions given out by **an individual** into the environment, which bring about a specific response **in other members of the same species**. Some of the examples of the pheromones are as follows:

- **Common ants march on the floor or walls in a trail** on an invisible path laid down by a secretion from their bodies. It helps them to reach the destination one after another, as well as to return correctly to their own nest.
- **When disturbed honey bees give out an alarm pheromone** from their sting at the back and mandibles in the mouth. This alerts the inmates of the hive to face the attack.
- Females of a particular moth gives out a scent which can attract a male from as much distance as 3-4 kilometers.
- Introduction of a male mouse into a group of female mice shortens oestrus cycle (cycle of development of eggs in the ovary and ovulation).
- Introduction of a **strange male mouse** of a different strain disturbs to the extent that the **newly pregnant females abort their foetuses**. The source of pheromone of the strange male mouse is in its urine.

INTEXT QUESTIONS 17.6

1. Name the following

    (i) The organ in the neck on the trachea close to which thyroid is located

    ....

    (ii) The condition caused due to oversecretion of thyroxin

    ....

    (iii) The hormone concerned with facing dangers

    ....

(iv) The condition of passing much glucose in the urine

....

(v) The source gland of ADH

....

2. What are pheromones?

....

WHAT YOU HAVE LEARNT

- The coordination of body activities inside the body of an organism is brought about by two systems- the nervous and the endocrine systems.
- The nervous system is composed of the central nervous system (brain and spinal cord) and the peripheral nervous system (cranial and spinal nerves and the autonomic nervous system).
- The autonomic nervous system consists of a pair of chain of ganglia by the side of spinal cord. It is largely concerned with the normal functioning of the visceral organs.
- The nervous system of cockroach is made of brain or cerepral gangha, suboeso phaegeal ganglion, thoracic ganglia gangha and six abdominal ganglia from which nerves come out.
- Cerebrum is the largest part of the brain and is the seat of intelligence.
- Cerebellum is the centre of balance.
- Medulla oblongata controls breathing and heart beat.
- Spinal cord is the centre for simple reflexes.
- The sensitive layer of the eye is the retina which is composed of rods (sensitive to dim light) and cones (sensitive to bright light and for colour vision).
- The internal ear performs two tasks perception of sound by the cochlea and that of disturbance in body balance by the semicircular canals, utriculus and sacculus.
- The nose perceives chemical stimuli by the chemicals carried by the air and the tongue by direct contact with them.
- Skin possesses receptors for touch, pain, heat cold etc.
- Chemical coordination is brought about by hormones produced by the ductless glands, that are carried by the blood and which act on the target cells or organs away from their source.
- There is a close link between the nervous and the endocrine systems, shown by the way in which the pituitary gland interacts with the hypothalamus of the brain.

- Our endocrine glands include the pituitary, thyroid, parathyroid, thymus adrenals, pancreas, gonads and placenta.
- The pituitary controls and regulates the activities of almost all other endocrine glands.
- The undersecretion as well as the oversecretion of the hormones, both produce ill effects.
- Hormone levels are generally controlled by feed back mechanism.
- Pheromones are secretions released outside in the enviroment, which produce response in other individuals of the same species.

TERMINAL QUESTIONS

1. Name the two divisions of the nervous system?
2. What is gray matter?
3. Name the chemical involved in the transmission of nerve impulse across a synapse.
4. Give two examples of sensory nerves.
5. Name the respective areas of the retina concerned with best vision and no vision.
6. What is the role of the eustachian tube in the ear?
7. Name the hormone and its source glands, whose deficiency leads to diabetes insipidus.
8. What are pheromones?
9. Name and explain the event that happens immediately when a nerve fibre gets stimulated?
10. Are the endocrine glands and the ductless glands one and the same thing? Give one example.
11. Describe any one example of condition reflex in the humans.
12. List the functions of medulla oblongata.
13. Differentiate between sympathetic and parasympathetic nervous systems.
14. What are the two principal tasks of insulin?
15. Explain the following terms: (i) synapse (ii) stimulus and (iii) impulse
16. Draw a diagram to show the arrangement of the bones inside the middle ear.
17. Write short notes on the following :
    (i) myopia
    (ii) taste buds
    (iii) accommodation of the eye

18. How do sympathetic and parasympathetic nervous systems act differently on (i) pupil of the eye, and (ii) urinary bladder?

19. Draw a labelled diagram of the cross section of the spinal cord and the nervous pathway of a simple reflex concerned with it.

20. Explain the role of ciliary muscles in our eyes

21. Taking the example of thyroxine secretion, explain what is meant by feedback mechanism?

ANSWERS TO INTEXT QUESTIONS

17.1

1. FIg. 16.1, page 337
2. (a) supraoesophageal ganglion (b) sub oesophageal ganglion
3. Ventral nerve cord
4. Cerebrum, cerebellum, medulla oblongata, thalamus and hypothalamus
5. (i) Cerebrum–intelligence/thinking/reasoning/memory;
   (ii) Cerebellum– balance/muscular coordination
   (iii) Medulla oblongata–involuntary actions
   (iv) Hypothalamus–homeostasis
6. Gray matter–composed of neuron cell bodies
   White matter–composed of axon fibres
7. Cerebrospinal fluid

17.2

1. Sympathetic nervous system and parasympathetic nervous system
2. (i) parasympathetic nervous system
   (ii) parasympathetic nervous system
   (iii) sympathetic nervous system
   (iv) parasympathetic nervous system
   (v) parasympathetic nervous system
3. because it connects the periphery (surface) of the body
4. sensory = afferent, motor = efferent

17.3 1. (i) simple (ii) conditioned (iii) conditioned

(iv) simple (v) conditioned

17.4 1. (i) contracts and dilates pupil

(ii) helps in near vision/contracts to make lens thicker

(iii) controls amount of light entering the eye

(iv) maintains shape of the eye ball and protects retina

(v) produces nerve impulses into the optic nerve

2. (i) yellow spot (ii) concave lens

(iii) cataract (iv) accommodation

17.5 1. (i) vestibule (ii) cochlea

2. (i) auditory meateus

(ii) static balance

(iii) touch/pressure/warmth/cold/ ….

17.6 1. (i) larynx, (ii) cretinism, (iii) adrenaline (iv) diabetes mellitus,

(v) posterior pituitary

2. Pheromone is a secretion from one individual that is given out into the environment and which elicits a response in other members of the same species.

18

HOMEOSTASIS : THE STEADY STATE

In the previous lesson you studied about the nervous system. There, you noted how the body functions in a coordinated manner to bring about any required effect or change. You also learnt about the hormones and how they work in a way so that the body knows when to start, when to speed up, when to slow down and when to stop an event that ocurs inside the body. In this lesson, you will study about the phenomenon called **homeostasis** which means 'keeping steady state'. Homeostasis operates for a variety of needs inside our body and one such need is the regulation of body temperature called **thermoregulation**. This lesson mainly covers various aspects of thermoregulation.

OBJECTIVES

After studying this lesson, you will be able to :

- *define the term homeostasis and explain its needs in the body;*
- *explain the term thermoregulation and justify its need in the body;*
- *differentiate between endotherms and ectotherms;*
- *list the body parts involved in thermoregulation and explain how they contribute towards heat production and heat loss;*
- *name the principal heat regulating centre in our body and describe how it acts;*
- *explain the term 'feed back' and differentiate between positive and negative feedback mechanisms.*

18.1 CONCEPT OF HOMEOSTASIS

Homeostasis (*homeo* : same/steady, *stasis* : state) is a phenomenon in which the body regulates its functions to keep the internal conditions as stable as possible.

Homeostasis is necessary because the body cells need to have suitable conditions around them for proper functioning. These conditions include, the presence of proper concentration of chemicals, proper temperature, and a suitable pH (degree of salinity or acidity), etc. inside its cells. But these conditions inside our body as well as inside other organisms keep fluctuating within a narrow range. Tolerance to any change from this range differs in different organisms. Organisms adopt a variety of measures to cope with such changes.

To understand the concept of homeostasis (keeping steady state) consider the following five examples in the humans:

Example 1. Drinking water and keeping a 'steady water balance'.

In all kinds of weather, your blood and other body fluids must maintain a particular percentage of water. If the volume of water in the body tends to rise, the excess is passed out in urine and, if it tends to fall short, more water is withheld inside the blood to the extent required. Thus, the body maintains a steady state (= homeostasis) of water content.

- In hot summers you feel thirsty at regular intervals. You drink lots of water or even cold drinks, yet you do not urinate much. The urine passed out is more concentrated. This is because during hot weather you lose more water through perspiration but your body needs to maintain its requisite amount of water and so the water is withheld within, by passing out only little and concentrated urine.
- In cold winters you donot feel much thirsty. You do not drink large quantities of water. But, may be, you take more of hot drinks only to keep warm. During such days you urinate more frequently and the urine passed out is more dilute.

Example 2. Eating sugar and keeping steady sugar level in blood

Suppose you have been consuming too much sugar in food, beverages and sweets. Presuming you are otherwise normal, your body will handle the excess sugar (more than the normal percentage in the blood) by storing it in the form of **glycogen** in the liver.

At some other time, when you are fasting or doing much physical work, your blood sugar is used up rapidly. At that time, the liver converts the stored glycogen back into its usable form, that is glucose, to fill the gap and restore the normal blood sugar level.

Example 3. Maintaining normal steady state of blood alkalinity

Sometimes you eat too much salt (sodium chloride) in your food. But your blood normally maintains only the particular level of alkalinity (pH 7.34-7.43) which is only slightly alkaline. Any extra salt consumed is passed out through urine as it cannot be stored in the body.

If at some other time you have been eating too little salt, or you are losing much of it through sweating, your kidneys will hold back the required quantity through sodium-potassium balance.

Example 4. Managing the number of red blood cells

A normal human adult possesses about 5 million red blood corpuscles (RBCs) per cubic millimetre of blood.

Whenever a plain-dweller visits a hill station at high altitude without any break-journey in between, he is likely to feel exhausted for a couple of days. Later, the person becomes normal. At high altitudes the atmospheric pressure is lower and the amount of oxygen carried by this normal number of RBCs is insufficient. Within a day or two, the body adds more RBCs into the blood to pick up the normal required quantity of oxygen.

When the same person returns to the plains at a lower altitude the higher RBC level that was acquired at the hills now begins to take up oxygen in excess, which is harmful. The body readjusts the red blood cells which get reduced in number to become stable at the original level.

Example 5. Warming and cooling of the body (maintaining steady body temperature)

During hot summers you wear light clothes. You perspire a lot, you sit under a fan or under a tree and feel comfortable. Your body is trying to cool against the higher temperature outside.

Then, there is the reverse side, that is, cold winter. Inspite of wearing thick warm clothes you still feel cold. In mid-daytime, you go out in the open sunshine to warm yourself. At night, you cover yourself with a thick blanket. You are doing all this to maintain warmth inside steadily your body.

In both the above situations, you are trying to regulate your internal body temperature. This is called thermoregulation. You will learn more about thermoregulation in subsequent sections of this lesson.

INTEXT QUESTIONS 18.1

1. Define homeostasis.

   ....

2. List any three chemicals whose concentration in our body has to be maintained at partcular levels.

   (i) ....

   (ii) ....

   (iii) ....

3. To obtain enough oxygen for respiration at high altitudes, what does the body do?

   ....

18.2 THERMOREGULATION — WHY IS IT NECESSARY?

18.2.1 Limits of heat tolerance

The living organisms can normally survive only within a certain range of temperature of about 0-45° C. However, organisms tend to make adjustments, if they happen to be at places of higher or lower temperature.

A. **Above 45°C,** the organisms may suffer in many ways:

- the enzymes are destroyed,
- proteins get denatured,
- plasma membrane breaks down, and
- cells suffer lack of oxygen.

B. **Below 0°C.** At temperatures below freezing point, the cells may burst by the formation of needle-like ice crystals inside and between the cells and the organisms cannot survive.

The above stated effects due to temperature changes are because enzymes function normally within a certain range of temperature.

18.2.2 Efficiency of enzymes at different temperatures

Enzymes carry out almost all the chemical reactions occuring inside our body. They have several characteristics and the most important one is their relation with respect to temperature.

- **At 0°C**. The enzymes are inactive.
- The rate of enzyme-catalyzed reactions doubles with every 10 degrees rise in temperature between 4-40°C.
- **On warming.** Whenever the temperature rises, the enzymes start working faster. If the temperature becomes too high (more than 40°C) the enzymes begin to work too rapidly and produce unwanted intermediate chemicals and not the required ones. At still higher temperatures the enzymes get denatured (destroyed).
- The enzymes act best at a narrow temperature range, usually between 35-40°C (optimum temperature meaning the most suitable temperature)
- **On cooling.** At temperatures lower than the optimum temperature the enzymes become less and less efficient. At freezing temperatures the enzymes may turn totally inactive.

INTEXT QUESTIONS 18.2

1. How do the following temperatures affect the enzymes?

   (i) 45°C and above ....

   (ii) 0°C and below ....

2. (i) At what temperature range do enzymes act best?

....

(ii) What technical term do you use for this temperature?

....

18.3 CLASSIFICATION OF ANIMALS BASED ON THEIR TEMPERATURE TOLERANCE

Based on the capability and the manner of regulating body heat, all animals found on earth are grouped into two main categories: endotherms and ectotherms

18.3.1 Endotherms and Ectotherms

A. ENDOTHERMS (*endo* : inside, *therm* : heat) : Examples: All birds and mammals. Endotherms are organisms, which maintain a steady body temperature irrespective of the temperature of the surroundings. Two other terms often used synonymously for endotherms are

- **Homoiotherms** (homoio: same; therm: heat) refers to keeping the same or constant (warm) body temperature, and
- **Warm-blooded** (oldest term and seldom used now) means animals which are felt warm whenever touched. If you hold a pigeon in your hand or feel a rabbit by touch even when it is intensely cold outside, you will find them warm.

B. ECTOTHERMS (ecto: outside, therm: heat) : Those animals whose body temperature rises and falls with the rise and fall of surrounding temperature are termed Ectotherms. All animals other than birds and mammals are ectotherms. Examples: Fish, frogs, lizards, insects, earthworms, etc. Two other terms often used synonymously with ectotherms are

- ***Poikilotherms*** (*poikilo* : changing/varying, therm: heat) referring to acquiring the body temperature from that of the surroundings.
- ***Cold-blooded*** (oldest term and seldom used now) means animals which are cold when touched. If you hold a frog in your hand or feel the touch of a cockroach, they are always colder than your body.

18.3.2 Characteristics of Endotherms

1. With an **internal heat-regulating mechanism,** the endotherms (birds and mammals) are able to maintain their body temperature within a narrow range of 2°C (37-39°C.) irrespective of the outside temperature whether intensely cold or severely hot. Birds are usually slightly warmer than the mammals.
2. An **efficient insulation mechanism** helps maintain body temperature
   - Birds have feathers to trap air for preventing heat loss. When cold, the feathers are raised (fluffing) to trap more air to increase insulation.

- Mammals have two sources of insulation: (i) hairs and (ii) subcutaneous or under-skin fat. The hairs trap the air. When it is too cold the hairs are raised (goose flesh) to increase insulation. The under-skin fat prevents conduction of heat outwards. This fat layer is thicker in the colder region inhabitants for better prevention of heat loss and thinner in those living in warmer regions to allow greater heat loss.

18.3.3 How some endotherms cope with unfavorable temperatures

- **Polar bears, penguins** and several other animals live in the ice-covered polar regions. They maintain their body temperature by generating heat and preventing heat loss through thick fur and a thick layer of under-skin fat.

- **Camels, desert rats** and several other tolerate the intense heat of the tropical deserts mainly by promoting heat loss.

> Camel is a desert dweller of hot climate. It needs to possess more of heat loss mechanisms and cut down the heat- retaining ones. Most of its skin has no fat layer. But, look at the hump, it stores a huge bulk of fat only as reserve food.

- **Squirrels, goats, pigeons** etc. live in moderate climate and they too have to adjust their body temperature according to the changing conditions of the outside. They adjust both in winter and summer to maintain normal body heat.

  Humans too are endotherms. When required we supplement our natural heat-regulating mechanisms by artificial methods like clothing, using the fan, bathing, room heating, room- cooling, etc.

18.3.4 Some ectotherms and how they cope unfavorable temperature conditions

Consider the following examples:

- **Frogs** hibernate under the ground in cold winters and aestivate during hot summers to avoid heat and escape from cold. Hibernation or wintersleep is characterised by the animal slowing down its activites and resting underground. During hibernation the 'basal metabolic rate' remains low.
- **Fishes** live in water. Water seldom undergoes extreme temperature changes like the ones on land. Still, fishes either make minor adjustments in their body parts to minimize the heat loss or heat gain or, if they are unable to do so, they migrate to less harsh regions.
- **Lizards** and **crocodiles** bask in the open sun to warm themselves during cold weather. When hot, they move to shades. When feeling hot, the crocodiles even open their mouths wide to allow evaporation of water for cooling purposes, something like the panting of dogs.
- **Honey bees**, during cold winter nights, huddle together inside the hive to conserve body heat collectively. During hot summers they even operate a kind of 'desert cooler' by sprinkling some water on the honeycombs and fanning with their wings for cooling the honey combs.

INTEXT QUESTIONS 18.3

1. Classify the following animals as endotherm or ectotherm:

   Camel, Bat, Earthworm, Cockroach, Fish, Wall lizard, Polar bear, sparrow

   Endotherms ....

   Ectotherms ....

2. Explain the following terms and give one or more synonymous terms for each:

   (i) Poikilotherms ....

   (ii) Homoiotherms ....

3. Mention one way each by which each of the following fight severe cold:

   (i) Crocodile ....

   (ii) Honey bee ....

   (iii) Common frog ....

   (iv) Wall lizard ....

18.4 MECHANISM OF HOMEOSTASIS OF BODY TEMPERATURE (THERMOREGULATION) IN HUMANS

18.4.1 Normal core body temperature

The starting point in any homeostasis is the identification of its set or the normal point. The set point of human body temperature is taken as 37°C, which is also called the normal or core body temperature. The core body temperature refers to the temperature of the combined portion of the trunk, head and upper part of arms and legs. Our body temperature otherwise is not uniform throughout.

- The surface skin temperature is usually lowest but it varies considerably due to a variety of external and internal conditions.
- The armpit usually records 1 degree less than the temperature inside the mouth.
- The anal temperature is 1 degree higher than the core body temperature. In very young children, the clinical thermometer is placed inside the anus and the temperature recorded is reduced by one degree to assess if the child is having any fever.
- For all practical purposes, the oral (mouth) temperature is taken as normal body temperature, which is usually 37°C (±0.5).

Whenever the core body temperature departs from the normal, the body takes corrective measures. For example :

- If the temperature falls, there is increased heat production in the body along with prevention of heat loss.
- If body temperature rises there is cooling to give out excess heat.

You will read about such steps in more details in the next sub-section.

18.4.2 Mechanisms of Thermoregulation

The principal heat-regulating centre is located in the **hypothalamus**, a part of the forebrain. This part acts like a thermostat.

- When the body has to face cooling below the normal temperature, it '*switches on*' or speeds up the heat-producing processes and simultaneously '*shuts off*' the heat-losing ones.
- When the body faces overheating during summer or after intense physical exercise, it accelerates the cooling process and '*switches off*' the heat- producing ones.

A. Keeping warm in cold weather

Thermoregulation in cold weather is achieved in two ways : preventing loss of body heat and generating more body heat.

1. **Preventing loss of body heat** - This is achieved in two ways:

   (a) ***Vasoconstriction***. Vasoconstriction means narrowing of blood vessels (Fig.18.1a). As a result of vasoconstriction in the skin,

   - the blood supply to the skin is reduced and there is less loss of heat by convection, conduction and radiation.
   - With the reduced blood supply to the sweat glands in the skin, there is less or no secretion of the sweat and thus there is no evaporation of water and no loss of heat

   Have you ever observed that in very cold weather you look pale or bluish? This is due to reduced blood supply to the skin caused by vasoconstriction.

   (b) ***By posture***. At times when we feel cold,

   - We hold our arms cross-folded tightly over the chest while standing or sitting.
   - While sleeping in bed we often hold our arms and legs closely folded near the body in a curved posture.

   Such postures reduce the exposed body surface for heat radiation.

2. **Generating more body heat :** The metabolic rate is increased and more heat is produced in the body cells. The muscular activity is also increased which is sometimes in the form of shivering.

B. Keeping cool in hot weather (Fig. 18.1b)

When the outside temperature is high or when a person is engaged in strenuous physical work there is overproduction of heat within the body. The extra heat is given out in two principal ways.

1. **Increased heat radiation from the body**. This is brought about by increasing the blood supply to the skin through vasodilation (widening of the blood vessels). The increased blood flow into the skin allows more heat to reach the body surface and radiate out heat. (Fig. 18.1b).
2. **Increased sweating.** Increased blood supply to the skin through vasodilation makes more water available to the sweat glands. They pour out more sweat and the evaporation of sweat cools the body. We often speed up evaporation of sweat by using fans. The fans by themselves do not cool the air, it is the movement of air that increases evaporation of the sweat to produce more cooling.

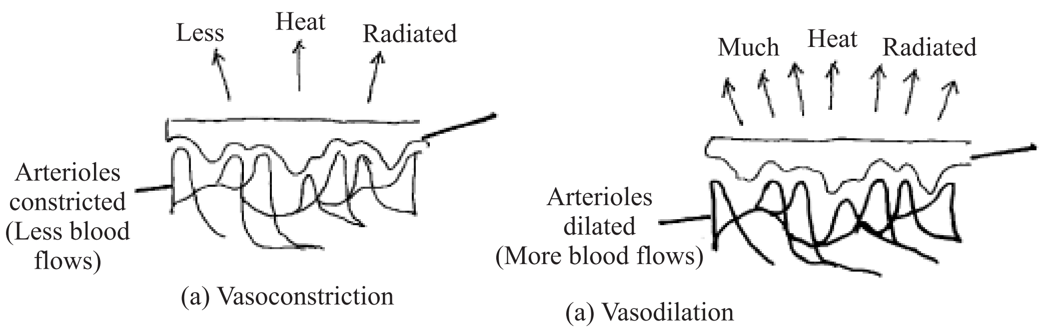


Fig 18.1 Blood vessels in the skin during temperature regulation.
(a) Vasoconstriction for cutting down heat loss
(b) Vasodilation to increase heat loss

18.4.3 Components of Homeostasis

Homeostasis of any kind involves four components:

1. **Set point or the norm** - This is the normal level of any factor in the body. The set point may have a small or large range. For example, the normal set point of human body temperature is approximately 37° C (with 0.5° C plus or minus).
2. **Sensor -** This consists of the sensory part that perceives the change in the set point. The sensor in thermoregulation comprises the heat receptors in (i) the skin and (ii) hypothalamus, the part of the brain which perceives the temperature of the flowing blood.
3. **Integrating centre -** The integrating centre is the part, which receives the information about the change in the set point of the particular state, interprets it and then sends the command for correction. In thermoregulation the integrating centre is hypothalamus plus some adjoining parts of the brain.
4. **Effectors -** The effectors are the agencies, which act to restore the set point. For example, (i) ***Sweat glands***, which pour out the sweat to produce cold by evaporation, (ii) ***Skin blood vessels***, which widen (vasodilate) to bring more blood to the body surface for radiating out heat and (iii) ***Skeletal muscles***, which vigorously contract (shivering) to produce heat

The flow chart given here (Fig.18.2) explains the different steps in thermoregulation in humans.

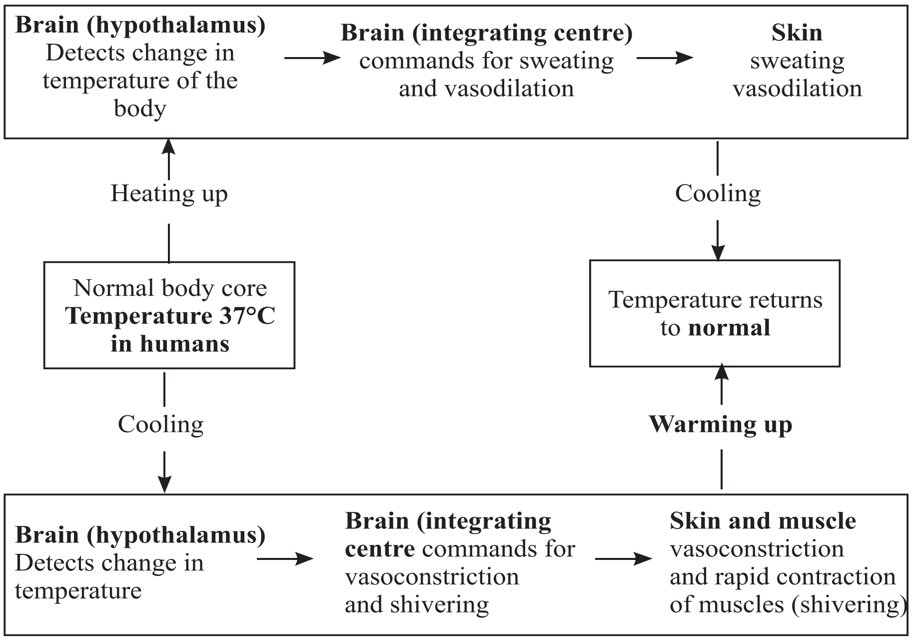


Fig 18.2 Mechanism of temperature control in humans

18.4.4 Types of Regulatory Systems– Physiological and Behavioral

The regulatory steps for thermoregulation in humans as described above can be considered under two headings – **physiological** and **behavioral.**

Physiological regulation : Changes in blood circulation like vasodilation or vasoconstriction, sweating or not sweating, increase or decrease in cell metabolism, shivering, etc. All these adjustments are not under the control of will.

Behavioral regulation. It includes the conscious and subconscious acts. For example:

When it is hot we often

- Fan ourselves (to promote evaporation of sweat)
- Move to any shaded or cooler place,
- Stretch out the limbs while resting in the bed.

When it is cold we

- move to warmer places (open sunshine or in front of heat radiators)
- prevent entry of cold winds (close the windows)
- wrap ourselves inside blanket (to cut down heat radiation)
- fold both arms or both arms and legs tightly close to the body (to reduce radiation of heat from the body).

INTEXT QUESTIONS 18.4

1. Rearrange the following in their correct sequence in homeostasis:

   Effector, Set point, Integrating centre, Sensor.

   ....

2. State in one word or sentence :

   (i) The normal body core temperature of humans.

   ....

   (ii) The function of feathers in bird and the hairs of rabbit.

   ....

   (iii) Effect of shivering.

   ....

18.5 FEEDBACK MECHANISMS–NEGATIVE AND POSITIVE

The feedback in the living systems are of two types: negative to reverse a condition and positive to continue in the direction of the change.

In thermoregulation the kind of feedback mechanism operating is of the negative type. Any **deviation from the set point has to be reversed** to bring it back to the normal condition. Therefore, a command has to be given to the organs concerned to function in a manner so that the deviation is corrected and brought back to the normal state.

Positive feedback is very rare in the living systems. One such example is that of coagulation of blood. This process includes several steps in succession. The first feedback does not revive the set point, so it is not a negative feedback, instead it produces the next and the third and so on until the last one completes the process by plugging the cut in the blood vessel. All the feedback mechanisms in blood coagulation are of the positive type.

INTEXT QUESTIONS 18.5

1. Name the two kinds of feed back mechanisms.

   ....

2. Which kind of feed back mechanism normally operates in homeostasis?

   ....

WHAT YOU HAVE LEARNT

- The term homeostasis means steady state. The homeostatic processes keep the conditions in the body within narrow limits.
- Homeostasis occurs for several conditions in the body such as water content, sugar level, body temperature, etc.
- Most homeostatic regulations work through negative feed back which means reversing the change to the norm. Very seldom there is positive feedback which produces changes in the same direction as the first one.
- Enzymes are highly sensitive to temperature changes. They work best at about 37°C called optimum temperature.
- The animals are categorized into two groups: Endotherms with internal heat-regulating mechanisms such as birds and mammals, and ectotherms whose body temperature rises or falls with that of the surroundings, such as frogs, fishes, insects, etc.
- The endotherms have a variety of heat regulating systems such as sweating and vasodilation to lose heat during hot weather, increasing body metabolism or shivering to generate heat and presence of heat insulating structures like feathers, hairs and subcutaneous fat when it is cold.
- The ectotherms avoid excessive cold or excessive heat by hiding underground – hibernation(winter sleep) and aestivation (summer sleep)
- All homeostatic mechanisms consist of a norm or set point, a sensor, an integrating centre and the effectors.
- In thermoregulation in humans, the sense receptors in skin and hypothalamus serve as sensor, hypothalamus and some adjoining parts of the brain as integrating centre, and the skin, blood vessels contained in the skin and skeletal muscles etc serve as effectors.

TERMINAL EXERCISES

1. List the three conditions necessary for the body cells to function properly.
2. When do we pass out more concentrated urine–during hot summers or cold winters ?
3. How does our body deal with any extra sugar absorbed into the blood after meals?
4. What is our normal RBC count per cubic millimetre? Will it go up or go down if a plain dweller shifts to a mountain or hill?

5. In which temperature range do the enzymes in our body act best?
6. Name the two terms often used synonymously for ectotherms.
7. Name any two animals, which tolerate the intense heat of the deserts by promoting heat loss.
8. Which kind of feedback mechanism–the positive or the negative, normally operates in bringing about water-salt balance in our body.
9. How is the enzymatic activity affected upon cooling?
10. How do honeybees fight cold during intense winter?
11. Differentiate between the two terms homeotherms and poikilotherms.
12. Give any two examples of preventing loss of body heat by postural behaviour in humans.
13. List the components of homeostasis in their proper sequence.
14. Differentiate between positive and negative feedback mechanism.
15. Explain the role of the following in thermoregulation in humans:
    (i) Sweat glands
    (ii) Skeletal muscles
    (iii) Blood vessels in the skin
16. What is meant by feed back mechanism? What are its two types? Which one of these is applicable to thermoregulation and why?
17. Why is thermoregulation required in our body?
18. Differentiate between endotherms and ectotherms. Which ones of these do you think can survive better if there is a suden change in environmental temperature?
19. Differentiate between physiological and behavioral responses for thermoregulation in humans.
20. Explain the role of hypothalamus during heat regulation in humans.
21. Explain the relationship between sensor and integrating centre during any one kind of homeostasis.

ANSWERS TO INTEXT QUESTIONS

18.1 1. Homeostasis is the regulation of a steady internal condition.

2. (i) sugar, (ii) salt, (iii) water

3. The body adds more RBCs to the blood

18.2 1. (i) Denatured (ii) inactive

2. (i) 35-40°C, (ii) Optimum temperature

18.3 1. Endotherms : Camel, Bat, Polar bear, sparrow

Ectotherms : Earthworm, Cockroach, Fish, Wall lizard

2. Poikilotherms : Animals whose body temperature changes along with that of the surroundings

Warm blooded : Animals whose body temperature remains steady and does not change with that of the surroundings

3. **Crocodile :** Basks in the sun on the land

Honey bees : Crowd together for collective warmth

Common frog : Hibernates

Wall lizard : Hides at safe places

18.4 1. Set point, Sensor, Integrating centre, Effectors

2. (i) 37°C (ii) trap air to prevent heat loss

(iii) warms up in cold weather

18.5 1. Negative and positive

2. Negative.

GLOSSARY

LESSON 1 TO 18

Absorption spectrum	:	A graphic representation of the relative absorbance of different wavelengths of light by a given pigment in solution.
Absorption (Animal)	:	Gradual taking in of digested food and nutrients from the gut by the cells for assimilation by the body tissues.
Actinomorphic	:	An organ or organism showing radial symmetry, such as a flower, fruit can be divided into two equal halves through any radius.
Action spectrum	:	A graphical representation of activity of different wavelengths of light absorbed by photosynthetic pigment in terms of evolution of O_2 or consumption of CO_2 during the process of photosynthesis.
Adhesion	:	Force of attraction or attachment between dissimilar molecules, or dissimilar organs e.g. stamens and carpels.
Adventitious root	:	Roots that develop from any part of the plant except the radicle.
Aerobic respiration	:	Biological oxidation of food in the living cells in the presence of oxygen.
Agglutination	:	Is the process by which red blood cells clump together when the antigens on their surface react with complementary antibodies.
Alternation of generations	:	The alternation of two distinct gametophytic and sporophytic phases in regular succession during life cycle of an individual.
Amino acid	:	A biomolecule with an amino group, carboxyl group, Hydrogen and any organic group e.g. CH_3; it acts as the basic unit of proteins representing one or more polypeptides.
Anaerobic respiration	:	Partial biological oxidation of food in living cells in the absence of oxygen.
Antibody	:	Specific proteins produced for body's defence in response to antigen (any foreign agent) in a living cell.
Antitranspirants	:	The chemicals that reduce transpiration without affecting the CO_2 uptake and oxygen evolution by a green plant.
Antidiuretic hormone (ADH)	:	Hormone released by the neurohypophysis of the pituitary which influences, the kidney and promotes the conservation of body water.
Antigen	:	Any foreign substance capable of generating antibodies in living cells to help in the immune system, of the concerned organism.

Apical meristem	: Group of cells which divide actively to produce primary plant body and are present at the tip of root and shoot.
Assimilatory roots	: Roots when exposed to sun develop chlorophyll, turn green and manufacture food by photosynthesis.
Assimilation	: Utilization of digested food nutrients by the body tissues.
ATP	: Adenosine Tri-phophate unit of bio-chemical energy that can be utilized, readily in living cells. It is also called "energy currency" of the cells.
Antheridia	: Multicellular and jacketed male sex organs in Bryophytes and Pteridophytes which produce antherozoids by mitosis.
Autonomous nervous system	: Self governing or involuntary nervous system supplying most visceral organs.
Autotrophs	: Organisms (Green plants and chemosynthetic bacteria) which synthesize their organic requirements (food) from inorganic substance.
Blood pressure	: Pressure exerted by flow of the blood in the arteries on their elastic wall is called blood pressure.
Bulliform cells	: Special large thin-walled cells on the upper surface of monocot leaves, that help in reducing loss of water through transpiration.
Capillary water	: The water held in the capillary like spaces between the soil particles.
Casparian strips	: A band like thickening of lignin and suberin typical of endodermal cells, named after R. Caspary, who first investigated them.
Chemosynthesis	: The process of synthesis of organic food by some bacteria by using inorganic compounds without the use of light.
Chlorosis	: The yellowing of leaves because of disease either due to infection or due to mineral deficiency.
Circulation	: The work of transportation of nutrients, gases, wastes or other substances from one part of our body to the other part carried out by blood.
Clumping	: Is a condition where the antibodies present in the plasma of recipient cause agglutination of donor's blood cells.
Coacervate	: Cell-like aggregates of molecules.
Coenzyme	: A non protein, often complex organic molecule which is temporarily bound to an enzyme and acts as a link between metabolic pathways to catalyse a given chemical reaction eg. NAD, FAD.
Cohesion	: Force of attraction between similar molecules or organs.
Collateral vascular bundle	: Occurrence of xylem and phloem on the same radius where phloem is towards the periphery, and xylem towards the centre.
Complete flower	: Flower possessing all four whorls i.e. calyx, corolla, androecium and gynoecium.

Conjoint	:	Occurrence of xylem and phloem together in one vascular bundle
Descending	:	Growing downwards or arranging some things in such a way that the largest is placed first and smallest is placed the last.
Dialysis	:	Separation of colloids from small molecules and ions by their inability to pass through semipermeable membranes. The process is used in removing nitrogenous wastes (Urea etc.) from the blood when the kidney fails to work normally.
Diaphragm	:	A muscular sheet separating abdominal cavity from the thoracic cavity.
Diffusion pressure	:	An older term for water potential. Has a positive value.
Diffusion	:	Movement of molecules from their region of higher concentration to their region of lower concentration.
Digestion	:	Conversion of complex food into a simpler absorbable form
Ectotherms	:	Are those animals whose body temperature rises and falls with the changes in surrounding temperature.
Effectors	:	Muscles or glands, which on receiving the impulse from the B brain or spinal cord contract or secrete substances.
Egestion	:	Removal of undigested and unabsorbed roughage with waste food from the body.
Endodermis	:	Innermost layer of cortex surrounding the vascular region and characterized by the presence of casparian strips.
Endotherms	:	Are the organisms which maintain a steady body temperature irrespective of the changes in temperature of the surroundings.
Epiblema	:	Outer most layer of root
Epinephrine	:	Is the hormone of adrenal medulla.
Epiphytic roots	:	Aerial roots of epiphytes covered with velamen with which they absorb atmospheric moisture.
Essential elements	:	Are those minerals or nutrients which are essential for the healthy growth of the plants.
Eukaryote	:	Organisms possessing true nucleus in its cell, along with membrane bound organelles.
Evolution	:	Gradual formation of complex organisms from simpler ones.
Exarch xylem	:	Xylem strands in which maturation of cells progresses centripetally i.e. the first formed xylem elements (protoxylem) are produced away from centre.
Exarch	:	Xylem bundle having protoxylem towards the outside and metaxylem towards the centre.

Excretion	:	Elimination by an organism of the waste products of metabolism, chiefly water, carbon dioxide and nitrogenous compounds (Urea, Uric acid etc.)
Expiration	:	The process of forcing air out.
External respiration	:	Involves gaseous exchange between the external environment and the body of the organism.
FAD	:	Flavin Adenine Dinucleotide.
Ganglion	:	A mass of nerve cell bodies
Glucagon	:	A hormone secreted by the alpha-cells of islets of Langerhans in pancreas which regulates the sugar level in the blood.
Gravitational water	:	The rain water that passes down the soil to reach the water table.
Gray matter	:	Regions of brain and spinal cord that appear grey and are consisting chiefly of cell bodies of neurons.
Guttation	:	The exuding of excess of water in the form of liquid having dissolved salts from the tips of leaves in certain plants (supposed to be due to root pressure)
Haemophilia	:	A genetic disease that results in a condition where blood fails to clot.
Heterophylly	:	Plants possessing more than one type of leaves.
Heterotrophic	:	Mode of nutrition in which organisms derive their organic food from other plants and animals or decaying matter.
Heteterotrophs	:	Organisms which can not prepare their own food and desive it from other sources like plants, animals or decaying matter.
Homeostasis	:	Is a phenomenon in which the body of a living organism regulates its biological processes to keep the internal conditions as stable as possible.
Homoeotherms	:	Refers to organisms which keep the same or constant (warm) body temperature.
Hormone	:	A chemical substance produced by the endocrine organs which influences the growth, development and function of some other parts of the body. It is effective in small quantity.
Hygroscopic water	:	The water held tightly as a thin film around the soil particles due to forces of adhesion between water and soil particles.
Imbibition	:	Adsorption of water by cell wall constituents both by diffusion and capillary action.
Immunity	:	The body's ability to resist or protect itself from the harmful effects of disease producing substance or organisms.
Impulse	:	A wave of electrical disturbance that travels across the nerve cell and its fibre.

Ingestion	:	Taking in of the food, by chewing or sucking and swallowing
Inspiration	:	The process of taking air into the body
Internal respiration	:	Enzymatic breakdown of food and release of energy. Since it occurs within the cell, it is also known as cellular respiration.
Isotonic	:	Solutions with same concentration of water and solutes as inside a cell.
Leghemoglobin	:	The pigment protein present in legumes, which acts as a scavenger of oxygen.
Melanin	:	Black or brown pigment giving colour to animal skin, and also present in resting spores in algae and fungi.
Metaxylem	:	Part of primary xylem which undergoes differentiation after the formation of protoxylem.
Mineral nutrition	:	The process of how plants get mineral elements and utilize them for their growth and development is called mineral nutrition.
Molecular nitrogen	:	The dinitrogen with triple bonding present in atmospheric air.
Monoadelphous	:	Condition in a flower where all the stamens are joined by their filaments in one bundle.
Monocots	:	Group of angiosperms with one cotyledon in their embryo.
Mutation	:	A sudden inheritable change in the structure content and organization of genetic material.
Mycelium	:	A group of hyphae of fungi.
Nacked seed	:	Seed not enclosed in ovary wall.
NADH	:	Reduced Nicotinamide Adenine Dinucleotide.
NADPH	:	Reduced Nicotinamide Adenine Dinucleotide Phosphate.
Necrosis	:	Death of chlorotic tissue followed by brown colouration in leaves and stems of a diseased plant.
Nerve	:	A bundle of nerve fibres connecting central nervous system with other parts of the body.
Nitrate reductase	:	The enzyme that catalyzes nitrate to nitrite.
Nitrite reductase	:	The enzyme that catalyzes nitrite to ammonia.
Nitrogenase	:	The enzyme that catalyzes reduction of N_2 to ammonia.
Nodules	:	The morphological structures formed due to interaction of Rhizobium and legume roots, where N_2 is reduced to ammonia in the presence of a pigment called leghemoglobin.
Nutrition	:	The process of acquiring, digesting and utilizing food substances in the body.

Osmosis	:	Movement of water molecules from a region of their high concentration to a region of their lower concentration through a semi permeable membrane.
Osmotic potential	:	A term now more commonly used in place of osmotic pressure. It is given a negative sign.
Osmotic pressure	:	It is the pressure a solution would generate if allowed to come to equilibrium with pure water, separated by semipermeable membrane.
Pacemaker	:	An artificial device attached to heart for the regulation of abnormal heart beat. It is needed by people who have defective sinu-auricular node (S.A node)
Paleontology	:	Study of fossils
Parathormone	:	Hormone produced by parathyroid gland which regulates the calcium and phosphorus metabolism in animal body.
Passage cells	:	Thin walled cells of endodermis which permit passage of water having dissolved salts from cortex of root to xylem elements in the stele.
Periblem	:	The part of the apical meristem that gives rise to the cortex.
Pericycle	:	The outer most zone of cells of the stele immediately inner to the endodermis, it is responsible for giving rise to lateral roots; and parts of vascular cambium responsible for production of secondary vascular tissues during secondary growth of dicot roots.
Pinocytosis	:	Folding in of membrane for intake of fluid droplets, containing food nutrients.
Phagocytosis	:	Folding out of membranes for intake of solid food particles.
Phellogen (cork cambium)	:	A lateral meristem which produces cork towards outside and phelloderm or secondary cortex towards inside.
Phellem (cork)	:	A protective tissue, formed by the activity of cork cambium, composed of non-living suberized cells.
Phelloderm	:	The secondary cortex formed on the inner side of cork cambium.
Phellogem	:	Cork cambium giving rise to cork and secondary cortex.
Pheromones	:	Are chemical substances secreted by organisms that trigger behavioral or developmental process when perceived by other members of the same species.
Photorespiration	:	Respiration that is initiated in chloroplasts in presence of light only, and there is no production of any ATP.
Photosynthesis	:	Synthesis of glucose by green plants in the presence of sun light, water and CO_2
Phyllotaxy	:	Arrangement of leaves on stem or its branches.
Pneumatophores	:	Conical roots of mangroves in marshy plants, which are –vely geotropic

Poikilotherms	:	Are those animals whose body temperature can not be regulated but varies according to environmental temperature.
Progesterone	:	Female sex hormone secreted by the corpus luteum and placenta and is responsible for proliferative changes in endometrium and breasts.
Protoxylem	:	The first formed elements of the primary xylem.
Quiescent zone	:	A central group of inactive cells in the root apex just below the root cap.
Radial vascular bundle	:	Vascular bundles which are represented by patches of phloem and xylem on different radii, as in roots.
Reaction centre	:	Groups of 250-300 chlorophyll molecules present in the grana of chloroplasts that trap solar energy and converts into chemical energy.
Receptors	:	The nerve cells which on receiving the stimulus, set up wave of impulse towards the central nervous system (brain and spinal cord).
Respiration	:	Is stepwise biological oxidation of glucose which results in production of energy stored in the form of ATP. Whenever energy is required by our body. ATP is broken down and large amount of energy is released.
Respiratory chain	:	A series of transfer of hydrogen or electron through carriers which are finally accepted by oxygen, present in the inner membrane of the mitochondria. They are associated with the final step of aerobic respiration, and result in the formation of ATP, finally forming water at the last step.
Response	:	A change in the activity of the organism caused due to internal or external stimulus.
Root pressure	:	The pressure that develops in a root as a result of active process and brings about the pushing up of xylem sap towards higher branches of the stem.
Respiratory quotient (RQ)	:	It is the ratio of the volume of CO_2 evolved to the volume of O_2 consumed in aerobic respiration.
Rubisco	:	An enzyme called ribulose bisphosphate carboxylase.
RUBP	:	A 5-carbon molecule, ribulose- 1, 5-biphosphate which acts as CO_2-acceptor in Calvin Cycle.
Svedberg Unit	:	Coefficient of sedimentation of different cell organelles during centrifugation.
Saprophytic	:	Plants which derive their nutrition from dead organisms.
Semiautonomous	:	Incapable of independent existence but can self duplicate in their in vivo system.
Speciation	:	Evolution of new species.
Spermatophytes	:	Group of plants producing seeds, e.g. angiosperms and gymnosperms.
Stimulus	:	An agent or sudden change of the external or the internal environment that results in a change in the activities of the organisms.

Symbiotic	:	A long lasting close relationship between two different types of living organisms in which both are benefitted from each other.
Syncarpous	:	A condition where two or more carpels are fused.
Synovial fluid	:	Fluid contained in the joint cavity serving to lubricate the joints in the animals.
TCA cycle	:	Tri-carboxilic acid cycle also known as Krebs cycle or citric acid cycle. Aerobic pathway occurring within mitochondria, in which food metabolites are oxidised and CO_2 is liberated, and coenymes (NAD and FAD) are reduced.
Thyroxine	:	Hormone secreted by thyroid gland.
Tracheophyta	:	Plant groups which possess vascular tissue, consisting of tracheids and vessels.
Transaminases	:	The enzymes that transfer amino group from one amino acid to an organic acid.
Transcription	:	Synthesis of complementary RNA on a DNA template.
Translation	:	Synthesis of a polypeptide on the basis of information on mRNA.
Translocation	:	Movement of organic and inorganic solutes from one part of the plant to another.
Transpiration	:	The loss of water in the form of water vapour from all the aerial parts of the plants.
Turgor pressure	:	Hydrostatic pressure developed by the fluid in a turgid plant cell. It is the pressure exerted by the protoplasm against the cell wall.
Universal donor	:	A person who can safely donate blood to all the persons having any other blood group without causing any reactions. A person with blood group O and Rh –ve factor.
Universal recipient	:	A person capable of receiving any of the blood groups A, B, AB and O. A person with blood group AB.
Vasoconstruction	:	Narrowing of blood vessels.
Vestigial organ	:	A small degenerate or imperfectly non functional organ which may have been functional in ancestors.
Wall pressure	:	Backpressure exerted by the cell wall in a turgid plant cell. It is equal and opposite to turgor pressure.
Water potential	:	It is the capacity of a solution to give out water wherein highest value is represented by the pure water, and it is equal to zero.
White matter	:	Regions of brain and spinal cord that appear white consisting chiefly of nerve fibres.
Zygomorphic	:	Showing bilateral symmetry of flowers, wherein the flower can be divided into two equal halves only through one radius.

Awards Won by NIOS


web ratna awards 2012
Platinum Icon
Outstanding Content
is hereby conferred upon
'National Institute of Open Schooling'
Project Team:
Dr. S.S. Jena
U.N. Khaware, C. Dharuman, Dr. Kuldeep Agarwal
Dr. Sanyam Bhardwaj, Dr. K.P. Wasnik, S.K. Prasad, Pramod Tripathi
on 10 th of December 2012 at New Delhi
Dr. Y.K. SHARMA
Director General
National Informatics Centre
J. SATYANARAYANA
Secretary
Dept. of Electronics & Information Technology
india.gov.in
INITIATIVE

Web Ratna Awards 2012 Platinum Icon under Outstanding Web Content for Acknowledging exemplary initiatives/practices in the realm of e-Governance for dissemination of information & services instituted by Department of Information Technology, Ministry of Communications & IT (MC&IT) and National Informatic Centre (NIC), Government of India. The award has been conferred by Hon'ble Minister of Communications and Information Technology Shri Kapil Sibal on 10th December 2012 at Dr. D.S Kothari Auditorium, DRDO Bhawan, Dalhousie Road, New Delhi.

TOI Social Impact Award 2012

NIOS has been selected as winner of the Social Impact Award 2012 instituted by Times of India in partnership with J P Morgan The Award is given in the recognition of magnificent work done by an individual or groups or institutions making an impact in the society in various segment including Education. NIOS feels honoured to accept the award.

The award was conferred on 28th January 2013 at a function in presence of President of India and high level dignitaries.

National Awards for the Empowerment of Persons with Disabilities, 2012

The NIOS received the National Award for the Empowerment of persons with disabilities, 2012 Instituted by Ministry Social Justice and Empowerment, Govt. of India. The NIOS got this award under the category of best accessible Website for making its website www.nios.ac.in completely accessible for person with disabilities. The website is bilingual in Hindi and English. It also has provisions of Screen Reader, increasing text size, colour contrast scheme etc. for disabled learners. This award was conferred by the Hon'ble President of India at Vigyan Bhawan, New Delhi on 6th February, 2013. Dr. S.S. Jena Chairman, NIOS received the award.

CURRICULUM OF SENIOR SECONDARY COURSE IN BIOLOGY (314)

RATIONALE

Biology arose in a twofold manner - firstly, as a practicing art towards exploring and improving a variety of usable plant and animal products as well as towards maintaining good health; secondly, as an academic pursuit out of curiosity to know about humans and other living beings and to understand their position on the planet Earth. In other words, the storehouse of knowledge about living beings started building up only when humans were curious to know about life. The course in Biology helps us to respect and appreciate the great diversity of life at all its levels of organization and to understand the impact of progress in biology on our life style.

Biology is not merely a correlational science but also an experimental discipline, which deals with different tools and techniques. In most of the activities that we perform, biology has a role to play. Therefore, the present course aims at imparting biological knowledge vis-a-vis the ever growing human needs. Besides integrating the content and adequate depth into the subject recent advancements in concepts as well as emerging areas like biotechnology and immunology have also been introduced.

OBJECTIVES

The course would enable the learner to,

- acquire knowledge of biological terms, facts, concepts, principles and processes in order to understand the living world as a whole;
- appreciate diversity in the living world as also the interrelationships of various living organisms, ecological balance in nature, and the role of biology in human welfare;
- visualize the hazards of environmental pollution, and to create awareness for sustainable use of natural resources in the service of humankind;
- develop insight into the role and impact of Biology in various allied areas such as medicine, agriculture, forestry, biotechnology, veterinary sciences and pharmacology etc.;
- develop interest in the living world with an aim to respect life.

As a part of this process, the curriculum also aims at developing the following abilities in the learners such as to –

- apply knowledge and understanding of biology in situations which are novel and unfamiliar by developing abilities to analyze, hypothesize, extrapolate draw conclusions and predict results;
- develop skills in handling and improvising scientific apparatus, and recording observations and data;
- inculcate scientific attitude and practice it in day to day life.

COURSE STRUCTURE

The present curriculum contains 5 modules. These modules are compulsory for all learners, thus, each learner studies five modules in all. Each module has been divided further into units and then into lessons. The number of lessons, suggested study time and marks allotted for each unit are as follows:

Unit wise Distribution of Core Modules	Marks	Minimum Study Time (hours)
Module 1 : Diversity and Evolution of Life	12	50
Module 2: Forms and Functions of Plants and Animals	26	70
Module 3: Reproduction and Heredity	22	60
Module 4: Environment and Health	13	50
Module 5: Emerging Areas in Biology	7	10
	80	**240 hrs**

COURSE DESCRIPTION

Introduction to Biology (Non-Evaluative)

Biology and its branches, relationship with other sciences, scientific methodology, historical breakthroughs, recent advancements and careers in biology.

Module 1 Diversity and Evolution of Life

Time: 50 hr **Marks : 12**

Approach

This module would enable the learner to visualize the origin of life on earth and the vast diversity in the living world, and also to group them together at various classification levels. It also intends to stimulate our learner to understand the concepts and theories of evolution. The module also highlights the cell as the basic unit of life and its organization into various forms of tissues.

Unit 1 Evolution and Classification of Organisms

Time: 30 hr **Marks: 8**

1.1.1 Origin and Evolution of Life and Introduction to Classification

Characteristics of life, origin of life, spontaneous generation, Oparin-Haldane theory, Stanley Miller's experiment, organic evolution, evidence of evolution, sources of variation, natural selection, isolation and speciation. Hardy-Weinberg Equilibrium

Need for classification of organisms, principles of classification and taxonomic categories, Linnaeus and binomial nomenclature, position of virus, characteristics, structure and habit of virus, infective properties of viruses (general account of TMV, Polio, HIV, Influenza virus, Bacteriaphage) Viroids.

Scheme of five kingdom classification, merits and demerits of five-kingdom classification.

1.1.2 Kingdoms Monera, Protoctista and Fungi

Kingdom Monera - General structure and characteristics of bacteria and cyanobacteria with examples.

Kingdom Protoctista - General structure and characteristics of protozoa and algae with common examples.

Kingdom Fungi - General characteristics of fungi with common examples.

1.1.3 Kingdoms Plantae and Animalia

Classification and characteristics of Plantae up to division - Algae, Bryophyta, Pteridophyta, Spermatophyta, classification of Spermatophyta upto classes - Gymnospermae and Angiospermae, Dicotyledonae (Malvaceae and Fabaceae) and Monocotyledonae (Poaceae and Liliaceae).

Classification and characteristics of Kingdom Animalia upto phyla - Porifera, Cnidaria, Platyhelminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata, Hemichordata, Chordata, Classification of Arthropoda and Chordata upto classes, class Mammalia upto major orders.

Unit 2. Cell and Tissues

Times 20 hr **Marks: 4**

1.2.1 Cell - the basic unit of life

Cell - Cell theory, prokaryotic and eukaryotic cells, animal and plant cells.

Cell organization - plasma membrane, cell wall, cytoskeleton, endoplasmic reticulum, cilia and flagella, nucleus, ribosomes, mitochondria, chloroplasts, golgi bodies, centrosome, peroxisomes, cell inclusions.

Cell molecules - water, mineral ions, carbohydrates, lipids, amino acids, proteins, nucleotides, nucleic acids, enzymes, vitamins, hormones, steroids and alkaloids.

Cell cycle - significance of mitosis and meiosis, karyotype analysis.

1.2.2 Tissues

Plant Tissues - classification, structure and functions of meristematic and differentiated tissues.

Animal tissues - structure and functions of epithelial, connective, muscular and nervous tissues.

Module 2 Form and Functions of Plants and Animals

Time : 70 hr **Marks : 26**

Approach

This module highlights the complex nature of the structure and function of the different organ systems in plants and animals with special emphasis on the life processes.

Unit 1. Plants - Morphology and Physiology

Time : 35 hr **Marks: 12**

2.1.1 Root System

Characteristics and regions of root, primary structure of dicot and monocot roots, secondary growth in dicot roots, types and modifications of roots, common functions of roots.

2.1.2 Shoot System

Characteristics of stem, structure of monocot and dicot stems, difference between dicot and monocot stem, secondary growth in stem: wood, origin of lateral branches, types and modification of stem, functions of stem.

Structure and modifications of leaf, internal structure of a typical dicot and monocot leaf, stomata, hair and hydathodes, phyllotaxy.

Flower - Parts of flower, arrangement of various floral parts, placentation, inflorescence, major types of inflorescence.

Fruit - Definition, structure, major categories, edible parts of common fruits.

2.1.3 Absorption, Transport and Water Loss

Water relation - permeability, diffusion, osmosis, plasmolysis, active and passive absorption and movement, imbibition, water potential, Transpiration - The process and its significance, factors affecting rate of transpiration, opening and closing mechanism of stomata (potassium ion theory), factors affecting stomatal movements, guttation and factors affecting rate of guttation, translocation of solutes.

2.1.4 Plant Nutrition

Mineral nutrition, functions of minerals (aeroponics and hydroponics), macro and micro nutrients, deficiency symptoms of elements, mode of nutrition in plants - autotrophic, heterotrophic, saprophytic, parasitic and insectivorous plants.

2.1.5 Nitrogen Metabolism

Molecular nitrogen, nitrogen fixation (biological and abiological both), nitrogen fixation by free living organisms and symbiotic nitrogen fixation, nitrate and ammonia assimilation by plants, amino acid synthesis by plants. Nitrogen cycle

2.1.6 Photosynthesis

The process and its significance, site of photosynthesis (functional aspect of chloroplast structure), photosynthetic pigments photo-chemical aspects of photosynthesis, photo-phosphorylation (cyclic and non-cyclic), C3 and C4 pathways, factors affecting photosynthesis, chemosynthesis, Chemiosmotic synthesis.

2.1.6 Respiration

Aerobic and anaerobic respiration, respiratory quotient, glycolysis, Krebs cycle, pentose phosphate pathway, factors affecting respiration (excluding biochemical pathways), fermentation, photorespiration, Amphibolic Pathway.

Unit 2. Animals -Morphology and Physiology

Time: 35 hr **Marks: 14**

2.2.1 Nutrition and Digestion

Nutrition and its types, digestive system of invertebrate (Cockroach), digestive system and process in humans (ingestion, digestion, absorption, assimilation, egestion), intracellular and intercellular digestion, role of enzymes and hormones in digestion.

Some of the digestive disorders are vomiting, diarrhoea, constipation, Indigestion and jaundice

2.2.2 Locomotion and Movement

Movement and Locomotion, types of movements for locomotion, flagellar movement. Muscular movement in animals structure of muscle, myofilaments, the sliding of muscle contractions, stimulation of muscle contraction.

2.2.3 Respiration and Nitrogenous Waste Elimination

Respiratory organs of humans, mechanism of breathing and its regulation, gaseous transport through blood and tissue respiration, gaseous exchange in animals (earthworm/cockroach), common respiratory disorders - prevention and cure.

Ammnotelism, ureotelism, uricotelism, urinary system in cockroach and humans, finer structure of mammalian kidney, ultrafiltration and urine formation, role of kidney in osmoregulation, kidney failure, dialysis, kidney transplantation, role of Antidiuretic Hormones (ADH), role of liver in excretion.Emphysema, Renin-angiotensin and Atrial Antinatriuretic factor.

2.2.4 Circulation of Body Fluids

Types of blood circulation, open circulatory system in cockroach, circulatory organs in humans, blood circulation, histology and functions of blood, blood coagulation, blood transfusion, blood groups, blood pressure, lymph and lymph glands, spleen, immune system (basic idea of immunocytes and immunity), blood related disorders - hypertension, atheroma and arteriosclerosis, ECG, pacemaker.

2.2.5 Coordination and Control

Central and Peripheral Nervous System in humans, structure and function of brain and spinal cord, transmission of nerve impulse, reflex action, sensory receptors, sense organs - structure and functions.

Endocrine glands, nature and role of hormones, an elementary knowledge of pheromones, hormonal imbalance and diseases, role of hormones as messengers and regulators - hypothalamo-hypophyseal axis, feed-back mechanism.

The skeletal system, types of skeleton, human skeleton muscular and skeletal disorders, movement in plants

Nervous system in animals, central nervous system peripheral nervous system sympathetic nervous system

2.2.6 Homeostasis

Concept, regulation of body fluids, feedback mechanism - positive and negative, thermoregulation including skin.

Module 3: Reproduction and Heredity

Time : 60 hr **Marks: 22**

Approach

This module is designed to highlight the diverse methods of reproduction in living beings from unicellular organisms to complex forms including humans. This module highlights the increase in human population all over the world and also provides adequate information about the methods of family planning and birth control. The principles and mechanisms of heredity in determining the characteristics of organism has also been discussed in this module.

Unit 1. Reproduction, Growth and Development

Time : 30 hr **Marks: 12**

3.1.1 Reproduction in Plants

Vegetative, asexual and sexual reproduction in lower plants (general account), Apomixis reproduction in flowering plants - juvenility, flowering, factor affecting flowering (photoperiodism), flower as a reproductive organ, development of gametes in flowering plants, polyembryony pollination - types and agencies, adaptation to promote cross pollination, fertilization and seed formation, seed - structure of dicot and monocot seeds, seed germination, parthenocarpy.

Natural and artificial vegetative propagation, advantages and disadvantages of vegetative propagation, micropropagation, advantages of micropropagation.

3.1.2 Growth and Development in Plants

Definition of growth and development, growth curve, growth regulators (phytohormones) -

Auxins, gibberellins, cytokinins, ethylene, abscissic acid; seed germination - mechanism and factors affecting germination, role of growth regulators in seed dormancy, vernalisation, senescence, abscission, stress factors (salt and water), measurement of growth, plant movements - geotropism, phototropism, turgor growth movements (tropic, nastic and turgor), phytohormones and their role in plant development. Differentiation, dedifferentiation

3.1.3 Reproduction in Humans and Population Management

Female and male reproductive organs, histology of gonads, gametogenesis, fertilization, cleavage, blastulation, gastrulation, fate of germ layer (general account only), embryonic development and nutrition, childbirth, twins, growth, ageing and senescence, death, in-vitro fertilization.

Demography - birth rate, death rate and population growth rate, position of India in world population, consequences of overpopulation management of population growth, methods of contraception. Lactation, gemmule, Reproductive system of insects, male reproductive system, female reproductive system

Unit 2. Principles and Applications of Genetics

Time: 30 hr **Marks:10**

3.2.1 Principles of Genetics

Heredity and variation, Mendel's laws of inheritance, incomplete dominance, lethal genes, pleiotropic genes, polygenic inheritance with examples, chromosomal basis of inheritance, linkage and crossing over, cris-cross inheritance, maternal inheritance. Sex Determination in Birds, Sex Determination in Honey Bees.

Human karyotypes, autosome and sex chromosomes, abnormalities due to multiple sets of genome - colour blindness, haemophilia, Down syndrome (Mongolism), Turner syndrome, Klinefelter syndrome, Rh factor, ABO blood group, amniocentesis, human genome.

3.2.2 Molecular Inheritance and Gene Expression

One-gene-one enzyme hypothesis, discovery of DNA as genetic material, structure of DNA and RNA, types of RNA, functions of nucleic acids, DNA replication, protein synthesis, transcription and translation, house keeping genes, regulation of gene expression, positive and negative control systems, Operon model, mutations and their types, mutagens, useful and harmful effects of mutation.

3.2.3 Genetics and Society

Genetics through ages, recombinant DNA technology, gene cloning, gene bank, Polymerase Chain Reaction, DNA fingerprinting, genomics, genetic engineering and its importance, transgenic plants, animals and microbes, genetic counselling. Bt crops, Biopiracy, Biopatent

Module 4 Environment and Health

Time: 50 hr **Marks: 13**

Approach

This module emphasizes the basic understanding of rules governing the interrelationships in a biotic community. It brings out the basic principle of conservation by pointing out that conservation of natural resources would brighten the prospect of future of humankind. This module aims to create an idea about healthy living. It also imparts knowledge regarding role of proper and balanced diet to prevent nutritional deficiency diseases. The types, causes and modes of transmission of human diseases are discussed *in this module. This module also intends to make the learner understand various emerging areas in biology.*

Unit 1. Environment and its Conservation

Time: 25 hr **Marks : 7**

4.1.1 Ecological Principles

Biotic and abiotic factors in ecosystem, interrelationship between plants and animals, energy flow in the biosphere, food chain, food web, man's place in the environment, biomes, flora and fauna of different biomes.

4.1.2 Conservation and use of Natural Resources

Population growth, Ecological succession biotic interaction

Types of natural resources – non-renewable and renewable with examples, need for conservation and restoration, Indian traditions of conservation of nature, conservation of soil, water and biodiversity, endangered and threatened species, wildlife reserves in India, agencies (national and international) dealing with conservation of wildlife, environmental legislation, sustainable development, conventional and non-conventional sources of energy (hydel, wind, tidal, nuclear, solar, geothermal, hydrogen energy, biogas and bio fuels), depleting energy resources, conservation of energy.

- Our Biodiversity Richness
- Non-conventional Sources of Energy

4.1.3 Pollution

Causes, prevention and control of different kinds of pollution, (air, water, thermal, soil, noise and radiation), entry and translocation of pollutants in our body, waste management.

Unit 2. Healthy Living

Time: 25 hr **Marks: 6**

4.2.1 Nutrition and Health

Health and nutrition, types of nutrients - macro and micronutrients, sources and functions of carbohydrates, fats, proteins, vitamins, minerals, water and roughage; energy requirement of the body, balanced diet, balanced diet for special needs growing children, persons in different occupations, pregnant and lactating mothers, deficiency diseases - Protein Energy Malnutrition (PEM), mineral deficiency and vitamin deficiency with examples - hypervitaminosis, obesity, food-fads.

4.2.2 Diseases

Definition, types and transmission of diseases, define - parasite, pathogens, infection, infestation, vector; causes, symptoms, prevention and control of some common communicable diseases - influenza, measles, polio, hepatitis, tuberculosis, diphtheria, leprosy, malaria, filariasis and dengue; cardiovascular diseases - diabetes, osteoporosis, cancer, allergy, syphilis, gonorrhea and AIDS (awareness, symptoms and prevention), drug abuse.

Module 5 Emerging areas in Biology

Time: 10 hr **Marks: 7**

Approach

This module has been included in the Biology course to familiarize the learners with the importance of the new emerging areas of biology like Biotechnology and Immunology which have an impact on human lifestyles.

5.1.1 Biotechnology

Introduction, industrial biotechnology (alcohol, beverages, yoghurt, cheese, vinegar, antibiotics), general idea of genetic engineering, importance of transgenic organisms, gene therapy, bioremediation, biopesticides.

5.1.2 Immunology

Types of defense mechanisms of body, cells of immune system (T-cells, B-cells, macrophages), antigens and antibodies humoral and cell mediated immune response, types of immunity, immunization.

PRACTICAL WORK

Purpose

The purpose of teaching biology is not only to acquaint the learners with biological terms, facts, concepts and principles but also to develop practical skills. Development of practical skills leads to better understanding through firsthand experience and mutual reinforcement. It takes into account the development of psychomotor skills. Since this is an import aspect of development, the present biology course considers practical work as an integral part of the theory.

The skills which the present course intends to develop are:

(i) observational skills in the form of identifying relevant details in given specimens, locating the desired parts in a dissection or specimen.

(ii) manipulative skills in the form of arranging, handling and reading apparatus and instruments.

(iii) collecting, mounting and preserving skills.

(iv) drawing, labelling and reporting experimental results thereby interpreting them.

List of Practicals

1. To study parts of a compound microscope.

2. To prepare temporary stained glycerine mounts of
   - (i) epidermal peel of onion
   - (ii) cheek cells of humans
   - (iii) epidermal peel of leaf to observe stomata
   - (iv) T.S. of stem to observe xylem and phloem
   - (v) striated muscles from cockroach leg.

3. To study the various modifications in root, stem and leaf
   - (a) Root (i) Storage (carrot beet root/ radish) (ii) Support -Prop root, stilt root
   - (b) Stem (i) Underground - Rhizome, tuber, corm, bulb (ii) Aerial - Tendril, thorn, phylloclade, cladode
   - (c) Leaf (i) Tendril (ii) Spine (iii) Phyllode

4. To observe and study the T.S. of dicot and monocot root and stem from permanent slides.

5. To study the microscopic structure of human cartilage, bone, blood, testis and ovary from permanent slides.

6. To study the structure and function of different parts of the following flowers : China rose, Petunia

7. To identify the characteristic features of the following animals and classify upto class sponge, earthworm, butterfly, snail, starfish, bony fish, cartileginous fish, toad, houselizard, pigeon and bat.

8. To study the stages of mitosis from temporary stained mount of onion root tips.

9. To study the morphological adaptations of (a) plants living in xeric and aquatic habitats e.g. cactus and water hyacinth. (b) animals to parasitic mode of life e.g. tapeworm.

10. To study the (a) texture and (b) water holding capacity of two different types of soils.

Curriculum

11. To study osmosis by potato osmometer.
12. To study the rate of photosynthesis in aquatic plants.
13. To study the structure and germination in gram and bean seeds.
14. To demonstrate respiration in germinating seeds.
15. To study the action of salivary amylase on starch.

SCHEME OF STUDY

The revised course in Biology provides you with package of learning opportunities which comprise of:

- Printed Self Learning Material (SLM) is in three parts i.e. Part-1 , Part-2 and a laboratory manual.
- Supplementary Materials in the form of Audio and Video Programmes.
- Video tutorials in Chemistry available on the NIOS website (www.nios.ac.in) as well as YouTube.
- 30 Personal Contact Programme (PCP) sessions for theory part and 06 Personal Contact Programme (PCP) sessions for practicals at your study centre. Please contact your study centre for the PCP schedule or visit our NIOS website at www.nios.ac.in.
- Face-to-Face Personal Contact Programme (PCP) at your study centre, live Personal Contact Programmes (PCPs) through audio streaming are webcast on Mukta Vidya Vani, which can be accessed through NIOS website (www.nios.ac.in).

SCHEME OF EVALUATION

The learner will be assessed through Continuous and Comprehensive Evaluation (CCE) in the form of Tutor Marked Assignment (TMA) as well as Public Examination. The following table shows the details:

Mode of Evaluation	Syllabus/Contents	Duration	Weightage
Tutor Marked Assignment (TMA)	All Contents assigned for TMA	Self Paced	20%
Public/Final Examination	All Contents assigned for PE and Practical Examination	3 Hours	80%

PRACTICAL EXAMINATION

There will be a practical examination of 3 hours duration and maximum marks 20, apart from the theoretical examination. The distribution of marks is as follows

(i)	Performing an experiment	4	marks
(ii)	Submitting a project	2	marks
(iii)	Identification of given samples (4 samples)	2	marks
(iv)	Preparing mounts	2	marks
(v)	Maintenance of record book	3	marks
(vi)	Viva-voce	2	marks
	Total	15	marks + 5 marks for CCE
	Total	20	marks

Success Stories

Kavya Madhavan
Enrolment No. 090008103065

Kavya Madhavan is a highly acclaimed actress in the Malayalam film world. Making her debut as a child artiste, Kavya quickly managed to find a place in the hearts of malayalees. However, all this was at the cost of dropping out of school at the Secondary level. Like many others, she too nurtured a dream of acquiring a college degree. Motivated to join the National Institute of Open Schooling (NIOS), Kavya Madhavan appeared for the Senior secondary level examination in Malayalam medium and emerged successful. But this was not achieved easily, she says.

Thanks to the Open Schooling system, Kavya Madhavan has now registered for B.Com in M.G. University, Kottayam, Kerala.

Ganesh
Enrolment No. Secondary Course: 25001292005
Senior Secondary Course: 250012103570

Ganesh has cleared the Secondary course of NIOS with first division and has now appeared in 4 subjects of Senior Secondary course. What differentiates Ganesh from other students is that he is suffering from a non-healing ulcer of bone infection. There is no treatment for his ailment; his lower part below the belt has not grown. The puss leaks from his body continuously. He cannot move, and even has no sensation in the lower part of his body. He has to be carried to be moved from one place to another.

However, support from his family members and the Chief Commissioner of Disabilities facilitated his enrolled as a student under Sarva Shiksha Abhiyan as a private candidate, thereby enabling him to clear Class 5 and Class 8. It was at this point that NIOS came to his rescue by providing the flexibility of studying at his own pace through credit accumulation. He could also study subjects of his own choice and was further allowed to appear for the examination in his house. UT Chandigarh continued to support him by providing him with the facility of tutors, who taught him Maths and Science.

With a keen interest in religion, he has read about the various *Puranas, Ramayana* etc., from which he has derived a lot of internal strength.

Ganesh is certainly determined to study further and wishes to pursue a course in Computer Science after clearing his Senior Secondary course from the NIOS.

Complete and Post the feedback form today

Final fold and seal

Feed back on Lessons

Lesson No.	Lesson Name	Content			Language		Illustrations		What You Have Learnt	
		Difficult	Interesting	Confusing	Simple	Complex	Useful	Not useful	Very helpful	Not helpful
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
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14.										
15.										
16.										
17.										
18.										

---Fourth fold----

---Third fold----

Dear Learners,

You must have enjoyed going through your course books. It was our endeavor to make the study material relevant, interactive and interesting. Production of material is a two way process. Your feedback would help us improve the study material. Do take a few minutes of your time and fill-up the feedback form so that an interesting and useful study material can be made.

Thank you
Coordinator
(Biology)

Feed back on Questions

Lesson No.	Lesson Name	Intext Questions		Terminal Questions		
		Useful	Not useful	Easy	Diff.	V. diff.
1.						
2.						
3.						
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18.						

Second Fold

Yours suggestion

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Did you consult any other book to study Biology? Yes/No

If Yes, give reason for consulting it

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Name : ____________________

Enrolment No: ____________________

Address : ____________________

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Subject : ____________________

Book No: ____________________

Assistant Director (Acad.)
National Institute of Open Schooling
A-24-25, Institutional Area
Sector-62, NOIDA (U.P.)

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