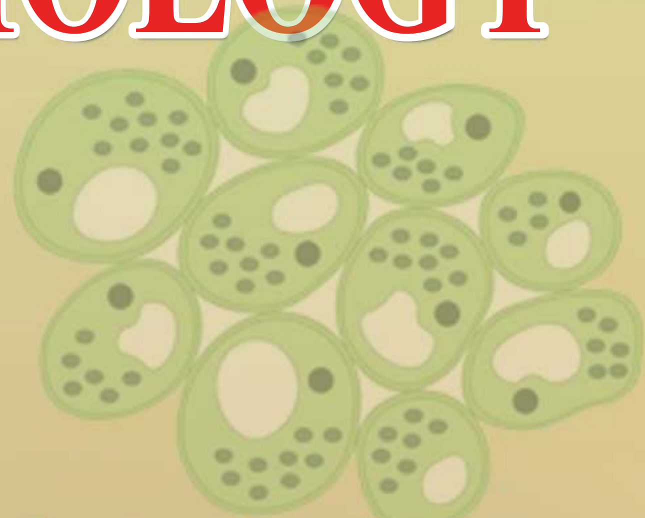
INTERMEDIATE(TOSS) Course

BIOLOGY



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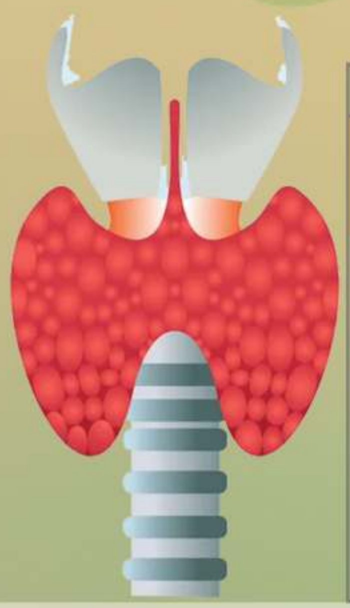

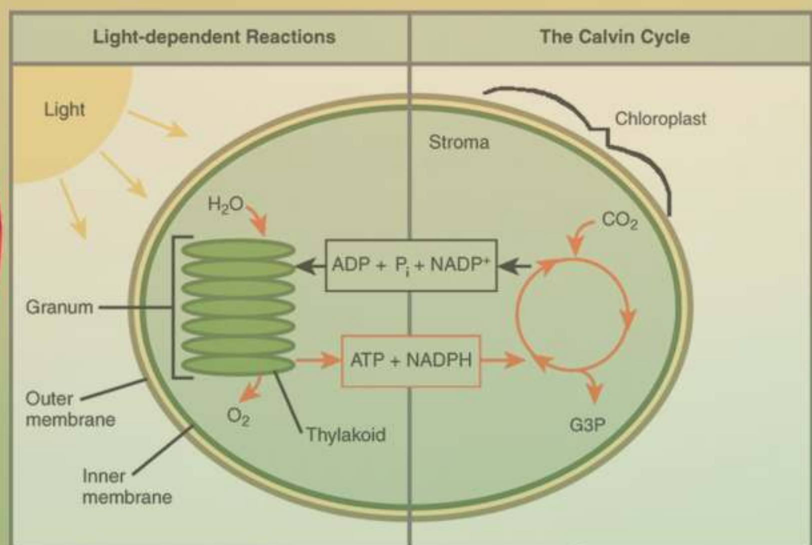

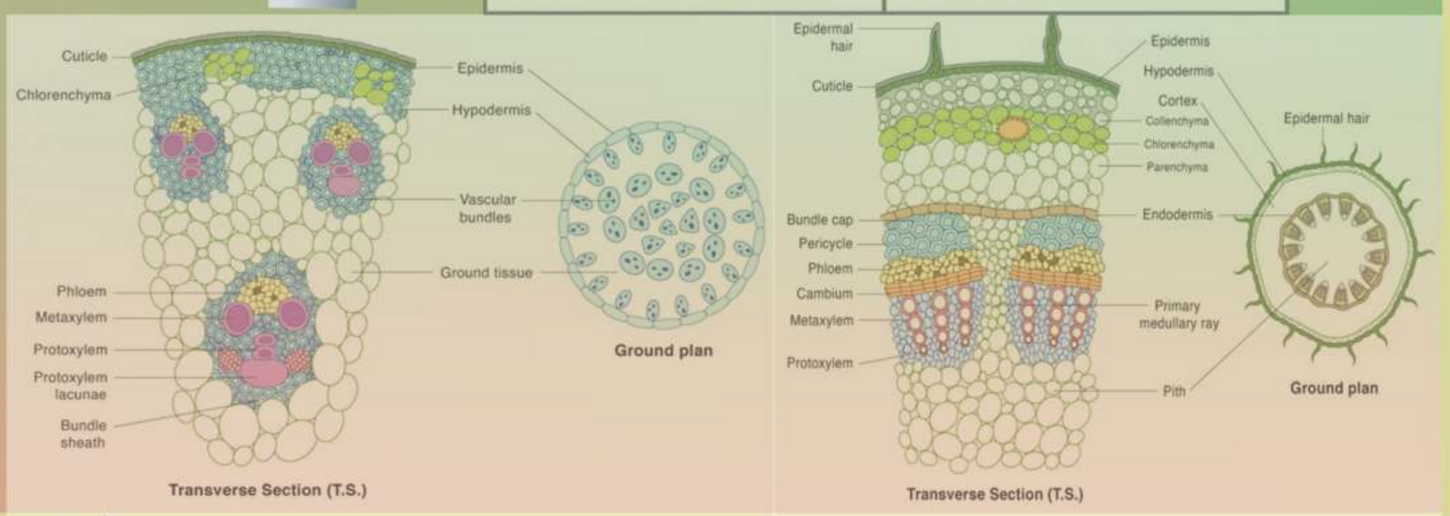

TELANGANA OPEN SCHOOL SOCIETY YHYDERABAD

INTERMEDIATE (TOSS) COURSE BIOLOGY-1

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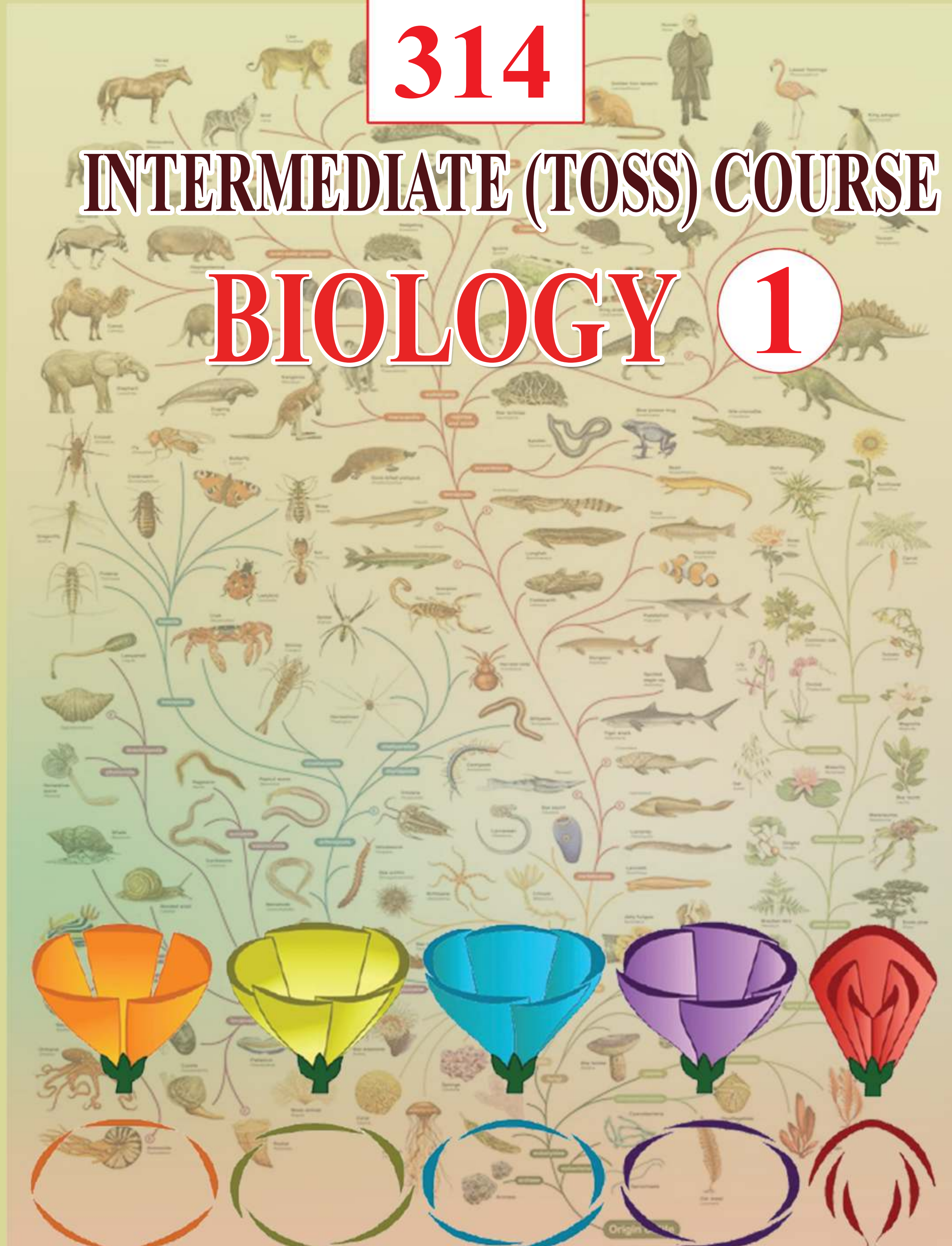
INTERMEDIATE (TOSS) COURSE

BIOLOGY 1



TELANGANA OPEN SCHOOL SOCIETY YHYDERABAD

314

BIOLOGY - 1

Chief Advisor

Smt. Vakati Karuna, IAS,
Secretary to Government, Education Department,
Govt. of Telangana,
Hyderabad.

Chief Editor

Dr. Nageswara Rao Amanchi M.Sc., Ph.D.
Asst. Professor, Department of Zoology,
University College of Science, Osmania University,
Telangana, Hyderabad.

Textbook Printing Council

Smt. A. Sridevasena, IAS,
Director, School Education,
Telangana, Hyderabad.

Sri P.V. Srihari,
Director, TOSS,
Telangana, Hyderabad.

Sri S. Srinivasa Chary,
Director, Textbook Press,
Telangana, Hyderabad.

Coordination

Sri M. Somi Reddy,
Joint Director, TOSS,
Telangana, Hyderabad.

Sri B. Venkateswara Rao,
State Coordinator, TOSS,
Telangana, Hyderabad.

Telangana Open School Society (TOSS), Hyderabad.
SCERT Campus, Opp: L.B. Stadium,
Basheerbagh, Hyderabad - 500 001
Phone: 040-23299568, Website: telanganaopenschool.org,
E-mail: dintoshyd@gmail.com

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Foreword

Providing education to children is a fundamental right, and it's essential for the overall development of society. The government of Telangana plays a crucial role in ensuring that education is accessible to all, and they often establish institutions like the Telangana Open School Society (TOSS) to cater to children who may be unable to access formal education due to various reasons.

To provide quality education to learners studying Intermediate Education in Telangana Open School Society starting from the 2023 academic year, the textbooks have been revised to align with the changing social situations and incorporate the fundamental principles of the National Education Policy 2020. The guidelines set forth in the policy aim to enhance the overall learning experience and cater to the diverse needs of the learners. Earlier Textbooks were just guides with questions and answers. TOSS has designed the textbook with a student-centric approach, considering the different learning styles and needs of learners. This approach encourages active engagement and participation in the learning process. The textbooks include supplementary teaching materials and resources to support educators in delivering effective and engaging lessons.

Biology plays a valuable part in general education and needless to justify its study in fact directly useful to you in finding employment opportunities as a biology teacher, lecturer, or employment in Pharmaceutical, Animal Biotechnology, Plant Biotechnology and other similar industries. You can be accommodated as a field expert in Agriculture, Horticulture, Forestry and Healthcare sector. Marine and Freshwater Biology Research areas offer plenty of opportunities to young graduates these days. Our Revised Biology Course of Telangana Open School System is based on the National Institute of Open School (NIOS) and the National Common Core Curriculum. It's also worth mentioning that The Revised Curriculum is made very simple and suits exactly to the needs and requirement of the students those who are pursuing. This course is having 3 volumes consisting both theory and practical with special focus on applied biology. I hope you will find the new material interesting and exciting with a lot of activities to do. Further, we also welcome suggestions and inputs for further improvement.

We are indeed very grateful to the Government of Telangana and the Telangana State Board of Intermediate Education. Special thanks to the editor, co-coordinator, teachers, lecturers, and DTP operators who participated and contributed their services tirelessly to write this text book.

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Place: Hyderabad.

Director, TOSS,
Hyderabad.

Chief Editor & Coordinator

Dr. Nageswara Rao Amanchi M.Sc., Ph.D.
Asst. Professor, Department of Zoology,
University College of Science, Osmania University, Telangana, Hyderabad

Textbook Development Committee

Editors

Dr. Rama Krishna Kancha, M.Sc., Ph.D.
Asst. Professor, Centre for Plant Molecular Biology (CPMB), Osmania University, Telangana, Hyderabad

Dr. Sandhya Annamaneni, M.Sc., Ph.D.
Asst. Professor, Department of Genetics, University College of Science, Osmania University, Hyderabad, Telangana

Dr. A. Vijaya Bhasker Reddy, M.Sc., Ph.D.
Asst. Professor, Department of Botany University college of Science Osmania University Hyderabad, Telangana State

Authors

Dr. B. Vijayapal Reddy, M.Sc., Ph.D.
Asst. Professor, Department of Botany Kakatiya Government College, Hanumakonda, Telangana

Dr. Nalla Manoj Kumar, M.Sc., Ph.D.
Assistant Professor, Department of Botany Government Degree College, Peddapalli, Peddapallli Dist., Telangana

G. Vijaya Basker Reddy
Asst. Professor Department of Botany, Government Degree College, Gajwel, Siddipet Dist., Telangana

Dr. A.Sunil Kumar, M.Sc., Ph.D.
Department of Zoology Telangana University South Campus, BTS, Bhiknoor, Kamareddy, Telangana

Dr. P. Subhashini, M.Sc., Ph.D.
Assistant Professor, Department of Zoology, Government Degree College - Parkal, Hanumakonda, Telangana

G. Paramesh
Asst. Professor, Department of Zoology
Government Degree College Huzurabad, Karimnagar, Telangana

Mr. Vemula Balaraju
Principal, Director of School Education, Telangana State Model School & Jr College Anantharam, Thirumalagiri, Suryapet Dist., Telangana

T. Swarupa
Principal, Government Junior College (Girls) Bellampalli, Mancherial Dist., Telangana

G. Bhagirath
Assistant Professor, Department of Botany, Government Degree College, Rangasaipet, Warangal Dist., Telangana

Technical Support

Sri B. Venkateswara Rao
State Coordinator, TOSS, Telangana, Hyderabad.

Sri P.B.S.P.S. Kumar
Subject Coordinator, TOSS, Telangana, Hyderabad.

Sri V. Venkataswamy
Technical Coordinator, TOSS, Telangana, Hyderabad.

Cover page & Layout Design

Arifa Sultana,
SCERT, Telangana, Hyderabad.

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1 ORIGIN AND EVOLUTION OF LIFE AND INTRODUCTION TO CLASSIFICATION

Before going to discuss origin and Evolution of life, we should know the difference between living and nonliving organisms. Living Organisms exhibit three charecter, especially, Irritability, Growth and Reproduction. Nonliving things which donot exhibit these charecters.

Now we will discuss origin and evolution of life. The planet earth come into existence 4 and 5 billion years ago. Life evolved on planet earth 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 learn how life originated on earth and how much vast variety of organisms, popularly known as biodiversity, evolved through variations and Natural selection.

The study of such a wide variety becomes convenient only when organisms are grouped according to similarities and differences among them, named and their evolutionary relationships established. We will learn about the importance and method of classiification of organisms.

Objectives

After completing this lesson, you will be able to:

- Discribe various theories of origin of life explain what is organic evolution.
- Give morphological, palaentological, embryological and molecular evidences in favour of organic evolution.
- Explain the sources of organic variations (gene and chromosomal mutations, recombinations, gene flow and genetic drift)
- Explain natural selection with examples.
- Explain the role of isolation in evolution.
- List the various isolating Mechanisms.
- Explain speciation.
- Define Classification.
- Justify the need for classfication of organisms

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 atd that high temperature was not possible so, 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 appearence of simplest primordial life from non-living matter. Evolution of life means the gradual formation of complex organisms from simpler ones. Different theories explain origin of life among all theories acceptable theory is chemosynthetic Theory.

Chemosynthetic theory of origin of Life

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

Chemosynthetic Theory

Life have first originated 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 cooldown 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.
- Heavy rains fell on hot surface of earth and 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 occured and gave rise to ammino acids, nitrogenous base, sugars and fatty acids etc. Which further reacted and combined to given large molecules of life such as proteins and nucleic acids.

Probable stages in the Origin of Life

First Stage

The sources of energy - Ultraviolet rays on electric discharge (lightening) or heat or a combination of these caused reactions that proceduced 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.Urvey in 1953 set up an experiments with an air-tight appratus in which four gases (NH_4, CH_4, H_2 and H_2O) were inoculated through 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, Lactic acid etc.

Second Stage

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

Third Stage

The large molecules of different kinds combined together to form multi-molecules 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 "coacervate drops" of microscopic size moving in the liquid with a difinite boundary (Coacervate means "heap" referring to the combining together of the molecules).

Coacervate like aggregates were probably the precussors of the first living cellsThe apparatus used by stanley Miller and Harold C.Urey to demonstrate the synthesis of amino aicds under conditions that existed on the primitive earth.

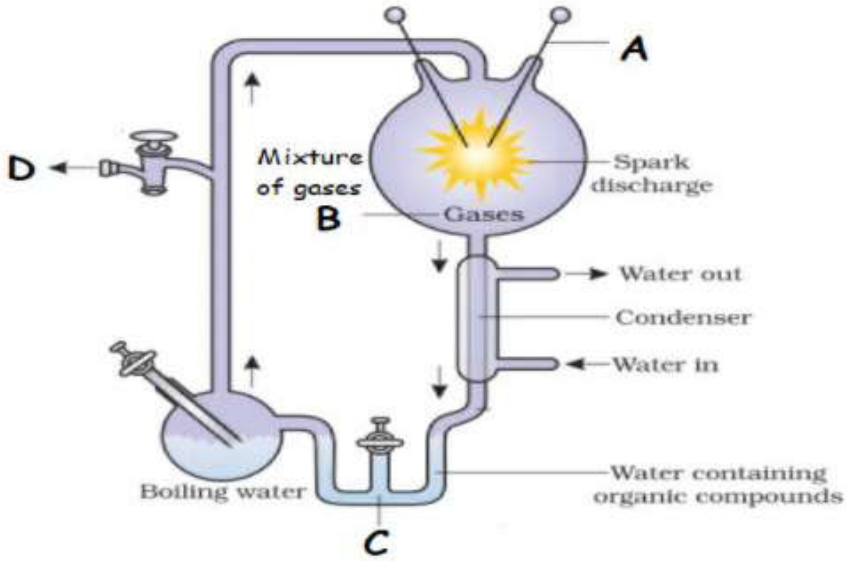


Fig : Uri-Miller Experiment

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

Some of the earliest formed proteins might have acted like enzymes and would have effected the rate of reactions. It is also believed that RNA molecules might have shown enzymatic activity in the "Primoordial soup". Such molecules have been termed ribozymes.

Fourth stage

Some sort of nucleoprotiens or nucleic acids may have evolved by random combinations which have provided two more properties to coacervate like bodies.

This include:

(i) Chemical reactions to form the nucleic acids.

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

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).

- As 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 chlorophyl bearing units of life for the first time started using the solar energy for production of food as well as Liberating free oxygen into the atmosphere.

  Early atmosphere of earth had no free oxygen. Chlorophyll bearing organisms later released free oxygen which gave greater possiilities for life to evolve.

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

Evidences for Biological Evolution (or) Organic Evolution

The theories that explain the evolution are hypothetical. There is no practical proof for them. Infact, it is not possible for any body to observe even a single change in favour of evolution that occurs in the body of organisms as our life span is too short to notice such slow changes. Hence scientists collected evidences from different branches of biology.

Some of them are:

1. Palaentological evidences
2. Embryological evidences
3. Anatomical evidences
4. Molecular evidences

1. Evidences from Palaentology **:**

Palaentology (Gr. Palaios - Old, on existing, Cogos - to study) is the study of prechistoric life through fossils. Fossils are the remanents of plants or animals that were preserved in layers of earth and have been excavated from the soil. They are of various types like Moulds, Casts, petrifications, coprolites (fossilizes faecal matter), actual remenants of animals preserved in ice etc, they support the idea that life has gradually evolved on earth. Some connecting links are proof to gradual evolution eg. Eusthenopteron connecting link between fishes and Amphibians. Symuria is connecting link between amphibian and Reptiles. Archaeopteryx between Reptiles and birds Cynognathus - connecting link between reptiles and Mammals.

2. Evidences from Embryology

The study of the early development of organisms is called Embryology.

Ernst Hacckel is considered as Father of Embrology and VonBacr is considered the Father of Modern Embryology.

When the Embryos of different animals are observed, we find fundamentals similarity which tell us that there is a relationship among the animals.

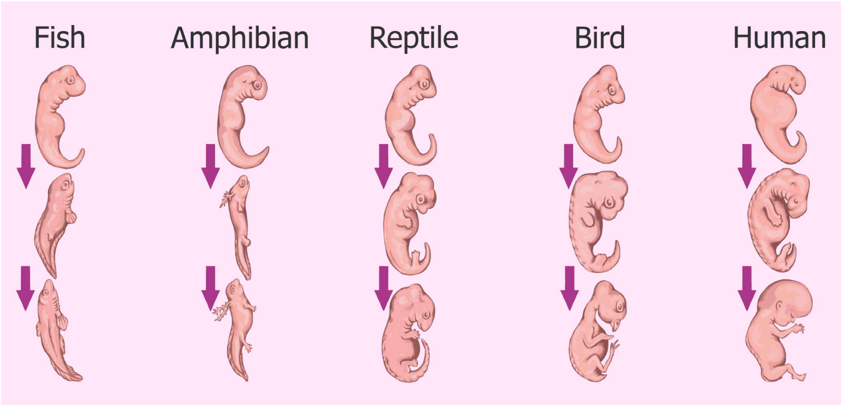


Fig : Embryos of different chordates showing similarities at early stage

If we observe embryos of Fish, Salamander, Tortoise, Chick and Man - we can find similarities in the early embryos. It indicates that the above animals have a common ancestor. The life of all multicellular organisms begins with a single celled stage, the zygote. It undergoes cleavages to produce morula, morula to blastula, blastula to gastrula. This sequence of embryos show that every multicellular organisms passes through the above stage representing their common ancestry.

3. Evidences from Comparative Anatomy

When we compare the anatomy of different animals, we find some similarities among them. For example, the fore limbs of different vertebrates are similar in origin and internal structure.

(i) Homologous Organs

(ii) Analogous Organs

(iii) Vestegial Organs

(iv) Atavistic Organs

(v) Connecting Links.

(i) Homologous Organs

The Organs which have similar structure and orign but not necessarily the same function are called Homologous organs.

Eg: The appendages of vertebrates such as flippers of whale, wings of bat, forelimbs of horse, Paw of Cat and hand of Man, have a common pattern in the arrangements of bones eventhough their external form and functions may vary to suit their mode of life. It explains that all the vertebrates might have had a common ancestor.

(ii) Analogous Organs

The Organs which have dissimilar structure and origin but perform the same function are called the analogous organs.

Analogous organs suggest 'convergent evolution'

Eg: Wings of a butterfly and wings of a bird.

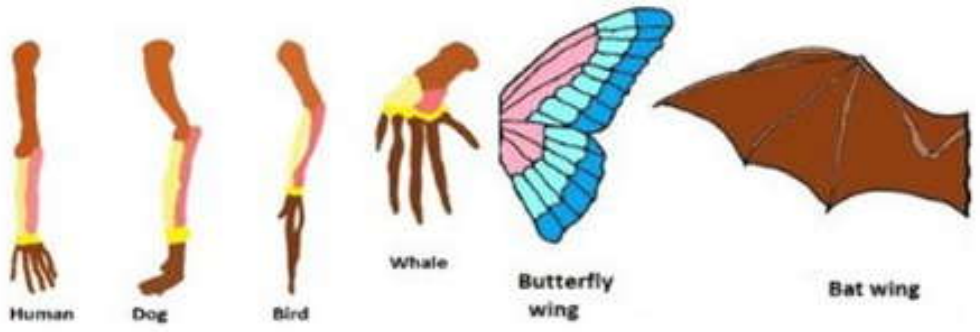


Fig. Homologous and analogous organs

(iii) Vestegial Organs

The Organs which were functional in the ancesstors but non-functional or reduced in descendants are called vestigial organs.

Eg: Hindlimbs of Python

Hindlimbs and Pelvic Girdle in Whale.

Wings of flightless birds.

Vermiform appendix.

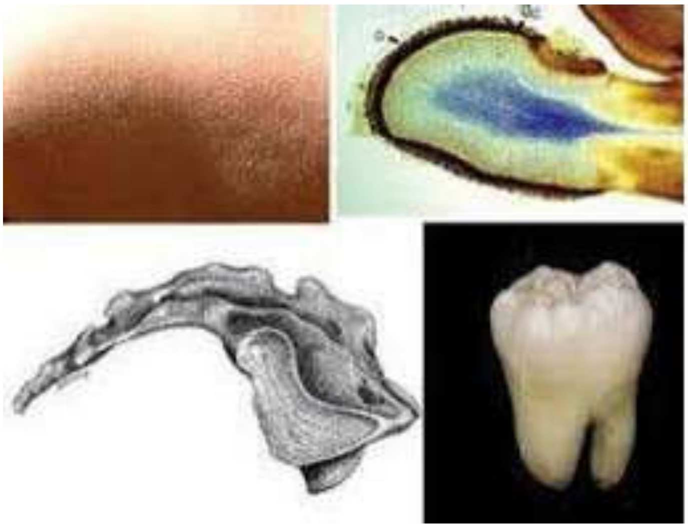


Fig. Vestigial organs

(iv) Atavistic Organs

Sudden appearence of some vestigial organs in a better developed condition as in the case of the failed human baby is called atavism. Such organs are called atavistic organs they strongly supports the concept of organic evolution.

(v) Connecting Links

The Organisms which possess the charecters of two different groups, they are called connecting links.

Eg: Archaeopteryx - Connecting link between Reptiles and Birds.

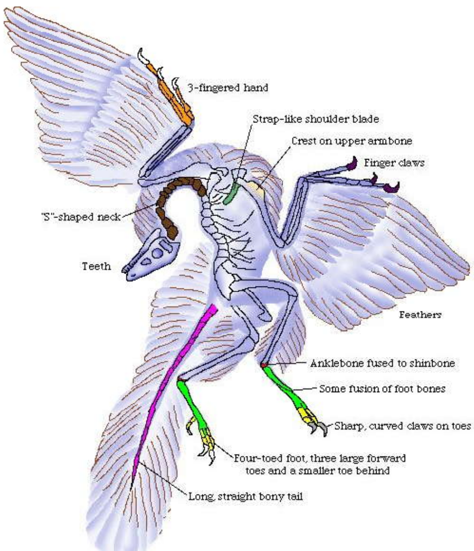


Fig. Reptiles and Birds.

4. **Molecular evidences of Evolution**

- All organisms have cell as the basic unit of life. The cell is made of biomalecules common to all organisms.
- Ribosomes, the cellular organelles are of universal occurence in organisms.
- DNA is the hereditary material of all organisms.
- ATP is the molecule which store energy and release energy for biological processes.
- The same 22 aminoacids form the constituent of proteins of almost all organisms.
- The genetic code is universal.
- Replication, Transcription, Translation are similar in all organisms.
- Sequence of nucleotides such as that in the promoter gene (TATA BOX) is common in all organisms.

INTEXT QUESTIONS

1. Define Organic Evolution.

____

2. Name one fossil animal.

____

3. Define vestigial Organ.

____

4. Give one example of connecting link among living beings.

____

5. Which Organ in Man is homologous to wings of birds.

____

Theories of Evolution

Various theories have been proposed to explain the process of evolution, but the theories that explain the scientific basis of organic evolution are lamarckism, Darwinism, Mutation theory of derveis, Modern synthetic theory (Neo Darwinism)

Darwin's theory of Natural Selection

An English Scientist, Charles Darwin (1809-1882) explained the mechanism of evolution through this theory of natural selection. He is still regarded as the father of evolution because two very significant contributions. He suggested .

(i) that all kinds organisms are related through ancestry.

(ii) he suggested a mechanism for evolution named it as natural selection.

According to Darwin organisms produce more offsprings but few of them can survive because environmental resources are limited. During struggle for existence, organisms with advantageous variations are protected and allowed to reproduce while dis-advantageous variants are eliminated from nature. This is what was termed natural selection by Darwin.

Creation of new species according to Darwin

As the environmental changes, new adaptations get selected in nature and after many generations sufficient charecteristics will have been changed so as to alter the species into a new one (origin of species). Darwing talked about variations but did not know about the sources of variation were discoverd and Darwins Original theory of Natural selection modified. This new theory was termed Neo-Darwinism or modern synthetic theory.

According to Neo-Darwinism

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. The heritable genetic changes in the individuals of a population are the basis of evolution.
3. The heritable changes or variations occur due to small mutations in the genes or in the chromosomes and their recombinations.
4. Natural selection selects the variations which helps in adapting to the environment.
5. A change in genetic constitution of a population selected by natural selection is responsible for evolution of a new species.
6. More offsprings with favourable genetic charges are born. This is called Differential reproduction Reproductive isolation helps in keeping species distinct.

Elemental forces of Organic Evolution

Evolution is caused by action of

(i) Natural Selection on variation.

(ii) Reproductive isolation

Variations arise in an individual by Mutation, Genetic recombination, Gene flow, Genetic drift. Natural selection is explained by taking Industrial Melanism as Example.

Industrial Melonism

A commonly quoted example of natural selection in action is that of the pepperd moth, Biston betularia. The moth with its light coloured wings dotted with spots. The colour of moth blended well with the lichens gowing on the houses and tress on which it rested. Once in a while once in a while if a mutated form of the moth which was black in colour it was eaten up by birds as it was conspicuous because of its black wings. This was observed in the British Isels before the Industrial revolution. After the Industrial revolution, the genes of black wings proved favourable on the soot covered lichens growing on the wall of houses. Natural selection acted through agency of the birds which now ate up conspicuous light colour winged peppered moth which were therefore, soon replaced by the balck vaiety.

There are several examples -

DDT Resistant Mosquitoes

Metal tolerance in Grasses

Fig: Industrial Mellanism - Peppered moth

Role of Reproductive Isolation

Once a new species arise from the parental species due to the effect of variation and natural selection. Reproductive isolation operates in following ways, Ecological isolation, seasonal isolation, Ethological (Behavioural) isolation Mechanical isolation, Physiological isolation.

These are different types of isolations, because of isolation the organisms/animals which are not allowed to make or participate in reproduction by that it leads to speciation.

Speciation:

The evolution of new species is termed speciation. Speciation occurs in following ways and is termed accordingly, Allopatric speciation and sympatric speciation.

CLASSIFICATION

Meaning of Classification

Classification mean 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 marphological 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 of between molecules such as DNA and RNA are studied to establish evolutionary relationships.

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 lower most category is species. Other categories are arranged above species so that there is a herarchy of categories. The various taxonomic categories are given below:

Species : Group of individuals of one kind which can interbredd to produce fertile offspring.

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

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

Order : Different families included in one order.

Class : Different orders included in one class

Phylum : Different classes included in one Phylum

The various Phyla belong to their respective kingdoms. There are five kingdoms about which you will learn.

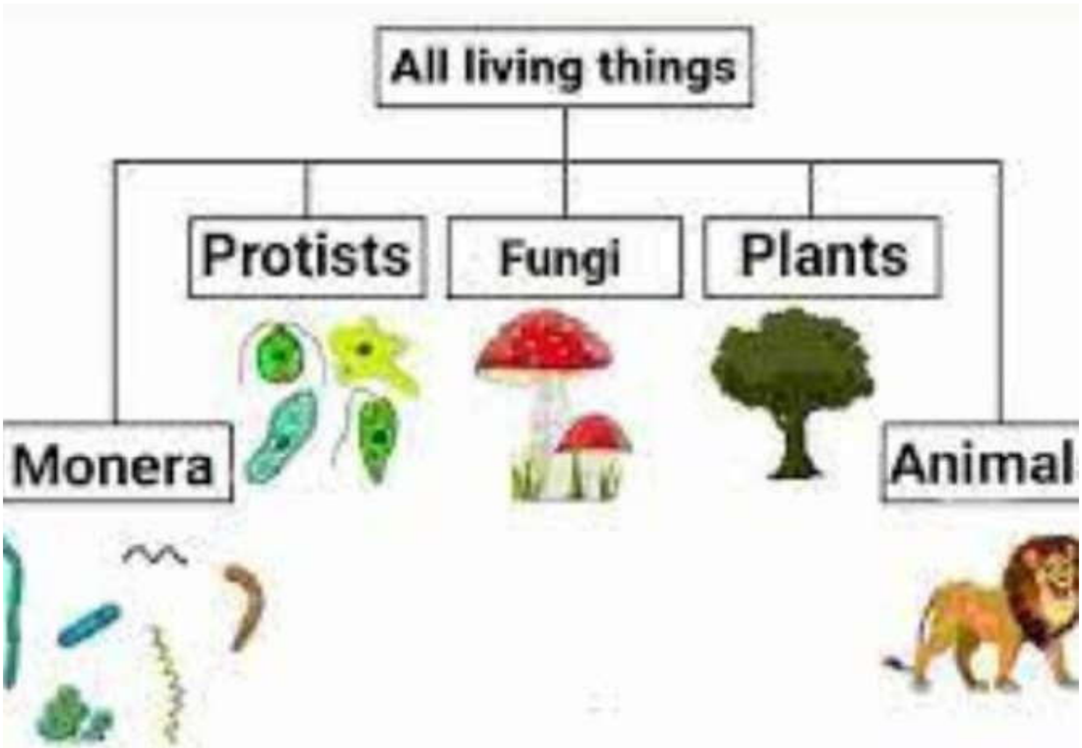


Figure : Five Kingdom Classification

Scientific naming of Organisms

Differetn 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. There arose the need to given organisms names which could be understood through out the world. So, the scientific names were given to organisms. Scientific names of organisms are understood all over the world.

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 homenclature simply means two-name system of naming. The name of every kind 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 biological name of Mango. Three main features of biological naming are as follows:

1) A Scientific name by convention is printed initalics or underlined when hand written.

2) Scientific naming is according to a set of scientific rules of nomen-clature.

3) Scientific names are mostly in Greek and Latin. They are understood all over the world and have made communication about organisms easier.

2 THE KINGDOM MONERA, PROTISTA AND FUNGI

The kingdom Monera includes bacteria and cyanobacteria. The kingdom Protista includes protozoa, diatoms and some algae. The bacteria, Protista and many fungi are microscopic and generally referred to as microorganisms. You will learn about the three kingdoms in this lesson.

Objectives

- State the basis for classifying organisms Monera, Prototista and Fungi.
- Emphasize the fact that kingdom Monera is the only prokaryotic kingdom and also most primitive.
- Describe the generalized structure of a bacterium and cyanobacterium.
- Describe the characteristics of kingdom Prototista.
- List the uses of protists to humans and mention the diseases causing protozoa;
- List the general characteristics of fungi with examples
- Describe the economic importance of fungi.

Kingdom Monera

If includes prokaryotic, unicellular (Monera means single) organism.

Examples: Bacteria cyanobacteria (Blue Green Algae).

Kingdom Monera consists of Archaebacteria, Eubacteria, Mycoplasma and Actinomycetes

Archaebacteria Archaebacteria includes bacteria that lives in unusual environments such as salty areas (halophiles), hot springs (thermoacidophiles), sewage and intestinal tracts of animals (methanogens). Unlike bacteria their cell wall consists of pseudomurein.

Eubacteria: (EU=True bacteria)

It includes bacteria and cyanobacteria. Bacteria are the most abundant microorganisms. They are present in soil, air and water.

Based on the shape, Bacteria categorised in four groups.

1. Spherical (Coccus)
2. Rod shaped (Bacillus)
3. Sphiral shaped Spirillum
4. Comma shaped (Vibrio)

Structure of a bacteria

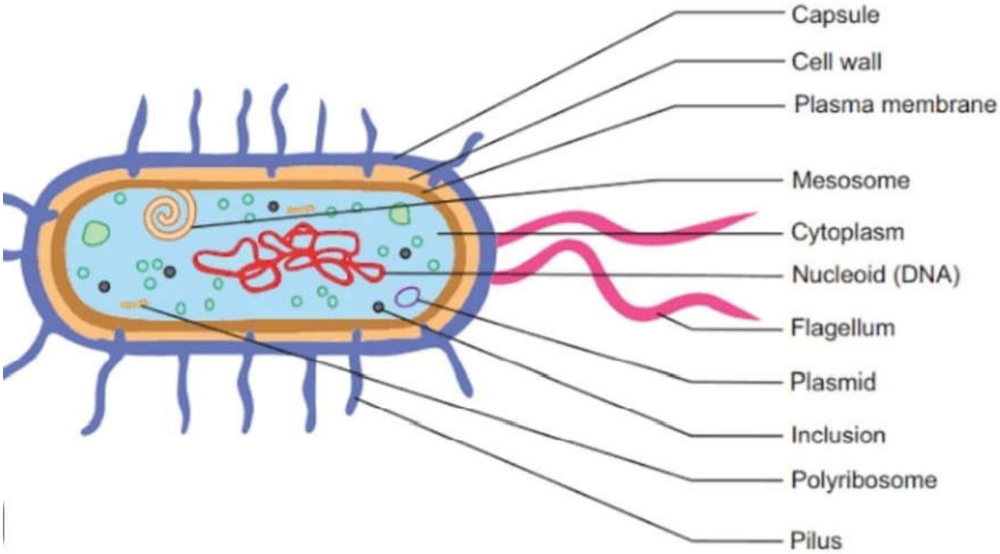


Fig Structure of Bacteria

Cell Wall It consists of rigid cell wall composed of peptidoglycan.

Pili Pili are short and thin thread like structures projecting out from the cell wall of some bacteria. Pili helps the cell stick to a surface.

Flagella Bacteria bears flagella which helps in locomotion.

Plasma Membrane Thin layer of plasma membrane is present inner to cell wall which encloses cytoplasm and other cell contents. An invagination of plasma membrane is called as mesosomes which helps respiration at cellular level.

Genetic Material

1. Circular chromosome made of double helical molecule of DNA is located in a region of the cytoplasm called as Nucleoid.

2. Plasmids are the extra chromosomal genetic material and bear genes for antibiotic resistance, sex factor, etc.

Cell Organelles All single and double membrane cell organelles like Endoplasmic Reticulum, Golgi Chloroplast Complex, Mitochondria are absent. Only Ribosomes (70 s type) are present in which membrane is absent.

Monera -General Characteristics

A. Nutrition in Bacteria In bacteria, Nutrition is of four tyepes.

1. Autotrophs (prepare their own food)
2. Saprophytes (feed on dead and decaying organic matter)
3. Parasites: (depends on living organisms for food and cause disease to host)
4. Symbionts: (Associated with other living organisms for mutual benefit.)

B. Respiration Both aerobic and Anaerobic respiration is found

C. Reproduction

(1) Asexual Reproduction: Bacteria reproduce asexually by binary fission. Under favourable conditions such as food availability, pH of medium, Temperature, it takes about 20 minutes for one bacterium to divide into two.

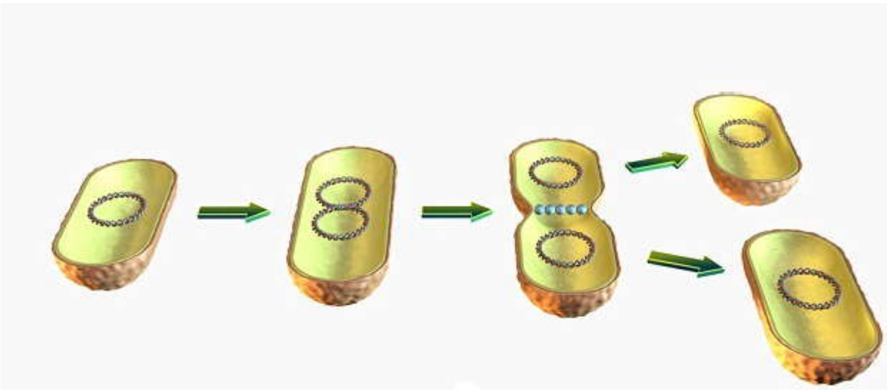


Fig : Binary fission in bacteria

2. **Sexual Reproduction**

Some bacteria show a primitive mode of sexual reproduction. It is different from sexual reproduction higher forms.

The steps involved in sexual reproduction are:

(a) Two conjugating (very close for exchange of DNA) bacteria are held together by pili

(b) A segment of DNA strand is transferred from one bacterium to another bacterium.

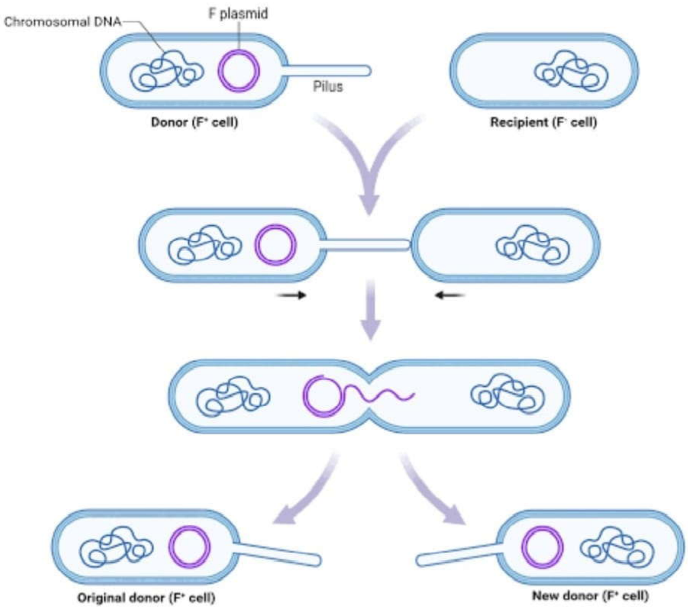


Fig. Sexual reproduction bacteria

INTEXT QUESTIONS

1. The circular single chromosome of a bacterium is made up of?

____

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

____

3. Mention the composition of prokaryotic cell wall.

____

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 reproduction in a bacterium?

____

Beneficial and harmful bacteria

They harm us by causing many diseases. On the other hand, some bacteria are very useful to mankind

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 the bacterium	Activities
1.	*Rhizobium*	Found in roots of legumes, (Peas, grams, Pulses, etc) 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.	Streptomytes	Produces Streptomycin which is an antibiotic.
4.	Lactobacillus	Ferments lactose (milk sugar) to lactic acid. This helps in setting of milk into curd
5.	Methanogenic bacteria	useful in Sewage treatment

Cyanobacteria

These were earlier called as blue green algae. 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 has increased.

Fig. a-b Cyanobacteria (blue green algae)

INTEXT QUESTIONS

1. Name the bacteria that:

(1) Fix atmospheric nitrogen in the soil

____

(2) Set milk into curd

____

(3) Cause tuberculosis

____

(4) Cause tetanus

____

Kingdom Protista

Protista are unicellular eukaryotes. Examples: Protozoa, Diatoms and Algae.

Protists have membrane bound cell organelles like Mitochondria, chloroplast (In photosynthetic protists only), Golgi Complex, Endoplasmic Reticulum (RER, SER) Ribosomes, Nucleus, Lysomes etc. Protistan cells contain well defined nucleus with chromosomes enclosed in nuclear membrane. Protists may have Cilia or Flagella. Protists are either Photosynthetic, Parasitic or Saprophytes. Protists reproduce asexually by fission or spores and sexually by a process called cell fusion.

Classification of Protista

Kingdom Protista includes

1. Phylum Protozoa which has following four classes:

a. Rhizopoda: Ex: *Amoeba*

b. Flagellate: Ex*: Euglena*

C. Ciliata: Ex: *Paramecium*

d. Sporozoa: Ex*: Plasmodium*

2. Class Bacillariophyta: Ex: Diatoms

3. Class Chlorophyta: Ex: *Chlorella*

4. Class Phaeophyta: Ex: Brown algae (Ectocarpus)

5. Class Rhodophyta: Ex: Red algae (Polysiphonia)

6. Class Oomycota: Ex: *Phytophthora*

Fig. Examples of Protista

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.
- Some algae can fix atmospheric nitrogen, so they are a source of natural fertilizer for the plants.
- A group of algae (diatoms) deposit silica in their walls. After their death these algae are preserved as fossils. Their deposits in large amounts are used as filters, and for lining of furnaces.

INTEXT QUESTIONS

1. Protista are single celled like Monera. Why have they been put in a separate kingdom? Answer in one short sentence.

   ____

2. Whcih is the kind of asexual reproduction found in Protista?

   ____

3. A group of algae which are preserved after their death is

   ____

Kingdom –Fungi (Mycetae)

Fungi are a diverse group of organisms that are neither plants nor animals, but they play a vital role in our ecosystems. However, their distinct characteristics and life processes set them apart as an independent kingdom. Unlike plants, fungi lack chlorophyll, the green pigment responsible for photosynthesis, making them incapable of producing their own food through sunlight. Instead, they are primarily decomposers, breaking down organic matter and recycling nutrients back into the ecosystem. From big mushrooms to tiny molds, fungi are everywhere around us, even if we don't always notice them. With over 144,000 known species and an estimated millions yet to be discovered, fungi are a kingdom of life that often remains hidden in plain sight. From towering mushrooms to microscopic molds, this vast and varied group of organisms holds a unique position in the tree of life. Fungi are essential for many living things, including us! They form partnerships with plants, where they exchange nutrients, helping each other grow stronger. Some fungi are delicious to eat, like mushrooms, while others have medicinal properties and are used to make medicines.

Objectives

After studying this unit you should be able to:

- Classify fungi based on their major taxonomic groups, such as Zygomycota, Ascomycota, Basidiomycota, and Deuteromycota, understanding the key characteristics that distinguish each group and their representative species.
- Identify and differentiate fungi as a distinct kingdom of life, understanding their unique characteristics that set them apart from plants and animals.
- Explain the ecological significance of fungi in the ecosystem, recognizing their role as decomposers and nutrient recyclers, and their symbiotic relationships with plants.
- Recognize the importance of fungi to humans, including their culinary and medicinal uses, fostering an appreciation for the impact of fungi in everyday life.

Fungi are eukaryotic, achlorophyllous, spore bearing , heterotophic organisms that made up of single and multiple cells with chitinous cell wall.

Classification of Fungi based on Mode of Nutrition:

Fungi exhibit various modes of nutrition. The three main modes of nutrition in fungi are saprotrophic, parasitic, and mutualistic.

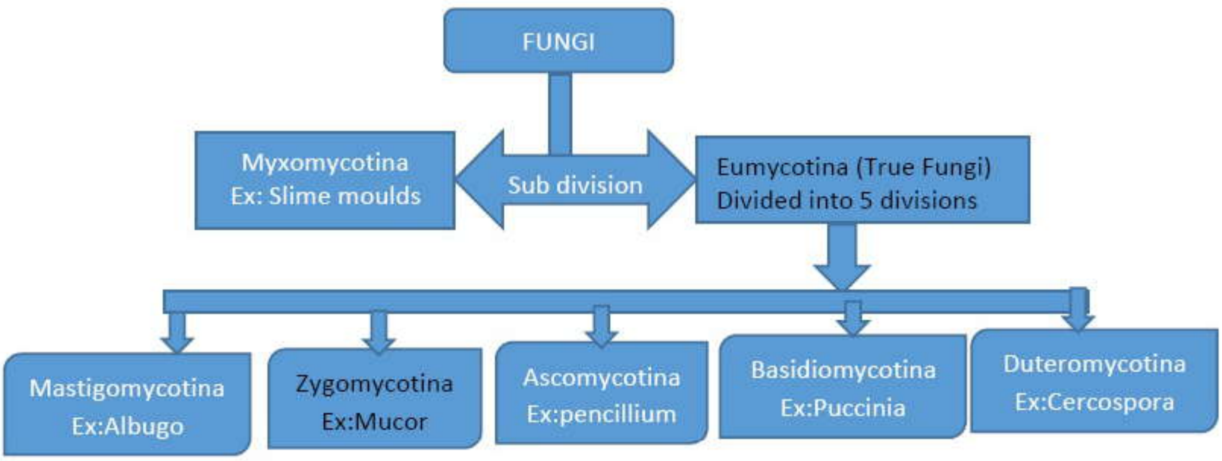
1. **Saprotrophic Fungi:** Saprotrophic fungi are nature's recyclers. They obtain their nutrition by decomposing dead organic matter, such as fallen leaves, wood, and dead animals. By breaking down these organic materials, they release essential nutrients back into the ecosystem, enriching the soil and providing nourishment for other living organisms. Examples of saprotrophic fungi include many species of molds and certain types of mushrooms.

2. **Parasitic Fungi:** Parasitic fungi derive their nutrition by infecting living organisms, known as hosts. They can cause diseases in plants, animals, and even other fungi. These fungi penetrate their hosts and absorb nutrients from them, often leading to the deterioration of the host's health. Some well-known examples of parasitic fungi are the rusts and smuts that attack various plants and the infamous "athlete's foot" fungus, which affects human skin.

3. **Mutualistic Fungi:** Mutualistic fungi form mutually beneficial relationships with other organisms. One of the most well-known mutualistic associations involving fungi is mycorrhizae. Mycorrhizal fungi form a partnership with plant roots, aiding in the absorption of water and nutrients from the soil while receiving sugars produced by the plant. This symbiotic relationship benefits both the fungus and the plant, enhancing their growth and survival.

Classification of Fungi based on Spore Formation:

Fungi reproduce by producing spores, which are tiny reproductive structures that can be dispersed through the air or other means. The structure and formation of spores are crucial factors in classifying fungi.



Flow chart of fungi classification

Fungi were broadly divided into two sub divisions 1. Myxomycotina 2. Eumycotina

Myxomycotina comprises the slime moulds. Slime moulds are saprophytic organisms that form multi nucleated cytoplasm called as ‘plasmodium’. The plasmodium forms spores during unfavourable conditions. The spores have true cell walls. Ex: Physarium

Eumycotina is called as true fungi. This sub division classified into 5 classes. Which are

i) Mastigomycotina : It is a zoosporic fungi. Some fungi reproduce asexually by means of flajellated spore in Zoosporangium. Sexual gametangia are dissimilar .Sexual reproduction takes place by oospores. Eg: Albugo.

ii) Zygomycotina: Zygomycotina fungi produce spores within distinctive structures called zygospores. These fungi are typically fast-growing molds found in soil and decaying organic matter. The common black bread mold (*Rhizopus stolonifer*) is a well-known example of Zygomycotina.

iii) Ascomycotina: Ascomycotina, also known as sac fungi, produce spores within sac-like structures called asci. These spores are usually formed in groups of eight. Ascomycota includes a vast array of fungi, ranging from microscopic yeasts to complex cup fungi and morels. Some important examples are baker’s yeast (Unicellular Fungi-Yeast:*Saccharomyces cerevisiae*) and the morel mushroom (*Morchella* spp.).

iv) Basidiomycotina: Basidiomycotina fungi produce spores externally on specialized structures called basidia. These spores are usually borne on the surface of gills in mushrooms or on the undersides of conk fungi. Basidiomycotina includes many well-known mushrooms, such as the button mushroom (*Agaricus bisporus*) and the fly agaric (*Amanita muscaria*).

v) Deuteromycotina: (Fungi Imperfecti): Deuteromycotina is a group that comprises fungi for which no sexual reproductive stage has been observed. These fungi reproduce only asexually through the production of spores called conidia. (eg.Cercospora). Some members of this group include common molds like *Penicillium*, which produces the antibiotic penicillin, and *Aspergillus,* which can cause respiratory infections.

Uses of Fungi:

Uses of Fungi:

Food Production: Many types of fungi are edible and used in cooking. Mushrooms, such as button mushrooms, shiitake, and oyster mushrooms, are popular additions to various dishes, providing essential nutrients and flavors.

Baking and Brewing: Yeast, a type of fungus, plays a crucial role in baking and brewing industries. It ferments sugars to produce carbon dioxide, causing bread to rise and creating alcohol during the fermentation of beer and wine.

Medicine: Fungi have contributed significantly to medicine. Antibiotics like penicillin and cephalosporin are derived from certain fungi, helping to combat bacterial infections and save lives.

Biological Pest Control: Some fungi act as biological control agents, helping to manage pests. They infect and kill insect pests, offering an environmentally friendly alternative to chemical pesticides.

Bioremediation: Fungi play a vital role in bioremediation, a process that uses living organisms to clean up pollutants from the environment. Certain fungi can absorb and break down toxic substances, such as oil spills and industrial pollutants.

INTEXT QUESTIONS

1. Write characteristics of fungi.

___

2. Write a short note on fungi classification.

___

3. Write briefly about economic importance of fungi.

___

3 KINGDOM PLANTE AND ANIMALIA

The Kingdom Plantae includes plants which are multicellular, eukaryotic, photosynthetic and producers. The cell walls possess mainly cellulose. The plant body may be thalloid or differentiated into root, stem and leaves. They may be non vascular or vascular. They have two stages in their life cycle- a **haploid, sexually reproducing gametophytic generation** and a **diploid, asexually reproducing sporophytic generation**. The two generations alternate. This is called **alternation of generations**.

Kingdom Plantae

- **Thallophyta**
  1. Chlorophyceae
  2. Phaeophyceae
  3. Rhodophyeeae
- **Embryophyta**
  - Bryophyta
  - Tracheophyta
    - Pteridophyta
    - Gymnosperms
    - Angiosperms

Objectives

At the end of this unit, you should be able to:

- To know the characters of algae
- To know the criteria for classification of algae
- How differ algae from bryophytes
- Characters of pteridophytes
- Mention the various divisions in the classificatin of seeds plants
- Outline the meanings of gymnosperms and angiosperms
- Difference between gymnosperms and angiosperms

ALGAE

Algae is mostly aquatic, autotrophic photosynthetic and thallophytic. Their vegetative body is unicellular (*Chlamydomonas*), multicellular Colonial form (*Volvox*) or filamentous form (*Spirogyra*), thalloid form (*Sargassum*) and pseudoparenchymatous form (Ulva). They reproduce by vegetative (commonly fragmentation), asexual (spore formation) and sexual methods. Sexual reproduction involves fusion of similar gametes - **isogamy** (eg:- *Spirogyra)* or fusion between gametes of dissimilar in size - **anisogamy** (eg:- some species of *Chlamydomonas)* or one large non-motile female gamete and a small motile male gamete - **oogamy** (eg:-*Fucus, Volvox)*

The algae is divided into three classes based on the pigments–**Chlorophyceae**(Green algae) contain chlorophyl a.b. (e.g.*Chlamydomonas, Volvox,Ulothrix,Spirogyra;*) **Phaeophyceae** (Brown algae) contain chlorophyll a,c and fucoxanthin (e.g. *Ectocarpus, Dictyota, Laminaria);* **Rhodophyceae** (Red algae) contain chlorophyll a, d and phycoerythrin (e.g. *Polysiphonia, Porphyra)*

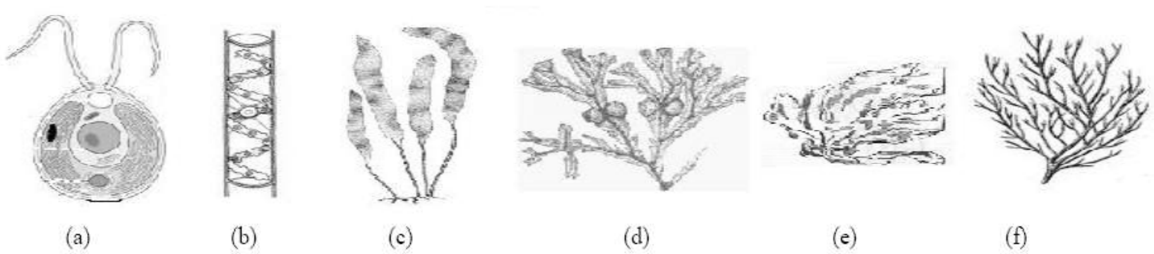


Fig: Algae : a) Chlamydomonas, b) Spirogyra, c) Laminaria, d) Fucus, e) Porphyra, f) Polysiphonia

BRYOPHYTES

The bryophytes generally called as liverwort, hornwort and mosses. They are called **amphibians of the Plant Kingdom because they live in moist soil but require water for sexual reproduction**. The dominant phase in the life cycle is haploid **gametophyte**. It may be a flattened thallus or differentiated into stem-like, root-like and leaf-like structures. The root-like structures are called **rhizoids.** The gametophyte bears sex organs called **antheridia** (male) and **archegonia** (female) which produce gametes called **antherozoids** and **eggs** respectively. The antherozoid fuses with the egg to produce **zygote**. The zygote produces a multicellular **sporophyte.** The sporophyte is dependent on the gametophyte. The sporophyte reproduces asexually by producing spores. Meiosis takes place during spore formation , hence they are haploid. The spores germinate to produce the gametophyte.

The bryophytes are divided into three classes – **Hepaticopsida** - Liverworts (e.g. *Riccia, Marchantia);* **Anthocerotopsida** - Hornworts (e.g. *Anthoceros, Notothylas);* **Bryopsida** - Mosses – (e.g. *Funaria, Sphagnum, Polytrichum)*

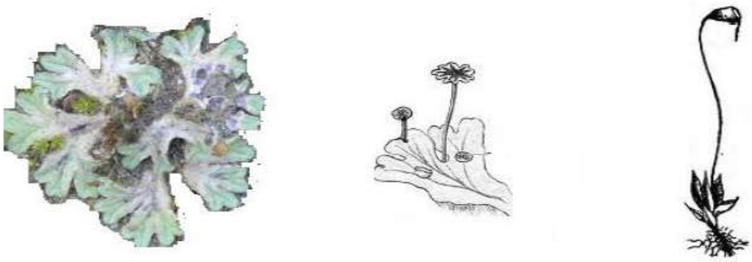


Fig: Bryophytes: (a) Riccia, (b) Marchantia, (c) Funaria

PTERODOPHYTES

They are the first land plants which possess vascular tissues i.e. **xylem** and **phloem**. The plant body is a **sporophyte** which is differentiated into root, stem and leaves. Majority of the pteridophytes produce only one kind of spores in sporangia and the plants are called **homosporous** (e.g.:- *Nephrolepis, Lycopodium*). Some produce two kinds of spores- megaspores (large) and microspores (small) such plants are called **heterosporous** (e.g.:- *Selaginella, Salvinia*). The spore germinates to produce free- living, photosynthetic, haploid gametophyte called **prothallus**. The sex organs- **antheridia** and **archegonia** are produced on the prothallus. Fertilization results in the formation of zygote which develops into sporophyte.

The pteridophytes are divided into four classes- **Psilopsida** - Whisk ferns (e.g.: - *Psilotum)*, **Lycopsida** - Club mosses (e.g.:- *Lycopodium, Selaginella)* **Sphenopsida** - Horse tails (e.g.:-*Equisetum)* and **Pteropsida** - Ferns (e.g.:- *Nephrolepis, Pteris, Adiantum)*

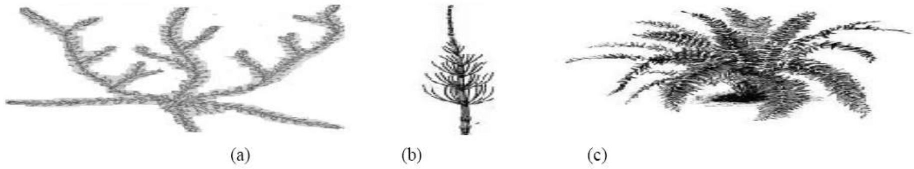


Fig: Pteridophytes: (a) Selaginella, (b) Equisetum, (c) Nephrolepis

Gymnosperms:

Gymnosperms are more advanced than the pteridophyata and primitive than the angiosperms. Under spermatophyta group gymnosperms and angiosperms clubbed together due to seed production. The term gymnosperms refers as (gymnos-naked, sperma-seeds) plants with naked seeds. Gymnosperms are the seed bearing, fruitless, heterosporous and autotrophic land plants. Mostly gymnosperms are perineal, evergreen woody plants ranges from medium to atall trees and shrubs. The sporophytic diploid adult plant body differentiated into root, stem and leaves. The root system consists of tap roots. The stem can be branched (eg. Pinus) or un branched (eg. Cycas). Leaves are simple or compound. During reproduction the microsporophylls and mega sporophylls are arranged to form compact male and female cones. Pollen grains are produced in microsporangia of male cone. Pollination is direct and pollen grains reach to ovule through the wind (anemophily). Ovules are not enclosed in ovary as in angiosperms, but are born directly on mega sporophylls of female cone. Single true fertilization takes place in the ovule. The fertilized ovule then develop into a seed. Endosperm is formed before fertilization and it is found in haploid (x) condition. Common examples: Pine (Pinus), Red wood (Sequoia), Cedar (Cedrus), Gnetum, Tuja

ANGIOSPERMS

These plants are called **flowering plants** which bear flowers and produce **fruit enclosing the seeds**. The plant body is a sporophyte which differentiated into underground root system and aerial shoot system. The flowers have male parts (stamens) and female parts (carpels).The anthers of the stamens produce pollen grains. The ovary of the carpel encloses ovules. A highly reduced haploid female gametophyte is called**embryo sac** develops inside the ovule. The pollen grain germinates to produce the male gametophyte (pollen tube) containing two male gametes which are released into the embryo sac. Out of two, one gamet fuse with egg cell (Syngamy) to form zygote and other sperm cell fuse with Secondary Nucleus is called Triple Fusion. The above two fertilizations are called double fertilization. After fertilization the ovary develops into fruit and the ovules develops into seeds.

Angiosperms are divided into two classes-**Dicotyledonae** (eg:- Mustard, Bengal gram etc) and **Monocotyledonae** (eg:- Grasses, Coconut etc)

SUMMARY

Plant Kingdom includes Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms. Algae is mostly aquatic, simple , photosynthetic, thalloid forms. They are classified into Chlorophyceae, Phaeophyceae and Rhodophyceae. They reproduce vegetatively by fragmentation, asexually by spore formation and sexually by isogamy, anisogammy or oogamy.

Bryophytes are amphibians of plant kingdom. Dominant phase of their life cycle is a haploid gametophyte which is simple thallus or having root-like, stem-like, leaf-like structures. They are attached to the substratum by rhizoids. The gametophyte bears sex organs-antheridia (male) and archegonia (female) which produce antherozoids and eggs respectively. The male and female gametes fuse to produce a diploid zygote which develops into the sporophyte. The sporophyte produces haploid spores which germinate to form gametophytes. Pteridophytes possess well differentiated sporophyte with root, stem and leaves. The sporophyte bears sporangia which produce spores. The spores germinate form an independent gametophyte. The gametophyte bears male and female sex organs. The male and female gametes fuse to produce a zygote which produces sporophyte.

Gymnosperms are naked seeded plants. The plant body is a sporophyte. The spores are of two types- megaspores and microspores. Megaspores produce female gametophyte and microspores produce male gametophyte. After fertilization the ovule develop into seed.

Angiosperms are flowering plants bearing flowers having male parts (stamens) and female parts (carpels). The anther of the stamen produces haploid pollen grains. In the ovary of the carpel, ovules are present. The female gametophyte (embryo sac) develops within the ovule. The pollen grain produces a pollen tube which releases two male gametes. It fuses with egg cell and secondary nucleus.

INTEXT QUESTIONS

1. What does the term thallus means?

2. Mention two sex organs of bryophytes.

3. Which group of plants considered as first land plants

4. Differences between gymnosperms and angiosperms.

5. Name any two common examples of Gymnosperms.

6. Define alternation of generations.

7. Define prothallus.

ANIMAL KINGDOM AND CLASSIFICATION

There are over 9 million different kinds of animals present on earth. Of these about 1,250,000 types of animal species are identified and are known today. The identified animals, five percent are chordates; animals with a vertebral column or backbone, and the rest are invertebrates. Among the invertebrates, arthropods are the most abundant, which are followed by mollusks

The classification of the animal kingdom is based on certain principles and guided by a set of rules. Some 500 years ago people classified the animals on the basis of similarities. As the science of taxonomy advanced and various branches of zoology progressed, classification was based on morphology, embryology, life-histories, behavior and physiology. After the advent of genetics, molecular biology, biochemistry, serology and allied sciences, also constituted essential aspects of classification

1) Taxonomy

According to **Simpson,** 'taxonomy' is the study of classification, including its basic principles and rules. These principles and rules were first proposed by Op de Candolle in 1813 for plant classification. Later on these were adopted for the classification of animals also. Taxonomy has three aspects.

They are (1) **identification** (2) **classification** and (3) **nomenclature**.

1) **Identification**: Identification of species by their external and internal morphological characters

2) **Classification**

   It is the orderly grouping of animals into groups or sets on the basis of their relationships.

3) **Nomenclature**

   It is the application of distinctive names to each of the groups recognized in classification. This has been defined as the scientific study of the kinds and diversity organisms and of relationships among them.

Taxonomic hierarchy

All major groups of animals can individually be divided and subdivided into smaller and smaller sub-groups. To facilitate the position of an individual animal it has been arranged in categories of different grades.

Carolus Linnaeus (1606 - 1668) was the first taxonomist who recognized only five categories. They are **class, order, genus, species and varieties**. But in the course of time it was modified a n d the following categories are accepted**: Kingdom, Phylum, Class, Order, Family, Genus, and Species.** How a given animal is categorized into these divisions is given below for a few animals.

This can be applied to all the animals

Kingdom	Animalia	Animalia	Animalia	Animalia
Subkingdom	Metazoa	Metazoa	Metazoa	Metazoa
Phylum	Chordata	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Amphibia	Insecta
Order	Primates	Carnivora	Anura	Orthoptera
Family	Hominidae	Canidae	Ranidae	Blattidae
Genus	*Homo*	*Canis*	*Rana*	*Periplaneta*
Species	*sapiens*	*familiaris*	*tigrina*	*Americana*

All the animals apart from their common names are known by their scientific names. This is a **universal method** which was developed and practiced by taxonomists. Each kind of animal has a scientific name and it is used all over the world by scientists. Before we go any further, it is better if we define the terms genus and species, as they will be frequently used in our animal descriptions.

Kingdom

This is the largest unit of classification. Initially it was thought that there were only two kingdoms: Plant Kingdom and Animal Kingdom. Eventually microscope and other tools helped clarify the existence of other organisms.

Now, there are a total of 5 kingdoms.

- Animalia - The largest with over 1 million named species.
- Plantae - 350,000 species.
- Fungi - 100,000 species.
- Protista - 100,000 species, green, golden, brown, and red algae, flagellates;
- Monera - 10,000 species, blue-green algae or cyanobacteria.

Phylum / Division

The next most specific unit of classification is Phylum. This further divides the kingdom into divisions based on very distinct and defining characteristics. For example, within the Animal Kingdom, a major division is chordata which includes animals with notochord.

Class - This is the next stage of classification. It separates them into categories that make them very similar in terms of certain basic features.

Order - Organisms of the same order are more similar than those in the same class..

Family - Even more specific, the animals within a family share many similarities between each other. Most will probably have the same behavior patterns, feeding habits, and general functions.

Genus - This is the part that makes up the first word of the binomial nomenclature of an organism. All the organisms within their genus may look very similar to each other. The term genus (plural: genera) was coined by English naturalist, John Ray (1626-1605).

Species - The species is the basic unit of taxonomic classification of all animals and plants. It is the most important category in the taxonomic hierarchy.

Definition of species may be that they are group of animals which always breed true, in the sense that they never produce individuals other than, their own. Species have also been defined by Mayr in 1942 'as a population of interbreeding individuals which recognize each other as potential mates for the purpose of reproduction'.

Species is a dynamic group of organisms which resemble each other in all essential respects, differ visibly from all other groups, interbreed freely under natural conditions to produce offspring and are reproductively isolated from other groups and share a common gene pool (sum total of genes present in a species is called gene pool). classification of the animal kingdom is advocated by Hyman (1940).

The animal Kingdom is divided into two major groups- The Sub- Kingdoms, Protozoa and Metazoa. The basic difference is that the former one is unicellular and the latter is multicellular. However, in recent years, because of some unique characters, protozoa is being considered as an individual kingdom – Protista. Modern zoologists start the classification of animal kingdom with metazoan. The Metazoa is further divided into two branches- Parazoa and Eumetazoa (true metazoa)

Animals in the Parazoa are multicellular animals but have a low level of body organization and tissues are not organized to organ level. Sponges which are the animlas included in phylum porifera are typical examples for parazoa. Eumetazoa are further divided into two grades or groups Radiata (or Diploblastica) and Bilateria (or Triploblastica). Those animals which are radially symmetrical and have two layers in their body wall (ectoderm and endoderm)are included into Radiata or Diploblastica. Animals belonging to phylum Coelenterata (likeHydra) are members of this group. Animals, which exhibit bilateral symmetry and have threelayers in their body wall (ectoderm, mesoderm and endoderm) are included in Bilateria orTriploblastica. Bilateria is further divided into three dvisions based on the nature of the coelom they have in their body. These are Acoelomata (no Coelom), Pseudocoelomata (false coelom) and Coelomata (those having true coelom). All the animal phyla are included into one of these three divisions.

Animal kingdom

Protozoa
Ex. 1.Phylum Protozoa

subkingdoms

Metazoa

Parazoa
Ex. 2.Phylum Porifera

Branches

Eumtazoa

Radiata
Diploblastica
Ex.3.Coelentarata (Cnideria)

Bilateria
Triploblastica

Division

Acoelometa
Ex.4.Phylum Platyhelminthes

Pseudocoelomata
Ex.5.Phylum
Aschehelminthes

Coelomata
Ex.6. Phylum Annelida
7. Phylum Arthropoda
8 Phylum.Mollusca
9.Phylum Echinodermata
10. Phylum Chordata

PHYLUM PROTOZOA

The animal kingdom is divided into 2 main groups unicellular and multicellular. Unicellular group has only one branch, protozoa. Multiicellular group is further divided according to the cellular organization into many invertebrates and vertebrates. The scheme for the classification of protozoa was introduced by Hymen in 1940. In recent years, the protozoa is included into the kingdom protista along with the algae and fungi to avoid confusion. However, the following classification is based on the old system of conventional classification.The conventional classification of protozoa is based on the mode of locomotion and the patterns of sexual and asexual reproduction. The phylum protozoa is divided into two subphyla - plasmodroma and ciliophora. The subphylum plasmodroma is divided into four classes while ciliophora has only one class. All the protozoans in the subphylum ciliophora, as the name indicates, perform their motor activities with the help of cilia.

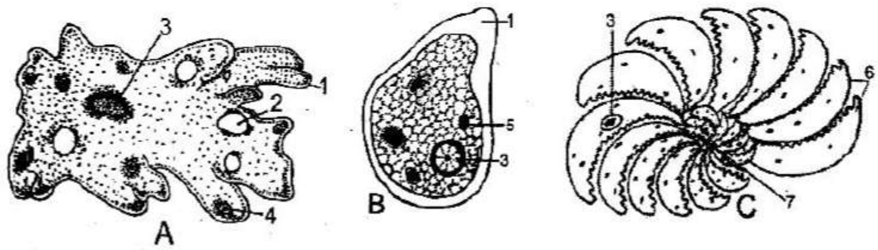
The cili are absent in the plasmodroma.

PHYLUM	Protozoa	
SUB PHYLUM	Plasmodroma	Ciliophora
CLASS	Sarcodina, Mastigophora, Opalinata, Sporozoa	Ciliata

1. Class Sarcodina (G. Sarcodes: Fleshy)

1. Animals of this class are found in fresh water, sea water and in moist soil.
2. Their body is naked; some of the animals in this class have a test or a shell around body. Firm pellicle is absent.
3. Majority of these animals are free living while some lead a parasitic life and holozoic. nutrition
4. The animals in this class use pseudopodia for locomotion and food capture.
5. Asexual reproduction is by binary fission, multiple fission, spore formation and budding and Sexual reproduction is by syngamy.

More than 8,000 spieces have been identified.These are subdivided into 2 subclasses (Rhizopoda and actinopoda) and many orders



Ex: Amoeba, Entamoeba, Arcella, Elphidium or polystomella.

Fig. (A) Amoeba, (B) Entamoeba, (C) Polystomella. 1.Pseudopodium 2.ContractileVacuole 3. Nucleus 4. Food vacuole 5.Food vacuole with RBC 6. Shell chambers 7.Proloculum

2. Class Mastigophora (G.Mastik: Phoros: bearings) or Flagellata (L. Flagrum : whip)

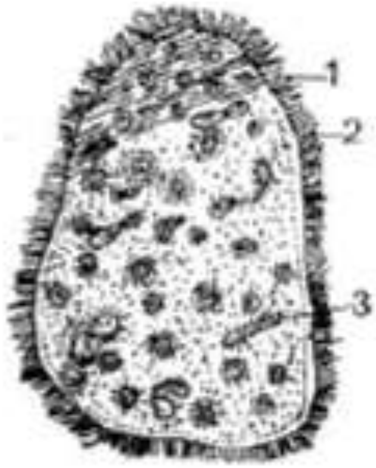
1. Both free living and parasitic forms are present in this class and are usually called as Flagellates , found in fresh water, sea water and moist soil
2. Body with a definite shape, covered by a thin firm pellicle or test made of cellulose or chitin or silica particles.
3. Animals in this class may have one or more flagella for locomotion and for food capture
4. These animals have a monomorphic nucleus. .
5. Nutrition is holophytic (autotrophic), holozoic (hetrotrophic), saprozoic or mixotrophic.
6. Sexual reproduction occurs in some groups by syngamy

About 2,000 species are present in this class. They are included into two subclasses (which are identified by the mode of their nutrition) – Phytomastigina (Ex: Euglena, Autotrophic animals) and Zoomastigina (Ex: Mastigamoeba, Holozoic animals).

Fig : (A) Euglena, 1. Flagellum. 2. Contractile vacuole. 3. Nucleus 4. Paramylum bodies 5. Pellicle

3. Class Opalinata

1. Protozoans in this class are endoparasites (live in the body of the host) They are found in the rectum of cold blooded vertebrates (frogs and toads)
2. The body is completely and uniformly ciliated and they have two or more nuclei
3. Saprozoic(saprophytic) mode of nutrition occurs-they transport the nutrients from the surrounding medium into the cell
4. Asexual reproduction is by binary fission and, sexual reproduction by gametes.
5. Undergo encystment during the breeding season of host.

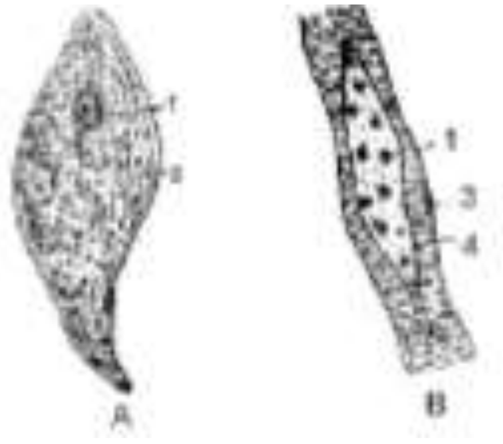


Ex: Opalina

Fig : Opalina. 1. Cilia. 2. Pellicle. 3. Nucleus.

4. Class Sporozoa (G.Spora :seeds: zoon : animal)

1. The class consists exclusively of internal parasites in vertebrates,arthropods,worms and Mollusks Their body is coverd with a thick pellicle. Nutrition by saprozoic(may also be holozoic)
2. Locomotory organelles, cytostome and vacuoles are absent.
3. Asexual reproduction is by multiple fission.
4. Sexual reprodution is by spore formation and syngamy, where infective stages of the life cycle called the sporozoites are formed.
5. Life cycle shows, 'alternation of generations' Over 2,000 species are known – grouped into 5 subclasses and 10 orders.



Ex: Monocystis,plasmodium,sarcocystis etc.

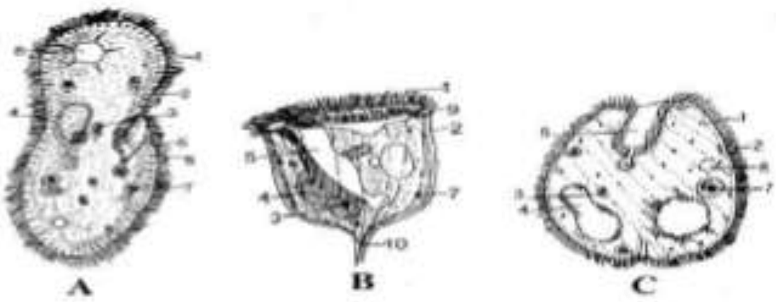
Fig: (A) Monocystis (B) Sarcocystis

1. Nucleus 2. Myoneme 3. Muscle fibre. 4. Host

5. Class Ciliata or Infusoria

1. This is the only class in the subphylum ciliophora. these animals is the presence of cilia on their body surface. Hence the name ciliata. The body is covered by a firm pellicle. Cilia are used both for locomotion and food capture. These are found in fresh water or seawater.
2. Majority of these animals are free living (sedentary or colonial) while a few of them are parasites. Holozoic mode of nutrition
3. Two types of nuclei are present. The large macronucleus regulates the vegetative activities of the cell while the small micronucleus participates in sexual reproduction.
4. Asexual reproduction is by transverse binary fission or budding.
5. Sexual reproduction is by conjugation and autogamy.

About 5,000 species are known – grouped into 4 subclasses and 15 orders. Their classification is based on the arrangement of cilia



Ex: Paramoecium, Vorticella, and Balantidium
Fig : (A) Paramoecium (B) Vorticella (C) Balantidium 1. Cilia 2. Pellicle 3. Micronucleus. 4.Macronucleus 5. Vestibule 6. Trichocyst 7. Food vacuole 8. Contractile vacuole 9.Collar 10. Stalk

PHYLUM PORIFERA

Introduction

Phylum Porifera (L. porous: pore: ferra: to bear) marks the beginning of the evolution of multicellular animals. The group constitutes plant-like animals that are incapable of movements. Their body organisation is higher than protozoa. But when compared to other Metazoa, they are simple and most primitive. They do not possess well-defined tissues and organs. Studies on the histology, cytology and embryology confirmed that these are animals with a low level of organization. As a result, they have been given a separate status of a phylum and some scientists prefer to call these animals as “parazoa”. Porifera includes about 9000 species of which 4000 are extinct species.

General characters of Porifera

1. They are all aquatic and mostly occur in sea water and are found attached to some substratum. Only one family of sponges are found in fresh water – spongillidae.
2. Body shape is variable. – vase – like, cylindrical, globular (in all these cases body is symmetrical) or irregularly branched without symmetry.
3. They may be found as solitary animals or as colonial forms where a group of sponges exists as a colony. . No organs for locomotion in the adults are present. All the adults are sedentary
4. All the members of this phylum are multicellular and diploblastic (having two layers of cells in the body). Outer layer is called dermal layer (pinacoderm). The inner layer is known as flagellated layer (Choanoderm), it consists of flagellated cells called choanocytes which are characteristic feature of Phylum Porifera.
5. Large number of pores, canals or chambers are present in the body, through which the water current flows into and out of the body cavity.
6. Body is supported by a skeleton made up of rods of different shapes called spicules. Spicules are made of either calcium or silica. Fibres, made of an elastic material called, Spongin, hold the spicules in position.
7. There is no mouth or alimentary canal. Digestion is intracellular and nutritional mode is holozoic.

8. Asexual reproduction is by budding by a special cell masses called genunules.
9. Sexual reproduction is by the production of eggs and sperms. A free swimming larva is found in the life cycle.
10. Sponges have great capacity for regeneration.

Phylum Porifera comprises three classes. They are :

1. Calcarea
2. Hexactinellida
3. Demospongia

Class 1 : Calcarea or Calcispongiae

1. This class consists of marine sponges inhabiting shallow waters.
2. Their skeleton is made up of calcareous spicules. Body is radially symmetrical and vase shaped.
3. Body surface is bristly due to projecting spicules.
4. Asexual reproduction is by budding. A free-swimming larval stage is present in the life cycle.

   E.g. Sycon, Grantia, Leucosolenia

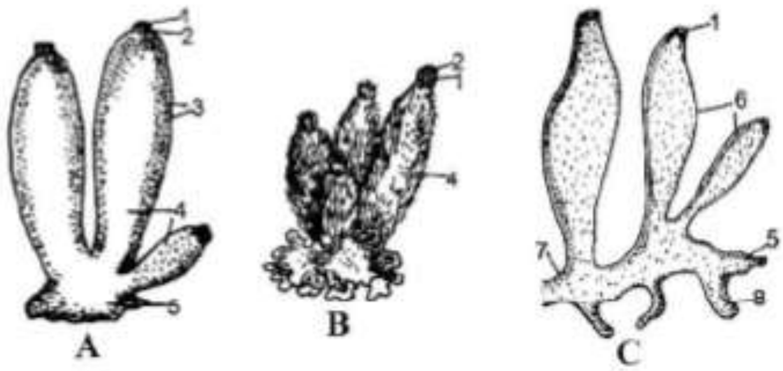


Fig.: Sponges – (A) Sycon (B) Grantia (C) Leucosolenia 1. Osculum 2. Oscular fringe. 3. Ostia 4. Cylinder 5. Base 6. Vertical tubes 7. Horizontal tube 8. Adhesive disc.

Class 2. Hexactinellida or Hyalospongiae

1. Hexactinellidans found in deep sea, at depths of 300 feet to three miles.
2. These are commonly known as glass sponges. The skeleton is made up of hexactinal siliceous spicules found either separate or in networks.
3. Body wall lacks epidermal cells and mesenchymal matrix. The latter is made up of a network of strands formed by the union of branching pseudopodia of the amoebocytes.

4. The canal system is simple.
5. Budding is the mode of asexual reproduction. Larva is called sterogastrula.
6. Class Hexactinellida comprises a few economically important sponges like Euplectella and Hyalonema. Dried Skeleton of Euplectella is a costly marriage gift in Japan.

   Hyalonema is beautiful decorative sponge.

   Ex.: Hyalonema, Euplectella, and Pheronema

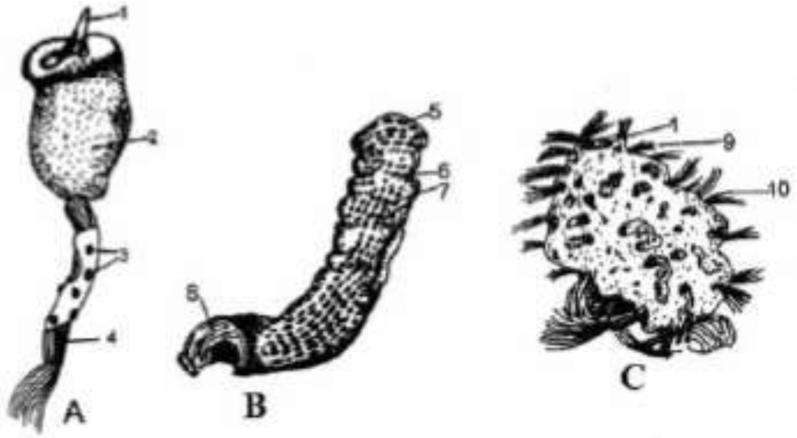


Fig: Sponges – (A) Hyalonema (B) Euplectella (C) Pheronema 1. Gastral cone 2. Body 3. Symbiotic polyps 4. Root spicules 5. Oscular sieve 6. Parietal gaps 7. Marginal prostals 8. Pleural prostals 9. Stick 10. Cups of corals

Class 3 : Demospongia

1. The Demospongia are most abundar in their occurrence when compare to other sponges, with a wid distribution. About 80% of th members of phylum Porifera belon to this class.
2. Skeleton, when present, is o siliceous spicules and sponging fibres.
3. Canal system is complicated.
4. Asexual reproduction is by internal buds called gemmules. Larva is a sterogastrula

   E.g.: Spongilla, Cliona, and Chalina.

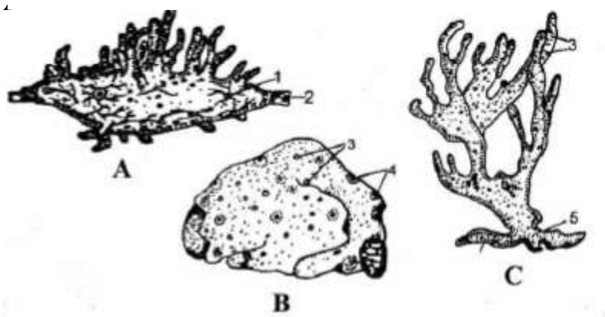


Fig: Sponges – (A) Spongilla (B) Cliona on a piece of coral (C) Chalina 1. Osculum 2. Stick 3. Ostia 4. Cups of coral 5. Base.

PHYLUM CNIDARIA (COELENTERATA)

General Characters

1. Cnidaria are multicellular animals. All are marine except a few fresh water forms. All the adult Cnidarians exhibit radially symmetry.
2. Some animals have either an exoskeleton or an endoskeleton. The skeleton may be made of inorganic or organic matter.
3. The outer ectoderm and inner gastrodermis are separated by a jelly like mesoglea. In some animals (like in hydra) mesoglea is very thin while in some animals (like jelly fish) it forms the bulk of the animal.
4. The gastrodermis encloses a cavity – gastrovascular cavity or coelenteron. This cavity is not similar to coelom–hence these animals are acoelomate animals. This cavity participates in gaseous exchange (respiration), digestion and excretion. So, these animals do not have definite excretory, respiratory and circulatory systems.
5. Tentacles are provided with nematocysts – (stinging cells). They help in capturing food and in defending from other animals. Most of these animals are passive feeders – they feed on the food particles which come in contact with their tentacles. They do not go in search of food.
6. Digestion is both intracellular and extracellular.
7. Nematocysts have a long whip like thread. These are secreted by the Golgi complex of specialized cells called cnidoblasts. Technically speaking, nematocyst is not an organelle but a complex secretory product.
8. Nervous system is primitive consisting of diffuse network of nerve cells.
9. These animals exist in two morphological forms – the asexual sessile polyp form and sexual free swimming medusa form. Some of these animals exhibit either one of these forms while most of the animals in this phylum exhibit both these forms.
10. Asexual reproduction is by budding and sexual by the formation of ova and sperms.
11. Some animals are hermaphrodites while in other sexes are separate.

12. These animals show alternation of generation or metagenesis. Sexual free swimming medusoid generation alternates with asexual and sessile polyp generation.

13. The larva is usually a planula larva.

The phylum cnidaria comprises three classes.

They are 1. Hydrozoa, 2. Scyphozoa, 3. Anthozoa or Actinozoa

Class: Hydrozoa

1. There are colonial forms which instead of remaining fixed, swim or float freely on the surface of ocean. Such pelagic forms are always found to exhibit a remarkable degree of polymorphism, having the zooids of various forms performing diverse functions.

2. There are two types of zooids – Gastrozooids and Blastozooids (or Gonozooids). Gastrozo oids are more in number.

   The Blastozooids are modified zooids for asexual reproduction. They produce medusae which in turn produce gametes.Body is radially symmetrical in all the animals.

3. Body wall is diploblastic, consisting of ectoderm and endoderm. Space between the ectoderm and endoderm is filled with non-cellular gelatinous mesoglea. Epidermisconsists of muscle cells, interstitial cells, sensory cells, gland cells and nerve cells.

   Epidermis secretes a horny cuticle called perisarc. In some of hydrozoans, the perisarc is calcareous and forms a hard stone like structure called coral.

4. Animals in this class have characteristic organs of offence and defense called stinging cells or nematocysts.

5. Gametes are haploid and fuse to form a diploid zygote. Fertilization may be internal in the medusa or external in the sea water.

6. The fertilized egg develops into a ciliated planula larva, then into a hydrula larva. This larva metamorphoses into a hydroid form. Medusoid forms are never produced form the fertilized egg.

   Ex. Obelia, Physalia, Millepora, Porpita

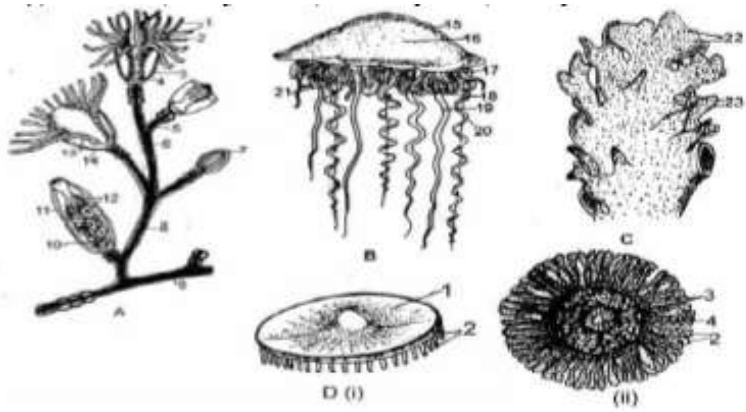


Fig: Hydrozoans – (A) Obelia 1. Tentacles, 2.Hypostome. 3.Hydrotheca. 4.Shelf 5.Perisare. 6.Coenosare.7.Bud 8.Hydrocaulus. 9.Hydrorhiza. 10.Blastostyle. 11.Gonotheca. 12.Developing medusae buds. 13.Hydroid. 14.Hydrotheca., (B)Physalia – 15.Sail. 16.Pneumatophore. 17.Smaller dactylozooid. 18.Gastrozooids. 19.Larger dactylozooid. 20.Tentacle bearing nematocysts. 21.Gonozooids.,(C) Millepora – 22.Gastropores. 23.Dactylopores., (D) Porpita. (i) Dorsal View, (ii) Ventral View – 1.Pneumatophore. 2.Dactylozooids. 3.Gonozooids. 4.Large Central gastrozooid.

Class : Scyphozoa

1. Animals in this class are known as Jelly fishes and all of them are of medusa form. Medusoid form is the dominant form.
2. Gastro-vascular cavity may or may not be divided by septa into four inter-radial pouches.
3. Gametes are produced by the medusae which are dioecious and the sperms are released into gastrovascular cavity and they are carried out by water.
4. The male gametes enter into another animal along with water current.
5. The ova when ripe are shed into the gastrovascular cavity.
6. Fertilization may be internal or external. If it is internal, it occurs in the gastrovascular cavity of female.
7. The zygote is released from gastrovascular cavity and lodges itself in the grooves of oral arms and develop into ciliated planula larva.
8. Planula later develops into a greatly reduced polyp stage called scyphistoma.
9. Scyphistoma produces medusae directly or by a process of terminal budding or transverse fission called strobilation.

10. The medusae produced by scyphistoma are called Ephyrae (singular: Ephyra) which develop into adult animals.

    Ex. Aurelia, Rhizostoma

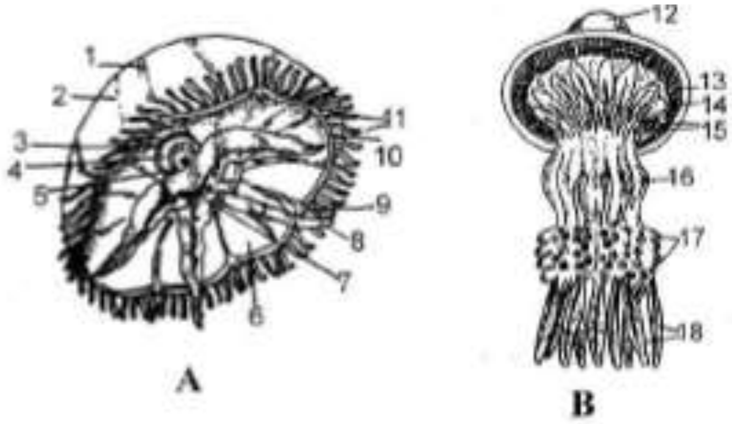


Fig: Scyphozoans – (A) Aurelia, (B) Rhizostoma, 1.Perradial canal. 2.Adradial canal. 3.Gonad. 4.Gastric filament. 5.Sub-genital Pit. 6.Subumbrellar Surface. 7.Mouth. 8.Oral arm. 9.Tentaculocyst. 10.Circular canal. 11.Marginal tentacles. 12.Exumbrella. 13.Rhopalium. 14.Coronal muscle. 15.Scapulets. 16.Mass of Oral arms. 17.Suctorial mouths. 18.Appendages.

Class: Anthozoa

1. They exist in polyp form. Medusa stage is not known in this class.
2. Body is cylindrical in shape with biradial symmetry and body wall is triploblastic in nature. The mesoglea is well-developed and has fibrous connective tissue and cells. It separates the endoderm and ectoderm.
3. Gastro-vascular cavity of Anthozoa differs from the Hydrozoa in having stomodaeum and radiating mesenteries or vertical radiating partitions. The mesenteries bear coiled mesenteric filaments or gastric filaments.
4. The muscular system is well developed. It consists of the processes of epitheliomuscular cells of both ectoderm and endoderm.
5. The fertilized egg develops into a planula which after a short free existence settles down and undergoes metamorphosis into adult.

    Ex. Pennatula (Sea pen), Corallium (Red coral), Alcyonium (Dead man's finger)

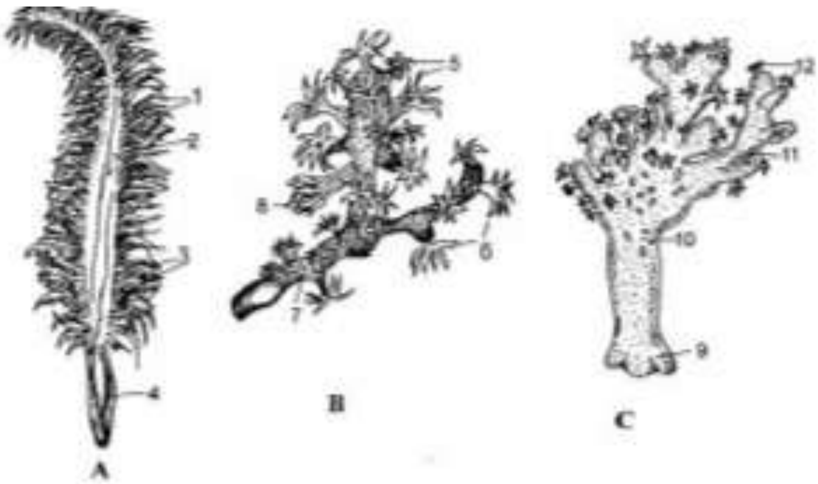


Fig: Anthozoans – (A) Pennatula, (B) Corallium, (C) Alcyonium, 1. Pinnules or leaves 2. Rachis 3. Zooids 4. Peduncle 5. Pinnate tentacles 6. Expanded anthocodia 7. Coenenchyme 8. Retracted anthocodia 9. Base 10. Stalk 11. Lateral branch 12. Polyps.

PHYLUM PLATYHELEMINTHES

General Characters

1. Platyheleminthes are triploblastic bilaterally symmetrical, acoelomate metazoans.
2. These are called flat worms because they are dorsoventrally flattened.
3. These are free-living and parasitic.
4. Some parasites have chitinous hooks and suckers for attachment.
5. The space between the various organs is filled with a special connective tissue called parenchyma.

The classification of phylum Platyhelminthes is a subject of controversy. Some investigators classify this phylum into three classes, some into four and some into five classes. Animals belonging to the groups monogenea and digenea are given the status of class by some investigators while others consider them as orders in the existing three classes. Yet others consider monogenea as a separate order but not digenea. The reason for this discrepancy is due to polyphylitic origin of Platyhelminthes. This means that these animals have not evolved from a common ancestor but different groups have evolved from different phyla.

The phylum Platyhelminthes comprises of three classes. They are :

(1) Turbellaria, (2) Trematoda, (3) Cestoda.

Class : Turbellaria

1. These are mostly free- living, occur in moist soil, fresh water and sea. Some are pelagic forms while others live in the mud and sand of the ocean floor. Body may be slender, leaf-like, round or oval in shape, bilaterally symmetrical and unsegmented.
2. The anterior end is differentiated into "head".
3. Alimentary canal consists of ventral mouth, protrusible pharynx and intestine. In some of the turbellarians, the intestines are extensively branched while in small animals it is entirely absent.
4. With rare exceptions all Turbellaria are hermaphrodites.Development is direct with Juvenile form. Occasionally a free-swimming larva is present. .
5. Some Turbellarians are commensals or parasites.

   Ex: Planaria, Temnocephala

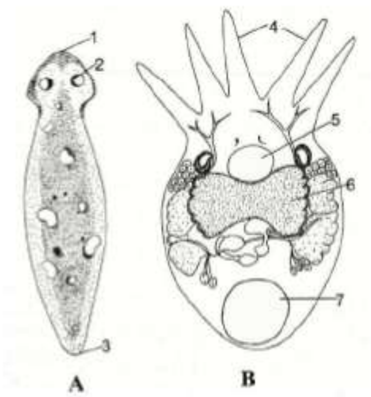


Fig: Turbellaria. (A) Planaria. (B) Temnocephala.

1 .Anterior end.2.Eye. 3.Posterior end. 4.Tentacles. 5.Pharynx. 6.Intestine. 7.Sucker.

Class : Trematoda

1. Adults are ecto- or endoparasites in other animals.
2. These animals are endowed with either suckers or hooks or both to get a hold and attach themselves to the tissues of the host animal.

   There are two suckers — oral sucker near the mouth and ventral sucker at the posterior end.
3. A primitive circulatory system is present in several of these animals.
4. Protonephredia are the excretory organs.
5. Nervous system is simple having a pair of cerebral ganglia and longitudinal nerve cords with transverse connections.

6. Reproductive system is well developed with two to many testes but a single ovary. Both testes and ovary are highly branched.
7. Life history is complicated having two or more hosts.

   Ex. Fasciola hepatica, Aspidogaster, Schistosoma, Paragoninus

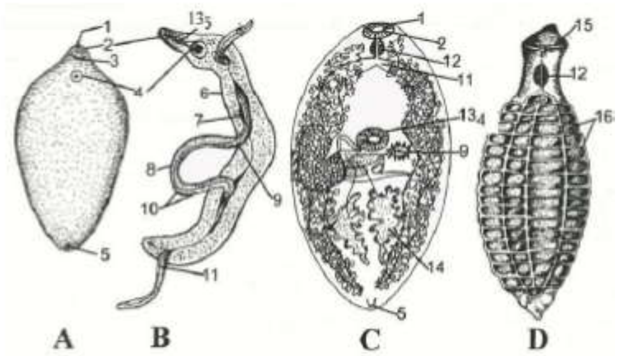


Fig: Trematoda.(A) Fasciola hepatica, (B) Schistosoma,

(C) Paragonimus, (D) Aspidogaster.1.Mouth.2.Oral sucker. 3.Gonopore. 4.Acetabulum. 5.Excretory pore. 6.Male. 7.Gynaecophoric canal. 8.Female. 9.Ovary. 10.Vitellaria. 11.Intestine. 12.Pharynx. 13.Oesophagus. 14.Testis. 15.Mouth funnel. 16.Alveoli.

Class : Cestoda

1. These are commonly called as tapeworms because of their flat ribbon like form.
2. Three distinct divisions can be identified in the body of tape worm — scolex, neck and strobila.
3. The body after the neck is called strobila and is divided into a large number of segments called proglottids. The proglottids at the anterior end are small and narrow while those at the posterior end are broad. The number of proglottids may vary from 4 to 4000.
4. With few exceptions, the anterior portion of the body is differentiated into a head-like structure called scolex. Scolex is not a true head - as it has no sense organs and mouthit is only an anchoring organ which helps to keep the parasite in position in the tissues of the host.
5. A narrow neck is present immediately after the scolex.
6. Digestive system is absent in tapeworms.
7. Excretory system consists of flame cells which open into canals. These canals travel all along the body of the animal.

8. Nervous system consists of a pair of ganglia in the form of a ring in the scolex and two lateral longitudinal nerve cords that travel all along the length of the animal.

9. Self-fertilization takes place.

10. A characteristic onchosphere(six hooked) stage is seen during development.

11. The life-cycle in different species of this class involves one or more intermediate hosts..

    E. g. Taenia, Diphyllobothrium, Echinococcus

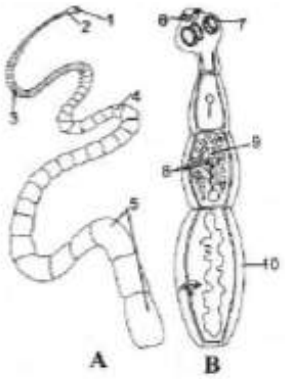


Fig: cestoda.(A) Taenia. (B) Echinococcus. 1.Scolex. 2. Neck. 3.Proliferating proglottids. 4. Young proglottids. 5.Gravid proglottids. 6.Hooks. 7. Sucker. 8. Genital opening. 9. Branched uterus. 10. Gravid proglottid.

PHYLUM ASCHELMINTHES

The name Aschelminthes was proposed by Grobben (1910).

1. These are bilaterally symmetrical, triploblastic, pseudocoelomate metazoans with a cylindrical worm like body.

2. Body is covered with thick flexible cuticle. Cuticle often bears spines, bristles.

3. Digestive tract is a straight tube from mouth to anus without musculature except the pharynx, which is well developed and muscular. This is a peculiar feature as the propulsion of food in the gut is aided by contraction of gut muscles in all the other animals. It is not known how the food is propelled in the gut of these animals.

4. Respiratory and circulatory systems are absent.

5. Excretory system consists of canals and protonephridia.

6. Sense organs consist of ciliated pits, papillae, bristles and eye spots.
7. Mostly dioecious i.e., sexes are separate. Males are usually smaller than females. Gonads are single or double. Eggs are microscopic with chitinous shell.

The phylum Aschelminthes comprises five classes :

(1) Nematoda, (2) Nematomorpha, (3) Rotifera, (4) Gastrotricha and (5) Kinorhyncha.

1. Class : Nematoda

1. Nematodes are popularly known as round worms. They are bilaterally symmetrical, triploblastic pseudocoelomate metazoans.
2. These animals live in moist soil, fresh water, sea water, and either as free-living or as parasites on plants and animals.
3. Nematoda includes species infecting food crops, domestic animals and man and as such one of the most important of the parasitic group of animals.
4. The digestive tract is straight and consists of mouth, buccal cavity, oesophagus, pharynx and intestine. The pharynx is muscular and has a triradiate lumen. There are no muscles in the intestine.
5. Respiratory and circulatory systems are absent. Nervous system comprises a circumpharyngeal ring with attached ganglia and six anterior and six posterior nerves. Special sense organs, amphids(anterior sense organs), Phasmids(posterior sense organs) and papillae are present in the head and tail regions.
6. The excretory system is different in different species of this phylum.
7. Hermaphroditic and parthenogenetic forms are also known.
8. Fertilization is internal. Development is indirect with at least four larval stages. The fourth larval stage is usually infective stage.

Examples :

1. Ascaris lumbricoides - round worm.
2. Enterobius vermicularis - seat worm or thread worm.
3. Ancylostoma aduodenale - old world hook worm.
4. Necator americanus - new world hook worm or American killer

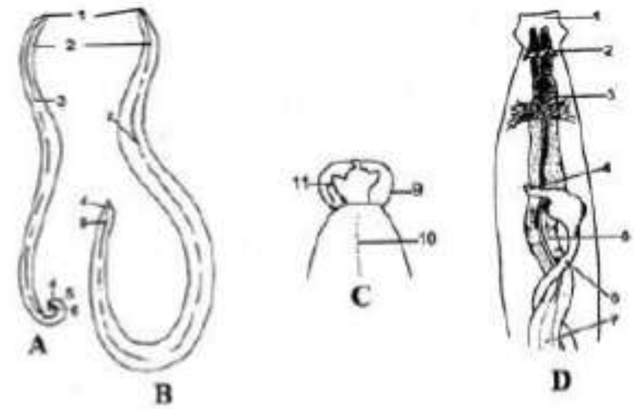


Fig: Ascaris lumbricoides (A) Male. (B) Female (C) Anterior end - dorsal view. 1 .Mouth. 2.Genital pore. 3.Lateral line. 4.Curved tail. 5.Cloaca. 6.Penial spicules. 7.Female genital pore. 8.Anus. 9.Dorsal lip. 10.Dorsal line.11 .Papillae. (D) Wuchereria bancrofti - female,anterior part 1 .Mouth. 2.Nerve ring. 3.Pharynx. 4.Vulva. 5.Pharynx. 6.Vagina. 7.Intestine.

2. Class : Nematomorpha

1. Another name for this class is Gordiacea but the common name for these animals is horse hair worm. This is a small class of very long animals (10 mm to more than 1 meter) which superficially resemble Nematodes.
2. Animals in this class differ significantly from other classes of this phylum by the presence of cloaca in both sexes.
3. The digestive system is well developed in larval stages but degenerate to various extents in adult animals. The adult worms do not feed - reproduction is their major function.
4. Circulatory, respiratory and excretory systems are absent.
5. Sexes are separate with paired gonads and gonoduct.
6. Fertilization is external and the egg develops into a larva known as Gordid larva.
   Ex: Nectonema, Paragordius tricuspidatus.

3. Class :Rotifera

1. Animals in the class Rotifera are found in fresh water ponds lakes and some are found in the sea. Majority of these animals are free living and very few of them are parasites.

2. Body is bilaterally symmetrical and unsegmented and is divisible into head, trunk and tail. They are known as "wheel animalcules" because the anterior end of the body bears a ciliary apparatus- Corona.
3. Excretory system consists of flame cells.
4. The nervous system is simple with a single, ganglion without any nerve cords. Eye spots are usually present.
5. Reproduction is sexual as well as parthenogenetic. Both ovo-viviparous and viviparous conditions are seen in these animals.
6. No larval stages are present during development.

   Examples :Brachionus rubens, Epiphanes senta, Asplanchna, Chonchilu

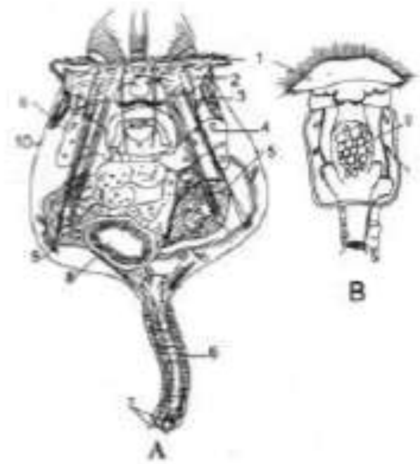


Fig: Brachionus rubens - (A)Female (B)Male. 1. Trochal disc. 2.Brain. 3.Nephridial tube. 4.Pharynx. 5.Germarium. 6.Tall. 7.Toes. 8.Intestine. 9.Stomach. 10.Lorica. 11.Muscular bands. 12.Testis. 13.Flame cell.

4. Class : Gastrotricha

1. These are small group of free-living aquatic microscopic animals. They occur both in marine and fresh water.
2. Body is worm-like and unsegmented. Ventral surface is fiat with cilia.
3. Locomotion is brought about by the cilia present on ventral surface of the body.
4. Sexes are united or only females are present. Reproduction is by sexual method.
5. Development is direct from zygote or from unfertilized ova by parthenogenesis.

Ex. Chaetonotus, Lepidodermella

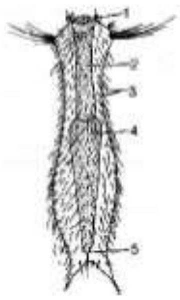


Fig: Chaetonotus- l.Mouth. 2.Pharynx. 3.Cilia. 4.Intestine. 5.Anus.

5. Class :Kinorhyncha

Kinorhyncha is also known as Echinodera.

1. These are minute cylindrical animals living on muddy bottoms usually in shallow marine habitats.
2. Body is superficially segmented into 13 rings.
3. Cuticle is spiny but without cilia. These animals have a retractable head covered with circlets of spines.
4. Sexes are separate, gonads are tubular sacs. Penial spicules are present in males.
5. Development is indirect including several larval stages and metamorphosis.

   E.g. Echinoderes, Centroderes

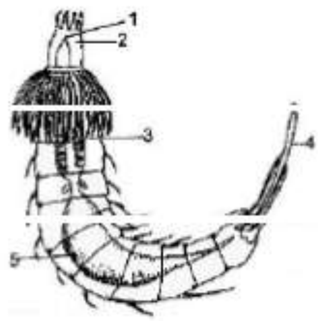


Fig: Echinoderes. l.Mouth. 2.Pharynx.3.Cilia. 4.Intestine. 5.Anus.

PHYLUM: ANNELID A

Earlier, it was a common practice to include all soft bodied animals in a group called 'Vermes'. This group 'vermes', therefore, included animals like the parasitic worms, a few arachinds and even crustaceans.

However, Lanmark in 1809 gave the name Annelida to the phylum on the basis of ring-like, segmented body, (Lat, annulus; a little ring; Gr.eidos: form). In the evolution of metazoan, metamerism has been a progressive step helping and supporting the animal in different directions. Nephridia are ectodermal in origin and exhibit a wide variety in size, position, and nature or openings. Coelomoducts are mesodermal in origin. In some animals these fuse with nephridia there by increasing the efficiency of the organ so formed in the discharge of bothfunctions of excretion and exit of gametes

1. Annelids are multicellular, triploblastic, bilaterally symmetrical, coelomate worm-like animals.
2. The body is divided into a number of ring-like segments or metameres or somites. The segments are separated from each other externally by transverse grooves and internally by septa. The segmentation is known as metamerism. In some animals external segmentation corresponds with internal segmentation.

   (eg. pheretima). In some like leeches only external segmentation is present.
3. Annelids are marine, fresh water and terrestrial forms. Most of them are free moving, a few live in burrows. A few lead an ectoparasitic life.
4. There is a single preoral segment called prostomium. The first segment is known as peristomium. The anal segment is called pygidium. In between the prostomium and pygidium, all the segments are similar in structure.
5. Annelids are coelomate animals. The body cavity is a true perivisceral coelom which lies between two mesodermal layers. The coelom is filled with coelomic fluid which acts as a hydraulic skeleton. In leeches, the coelom is very much reduced.
6. Annelids are the first animals with a well developed closed blood vascular system. Haemoglobin is the respiratory pigment present dissolved in plasma of blood.
7. Most of the annelids are bisexual. (monoecious.) In polychaetes, the sexes are separate. The gonads develop from the coelomic epithelium. The gametes may pass out through the nephridia or through coelomoducts.
8. Development is direct in monoecious forms. (in oligochaeta and Hirudinea). It is indirect in dioecious forms. (Polychaeta and Archiannelida). In the indirect

development a trochophore or trochosphere larval stage occurs.

9. Cleavage of the egg is spiral and determinate.

10. Asexual reproduction by budding is seen in some (eg. Syllis ramosa).

The phylum is divided into four classes.

These are (1) Polychaeta; (2) Oligochaeta (3) Hirudinea and (4) Archiannelida.

1. Class : Polychaeta

Polychaeta, a Greek word means many bristles. These animals are with many setae that appear as bristles on the body. Polychaeta is the largest group of annelids including about half of known annelids. It has 64 families, about 1600 genera and about 5340 species. The attempts of Fauvel (1959), Dale (1967) and by many others to group in the class hetero genous and hence for convenience this group into two sub-classes - Errantia and the Sedentaria.

1. The body is cylindrical, elongated and segmented with numerous similar segments.
2. A distinct head with sense organs such as eyes, tentacles, cirri, palps and mouth is present. Last segment is called pygidium.
3. Generally each body segment bears a pair of flattened, lateral outgrowths of the body wall, the parapodia a paired appendages with numerous setae arranged as bundles, hence the name polychaeta.

   Each parapodium is devided into Natopodium and Neuropodium and these are the organs of locomotion and respiration.
4. A clitellum is absent.
5. Respiration is by the skin. In some polychaetes (eg. Aphrodite) some setae are modified to extract dissolved oxygen from water. These are called elytra. In some polychaetes the setae are modified as gill like structures (eg. Arenicola).
6. Sexes are separate (dioecious). In some (eg. Eunice viridis) the sexual and non-sexual parts of the body are distinct. The non-sexual part of the body is called ‘atoke’ and the sexual part ‘epitoke’ During the breeding season the epitoke separates from atoke, leading an independent existence till the gametes are released to outside. In some (eg. Syllis, Hyalina) the epitoke develops head and becomes an independent male or female.
7. Gonoducts are absent. Fertilization is external. Cleavage is spiral and determinate. Development includes a trochophore larva that undergoes metamorphosis. In many, asexual reproduction is by serial or lateral budding. Eg. Chaetopterus, Arenicola, Neanthes (Nereis), Syllis, Aphrodite

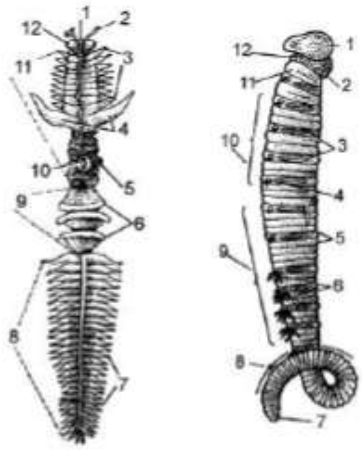


Fig: Polychaetes : (A) Chaetopterus. (B) Arenicola. (A) 1.Mouth. 2.Peristomial cirri. 3.Notopodia. 4.Great wings-food scoop of 10th notopodia. 5.Sucker. 6.Fans. 7.Parapodia. 8.Posterior region. 9.Middle region. 10.Food cup. 11.Anterior region. 12.Peristomial collar. (B)1 .Pharynx. 2.Buccal papillae. 3.Notopodium. 4.Neuropodium. 5.Metameres. 6.Gill. 7.Anus. 8.Post-branchial region.9.Branchial region. 10.Pre-branchial region. 11.Peristomium. 12.Prostomium.

2 Class: Oligochaeta

The class oligochaeta (oligo : few, Chaeta : setae) consists of about 3100 species. This group includes the familiar earthworms. These are typically metamerically segmented. These animals are of variable length. Some fresh water forms measure only 0.5 mm while a few earthworms grow to giant size, reaching 3-4 m long.

1. In earthworms, a portion of the body is thickened without segmentation and is called clitellum. The secretions of the clitellar glands help in copulation and cocoon formation.
2. The body wall is typically dermomuscular. The epidermis secretes a thin layer of cuticle that covers the body wall. The musculature is well developed with circular and longitudinal muscles.
3. The body cavity is a true coelom being lined by coelomic epithelium of mesodermal origin. Transverse septae divide the coelom into compartments which are filled coelomic fluid that acts as a hydraulic skeleton. The coelomic fluid comes out through dorsal pores and keeps the skin moist for respiration.
4. Locomotion is by the alternate contraction and relaxation of the circular and longitudinal muscles. Setae also play a part in locomotion.

Blood vascular system is of closed type with dorsal, ventral, sub-neural vessels and lateral hearts. Haemoglobin is dissolved in plasma of blood.

5. A special feature is the presence of chloragogen cells around the intestine. These cells have a major role in excretion. It is proposed recently that these cells play a vital role in intermediary metabolism, similar to liver of vertebrates.

6. Oligochaetes are hermaphrodites (monoecious). The gonads are distinct with gonoducts. The reproductive cells mature in seminal vesicles or in ovisac.

7. The ova and spermatozoa are discharged into the cocoon secreted by the clitellum in which fertilization occurs, and hence it is external fertilization.

   Ex. : Megascolex (earthworm), Pheretima (earthworm), Tubifex.

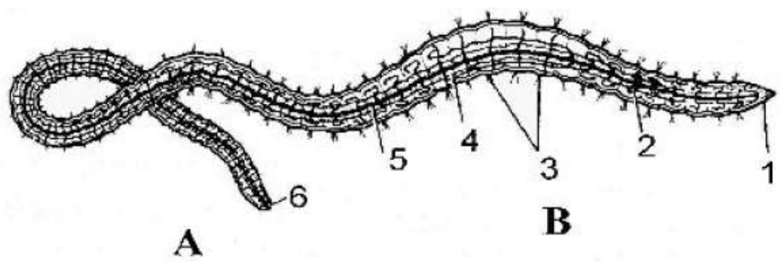


Fig: Oligochaete - Tubifex. l.Prostomium. 2.Heart.3.Body segments. 4.1ntestine. 5.Dorsal blood vessel. 6.Anus.

3 Class: Hirudinea

The class Hirudinea has about five hundred species of fresh water, marine and terrestrial worms and includes the familiar leeches. The Hirudineans resemble the Oligochaetes in many characters. These resemblances suggest a common ancestry. The salient features of the group are as follows.

1. Majority of the animals in this class are ectoparasitic and blood sucking.
2. The body of leeches is typically dorso-ventrally flattened and is oval or elongated.
3. There are no setae or parapodia. Suckers are present . The segments at both the ends are modified to form suckers. Only leeches of the order Acanthobdella possess setae.
4. A permanent clitellum is absent. It develops only during the breeding season, encircling segments 9,10 and 11.

5. The leeches differ from the other annelids in the loss of coelom. This is due to extensive growth of parenchymatous tissue. The coelom is reduced to small spaces or sinuses or channels. In the genus Hirudo and allied leeches a massive growth of tissue called botryoidal tissue reduces the Coelom.

6. In many leeches the digestive system is organized to suit to the blood sucking (Sanguivorous) ectoparasitic life. The alimentary canal has two parts, a storage part and a digestive part. The storage part is called crop. The saliva of a few leeches contain an anticoagulant called hirudin.

7. There are no special respiratory organs in leeches. Cutaneous respiration occurs.

8. Excretory organs are nephridia. These are 10 to 17 pairs, lying one pair per segment. Ammonia is the chief excretory product.

9. Fertilization is internal. Fertilized eggs are discharge into the cocoon. A clitellum develops during breeding season which forms the cocoon.

10. Development is direct and there is no larval stage.

    E.g. Hirudinaria granulosa (Indian cattle leech), Pontobdella (Skate-sucker), Branchellion (Marine leech)

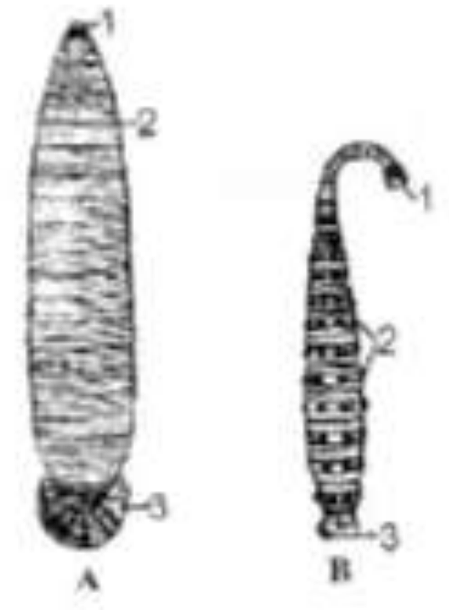


Fig: Hirudinea : (A)Hirudinaria. (B)Pontobdella. (A) 1 .Prostomium. 2.Segmental receptors. 3.Posterior sucker. (B)1.Anterior sucker. 2.Warts. 3.Posterior sucker

4 Class: Archiannelida

Archiannelida (Archi=primitive) are a heterogeneous group of unrelated animals showing some resemblances to annelids. The name archiannelida was given with a belief that these animals are primitive and ancestors of the annelids. This was based on the simplicity and degenerate condition of the organ systems found in these animals. These are now a days treated as separate minor phylum. The salient features of the class are:

1. Majority of these worms are marine in their habitat. Few of them are found in brackish water and very few in fresh water.

2. Clear external segmentation is not seen in these animals However, segmentation is complete internally in this group of animals.

3. A circlet of adhesive papillae is present around the anus in Polygordius. A ventral ciliated groove is present in Protodrillus.

4. Epidermis is distinct and may or may not have cilia.

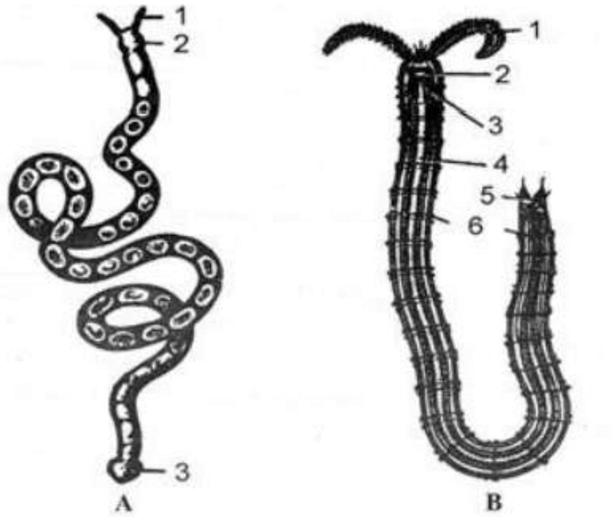


Fig: Archiannelids : (A) Polygordius. (B) Portodrillus. (A) I .Tentacle. 2.Head. 3.Anal segment. (B) 1 .Tentacle. 2.Oesophagus. 3.Muscular appendage of oesophagus. 4.Intestine. 5.Anus. 6.Circlets of cilia

5. Development is indirect in some animals (Polygordius) and is direct in others (Protodrillus). The larva of Polygordius is known as Loven's larva which is similar to trochophore larva.

   E.g. Polygordius, Protodrillus, Dinophilus, Nerilla

In addition to the above, worms belonging to groups Echiurida, Sipuncula, Priapulida are also considered to be related to annelids in metamerism, in larval development, presence of setae or parapodia, coelomic cavities, construction of body wall, nervous system and excretory systems. However, their systematic position is not clear.

PHYLUM ARTHROPODA

Arthropoda means jointed legs. (Arthros = jointed, Podus = foot). Von siebold gave the name arthropoda because of their jointed legs. Arthropoda is the largest group in animal kingdom outnumbering all other groups. This dominant group comprises about 78 to 80% of all known animals in numbers. There are about 9,00,000 species out of which 8,70,000 are those of insects alone. Insects of arthropoda are theonly invertebrates that have the capacity for flight.

The greatest success of the Arthropods is due to their highest degree of adaptive radiation, which is not exhibited by any other animal group. These extend from 600 meters high mountain ranges to a depth of 540 meters in the sea. These inhabit fresh water lakes, streams, ponds, sulphur springs, hot springs, deserts, underground, brackish water, air etc. Based on the economic importance, the insects can be divided into two groups —

(a) Beneficial insects

(b) Harmful insects

General characters

1. Arthropods are bilaterally symmetrical, triploblastic and metamerically segmented animals. Generally the number of segments in the body is fixed. These animals show a highest degree of cephalization among all invertebrates, where a few of the anterior segments fuse and form a distinct head. The body is divisible into three distinct regions. Head, thorax and abdomen.
2. All or some of the segments of the body bear a pair of jointed appendages. The segments of an appendage are known as podomeres, which are connected to one another by an articular membrane, called arthrodial membrane.
3. True coelom is greatly reduced in the adult and is restricted to reproductive and excretory organs. The body cavity of the adult is filled with blood and is a haemocoel.
4. The alimentary canal is complete starting with mouth and ending with anus.

5. Blood vascular system is of 'Open type'. Heart is dorsal and many chambered with lateral valvular ostia.
6. Sense organs are well developed. Antennules and Antenna are tactile in function.
7. Nephridia are absent. Excretion is carried on by malpighian tubules and green or antennary glands. In some, coxal glands are excretory in function.
8. Fertilization is internal.
9. Development may be direct or indirect. Indirect development involves one or more larval forms and metamorphosis.
10. Some like aphids reproduce by parthenogenesis.
11. Some Arthropods exhibit parental care. The eggs are carried on until they are hatched. Some animals like Scorpion carry the young ones.

Classification: The classification followed here is that of Marshall and Williams (1979). Phylum arthropoda is divided into the following seven sub-phyla.

1. Subphylum-Onychophora
2. Sub-phylum-Tardigrada
3. Subphylum-Pentastomida
4. Subphylum-Trilobitomorpha
5. Subphylum-Chelicerata
6. Subphylum-Pycnogonidia
7. Subphylum-Mandibulata

Sub-phylum 1: Onychophora

Distinguishing Characters:

1. The body is divided into an anterior indistinct head and an unsegmented elongated trunk.
2. Exoskeleton is absent.
3. Appendages or legs are unjointed unlike other arthropods. The number of appendages arise ventrolaterally from the trunk and varies from 14 to 43 pairs

depending on the species. Each leg is hollow and conical and bears a pair of terminal curved claws.

4. A pair of slime glands is present, one on either side in body cavity open on oral papillae. Their secretion helps in the capture of prey.
5. Nephridia are the excretory organs. These are paired and segmentally arranged. The number of nephridia corresponds to the number of legs. A series of paired glands present in lateral compartments, called coxal or crural glands and a series of coxal organs also serve excretory function.
6. Sexes are separate (unisexual) gonads and gonoducts are paired. In some female formsovipositors are present. Fertilization is internal. Most of the species are viviparous while some are Oviparous . The eggs of Oviparous species contain a lot of yolk.

   Examples:-Peripatus, Peripatopsis.

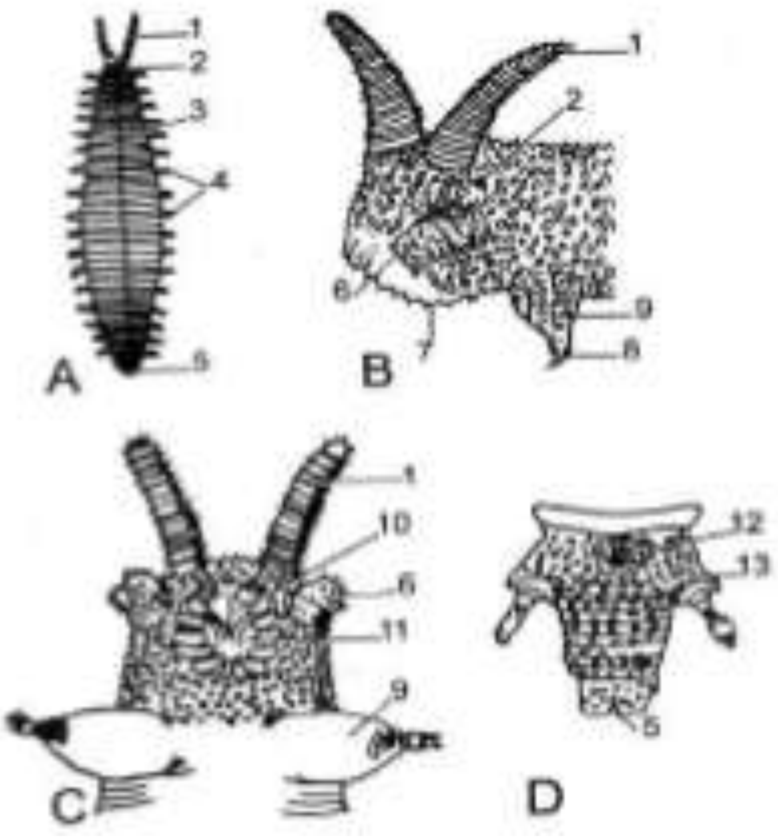


Fig: Peripatus : (A) In dorsal view. (B)Anterior end in side view. (C)Anterior end in ventral view. (D)Posterior end in ventral view.1.Antenna. 2.Eye. 3.Trunk. 4.Legs. 5.Anus. 6.Oral papilla. 7.Mouth. 8.Claws. 9.First leg. 10.Tongue. 11.Jaw. 12.Genital pore. 13.Leg.

Sub-phylum 2: Tardigrada

1. These animals are popularly called as 'bear-animalcules' or `Water-bears'.
2. Segmentation is not visible and the body is not divisible into different regions.
3. Respiratory and excretory systems are totally absent.
4. Sense organs include a pair of eyespots.
5. Sexes are separate. Gonads in both sexes open into the terminal part of intestine. Often females are more numerous than males. In some forms. males are unknown.
6. Parthenogenesis is common. Development is direct.

   Ex:-Echiniscus, Macrobiotus, Hypsibius

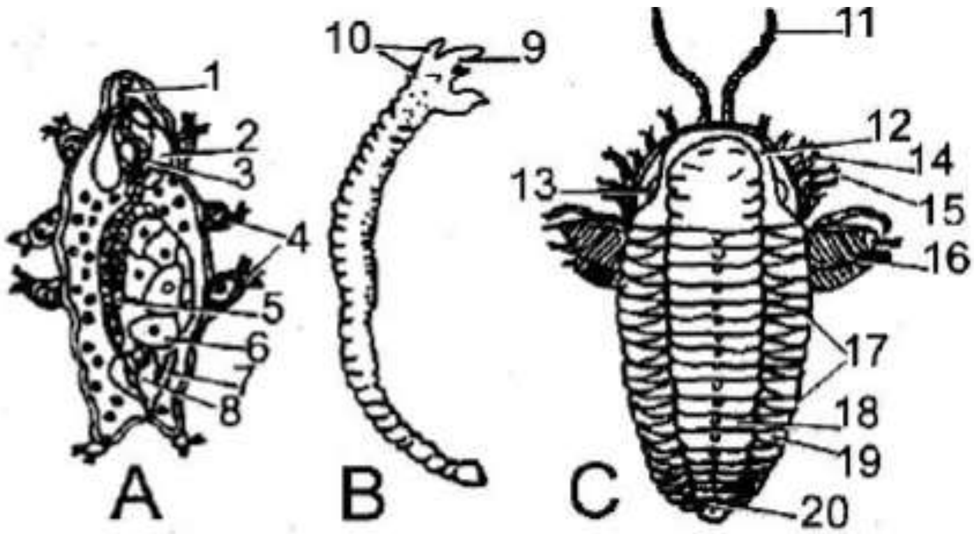


Fig: Arthropods. (A)Macrobiotus. (B)Cephalobaena. (C)Triarthrus (dorsal view).1.Buccal cavity. 2.Salivary glands. 3.Pharynx. 4.Appendages. 5.Stomach. 6.Ovary. 7.Malpighian tubule. 8.Accessory gland. 9.Mouth. 10.Legs. 11.Antenna. 12.Cephalon. 13.Eye. 14.Telepod. 15.Pre-epipod. 16.Gill. 17.Thorax. 18.Axial lobe. 19.Pleural or lateral lobe. 20.Pygidium.

Sub-phylum 3: Pentastomida or Limguatulida

These are commonly called 'Tongue worms'. These parasitic animals live in the lungs and nasal passages of vertebrates like snakes, dogs, foxes, crocodiles etc. There are about 70 species in this group.

1. The body is vermiform and unsegmented. It consists of a short cephalothorax and an elongated abdomen.

2. The alimentary canal is simple and straight whose anterior end is modified to suck blood from the host. (Suctorial Pharynx)
3. Respiratory, circulatory, excretory systems, and sense organs are all absent.
4. Nervous system resembles that of annelids and arthropods. A ventral nerve cord with serially arranged ganglia is present.
5. Sexes are separate (dioecious). In both sexes gonad is unpaired. Fertilization is internal.

   Embryonated eggs are coughed or sneezed out or pass out along with the faeces of the host. In the life cycle, there is an intermediate host which is usually a herbivorous animal.

   Larval development involves a number of moultings in intermediate host

   Ex: Cephalobaena, Linguatula, Porocephalus, and Pentastomum.

Sub-phylum 4: Trilobitomorpha

The trilobites are an extinct group. These are now represented by fossil trilobites. These primitive and exclusively marine arthropods were abundant in Paleozoic era. They reached their highest development during Cambrian and Ordovician periods. By carboniferous era they became extinct.

1. The body was oval, dorsoventrally flattened and divided into head, thorax and pygidium. It was usually 3 cm.long.
2. The trilobite fossils are found in preserved condition as the dorsal surface of the body was covered by a hard exoskeleton.
3. The head was covered dorsally by a carapace or cephalic shield. The middle, elevated region of carapace is called glabella.
4. The head had a pair of antennae, 4 pairs of biramous maxillipeds and a pair of compound eyes.
5. Book-gills, book-lungs, tracheae or skin were the respiratory organs.
6. The exact systematic position of trilobites is uncertain. Different workers adopted different yardsticks regarding their position in animal kingdom. The material that is available establishes them as arthropods. They show nearest affinity to crustaceans such as Apus. But undoubtedly trilobites are more primitive than crustaceans.

   Ex:-Triarthrus, Megalaspis, Phacops.

Sub-phylum 5: Chelicerata

1. The body is divided into a prosoma or cephalothorax and opisthosoma. Opisthosoma is divided into anterior mesosoma (Pre-abdomen) and metasoma. (Post-abdomen).
2. Antennae and mandibles are absent.
3. Mouth parts and alimentary canal are suited for sucking the food.
4. Respiration occurs through book-gills or book lungs or tracheae.
5. Excretion is through malpighian tubules or coxal glands or by both.
6. Sexes are separate, fertilization is internal. Mostly Oviparous and a few are viviparous. Development may be direct or indirect with a larval stage.

There are two classes in this sub-phylum — (1) Merostomata and (2) Arachnida. Some authors included Pycnogonidia in this sub-phylum because of Chelicerae like first appendages.

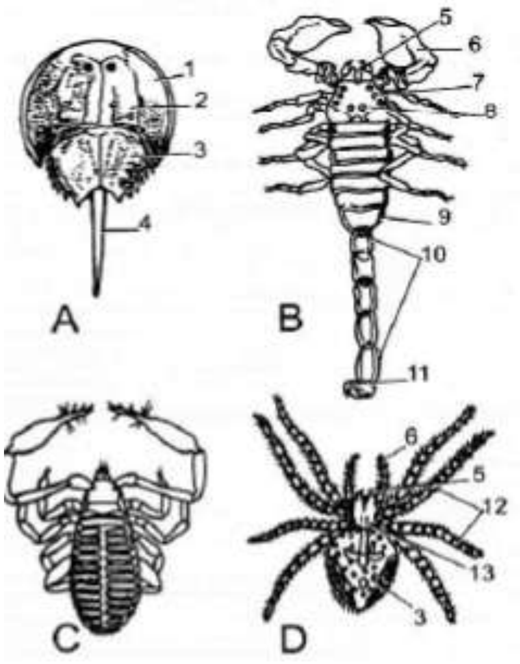


Fig: The chelicerata. (A) Limulus. (B) Palamnaeus. (C) Chelifer. (D) Aranea 1.Carapace. 2.Eye. 3.Abdomen. 4.Telson. 5.Chelicera. 6.Pedipalp. 7.Lateral eye. 8.Median eye. 9.Mesosomal tergite. 10.Metasoma. 11.Sting. 12.Walking legs. 13.Cephalothorax.

Class: 1. Merostomata

1. All are marine chelicerates.
2. Body is divided into an anterior prosoma and a posterior opisthosoma. Opisthosoma is divided into mesosoma and metasoma. Mesosoma has 6 segments. Metasoma isunsegmented and vestigial with a long and spine like telson.
3. Excretory organs are a pair of coxal glands.
4. There is a free-swimming larval stage in the lifecycle called “trilobite” larva.

Ex:-Limulus.

Class: 2. Arachnida

This group includes scorpions, spiders, ticks and mites.

1. The body is divided into an anterior prosoma or Cephalothorax and a posterior opisthosoma. Prosoma has 6 and opisthosoma 13 segments.
2. The prosoma has simple and sessile eyes.
3. Prosoma is with 6 pairs of appendages, the first pair is chelicerae, the second pair, pedipalps and the other four pairs are walking legs. Antennae and true jaws are totally absent.
4. Opisthosoma has a pair of pectines in scorpions and a pair of spinnerets in spiders.
5. Tracheae, book-lungs and book-gills are the respiratory organs.
6. Fertilization is internal. Majority of these animals are Oviparous and a few are viviparous. Development is direct

   Examples: Buthus (House Scorpion) Lycosa (Wolf spider), Palamnaeus (field scorpion) Aranea (House spider), Chelifer (Pseudoscorpion) Sarcoptes (Itch mite), Phalangium (Harvestmen) Ixodes (ticks) etc.

Sub-Phylum 6: Pycnogonida or Pantopoda.

1. These are small, marine spider like arthropods, commonly called as ‘Sea spiders’.
2. These are usually found crawling over sea-weeds at the bottom of the sea, varying from tidal limits to great depths.
3. The body consists of cephalothorax, three thoracic segments and a rudimentary abdomen.
4. Sexes are separate and sexual dimorphism is exhibited. Females can be identified by the poorly developed condition of ovigerous legs or by their complete absence.
5. Males carry the eggs on their ovigerous legs till they hatch.
6. In many the development is indirect with a larva bearing 3 pairs of appendages and a superficial resemblance to nauplius larva.

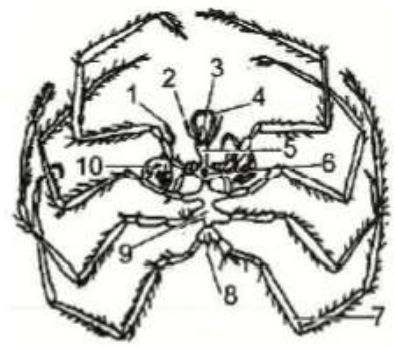


Fig: Nymphon.1.Ovigerous leg. 2.Palp. 3.Proboscis. 4.Chelicera. 5.Cephalon. 6.Eye. 7.Leg. 8.Anus. 9.Trunk

Sub-phylum 7: Mandibulata

The subphylum Mandibulata is created to include all those animals with mandibles and antennae.

1. These are terrestrial, aquatic both fresh and marine water animals.
2. The body is divisible into cephalothorax and abdomen or head, thorax and abdomen.
3. Cephalic (head) appendages are one or two pairs of antennae, a pair of mandibles and one or two pairs of maxillae.
4. Malpighian tubules and green glands are the excretory organs.
5. Sexes are usually separate with sexual dimorphism.
6. Development may be direct but in majority it is indirect with a larval stage.

This sub-phylum is divided into 6 classes.

1. Class- 1:Crustacea
2. Class- 2:Pauropoda
3. Class- 3:Diplopoda
4. Class- 4:Chilopoda
5. Class- 5:Symphyla
6. Class- 6:Insecta

Class : 1. Crustacea

Crustacea includes some of the most common and familiar arthropods such as crabs, shrimps, lobsters, crayfish. These are mostly aquatic arthropods living in fresh and marine water and some even in moist places. Most of the crustaceans are marine and occur in such abundant numbers that they are called 'Insects of the sea'. Some are parasitic and some are sedentary while all are carnivores or scavengers.

There are 26,600 species of Crustacea. These animals play an important role in aquatic food chain.

1. The body is divisible into head, thorax and abdomen. In some animals the head is fused with a few or all-thoracic segments forming a cephalothorax. The cephalothorax is covered fully or partly by carapace.
2. An appendage has a basal segment, the protopodite on which an outer and an inner branches are present called exopodite and endopodite respectively. Such an appendage is called biramous appendage. All the appendages except the antennae are typically biramous.

3. Excretory organs are antennary or green glands (occur in the second segment of antennae) and maxillary or shell glands (occur in maxilla). In any animal usually any one of the two occurs.
4. Sexes are separate with the exception of cirripedia. Sexual dimorphism is well marked.
5. In most forms development is indirect with a free-swimming larval stage. The embryonic larval stage is called nauplius. In few, development is direct. Autotomy and regeneration are very common.

   Examples:- Palaemon (Fresh water prawn) Cancer (crab), Penaeus (Marine prawn) Cyclops (water flea), Palinurus (spiny lobster) Balanus (Acorn barnacle),Eupagurus (Hermit crab) Lepas (Goose barnacle), Bingus latro (coconut crab) Sacculina (Root-headed barnacle)

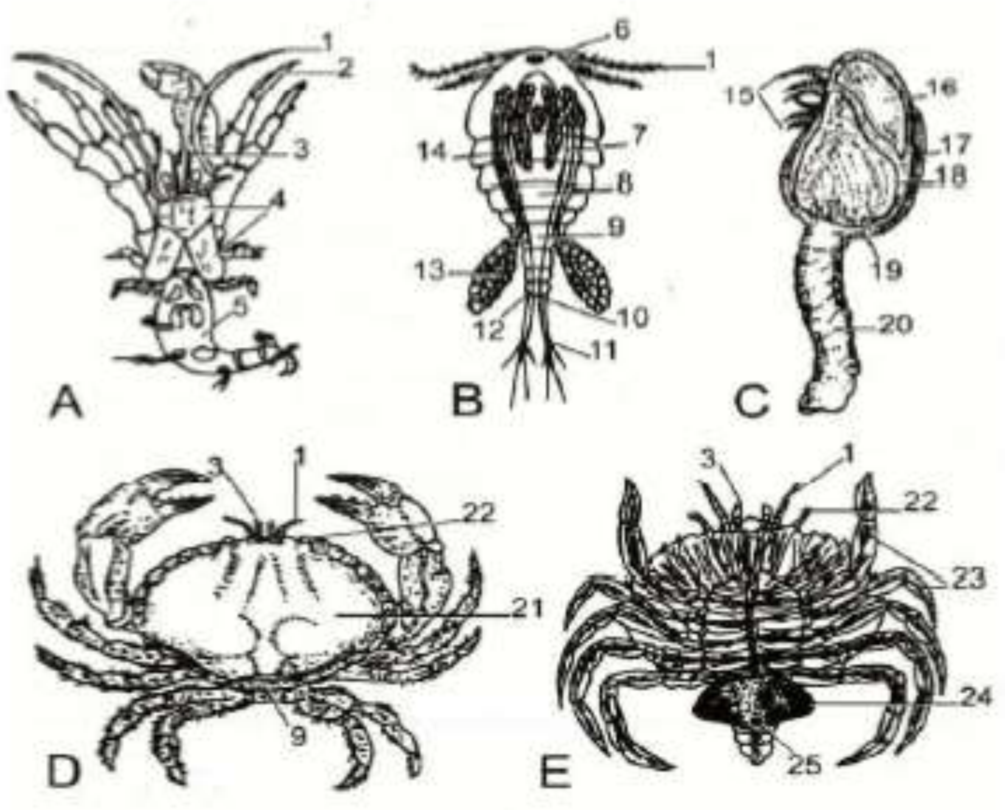


Fig: Crustaceans - (A)Eupagurus. (B)Cyclops. (C)Lepas. (D)Cancer. (E)Sacculina.1.Antenna. 2.Chelate leg. 3.Antennule. 4.Cephalothorax. 5.Soft abdomen. 6.Median eye. 7.Oviduct. 8.Midgut. 9.Abdomen. 10.Anus. 11.Caudal style. 12.Telson. 13.Egg sac. 14.Ovary. 15.Thoracic appendages. 16.Tergum. 17.Carina. 18.Mantle. 19.Capitulum. 20.Pedicel. 21.Carapace. 22.Compound eye. 23.Root-like processes seen spreading in the body of host 24. Sacculina. 25.Genital aperture of sacculina.

Class : 2. Pauropoda

1. These are minute, soft-bodied arthropods living in damp places, under stones, logs, bark of dead wood etc or in soil.
2. Body is divisible into head and trunk.
3. Head has a pair of antennae, mandibles and two pairs of maxillae.
4. Respiratory system is degenerate. Tracheae are absent.

   Examples:-Pauropus, Decapauropus, Brachypauropus, Eurpauropus.

Class : 3. Diplopoda

These are commonly called 'millipedes' or 'thousand legged animals'. These are sluggish and timid animals hiding in dark and damp places. These are herbivorous and scavengers feeding on decaying matter.

1. Body is cylindrical, elongated and can be rolled up like a watch spring.
2. Body is divided into head, thorax and abdomen.
3. Head consists of 5 segments, thorax of 4 segments and abdomen of 20 to 100 segments.
4. Each trunk segment bears a pair of legs hence the name Diplopoda.

   Examples: Julus (Snake millipede) Spirobolus (Snake millipede)

Class : 4. Chilopoda

These are commonly called as 'centipedes' or 'hundred-legged animals'.

1. Body is elongated and dorso-ventrally flattened. The number of segments varies from 8 to 181 in different species.
2. Body is divided into head and trunk.
3. Head has a pair of antennae, a pair of mandibles and two pairs of maxillae. Antennae are long and many jointed. Mandibles are toothed.
4. The poisonous glands open in the first pair of legs that bear the claws.
5. Sexes are separate. The genital opening is situated at the hind end of the body on the last but one segment. Examples: Scolopendra, Scutigera, Lithobius.

Class : 5. Symphyla

1. These are commonly called `garden-centipedes'. These are terrestrial, found in damp places with humus.
2. These small animals are found in damp places under stones and avoid light. These are commonly called as 'garden-centipedes'.
3. The head is distinct. It bears a pair of antennae, a pair of mandibles, and two pairs of maxillae.
4. The trunk has 12 segments each with a pair of legs and 12 legless segments intercalated between leg-bearing segments.
5. Gonads are paired and lateral with ducts opening to the exterior by a median opening between the fourth pair of legs. Example : Scutigerella, Scolopendrella

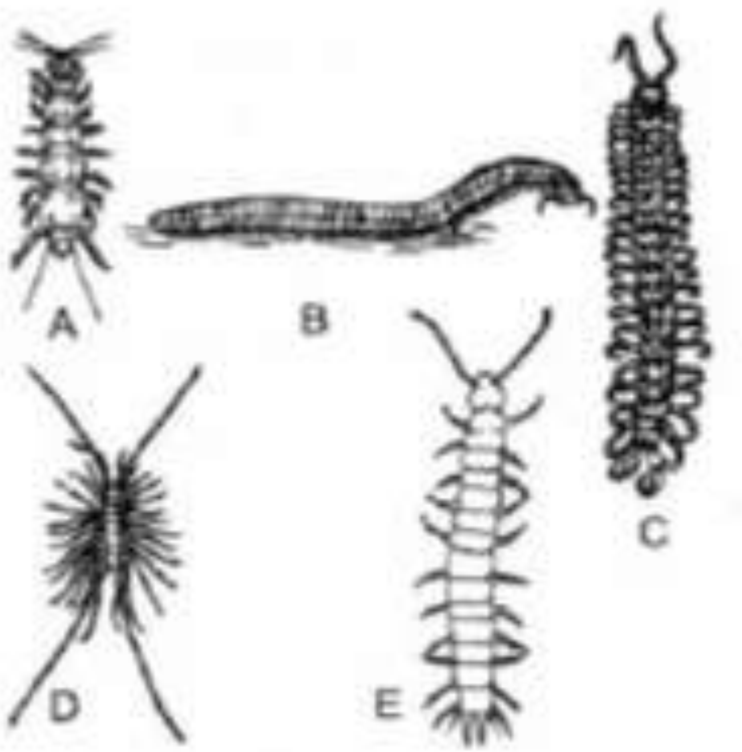


Fig: (A)Pauropus. (B)Julus. (C)Scolopendra. (D)Scutigera. (E)Scutigerella.

Class : 6. Insecta

These animals are also called 'hexapods' due to the presence of 6 legs. Insecta containsabout 8 lakh species and many more are yet to be described. These are the dominant animals at the present times. Insects form the largest group of animals far exceeding all other groups in the number of species and individuals. These live in every conceivable habitat from arctic to tropics, on land, air and water. Their rapid multiplication enables the species to survive even in unfavourable environments. Their exoskeleton protects them from infections, injuries and dehydration. Insects are the only invertebrates that have the capacity to fly, which has enabled them to avoid unfavourable conditions and to disperse far and wide. They can survive in areas where other animals find it impossible to survive, because of their variety of feeding habits. There arebeneficial as well as harmful insects.

1. The body is divided into three distinct regions — head, thorax and abdomen. The body is covered by a hard chitinous exoskeleton.
2. The head is formed by the fusion of 6 segments. The thorax consists of 3 segments (prothorax, mesothorax, meta-thorax) and abdomen from 7 to 11 segments.
3. Head bears a pair of compound eyes and sometimes simple eyes or ocelli, a pair of antennae, a pair of mandibles and, 2 pairs of maxillae.
4. The mouthparts are modified for chewing, biting, piercing, sucking and siphoning of food. Alimentary canal consists of fore, mid and hindgut.
5. Each thoracic segment bears a pair of jointed legs. In arboreal or flying insects each of the second and third thoracic segments has a pair of wings.
6. Sexes are separate. Gonads are paired. Fertilization is internal. Development may be direct or indirect with incomplete or complete metamorphosis.

   Examples:- Lepisma (Silverfish) Pediculus (Head louse), *Periplaneta americana* (Cockroach) Cymex (Bed bug), *Apis mellifera* (Honey bee), *Bombyx mori* (Silk moth), Anopheles (Mosquito), *Musca domestica* (House fly)

PHYLUM MOLLUSCA

The Phylum Mollusca, includes animals like snails, mussels, oysters, cuttlefish, squids, pearly nautilus etc. Molluscs can be found in nearly every ecosystem on our earth; from high, barren mountains and grassy plains, to the depths of our rain forests, from lakes and rivers and of course, in all corners of our seas and oceans. The only environment they cannot cope with are very dry regions, as their moist skin is easily desiccated. The name Mollusca (from the Latin mollis "soft"), was first used by the great French zoologist Cuvier in 1798 to refer to cephalopods like squids and cuttlefish. It was later extended to include other organisms of this group, such as snails and bivalves. These soft bodied animals (mollis : soft) form the second largest phylum of invertebrates. Molluscan evolution began more than 500 million years ago, during Pre-Cambrian period. Some of these "oldest" molluscs resembled today's chambered Nautilus.

Nearly 130,000 living species of molluscs have been identified so far and about 35,000 fossil species have been recognized. Some of molluscs are of considerable economic importance and are fished for food; forthe pearls they yield and their shells utilized in various ways.

GENERAL CHARACTERS

Body and Symmetry: The body is unsegmented, triploblastic and bilaterally symmetrical. In some molluscs such as gastropods, bilateral symmetry is secondarily lost due to torsion. The body is enveloped in a loose, fleshy lobe called the mantle.

Shell: The shell is secreted by the mantle. The shell may be external or internal or absent insome. It may be bivalved or univalved. The molluscan shell is a tough, protective structure composed predominantly of calcite or aragonite $CaCO3$ crystals.

Foot: In some molluscs, ventral body wall is modified into a muscular, flat or wedge-shaped foot.

Visceral Mass: The visceral mass is the fleshy 'back' of a mollusc.

Mucus (Slime) Secretion: Molluscs secrete mucus especially through the glands present on their foot. Mucus helps in movement, defence, water retention, nutrition and reproduction.

Digestive System: The digestive tract is complete and ciliated, with a mouth, anus and complex stomach. The radula is a distinguishing feature of the molluscs used in feeding. Radula is absent in molluscs belonging to class Pelecypoda.

Respiratory System: Gaseous exchange can occur directly over the mantle surface as well as over discrete respiratory surfaces. The gills, or ctenidia are located in the mantle cavity, and are typically flattened, lamellar structures with a central axis from which numerous smaller gill filaments project. The respiratory pigment is haemocyanin, which is a blue-green colour when loaded with oxygen. Circulatory System: Most molluscs have an open type circulatory system.

Excretory System: Excretion is by kidneys, also called nephridia.

Nervous System and Sense Organs: Molluscs have a relatively complex nervous system, usually with a number of discrete ganglia, serving the cephalic, pleural and pedal regions and a network of interconnecting nerve cords. Statocysts, organs of equilibrium are generally present, as are Ospharadia, which effectively monitor quality of water entering the organism.

Reproductive System : Most molluscs are dioecious, although hermaphrodite forms are also Development: Molluscs are mostly oviparous, a few are viviparous. Development is direct orindirect. When indirect metamorphosis takes place, there are different types of larval stagescalled trochophore, veliger and glochidium

CLASSIFICATION

The Phylum Mollusca has been divided into eight classes. They are:

Class : 1 Caudofoveata

1. This is a small class of animals containing marine, worm-like molluscs adapted to burrowing habits in mud.
2. These animals are 2 mm to 14 cm in their size.
3. The body has very few distinct regions, but a head may be demarked by a ring of constriction about the ‘neck’.
4. Sexes are separate, eggs are brooded in the cloacal pouch
5. Development typically includes a free-swimming trochophore larval stage.

Examples: Chaetoderma.

Class : 2 Solenogastres

1. They are predominantly deep water invertebrates, found to depths of 3000 metres feeding predominantly on cnidarians.
2. The head is reduced but bears an oral opening.
3. The trunk has a ciliated ventral furrow, used in a creeping form of locomotion and representing all that is left of the muscular foot.
4. Eggs are brooded in a posterior cloacal cavity before hatching into a trochophore or developing directly into the adult form. Example - Neomenia, Chactoderma.

Class : 3Monoplacophora (Gr. Monos : One; Plax : Plate; Phorin : Bearing)

1. All are marine and live at great depths. These animals are marine detritus feeders.
2. The head is reduced, but bears a mouth with oral tentacles and radula.
3. Foot is broad and flat with eight pairs of pedal retractor muscles.
4. A radula is present in the radular sac in the buccal cavity.
5. The intestine is much coiled.
6. Five pairs of gills are present. They are located in the mantle cavity.
7. Heart consists of two pairs of auricles and two ventricles.
8. The nervous system consists of combined cerebral ganglia that extend a pair of visceral and pedal nerve cords, with interconnecting processes.
9. The sexes are separate and 2 pairs of gonads are located in the middle of the body.
10. Fertilization takes place externally.

    Example: Neopilina galatheae which is a living fossil.

Class : 4 Polyplacophora

1. The common name for this class of molluscs is chitons.
2. Chitons typically are small in size ranging from 3 mm onwards but can attain a length of 40cm in the case of the Indo-Pacific form, Cryptochiton.
3. They are slow-moving, herbivorous grazers feeding by scraping plant material with their radula.

4. Head is poorly developed without tentacles and eyes.
5. The numerous paired gills are situated in a groove between the margin of the mantle and the foot.
6. Excretion is carried out by a single pair of nephridia.
7. The nervous system consists of a series of interconnected nerve cords, forming a plexus but no true ganglia.
8. The sexes are separate and possess a single large gonad.
9. There is no copulation, the fertilization takes place externally or eggs are spiny may be initially brooded within the mantle cavity of female, before being released as a trochophore larva.

   Example: Chiton (also called Coat of mail shell) - Shell is made up of eight transverse plates or valves.

Class : 5 Scaphopoda

1. This class of animals have been in existence since Ordovician period, and are commonly known as the 'tusk shells', or 'toothed shells'.
2. The foot is frequently tri-lobed, and adapted for burrowing, whilst the head bears the mouth at its apex, and is also protrusible.
3. Scaphopods have specialised feeding filaments called captacula, which project from oral lobes. The captacula have knobs at their terminus, and are covered in mucus and cilia.
4. The scaphopods are very primitive animals, possessing neither gills nor eyes nor a heart. A rudimentary heart is merely an enlargement of sinus near anus. Pericardium is absent.
5. Excretion is carried out by paired kidneys.
6. The tusk shells are dioecious, with external fertilization and development through both trochophore and veliger larval stages.
7. The bivalves are a potential sister-group of the scaphopods, sharing a substantial mantle cavity and burrowing habit (Ruppert and Barnes, 1994).

   Example: Dentalium (Elephant tusk shell).

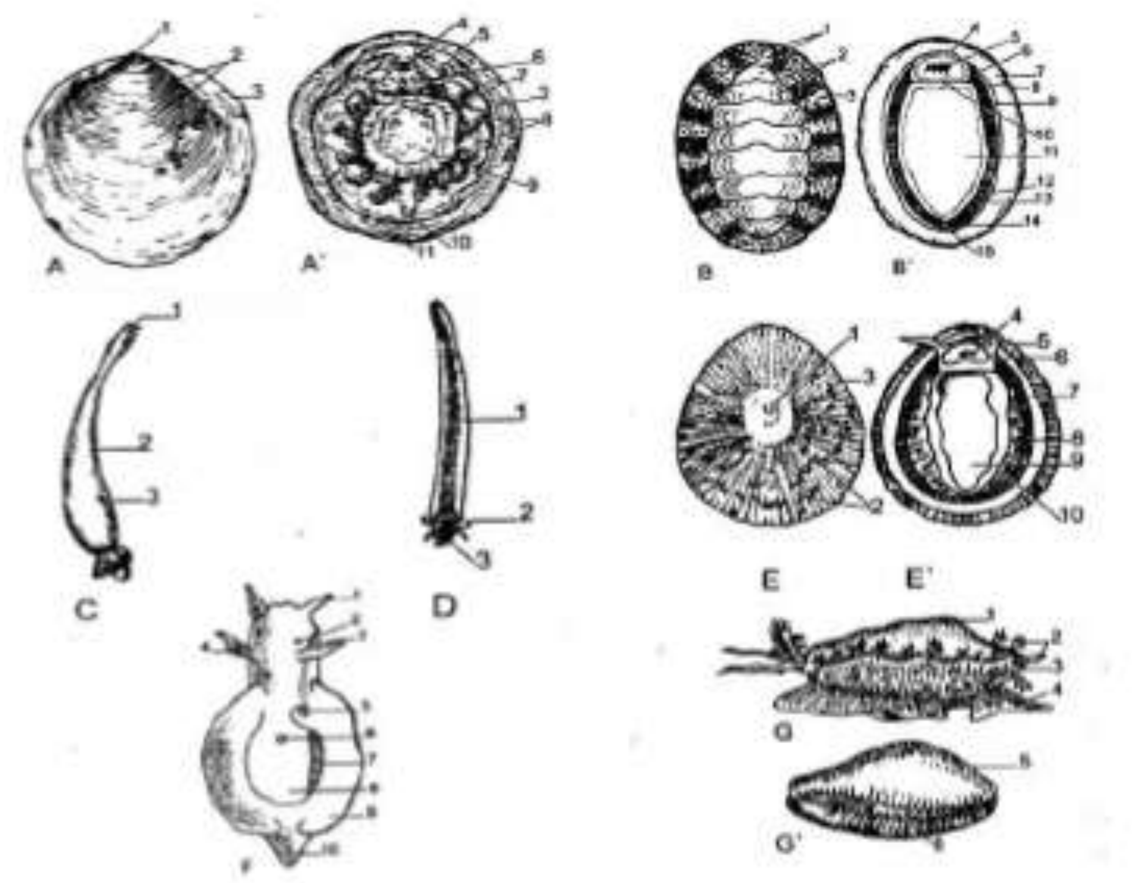


Fig: Molluscs (A) Neopilina. (B)Chiton. (C)Chaetoderma (D)Dentalium. (E)Patella. (F)Aplysia. (G)Cypraea. (A)1.Apex. 2.Growth lines. 3.Shell border. 4.Mouth. 5.Palp-like appendage of velum. 6.Post-oral tentacle. 7.Pallial or mantle groove. 8.Branchiae or gills. 9.Foot. 10.Anus. 11.Pallial margin. (B)1.Calcareous spicules. 2.Calcareous shell plates. 3.Mantle edge. 4.Flattened head. 5.Mouth. 6.Mantle cavity. 7.Fleshy mantle. 8.Ctenidia. 9.Mantle groove. 10.Furrow. 11.Broad foot. 12.Genital opening. 13 .Excretory opening. 14.Anal papilla. 15.Anus. (C)1.Mouth. 2.Body. 3.Mantle. (D)1.Shell. 2.Capitulum. 3.Foot. (E) 1.Apex. 2.Lines of growth. 3.Radiating ribs of shell. 4.Mouth. 5.Tentacle. 6.Mantle cavity. 7.Mantle. 8.Leaf like secondary gills. 9.Foot. 10.Muscles. (F)1.Anterior tentacle. 2.Eye. 3.Spermatic or seminal groove. 4.Rhinophore. 5.Common genital opening. 6.Opening of shell sac. 7.Ctenidium. 8.Visceral hump. 9.Parapodium. 10.Tail. (G) 1.Shell. 2.Mantle tentacles. 3.Mantle. 4.Foot. 5.Shell. 6.Aperture of shell.

Class : 6 Gastropoda

1. This class includes the slugs, snails, limpets, nudibranchs, sea hares, sea butterflies, periwinkles and many more with sizes ranging from 0.3 mm to more than 1 m.
2. The body is unsegmented, asymmetrical due to a biological phenomenon called torsion.
3. In the gastropods, head is well developed, with tentacles and a radula.
4. The foot is a large, flattened structure, commonly used in muscular gliding. Some species the foot is modified to lateral fins and is used in pelagic swimming as in Aplysia (Sea Hare).
5. Respiration is performed by gills or ctenidia. To carry out respiration on land, amphibious gastropods have pulmonary sacs in addition to the gills.
6. Circulatory system is open and the heart is enclosed in a pericardium. Haemocyanin is the oxygen carrying pigment and is present in blood.
7. Excretion is carried out by a single kidney.
8. Sensory organs may include statocysts, ospharadia and eyes mounted upon tentacles.
9. The gastropods may be dioecious or monoecious, with fertilization typically internal.
10. Larval stages occur; they generally include a trochophore and veliger stages. Veliger is said to be a modified form of trochophore.
11. Development is indirect. Some gastropods of the freshwater tide over unfavourable conditions by undergoing aestivation. These burrow themselves in the earth and go through summer sleep. Examples: Pila (Apple snail or pond snail), Patella, Aplysia, Cypraea etc.

Class : 7 Bivalvia (or Pelecypoda or Lamellibranchiata)

1. Class Bivalvia is also known as Pelecypoda and Lamellibranchiata. The Bivalvia are a familiar group of animals, predominantly in marine environments, but also in freshwater ones. There are no terrestrial bivalves.

2. Allmost all the bivalves are free living although few of them are either commensals and parasitic species, often highly host-specific, and comprise some of the rare animals.
3. Bivalves are bilaterally symmetrical, laterally compressed with two lateral valves.
4. Viscera include a well developed heart and stomach as well as intestines, kidneys, gonads, adductor muscles and a vascular system.
5. The head of bivalves is scarcely recognizable, having become basically vestigial, but a mouth is situated anteriorly, at the base of labial palps.
6. Pharynx, jaws, radula and tentacles are absent.
7. The foot is a wedge-shaped muscular structure hanging down ventrally from the visceral mass. It is commonly used for burrowing and for locomotion
8. Gills or ctenidia are leaf like, hence the name Lamellibranchiata.
9. Excretory organs are paired nephridia or kidneys, also known as organs of Bojanus. In some Keber's organ or pericardial gland also functions as excretory organ.
10. Heart is enclosed in pericardium. It consists of two auricles and a median ventricle.
11. The nervous system of bivalves essentially constitutes a series of dispersed ganglia typically four pairs of ganglia-cerebral, pleural, pedal and visceral ganglia connected by a series of nerve cords.
12. Sense organs are statocysts and osphradia.
13. Bivalves are generally dioecious, and most marine forms have external fertilization.
14. Development is normally through both trochophore and veliger larval stages. In some bivalves a larval stage glochidium is seen.

    Examples: Lamellidens or Unio (Fresh water mussel); Mytilus - Sea mussel; Ostrea - Edible oyster; Pinctada - Pearl oyster; Pecten - Scallop; Teredo - Ship worm; Solen - Razor clam or razor shell.

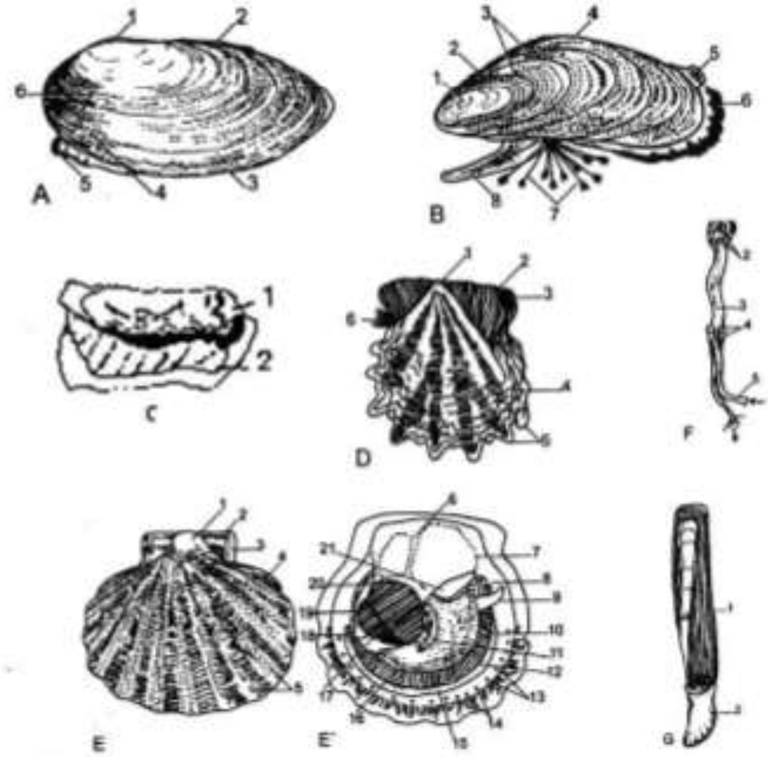


Fig: (A)Lamellidens. (B)Mytilus. (C)Ostrea. (D)Pinctada. (E).Pecten. (F)Teredo. (G)Solen. (A)1.Umbo. 2.Hinge ligament. 3.Shell margin. 4.Lines of growth. 5.Foot. 6.Shell. (B) 1.Umbo. 2.Hinge ligament. 3.Lines of growth. 4.Left shell valve. 5.Excurrent siphon. 6.Mantle edges lined by tentacles. 7.Byssus. 8.Foot. (C)1.Movable right valve. 2.Left valve. (D) 1 .Umbo. 2.Ear-like process. 3.Hinge. 4.Shell valve. 5.Finger-like projections. 6.Byssus (E) 1 .Umbo. 2.Hinge. 3.Wing. 4.Shell valve. 5.Radiating striations. 6.Heart. 7.Visceral mass. 8.Mouth lips. 9.Foot. 10.Testis. 11.Right kidney. 12.Gill-lamellae. 13.Velar tentacles. 14.Eyes. 15.Velum. 16.ovary. 17.Smooth adductor muscle. 18.Anus. 19.Intestine. 20.Striped adductor muscle. 21.Right labial palps. (F)1.Dorsal fold of mantle. 2.Shell valves. 3.Body. 4.Pallets. 5.Inhalent siphon. (G)1 .Shell valve. 2.Foot.

Class 8: Cephalopoda

1. This is a small group of highly advanced, well organized exclusively marine animals. The octopus, squid, cuttlefish, and chambered nautilus are familiar representatives.
2. Cephalopods may be pelagic or benthic forms but most are bottom-dwelling and are restricted to the continental shelf and its slope.
3. The head is well developed. It bears a pair of highly developed eyes, mouth and a number of arms or tentacles.

4. The viscera of a generalized cephalopod is covered with a dome-shaped or elongated sheath of muscle, the mantle. The alimentary system consists of a buccal mass with a pair of jaws (mandibles) and a rasping tongue (radula), esophagus, salivary glands, stomach, caecum, digestive gland ("liver"), intestine, and anus.
5. All members of the Cephalopoda (octopuses, squids, and cuttlefishes) possess a closed circulatory system of blood vessels.
6. The excretion of nitrogenous wastes is carried out by kidneys. There are four kidneys in Nautilus.
7. In cephalopods, sexes are separate (dioecious).. Development is direct without metamorphosis.

   Examples: Sepia (cuttle fish), Loligo (squid) .

   Octopus : Devil fish

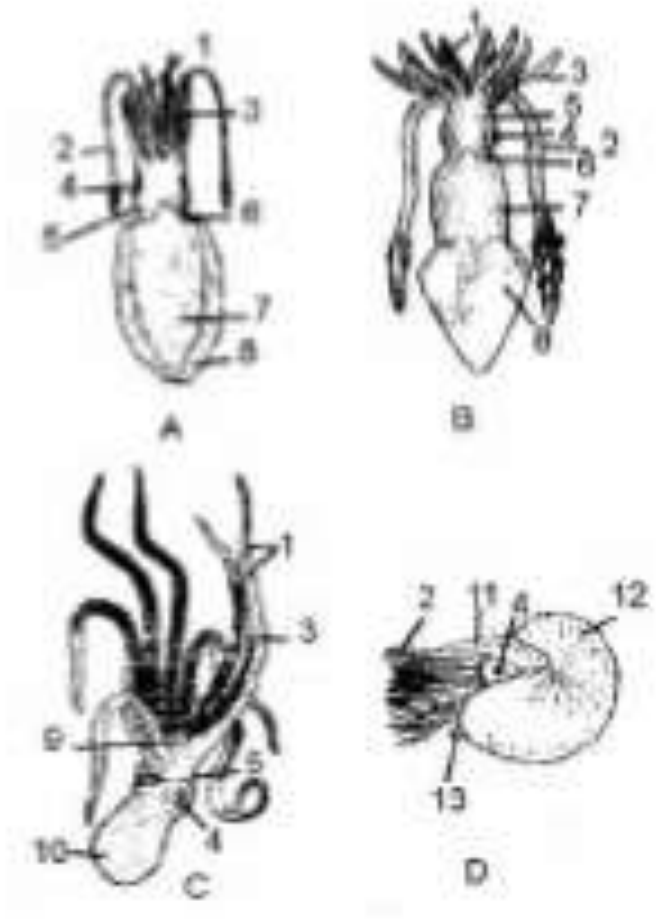


Fig: Molluscs -(A) Sepia. (B) Loligo (C) Octopus. (D) Nautilus.
1. Oral arms. 2.Tentacle. 3.Suckers. 4.Eye. 5.Head. 6.Collar. 7.Trunk. 8.Lateral fin.
9.Web. 10.Visceral hump. 11.Hood. 12.Sheel. 13.Funnel.

PHYLUM ECHINODERMATA

Echinoderms are very ancient animals, having appeared some 600 million years ago in the Cambrian period. The name Echinodermata (Gk. Echinos : hedgehog (spiny); derma: skin) was given by Jacob Klein in 1734: The phylum consists of about 6000 existing species and about 13,000 extinct species. Echinoderms are exclusively marine, and most are benthic.

GENERAL CHARACTERS

Echinodermata possess many characters that distinguish them from other animals. The important characteristic features of phylum Echinodermata are as follows:

1. **Habitat and habits:** They are exclusively marine - found in deep sea all over the world. Sometimes they are present in brackish water. A few are pelagic, some are sessile or sedentary. They are free-living, non-colonial, slow moving animals.
2. **Size and Shape:** Most of the Echinoderms are of moderate size. Echinoderms exhibit a variety of shapes and sizes. Shapes vary from - star like, disc-like, cylindrical, flattened or flower-like.
3. **Body Symmetry**: Echinoderms have an unsegmented body, hence they do not show metamerism. Echinoderms are generally radially symmetrical, with adults displaying a secondary pentaradial symmetry that is, the body can be divided into five more or less similar portions around a central axis.
4. **Germ Layers:** All Echinoderms are triploblastic - with three germinal layers - outer ciliated epidermis, middle dermis and an inner lining of peritoneum.
5. **Body Surface:** A head and an anterior end are absent in Echinoderms. Body has two distinct surfaces - an oral surface with mouth, and an aboral surface with five symmetrical radial areas called ambulacral areas, which are intercepted with five alternating inter-ambulacral areas. The mouth is located centrally on the upper or lower surface of the animal (oral surface), or at the anterior extremity. The other surface is termed the aboral surface.
6. **Skeleton:** The main portion of the body skeleton, known as the theca or calyx, both exo and endo skeletons are present in echinoderms.
7. **Coelom:** In Echinoderms, the body cavity or coelom is well developed, spacious, lined by ciliated peritoneum. In adult Echinoderms, the coelom is not a single cavity and is divided into various chambers.

8. **Organ Systems and Physiology:** The organ systems are highly developed and organised in Echinoderms. A unique water vascular system or ambulacral system or hydrocoel consisting of reservoirs and ducts filled with watery fluid which is similar to blood and lymph is present in Echinoderms.

9. **Locomotion:** Locomotion is carried out in these animals by the ambulacral system with the help of contractile tube feet or podia.

10. **Water vascular System:** The water vascular system is an interesting system and is not present in any other phylum. The water vascular system of Echinoderms is best developed in the starfishes and functions as a means of locomotion and respiratory exchange.

11. **Digestive System:** The alimentary canal is complete, running from the mouth to the anus. In some groups anus may be absent or non-functional. The mouth is located centrally on the upper or lower surface of the animal (oral surface), or at the anterior extremity. A coiled gut extends from the mouth to an anus.

12. **Circulation and Respiration:** Circulatory system is called a haemal system. It is simple and of open lacunar type. A heart is absent, but blood vessels are present. The water-vascular system takes over some of the functions of these systems.

13. **Excretory System:** No definite organs of excretion are present. However, elimination of nitrogenous wastes takes place by diffusion in class Ophiuroidea, solid waste is extruded through the mouth as they do not have anus.

14. **Nervous System and sense organs:** Nervous system is simple in Echinoderms. As there is no cephalization, these animals do not have a brain like structure.

15. **Reproductive system:** Sexes are separate and distinct. Reproduction is sexual. Gonads are inter-radial with separate ducts to the exterior and ova and sperms are freely discharged into the water. Fertilization is external in the sea water.

16. **Development:** Development may be direct or indirect. Different larval forms are met within different groups. The larvae have evolutionary importance as they resemble those of the succeeding higher groups. Autotomy and regeneration - also occur.

CLASSIFICATION

Phylum Echinodermata has been classified by Fell in 1965 into four sub-phyla. Each subphylum comprises different classes. The classification is as follows:

Sub-Phylum. I: Echinozoa

It is divided into five classes. The distinguishing characters and examples of these classes are mentioned below:

Class : 1 Helicoplacoidea

1. Free-living ancient Echinoderms, belonging lower Cambrian era of California.
2. Body is bursiform.
3. The plates of the body wall form a flat test, folded in counter clockwise helical spirals.
4. Oral and anal apertures are at opposite ends of the body.

   Example: Heliocoplacus.

Class : 2 Holothuroidea

1. Free-living ancient Echinoderms.
2. Body is elongated, cylindrical, five sided and cucumber-like.
3. Arms are absent.
4. Body wall is soft, without spines or calcareous plates.
5. Endoskeleton of many microscopic spicules or ossicles is present.
6. Mouth is surrounded by a ring of retractile branched tentacles.
7. Anus is at the posterior end.
8. A double row of suctorial tube feet is present on each side of the body.
9. Pedicellariae are absent.
10. Alimentary canal is long and coiled.
11. Ambulacral system is well developed.

12. Nerve ring surrounds the mouth. It spreads into five radial nerves.

13. Sexes are separate.

Examples: Cucumaria, Molpadia, Thyone

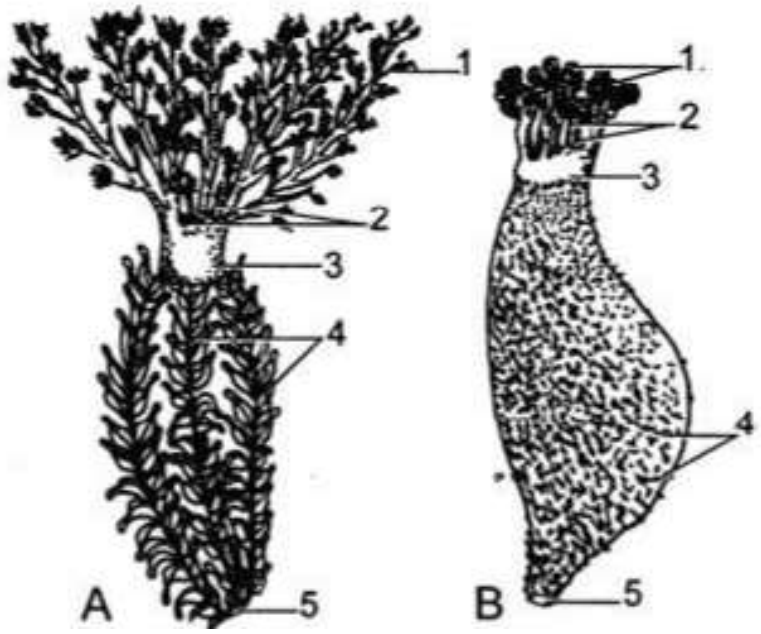


Fig: Echinoderms. (A)Cucumaria. (B)Thyone. 1.Normal dendritic tentacles. 2.Dwarfed mid ventral pair of tentacles. 3. Introvert. 4.Ventral locomotary podia. 5.Anus.

Class : 3 Edrioasteroidea

1. Appeared in mid-Cambrian period and became extinct in Carboniferous era
2. Test is flexible
3. Mouth and anus are both on the upper side of the test.

   Examples: Edrioaster, Isorophus.

Class : 4 Echinoidea

1. Body is globular, discoid or heart-shaped and is enclosed in a well-developed test.
2. Mouth and anus are on the oraland aboralsurfaces respectively.
3. Immovable calcareous ossicles are present in the endoskeleton.
4. Cylindrical, solid, movable spines which can turn in all directions are present on the body surface.
5. Five double rows of suctorial tube feet are found among the spines.
6. Ten shrub-like dermal branchiae are found on the peristome.

7. A complex, specialised jaw mechanism, Aristotle's Lantern, is present inside the mouth. It is in the shape of a five sided pyramid and has five long and curved teeth.
8. Pedicellariae are stalked and possess three jaws.
9. A vascular gland is associated with the water vascular system. It is probably excretory in function.

   Examples: Echinus, Echinocardium, Clypeaster, Lovenia

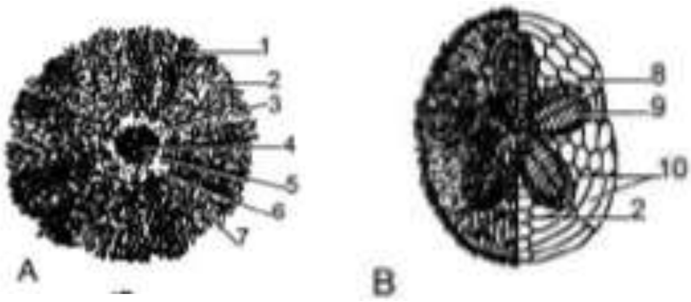


Fig: Echinoderms - (A) Echinus. (B) Clypeaster rosaceous. (C) Echinocardiu Cordatum. 1.Ambulacrae. 2.1nter ambulacra.3.Peristome. 4.Oral test. 5.Teeth. 6.Branchiae. 7.Spines. 8.Gonopore. 9.Madreporite. 10.Petaloid ambulacra. 11.Modified anterior ambulacra. 12.Peristomial membrane. 13.Mouth. 14.Small ambulacral spines. 15.Posterior most inter ambulacrum.

Class : 5 Opisthocistididea .

1. These are extinct echinoderms.
2. Polygonal plates are found on the test.
3. Mouth is with five interradial jaws.
4. Eight pairs of tube feet arise from each ambulacrum.

   Example: Volchovia

Sub-Phylum. II : Homalozoa

1. These are extinct Echinoderms.
2. Body is dorso-ventrally flattened.
3. Bilateral symmetry is observed.
4. Mouth possess a pair of arm-like organs on either side.

5. A locomotor appendage in the shape of a tail like peduncle is present.
6. Alimentary canal is `U shaped.

   Examples: Enoploura, Dendrocysties

Sub-Phylum. III : Crinozoa

This sub-phylum is represented by a solitary class - Crinoidea.

Class : Crinoidea.

1. Body is made up of a central disc and five bifurcated radiating arms.
2. The aboral surface is directed downwards, while the oral surface, upwards.
3. The feather-like flexible bifurcated arms act as organs of locomotion.
4. Mouth and anal openings are ventral.
5. The dorsal side of the disc contains ossicles.
6. Water vascular system comprises a ring vessel and radial vessels. The tube feet do not perform locomotion. They capture food.
7. Sexes are separate.

   Examples: Antedon, Metacrinus

Fig: Antedon bifida.1.Pinnules. 2. Ambulacral grooves. 3. Arms. 4. Cirri.

Sub-Phylum – IV: Asterozoa

This sub-phylum comprises a single class viz., Stelleroidea.

Class: Stelleroidea.

1. Free-living, and radially symmetrical animals
2. Body is star-shaped with a central disc and five arms.
3. Mouth is located on the oral surface. Anus is on aboral surface
4. Two double rows of tube feet are present in the ambulacral grooves.
5. Body cavity is lined with ciliated epithelium and is filled with coelomic fluid.
6. Alimentary canal is well developed with distinct parts.
7. Pedicellariae are present.
8. Sense organs are in the form of sensory tentacles and eye spot.
9. Sexes are separate. Development is indirect.

Examples: Asterias, Ophiothrix, Solaster

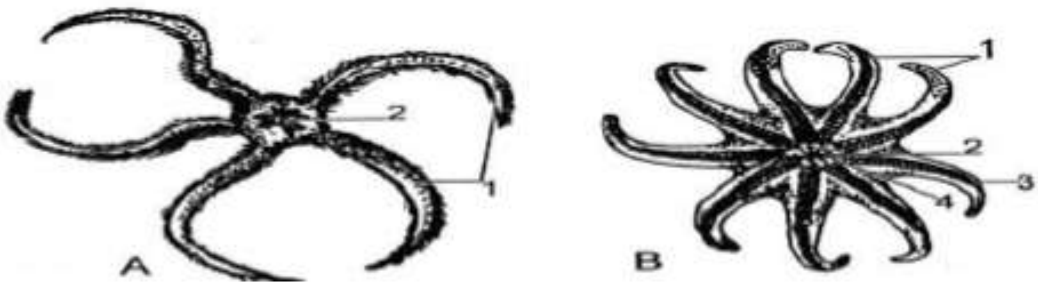


Fig: Echinoderms – (A) Ophiothrix. (B) Solaster. 1. Arms. 2. Mouth. 3. Marginal plates. 4. Disc.

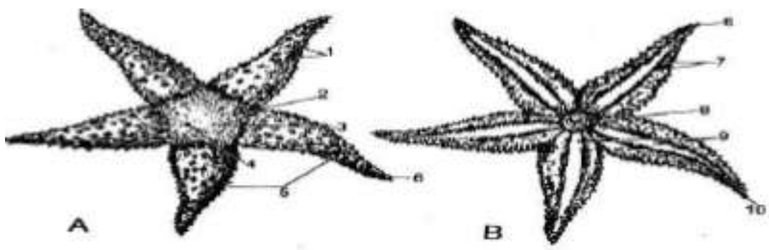


Fig: Asterias - External Features - (A) Aboral view. (B) Oralview. 1.Marginal spines. 2.Madreporite. 3.Central disc. 4.Anus. 5.Arms. 6.Terminal tentacles. 7.Tube feet. 8.Mouth. 9.Ambulacral groove. 10.Eye

CHORDATA

Phylum Chordata was established by **Balfour** in 1800. Early chordates evolved during Ordovician period of palaeozoic era. The ancestors of primitive chordates are Echinoderms. According to **Garstrong, chordates evolved from Auricularia larva** of Holothuroidea by neoteny or paedegenesis Previously Hemichordata, Urochordata and Cephalochordata were included in protochordata. Hemichordates show more affinities with invertebrate phyla rather than with chordates. As such Hyman separated it from chordata and a status of invertebrate phylum was accorded. Present day authors follow this system. The protochordates show affinities with chordates and some non-chordates. They also possess their own specialized characters

1. **Notochord or chorda dorsalis**

   It is a semi flexible rod present along the length of the body immediately below the nerve cord. It consists of specialized vacuolated cells surrounded by a firm but elastic sheath. It is present in some stage of life in all chordates.

   In tunicates it is lost in the adults.In vertebrates the notochord is present in the embryo, in the adults it is **replaced by vertebral column**.

2. **Dorsal tubular nerve cord**

   This is a single, tubular, fluid filled, non-ganglionated chord. It is present in mid-dorsal line above the notochord.

   In chordates nerve cells are present in the centre and nerve fibres are at the periphery in the nerve chord. In non-chordates the reverse is the condition. It persists throughout the life. Differentiated into: Anterior wide – “brain” and Posterior long slender – “spinal cord”

3. **Gill slits or pharyngeal slits**

   Gill slits are the lateral paired openings that appear during early development. The Pharynx communicates to the outside through these gill slits.

   In course of evolution various modifications occurred in gills.

   a) In primitive chordates gills are modified for filtering food particles from water

   b) In fishes, amphibians they are modified for gaseous exchange

   c) In land-living chordates-the gills are present only in embryo. In human embryo they are vestigial.

d) In land-living chordates-the gills are present only in embryo. In human embryo they b are vestigial.

Other chordate characters

1. Bilaterally symmetry: The body can be divided into two equal halves in the median longitudinal plane only.
2. Distinct cephalization: Anterior segments fuse into a head with brain and sense organs.
3. Triploblastic: Presence of three embryonic germ layers – ectoderm, mesoderm and endoderm are present.
4. The Coelome: a perivisceral space lined by mesodermal epithelium.
5. Duterostomus condition: Blastopore forms the anus and a new mouth develops.
6. Metameric Segmentation: More conspicuous in embryonic stages

DIFFERENCES BETWEEN CHORDATES AND NON- CHORDATES

CHORDATES	**AND NON- CHORDATES**
Notochord Present	Notochord absent
Dorsal nervous system	Ventral nervous system
Hollow nervous system	Solid nervous system
Tubular Nervous system	Double nervous system
Heart Ventral.	Heart Dorsal
Blood flows dorsally backward and ventrally forward	Blood flows dorsally forward while ventrally backwards
Visceral clefts present in pharynx	Visceral clefts absent
Limbs derived from several segments.	Limbs derived from one segment
Anus opens before the last segment	Anus opens into the last segment

Kingdom

Animalia

Phylum

Chordata

Presence of motochord, dorsal nerve cord and gill slits

Group

Acraniata
or
Protochordata

Animals without cranium or brain box

Craniata

Animals with cranium or brain box

Sub Phylum

Vertebrata

Animals with vertebral column

Sub Phylum

1 Urochordata

Class

1 Ascidiacea
Ex:
1. Herdmania
2. Ciana
3. Ascidia

2 Thaliaceae
Ex: 1. Pyrosoma
2. Salpa
3. Doliolum

3 Larvacea
Ex:
1. Oikopleura
2. Appendicularin

2 Cephalochordata

Class

Leptocordii Ex: Amphioxus Lanceolats

Sub phylum

Vertebrata

Division

Agmartha (With out Jaws)

Class

Ostracodermi
Ex. Cephalaspis

Cyclostomata
Ex: 1. Petromyzon 2. Myxine

Gnathostomata (Gnthos - jaws

Stom - mouth

Division-2
Ganthostomata

Supaer Class

1
Pisces

Piseces - Fish
Ex: All fishes

2
Tetrapoda
Tetra - four,
Podus - foot

Class

Placodermi
Palce - Shield
Dermi - Skin

Choudrinkhthyes
or
Elasmobranchii
Choudro -
Cartlage
Khehyes - fish
Ex: Sharks, rays
& skaies

Osteichthyes
or Teleostomi
Osteon - bomo
Ichthyos - fish
Ex: Majority of
the Living fishes

Super Class - 2

Tetrapoda

Class

1
Amphibia
Amphi-both
Bios-lifo
Ex: Frogs, Toads
& Salamanders.

2
Reptilia
Repton - to creep
Ex: Lizards,
Snakes
Tortoises and
Crocodiles.

3
Aves
Avis - bird
Ex: All birds

4
Mammalia
Mamma - breast
Ex: Duck bill
platypus,
Bats, Man, Moles,
Dogs, Cats.

Chordate divided in to two groups based on presence or absent of cranium

1. Acraniata :Animals with out cranium. It is also called protochordata
2. Craniata : animals with cranium

Protochordata

1. The protochordates are exclusively marine, solitary, or colonial primitive and triploblastic coelomates.
2. A single layer of transparent epithelium or tunic covers the body.
3. A bony skeleton is entirely absent. Sometime's the basement membrane is thickened to form supporting structures.
4. Pharyngeal gill-slits are present. These are lined with cilia and supported by a branchial skeleton called branchial basket.
5. In urochordates the notochord occurs in the tail of the larva. It is absent in the adult. In cephalochordates the notochord extends throughout the body.
6. These are muco-ciliary feeders. The dorsal lamina and endostyle play an important role in the movement of food from pharynx.
7. The circulatory system consists of a chamberless heart, blood vessels and sinuses. The ascidian heart beats in the reverse direction also.
8. The nervous system is primitive. In urochordates, the nervous system is present in the larva. In the adult, it is reduced to simple ganglion. In the cephalochordates it is relatively much developed.
9. Excretory organs are nephridia, glomerulus and neural gland.
10. Reproduction is both by asexual and sexual methods. Development may be direct or indirect Protochordata is divided into two sub-phyla. (1).Urochordata and (2).Cephalochordata.

    Sub-phylum Urochordata consists of three classes -(1) Ascidiacea, (2) Thaliacea and (3)Appendicularia.

    Sub-phylum Cephalochordata consists of a single class cephalochordata.

Urochordata - General Characters

The members of Urochordata (Uros : tail; chorda : notochord) possess notochord in the tail region alone, hence the name of the subphylum. These are commonly called sea squirts.

The larval stage exhibits many chordate characters. The chordate characters are lost during metamorphosis. Urochordata is also known as Tunicata (Tunica : an undergarment). Entire body is covered by the test or tunic, hence the name Tunicata.

Aristotle (384-322 B.C.) first described a simple ascidian. Lamarck in 1816 established the groups name Tunicata after studying the test. Kowaleysky, a Russian scientist placed them under true chordates after a detailed study of larva. Herdman, Bateson, Garstang, Berrill and Das contributed valuable information regarding urochordates

1. Urochordates are marine animals of worldwide distribution.
2. Some are solitary and some are colonial.
3. The tadpole larva leads a free-swimming life. Adult is inactive and leads sedentary life, fixed to a substratum.
4. Colouration of the body varies. The body may be transparent, translucent or opaque,
5. Shape and size also vary according to genera.
6. The entire body is enclosed in a test or tunic. It is made up of tunicine.
7. The animals have two siphons. One is branchial siphon, present on the anterior side. Second is atrial siphon present on the dorsal side. Water enters the branchial siphon through the branchial aperture. It comes out through the atrial aperture situated on atrial siphon. Incoming water bringsfood material and oxygen. Outgoing water carries away carbondioxide, faecal matter, other excretory products and sex cells.
8. There is a spacious atrial or peribranchial cavity. The viscera are placed in it.
9. Pharynx occupies a large part of the atrial cavity. It has numerous perforations called stigmata which open into the atrial cavity.
10. Dorsal lamina or hyperpharyngeal fold is present on the mid-dorsal side of the pharynx. Midventral side of the pharynx is occupied by the endostyle.
11. Circulatory system consists of tubular heart. It is located on the ventral side. Numerous blood sinuses and blood vessels are present. Blood contains various types of cells. Flow of blood is reversed periodically. So the same blood vessels act as an arteries for some time and as a veins for some time i.e., They carry oxygenated blood and deoxygenated blood alternately.
12. Asexual reproduction takes place by budding. Sexual reproduction is by testes and ovary.

13. The animals exhibit hermaphroditism i.e., both male and female sex organs are present in the same individual. Each lobe of the gonad has male and female sex organs.
14. Regeneration, dimorphism, polymorphism are common in these animals.
15. Development is indirect with a tadpole larva. It possesses chordate characters which degenerate during metamorphosis. It is called retrogressive metamorphosis. In some members neoteny or paedogenesis is noted.

Classification of Urochordata

Class— 1 Ascidiacea

1. The members of Ascidiacea are all free-swimming or sedentary.
2. They are all marine and their size is variable.
3. The body is enclosed in a test made of tunicine. It possesses connective tissue fibres, cells and blood vessels.
4. Typically the branchial aperture is on the anterior side and the atrial aperture is on the dorsal side.
5. The Ascidians may be solitary or colonial. In colonial forms, each individual zooid may have a separate test or all the zooids may have a common test. This appears as a compound strucutre.
6. Well developed atrial cavity or peribranchial cavity is present.
7. Innumerable gill pores or stigmata are present on the walls of the pharynx. The walls of the stigmata are heavily ciliated.
8. The notochord is present only in the larval stage.
9. Intestine is looped.
10. Nervous system is reduced to a solid nerve ganglion with few nerves.
11. Heart is enclosed in a tubular pericardium.
12. Asexual reproduction is by budding. Buds arise from basal stolon. It is the outgrowth of branchial sac.
13. Sexual reproduction occurs through testes and ovaries

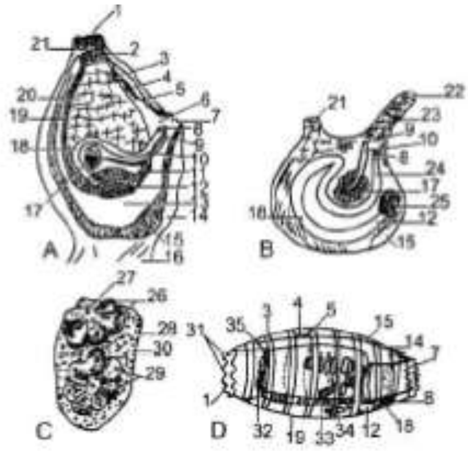


Fig: Urochordates - (A)Ascidia. (B)Molgula. (C)Botryllus. (D)Doliolum (Gonozooid).

1.Branchial aperture. 2.Tentacles. 3.Dorsal tubercle. 4.Neural gland. 5.Nerve ganglion. 6.Cloaca. 7.Atrial aperture. 8.Anus. 9.Genital pore. 10.Genital duct. 11.Oesophagus. 12.Stomach. 13.Atrial cavity. 14.Test. 15.Mantle. 16.Base. 17.Gonad. 18.Intestine. 19.Endostyle. 20.Pharynx. 21.Branchial siphon. 22.Atrial siphon. 23.Muscle bands. 24.Rectum. 25.Liver lobe. 26.Individual branchial aperture. 27.Common atrial aperture. 28.Debris. 29.Zooids. 30.Common test. 31.Branchial lobes. 32.Peripharyngeal bands. 33.Stigmata. 34.Heart. 35.Pre-branchial zone

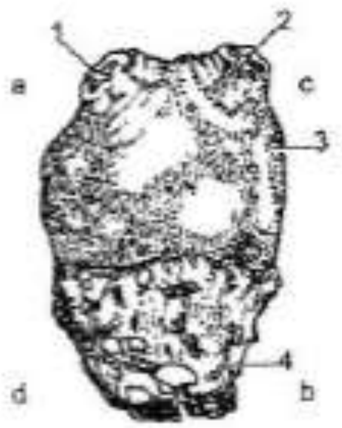


Fig: Herdmania Pallida. 1 .Brauchial aperture. 2.Atrial aperture. 3.Test. 4.Foot. (a).Anterior side. (b).Posterior side. (c).Dorsal side. (d).Ventral side.

Class - 2 Thaliacea.

1. The thaliaceans are widely distributed free swimming and pelagic tunicates.
2. Some are simple and some form colonies.
3. Caudal appendage is absent in the adult condition.
4. Test is clear, transparent and permanent.
5. Body is barrel shaped. It is of medium size.

6. Muscular fibres of the body wall are arranged in complete or incomplete ring like bands.
7. The branchial and atrial apertures are at the opposite ends of the body.
8. In some forms two large stigmata are present. In others many small stigmata are present. These open into the atrial cavity which in turn opens to the exterior.
9. The adult does not possess the notochord, nerve cord, and tail.
10. Exhibits hermaphroditism.
11. Development is direct or indirect.
12. Most remarkable type of alternation of generations is found.
13. Some thaliaceans perform locomotion by ejecting a jet of water from posterior side.

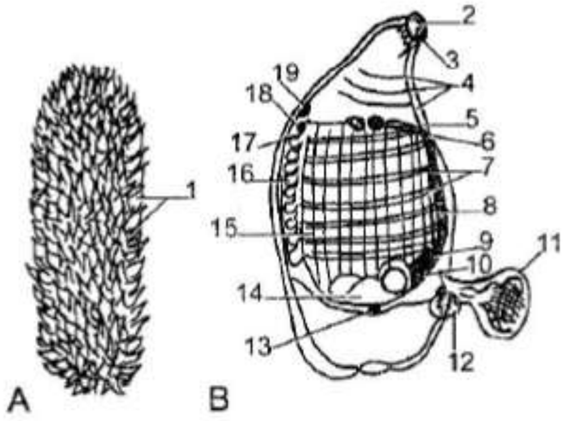


Fig: Colony of Pyrosoma —(A)Colony (B)Single Ascidiozooid. I .Process of the test. 2 .Branchial aperture. 3.Tentacles. 4.Muscular bands. 5.Test. 6.Luminiscent organ. 7.Stigmata. 8.Endostyle. 9.Intestine. 10.Heart. 11 .Bud. 12.Gonad. 13.Atrial aperture. 14.Anus. 15.Stomach. 16.Branchial sac. 17.Dorsal lamina. 18.Peripharyngeal band. 19.Dorsal tubercle. 20.Nerve ganglion

Class 3- Appendicularia (Larvacea)

1. Larvaceans are transparent, free swimming and marine animals.
2. The test is in the form of large envelop called the ‘house’ which is renewed frequently.
3. House is protective, hydrostatic, respiratory and food filtering structure.
4. Tail possesses a notochord which is enveloped by a sheath.

5. There is no atrium.
6. Nerve cord extends upto the tip of the tail.
7. These are hermaphroditic.
8. Larva develops the sex organs and reproduces. This is called neoteny or paedogenesis, hence the name Larvacea. Example: Oikopleura

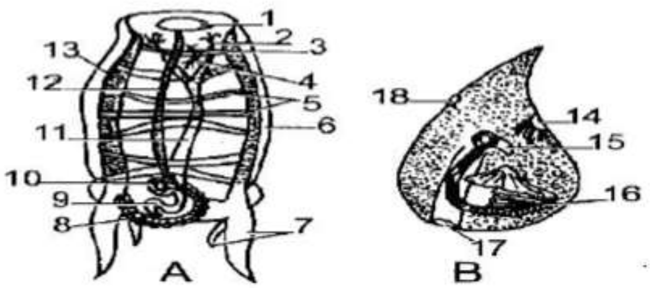


Fig: (A)Salpa-oozooid (B)Oikopleura in the house. 1 .Branchial aperture. 2.Branchial muscle. 3.Dorsal tubercle. 4.Nerve ganglion. 5.Muscle bands. 6.Test. 7.Test process. 8.Stolon. 9.Intestine. 10.Heart. 11.Dorsal lamina / gill bar. 12.Endostyle. 13.Mantle. 14.Incurrent pore. 15.Animal. 16.Filter apparatus. 17.Excretory pore. 18.Back door.

General Characters of Cephalochordata

1. These are marine solitary organisms of worldwide distribution.
2. Body is fish-like, with burrowing and swimming habits.
3. Symmetry is present in Amphioxus but absent in Asymmetron.
4. Cephalochordates lack head, brain, eyes, auditory appartus and jaws and there are no paired appendages. Trunk and tail are present.
5. Dorsal fin is median in the form of a low hollow fold of skin.
6. Caudal fin is in the form of lobes.
7. Oral hood is an outgrowth of the skin at the anterior ventral part of the body.
8. Attached to oral hood 10-20 pairs of stiff ciliated buccal cirri or oral cirri are present.
9. Oral hood encloses a wide cavity called vestibule.
10. At the base of the vestibule a circular sphincter partition is present. It is called velum. It has velar tentacles. Enterostome is present at its centre.
11. Exoskeleton is absent. Muscles are dorso-lateral and arranged as 'V' shaped blocks called myotomes.

12. Notochord is persistent. It extends from rostrum to tail.

13. Coelom is obliterated by atrial or peribranchial cavity.

14. Pharyngeal wall has numerous gill slits which open into atrial cavity. A continuous water current is maintained for feeding and respiration. Water enters through mouth, goes into pharynx, then into atrial cavity and goes out through atriopore. . These are filter feeders or mucociliary feeders.

15. Hepatic caecum is the only digestive gland.

16. Circulatory system is on chordate plan but blood is colourless. Respiration is through general body surface.

17. Excretory system consists of nephridia which is the characteristic feature of Annelida.

18. Nervous system is as in vertebrates. It consists of hollow and tubular dorsal nerve cord. It is present above the notochord.

19. Sexes are separate. There are numerous gonads which are metamerically arranged. Gonoducts are absent.

20. Fertilization is external.

Classification of Cephalochordates

Subphylum Cephalochordata consists of only one class, Cephalochordata. It is represented by two genera, the Amphioxus and Asymmetron.

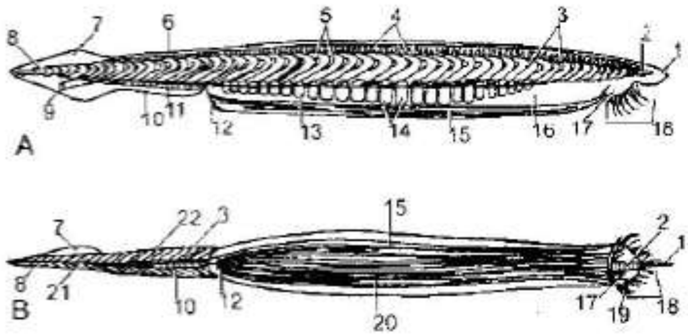


Fig: Amphioxus—External features. (A)Lateral View. (B)Ventral View. 1.Rostrum. 2.Notochord. 3.Myotomes / myomeres. 4.Dorsal fin ray boxes. 5.Myocommata / myosepta. 6.Dorsal fin. 7.Candal fin. 8.Tail.

VERTEBRATA - GENERAL CHARACTERS

1. The chorda dorsalis or notochord: The name 'chordata' for the Phylum has come from this structure (Gr. Noton = back, L. chorda = a cord). It is a long flexible cord consisting of specialised vacuolated cells extending-from the head to tail along the dorsal midline in the embryos of most chordates. It lies between the alimentary canal and the dorsal cord of the Central Nervous System.
2. The branchial clefts: Another important feature of chordata is the presence of vascular clefts. There are pairs of perforations leading from the pharynx. The gills of many aquatic animals lie within these clefts. Branchial clefts are found in the embryos of creatures equipped with lungs. The branchial clefts apparatus sometimes will be converted to endocrine and other functions of adult vertebrates. In lower vertebrates the branchial apparatus is used in feeding mechanism
3. Central Nervous System: It is a dorsal tubular structure filled with fluid in advance forms. It is differentiated into a brain anteriorly. Presence of dorsal tubular nervous system in another structure common to most chordates in the larval or later stages.

Vertebrates divided into two divisions based on jaw suspension

1.Agnatha (Without jaws)

2. Gnathostomata-(Jawed vertebrates Gnathos = Jaws)

1. **Agnatha:** divided into two classes b1.1.Ostracodermi

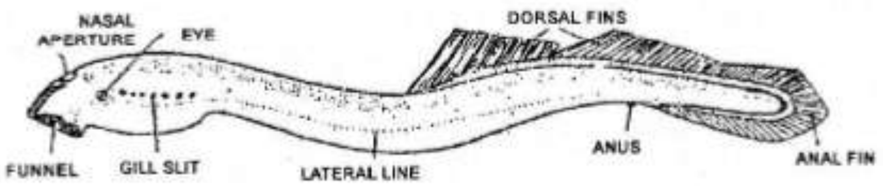
These are most primitive extinct and oldest vertebrates.

The body is covered by Bony exoskeleton hence they are called shelled vertebrates. Ex: Cephalaspis, hemicyclopsis (extinct).

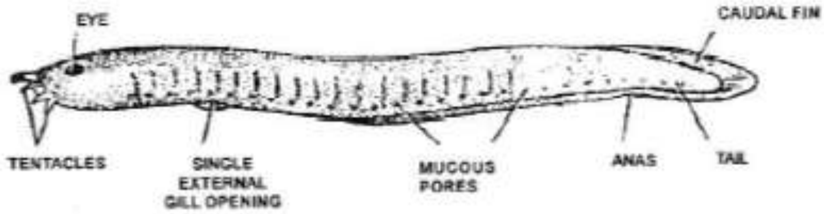
1.2. Cyclostomata : Cyclo-round , Stomum-mouth

1. Early vertebrates with incomplete and cartilaginous skeleton.
2. Circular sectorial mouth without jaws
3. Paired fins are absent.
4. Skin scaleless.
5. Gills 6-14 pairs

Ex: Petromyzon, Myxine



Petromyzon



Myxine

Fig:

Gnathostomata: it is divided into 1.Pisces and 2.Tetra pods

1.pisces 2.Tetrapods

1. **pisces** divided into three classes 1.placodermi 2.chondrichthys3. Osteichthyes

1.1 Placodermi

1. It includes extinct fishes.
2. They lived during the Silurian
3. Devonian and carboniferous periods of the palaeozoic era.
4. The body is covered by heavy bony plates or bony armature.

   Ex: Palaeospondylus

1.2. Chondrichthyes

1. The cartilaginous fishes.
2. Devonian to Recent.
3. Marine fishes.
4. Body covered by placoid scales or may be devoid of it.
5. Mouth is ventral in position.
6. Gills are five pairs and operculum is absent.
7. Tail fin is heterocercal.
8. Male members are provided with claspers.

   Ex: Sharks, rays & skates.

1.3 Osteichthyes

1. The bony fishes. Devonian to Recent
2. Marine or freshwater fishes.
3. Body covered by Ctenoid, Cycloid or Ganoid scales
4. Mouth is terminal or subterminal
5. Gills are four pairs and covered by operculum.
6. Tail fin is either heterocercal or homocercal type.
7. Male members have no claspers. Ex: All bony fishes.

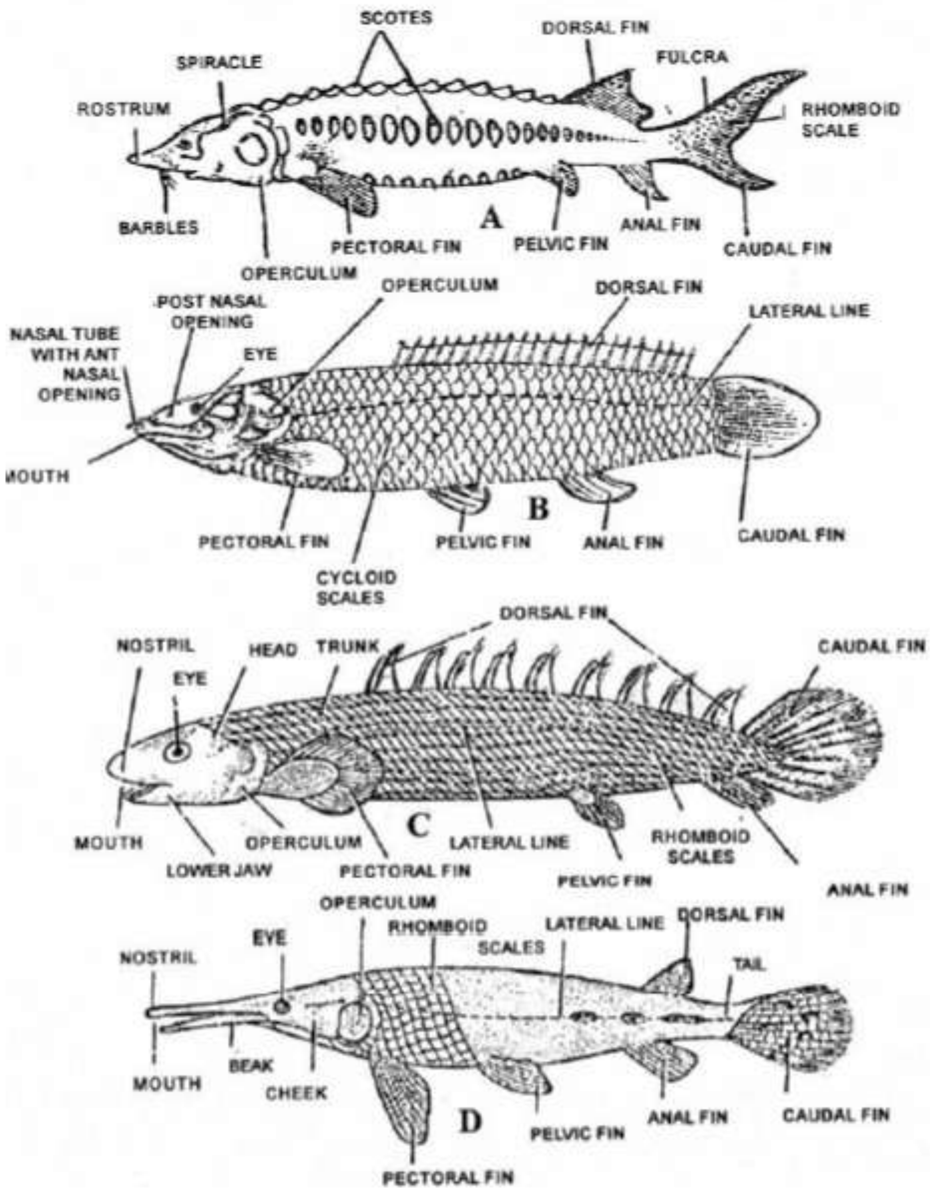


Fig: Fishes A. Acipenser B. Amia C. Polypterus D. Lepidosteus

Tetrapods divided into 4 superclasses :1..Amphibians 2.reptiles 3..Aves 4..Mammales

2.Amphibia

It is very difficult to classify amphibians. Different authors adopt different methods of classification. The classification given in **Parker** and **Haswell**, revised by **Marshall** (1974) recognizes two subclasses, the Apsidospondyli and Lepospondyli. It includes the living order Anura under the Apsidospondyli, while Urodela and Gymnophiona are kept under the subclass Lepospondyli. Recent studies however, indicate that the three orders must have evolved from a common ancestor (monophylitic origin) and a separate subclass Lissamphibia is created to include the three modern amphibian orders. Romer whom Parker and Haswell quotes extensively, in a recent book on the vertebrates body (Romer, A.S. and Parsons, T. S. 1977. **The Vertebrate Body**) has recognized the monophyletic origin of these three orders and accepts the creation of the subclass Lissamphibia to include the living orders.

In order to avoid major confusion and detailed on the discussion on the divergent views on classification we shell deal with the classification under two separate heads, the extinct and the modern amphibia.

1 Extinct Amphibia

The extinct amphibia, which flourished through **Devonian to Carboniferous** period are grouped under two subclasses, the **Apsidospondyli** and the **Lepospondyli**.

Sub Class : Apisdospondyli

1. Amphibians grouped under this sub-class are considered to have derived directly from the crossopterygean ancestors.
2. There are two cartilaginous units of centra, the anterior intercentra and the posterior pleurocentra.
3. This subclass is represented by super order labyrinthodontia

1 Amphibia

1. Devonian to Recent
2. Cold blooded vertebrates that are capable of living in water (fresh water) as well as on land.
3. Skin is smooth, moist and without scales.
4. Heart is three chambered.

5. Lungs are used for aerial respiration.
6. Limbs are tetrapodus, digitate, pentadactyl and are used for locomotion.

   Ex: Frogs, Toads and Salamanders.

Sub Class :Apisdospondyli

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2. There are two cartilaginous units of centra, the anterior intercentra and the posterior pleurocentra.
3. This subclass is represented by super order labyrinthodontia.

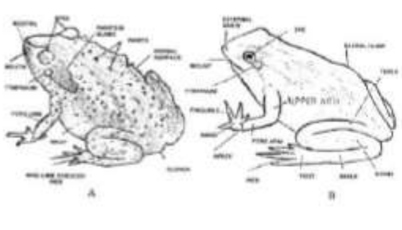
Sub Class Lepospondyli

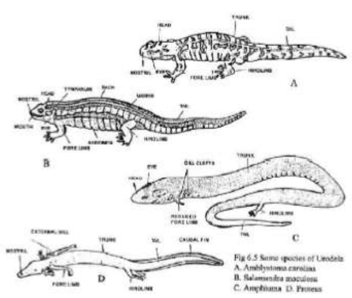
Members of this sub-class are characterized by the presence of lepospondylous vertebrae. The centrum of this sub-class has originated by the direct ossification of embryonic notochord. These animals appeared in the Carboniferous period but disappeared in the Permian period. The sub-class consists of three orders namely 1. Aistopoda 2.Nectridia and 3.Microsauria.

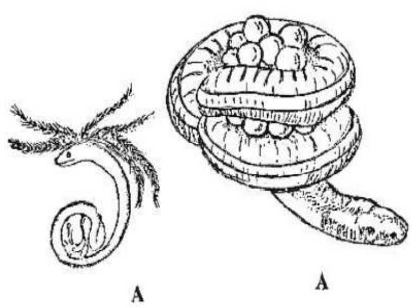
sub-class Lissamphibia

Modern Amphibia

All the living amphibians are grouped under one sub-class the Lissamphibia which is represented at present by **three orders** as follows: 1.Anura (or Salientia) 2. Urodela (or Caudata) and 3.Gymnophiona (or Apoda or Caecillia)







2.2 Reptilia

1. Reptiles – Carboniferous to recent.
2. Cold blooded terrestrial or secondary aquatic tetrapods.
3. Skin dry and covered by epidermal scales.
4. Limbs are tetrapodus digitate and the digits terminate in claws.
5. Oviparous. Reptiles lay eggs on land. (cleidoic eggs)

   Ex: Lizards, Snakes.

The skull and teeth are mainly utilised as criteria for classifying the reptiles. The temporal region of the skull as stated earlier is considered as the basis for classification purpose. The classfication as adopted by Parker and Haswell has been followed here.The class Reptilia is divided into 6 sub classes based upon the presence or absence and position of the temporal vacuities of skull. Orders Chelonia (sub class **Anapsida**), Rhyncocephalia, Squamata (Sub class.**Lepidosauria**) and Crocodilia (Sub class **Archosauria**) are only represented by living members.

1.Sub Class Anapsida

These comprise the earliest primitive forms of Carboniferous period. The temporal region of the skull is not perforated. This subclass is divided into **two orders**: **1.Cotylosauria,2.Chelonia**

2.Sub Class Icthyopterygia

This sub class includes **extinct reptiles** which lived in waters. Their body was fish-like and skull possessed single fossa. These reptiles are grouped into two orders, the Mesosauria which lived in fresh water lakes, had stronger hind limbs. e.g. ***Mesosaurus***. The Icthyosauria were marine whose limbs were paddle like e.g ***Icthyosaurus***. It was a fish like reptile without a neck, reached a length of 30 feet and possessed a dorsal fin.

3. Sub Class Synaptosauria

This sub class consists of extinct aquatic reptiles with a single upper temporal fenestra. The group had much diversified forms. It comprises **two orders**.**1. Protorosauria, 2.Sauropterygia**

4. Sub Class Lepidosauria

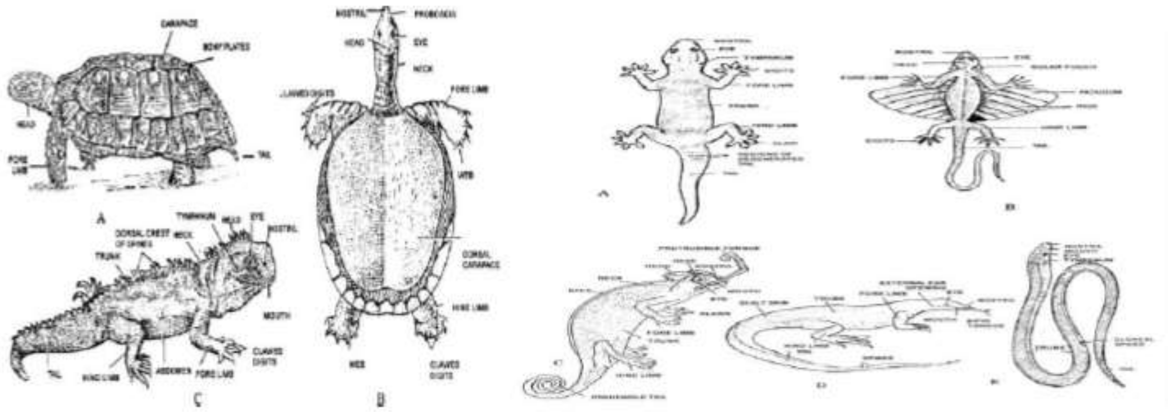
Representatives of this sub class primitively possess a diapsid skull typically with two temporal fenestrae an upper and a lower which in some cases, have become reduced. Out of its three orders, all members of order Eosuchia became extinct. The fossils of Youngina show much primitive condition.1**Rhynchocephalia,2.Squamata**

5. Sub class Archosauria

In reptiles which comprise the sub class Archosauria, the skull is typically diapsid. The interparietal,tabular bones and parietal foraman are absent. The hind legs were much longer than the fore limbs. Some forms because toothless almost with horny beaks and their distal tarsals fuse with metatarsals. As in birds, digits are reduced. There was a fosssa on the outside of the lower jaw between dentary sub angular and angular. An anteriobital fenestra is almost always present in front of the **orbit.** The sub-class consists of **five orders.**

6.Sub Class Synapsida

These were mammal like reptiles which became totally extinct. They had single infratemporal fossa on the lateral side of the skull and large dentary bearing heterodont dentition. Their fossils were excavated in India, North America, Africa and Russia. This sub class includes **two orders**. The order ***Pelycosauria*** were large lizard like reptiles, with a peculiar web of skin projecting on the back as a sail which is supported by internal skeleton consisting of enormously long neural spines e.g. ***Dimetrodon***.



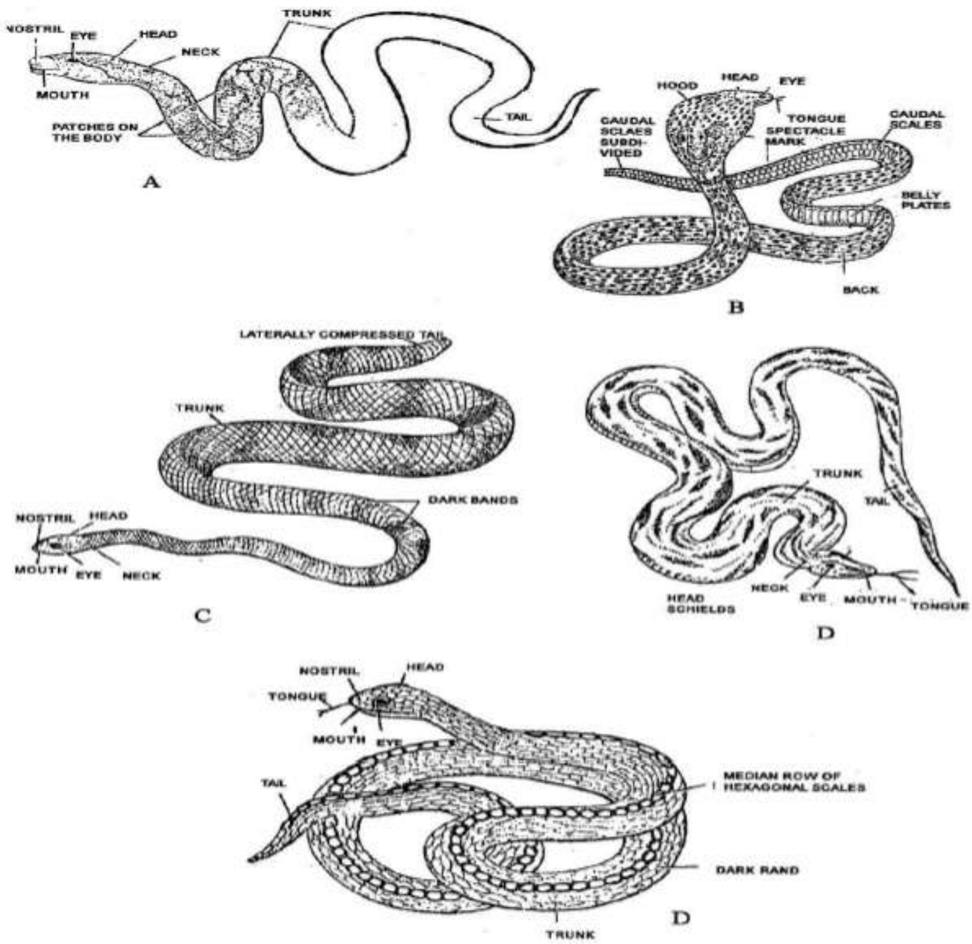


Fig: A. Python B. Naja naja (Cobra) C. Hydrophis D. Vipera ruselli E. Krait (Bungarus)

2.3 Aves

1. The birds-jurassic to Recent.
2. Warm-blooded tetrapods (or homiothermous) i.e. the body temperature remains constant.
3. Skin is covered with an epidermal exoskeleton of feathers, which helps the body in aerial life.
4. The fore limbs are modified as wings for flight.
5. The hind limbs are covered with scales and terminate in claws and are modified for bipedal walking, perching or swimming.
6. Jaws are devoid of teeth (adventurous) and are modified to form a beak.
7. Breast bone is often keeled to provide a surface for the attachment of flight muscles.

8. Heart is four chambered.
9. Lungs are provided with air sacs.
10. Oviparous.

Birds belong to class Ayes of the phylum vertebrate. The classaes is divided into **two subclasses 1) Archaeornithes 2) Neornithes**.

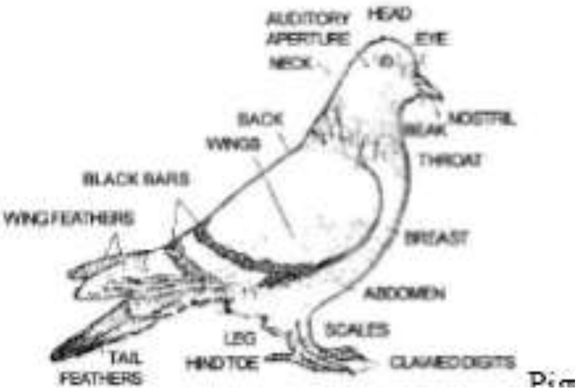
Subclass Archaeornithes (Gr. Archios-ancient, ornithos - birds)

1. Primitive extinct birds form upper Jurassic period.
2. These birds show some reptilian and some avian features
3. They forma link between reptiles and birds.

E.g. ***Archaeopteryx lithographica, Archaeonissimensi***

Sub class Neornithes (Gr. Neos - new; omithos - bird)

This subclass includes all living birds and some extinct birds. The birds belonging to neornithes first arosefrom cretaceous period. They have a short tail usually ending in a pygostyle. **Teeth are absent** in all theliving birds carpals and metacarpals are fused to form **carpometacarpus**. Fore limbs have three digitswithout claws, sternum is well developed with a keel.



2.4 Mammalia

1. The mammals – Jurrassic to Recent.
2. Warm blooded tetrapods.
3. Body is covered by hair.

4. Skin has glands such as sebaceous and sudoriferous glands.
5. External ears or pinna are present.
6. Males have testis lodged in scrotal sacs.
7. Females feed their young ones with the milk produced by mammary glands.
8. Heart is four chambered.
9. The diaphragm-a transverse muscular partition separates the chest cavity from the abdominal
10. Cavity is well developed.

Viviparous:

They give birth to the young ones directly.

Ex: Duck bill platypus, Bats, Man, Moles, Dogs & Rabbit.

Note: Only two mammals i.e. Ornithorhynchus and Echidna are oviparous i.e. Egg laying mammals

Class Mammalia is divided into **three sub classes**.

1. Prototheria 2. Metatheria or Marsupialia 3. Eutheria or Placentalia

Sub class - Prototheria

Prototheria is represented by primitive mammals comprising the order monotremata. Prototherians are described as primitive unfinished mammals by Romer. They possess the reptilian characters as well as mammalian characters.

Characters

1. Mammary glands are **without teats (nipple)**. These glands are modified sweat glands where as in Eutheria they are modified sebaceous glands.
2. Males also posses functional mammary glands and can feed the young ones. This feeding of young with milk by father and mother is known as '**Gynacomastism**'.
3. No corpus callosum in the brain.
4. Teeth are present only in young ones. Adults are with horny plates.
5. Testis are attached to the kidneys in the abdomen.
6. They act as **connecting link between reptiles and mammals**.

Sub class - Metatheria (Marsupialia or Didelphia)

The marsupials occupy the intermediate position between Prototheria and Eutheria. They are oldest placental mammals. A pouch, **marsupium** is on the belly of female into which newborn young one is kept and nourished.

They exhibit the following characters.

1. A **brood pouch or marsupium** is present in females. The mammary glands are present in the marsupium
2. Hind limbs are larger than the fore limbs.
3. Corpus callosum is less developed or absent.
4. Teeth are more in number. Teeth are formed only once in life time. (**monophyodont**)
5. Testis is situated in scrotal sacs. The **penis is bifid**.
6. The females have **2 oviducts, 2 uteri and 2 vaginae (dideiphic condition**) which open separately into urinogenital sinus.
7. The young ones are born naked and blind, but they posses clawed fore limbs by which they crawl into brood pouch.
8. The young ones are born in immature state,
9. Interclavicle is absent.
10. The brain is less developed, corpus callosum is absent.
11. Metatheria exhibit **discontinuous distribution**. Some marsupials like Kangaroos live in Australia and apposum live in South America

    Eg. ***Macropus*** *(Kangaroo)* is the largest marsupial.

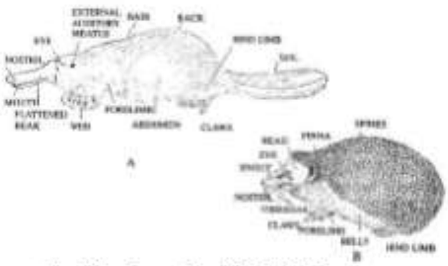
    Didelphis (American apposum)

Subclass - Eutheria

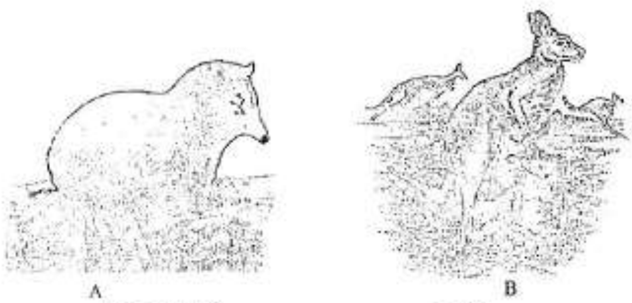
These are **placental mammals**. They are highly evolved with advanced organisation.

1. They are viviparous, young ones develop in the uterus of the mother. At the time of birth they are miniature adults.

2. A connection is formed between the developing embryo and uterus of mother called **placenta**. The nutrition, respiration and excretion of the foetus is carried through placenta.
3. Allantoic placenta is formed. There is no marsupium.
4. Brain is well developed with large cerebral hemispheres which are connected by corpus callosum.
5. Testis are in scrotal sacs. Copulatory organ is the penis.
6. Vagina is single. Anus and gential apertures are separate.
7. Mammary glands are with teats. They are modified sebaceous glands.
8. External ear, pinna are present.
9. All the sensory organs are well developed.
10. Some mammals like whales are secondarily adopted for aquatic mode of life.
11. They are distributed all over the world.



Ornithorhynchus B. *Echidna*



A.Didelphis B. Macropus

4 CELL STRUCTURE AND FUNCTION

All organisms like , animals, plants & microorganisms are composed with cells, which are the basic structural and functional units of life.Organisms may be composed of one cell or many cells based on this, organisms divided into the following types,

- Organisms whose body consists of a single cell are called **Unicellular organisms**, A single cell performs all vital functions such as feeding ,movement, respiration, etc.

  Ex : Bcteria, protozoans.

- Organisms whose body consists of many cells are called **multicellular organisms**.In multicellular organisms similar type of cells are grouped together to perform particular function.

  Ex : Plants and animals

- Viruses are Non cellular entities because they lack cell or cell- like structure

  The word "**Cell**" was termed by **Robert Hooke** in **1665** first he discovered cells in a piece of cork .Hooke published his findings in "**Micrographia"**. The cell is derived from the latin word "**cellula**" which means smallest component. Anton Von Leeuwenhoek who observed living cells under a microscope and named them animalcule, its meaning '**Little animal'**.

Objectives:

After completing this lesson , you will be able to;

- Define the terms mineral nutrition, macro and micro nutrients.
- 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 cell'
- illustrate the structure of plant and animal cells by drawing labeled diagrams

- describe the structure and functions of plasma membrane, cell wall, endoplasmic reticulum(ER),cilia flagella, nucleus, ribosome, mitochondria, chloroplast, golgi body, peroxisomes, glyoxysome, and lysosome;
- describe the general importance of the cell molecules- water,mineral ions,carbohydrates,lipids,aminoacids,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 karyotype analysis and its significance.

THE CELL THEORY

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: The cell theory was proposed by a german botanist, Schleiden and a british botanist Schwan in 1839.According to this theory all living organisms are composed with cells and the cell is the basic structural and functional unit of life. In 1855 , Rudalf Virchow developed an important" Extension of cell theory" which means all living cells arise from pre-existing cells (Omnis cellula- cellule)

Modern cell Theory

The following points are included in modern cell theory

- The basic structural and functional unit of life is a cell.
- All cells have the same chemical composition as well as Genetic information(DNA)
- All cells arise from pre-existing cells by division.

The cell : A cell may be defined as a unit of protoplasm bounded by a plasma membrane or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and include 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, pigments etc.

The bacteria have neither organelles nor a well formed nucleus. But every cell has three major components

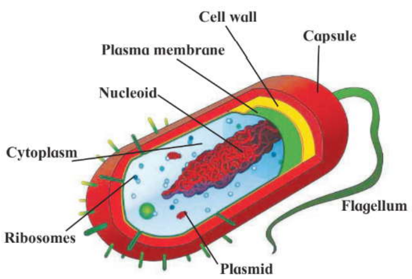
- Plasma membrane
- Cytoplasm
- DNA(nacked in bacteria and covered by a membrane in all other organisms
- Cell organelles

Two basic types of cells

Cytologists recognize two basic types of cells. Their differences have been tabulated below. Organisms which do not possess a well formed nucleus are Prokaryotes such as bacteria. All others possess a well defined nucleus covered by a nuclear membrane . They are eukaryotes.

Table Differences between prokaryotes and eukaryotes

Prokaryotes	Eukaryotes
1) Organisms in which the nuclear material is not bound by a nuclear membrane is called prokaryotes	1) Organisms with a definite nucleus are called eukaryotes
2) Nuclear material (DNA) floating in the cytoplasm	2) Nuclear material (DNA) present in the nucleus.
3) Prokaryotic cells have no ER, golgicomplex, mitochondria, lysosomes.	3) Eukaryotic cells have definite internal membranous structures like E R, Goligicomplex Mitochondria , lysosomes
4) 70 s ribosomes are present	4) 80 s ribosomes are present
5) No compartments in the cell	5) Distinct compartments in the cell i.e., the cytoplasm and nucleus



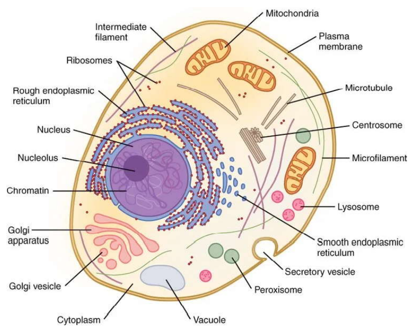
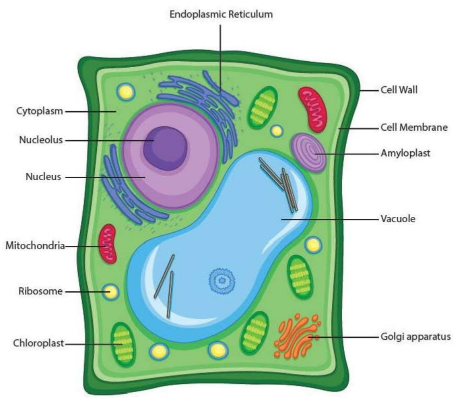
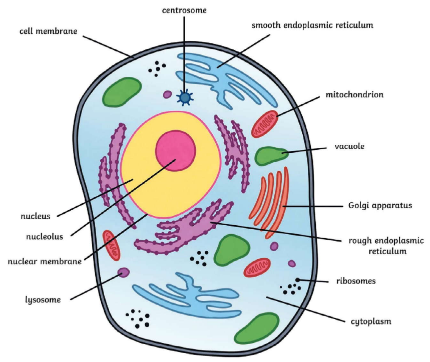


Table Differences between plant and animal cell

Plant cell	Animal cell
1) It is enclosed by a rigid cell wall	1) It is enclosed by a thin, flexible plasma membrane
2) A plant cell usually large in size	2) An animal cell is comparatively smaller in size
3) Plastides are present. Plant cells exposed to sunlight contain chloroplast	3) Plastides are usually absent
4) Golgi apparatus consists of a number of distinct or unconnected units called dictyosomes	4) Well developed golgibody is present
5) Food is reserved in the form of starch or fat Vacuoles are large in size	5) Food is reserved in the form of glycogen or fat An animal cell often possesses many small vacuoles
	

INTEXT QUESTIONS

1. What are the major components of the cell?
2. What are the differences between a prokaryotic cell and a eukaryotic cell?
3. Name the scientists who proposed the cell theory?
4. What are the differences between plant cell and animal cell?
5. Give two points about modern cell theory?
6. From where do new cells arise?

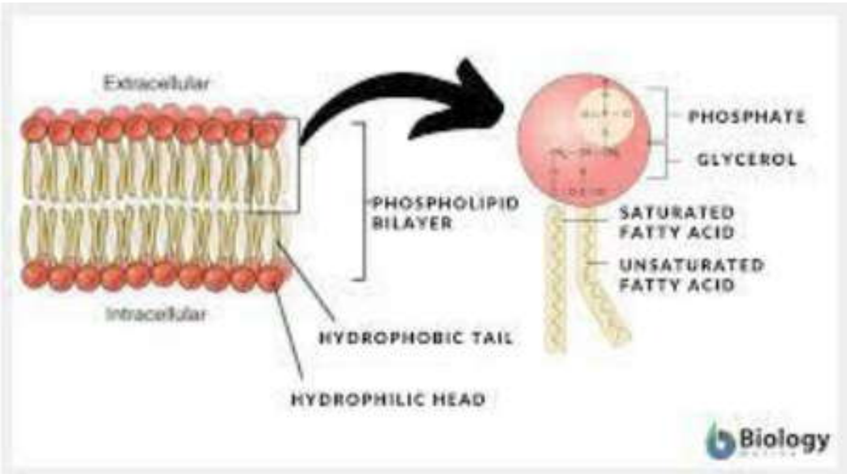
COMPONENTS OF THE CELL

The major components of the cell are

1) Cell membrane 2) Cytoplasm and 3) Nucleus

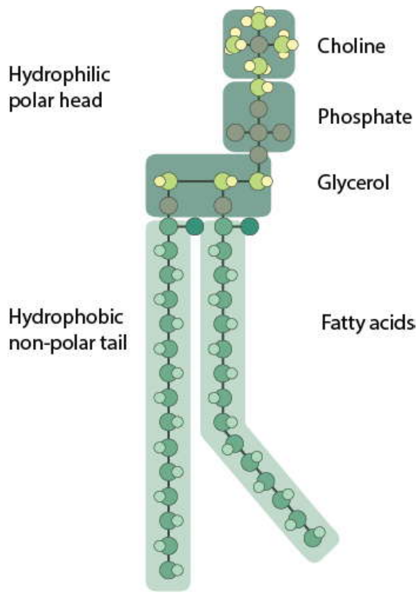
Cell membrane (Plasma membrane)

All cells are bounded by a thin membrane called the plasma membrane/ cell membrane. Plasma membrane is a dynamic, fluid structure and forms the external boundary of cells. Plasma membrane shows selective permeability that means it allows some solutes to cross it more easily than others. Several models were proposed to explain the structure and composition of plasma membrane. The "Fluid Mosaic" model is widely accepted. It was proposed by Jonathan Singer and Garth Nicolson in 1972. Plasma membrane is made up of a Lipid bilayer consisting of phospholipids and proteins.



Phospholipid molecules are amphiphathic, which have both hydrophilic or polar end which is known as the head and a hydrophobic or non polar end which is called as the tail. Hydrophilic end made up of Glycerol which is attached to phosphate. And Hydrophobic end made up of two fatty acids.

In phospholipid bilayer tailes face each other and heads are away from each other. Week force of attraction is present in phospholipids bilayer.



Phospholipid molecules that they show two types of movement

1) Transition movement
2) Flip flap movement

Proteins : α-globular proteins are present in lipid bilayer. These are two types

1) Extrinsic proteins/ Peripheral proteins

2) Intrinsic proteins/ Integral proteins

Extrinsic proteins are present on the outer side it means they are loosely bound to phospholipids' heads. Intrinsic proteins are partially or completely embedded in phospholipids' bilayer.

FUNCTIONS:

Plasma membrane performs a number of functions.

- It protects the cell from injury.
- Major function of cellular membrane is compartmentalization, as the plasma membranes separate the cell from their external environment.
- The membrane in folds help in the intake of material by **endocytosis**
- Secretory, excretory and waste products are disposed off by the plasma membrane through **exocytosis**
- Plasma membrane have carrier proteins for active transport
- It allows transport of certain substances into and out of the cell but not all substances, therefore it is termed as Selectively permeable membrane.
- Small molecules can be transported across the plasma membrane by any one of the following

  a) Diffusion: Molecules of substances move from their region of higher concentration to their region of lower concentration, They does not require energy. Example: Absoption of glucose in a cell.

  b) 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.

Transport of large molecules by Endocytosis (taking the substances in), passing the substances out (Exocytosis). Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally the cell dies.

Endocytosis

Phagocytosis (intake of solid particles)   Pinocytosis (intake of fluid droplets)

THE 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 of proptidoglycan. Given below is the the structure and functions of the plant cell wall.

Structure of the cell wall

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

FUNCTIONS

The cell wall protect the delicate inner parts of the cell

- Being rigid, it gives shape to the cell.
- Being rigid it does not allow distension of the cell, thus leading to turgidity of the cell that is usefull 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 remain connected with the other. These cytoplasmic strands which connect one cell to the other one are known as **Plasma desmata**.

* Walls of two adjacent cells are firmly joined by a cementing material called **middle lamella.**

INTEXT QUESTIONS

1. Which model is widely accepted to explain the structure and composition of plasma membrane?

   ____

2. What are the functions of plasma membrane?

   ____

3. What is the difference between exocytosis and endocytosis?

   ____

4. Give two functions of the plant cell wall?

   ____

5. What is the difference between phagocytosis and pinocytosis?

   ____

6. Give two functions of the plant cell wall?

   ____

7. 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) nicolson and singer

THE CYTOPLASM AND THE CELL ORGANELLES

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

1) Those that trap and release energy e.g mitochondria and chloroplasts
2) Those that are secretary or involved in synthesis and transport e.gGolgi, ribosomes and ER.
3) The organelles for motility- 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.

MITOCHONDRIA AND CHLOROPLAST- The energy transformers

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

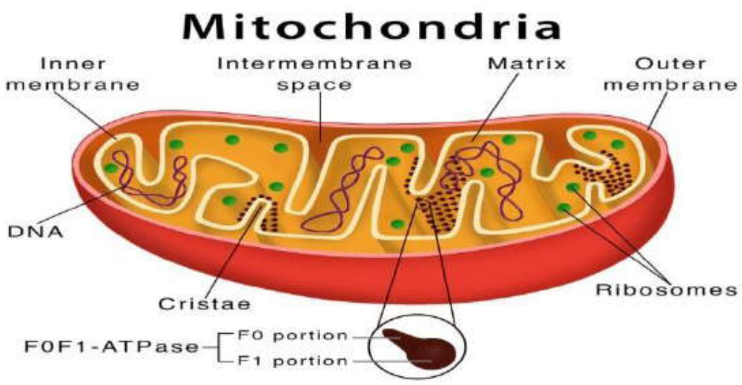
MITOCHONDRIA (singular – mitochondrian)

Appears as tiny thread like structure under light microscope, approximately 0.5-1.00µm (micrometer). Number usually a few hundred to a few thousand per cell (smallest number is just one as in an alga (Micromonas).

STRUCTURE

The term Mitochondria was coined by **C. Benda**. These are energy converting organelles. It is in disc shape/oval shape. It is commonly known as power houses of the cell or energy currency of the cell because the organelle which provides the cell or organism with energy ATP.

Each mitochondrion is a double membrane bound structure with outer and inner membranes.



OUTER MEMBRANE: It protects the organelle and contain specialized proteins such as porins which allows free passage for various molecules into the perimitochondrial space (The space between outer and inner membrane) of the mitochondria.

INNER MEMBRANE: It shows more number of folds which are called as the cristae. The cristae greatly increase the inner membrane's surface area. It has more proteins and is semi or selectively permeable. Inner membrane contains an enzyme coplex called ATP synthese or f0-f1 ATPase or Oxysome that makes the ATP.

Mitochondria has two spaces or compartments

1) Perimitochondrial space/ outer compartment, which is present in the central part of the mitochondria

2) Inner compartment/Inner mitochondrial space, which is present in the central part of the mitochondria

Inner space has material, which is known as the matrix. Matrix is rich in enzymes for cellular respiration. In matrix divalent ions are (mg^+, mn^+ Fe^+) present. These ions activates the enzymes which are responsible for the cellular respiration. It contains several identical copies of the dsDNA (as genetic material) tRNA, proteins and mitochondrial ribosomes.

FUNCTIONS

- It oxidizes pyruvic acid (break down of glucose) to release energy which gets stored it in the form of ATP for ready to use this process is called cellular respiration
- Matrix of mitochondria contains enzymes for the synthesis of fatty acids .
- Mitochondria regulates ca^{+2} ion concentration in the cell by storing and releasing ca^{+2} as required.

PLASTIDS

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

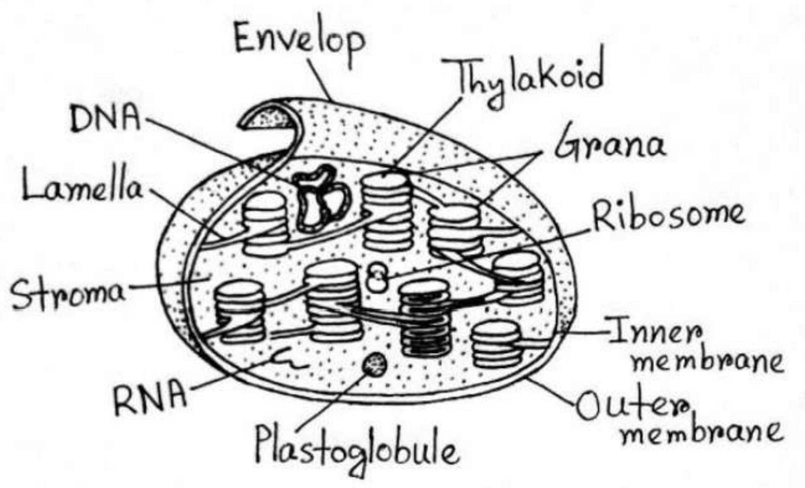
1) Leucoplast – white or colourless

2) Chromoplast - blue, red, yellow, etc.

3) Chloroplast - Green

CHLOROPLAST

Found in all green plant cells in the cytoplasm and algae.Number 1-1008.They are responsible for Photosynthesis, the process by which plants produce organic compounds and oxygen using energy from sunlight. These are typically disc- shaped and composed of several distinct regions, including outer membrane, inner membrane ,inter membrane space, stroma, thylakoid membrane, grana, thylakoid lumen.



Outer membrane: This is the outermost layer of the chloroplast and it separates the chloroplast from the cytoplasm of the cell. It is more permeable than inner membrane.

Inner membrane: Inner membrane of chloroplast is invaginated to form a series of parallel membranous sheets , called Lamellae, lamellae form a number of oval shaped closed sacs, called Thylakoids.

Inner membrane regulates the movement of ions and molecules in and out of the chloroplast.

Inner membrane space: The space between the outer and inner membrane of the chloroplast and contain enzymes involved in lipid synthesis and protein transport.

Thylakoid membrane: These are flattend, membranous sacs that are arranged in stacks called grana. The thylakoid membrane contain chlorophyll and other pigments ,that capture light energy during photosynthesis.

Grana: These are stacks of thylakoid membranes that are interconnected by stromal lamellae

Thylakoid lumen: This is the space inside the thylakoid membranes where protons are pumped during photosynthesis.

Chloroplast contain their own DNA and ribosomes , which are used to synthesize some of the proteins needed for photosynthesis.

Functions :

- The most important function of the chloroplast is Photosynthesis
- Chloroplasts are able to trap solar energy that change it into chemical energy, this chemical energy is used by all living organisms.

Similarities between mitochondria and chloroplast:

- Both have double membrane envolope.
- Both are Semi-Autonomous organelles.
- They produce ATP
- Both possess their own DNA as genetic material, RNS and ribosomes.
- The organelles occur in eukaryotes and are absent in prokaryotes.

INTEXT QUESTIONS

1. What is cell organelle?

   ____

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

   ____

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

   ____

4. Who discovered mitochondria?

   ____

5. Name the sac like structure which form the grana?

6. Why is the mitochondria called the "energy currency" of the cell?

7. State two similarities between mitochondria and chloroplast.

8. Which plastids impart colour to flower petals?

9. Which plastid is green in colour?

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

5 EXTERNAL MORPHOLOGY

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
- List the general characteristics of stem and distinguish them from those of root;
- Explain the types, modifications and functions of stem;
- Describe the general morphology of leaf and explain phyllotaxy;
- Describe and illustrate various modifications of leaf highlighting their functions;
- 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

External Morphology

Studying about the external characters (shape, size, function etc.)of various parts of plant is known as "External Morphology". Morphologically, plant shows vegetative parts like root, stem, leaves and reproductive structures like flower, fruit and seed. In plantae division, angiosperms are one of flowering plants from Phanerogams. It occupies in different habitats due to exhibit considerable variations in External and Internal structure.

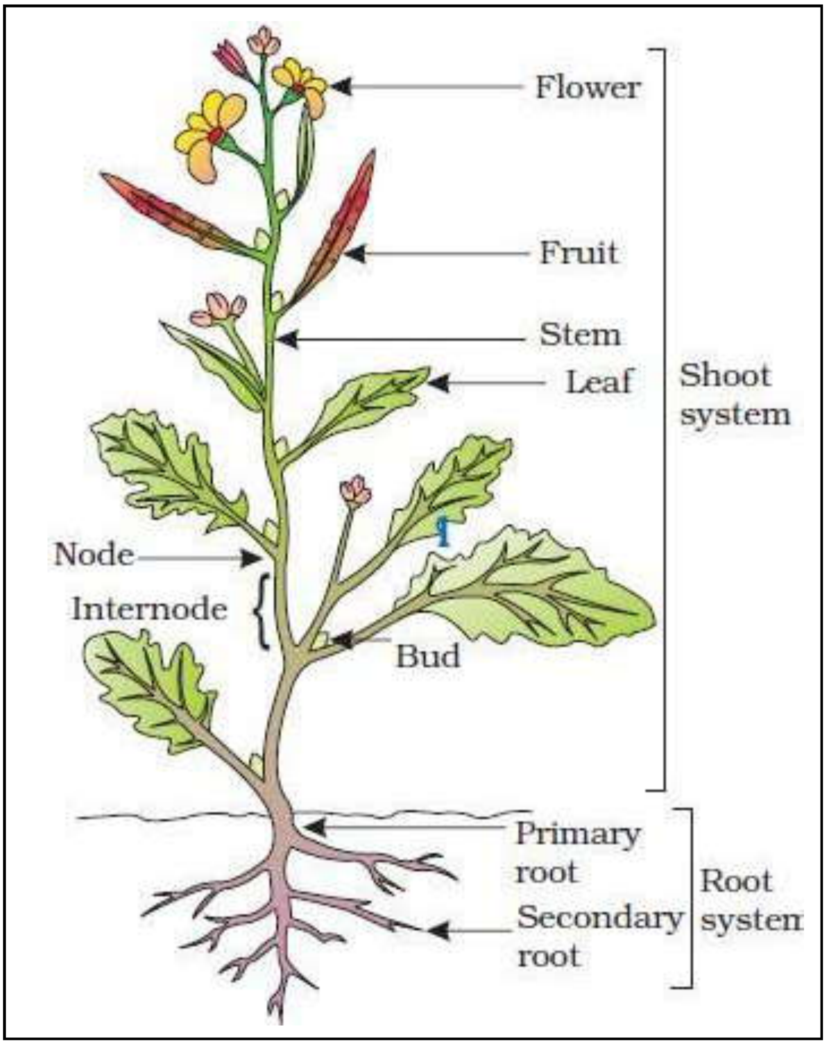


Fig : Parts of Flowering Plant

An angiospermic plant shows two kinds of systems.1.Root system 2.Shoot System

Root system

Root: Root is underground axis of plant body. It is developed from the radicle of the embryonical axis. which is positively geotropic, but negatively phototropic growth in nature. Roots are generally non-green, cylindrical and without nodes and internodes. Root system helps in fixation , absorption of water and minerals from soil.

Root Structure: A typical root has 4 different regions :

1. Region of meristematic activity: Cells of this region have the capability to divide.
2. Region of elongation: Cells of this region are elongated and enlarged.
3. Region of Root Hair zone: It is made up of numerous hair like outgrowths. The

epidermis produces tubular elongated unicellular structures known as root hair. They are in close contact with soil particles and increase surface area for absorption of water.

4. Region of Maturation: This region has differentiated into matured cells. This region helps in the fixation of plants and conduction of absorbed substances.

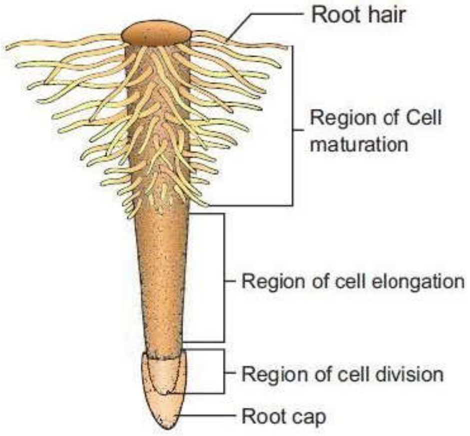


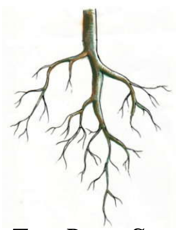
Fig : Regions of root

Types of Root

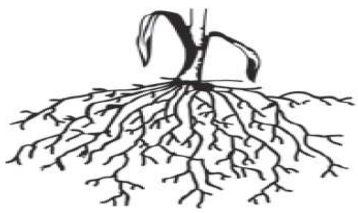
On the basis of origin, roots can be classified as Tap roots and Adventitious roots.

Tap root : The root which develops from the radicle of an embryo is known as tap root . The main root is called as Tap root; its branches of first order are called as primary roots whereas branches of second order are called as secondary roots .Tap root system is commonly seen in dicotyledonous plants. e.g. Pea-*Pisum*, Bean-*Dolicus*, Sunflower-*Helianthus* etc.

Adventitious roots : A root that develops from any part other than radicle is known as Adventitious root. Such root may develop from the base of the stem, nodes or from leaves. In monocots, radicle is short lived and from the base of stem a thick cluster of equal sized roots arise. They are called adventitious roots or Fibrous roots. eg. Maize-*Zea mays*, Wheat-*Triticum*, Sugarcane-*Sacharum* etc.



a) Tap Root System



b) Adventitious Root System

Fig : Types of Root System

Modifications of Root

When roots under go changes to perform some special type of function in addition to or instead of their normal function, these changes are called as root modifications. Roots are modified for mechanical support, storage of food, respiration, N_2 assimilation, balancing etc.

- For storage of food: Fusiform (radish-*Raphanus*), Napiform (*Beta vulgaris*), Conical (carrot-*Dacas carota*).
- For respiration: few aerial modified roots containing pneumatophores are Present in Mangroves. Ex: *Rhizophora*. *Avicennia*
- For support: Prop roots in banyan tree, stilt roots in maize and sugarcane.
- For Climbing: few weak stem plants produce roots at their nodes for upward movement Ex: Beetle leaf
- N_2 assimilation: Legume plants produce nodules on surface of root system. *Rhizobium* live in nodule and perform N_2 reduction.

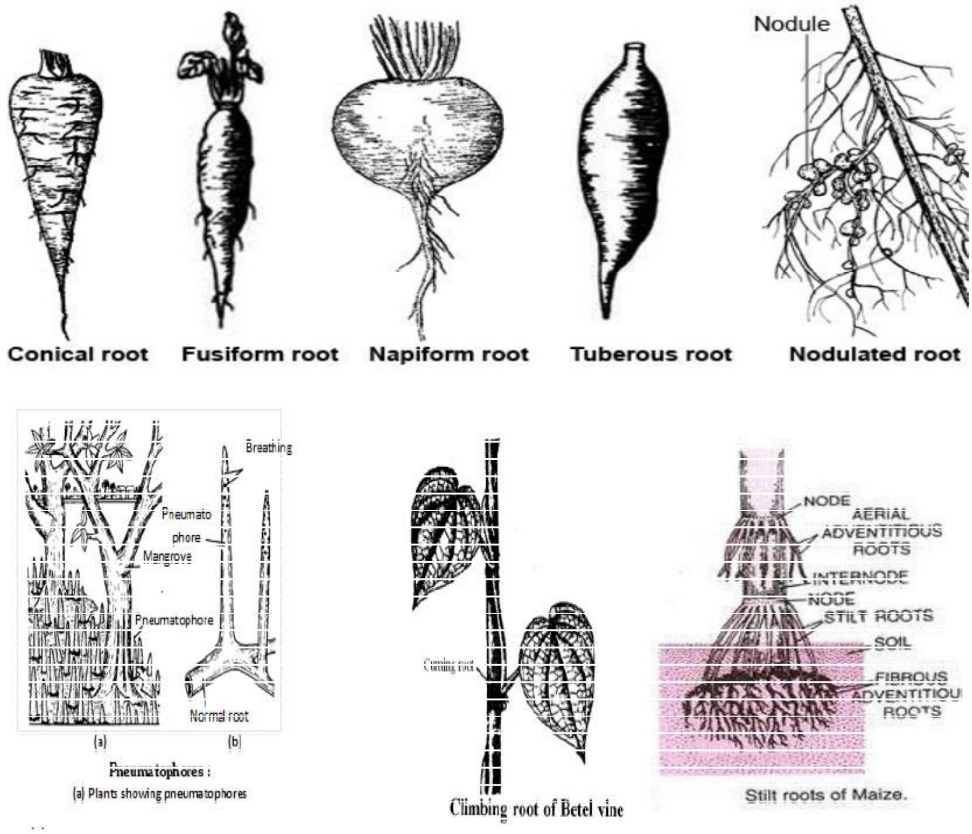


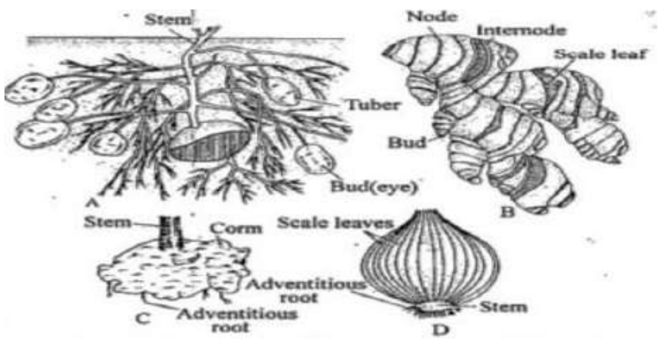
Fig. Root modifications

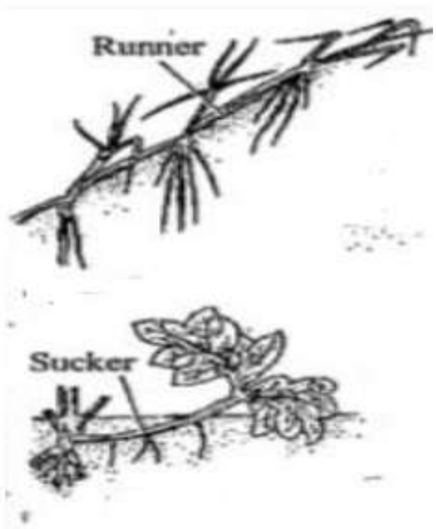
Shoot System: Stem is the aerial part of the plant and develops from plumule of the embryo.The aerial part of the plant body is known as the shoot system. Stem is the main axis of this shoot system. It differentiates into nodes and internodes bearing leaves and reproductive parts. The primary functions of the stem are to produce and support branches, leaves, flowers and fruits; conduction of water and minerals and transportation of food to plant parts.

Modifications of Stem

In some plants the stems are modified to perform the function of storage of food, support, protection and vegetative propagation.

- For food storage: Rhizome (Ginger-*Zingiber*), StemTuber (potato-Helianthus), Bulb (onion-*Alium*), Corm(*Colacasia*).
- For support: Stem tendrils of watermelon, grapevine(*Vitis*), cucumber.
- For protection: Axillary buds of stem of citrus, In Bougainvillea buds get modified into pointed thorns. They protect the plants from animals.
- For vegetative propagation: Underground stems of grasses are called Runner (Eg: Cynodon), lateral branches of mint are called Sucker (Ex.*Mentha*), *Chrysanthemum*.
- For assimilation of food: Flattened stem of Opuntia turned in to green and performs photosynthesis.





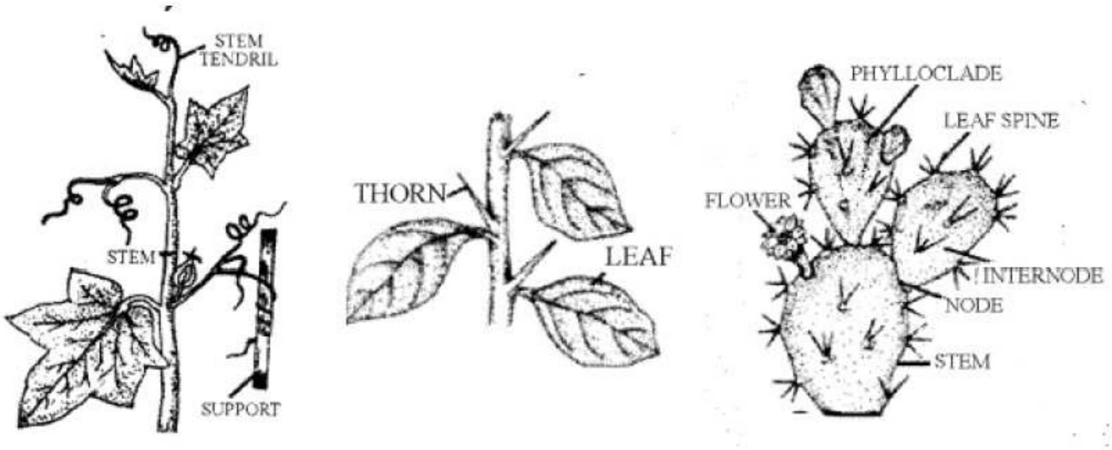


Fig : Stem modifications

LEAF: Green, thin, flattened, lateral, photosynthetic, ,limited growth organs of stem is called "Leaves". It is produced at nodes, develop from leaf primordium. Axil of leaf shows presence of axilluary bud.

Leaf Structure: Each leaf typically has four parts named as leaf base, leaf stipule, petiole, Leaf Lamina. The Leaf Base is the part where a leaf attaches to a stem or branch. The nature of leaf base varies in different plants. It may be pulvinus (swollen), sheathing or ligulate etc. Some leaves are attached to the plant stem by a petiole. Leaves that do not have a petiole and are directly attached to the plant stem are called sessile leaves. Leaves also have stipules, small green appendages usually found at the base of the petiole. Most leaves have a midrib, which travels the length of the leaf and branches to each side to produce veins of vascular tissue. The shape, margin, apex, surface and extent of incision of lamina varies in different leaves.

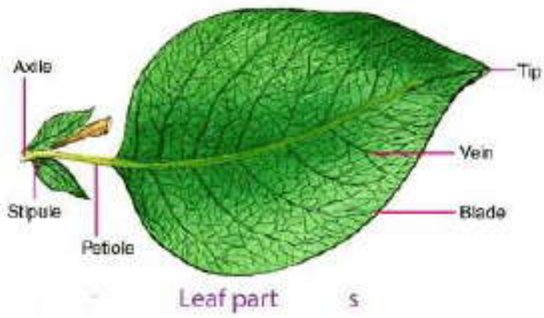


Fig : Parts of leaf

Venation : The arrangement of veins and the veinlets in the lamina of leaf is termed as venation. When the veinlets form a network, the venation is termed as reticulate,. When the veins run parallel to each other within a lamina, the venation is termed as parallel Leaves of dicotyledonous (Ex.peepal-*Ficus*) plants generally possess reticulate venation, while parallel venation is the characteristic feature of most monocotyledons. (Ex: Grass, maize, Banana-*Musa*)

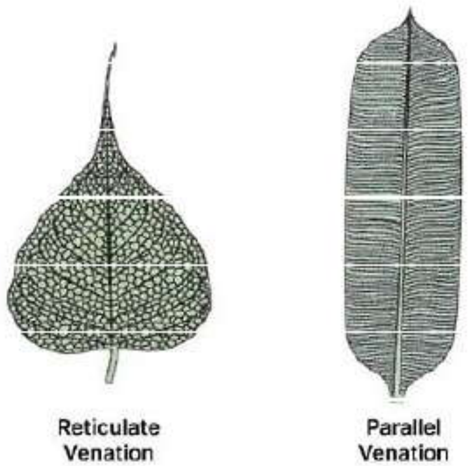


Fig : Types of Venation

Types of Leaves

A leaf is said to be simple, when its lamina is entire or when lobed, the cuts do not touch the midrib. When cuts of the lamina reach up to the midrib breaking it into a number of leaflets, the leaf is called compound. A bud is present in the axil of petiole in both simple and compound leaves, but not in the axil of leaflets of the compound leaf. The compound leaves may be of two types. In a pinnately compound leaf a number of leaflets are present on a common axis, the rachis, which represents the midrib of the leaf as in neem. In palmately compound leaves, the leaflets are attached at a common point, i.e., at the tip of petiole, as in silk cotton.

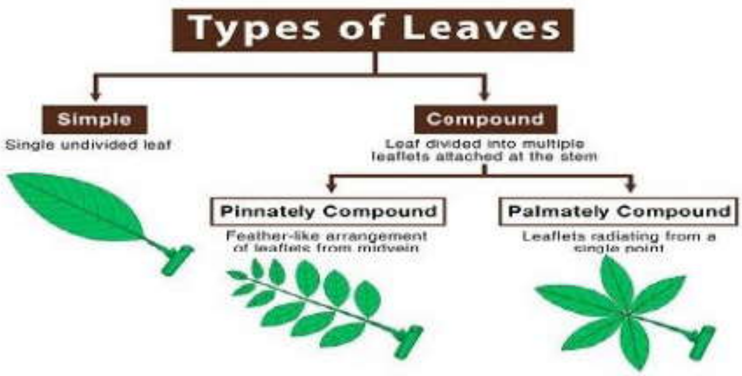


Fig. Types of leaves

Phyllotaxy : The mode of arrangement of leaves on the stem or branch is called as Phyllotaxy. This is usually of three types – alternate, opposite and whorled. In alternate phyllotaxy, a single leaf arises at each node in alternate manner, as in china rose, mustard and sun flower plants. In opposite type, a pair of leaves arise at each node and lie opposite to each other as in *Calotropis* and guava plants. If more than two leaves arise at a node and form a whorl, it is called whorled, as in *Nerium*.

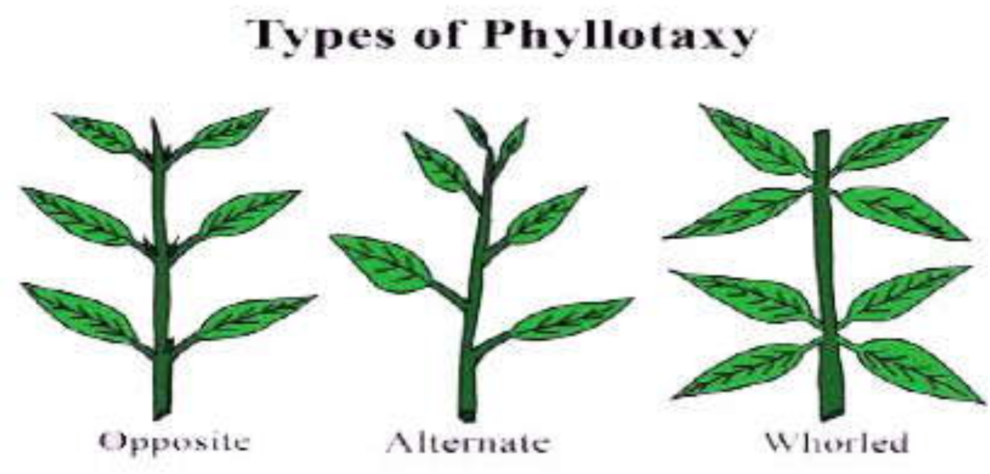


Fig : Types of Phyllotaxy

Modifications of Leaf

Leaves are often modified to perform functions other than photosynthesis. They are converted into tendrils for climbing as in peas or into spines for defence as in *opuntia*. The fleshy leaves of onion and garlic store food. In some plants such as *parkinsonia*, the leaves are small and short-lived. The petioles in these plants expand, become green and synthesize food. Leaves produce some epiphyllous buds and help in vegetative reproduction called as Reproductive Leaves. Leaves of certain insectivorous plants such as pitcher plant (*Nepenthes*) venus-fly trap (*Dionaea*) are modified into trap leaves for assimilation of Nitrogen.

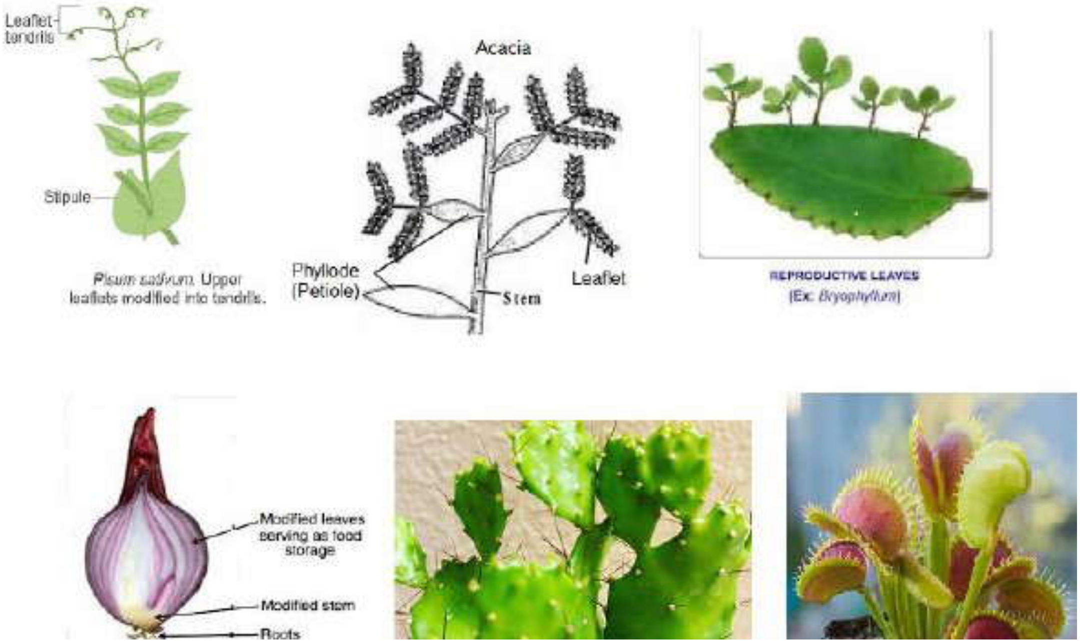


Fig: Leaf modifications

INTEXT QUESTIONS

1. From which part of the germinating seed does the root develop?

   ____

2. Which root system gives better anchorage and why?

   ____

3. Give two examples each of plants having fibrous and tap root system?

   ____

4. Give in a sequence, the various regions of root from its tip towards its base

   ____

5. What are the two main functions of roots?

   ____

6. Give two primary functions of stem.

   ____

7. Explain the different types of stem modifications?

   ____

8. What are the two types of compound leaves known as ?

   ____

9. Give two examples of insectivorous plants.

   ____

10. Write short note on leaf modifications?

    ____

Inflorescence

The mode of development and arrangement of flowers on the peduncle is known as Inflorescence.

1. **Racemose**: In this type of inflorescences the main axis continues to grow, the flowers are borne laterally in an acropetal succession Ex. Radish, Mustard, *Amaranthus*.

2. **Cymose**: In cymose type of inflorescence the main axis terminates in a flower, hence is limited in growth. The flowers are borne in a basipetal order Ex: Cotton, Jasmine, *Calotropis*.

3. **Special type**: In this type, arrangement and development of the flowers remain special. *Ficus, Salvia*, *Euphorbia*

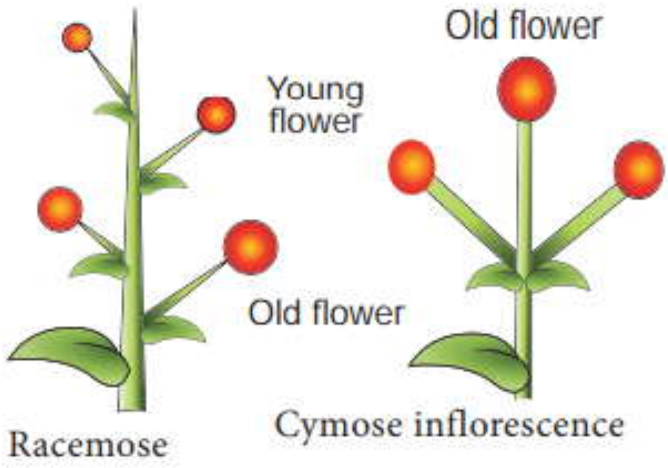


Fig : Types of Inflorescence

The Flower

Flower is a modified shoot. It is a reproductive unit of angiosperm plant. Flowers may be unisexual or bisexual, bracteate (Br) or ebracteate (Ebr). Some features of flower are as given below.

Symmetry of flower : The flower may be actinomorphic (radial symmetry) or zygomorphic (bilateral symmetry). When a flower can be divided into two equal radial halves in any radial plane passing through the centre, it is said to be actinomorphic, e.g., mustard, datura, chilli. When it can be divided into two similar halves only in one particular vertical plane, it is zygomorphic, Ex., pea, gulmohur, bean, cassia.

A flower is asymmetric (irregular) if it cannot be divided into two similar halves by any vertical plane passing through the centre, as in canna.

On the basis of number of floral appendages

A flower may be trimerous, tetramerous or pentamerous when the floral appendages are in multiple of 3, 4 or 5, respectively.

On the basis of position of calyx, corolla, androecium with respect of ovary on Thalamus

Hypogynous :In the hypogynous flower the gynoecium occupies the highest position while the other parts are situated below it. The ovary in such flowers is said to be superior, e.g., mustard, Hibiscus

Perigynous: . If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called perigynous. The ovary here is said to be half inferior, e.g., rose, peach

Epigynous : The margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary. Hence, the ovary is said to be inferior as in flowers of guava and cucumber.

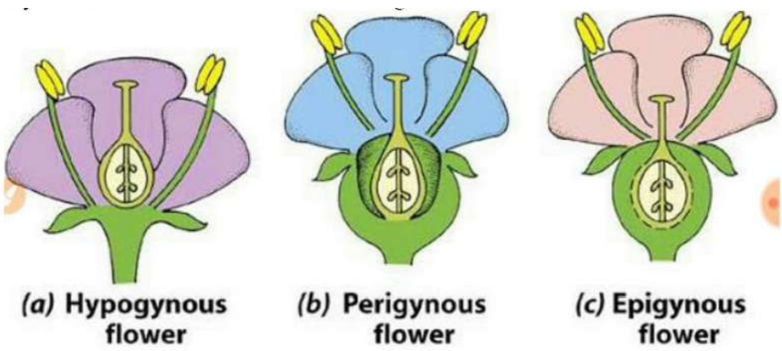


Fig: Types of flowers on the basis of ovary position on Thalamus

Parts of flower

Each flower normally has four floral whorls, viz., calyx, corolla, androecium and gynoecium.

1. **Calyx**: Sepals are generally green in colour and enclose to protect the flower bud. The calyx surrounds the corolla, and is typically divided into lobes called Sepals. Sepals may be united (Gamosepalous-Ex.*Hibscus*) or free (Polysepalous-Ex.Mustard) in outer whorl. These are frequently green in colour, leaf like whorl. In many flowers, the sepals enclose and protect the flower bud prior to opening.

2. **Corolla**: The inner lobes (petals) of a flower which surrounds the reproductive parts. Petals may be united (Gamopetalous-Ex. *Datura*) or free (Polypetalous-Ex.*Hibscus*). Petals, usually brightly coloured to attract insects for pollination.

3. **Perianth**: If calyx and corolla are not distinguishable, into sepals and petals are called as perianth.

4. **Androecium**: The unit of Androecium is stamen. Stamens are considered as male sex organs and produce pollen grains. Each stemen as filament and fertile portion known as Anther. Stamens may be epipetalous (attach to petals) Ex, *Solanum*, *Datura* or epiphyllous (attach to perianth – tepals are united).Stamens may be monoadelphous (united into one bundle) Ex. *Hibiscus*, diadelphous (two bundles) Ex. *Pisum* or polyadelphous (more than two bundles) Ex. *Citrus*.

5. **Gynoecium** : It is a female reproduct part. Each Carpel consists of stigma, style and ovary which bears one or more ovules. Carpels may be apocarpous - free (Ex. *Vinca)* or syncarpous - united (Ex. *Hibiscus)*.

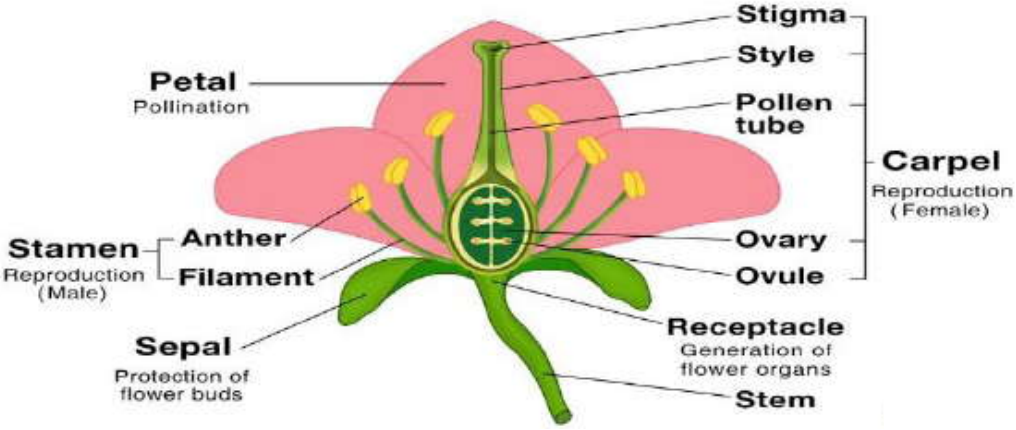


Fig: Parts of Flower

Aestivation- Arrangement of sepals, petals or perianth in floral bud is called Aestivation.

Types of aestivation:

1. **Valvate**: Sepals or petals do not overlap the sepal or petal at margins. Ex.*Annona, Calotropis.*

2. **Twisted**: Sepals or petals overlap the next sepal or petal. Ex. *Hibiscus, Gossipium.*

3. **Imbricate**: Out of five perianth, one petal or sepal completely inner, second petal are sepal completely outer, remaining three sepals arranged in alternate fashion. The margins of sepals or petals overlap one another but not in any definite direction. Ex. *Cassia, Crotalaria.*

4. **Quincuntial**: In the whorl, out of five perianth, two of petals or sepals completely inner, two petals or sepals completely outer, odd fifth petal or sepal arranged alternate fashion. Ex: Calyx of *Calotropis*

5. **Vexillary**: The largest petal (standard) overlaps the two lateral petals (wings) which in turn overlap two smallest anterior petals (Keel). Ex. *Pisum,Dolichus.*

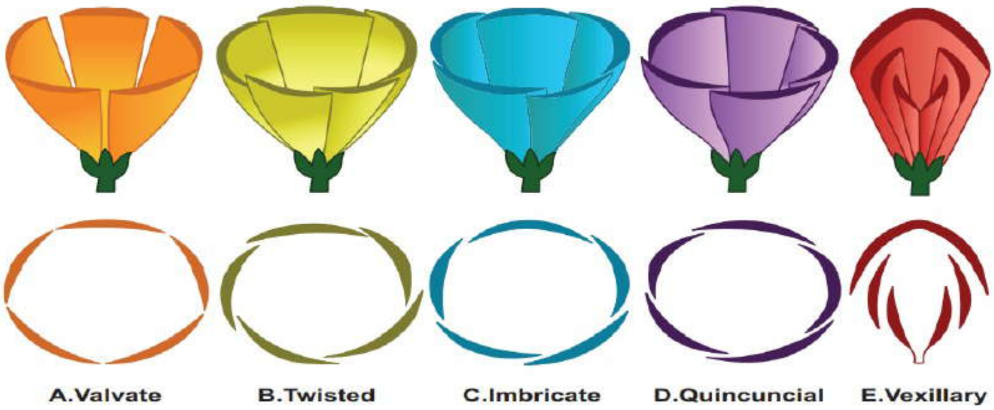


Fig. Types of Aestivation

Placentation - The arrangement of ovules on placentae in the ovary called as Placentation.

Types of Placentation

1. **Marginal**: Ovules are attached to the margin of Ovary wall. Ex. Pea, Bean.

2. **Axile**: Margins of carpels fuse to form central axis where ovules are attached. Ex. Citrus, Hibiscus.

3. **Parietal**: Ovules develop on inner wall of ovary. Ex. Cucurbita, Mustard.

4. **Free central**: Ovules borne on central axis, lacking septa. Ex. Dianthus, Primrose.

5. **Basal**: Ovules develop at the base of ovary. Ex. Sunflower, Marigold.

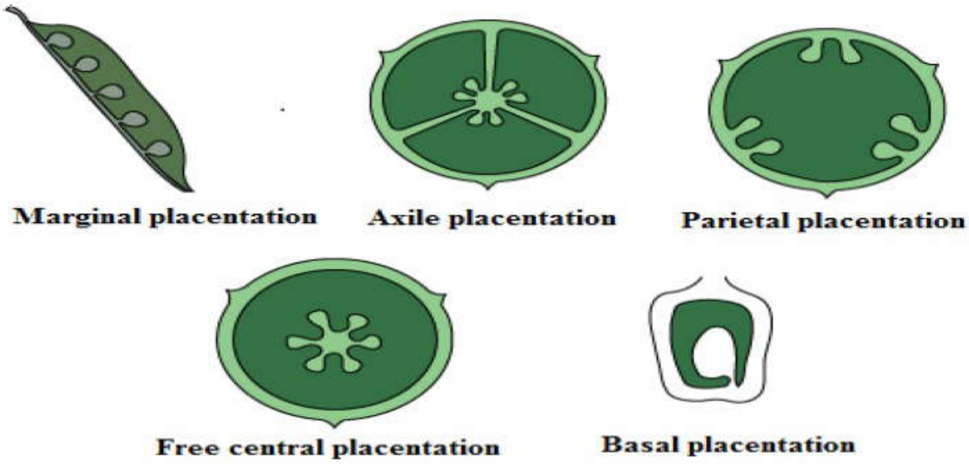


Fig. Types of Placentation

Fruit

After fertilization the mature ovary develops into fruit. The fruit consists of a wall or pericarp and seeds. The pericarp may be dry or fleshy. When pericarp is thick and fleshy, it is differentiated into the outer epicarp, the middle mesocarp and the inner endocarp

INTEXT QUESTIONS

1. Write a short note on Infloresence.

2. Classify the flowers based on the position of ovary on thalamus

3. What is aestivation. Explain types of aestivation.

4. Define Placentation. mention its types

5. Define Fruit.

6. Give the names of pericarp layers of a fleshy fruit.

Plant Taxonomy

Taxonomy is concerned with the laws governing the classification of plants. The term taxonomy includes two Greek words taxis – arrangement and nomos– laws. Plant taxonomy is otherwise known as systematic botany. Identification, nomenclature, classification are the basic principles of plant taxonomy. The knowledge gained through taxonomy is useful in the fields of medicine, agriculture, forestry, etc. The ultimate aim of classification is to arrange plants in an orderly sequence based upon their similarities.

Types of classification There are three types of classification systems available are artificial, natural and phylogenetic.

Artificial system - This system is based on one or two arbitrary (not clear) characters. This system of classification published in "Species Plantarum" by Carolus Linnaeus in 1753. (Eg. Linnaeus - sexual system of classification based on number of stemens - Monadrae (Only one stemen), Dianadrae (Two stemens) etc. Theophrastus - Grouped plants on the bases of habit into herbs, shurbs, trees.

Natural system

In this system of classification, plants are classified based on their natural affinities and more number of characters are taken into consideration. The most important natural system of classification of seed plants was proposed by two British botanists George Bentham and Sir Joseph Dalton Hooker known as Bentham and Hooker Classification system.

Phylogenetic system

This system is based on evolutionary sequence as well as genetic relationships among different group of plants. In addition to this, it employs as many taxonomic characters as possible. Charles Darwin's concept of Origin of Species had given enough stimulus for the creation of phylogenetic system of classification. Eg: Engler and Prantal, Takhtajan classification, Cronquist classification.

Study of some important Diotledanous families

Fabaceae

Plant examples of Fabaceac

Common Name	**Botanical Name**
1) Pea	*Pisum sativum*
2) Pigeon pea	*Cajanas cajan*
3) Green Gram	*Phaseolus aureus*
4) Soya-bean	*Glycine max*
5) Lentil	*Lens culinaris*
6) Ground nut	*Arachis hypogea*
7) Chick pea	*Cicer arietinum*

Vegetative Characters

Trees, shrubs, herbs

Root: Tap root system, branched, root nodules are present.

Stem: Aerial, Branched erect on prostrate

Leaves: Simple or compound, Alternate, Pulvinous leaf base stipulate, Petoliate, reticulate venation.

Inflorescence: Racemose

Flower: Bisexual, zygomorphic, complete

Calyx: Sepals five, gamosepalous; imbricate aestivation

Corolla: petals five, polypetalous, papilionaceous, consisting of a posterior standard, two lateral wings, and two anterior keel petals vexillary aestivation

Androecium : Stem ten, diadelphous are monoadelphous Anthers dithecous

Gynoecium: ovary superior, mono carpellar, unilocular with many ovules, marginal placentation.

Fruit: legume or Pod seed: one to many

Floral Formula: Br,Ebrl,%, ?$K_{(5)}$ $C_{1+2+(2)}$ $A_{(9)+1}$ G_{1}–

Economic importance

Many plants belonging to this family are sources of pulses (gram, arhar, sem, moong, soyabean; edible oil (soyabean, groundnut); dye (indigofera); fibres (sunhemp); fodder (Sesbania, Trifolium), ornamental (lupin, sweet pea) and medicinal (muliathi).

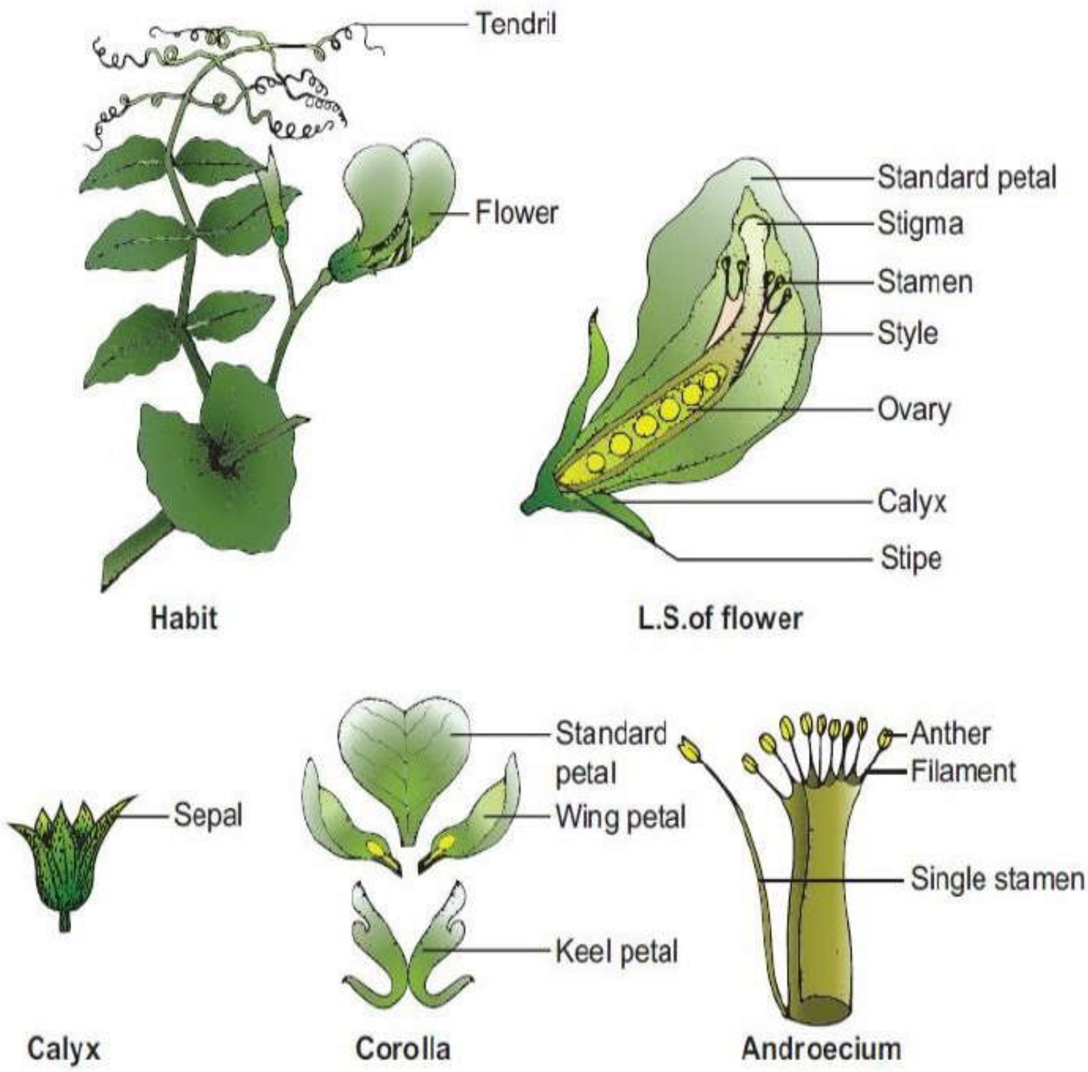


Fig :

Solanaceae

This family is, commonly called as the 'potato family'. It is widely distributed in tropics, subtropics and even temperate zones. Some plant examples are

Common Name	Botanical Name
1) Potato	*Solanum tuberosum*
2) Tomato	*Solanum esculentum*
3) Tobacco	*Nicotiana tabacum*
4) Chilli	*Capsicum annum*
5) Brinjal	*Solanum melongena*
6) Ummetta	*Datura metal*

Vegetative Characters

Plants mostly, herbs, shrubs and small trees

Root: Tap root system, branched

Stem: herbaceous rarely woody, aerial; erect, cylindrical, branched, hairy or glabrous, underground stem in potato (*Solanum tuberosum*)

Leaves: alternate, simple, exstipulate; reticulate Venation

Floral characters

Inflorescence : Cymose or Solitary

Flower: bisexual, actinomorphic, complete

Calyx: sepals five, gamosepatalous, persistent, valvate aestivation

Corolla: petals five, Gamopetalous ; valvate aestivation

Androecium: stamens five, epipetalous

Gynoecium: bicarpellar, syncarpous; ovary superior, bilocular, placenta swollen with many ovules

Fruit: Berry or capsule

Seed: Many, endospermous

Floral Formula: Br,Ebrl,, **?** $\mathbf{K_{(5)}\ C_{(5)}\ A_5\ G(_{2)}}$–

Economic Importance

Many plants belonging to this family are vegetables (tomato, brinjal, potato), spices (chilli); medicinal(belladonna, ashwagandha); narcotics (tobacco) and ornamentals (petunia)

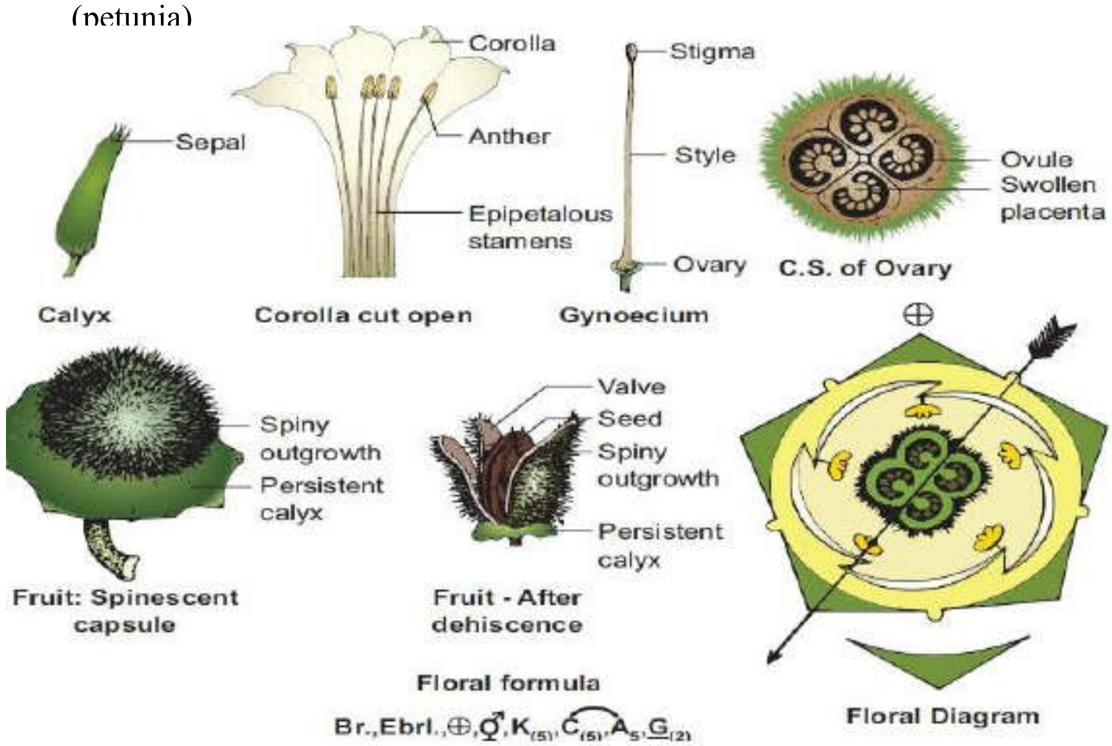


Figure 5.20: *Datura metel*

Liliaceae (Monocotyledanous family)

Commonly called as 'Lily family'.

Some examples of useful plants of Liliaceae

Common name	**Botanical name**
1) Kalabanda	*Aloe vera*
2) Satawari	*Asparagus racemosus*
3) Tulip	*Tulipa tulip*
4) Shakrapushpi	*Gloriosa superba*
5) Lily	*Lilium candidum*
6) Onion	*Allium cepa*

Vegetative characters

Habit Perennial herbs with underground bulbs/corms/ rhizomes

Root : Adventitous root system.

Stem: Aerial, erect,branched

Leaves: mostly basal, alternate, linear, exstipulate with parallel venation

Floral charatcters

Inflorescence: solitary / cymose; often umbellate clusters

Flower: bisexual; actinomorphic, Perianth tepals six (3+3), often united into tube; valvate aestivation

Androcium: stamens six, (3+3)

Gynoecium: tricarpellar, syncarpous, ovary superior, trilocular with many ovules; axile placentation

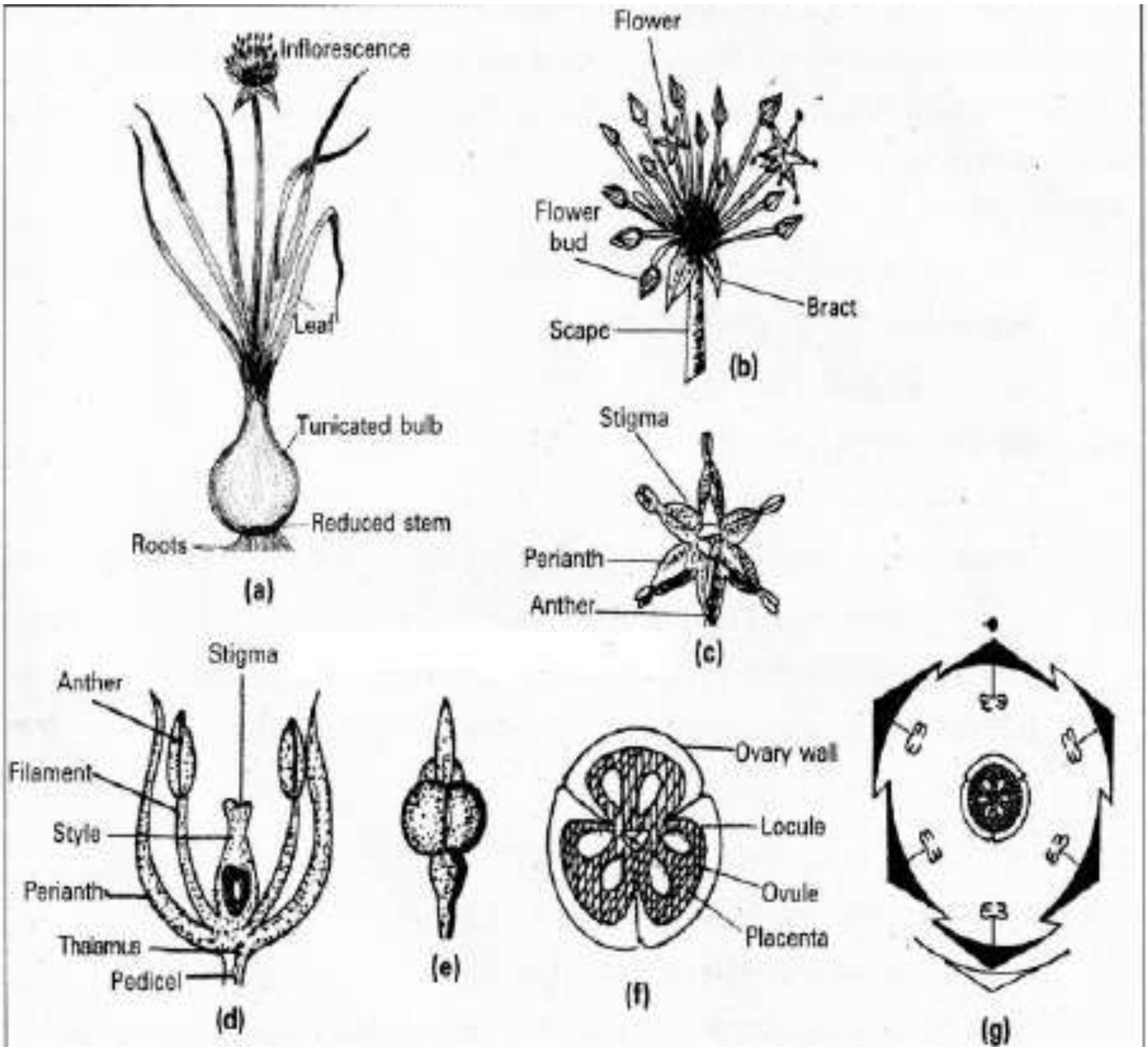
Fruit: capsule, rarely berry

Seed: endospermous

Floral Formula: Br,Ebrl,%, P3+3 A3+3 G(3)

Economic Importance

Many plants belongs to this family used as ornamental (tulip,Gloriosa) and medicinal (Aloe), (Asparagus).



Allium cepa **(onion) (a) Plant (b) Inflorescence (c) Flower (d) L.S. of flower (e) Pistil (f) T.S of ovary (g) Floral diagram**

Floral Formula : Br Ebrl $\oplus$ ⚥ $\widehat{P_{(3+3)}\,A_{(3+3)}}\,\underline{G}_{(3)}$

INTEXT QUESTIONS

1. Name one dicotyledonous and one monocotyledonous family.

   ____

2. Give the number of stamens in
   (a) Papilionaceae ______________________________
   (b) Liliaceae ______________________________

   Give botanical names of
   (a) Onion______________________________
   (b) Datura ______________________________
   (c) Kalabanda______________________________

4. What is the condition of petals in polypelae and Gamopetalae ?

a ________________________________

b ________________________________

5. Why Gymnosperms are called naked seeded plants ?

____

6. Name the important character of monocotyledonae.

____

7. Name the symbiotic bacteria which are present in the root nodules of fabaceae family members.

____

8 Write the scientific names of Ground nut and Red gram.

a ________________________________

b ________________________________

10. Name the type of corolla in fabaceae.

____

11. Name the sicentific names of any two plants in the family solanauae.

a ________________________________

b ________________________________

12. State the venation in Liliaceae

____

13. Explain about different types of classifications?

____

14. Write about the characters of the family fabaceae.

____

16. Describe the floral characters of fabaceae.

____

17. Describe about the corolla of fabaceae.

____

18. What is piston mechanism ? In which family do you find piston mechanism.

____

19. Mention the economic importance of fabaceae.

____

20. Describe the characters of solanaceae.

____

21. Mention the economic importance of solanaceae.

____

22. Describe the characters of Liliaceae.

____

6 PLANT TISSUES AND ANIMAL TISSUES

Cell is the fundamental structural and functional unit of organisms and that bodies of organisms are made of cells of various shapes and sizes. Group of similar cells aggregate to collectively perform a particular function. Such group of cells are termed "tissues". Organs such as stem, roots in plants made up of different kinds of tissues. whereas parenchyma, collenchyma, xylem and phloem are different tissues in plants.

Objectives

- To difine animal and plant tissues
- To know types of plant tissues and animal tissues
- To classify animal plant tissues
- Name the various kinds of plant tissues

A tissue is a group of cells with a common origin, structure and function. The study of tissues is called histology.

The plant tissues are mainly of two types:

I Meristematic (meristos : dividing)

II Permanent (non-dividing)

I. Meristematic tissues:

1. This tissue composed of immature or undifferentiated cells without intercellular spaces.
2. The cells may be rounded, oval or polygonal ,always living and thin walled.
3. Each cell has abundant cytoplasm and prominent nuclei in it.
4. Vacuoles may be small or absent.

Types of meristematic tissue

Based on the position

a) **Apical Meristem:** present at Root tip and shoot tip for Growth in length of plants.

b) **Intercalary Meristem**: At the base of leaves or Internodal region.

c) **Lateral Meristem**: They are found at the lateral sides of the plant body and it increase the thickness of the organs like stem and root.

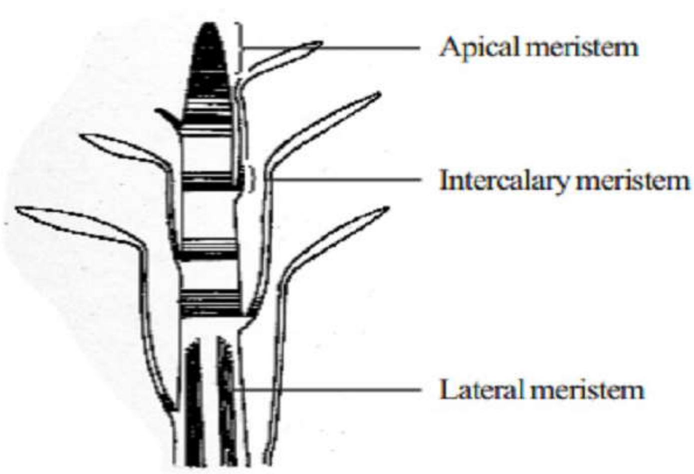


Fig: Position of meristems in the L.S. of plant axis

II. Permanent tissues

Permanent tissues are a group of mature cells which have lost the capacity of division either temporarily or permanently and perform a specific function.

These tissues are of three kinds

1) simple tissues 2) Complex tissues 3) Special tissues

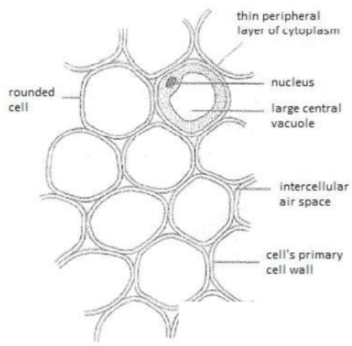
1. Simple tissues :

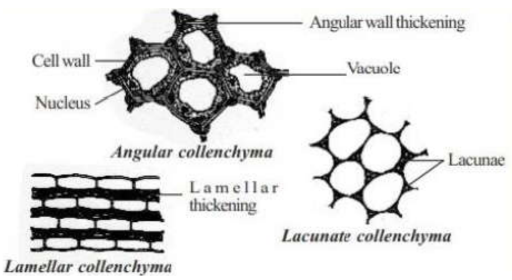
A group of cells which are similar in structure and function. Three types of simple tissue are found in plants.

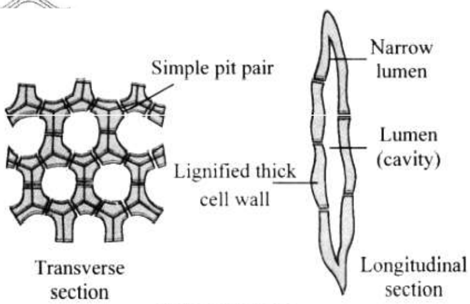
A. Parenchyma: It occupies a major part of the plant body. It is primitive tissue and found in all plant groups. It is living tissue ,the cells are isodiametric , oval, spherical and rectangular in shape. cell walls are made up of cellulose, hemicellulose and pectin. Intercellular spaces are present between the cells. A single central vacuole is present in every cell.

B. **Collenchyma :** It is a living mechanical tissue which is found in young stems ,petioles, peduncles and leaf margins. It is absent in monocot stems and leaves. The cells are elongated, round, cylindrical and contain vacuolated protoplasts. The cell wall is rich in cellulose and pectin.

C. **Sclerenchyma**: It is a simple mechanical tissue composed of dead cells. It is the most important tissue that provides strength and hardness to the plant body .The cells are elongated or vary widely in shape. The cell wall is made up of cellulose and lignin.







Sclerenchyma

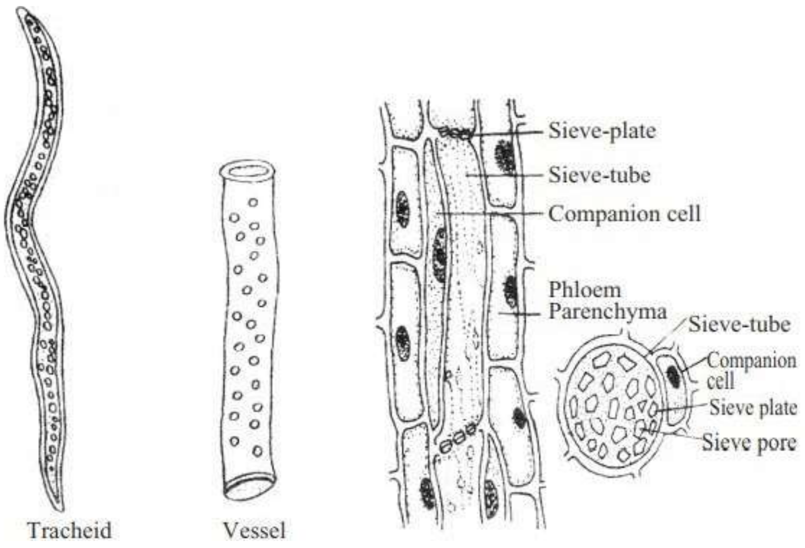
2. Complex tissues

Complex tissues possess a group of dissimilar cells but work collectively as a single functional unit and perform a specific function

Complex tissues are mainly of two types : A) Xylem B) Phloem

A. **Xylem :** 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 vascular bundles in roots and stems. 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 (d) Xylem Parenchyma

B. **Phloem :** It is a complex tissue that conducts organic solutes from the leaves to the other parts of the plant . Phloem is composed of (a) Sieve Tubes (b) Companion Cells (c) Phloem Fibre (d) Phloem Parenchyma



Xylem *Phloem*

Classification of Plant Tissues

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

3. Special tissues

These tissues are composed of secretory cells and are located in various parts of the plant body. These cells may appear in isolated form or in groups working as glands. The secretory tissues are classified into Digestive glands , Nectar glands , Osmophors and Secretory cavities.

INTEXT QUESTIONS

1. Define tissue.

   ____

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

   ____

3. Name that branch of Biology in which tissues studied?

   ____

4. What is a complex tissue?

   ____

5. Mention any two special features of meristematic cells.

   ____

6. 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.

   ____

ANIMAL TISSUES

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

Animal Tissues

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

I Epithelial Tissue

Structural Characteristics : The cells forming epithelial tissue –

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

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

(iii) not supplied with blood vessels.

Function : line the surfaces, help in absorption, secrete, also bear protoplasmic projections such as the Cilia.

Table : Types of epithelial tissue

Type	Structure	Location	Function
1. Squamous Epithelium	Flattened cells with a centrally placed nucleus.	Lining of air sacs in the lungs.	For exchange of O_2 and CO_2.
	Have irregular margins.	Lining of Kidney tubules.	For absorption.
		Lining of blood capillaries.	For exchange of materials.
2. Cubodial Epithelium	Cube like cells with a centrally placed nucleus, Cells appear polygonal.	Lining salivary and pancreatic ducts.	For absorption.
		Found in sweat, salivary gland.	For secretion
3. Ciliated Epithelium	Have cilia at free ends.	Lining of Kidney tubules.	For flow of nephric filterate. Secretion and absorption
4. Columnar epithelium	Tall column like cell, with nucleus at the basal end	Lining of stomach, instestine	
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	Lining of intestine	Increasing the surface area for absorption

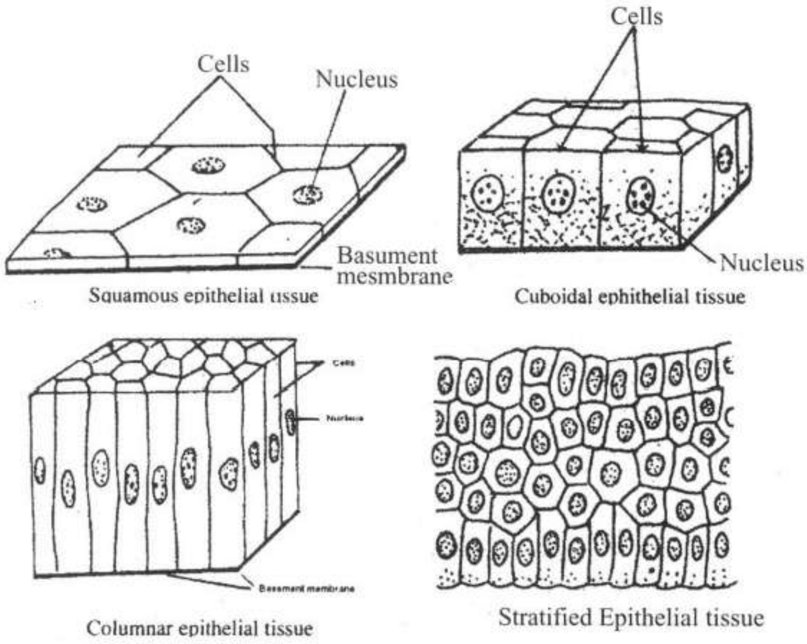


Fig: The structure of different epithelial tissue

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 skin, inner lining of cheeks etc.

INTEXT QUESTIONS

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

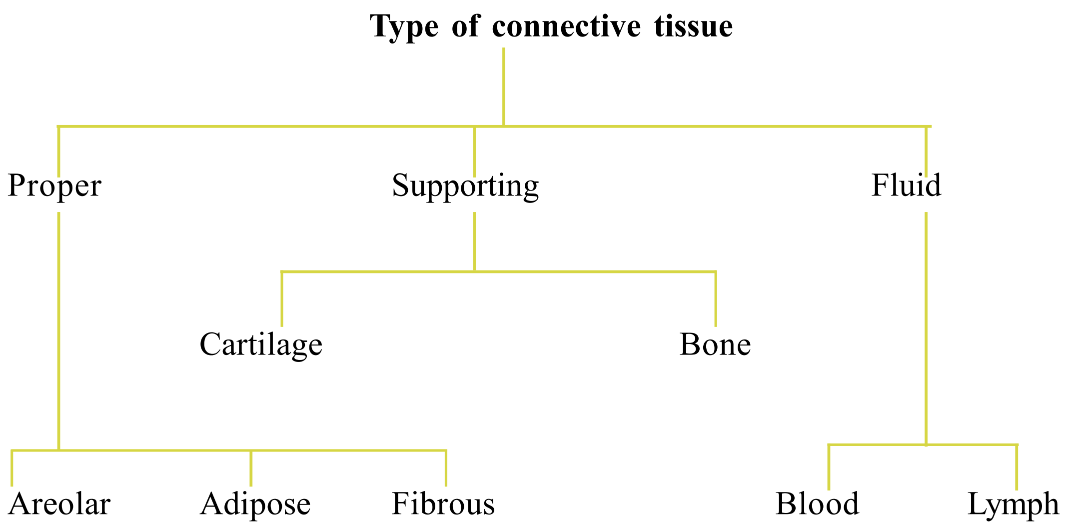
II Connecitve tissue

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). Matrix is the ground substance.



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 secrets heparin (helps in clotting of blood).

2. Adipose tissue : It has specialized cells storing fat called adipose cells. Help in forming paddings.

3. Fibrous : It is mainly made up of fibroblasts. It forms tendons and ligaments.

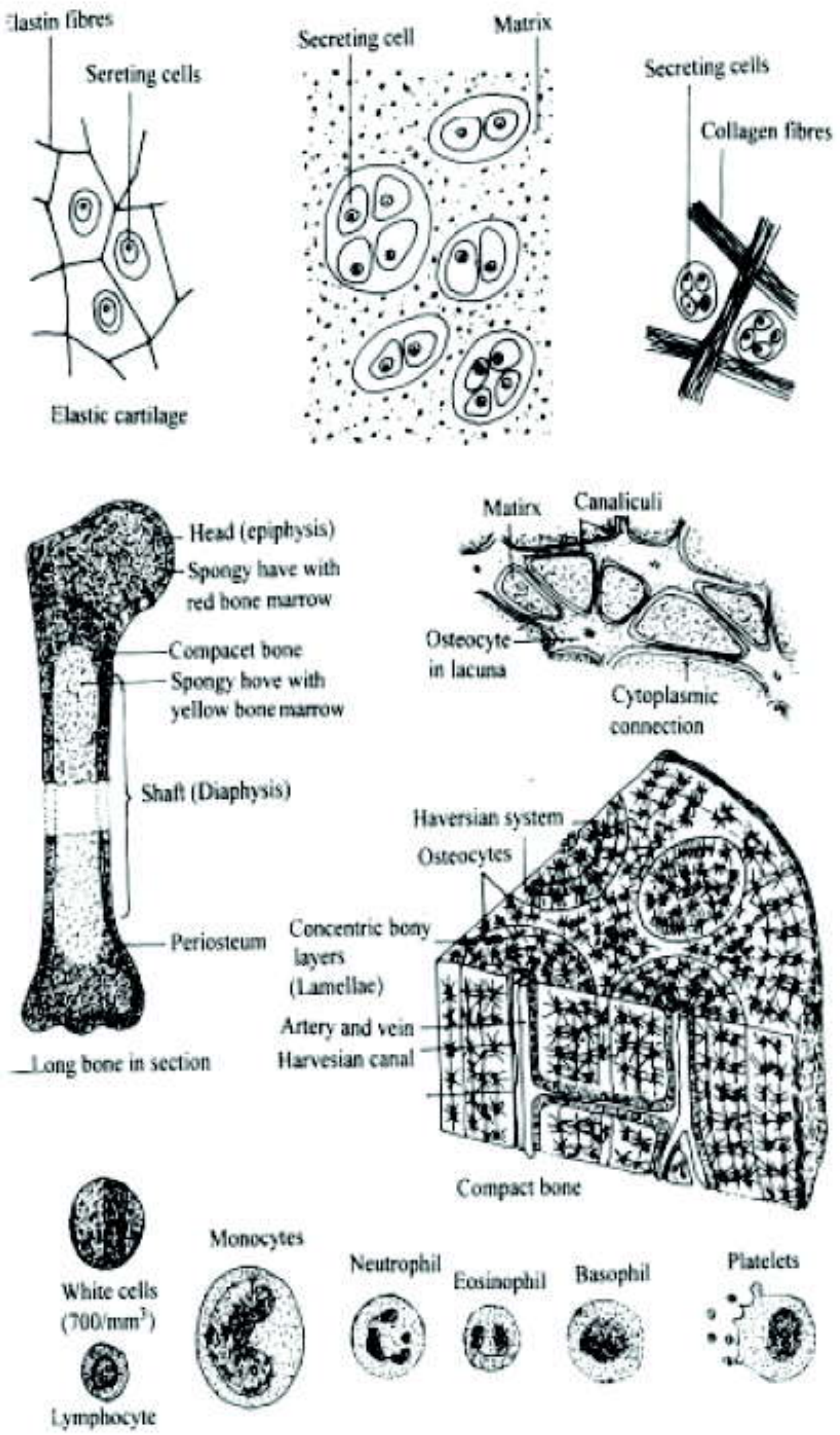


Fig: Some representative types of connective tissue.

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 pinna of ear.	1. Matrix is composed of ossein. Matrix also contains salts of calcium, phosphorus and magnesium. Matrix in mammalian long bones (such as thigh bone) is arranged in concentric rings. The osteocytes (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 may be fibrous, whose matrix has white fibres. Firbous cartilage is present in between vertebrae.	2. Bones are of two types : Spongy and Compact. In spongy bone, bone cells are irregularly arranged. Such bones are found at the ends of the of long bones.
3. The cartilage can be calcified where matrix is deposited with calcium salts 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 the fluid connective tissue.

Blood : It is a complex of blood cells and plasma. Plasma forms the matrix.

The blood cells

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 extra cellular fluid of matrix, the ground substance. It contains large number of proteins such as Fibrinogen, Albumin, Globulin to be transported to various parts of the animal body for various purposes.

III Muscle tissue

Muscle tissue is composed of long excitable cells containing parallel microfilaments of contractile proteins shape. 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 (iii) Cardiac according to shape and functions as mentioned in Table.

Table Types of Muscle Fibres

Striated/Voluntary/Skeletal	Unstriated/ Involuntary	Cardiac
Location		
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

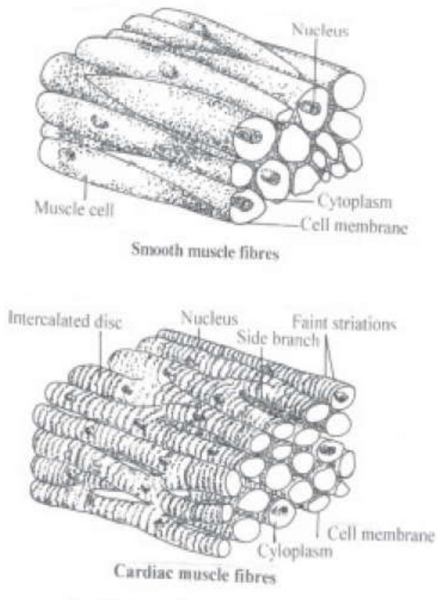


Fig: Types of Vertebrate Muscle Tissue

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

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. Unstriped 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

IV 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 following figure.

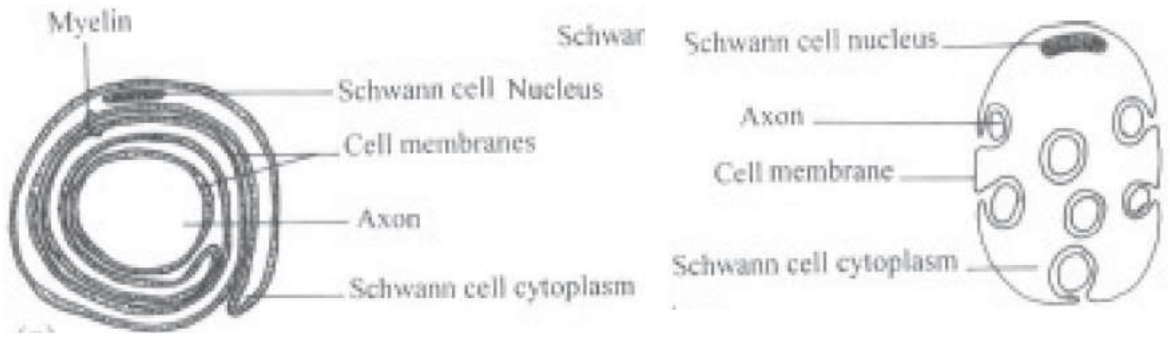


Fig: Nerve cell (a) non-myelinated nerve fibre (b) myelingated nerve fibre.

Like any other cells of the body, it 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 but branching processes of the cyton are called the **dendrites** (GK dendros = tree). The cell bounded by plasma membrane, possesses a nucleus and other organelles like mitochondria etc. The cyton also contains dark granules called Nissel bodies. These are made of RNA and Protein.

Transmission of nerve impulse : The branching dendrites receive the stimulus and transmit through the cyton to the axon, which finally transmits it through its variously branched end 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

INTEXT QUESTIONS

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

   ____

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 organism 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 grouping are known the levels of organization. These levels are as follows:

(i) **Cellular Level of Organization**– The organization of the activities by different organelles in a single cell. Example, white blood cell or a green cell 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 (veins, etc.) 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, diaphragm, etc.) in man or the shoot system (consisting of leaves, stem and branches, etc.) in a plant.

(vi) **Organism**– The complete individual made of different organ system. Examples: man, monkey, or a mustard plant.

INTEXT QUESTIONS

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 Organisation	Examples 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 same origin and performing similarly function.
- In plants there are, first of all two major categories of tissues- meristematc (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 to together (bones blood etc.), the contractile muscular tissue (different muscles,) and nervous tissue consisting of nerve cells adapted for conducting message (brain cells, etc.)
- 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.

7 ANATOMY - STEM AND ROOT

Introduction: Plants are one of the most important organisms on earth. a plant is made up of numerous parts like roots, stem ,leaves, flowers and fruits. Distinct parts serve different purposes .The study of plant organ tissue and cellular structure is known as plant anatomy or internal structure . It describes the structure and organisation of the cells tissues and organs of plant

1. Internal (anatomical) structure of dicot root

A thin transverse section of dicot root 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.

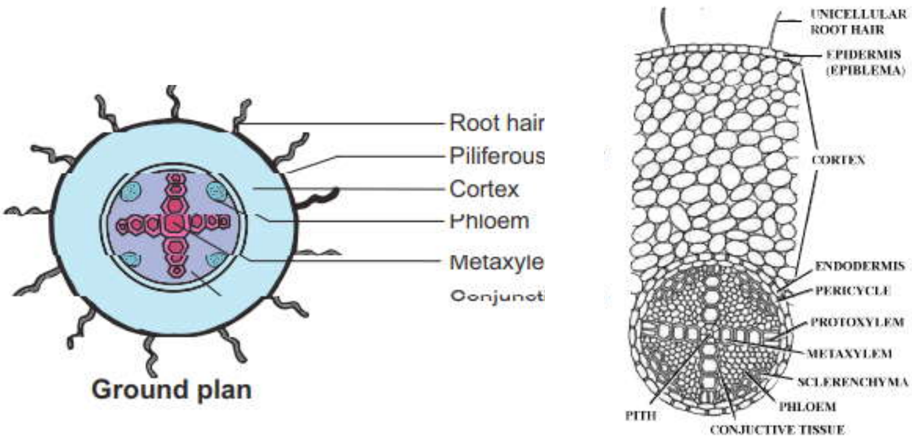


Fig: A portion of dicot root in transverse section

(iii) Endodermis : Innermost layer of cortex, cells barrel-shaped, closely packed, show band like thickenings on their radial walls called *casparian strips.* Some cells (opposite to 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 place of origin of lateral roots and vascular 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

2. Internal (anatomical) structure of dicot stem

Internal structure of dicot stem (Ex. Sunflower)

In a transverse section of a young dicot stem as the following structure of the plant

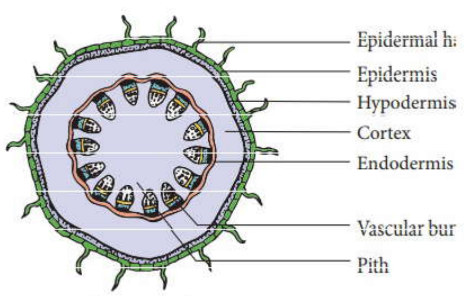
1. **Epidermis -** Outermost single layer, covered with cuticle, bears multicellular hairs, protective in function.

2. **Cortex** - Inner to epidermis, there are three regions.

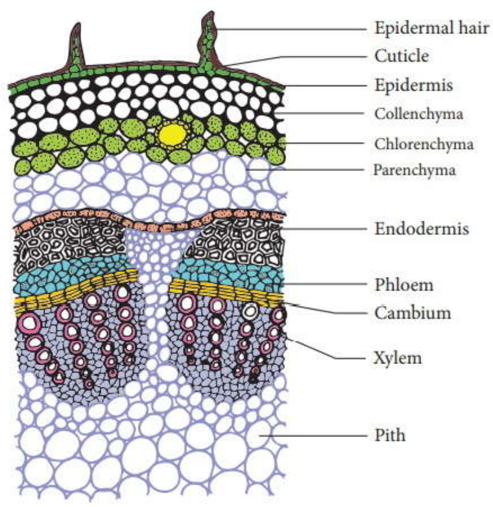
Hypodermis - 4-6 layers of collenchyma for mechanical support.

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.** multilayered, parenchymatous with patches of sclerenchyma.



Ground plan



3. **Vascular bundles -** Arranged in a ring ,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).

Medullary rays - Narrow regions of parenchymatous cells in between the vascular bundles.

Pith - The central parenchymatous zone with intercellular spaces.

3.Internal structure of monocot root (Ex: *maize*)

In a transverse section of a young monoco root you will see the following structure

Epidermis

It is the outermost layer composed of compact parenchymatous cells having no intercellular spaces and stomata.

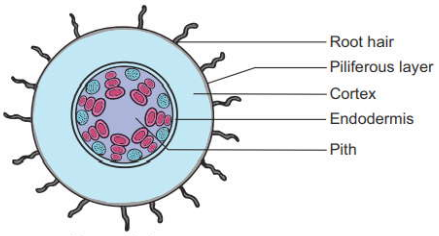
The tubular unicellular root hairs are also present on this layer Root hairs absorb water and mineral salts.

Cortex:

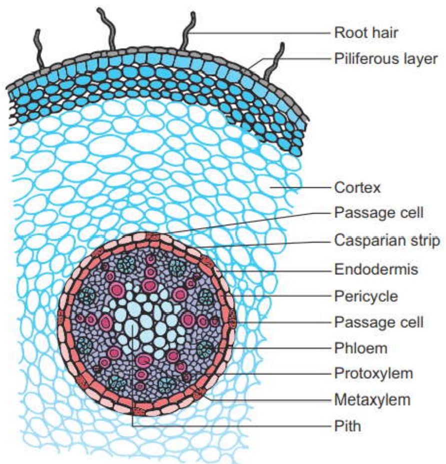
It lies just below the epidermis.

Cortex consists of thin walled multilayered parenchyma cells having sufficiently developed intercellular spaces among them.

Cortex functions storage of food ,protection when exodermis is formed in older parts.



Ground plan



A sector enlarged

Endodermis:

The innermost layer of the cortex is termed as endodermis. It is composed of barrel-shaped compact cells that lacks intercellular spaces among them. The function of endodermis is to regulate the flow of both inward as well as outward.

Pericycle:

It lies just below the endodermis and is composed of single layered sclerenchymatous cells intermixed with parenchyma.

Vascular tissue:

The vascular tissue contains alternating strands of xylem and phloem. The xylem forms discrete strands, alternating with phloem strands. The center is occupied by large pith which maybe parenchymatous or sclerenchymatous.The number of vascular bundles are more than six, hence called as polyarch. Phloem strands consist of sieve tubes, companion cells and phloem parenchyma.

Conjunctive tissues:

In between the xylem and phloem bundles, there is the presence of many layered parenchymatous or sclerenchymatous tissues. These help in storage of food and help in mechanical support.

Pith:

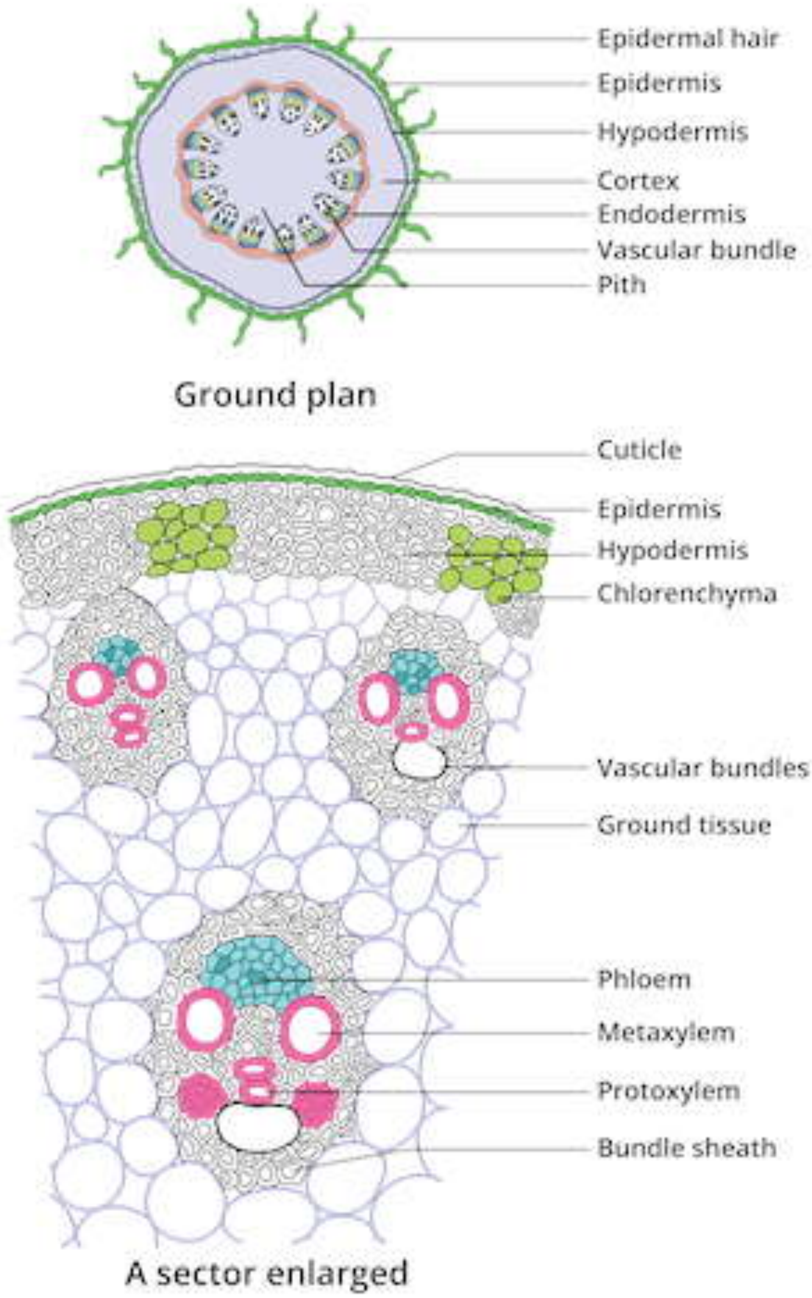
It is the central portion usually composed of thin-walled parenchymatous cells which appear polygonal or rounded in T.S. Intercellular spaces may or may not be present amongst pith cells.

4. Internal structure of monocot stem (Ex. maize)

A transverse section of monocot stem reveals the following structure

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.**

Vascular bundle- Numerous, scattered in the ground tissue each enclosed by sclerenchymatous bundle sheath. Each bundle **conjoint and colletral** and **closed** (no cambium strip between xylem and phloem) with **endarch** xylem. Xylem occurs in the form of letter 'Y 'and innermost protoxylem disintegrates to form a water cavity.



8 ABSORPTION, TRANSPORT AND WATER LOSS IN PLANTS

Water is the most important component of living cells. It enters the plants through roots and then moves to other parts and is also lost by transpiration 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

Absorption of water by plants

Water is absorbed by roots or in some cases absorbed by leaves and stems. capillary water of the soil is absorbed by root hairs. Once the water is absorbed by root hairs, it can move deeper into the root layers by two distinct path ways.

1. Apoplast pathway
2. Symplast pathway

Apoplast is the system of adjacent cell walls, except at the casparian strips of the endodermis in the roots which allow water movement into the plant by capillarity and absorption. Symplast consist of cytoplasm of the entire plant. Neighboring cells are connected through cytoplasmic threads that extend through plasmodesmata. The water absorbed through the roots is transferred radially to the xylem, from where it reaches to all the other parts of the plant by vertical conduction of water through the xylem vessels.

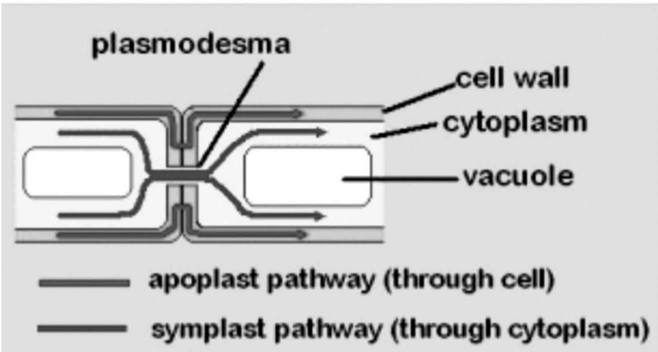


Fig: Variou pathways of water movement

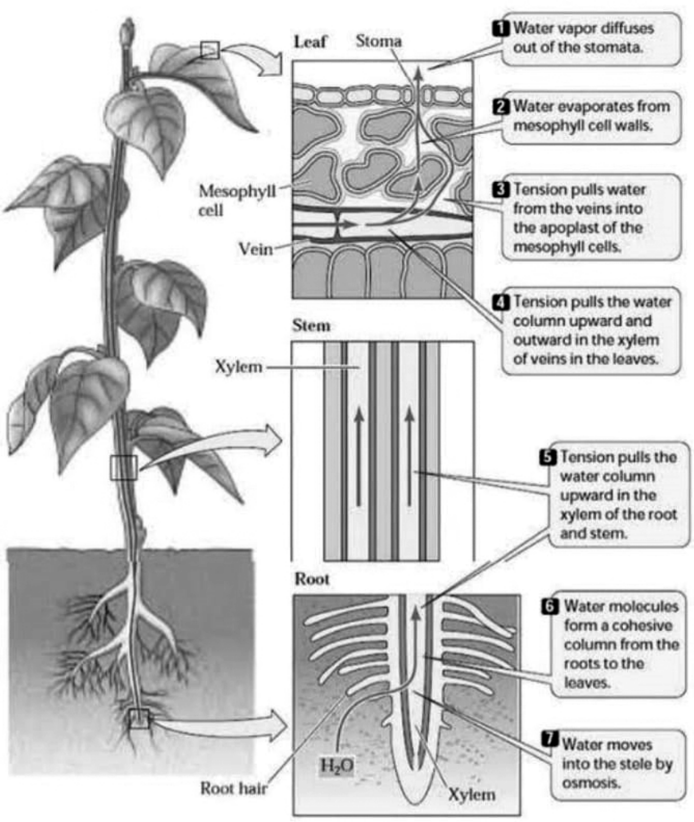


Fig:

Water movement up by plants

The content of the xylem vessels is known as xylem sap. Various theories have been postulated to describe the ascent of sap in the xylem (upward movement against gravity)

Root pressure

The positive pressure developed in the xylem of the root is called Root pressure. Root pressure is enough to raise water to small height in herbaceous plants. Root pressure does not play a major role in water movement in tall trees.

Cohesion Tension Theory

It is proposed by Dixon. This theory takes into account the physical forces which act in case of very tall trees. The three physical forces that act together are

1. Force of cohesion (Attraction between water molecules)
2. Adhesion (Attraction between molecules and walls of xylem)
3. Transpiration Pull -Which lifts the water column by creating a tension inside the xylem vessels.

Water ascent up against the gravity to greater heights as water form an unbroken column starting from the intercellular space of the leaf mesophyll to 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 as 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.

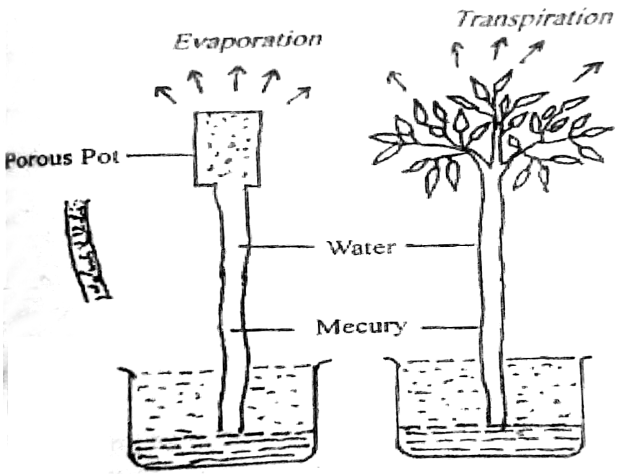


Fig: Effect of transpiration of absorption of water.

TRANSPORT OF WATER IN PLANTS

Diffusion

Diffusion is the movement of molecules from a region of higher concentration to a region of lower concentration down the concentration gradient. Diffusion is the effective method of transport over short distances. No energy is required for diffusion to occur hence diffusion is passive. Gaseous movement in plants occur through diffusion. If $CuSO_4$ crystals are placed in water, $CuSO_4$ dye molecules will dissolve in water and color is spread throughout the water.

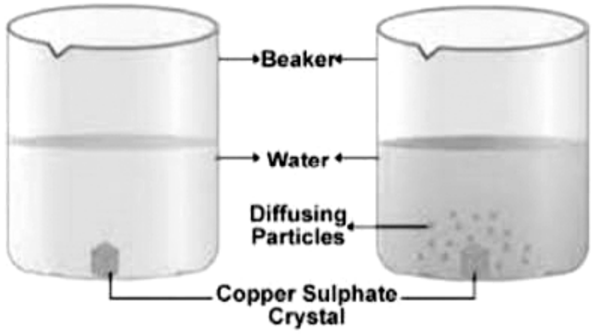


Fig: diffusion of $CuSo_4$ in water

Osmosis

Osmosis is the diffusion of water molecules from a region of higher concentration to lower concentration through a semi permeable membrane. Osmosis occurs due to concentration gradient difference, hence it occurs passively.

Experiment to demonstrate osmosis:

Experiment: To demonstrate the phenomenon of osmosis through plant membrane with the help of potato Osmoscope.

Requirements: A large potato tuber, 10% sugar solution, beaker, water scalpel, pin

Method: Take a large potato tuber and peel of its outer skin with the help of scalpel. Cut its one end to make the base flat. Now make a deep hallow cavity on the opposite side. Put 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 is below the level of potato.

Observation and Conclusion:

The level of sugar solution in the cavity rises. It is because of movement of water molecules in to the cavity from pure water in the beaker. This experiment shows the phenomenon of osmosis.

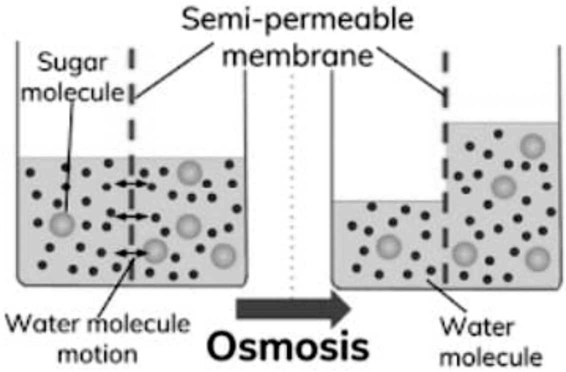


Fig: osmotic movement of water molecules through a semipermeable membrane

Explanation

The living cells of potato tuber collectively act as differentially permeable membrane. 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 membrane, into the sugar solution till the concentration become equal. 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 acts as impermeable layer.

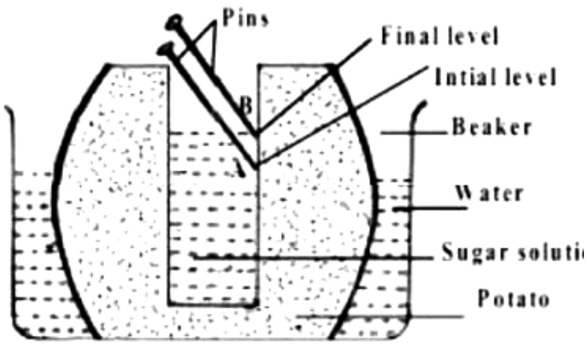


Fig: experiment to demonstrate osmosis

Osmotic pressure and osmatic potential

When pure water is separated from a solution by a semi permeable membrane, pure water tends to enter the solution by osmosis. Now the pressure required to prevent the osmatic entry of water in a solution is called osmatic pressure.

Imbibition

Imbibition is the adsorption of water by protoplasmic and cell wall constituents. When solid plant materials like dry wood, dead or living air dried seeds when comes in contact with water, imbibition occurs.

Imbibition is the initial step in fermentation of seeds. It causes swelling of seeds and breaking of seed coat.

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.

1. When a cell is placed in a hypertonic solution i.e., when the concentration of the outer solution is higher than the cell sap, the water from the cell moves out resulting in shrinkage of the protoplasm in the center of the cell and disappearance of the vacuole. This phenomenon is known as plasmolysis. The space between the cell wall and the protoplast is occupied by the bathing solution as of the cell wall is permeable.
2. When such 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 becomes fully turgid.
3. When a cell is placed in an isotonic solution or a solution with similar concentration as 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 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 conditions such as hypertonic soil solution.

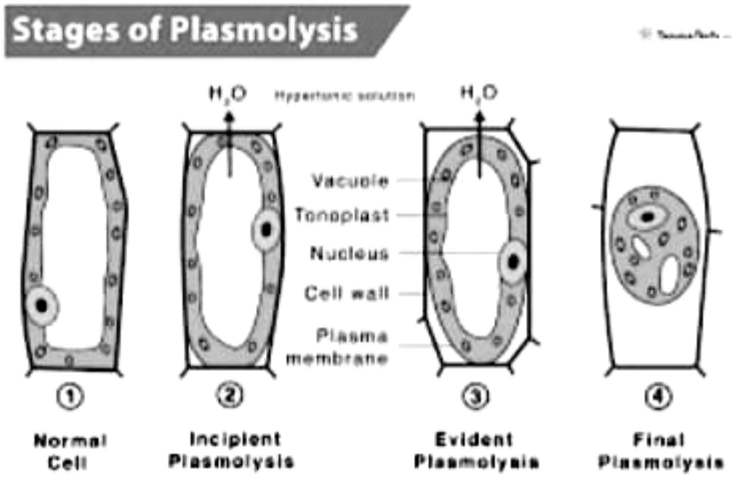


Fig: changes in a plant when placed in hypotonic, Hypertonic and isotonic solution

INTEXT QUESTIONS

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?

   ____

Water Potential

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.

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 cell or tissues.

TURGOR PRESSURE

Turgor Pressure is the pressure exerted by the protoplasm against the cell wall. 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 is called as wall pressure (WP). These two pressures are equal and opposite in direction. When TP becomes more than the WP the cell wall 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 able to resist the pressure. It is a real pressure not a potential one and can occur to a great extent. In case of animal calls, the plasma membrane bursts if the 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 of the guard cells.
- Certain plants like bean and Touch Me Not plant- *Mimosa pudica* show quick response of leaves by controlling the turgidity.

Availability of water in the soil

Plants absorb water through the root hairs from the soil. The soil contains water in three forms

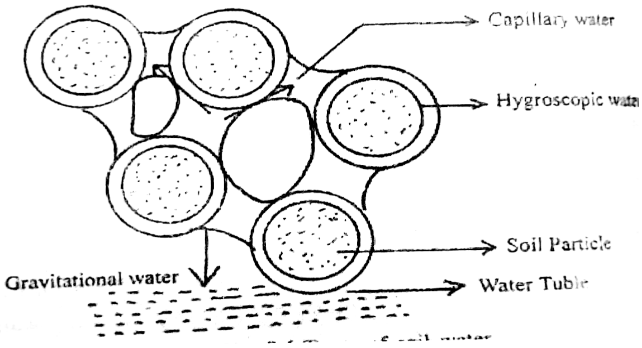


Fig: Types of soil water.

(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 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 attractive 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 to about 0.5%.

(iii) **Capillary Water**. The soil particles have very fine pores in between, forming a very fine capillary systems 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.

TRANSLOCATION OF ORGANIC SOLUTES

Movement of organic and inorganic solutes from one part of the plant to another is known as translocation.

In simple terms, transport of sugar in sieve tubes is called translocation.

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, rhizomes etc. 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 move along the water potential gradient created between the source (leaf) and sink (storage) cells. Here there is a mass movement of sugar solution from the leaf mesophyll to all parts of the plants.

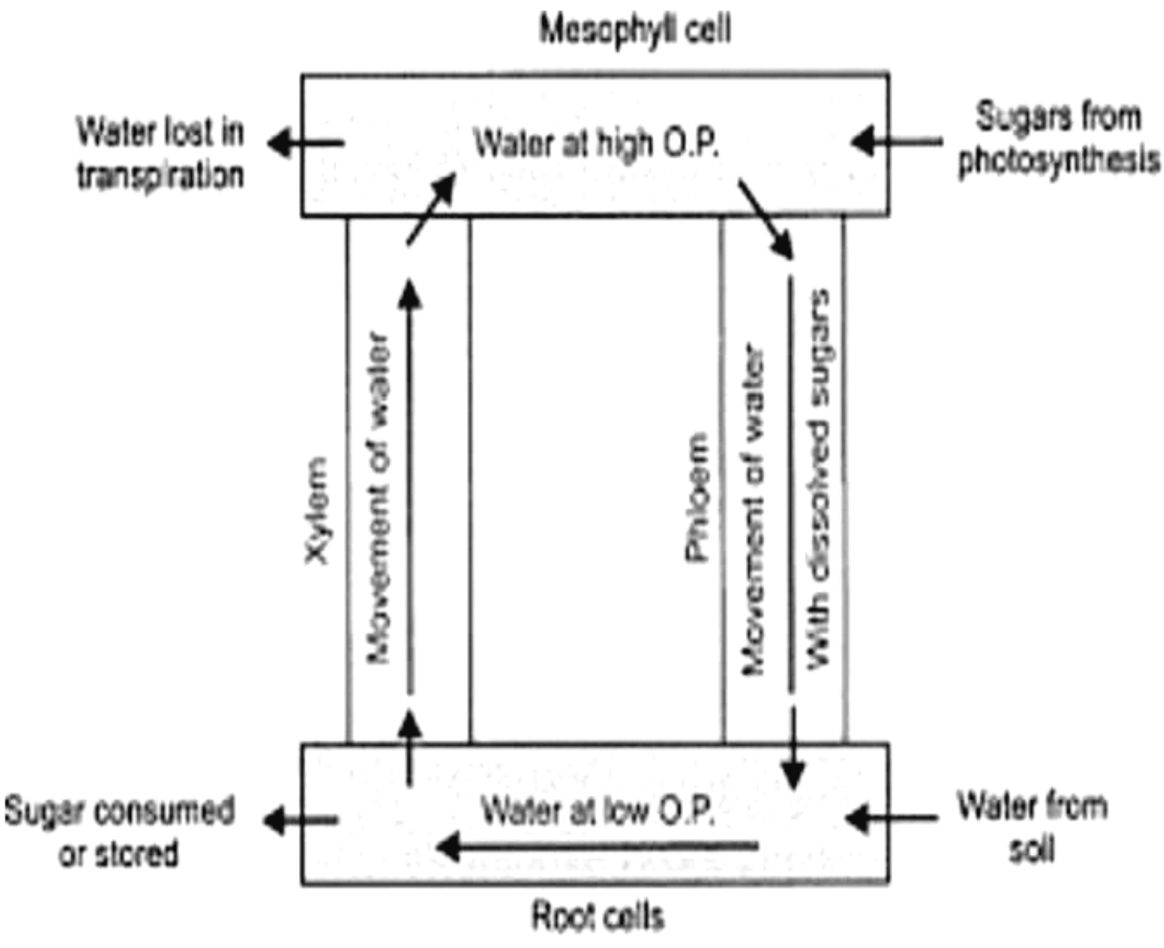


Fig: mechanism of translocation

This model known as Munch hypothesis or Mass flow theory is mostly acceptable model for phloem translocation.

INTEXT QUESTIONS

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?

TRANSPIRATION

What is transpiration

The loss of water from aerial parts of the plant in the form of water vapour is termed transpiration. Transpiration may occur through three main sites in the plant: 1. Cuticle, 2. Lenticels, 3. Stomata.

Stomata: Stomata are minute pores on the epidermis of leaves, whose opening and closing are controlled by guard cells. About 90 percent of water loss from plants take place through stomata known as stomatal transpiration.

Mechanism of transpiration

Transpiration occurs in two stages

(i) Evaporation of water from the mesophyll cells into the intercellular spaces.

(ii) Diffusion of this water vapour of the inter cellular spaces into the outside atmosphere, when the outside atmosphere is drier.

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.

(iii)Light: Light has got no direct effect in 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.

(i) 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 with 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 than the roots are able to absorb, even though there is enough water in the soil, it is known as temporary wilting as the plant recovers from such wilting in the late afternoon or at night

(ii) Atmospheric pressure: Reduction of atmospheric pressure reduces the density of external atmosphere thus permitting more rapid diffusion of water. Plants growing on high will show higher rate of transpiration hence they develop xerophytic characters.

(iii) 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 *Opuntia*)
- thick deposition of cutin (wax like substance) on the leaf surface.
- stomata found sunken in the cavities surrounded by hairs as in *Nerium* and *Cycas*.
- root shoot ratio, when there is more root and less of shoot system or leaves, there will more of transpiration. Root is the water absorbing surface and shoot or leaves Role of Stomata in Transpiration .

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.

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. They are generally closed during the night.

From early morning till midday, the stomata are open and hence the transpiration increases till midday.

During sunny afternoon, the stomata are closed and hence the transpiration decreases. 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.

Stomata

Structure of Stomata. It consists of a minute pore called stoma surrounded by two guard cells. The stoma acts as a turgor-operated valve, which closes and opens according to the turgidity of guard 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 turgor pressure in the guard cells. When the guard cells are turgid, the stoma opens and when guard cells lose water, stoma closes. The mechanism of dicots and monocots is as given 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

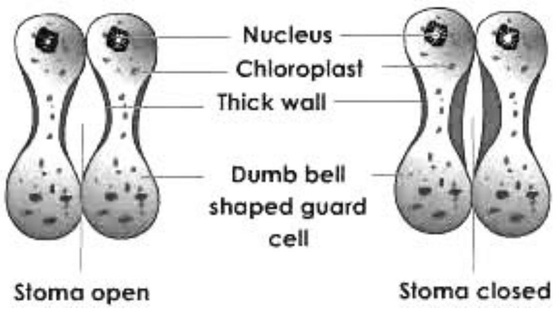


Fig: Stomatal action in dicots

(b) In monocotyledonous plants, the guard cells are dumb bell shaped with thickened 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 loose water → The inflated part sags → The thick walls collapse → Stoma close

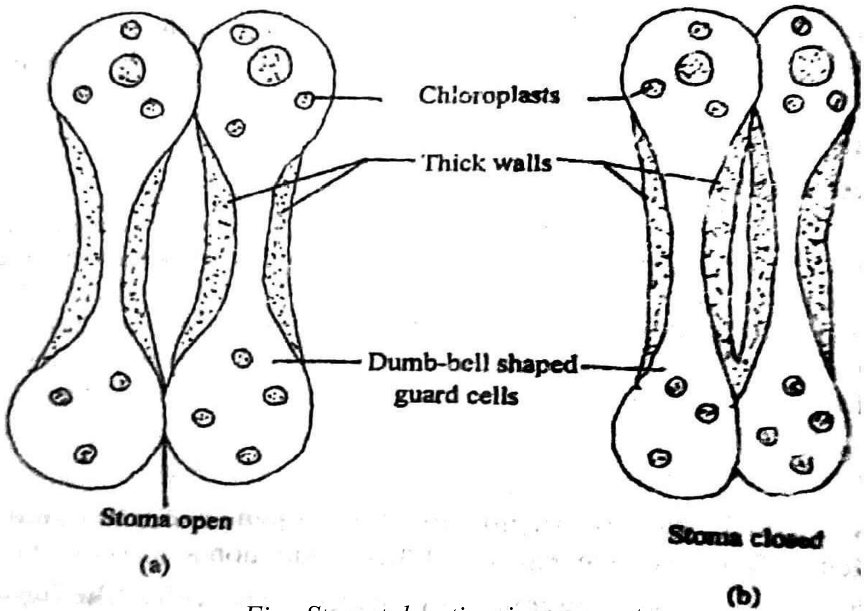


Fig: Stomatal action in monocots

Changes in turgidity 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

(ii) Effect of potassium ions (K+) on stomata

It has been convincingly proved that the accumulation of K+ ions bring the opening of stomata and loss of K+ ions, the closing of stomata.

During Day Light

Accumulation of K+ ions by the guard cells

↓

Increased solute concentration

↓

Endosmosis of water

↓

Increased turgidity

↓

Stoma open

During Night/Dark

Loss of k+ ions by guard cells

↓

Decreased solute concentration

↓

Exosmosis of water

↓

decreased turgidity

↓

stoma close

The update of k^+ ions is balanced by one of the following

(a) (Cl^-) ions as anions. These 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, guard cells close and check water loss.

Significance of Transpirtation

(i) Absorption of water. Transpiration 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 vacuole, it makes the cells turgid. This gives form and shape to the cells and to the plant 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 throughout the plant.

(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.

INTEXT QUESTIONS

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.

____

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 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 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.
- 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 wilting of the plant.

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 action 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.

9 NUTRITION IN PLANTS - MINERAL NUTRITION

Plants take up mineral elements in the form of inorganic ions. The inorganic ions are available in the form of minerals in the soil. The nutrition of inorganic ions of plants is called **mineral nutrition**. Mineral nutrition is a broad field including absorption, translocation of mineral nutrients from root to shoot, leaves and fruits and finally conversion of absorbed inorganic nutrients to organic form.

> The study of how plants obtain mineral elements and utilise them for their gorwth and development is called "Mineral Nutrition".

Objectives:

- Define the terms mineral nutrition, macro and micro nutrients.
- Explain the functions of minerals with reference to the techniques of hydroponics and aeroponics.

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.

ii. The requirement of the element is very specific and it **cannot be replaced** by another element

iii. The element is **directly involved** in the nutrition of a plant.

Plants needed 16 elements for nutrition as suggested by Arnon. These elements are known as **essential elements**. These elements are C, H, O, N, P, K, Ca, Mg, S, Fe, Zn, Cu, Mn, Mo, B, Cl.

These elements are divided into 2 types. They are (1) Macro nutrients (2) Micro nutrients.

A) Macro nutrients :

The nutrients required in large amounts are known as macro nutrients. They are carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S) etc. Carbon, Hydrogen, Oxygen are known as frame work elements. Deficiency of these elements leads to death of the plants. Carbon is available to plants as CO_2 from atmosphere, Hydrogen from water, O_2 is available to plants from both atmosphere and water. The other elements are available to plants from soil.

Nitrogen, phosphorus, potassium elements play an important role in life cycle of plants, so these elements are called as **critical elements**. N, P, K are mobile elements, so these reach the older leaves first than the younger leaves.

B) Micro nutrients :

These are the essential elements which are required in small quantities for plant growth and development. These are also referred to as **minor elements** or **micro elements** or **trace elements.** They are : Iron (Fe), Manganese (Mn), Boron (B), Zinc (Zn), Copper (Cu), Molybdenum (Mo) and Chlorine (Cl).

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.

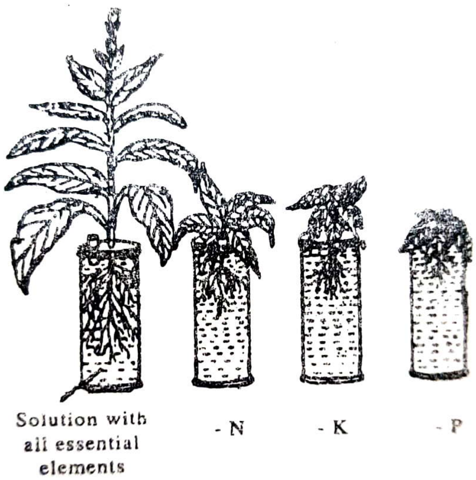


Fig: Water culture experiments

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.

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 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, Citrus plants and olives have been successfully growing through aeroponics.

INTEXT QUESTIONS

1. What are nutrients?

____

2. Define aeroponics.

____

3. Why is it necessary to aerate nutrient solution in water culture?

____

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 Ni.
- The essentiality of minerals may be determined by employing the 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.

10 NITROGEN METABOLISM

Introduction:

Nitrogen is an important element of life as it is part of biological molecules such as amino acids and nucleic acids. However, atmospheric nitrogen cannot be used directly by the living organisms. Therefore, atmospheric nitrogen is first brought to soil by precipitation. Certain bacteria within the roots convert the nitrogen into ammonia and other forms of nitrogen that can be used up by the plants. This process is called nitrification. The nitrogen from the decaying life forms is cycled back into the atmosphere by a process called denitrification, also performed by certain bacteria. As the inter-conversion of different forms of nitrogen involves the participation of both living organisms and physicochemical processes, the nitrogen cycle is a form of biogeochemical cycle.

Objectives

After completing this lesson , you will be able to;

- Describe the kinds of physical and biological Nitrogen fixation.
- Know the steps involved in Nitrogen fixation by free living organisms.
- Explain the mode of symbiotic nitrogen fixation in Legumes.
- Describe the assimilation of nitrate and ammonia by plants.
- Explain about amino acid synthesis in plants.

Molecular Nitrogen

Atmosphere contains 78% of nitrogen in the form of gaseous ,molecular state with highly stable(Na≡N)nature.Plants cannot utilize this dinitrogen, unless fixed in the form of ammonia or nitrates. The cyclic movement of nitrogen from the atmosphere to soil and from soil to atmosphere through plants, animals and microorganisms is called as Nitrogen cycle.

Nitrogen cycle involves five steps:

A. Nitrogen Fixation

B. Nitrogen Assimilation

C. Ammonification

D. Nitrification

E. Denitrification

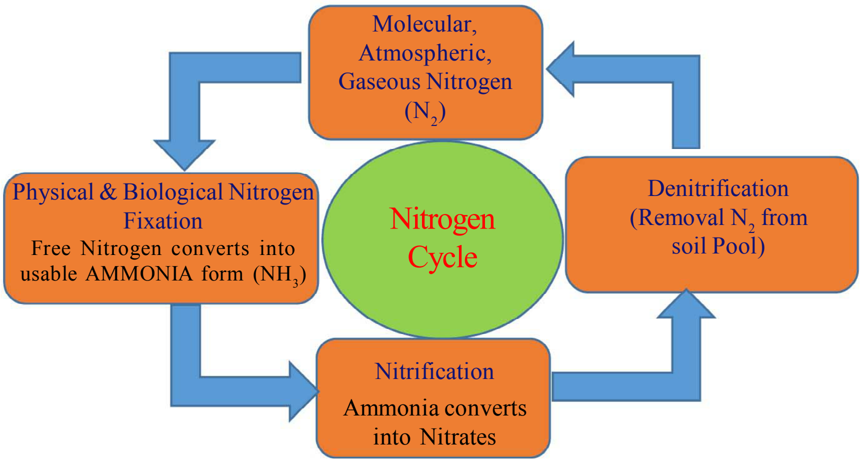


Fig: Steps in Nitrogen Cycle

Nitrogen fixation: Nitrogen can be fixed both by abiological and biological processes. Abiological nitrogen fixation involves the conversion of nitrogen to ammonia either by natural processes like thunderstorms or by industrial methods such as Haber's process.

$$\underset{\text{(Nitrogen)}}{N_2(g)} + \underset{\text{(Hydrogen)}}{3H_2(g)} \longrightarrow \underset{\text{(Ammonia)}}{2NH_3(g)}$$

This is industrial fixation and nitrogen reduced to ammonia

Biological nitrogen fixation is performed by soil microbes which are either free-living (Ex. Azotobacter, Clostridium and Klebsiella) or symbiotic with certain host plants (Rhizobium, Azospirillum and Cyanobacteria). An enzyme known as the nitrogenase catalyzes the conversion of molecular nitrogen into ammonia. Nitrogenase is a Mo-Fe (contains molybdenum and iron) protein and is sensitive to oxygen; therefore, a protein called leghemoglobin present in the root nodules of legumes scavenges oxygen for the optimal function of the nitrogenase. Plants that lack nitrogen-fixing bacteria absorb nitrates from the soil and convert them first into nitrites by the action of nitrate reductase enzyme and later into ammonia by the action of nitrite reductase enzyme. Taken together, ammonia is available either from atmospheric nitrogen via the action of microbial nitrogenase or synthesized from nitrates by plants themselves via the action of reductases.

The general equation for nitrogen fixation may be described as follows:

$$N2+16ATP+8H^{+}+8e \longrightarrow 2NH_3+16ADP+H_2+16Pi$$

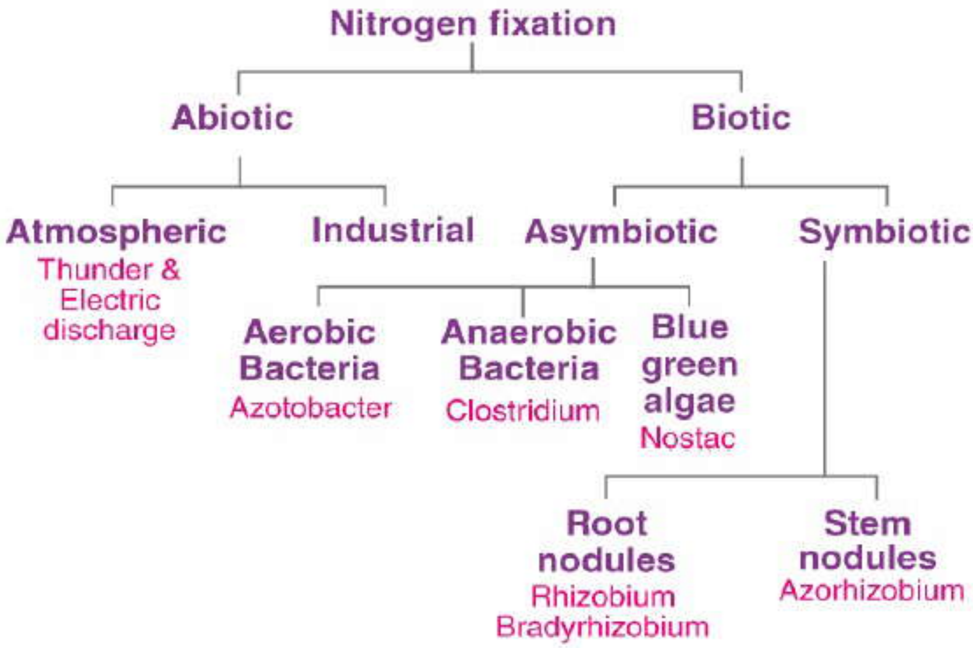


Fig : some free living microbes which fix nitrogen

Nitrogen metabolism: The ammonia produced or absorbed by plants is then incorporated into amino acids by a pair of chemical reactions called reductive amination and transamination within the cells. During reductive amination, ammonia combines with an alpha-keto acid to from the amino acid called glutamic acid. As a result, the free ammonia has now become an amino group within the amino acid. In transamination reaction, this amine group is transferred from glutamic acid to different alpha-keto acids resulting in the formation of respective amino acids. In summary, the ammonia is first converted to amine group of glutamic acid, from which it is transferred as amine group to form several amino acids from alpha-keto acids. These amino acids will further converted into a wide variety of nitrogen-containing biological molecules such as nitrogen bases which are constituents of nucleic acids DNA and RNA.

Reductive Amination:

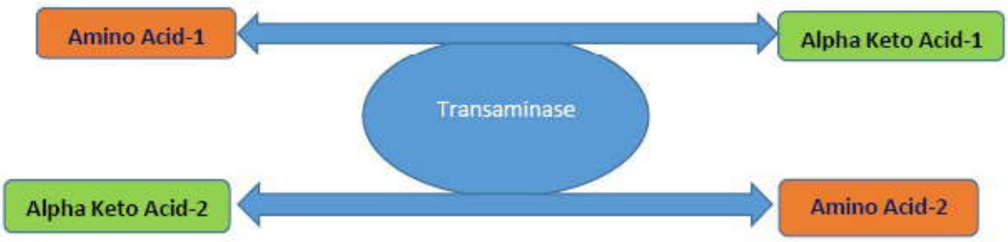
$$\text{a - ketoglutaric acid} + NH_4^+ + NAD(P)H$$

$$\xrightarrow[\text{dehydrogenase}]{\text{Glutamate}} \text{Glutamate} + H_2O + NAD(P)$$

$$\text{Oxaloacetic acid} + NH_4^+ + NAD(P)H$$

$$\xrightarrow[\text{dehydrogenase}]{\text{Aspartate}} \text{Asparatate} + H_2O + NAD(P)$$

2. TRANSAMINATION



Ex: a- Keto Gluatric Acid + Aspartic Acid $\longrightarrow$ Glutamic acid + Oxalo acetic acid

(Keto Acid) (Amino Acid) (Amino Acid) (Keto Acid)

INTEXT QUESTIONS

1. What is the most reduced form of inorganic nitrogen?

___

2. List out the steps in nitrogen cycle?

___

3. Name two biochemical reactions for biosynthesis of amino acids in plants.

___

4. Which group of enzymes catalyzes trasamination reaction?

___

5. Give examples for asymbiotic and symbiotic nitrogen fixing organisms?

11 PHOTOSYNTHESIS

Photosynthesis (Photo = light; synthesis = to join) is the single most important process on earth on which depends the existence of human 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 organism 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 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 plants carry out photosynthesis.

Objectives:

After completing this lesson , you will be able to;

- define photosynthesis;
- name the different pigments found in chloroplasts and describe the ultra-structure of a chloroplast with diagram;
- Define the terms absorption spectrum, electron acceptor, photophosphorylation and action spectrum;
- Explain the main aspects of the process of photosynthesis;
- Enumerate the steps involved in the light and dark reactions of photosynthesis;
- Distinguish between, light and dark reactions, cyclic and non-cyclic phosphorylation, C3 and C4 photosynthesis;

PHOTOSYNTHESIS

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, hence they are dependent on green pants for their survival.
4. Green plants can prepare organic food from simple inorganic elements (autotrophic) while all other organisms cannot prepare their own food and are called heterotrophic.
5. During photosynthesis, oxygen is liberated into the atmosphere that makes the environment livable for all other organism
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 other organisms of the earth.
8. Fossil fuels like coal, gas, oil etc represent the photosynthetic products of the plants belonging to early geological periods.

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. Current knowledge of photosynthesis has resulted from discoveries made over 300 years of work.

Some landmark experiments are given below.

- Joseph Priestly and later Jan Ingenhousz showed that plants have the ability to take up CO_2 from the atmosphere and release O_2.

- Ingenhousz 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 demonstrated that isolated chloroplasts evolve O_2 when they are illuminated in the presence of electron acceptor which get reduced. This reaction called as the Hill reaction accounts for the (breakdown) use of water (photolysis) as a source of electrons for CO_2 fixation and release of O_2 as the by-product.

Photosynthesis is represented by the following overall chemical equation

$$6CO_2 + 12H_2O \rightarrow C_6H12O_6 + 6H_2O$$

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) take place at different sites in the 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. Photosynthesis is a process by which plants and certain bacteria convert energy from the sunlight into chemical energy that can be utilized by living organisms. This chemical energy is in the form of ATP, NADPH and glucose. During the conversion of light energy into chemical energy, plants absorb atmospheric CO_2 and release oxygen. By doing so, plants reduce the concentration of greenhouse gases in the atmosphere and provide oxygen that is required for the survival of living organisms on the earth. The carbon atoms derived from the atmospheric CO_2 is used to build up energy molecules such as the glucose.

The process of photosynthesis involves two stages: (1) Light reaction, during which the sunlight is absorbed by the chlorophyll pigment to generate high energy electrons that are used to synthesize NADPH, and (2) Dark reaction, during which the energy contained in the NADPH is utilized to convert atmospheric CO_2 into sugar molecules such as the glucose, which are storage forms of the energy. Within the chloroplast, the site of light reaction is the grana thylakoid, while that of the dark reaction is the stroma.

LIGHT REACTION

PHOTOCHEMICAL AND BIOSYNTHETIC PHASE

The electrons 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 the ATP. In addition, NADP is reduced to $NADPH_2$.

Electron transport chain in photosynthesis: It starts as the PSII absorbs light energy and passes it on to its reaction centre, P680. When P680 absorbs light, it is excited and its electrons are transferred to an electron acceptor molecule (Primary electron acceptor) after losing an electron, P680 is oxidised and in turn it splits water molecule to release O_2. This light dependent splitting of water is called photolysis. With the breakdown of water electrons are generated, which are then passed on to the electron deficient P680. Thus, the oxidised P680 regains its lost electrons from the water molecules.

The reduced primary acceptor now donates electrons to the downstream components of the electron transport chain. The electrons are finally passed onto the reaction centre P700 of PSI. During this process, energy is released and stored in the form of ATP.

Similarly, PSI also gets excited when it absorbs light and P700 (Reaction centre of PSI) gets oxidised as it transfers its electrons to another primary acceptor molecule. While the oxidised P700 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) reducing it to NADPH2. 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 the reduction of CO_2 to carbohydrates in the biosynthetic path-way.

Reduction of CO_2 to carbohydrate also requires ATP which too are generated via electron transport chain.

Since this takes place in presence of light it is called Photo phosphorylation. It occurs in chloroplast in two different methods.

(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 electrons flow in unidirectional it is called non cyclic photophosphorylation

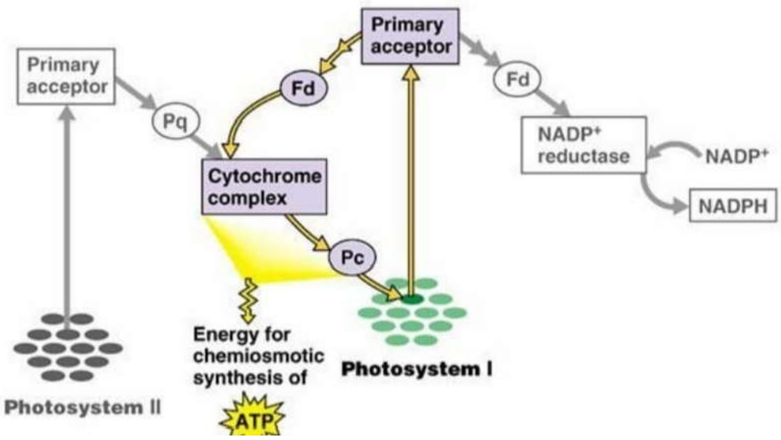
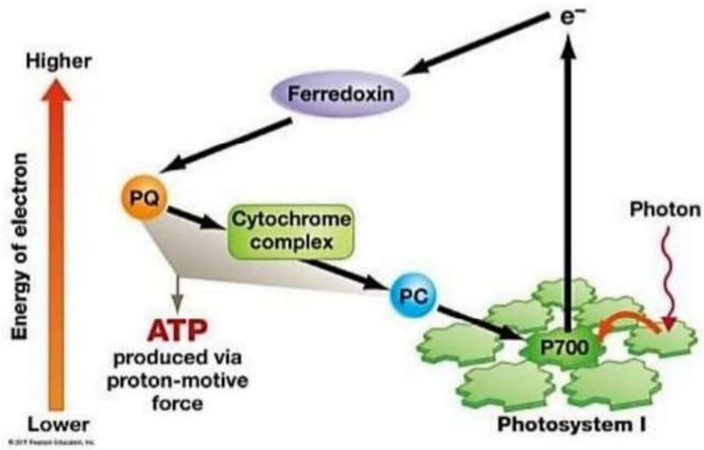


Fig : Non cyclic photophosphorylation

(b) Cyclic photophosphorylation under certain condition when non-cyclic photophosphorylation stops, cyclic photophosphorylation occurs and it involves PSI only. During this process electrons from PSI are not passed on to NADP. Instead, the electrons are returned to the oxidised P700 molecule. This downhill movement of electrons results in ATP formation. Thus this is termed as cyclic phosphorylation.



Dark reaction

Fig. cyclic photophosphorylation

DARK REACTION (C_3 cycle)

Also known as the Calvin cycle, dark reaction involves a series of biochemical reactions that are catalysed by enzymes.

The dark reaction (C_3 cycle) occurs in three steps:

(1) Fixation of atmospheric CO_2 by a five- carbon sugar called ribulose 1,5 bisphosphate (RuBP),

(2) Synthesis of sugars using the carbon from CO_2 and

(3) Regeneration of the RuBP.

In the first step, atmospheric CO_2 was combined with RuBP in the presence of an enzyme known as RuBisCo (Ribulose Bisphosphate Carboxylase/Oxygenase). This process of addition of CO_2 to RuBP is called carboxylation and hence the name of the enzyme is carboxylase. In addition to carboxylation, RuBisCo also has oxygenase activity i.e., it can also bind oxygen and result in the formation of unnecessary products resulting in the wastage of energy. This process is also called photorespiration. Therefore, it is important that the Rubisco has carboxylase activity rather than oxygenase activity. However, oxygenase activity increases with an increase in atmospheric temperature. This problem is solved by increasing the CO_2 concentration in the vicinity of the enzyme because of which carboxylase activity dominates despite higher temperature. For this reason, plants of desert or temperate climate adapt to higher temperature by increasing CO_2 concentration near the RuBisCO via C4 and CAM (Crassulacean Acid Metabolic) pathways.

In the second step, sugars such as glucose are synthesized using certain enzyme-catalysed reactions. During these reactions, energy from the ATP and NADPH that is generated during light reaction, is utilized to build sugars. In the third step, the RuBP that is utilized during the first step of carbon fixation is regenerated so that it continues fixing more CO_2 and helps in continued Calvin cycle. In summary, the dark reaction converts atmospheric CO_2 into sugars utilizing the energy generated during the light reaction.

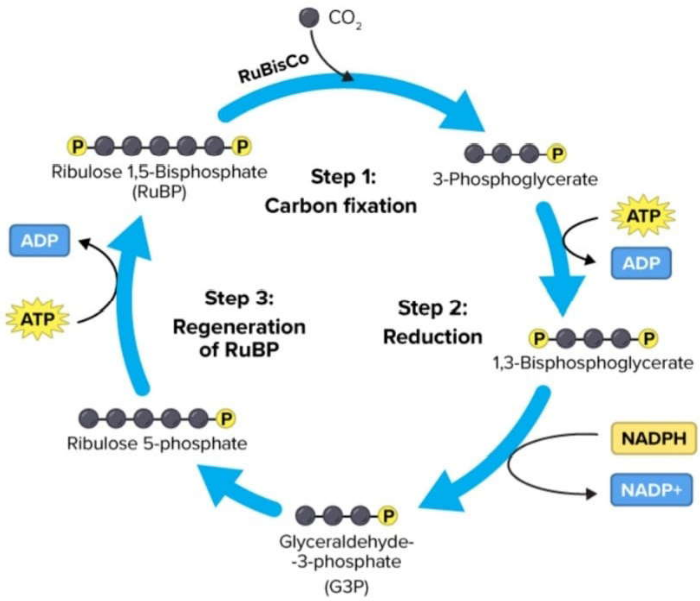


Fig The calvin cycle

C4 and CAM pathways:

As discussed in the dark reaction, the RuBisCO has both carboxylase and oxygenase activities and the oxygenase activity predominates at higher temperature. Certain plants use four-carbon (C4) molecule called phospho enol pyruvate (PEP) to fix atmospheric CO_2 instead of the five-carbon RuBP. Such plants are called C4 plants. In C4 plants, carbon absorption from the atmosphere is separated from the carbon fixation. In mesophyll cells that are directly in contact with the atmosphere, CO_2 is combined with PEP, which then transfers the CO_2 into the underlying bundle sheath cells. In bundle sheath cells, CO_2 is again separated while the PEP is cycled back to mesophyll cells. This process increases the local concentration of the CO_2 thereby enhancing carboxylase activity of RuBisCO instead of its oxygenase activity despite the higher temperature. The RuBisCO now fixes the CO_2 by combining CO_2 with the RuBP and continues Calvin cycle.

CAM PATHWAY

In case of desert plants, the stomata are closed during the day time to reduce transpiration because of which the absorption of CO_2 wouldn't happen. Therefore, the absorption of atmospheric CO_2 happens during the night time during which the stomata are open. Similar to the C4 pathway, PEP absorbs CO_2 at night and is stored in the vacuole as malate. During day time, malate releases CO_2 which is then fixed by the RuBisCO by combining it with the RuBP to continue Calvin cycle. By increasing the concentration of CO_2 during the day time despite high temperature, CAM plants maintain the carboxylase activity of the RuBisCO. In summary, C4 plants separate absorption of CO_2 and it's fixation by compartmentalization into different cells (mesophyll and bundle sheath cells), CAM plants do the same by compartmentalization into different times (day and night times)

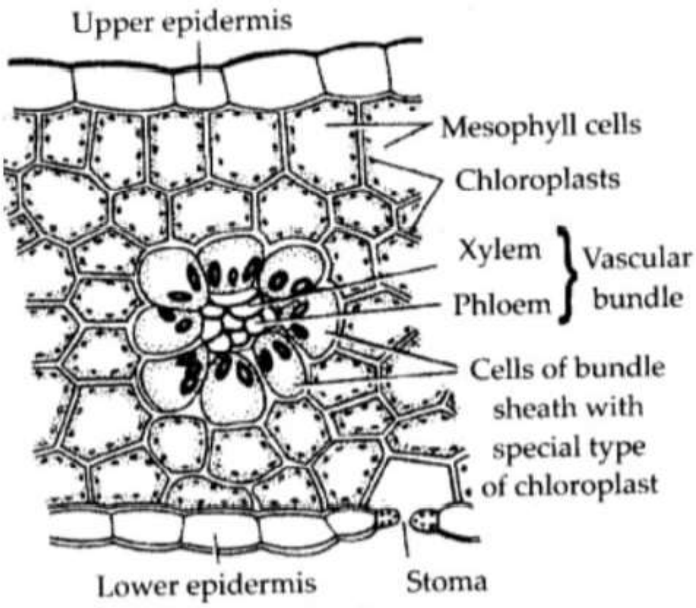
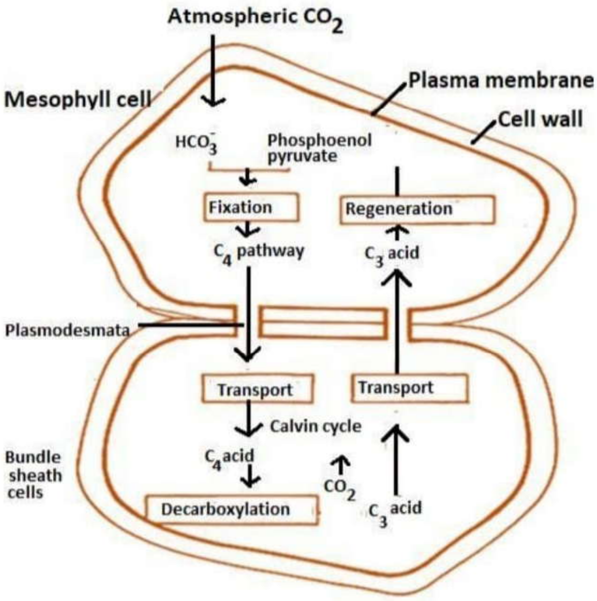


Fig . Transverse section of maize leaf (C4 Plant)



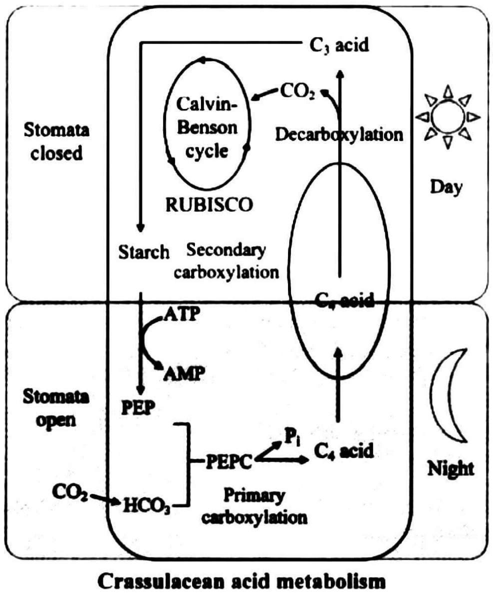


Fig . The c4 pathway & EAM pathway

Fig: Crassulacean acid metabolism

FACTORS AFFECTING RATE OF PHOTOSYNTHESIS

Factors affecting photosynthesis can be divided into two broad categories, the internal and external (environmental)

(i) Internal Factors

1. **Chlorophyll**: The amount of chlorophyll present has a direct relationship with the rate of photosynthesis because this pigment which is photoreceptive is directly involved in trapping light energy.

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 (iv) thickness of cuticle etc

3. **Demand for photosynthate** : Rapidly growing plants show increased rate of photosynthesis in comparison to mature plants. Demand for photosynthesis is lowered by removal of meristem.

(ii) External Factors

The major external factors which affect the rate of photosynthesis are temperature, light, carbon dioxide, water, mineral elements etc.

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. For example, out of 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 become suboptimal and the other factors remain optimal, the rate of the process decline substantially. This is known as the law of limiting factors or the law of minimum, was proposed 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.

Light: The rate of photosynthesis increases with increase in the rate of intensity of light in other words the rate of photosynthesis is directly proportional to the light intensity. Except on a cloudy day light is never a limiting factor in the 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 the compensation point. Wavelength of light also affects the rate of photosynthesis. Red light, and to some extent blue light, has an enhancing influence on photosynthesis.

Temperature: Very high and very low temperatures 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 in the dark reaction are inactived at high temperatures. Between 5°-35°C, with every 10°C rise in temperature rate of photosynthesis doubles.

Carbon dioxide: 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 a limiting factor in natural photosynthesis. At optimum temperature and light intensity, if carbon dioxide supply is increased, the rate of photosynthesis increases markedly.

Water: Water has an indirect effect on the rate of photosynthesis. Loss of water in the soil is immediately felt by leaves, which close down the stomata hampering the absorption of CO_2 from the atmosphere. This causes a decline in photosynthesis

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

  $$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

- Photosynthesis comprises two sets of reactions:

  (i) Light reactions: which take place in grana only in the presence of light.

  (ii) Dark reactions: Which occur in the stroma of chloroplast and are independent of light.

- Light energy is used for splitting of water, and actual reduction of CO_2 takes place in the dark reaction.
- Light reaction occurs in 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 leads to the formation of carbohydrates as well as the regeneration of RuBP.
- In C4 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 CO_2 fixation occurs in the bundle sheath cells .
- Rate of photosynthesis is influenced by

  (i) Environmental factors such as light, temperature, carbon dioxide concentration and water, and

  (ii) Internal factors which include the age of leaf, chlorophyll content and leaf anatomy.

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. Which pigments are known as accessory pigments and why?
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 C3 and C4 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. How does CO_2 concentration effect the rate of photosynthesis?

12 CELLULAR RESPIRATION IN PLANTS

All living cells require energy for synthesizing cellular components and for carrying out various functions such as uptake of materials, growth, development and movement. The energy needed by cells is obtained from the oxidation of complex organic compounds by cellular respiration. Even green plants that trap solar energy by photosynthesis and store it as organic compounds depend on respiration for their continuous energy supply.

Respiration is a catabolic, enzyme mediated oxidative process by which the C - C bonds of the food materials like carbohydrates (common respiratory substrate), fatty acids, amino acids and organic acids are broken down to release considerable amount of energy, hence an exergonic process.

Objectives

- Define respiration, fermentation.
- List the basic events of anaerobic respiration and write the chemical equation representing it
- Draw the flow chart to show the basic steps in Kreb's cycle; State the role of fermentation in industry;
- Explain how actually energy is released and stored in the form of ATP in the cell
- Comparison of aerobic and anaerobic respiration

Mitochondria are the cell organelles associated with the process of respiration (aerobic). In respiration, energy is released which is either lost in the form of heat or temporarily packed within a chemical compound known as the ATP (adenosine triphosphate). ATP is the energy currency of a cell. The biochemical process which occurs within cells and oxidizes food to obtain energy is known as **cellular respiration**. Various enzymes (biocatalysts) catalyse this process. Essentially there are two types of respiratory mechanisms with reference to the involvement of oxygen

Aerobic respiration - it occurs in the presence of oxygen

Anaerobic respiration - it occurs in the absence of oxygen

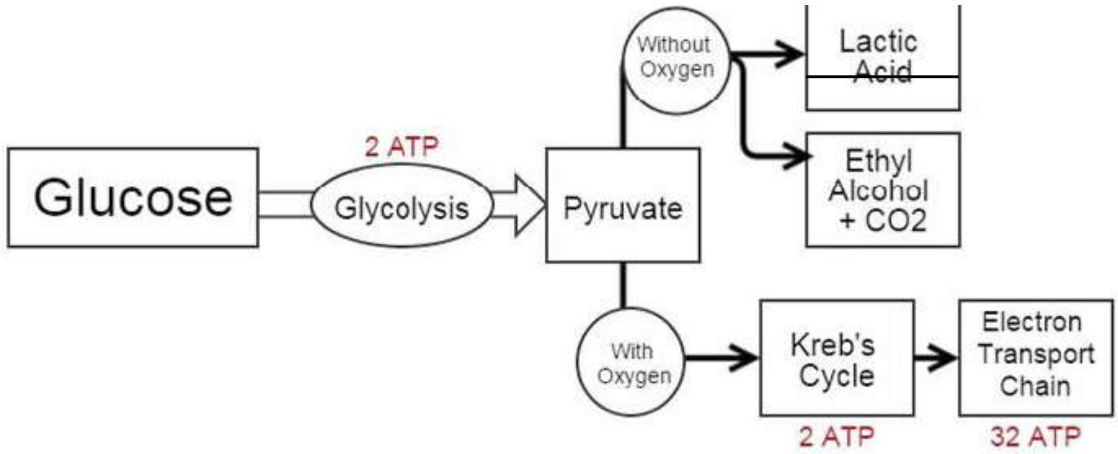


Fig: Cellular Respiration

1. Glycolysis

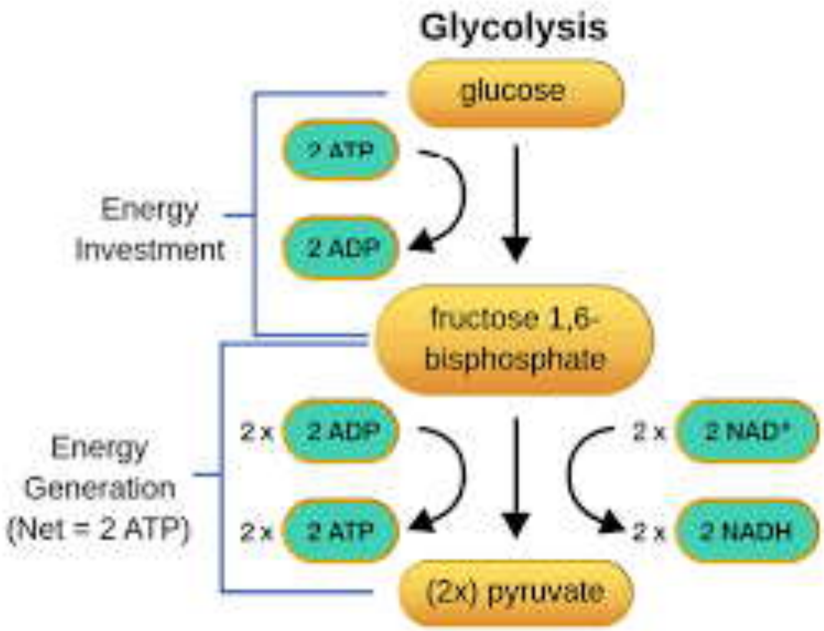
The various steps of this pathway was worked by German scientists-Gustav Embden, Andrew Mayerhoff and Jacob Paranas, hence called EMP-pathway to honour them. It is also known as the "Hexose diphosphate pathway". The salient features of glycolysis are:

a) It occurs in the cytosol of a cell

b) A glucose molecule (6C) is converted into two molecules of pyruvic acid(3C).

c) No oxygen is used in the process.

d) No carbondioxide is evolved during this process.



Glycolysis may be subdivided into 3 major phases:

1. Phosphorylation of glucose to fructose 1,6 diphosphate. This is activation of glucose and 2 ATPs are used.
2. Splitting of this compound into two 3-carbon sugar phosphates, which are interconvertible.
3. Oxidation by dehydrogenation. Each 3-C sugar phosphate is oxidized by the removal of hydrogen, reducing NAD to NADH and production of 2 ATPs.

2. Oxidative decarboxylation of pyruvic acid

This represents the second stage of aerobic respiration and it occurs in the mitochondrial matrix. Two molecules of pyruvic acid are produced at the end of glycolysis (in cytosol) are transported through the mitochondrial membrane into the matrix by a special protein called Pyruvate Translocator. Once the pyruvic acid is inside the matrix, it is converted to acetyl Co-A(2C).

3. Krebs cycle

Krebs cycle is named after Hans Krebs, an English biochemist who played a major role in the discovery of the reactions. This cycle is also known as the critic acid cycle because critic acid is one of the intermediates. As critic acid is a tricarboxylic acid, this cycle is also known as tricarboxylic acid cycle(TCA Cycle). Pyruvate is completely oxidised to CO2 and water by means of Krebs cycle and electron transport system.

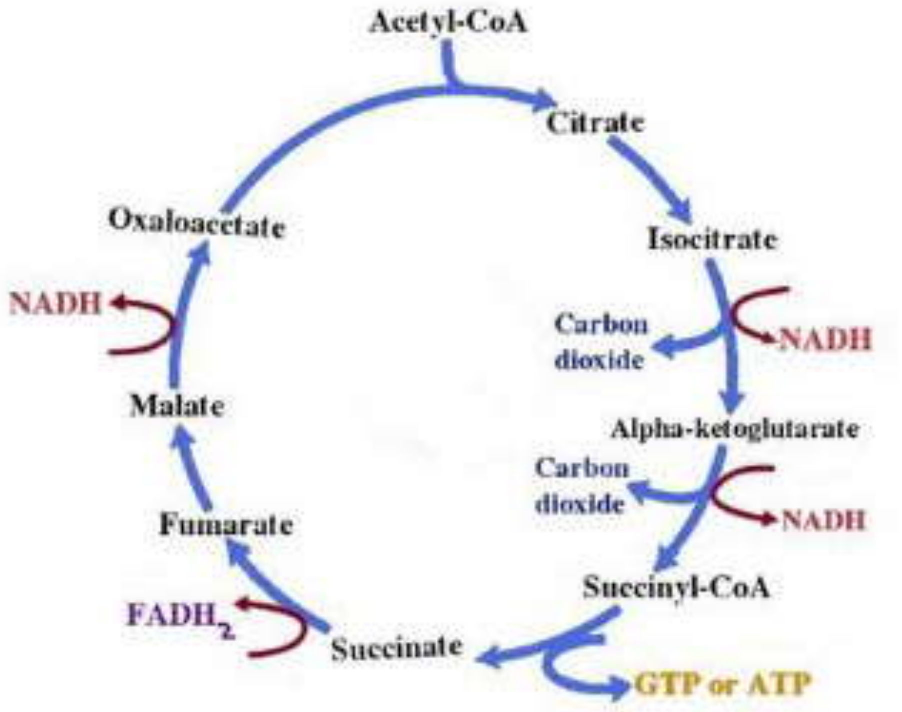


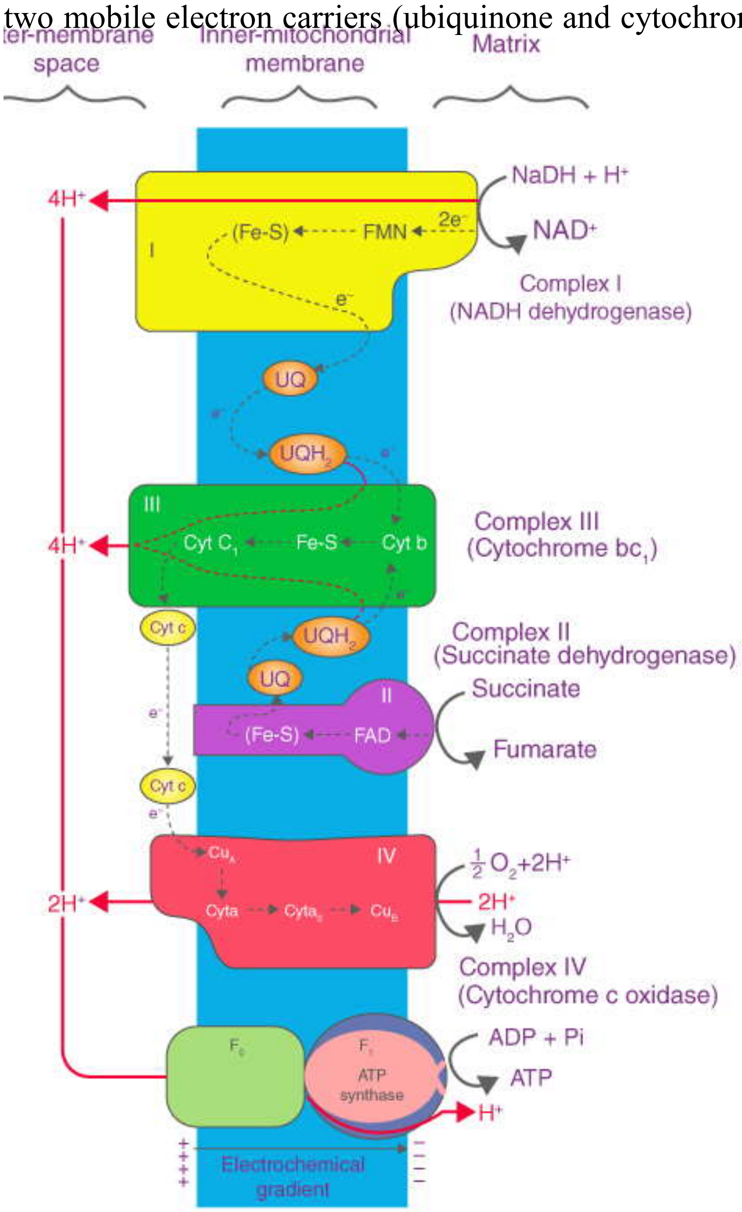
Fig: Krebs cycle

Significance of krebs cycle

Krebs cycle is a central metabolic pathway playing an important role both in catabolism and anabolism. In the catabolic role, it serves as a pathway for the oxidation of carbohydrates. In the anabolic role, the intermediates of this pathway(alpha-keto glutaric acid) serve as substrates for the synthesis of amino acids. Because this pathway is involved both in catabolism and anabolism, the term Amphibolic (dual purpose) pathway is used to signify Krebs cycle.

3. Electron transport system

This represents the fourth and the final stage of aerobic respiration. From the earlier three steps of aerobic respiration (glycolysis and Krebs cycle) a total of 12 high energy electron pairs are generated as (10) NADH+H+and (2) FADH2 for each molecule of glucose. ETC is the transfer of electrons from NADH and FADH2 to oxygen via multiple carriers. The electrons derived from NADH and FADH2 combine with O2 and the energy is released from these oxidation or reduction reactions is used to synthesize ATP fromADP and Pi. The transfer of electrons is done by multiple carriers which constitute the ELECTRON TRANSPORT CHAIN. This process involves five multiple protein complexes. (I to V) along with two mobile electron carriers (ubiquinone and cytochrome ‘C’).



$\frac{1}{2} O_2 + 2H^+ + 2e^- + H_2O$

II. Mechanism of Anaerobic Respiration:

The type of respiration occurring in the absence of oxygen where in partial oxidation of food substrates occur is termed as anaerobic respiration. The organisms which carryout this mode of respiration are called 'anaerobes'. They are of two types.

$$\begin{array}{l} \text{Glucose} \\ \quad \downarrow \quad \text{Glycolysis} \\ \text{Pyruvic acid} \\ \quad \downarrow\rightarrow \quad CO_2 \\ \text{Acetaldehyde} \\ \quad \downarrow\rightarrow \quad NAD^+ \\ \text{Ethyl alcohol} \end{array}$$

The mechanism of anaerobic respiration occurs in two steps i) Glycolysis and ii) Fermentation.

$$\begin{array}{ccccccc} \text{Glucose} & \rightarrow & \text{Pyruvic acid} & \rightarrow & \text{Acetaldehyde} & \rightarrow & \text{Ethyl alcohol} \\ & \uparrow & & \uparrow & & & \\ & \text{Glycolysis} & & \text{Fermentation} & & & \end{array}$$

Fermentation

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 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. There is no further release of ATP during fermentation.

Significance of Fermentation

Alcoholic Fermentation has been known to mankind since time immemorial. It is being utilized in the preparation of beverages by using yeast. It is also employed in bread making where the elimination of CO_2 helps to raise the dough.

Difference between aerobic and anaerobic respiration.

Aerobic	Anaerobic
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 38ATP$	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP$
1. Takes place in the presence of oxygen	1. Takes place in complete absence of Oxygen
2. Leads to complete oxidation of organic substances	2. Incomplete oxidation of organic substrate
3. It is most common in higher organisms (both plants and animals)	3. It takes place in lower organisms (Fungi, bacteria etc).
4. The end products are CO_2 and H_2O and 38 ATP molecules.	4. The end products are CO_2 and organic substrates (like Ethyl alcohol, Lactic acid et) and 2 ATP molecules.
5. Takes place in the cytoplasm and mitochondria in eukaryotes and plasma membrane in prokaryotes.	5. Takes place in the cytoplasm.

INTEXT QUESTIONS

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 product of Krebs' cycle.

6. How do fatty acids enter Krebs' cycle?

13 NUTRITION AND DIGESTION

Introduction

Plants manufacture their own food by photosynthesis, but all 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 food constituets is called digestion, which takes place in digestive tract. The digestive tract together with the associated glands constitute the digestive system.

Objectives

After completing this lesson, you will be able to

- define the term nutrition and give its types
- describe the steps involved in the nutrition of humans viz., ingestion, digestion
- differentiate between intracellular and inter cellular digestion
- tabulate the organs of digestion, the enzymes they secrete, the substances acted up-on
- explain the process of food absorption in various regions of digestive tract

Nutrition and Digestion

The process by which organisms obtain and utilize food for their growth, development and maintenance is called nutrition and the chemicals present in the food are called nutrients.

This lesson deals with various types of nutrition, digestion, the process of digestion of food, its absorption and assimilation in humans.

Types of nutrition

Nutrition

Autotrophic nutrition

Green plants and certain phtosynthetic bacteria synthesize their own food. using sunlight energy.

Ex: Blue green algae, Plants.

Heterotrophic nutrition

Depend on other organisms for food

Holozoic

Organisms take food into the body, digest it and absorb

Ex: humans.

Saprotrophic

Ogranisms secrete digestive enzymes on to dead animal/plants

Ex: Fungi

Parasitic

Food derive from other animals by living on or inside their body

Ex: Ascaris, Taenia

There are five major steps in animal nutrition (Holozoic nutrition)

The food we take contains highly complex substances like protein, carbohydrates and fats. These substances cannot be utilized as such by our body. These have to be broken down into simipler 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 utilised by our body. This breakdown of complex food constituents and their absorption is accomplished by the digestive system. This process will be carried out in following steps.

(i) **Ingestion :** Taking in of the food, its chewing or sucking and swallowing.

(ii) **Digestion :** Conversion of complex food into simpler absorbable form.

(iii) **Absorption :** Absorption of 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.

Two types of digestion (Intracellular and intercellular)

Generally two types of digestion are seen in heterotrophs:

(a) Intracellular (b) Intercellular or Extra cellular

(a) Intracellular Digestion (Intra = inside)

All five steps of nutrition occur inside the cell itself, as in **Amoeba**, **Paramecium** and other unicellular organisms.

Food vacuoles are temporary structures and whenever the amoeba feeds, a new food vacuole is produced. All free-living unicellular microorganisms carryout intracellular digestion

(b) Intercellular digestion (Extra = outside)

Digestion occurs outside the cell and all animals except sponges carryout extracellular digestion. They have a cavity, or a tube, or a food canal which receives the ingested food.

INTEXT QUESTIONS

1. List the five major steps in animal nutrition

   (i) ____________________

   (ii) ____________________

   (iii) ____________________

   (iv) ____________________

2. What is intracellular digestion? Give suitable examples.

   ____

The Human Digestive System

Human digestive system constitutes an alimentary canal and associated digestive glands. The alimentary canal (aliment: nourish) is a continuous muscular digestive tube that runs through the body. It digests the food, breaks it down into smaller substances, and absorbs the digested food.

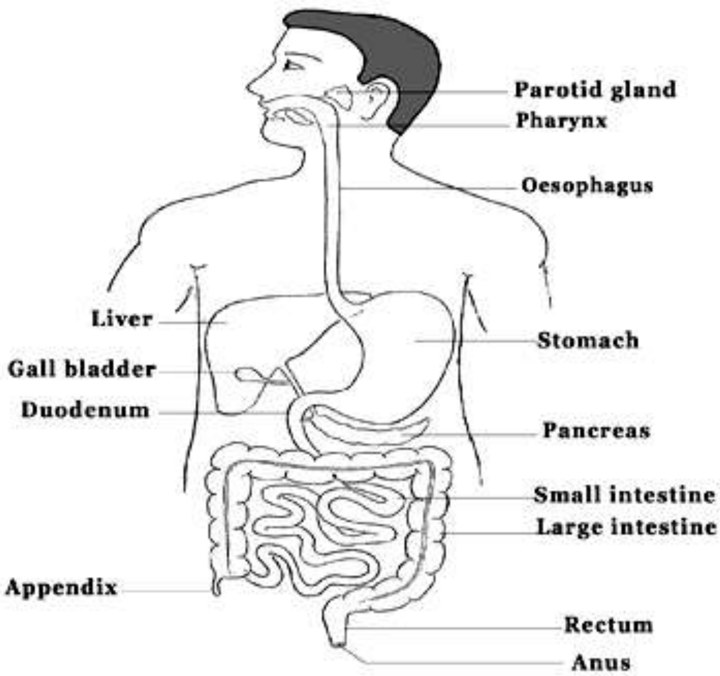


Fig: Human digestive system.

The alimentary canal has the following parts.

1. **Mouth** and associated organs (teeth, tongue)
2. **Pharynx :** 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, situated below the diaphragm.
5. **Small intestine :** A tube about 7 meters long and about 2.5 cm wide. Much coiled and folded, in the abdomen. This can be sub divided into three parts.

(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.

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:** It is over 1 meter long and has three parts termed ascending, transverse and descending limbs.

(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 organ in humans, but it is large and functional in herbivorous mammals.

The associated digestive glands are salivary glands, gastric glands, liver, pancreas and intestenal glands play a significant role in digestion.

INTEXT QUESTIONS

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 and the food swallowed.	(a) Small intestine
(2)	Elastic bag	(b) Duodenum
(3)	Has three limbs-ascending, transverse and descending	(c) Pharynx
(4)	Largest part of the food canal	(d) Appendix
(5)	Receives bile and pancreatic juice	(e) Stomach
(6)	Narrow worm-shaped projection	(f) Colon

Process of Digestion

Digestion involves two kinds of processes :

(a) Physical or mechanical process

Chewing, grinding and churning of food is mechanical process.

(b) Chemical processes in digestion

This includes the enzymatic breakdown of complex food 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.

1. In Mouth

Saliva contains an enzyme called amylase (Ptyalin) which acts on starch in two ways

Functions of saliva

1. It cleans the mouth cavity and tends to destroy germs that cause teeth decay.
2. It contains lysozymes which help in destroying the bacteria.
3. It moistens and lubricates food which again helps in swallowing.
4. It acts as solvent, dissolving some food particles to stimulate taste buds of the tongue.
5. Saliva helps in the digestion of food as it contains an enzyme salivary amylase which digests the starch.

   (i) Uncooked (Raw) → Starch dextrins

   (ii) Cooked → Maltose

2. In Oesophagus

Food as bolus moves into the stomach through peristalsis and salivary amylase continues digesting starch.

3. In Stomach

Initial digestion of starch by salivary amylase continues till the contents of stomach become acidic. The gastric juice produced from the epithelial lining of the stomach is a colourless, highly acidic liquid (pH 1-2). It contains water (98%), some salts, hydrochloric acid, the lubricant mucin and two enzymes namely Pepsin and lipase. Hydrochloric acid is secreted by Oxyntic (parietal) cells in the stomach wall.

HC*l* performs following functions :

(i) kills bacteria entering along with food,

(ii) loosens fibrous material in food,

(iii) maintains acidic medium for action by pepsin,

(iv) activates inactive pepsinogen into active pepsin

(v) Pepsin acts on proteins and breaks them down into proteoses and peptones.

$$\text{Proteins} \xrightarrow{\text{Pepsin}} \text{Proteoses} + \text{Peptones}$$

4. Small Intestine

In the small intestine, the food which is partially digested 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.

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 yellowish, green , alkaline liquid. 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, sodium taurocholate) which emulsify fats. 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). Bile has no digestive enzymes. It simply emulsifies fats.

(ii) Pancreas

Pancreas is reddish brown gland located in the bend of duodenum. Its digestive secretion (pancreatic juice) is poured into the duodenum by the pancreatic duct

Pancreatic Juice :

It contains six major categories of enzymes which act on Alkaline medium.

(a) **Amylase** – completes conversion of starch into maltose.

(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 contents in the food.

(d) **Trypsinogen** – the inactive precursor (proenzyme) of trypsin. It is activated into trypsin by the enzyme enterokinase secreted by the lining of duodinum tripsin act on remaining protines, 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 following enzymes

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).

Lipase completes the digestion of any lipid (fat) not digested by pancreatic juice.

Peptidases (aminopeptidase and dipeptidase) act on peptides and dipeptides to produce smaller peptides and amino acids.

Nucleases breakdown nucleotides into phosphate, sugar and different nitrogenous bases.

INTEXT QUESTIONS

1. How grinding of food in the mouth is 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 digestion of proteins.

   (i) __________ (ii) __________

   (iii) __________ (iv) __________

Absorption of Nutrients

Absorption occurs in mouth and stomach partially but complete 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 are absorbed in the mouth.

2. In Stomach

Water, glucose, ethane, certain minerals, vitamins and certain drugs may be absorbed into the cells lining the stomach.

3. Small Intestine

Major portion of digested food is absorbed 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 (sing villus) further increase the surface area of absorption.

(iii) Single cell eptithelial lining reducing 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.

Products absorbed into the lacteals (lymph vessels) of the villi are fatty acids and glycerol. Monosacharides and aminoacids are absorbed into blood capillaries.

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 directly.

4. Large Inestine

Most of the water present in the food is absorbed in the colon by diffusion. Some mineral ions are also absorbed by the colon.

Assimilation

The final conversion of the absorbed nutrients into the living substance, i.e. their utilization by the cells is called assimilation.

Egestion or Defaecation:

The undigested and unabsorbed subtances pass into the rectum and temporarily stored. 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 anal canal by the relaxation of sphincter muscle.

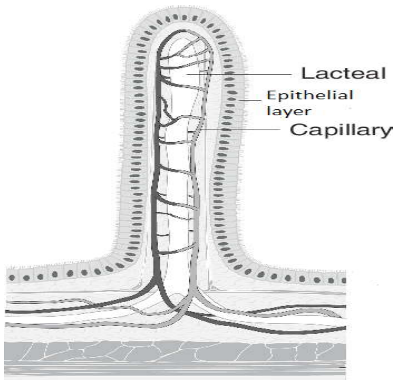


Fig..Intestinal villi

INTEXT QUESTIONS

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?

____

Role of Liver in Metabolism

Liver is the largest gland associated with alimantary canal. It is reddish brown in colour and located on the upper side of the abdomen just below the diaphragm.

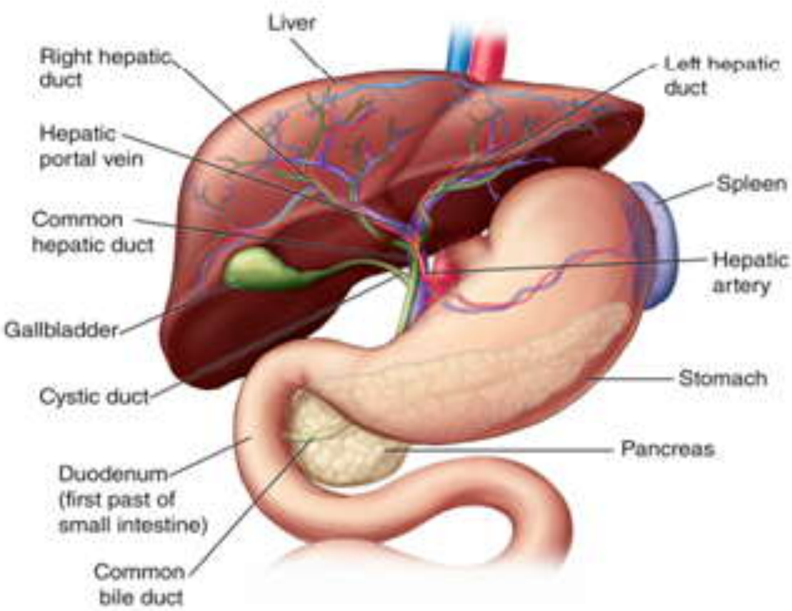


Fig: Liver

Liver's numerous functions can be grouped under three major categories :

1. 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) Destruction of dead and worn out red blood cells.

(v) Removal of toxic and metallic poisons from the blood (protective function).

2. Storage functions

(i) Storage of iron and some other metallic ions.

(ii) Storage of vitamins A, D and B

(iii) Converts extra blood glucose into glycogen and stores it.

3. Metabolic functions

(i) **Regulation of blood** sugar level by retaining excess glucose received as products of carbohydrate digestion from the intestines and storing it as insoluble glycogen to release it again as soluble glucose when the blood sugar levels down.

(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.

(iii) **Synthesizes fatty acids** from carbohydrates, which can be used or stored as fat.

INTEXT QUESTIONS

1. Name any three substances relating 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 ?

____

TERMINAL QUESTIONS

1. Explain the term "autotrophs". How are animals different from plants with regard to their mode of nutrition?

2. Define the term "digestion". List the digestive processes occurring in the small intestine.

3. How does digestion of carbohydrates and proteins take place in humans?

4 Write a short notes on

(a) absorption of the digested food (b) assimilation

(c) defaecation (d) role of liver in metabolism.

5. 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	....	....	....

6. Bile has no digestive enzyme yet it plays a key role in digestion. Justify.

7. Draw a well labelled diagram of alimentary canal in humans.

14 RESPIRATION AND ELIMINATION OF NITROGENOUS WASTES

RESPIRATION

Respiration is a step wise oxidation of glucose resulting in the release of energy stored in the form of ATP (adenosine triphosphate). Whenever energy is required to our body, ATP is broken down and some amount of energy is generated.

Objectives

After completing this lesson, you will be able to,

- Define breathing inspiration, expiration, respiration
- Describe briefly the gases exchange takes place in cockroach
- Draw a labelled diagram of human respiratory system
- Describe the exchange of respiratory gases in the lungs and their transport to and from the tissues
- Name some common ailments of respiratory system
- Define excretion and its importance
- Explain the terms such as ammonotelism, ureotelism, uricotelism
- Explain ultra filtration and describe how urine is formed
- Explain the mechanism of osmoregulation

Respiration can be studied 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 environtment 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 is called as ventilation or breathing.

b) Transport of respiratory gases (O_2 & CO_2) between the repiratory surface and the cells. This oxygen is consumed during cellular respiration inside the cell.

Step 2

Cellular Respiration: It is a complete molecular process 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.

(iii) Release of carbon dioxide and energy.

Thus ultimate goal of respirator system is to provide oxygen to the tissues and removal of CO_2 from them.

Tracheal System in Cockroach

You must have noticed that the insects keep expanding and contracting their abdomen. This is to allow gaseous exchange between outside environment and inside the body

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 cochroach, respiration does not involve and therefore is very fast and efficient. Tracheae open up to the exterior by paired slit like apertures called spiracles and these 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.

Respiratory System in Humans (Pulmonary Respiration)

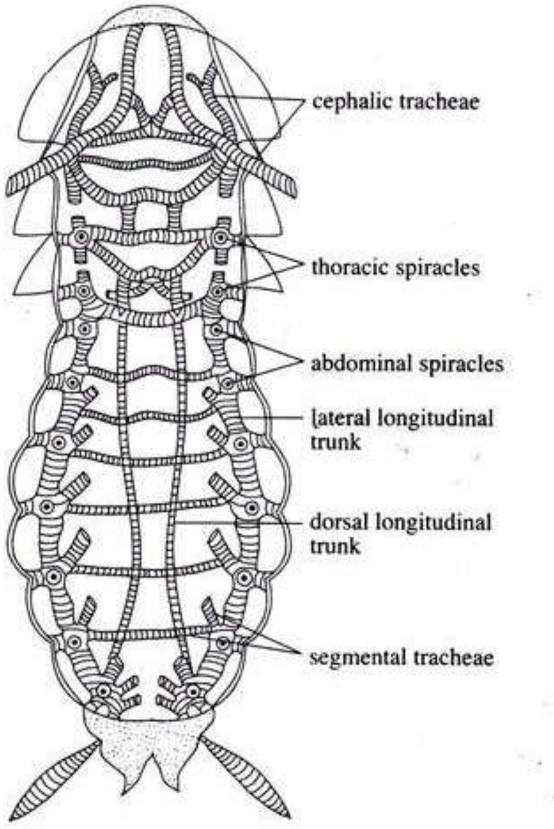


Fig. Tracheal system of cockroach

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 cavities, pharynx larynx, trachea and bronchi. The two bronchi branch extensively into bronchioles, terminal bronchioles and ultimately end in the air sacs called arveoli. The branchioles, 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. 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 structure called alveoli. Alveoliar membrane is very thin, moist and richly supplied with blood eapillaries. The walls of both the capillaries and alveoli consist of a single layer of flattened epithelial cells. Air passes through nostrils into bronchi, to bronchioles and into air sacs with a single layer of cells and heavily covered with blood capillaries. O_2 from alveoli . Alveoli are the organs where the actual gaseous exchange occurs.

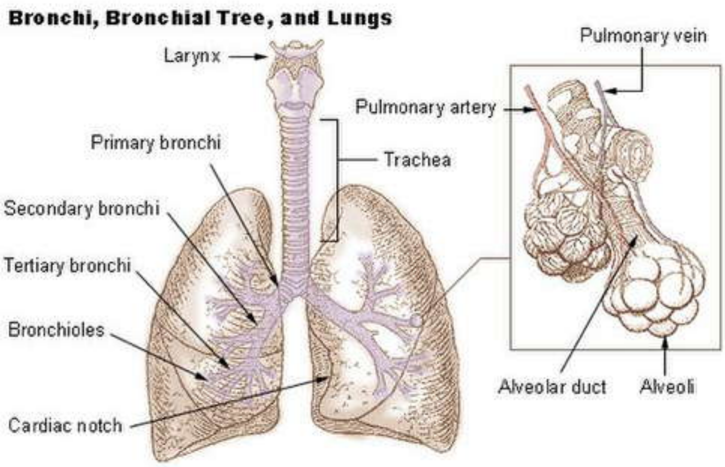


Fig: structure of Lungs

INTEXT QUESTIONS

1) Define respiration.

____

2) How oxygen is transported to the cells in cockroach?

____

3) How does trachea communicate with the exterior in cockroach?

____

4) Name the part of respiratory system where air is filtered, moisturized and warmed.

____

Mechanism of Pulmonary Respiration

The entire processe is achieved through the following steps.

1. Breathing and Pulmonary ventilation

It's 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 be voluntary also. Lungs contract and expand alternatively in two steps.

i. **Inspiration (Intake of air):** A muscular dome shaped diaphragm is present at the base of the lungs. On contraction it becomes flattened and lowered, at the same time external intercostal muscles contract and the rib cage moves out towards and upwards. All these developments results in increasing the volume of lungs and decreasing pressure inside. The air rushes filling the lungs with fresh air. Thus, inspiration is an active phase of breathing.

ii. **Expiration (Releasing air):** This step involves the relaxation of external intercostal muscles and contraction of internal intercostal muscles. As a result rib cage lowers and moves inwards and the diaphragm also relaxes and rises again into its original dome shape. This change decreases the volume of chest cavity thus increases in the air pressure within the lungs and the air with loaded CO_2 is forced out.

2. Exchange of gases at the cellular surface

Blood is the medium for transport of oxygen from the lungs to 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 in the surrounded alveoli.

There is more oxygen in alveolar air and more carbon dioxide in the capillaries. Due to this pressure gradient oxygen diffuses from alveolar air into the capillaries and carbon dioxide diffuses from blood capillaries into the alveolar air and finally, this oxygenated blood from lungs is taken to the heart by pulmonary vein.

3. Transport of gases

Transport of oxygen: Haemoglobin, the blood protein Plays a major role in transport of oxygen. This Iron rich blood protein is packed in red blood corpuscles giving blood red color. About 97% oxygen is transported from lungs to the tissues in combination with haemoglobin and only 3% of oxygen is transported in disolved form by plasma. Four molecules of oxygen make a reversible bond with haemoglobin to form oxyhaemoglobin.

$$\underset{\text{haemoglobin}}{\mathbf{Hb}} + \underset{\text{Free Oxygen}}{\mathbf{O_2}} \underset{\text{In tissues}}{\overset{\text{In alveoli}}{\rightleftharpoons}} \underset{\text{Oxyhaemoglobin}}{\mathbf{HbO_2}}$$

When the oxygenated blood that reaches the tissue surface in contrast, CO_2 breaks down from haemoglobin and releases CO_2 therefore exchange of respiratory gases (O_2 and CO_2) takes place against concentration gradient in tissues. The weak bond between oxygen and haemoglobin breaks down against concentration gradient and blood releases oxygen.

Transport of carbon dioxide: The comparatively high solubility of carbon dioxide makes it's transport more flexible. $C0_2$ is transported from tissues to the Lungs in the Three following ways.

1. About 5-7 percent of CO_2 is physically dissolved in blood plasma and transported
2. CO_2 directly combines with the hemoglobin of RBCs to form Carbamino hemoglobin compounds and around 23 per cent of CO_2 is transported in this form.
3. Major portion (about 70%) of CO_2 is transported in this way. Bicarbonate (HCO_3^-) is extremely soluble and combines with H^+ ions to form Carbonic acid in

the presence of enzyme carbonic enhydrase which breaks into CO_2 and H_2O in the alveoli of lungs. Finally CO_2 loaded alveolar air is breathed out.

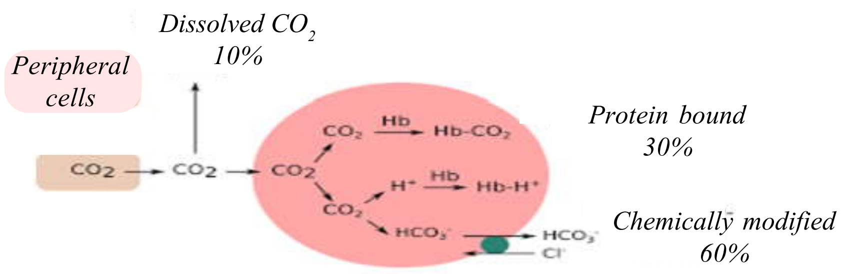
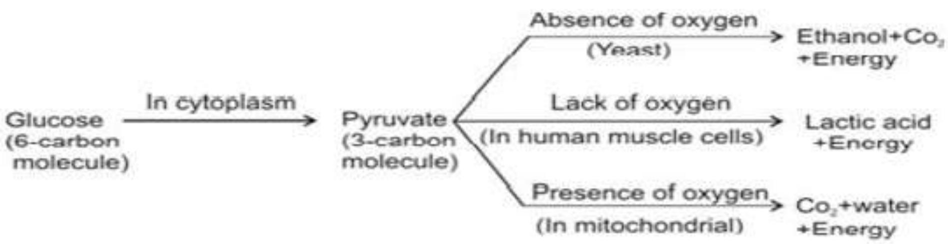


Figure: transport of CO_2

Cellular respiration: Oxygen transported to all living cells is utilized during complex cellular respiration. In mitochondria. During cellular respiration glucose is oxidized to release energy in the form of ATP. This process can be summed up as follows

$$C_6 + H_{12} + 6O_2 \longrightarrow 6CO_2 + 12HO_2 + ATP$$

Respiration takes place in the presence of O_2 is called aerobic respiration and is more efficient as high energy is released. Absence of oxygen may lead to anaerobic respiration in which only two molecules of ATP are released.



Break down of glucose by various pathways

INTEXT QUESTIONS

1) What is breathing?

____

2) What is the position of diaphragm at the time of expiration?

____

3) What is the maximum number of oxygen molecules that hemoglobin can combine with?

____

4) Name the blood vessel that carries oxygenated blood from the lungs to heart?

____

5) What are the three forms in which carbon dioxide is transported by the blood?

____

Respiration

Break down of glucose to release energy

Aerobic	Anaerobic
(Respiration in the presence of O_2)	(Respiration in the absence of O_2)
↓	↓
Glucose	Glucose
↓	↓
2 Pyruvic Acid	2 Pyruvic Acid
↓ ← O_2	↓
$6CO_2 + 6H_2O + 38ATP$	2CO2 + Alcohol + 2ATP
	↓
	2 Lactic acid + 2ATP

Common respiratory disorders and their prevention

Disease	Cause	Symptoms	Prevention
Bronchial asthma	It is an allergic disease caused due to certain foreign substance present 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. Wearing masks.
Bronchitis	Inflammation of bronchi caused by infection. It can also be caused by smoking and air pollution.	Regular coughing with greenish blue sputum	Avoiding exposure to smoke and dust.
Pneumonia	Acute inflammation caused by diplococcus bacterial infection in the alveoli of the lung that spreads through droplets of infected persons	In 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	Caused due to exposure to harmful substance like silica, asbestos, dust etc.	Weight loss, cough and pulmonary T.B. are common sympotms. 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	Dust, Silica and asbestos etc.,	It is expressed after exposure of 10-15 years or more. It causes fibrosis of the lungs.	Using protective masks and clothing. Regular health check-up is necessary.

TERMINAL ECERCISES:

1. List the major steps that are involved with respiration in humans.
2. What is the role of carbonic anhydrase in the transport of carbon dioxide in our body?
3. Which part of our respiratory system is known as the voice box?
4. Name one nitrogenous waste removed by the kidney.
5. Name the hormone, the absence of which will result in excretion of hypotonic urine.
6. Why inspiration is said to be an active phase and expiration as passive phase?
7. Differentiate between breathing and respiration.
8. List the special features of alveoli that enable easy gaseous exchange.
9. Draw the excretory system of human and label the parts.
10. Draw a neat labeled diagram of nephron.
11. How does ultrafiltration and reabsorption occur in nephrons?
12. Explain how gaseous exchange takes place in lungs.
13. How is oxygen transported from the lungs to the tissues and carbon dioxide from tissues to the lungs?
14. How water and salt balance is maintained by kidney?
15. List three characteristics of our lungs which make them suitable as respiratory surface.

EXCRETION

All animals produce some waste substances in their body during metabolic activities. These nitrogenous waste substances including CO_2, water, urea, uric acid, ammonia etc. are harmful if retained in the body, hence liminated. Removal of all harmful products specially nitrogenous wastes from the body is called excretion. Urea is the prime nitrogenous waste in our body formed by breakdown of amino acids and nucleic acids and Blood transports urea to the kidneys where it is filtered and removal through the process known as urine formation.

Animals are classified based on the excretory products they release.

I) **Ammonotelic** (highly toxic): Animals that produce nitrogenous waste in the form of ammonia are called ammonotelic. Ammonia is highly soluble in water and needs plenty of water for its excretion.

Ex: Bony fishes.

II) **Ureotelic** (less toxic): The Organisms that produce Urea as a nitrogenous waste are called Ureotelic animals. It is less soluble in water and needs less water to eliminate.

Ex: Amphibians, Mammals.

III) Uricotelic (least toxic): Nitrogenous waste is produced in the form of uric acid in certain animals. These animals are called Uricotelic and needs very little amount of water for elimination

Ex: Insects, Reptiles, Birds.

Excretory organs in humans

The human excretory system comprise a pair of kidney, a pair of ureters, a urinary bladder and urethra. Kidneys are bean-shaped organs located on the either side of vertebral column in lower abdominal cavity. On the concave margin of each kidney there is a notch called hilum which leads to funnel shaped space called renal pelvis. Pelvis is surrounded by outer renal cortex and inner renal medulla. As kidneys form the urine they also maintain the normal composition of body fluids. Urine formed in the kidney brought to the bladder through two narrow muscular tubes called ureters. Urination of urine through urethra is called micturition.

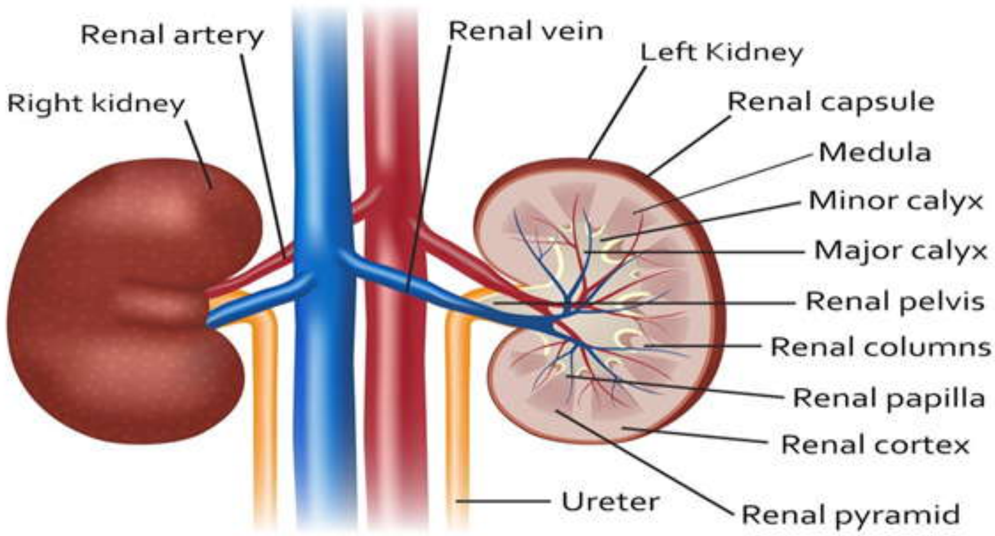


Fig: Structure of Kidney

Structure of Nephron: Kidney contains large number of minute tubular structures called nephrons. Nephrons are the structural and functional units of kidney. There are about 1 million nephrons in each kidney which filter about 180 liters of fluid per day, most of which is reabsorbed. Each nephron has following parts.

1. Renal corpuscle composed of Bowman's capsule and glomerulus. Glomerulus receives blood from renal artery.
2. Proximal convoluted tube— PCT.
3. Descending limb of loop of Henle.
4. Ascending loop of Henle
5. Distal convoluted tube- DCT
6. Collecting duct.
7. Pelvis formed by union of all collecting ducts.
8. Peritubular capillaries passing over tubules which unite to form renal vein.

Formation of urine: Formation of urine takes place in three steps

1. Ultrafiltration
2. Selective reabsorption
3. Tubular secretion

1) **Ultra filtration:** Each glomerular capillary receives blood flowing under high pressure from a branch of renal artery. All small molecules like water, glucose, minerals, amino acids etc are filtered out of the blood plasma into Bowman's capsule through capillary walls. Proteins remain glomerular fluid blood and protein free filtrate is collected in the lumen of Bowman's capsule

2) **Selective reabsorption:** While the glomerular filtrate flows through the tubules, several useful substances such as glucose, minerals are reabsorbed through the walls of renal tubules. The blood capillary network passing over nephrons absorb these substances. About 65 to 85% of filtrate is reabsorbed in the proximal convoluted tubule which includes water, glucose, amino acids, salts. 5% of water is absorbed in the descending limb. Only salts are absorbed in the ascending limb as it is impermeable to water. Distal convoluted tubule reabsorbs water under influence of ADH hormone and sodium ions under influence of Aldosterone hormone

3) **Tubular secretion:** Cells of the renal tubule also directly secrete certain unwanted substances into filtrate. These include uric acid, potassium, ammonia etc. The final filtrate is known as urine.

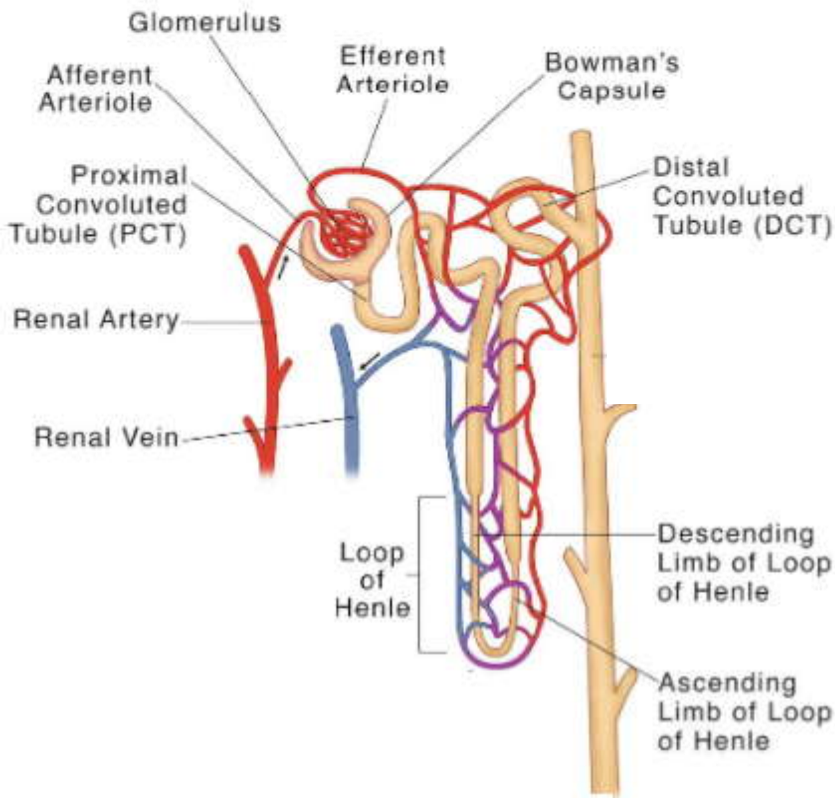


Fig Structure of Nephron

INTEXT QUESTIONS

1. List the parts of human excretory system.

   ____

2. Name the functional unit of kidney and its parts

   ____

3. What are the substances reabsorbed by the nephron?

   ____

4. What is the importance of tubular secretion?

   ____

5. What is the normal volume of urine excreted per day?

   ____

6. Name the organ where urea is produced?

   ____

7. Mention is the most toxic form of nitrogenous waste?

   ____

Osmoregulation by Kidney

Maintaining the solute optimal concentration of body fluids is called osmoregulation. Depending on the need of the water in the body, kidneys excretes hypotonic or hypertonic urine (concentrated urine). Osmoregulation is controlled by ADH and aldosterone hormones. When the water content in the body is more, ADH, that is, anti-diuretic hormone, decreases the permeability of distal convoluted tubules and collecting tubules so that less water is reabsorbed and diluted urine is excreted. When the water content of the body is less, permeability of renal tubules increase resulting in high absorption of water back to blood and concentrated urine is excreted. Urine is also concentrated by counter-current mechanism. In response to low sodium ion concentration, ADH released by adrenal cortex stimulates renal tubules to reabsorb sodium ions in exchange of potassium ions. Similarly, high sodium concentration inhibits reabsorption of sodium ions.

Haemodialysis: The blood urea level rises abnormally in patients suffering from kidney malfunction. In such patients, an artificial kidney is used for removing excess urea from blood by a process called haemodialysis. If kidney failure cannot be treated by available means, kidney transplantation is advised. The genetic make-off donor should be as close to the patient as possible to reduce the chances of graft rejection.

TERMINAL EXERCISE

1. List the major steps that are involved with respiration in humans.
2. What is the role of carbonic anhydrase in the transport of carbondioxide in our body?
3. Name the hormone, the absence of which will result in excretion of hypotonic urine.
4. Why inspiration is said to be an active phase and expiration as passive phase?
5. Differentiate between breathing and respiration.

15 CIRCULATION OF BODY FLUIDS

All living organisms need nutrients, gases, liquids etc., for the growth and maintenance of their body. All organisms would need to transport these materials to all parts of their body and different groups of animals have evolved various methods for transport of substances between body parts. Simple organisms such as sponges and cnidarians circulate water drawn from their surroudings through body cavities facilitating exchange of these substances. More complex organisms use special circulatory fluids to transport such materials. Blood is the most commonly used circulatory fluids by most of the higher organisms, including the humans. In addition to blood another body fluid, the Lymph also helps in the transport of certain substances.

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 system of circulation
- List and draw the organs of circulatory system in humans
- Compare the structure and functions of an artery, a vein and a capillary
- Explain the process of blood coagulation in humans
- Describe lymphatic system
- Name and describe some blood related disorders such as hypertension, Coronary Artery Disease (CAD), Angina Pectoris and Heart Failure.

Blood

Blood is a special connective tissue consisting of a fluid matrix, plasma and formed elements.

Lymph

As the blood passes through the capillaries in tissues some water along with many small water soluble substances move out into the spaces between the cells of tissues leaving the larger proteins and most of the formed elements in the blood vessels. This fuild released out is called the interstial fluid or tissue fluid. It has the same mineral distribution as that in plasma. Exchange of nutrients, gases etc... between the blood and the cells always occur through this fluid. An elaborate network of vessles called the lymphatic system which collects this fluid and drains it back to the major veins. The fluid present in the lymphatic system is called the lymph and it is a colourless fluid containing specialised lymophocytes for the immune responses of the body. Lymph is also an important carrier for nutrients, hormones etc.

Lymph Cappillaries in the Tissue Spaces

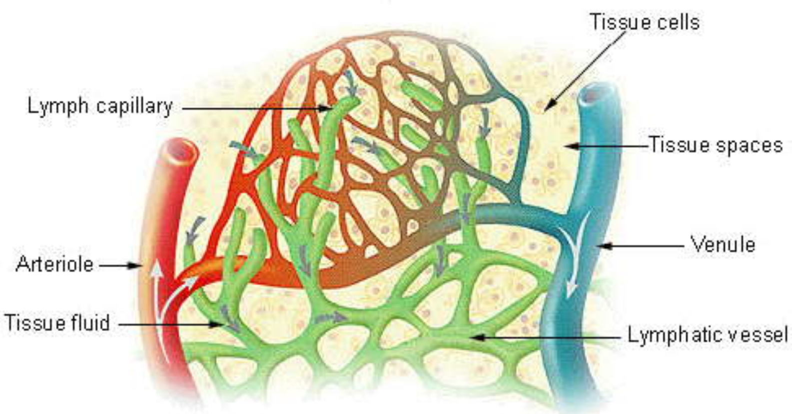


Fig: Lymph

Coagulation of blood

You know that when you get an injury, the blood flows out for only a short time. Then the cut is filled with a reddish solid material, this phenomenon is called as blood clotting. If blood did not clot, anyone with even a slight wound bleeds profusely.

When the blood flows out, the platelets release an enzyme called thrombokinase. Thrombokinase acts on another substance present in the blood called pro-thrombin converting it into thrombin. Thrombin acts on another substance called fibrinogen that is present in dissolved state converting it into insoluble fibrin. The blood cells entangle in the fibrin fibres forming the clot. The fibrin fibres are attached to the edges of the wound and pull them together. The yellowish straw coloured fluid portion after formation of the clot is called as serum.

$$\textbf{Prothrombrin} \xrightarrow{\text{thrombokinase}} \textbf{Thrombin}$$

$$\textbf{Fibrinogen} \xrightarrow{\text{thrombin}} \textbf{Fibrin}$$

Circulatory Pathways

The circulatery patterns are of two types

a) Open circulatory system

b) Closed circulatory system

a) Open Circulatory system

Open circulatory system is present in arthropods and molluses in which blood pumped by the heart passes through large vessels into open spaces or body cavities called sinuses.

b) Closed circulatory system

Closed circulatory system is present in Annelids and Chordates in which the blood pumped by the heart is always circulated through a closed network of blood vessles. This pattern is considered to be more advantageous as the flow of fluid can be more precisely regulated.

Plan of circulatory system in the vertebrates

All vertebrates posses a muscular chambered heart. Fishes have a 2-chambered heart with an atrium and a ventricle. Amphibians and the reptiles (except crocodiles) have a 3-chambered heart with two atria and a single verticle, whereas crocodiles, birds and mammals possess a 4-chambered heart with two artia and two ventricles.

In Fishes, the heart pumps out deoxygenated blood which is oxygenated by the gills and supplied to the body parts from where deoxygenated blood is returned to the heart (single circulation).

In amphibians and reptiles, the left atrium receives oxygenated blood from the gills/

lungs/skin and right atrium gets the deoxygenated blood from other body parts. However, they get mixed up in the single vertricle which pumps out mixed blood (incomplete double circulation). In birds and mammals oxygenated and deoxygenated blood received by the left and right atria respectively passes on to the ventricles of the same sides. The ventricles pump without any mixing up i.e. two separate circulatory path ways are present in these organisms, hence, these animals have double circulation.

INTEXT QUESTIONS

1. Write a note on Lymph?
2. Explain the process of coagulation of blood?
3. What are the difference between open type circulatory system and closed type circulatory system?
4. Plan of circulatory system in the following vertebrates
   a) Fishes ________________
   b) Amphibians _____________
   c) Reptiles ________________
   d) Aves and Mammals _______

Human Blood Circulatory System

It consists of a four chambered muscular heart, a network of closed branching blood vessels and blood.

Structure of the Human Heart

The heart is mesodermal in origin. It is a thick walled, muscular and pulsating organ. situated in the mediastinum and with its apex slightly turned to the left. It is of the size of a clenched fist. The heart is covered by a double walled pericardium which consists, the outer fibrous pericandium and the inner serous pericardium. The serous pericardium is double layered, formed of an outer parietal layer and an inner visceral layer. The parietal layer is fused with the fibrous pericardium, whereas the visceral layer adheres to the surface of the heart and forms its outer layer, the epicardium. The two layers are separated by a narrow pericardial space, which is filled with the pericardial fluid. This fluid reduces friction between the two membranes and allows free movement of the heart.

The wall of the heart consists of three layers. They are the outer epicardium, the middle myocardium (a thick layer of cardiac muscles), and the inner most endocardium (a thin layer of endothelium). The endothelium covers the heart valves and also is continuous with the endothelial lining of the large blood vessels connected to the heart.

External structure

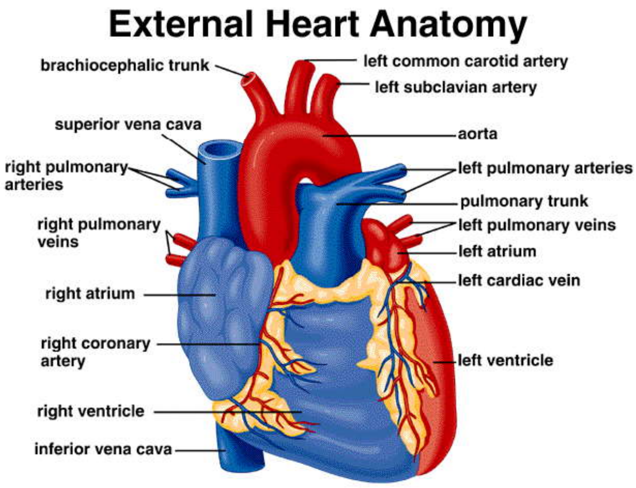


Fig : External structure of Heart

Human heart has four chambers, with two relatively small upper chambers called artria and two larger lower chambers called ventricles. Atria and ventricles are separated by a deep transverse groove called coronary sulcus (Atrio-Ventricular groove). The muscular pouch like projection from each atrium is called auricular appendix. The ventricles are separated by two inner ventricular grooves (anterior and posterior). In whcih the coronany arteries and their branches are lodged.

Internal structure

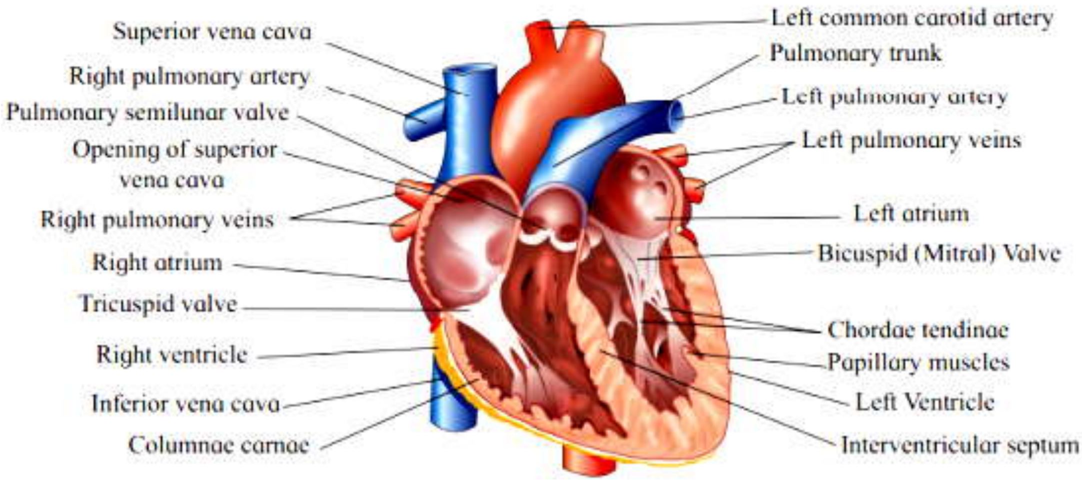


Fig. Internal Structure of Heart

Atria

Atria are thin walled 'receiving chambers' (upper champers) and are separated by thin inter-atrial septum. In the fetal heart, the atrial septum has a small pore called foramen ovale. Normally the foramen ovale closes at birth, when lungs become functional. It is represented by a depression in the septum between the right and left atria, called fossa ovalis. If the foramen ovale does not close properly, it is called a patent foramen ovale.The right atrium receives deoxygenated blood from different parts of the body (except lungs) through two caval veins. A precaval vein or superior vena cava collects blood from the head, forelimbs and thoracic region and a post caval vein collects blood from the hind limbs and abdominal organs.

The heart also receives blood from the myocardium (wall of the heart) through the coronary sinus, whose opening into the right atrium is guarded by the valve of the Thebesium. Opening of the postcoval vein is guarded by the valve of the inferior vena cava (or) Eustachian valve. It directs the blood to the left atrium through the foramen ovale, in the foetal stage but in adult it becomes rudimentary and non-functional. The opening of the precaval vein into the right atrium has no valve. The left atrium receives blood from each lung with the help of pulmonary vein.Atria and ventricles are separated by a membranous atrio-ventricular septum, which possesses left and right atrioventicular apertures. The left and right apertures are guarded by bicuspid (Mitral valve) and tricuspid valves respectively.

Ventricles

These are the thick walled blood pumping chambers (lower chambers), separated by an interventricular septum. The wall of the left ventricle is thicker than that of the right ventricle. The inner surface of the ventricles is raised into muscular ridges or columns called columnae carneae/trabecular carneae projecting from the inner walls of the ventricles. Some of these ridges are large, conical and are called papillary muscles whose apices are connected to the Chordae tendinae or heart strings. They are cord-like collagenous processes that connect the papillary muscles to the tricuspid valve and the mitral valve in the heart. They prevent the cusps of the atrioventricular valve from bulging too far into atria during ventricular systole.

Nodal Tissue

The entire heart is made of cardiac muscles. The wall of ventricles are thicker than that of the atria. A specialised cardiac musculature called the nodal tissue is also distributed in the heart. A patch of this tissue is present in the right upper corner of the right atrium called the sino-atrial Node (SAN). Another mass of this tissue is seen in the lower left corner of the right atrium close to the atrio-ventricular septum called the atrio-ventricular node (AVN). A bundle of nodal fibre called atrioventricular bundle (AV bundle/His bundle) continues from the AVN into the inter-ventricular septum. It divides into right and left bundle branches. These branches give rise to minute fibres called Purkinje fibres that extend throughout the ventricular musculature/walls of the respective sides.

Aortic arches

The pulmonary arch arises from the left anterior angle of the right ventricle. Its opening is guarded by the pulmonary valve and it carries deoxygenated blood to the lungs. The systemic arch (left) arises from the left ventricle and transports oxygenated blood to different parts of the body through it branches. Its opening is guarded by the 'aortic valve'. The pulmonary and aortic valves are madeup of three semilunar flaps each. A fibrous strand, known as ligamentum arteriosum is present at the point of contact of the systemic and pulmonary arches. It is the remnant of the ductus arteriousus, which connects the systemic and pulmonary arches in the embryonic stage.

INTEXT QUESTIONS

1. Describe the structure of the Heart of Man with the help of a well labelled diagram?
2. Where is the valve of Thebesius is found in human heart?
3. Distinguish between SAN and AVN?

Cardiac cycle (0.8 sec)

The cardiac events that occur from the beginning of one heart beat to the begining of the next constitute a cardiac cycle. The cardiac cycle consists of three phases to begin with all the four chambers of heart are in a relaxed state i.e., they are in joint diastole. As the tricuspid and bicuspid valves are open, blood from the pulmonary veins and vena cava flows into the left and right ventricles respectively through the left and right atria. The semilunar valves of the pulmonary and aortic arches are closed at this stage. The duration of a cardiac cycle is about 0.8 sec.

Atrial Systole (0.1 sec)

The SAN now generates an action potential which stimulates both atria to contract simultaneously causing the atrial systole. This increases the flow of blood into the ventricles by about 30% of the filling of the ventricles, the remaining blood flows into the ventricles before the atrial systole.

Ventricular Systole (0.3 sec)

The action potentials from the SAN reach the AVN from where they are conducted through the bundle of His, its branches and the purkinje fibres to the entire ventricular musculature. This causes the simultaneous ventricular systole, the atria undergoes relaxation (diastole) coinsiding with the ventricular systole. Ventricular systole increases the pressure causing the clossure of the AV valves preventing the back flow of blood.

It results in the production of the first heart sound known as 'LUB'. As the ventricular pressure increases further, the semilunar valves guarding the pulmonary artery and the aorta are forced open. This allows the blood in the ventricles to flow into the aortic arches and enter the circulatory pathway.

Joint diastole (0.4 Sec)

The ventricles now relax and the ventricular pressure falls causing the closure of the semilunar valves which prevents the back flow of blood. This results in the production of the second heart sound known as 'Dub' as ventricular pressure declines further, the AV valves are pushed open by the pressure in the atria excerted by the blood which flowed into them through the longer veins. The blood now once again flows freely into the ventricles. All the heart chambers are now again in a relaxed state (Joint diastole phase). Soon the SAN generates a new action potential and the events described above are repeated in that sequence and the process continues.

Note : The healthy human heart beats 72 times per minute normally.

Cardiac output

The volume of blood pumped out by each ventricle for each heart beat, is known as the stroke volume. The volume of blood pumped out by the heart from each ventricle per minute is termed cardiac output.

Cardiac Output = Stroke Volume x No. of beats per minute

= 70 ml / beat x 72 beats per minute

= 5040 ml

The body has the ability to atter the stroke volume as well as the heart rate and hereby the cardiac output.

Double Circulation

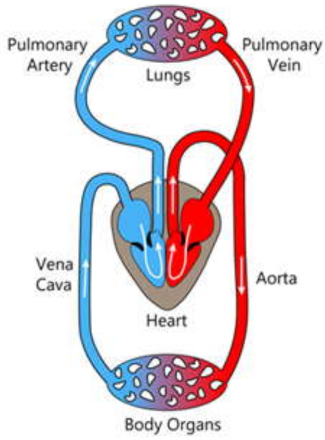


Fig: Mammalian Double Circulation System

The blood pumped by the right ventricle enters the pulmonary artery, whereas the left ventricle pumps blood into the aorta. The deoxygenated blood pumped into the pulmonary arch is passed on to the lungs from where the oxygenated blood is carried by the pulmonary veins into the left atrium. This pathway constitutes the pulmonary circulation. The oxygenated blood entering the aorta is carried by a network of arteries, arterioles and capillaries to the tissues from where the deoxygenated blood is collected by a system of venules, veins and vena cava and emptied into the right atrium. This is famously known as systemic circulation. The systemic circulation provides nutrients, O_2 and other essential substances to the tissues and collects CO_2 and other harmful substances away for their elimination.

INTEXT QUESTIONS

1. Describe the events in a cardiac cycle ?
2. Define the cardiac output?
3. What is double circulation?

Regulation of Cardiac Activity

Normal activities of the heart are regulated intrinsically, i.e., auto regulated by specialized muscles (Nodal tissue). A special neural centre in the medulla oblongoda will moderate the cardiac function through the 'autonomic nervous system (ANS). Neural signals through sympathetic nerves can increase the rate of heart beat, the strength of ventricular contraction and there by the cardiac output. On the other hand, parasympathetic neural signals decrease the rate of heart beat and thereby cardiac output. Adrenal medullary hormones, the epinephrine and nor epinephrine can also increase the cardiac output, similarly Thyroxine hormone also increases the heart rate and cardiac outupt.

Blood Vessels

The blood flows strictly by a fixed route through arteries and veins.Basically each artery and vein consists of three layers an innr lining of squamous endothelium (tunica intima), the middle layer of smooth muscle and elastic fibres (tunica media), an external layer of fibrous connective tissue with collagen fibres (tunica externa). The tunica media is camparatively thin in the veins. Capillaries are the smallest blood vessels of the body which connect arterioles and veins. The walls of capillaries are composed of one cell thick layer which is a simple squamous epithelium (or) endothelium.

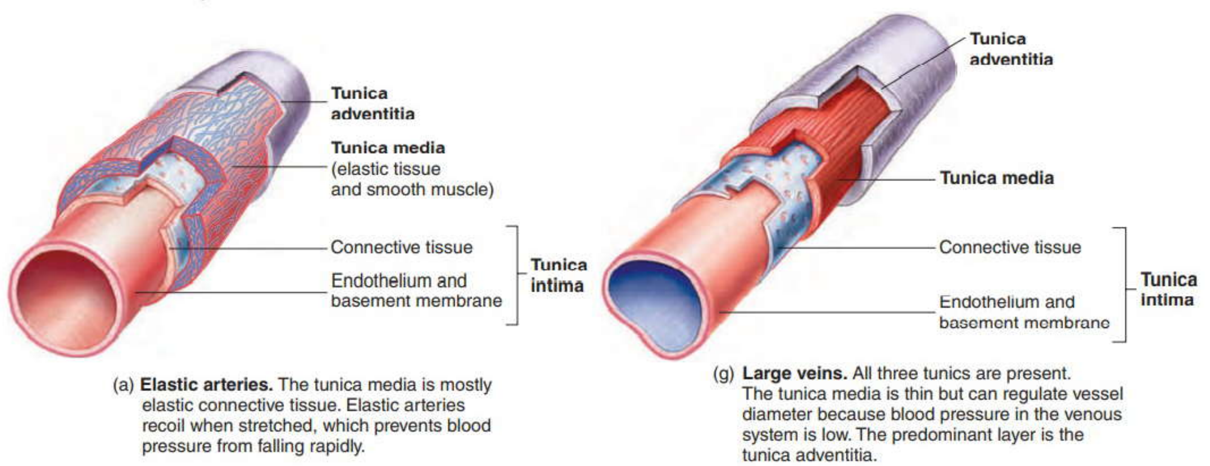


Fig : Blood Vessels

Disorders of Circulatory System

(i) Hypertension (High blood pressure)

Hypertension is a Chronic medical condition in which blood pressure in arteries is elevated. The normal blood pressure at rest is 120mm Hg systolic, 80mm Hg diastolic on an average. High blood pressure leads to heart diseases and also affects other vital organs such as brain and kidneys.

(ii) Coronary Artery Disease (CAD)

Coronary Artery Disease (CAD) often referred to as Athero Electronic Heart Disease. It is a result of the accumulation of Calcium, Fat, Cholestrol and fibrous tissue along the wall of coronary arteries which makes their lumen narrow. This narrow blood vessels reduces the blood flow to the heart. causes ischemia. Myocardial cells may die due to lack of oxygen and this called a myocardial infraction and It leads to heart muscle damage. CAD is associated with smoking, diabetes and hypertension.

(iii) Angina Pectoris

A symptom of acute chest pain appears when no enough oxygen is reaching the heart muscle. Angina can occur in men and women of any age but it is more common among the middle - aged and elderly. It occurs due to the conditions that affect the blood flow.

(iv) Heart Failure

Heart failure means, the state of heart when it is not pumping blood effectively enough to meet the needs of the body. It is sometimes called congestive heart failure because congestion of the lungs is one of the main symptoms of this disease. Heart failure is not the same as cardiac arrest or a heart attack. When the heart muscle is suddenly damaged by an inadequate blood supply is commonly called as heart failure.

INTEXT QUESTIONS

1. Describe the the disorders of circulatory system ?
2. Write a note on regulation of cardiac activity ?

16 COORDINATION AND CONTROL - THE NERVOUS AND ENDOCRINE SYSTEMS

Everyday we do many activities such as sharpening of a pencil, grasping a door knob, walking or running, driving, and a few physical actions. All these actions involve well coordinated movements made with well balanced postures. In fact, whenever we move some basic functions such as movement, balance and coordination work together in performing motions of body parts

As you know, the functions of the organs/organ systems in our body must be coordinated to maintain homeostasis. Coordination is the process through which two or more organs interact and complement the functions of one another. For example, when we do physical exercises, the energy demand is increased for maintaining an increased muscular activity and the supply of oxygen is also increased. The increased supply of oxygen necessitates an increase in the rate of respiration, heart beat and increased blood flow via blood vessels. When physical exercise is stopped, the activities of nerves, lungs, heart and kidney gradually return to their normal conditions. Thus, the functions of muscles, lungs, heart, blood vessels, kidney and other organs are coordinated while performing physical exercises. In our body the neural system and the endocrine system jointly coordinate and integrate all the activities of the organs so that they function in a synchronised fashion.The neural system provides an organised network of point-to-point connections for a quick coordination. The endocrine system provides chemical integration through hormones.

Objectives

After completing this lesson, you will be able to:

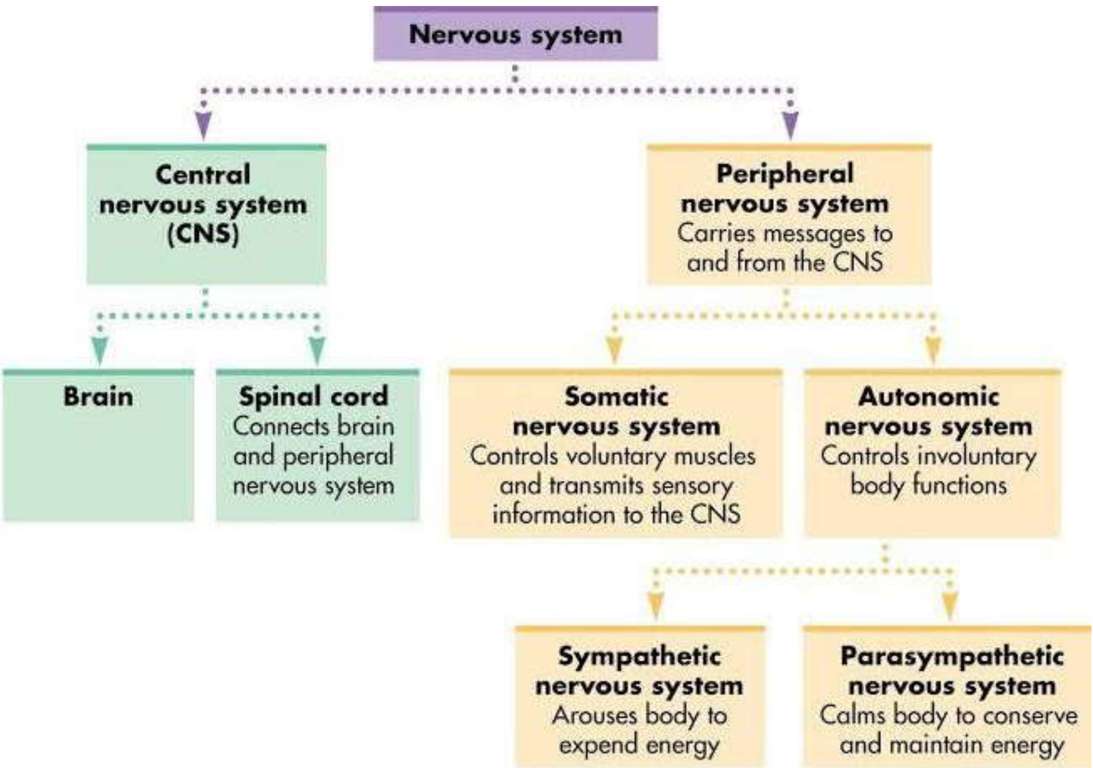
- describe the functions of the nervous system and list its subdivisions;
- List, draw and label the major parts of the brain and spinal cord and explain their functions;

- Explain the structure of a neuron, a nerve and describe the conduction of impulse through a nerve fibre and across the synapse.
- Express reflex action.
- List various sensory receptors in human body and describe the structure and functioning of the sense organs–eye, ear.

NEURAL SYSTEM (Nervous system)

The neural system is composed of highly specialised cells called neurons which can detect, receive and transmit different kinds of stimuli. The neural organisation is very simple in lower invertebrates. For example, in *Hydra* it is composed of a network of neurons. The neural system is better organised in insects, where a brain is present along with a number of ganglia and neural tissues. The vertebrates have a more developed neural system.

HUMAN NEURAL SYSTEM



The human neural system is divided into two parts :

(i) The central neural system (CNS)

(ii) The peripheral neural system (PNS)

The CNS includes the brain and the spinal cord and is the site of information processing and control. The PNS comprises of all the nerves of the body associated with the CNS (brain and spinal cord). The nervefibres of the PNS are of two types : (a) afferent fibres (b) efferent fibres

The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs. The PNS is divided into two divisions called somatic neural system and autonomic neural system. The somatic neural system relays impulses from the CNS to skeletal muscles while the autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body. The autonomic neural system is further classified into sympathetic neural system and parasympathetic neural system.

Visceral nervous system is the part of the peripheral nervous system that comprises the whole complex of nerves, fibres, ganglia, and plexuses by which impulses travel from the central nervous system to the viscera and from the viscera to the central nervous system.

CENTRAL NERVOUS SYSTEM (CNS)

The central nervous system includes the brain and spinal cord and It develops from neurectoderm.

BRAIN 'the living super computer'

It is the site of information processing and control. It is protected in the cranial cavity and covered by three connective tissue membranes called 'cranial meninges' namely, dura mater, arachnoid mater and pia mater. Dura mater is the outer most, thick, double layered membrane which lines the inner surface of the cranial cavity. Arachnoid mater is a thin, webby middle membrane covering the brain. Pia mater is the thin, innermost meninx which closely adheres to the brain. Pia mater is separated from the arachnoid membrane by th the subarachnoid space. The brain can be divided into three major parts called Forebrain, Midbrain and Hindbrain.

I. **Forebrain (Prosencephalon)** The forebrain consists of

   i. Olfactory bulb,

   ii. Cerebrum and

   iii. Diencephalon.

i) **Olfactory Bulb:** Olfactory bulbs receive impulses pertaining to smell from the olfactory epithelium.

ii) **Cerebrum**: Cerebrum forms the major part of the brain and is longitudinally divided into the left and the right cerebral hemispheres by a deep cleft called 'longitudinal fissure'. The two hemispheres are internally connected by a transverse, wide and flat bundle of myelinated fibres beneath the cortex, called corpus callosum (colossal commissure). It brings 'coordination' between the right and left sides of the cerebral hemispheres. The surface of the cerebrum is composed of grey matter and is called the 'cerebral cortex'. The neuronal cell bodies are concentrated in the cerebral cortex.

The surface of the cerebral cortex shows many convolutions or folds and grooves. The folds are called gyri (singular: gyrus), the deepest and shallower grooves between the folds are called fissures and sulci, respectively. Gyri and sulci increase the surface area of the cerebral cortex (which is an indication of the higher level of evolution of the human being).

Cerebral cortex has three functional areas called a)sensory areas, that receive and interpret the sensory impulses b) motor areas, which control voluntary muscular movements c) association areas, which are neither clearly sensory nor motor in function and they deal with more complex 'integrative functions' such as memory and communications. The cerebral medulla consists of mostly myelinated axons (white matter). Each cerebral hemisphere of the cerebrum is divided into four lobes namely frontal, parietal, temporal and occipital lobes.

iii. **Diencephalon (Thalamencephalon):** The main parts of the diencephalon are the epithalamus, thalamus and hypothalamus.

1) **Epithalamus:** It is the roof of the diencephalon. It is a non-nervous part which is fused with the pia mater to form the anterior choroid plexus. Just behind the anterior choroid plexus, the epithelium of the epithalamus forms a pineal stalk, which ends in a rounded structure called pineal body.

2) **Thalamus** It lies superior to the mid brain and is coordinating centre for sensory and motor signalling.

3) **Hypothalamus** (the thermostat of the body): It lies at the base of the thalamus. The hypothalamus forms a funnel-shaped downward extension called 'infundibulum', connecting the hypothalamus withthe pituitary gland. It also contains

several groups of neurosecretory cells, which secrete hormones called hypothalamic hormones. Hypothalamus controls and integrates the activities of the autonomous nervous system (ANS) and has osmoregulatory, thermoregulatory, thirst, feeding (hunger) and satiety centres.

Limbic system

The inner parts of the cerebral hemispheres and a group of associated deep structures like amygdala or amygdale, hippocampus etc. form the limbic system. The limbic system is involved in the regulation of sexual behaviour and expression of emotional reactions/ responses.

II. Midbrain (Mesencephalon)

The midbrain is located between the thalamus/hypothalamus of the forebrain and the Pons Varolii of the hindbrain. The ventral portion of the midbrain consists of a pair of longitudinal bands of nervous tissue called cerebral peduncles or crura cerebri (sing: crus cerebrum) which connect the cerebral hemispheres with the pons. The dorsal portion of the midbrain consists of four rounded lobes called corpora quadrigemina (Four optic lobes). The two larger anterior optic lobes are called superior colliculi and the smaller posterior lobes are called inferior colliculi. The superior colliculi and the inferior colliculi are concerned with visual and auditory functions, respectively.

III. Hindbrain (Rhombencephalon)

The hind brain comprises cerebellum, Pons Varolii and medulla oblongata.

i) **Cerebellum (the little brain):** It is the second largest part of the brain. It consists of two cerebellar hemispheres and a central vermis. Each cerebellar hemisphere consists of three lobes namely anterior, posterior and floccular lobes. It has a branching tree-like core of white matter called arbor vitae (the tree of life) surrounded by a sheath of grey matter (cerebellar cortex).

NOTE: Cerebellum is responsible for the control and coordination of locomotor movements. The cerebellum is called the gyroscope of the body because it maintains equilibrium. Damage to cerebellum often results in ataxia (uncoordinated voluntary muscle movements).

ii) Pons Varolii

It lies in front of the cerebellum below the mid brain and above the medulla oblongata. It consists of nerve fibres which form a bridge between the two cerebellar hemispheres. It is a relay station between the cerebellum, spinal cord and the rest of the brain. Pons has the pneumotaxic centre (involved in the control of the respiratory muscles as it regulates the amount of air a person can take in rate of breathing and depth of respiration).

iii) Medulla oblongata

It is the posterior most part of the brain. It extends from the pons Varoli above and continuous with the spinal cord below. It has a very thin, vascular folded structure called posterior choroid plexus. Medulla includes cardiovascular and respiratory centers, the centers for swallowing, vomiting, coughing, sneezing and hiccupping. The midbrain, pons and the medulla oblongata are together referred to as the brain stem. The medulla oblongata passes out of the cranium through the foramen magnum and joins the spinal cord.

Human brain consists of four ventricles. The first and second ventricles (lateral ventricles or paracoels) are present in the right and left cerebral hemispheres respectively. The third ventricle (diocoel) occurs in the diencephalon. The two paracoels are connected to the median diocoel individually by the two 'foramina of Monro (inter ventricular foramina). The fourth ventricle (myelocoel) is present in the medulla. The myelocoel and the diocoel are connected by a narrow canal called iter or aqueduct of Sylvius/cerebral aqueduct. The myelocoel is continuous with the central canal of the spinal cord.

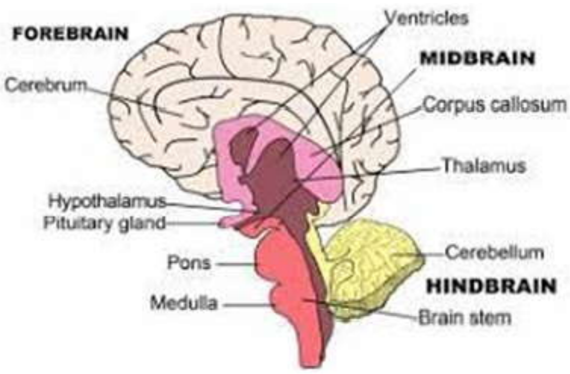


Fig: Structure of Human brain

The ventricles of the brain, and the subarachnoid space are filled with Cerebro-spinal fluid (CSF). CSF is an alkaline, colourless fluid which is filtered from the choroid plexuses into the ventricles of the brain.

INTEXT QUESTIONS

1. Write a short note on the followings
   a) Forebrain
   b) Hindbrain
   c) Midbrain

SPINAL CORD

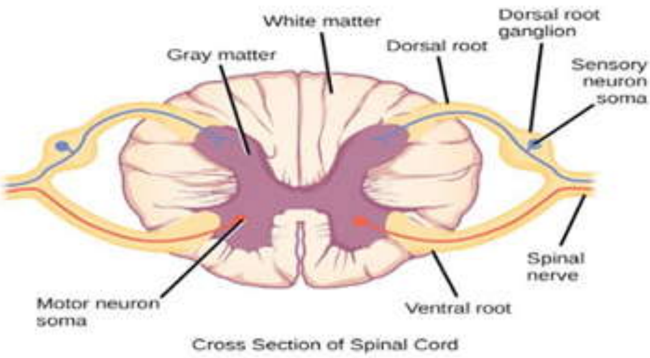


Fig: T.S of Spinal Cord

The spinal cord is located in the vertebral canal (neural canal) of the vertebral column. It is protected by the bony arch of each vertebra and the three spinal meninges called dura mater, arachnoid mater and pia mater. In the adult, it extends from the medulla oblongata to the superior border of the second lumbar vertebra. It has two conspicuous enlargements. the superior enlargement called. 'cervical enlargement' and the inferior enlargement called 'lumbar enlargement'. The spinal cord is divided into right and left halves by two grooves namely, the anterior (ventral) median fissure and the posterior (dorsal) median sulcus. Inferior to the lumbar enlargement, the spinal cord tapers to a conical portion known as the conus medullaris, which ends at the level of the intervertebral disc between the first and second lumbar vertebrae in the adult. The extension of the conus medullaris as the non-nervous fibrous tissue to the coccyx is called filum terminale'.

The internal anatomy of the spinal cord shows H- shaped or butterfly shaped central area of grey matter surrounded by the outer white matter. The grey matter is composed of cell bodies, neuroglia, dendrites and unmyelinated axons and it surrounds a narrow longitudinal cavity called ‘central canal’ or ‘spinal neurocoel’ which is the continuation of the fourth ventricle of the brain and is lined by the ependymal epithelium. The grey matter is subdivided into regions called ‘anterior and posterior horns’ on each side.

The white matter consists of bundles of myelinated axons and it is organized into the regions called anterior (ventral) funiculus, posterior (dorsal) funiculus and lateral funiculi, one on each side. The spinal cord acts as a coordinating centre for simple spinal reflexes. It also acts as the ‘middle man the receptors and the effectors, as it conducts sensory and motor between the impulses to and from the brain.

The Peripheral Neural System (PNS)

The PNS is formed by the nerves that are associated with brain (cranial nerves) and spinal cord (spinal nerves).

The Cranial Nerves

The nerves that are associated with the brain are called cranial nerves. They enter or emerge out of the cranium through different foramina. They are 12 pairs in man. Functionally they are of three types, namely, sensory. motor and mixed nerves.

i) Olfactory nerve (sensory)

ii) Optic nerve (sensory)

iii) Oculomotor nerve (motor)

iv) Pathetic or Trophlear Nerve (Motor)

v) Trigeminal nerve (mixed)

vi) Abducens nerve (motor)

vii) Facial nerve (mixed)

viii) Vestibulo-cochlear nerve / Acoustic or Auditory nerve (sensory

iv) Glossopharyngeal nerve (mixed)

x) Vegus Nerve (Mixed)

xi) Spinal accessory or accessory nerve (Motor)

xii) Hypoglossal Nerve (Motor)

Spinal Nerves

The spinal nerves are formed by the union of dorsal and ventral roots soon after they leave the spinal cord. The first pair of cervical spinal nerves emerges between the atlas and occipital bone of the cranium. All other spinal nerves emerge from the vertebral column through the intervertebral foramina between the adjoining vertebrae. There are 31 pairs of spinal nerves in man which are classified into five groups based on their location, they are:

i. Cervical (8 pairs)

ii. Thoracic (12 pairs)

iii. Lumbar (5 pairs)

iv. Sacral (5 pairs)

iv. Coccygeal/ caudal (1 pair).

INTEXT QUESTIONS

1. List the cranial nerves?
2. List the spinal nerves?

Somatic neural system (SNS)

The somatic neural system includes both sensory and motor neurons. The sensory neurons conduct sensory impulses from the different somatic receptors to the CNS. All these sensations normally are consciously perceived. Somatic motor neurons innervate the skeletal muscles and produce voluntary movements. The axon of a single myelinated somatic motor neuron extends from the CNS all the way to the skeletal muscle fibres. In the SNS, the effect of a somatic motor neuron always is excitation

Autonomic Neural System (ANS)

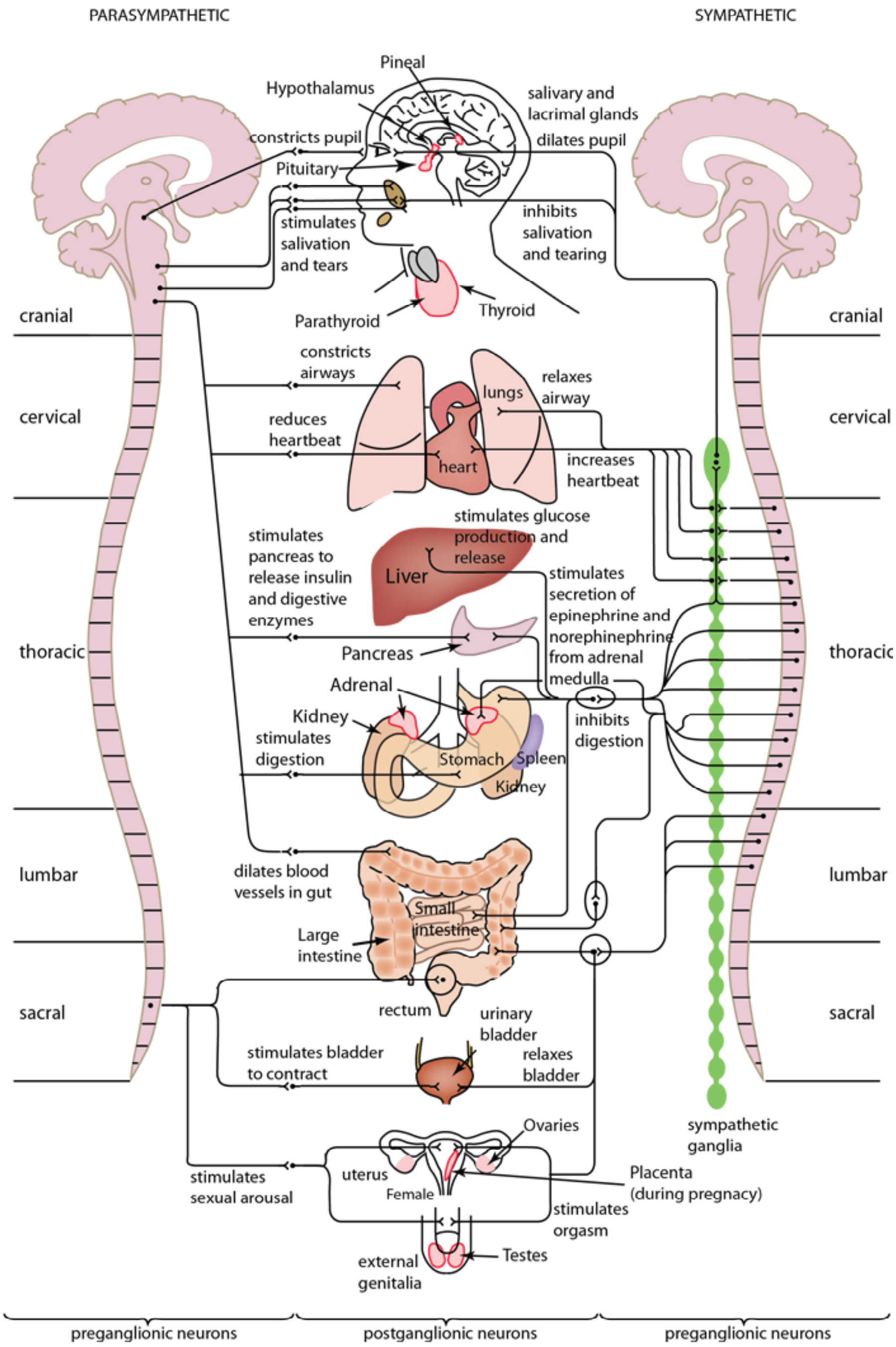


Fig: Autonomic Neural System (ANS)

The ANS usually operates without conscious control. The autonomic neurons are associated with interoceptors (located in the viscera and sense internal stimuli), such as chemoreceptors. These sensory signals are generally not consciously perceived. Autonomic motor neurons regulate the involuntary activities of the cardiac muscles, smooth muscle and glands. The ANS has two divisions:

1. Sympathetic division
2. Parasympathetic division.

1. **Sympathetic division**: In the sympathetic division, the preganglionle neurons arise from the thoracic and lumbar regions of the spinal cord, hence called Thoracolumbar division. The sympathetic nervous system is said to exhibit Thoracolumbar outflow' (outflow of information, which refers to its 'motor' signals). The sympathetic system consists of two sympathetic chains, pre-ganglionic sympathetic fibres, post-ganglionic sympathetic fibres and collateral ganglia. A pair of sympathetic chains / trunks of ganglia extend from the base of the skull to the pelvis of the body along the sides of the dorsal aorta. The 'chain ganglia' contain cell bodies of many neurons and are connected serially by nerve fibres extending between them in the trunk. The preganglionic sympathetic fibres may synapse directly with the post ganglionic neurons in the chain ganglia or may synapse directly with the collateral ganglia. There are three collateral ganglia located in the abdominal cavity close to the origins of arteries with the same names on each side. They are coeliac, superior mesenteric and inferior mesenteric ganglia. It means the postganglionic sympathetic neurons may have their cell bodies, either in one of the chain ganglia or in the collateral ganglia. As the sympathetic trunk ganglia are closer to the spinal cord, most sympathetic preganglionic axons are shorter and the postganglionic axons are longer. In general, postganglionic axons from the sympathetic trunk mostly innervate organs anterior to the diaphragm, whereas, post ganglionic axons from the collateral ganglia innervate organs posterior to the diaphragm.

2. **Parasympathetic division**: The cell bodies of the preganglionic neurons of the parasympathetic division are located in the brain and in the sacral region of the spinal cord. Hence, the parasympathetic division is also known as the cranio sacral division. The axons of the parasympathetic neurons that emerge from the brain occur in the III, VII, IX and X cranial nerves. The axons of the parasympathetic preganglionic neurons that emerge from the spinal cord occur in the II, III and IV sacral spinal nerves. The parasympathetic neural system is said to exhibit 'cranio-sacral outflow' (out flow of information / 'motor signals) as the 'efferent impulses of these nerves' originate in the cranial and sacral regions of the CNS. The 'cranial out flow' of the parasymapathetic unit includes the ciliary, pterygopalatine, submandibular and Otic ganglia which receive preganglionic fibres from the cranial nerves III, VII and IX and send post- ganglionic fibres to smooth muscles of the

eye ball, nasal mucosa, palate, pharynx, lacrimal glands and salivary glands in the heads

. The preganglionic fibres that leave the brain as part of the vagus nerve are the last components of the cranial out flow which extend to many terminal ganglia in the thorax and abdomen. It sends fibres to the heart, lungs and to the components of the digestive system. Sacral out flow includes the pelvic plexus which receives preganglionic fibres from the 2nd to 4th sacral spinal nerves and supplies nerves mainly to the urinary and genital systems. As the parasympathetic ganglia are nearer to the organs they innervate, most parasympathetic preganglionic axons are longer and the postganglionic axons are shorter.

Difference between Sympathetic and Parasympathetic neural system

	Sympathetic neural system	Parasympathetic neural system
1.	SNS originates in the thoracic and lumbar regions of the spinal cord	PNS originates in the cranial region of the brain and the sacral region of the spinal cord
2.	Its ganglia are linked up to form a chain (one chain on each side of the vertebral column)	Its ganglia remain isolate
3.	Preganglionic fibres are short and the postganglionic fibres are long	Preganglionic fibres are long and the postganglionic fibres are short
4.	Norepinephrine is produced at the terminal ends of the post- ganglionic fibres at the synapses on the effectors organ. Hence the system is called 'adrenergic' usually.	Acetylcholine is produced at the terminal ends of the postganglionic fibres at the effector organ. Hence the system is called 'cholinergic' usually.
5.	Active during stressful conditions, preparing the body to face them.	Active during relaxing times, restoring normal activity after stress.
6.	The overall effect is excitatory and stimulating.	The overall effect is inhibitory.

Comparison of effects of sympathetic and parasympathetic systems on certain organs

Sl. No.	ORGAN	SYMPATHETIC (Fight or Flight response)	PARASYMPATHETIC (Rest and digest response)
1.	Eye	Dilates pupil of the eye	Constricts pupil of the eye
2.	Heart	Increases rate and force of contraction	Slows down the rate and force of contraction
3.	Blood Vessels	Constricts	Dilates
4.	Digestive tract	Inhibits peristalsis	Increases peristalsis
5.	Salivary glands	Inhibits salivary secretion	Stimulates salivary secretion
6.	Pancreas	Inhibits activity of pancreas	Stimulates activity of pancreas
7.	Lungs	Relaxes bronchi	Constricts bronchi
8.	Kidney	Increases secretion of renin	Decreases the secretion of renin
9.	Urinary bladder	Inhibits emptying bladder	Promotes emptying the bladder

Generation and Conduction of Nerve Impulse

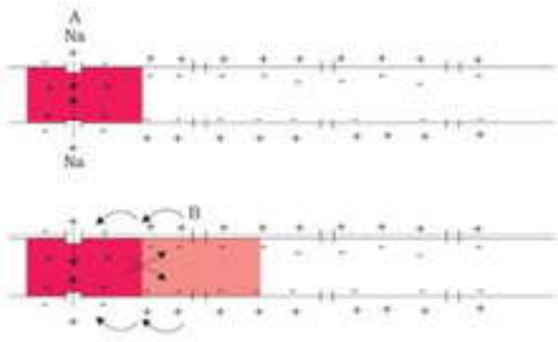


Fig : Generation and Conduction of Nerve Impulse

Neurons are excitable cells because their membranes are in a polarized state. *Do you know why the membrane of a neuron is polarised?* Different types of ion channels are present on the neural membrane and these ion channels are selectively permeable to different ions. When a neuron is not conducting any impulse, i.e., resting, the axonal membrane is comparatively more permeable to potassium ions (K+) and nearly impermeable to sodium ions (Na+). Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm. Consequently, the axoplasm inside the axon contains high concentration of K+ and negatively charged proteins and low concentration of Na+. In contrast, the fluid outside the axon contains a low concentration of K+, a high concentration of Na+ and thus form a concentration gradient. These ionic gradients across the resting membrane are maintained by the active transport of ions by the sodium-potassium pump which transports 3 Na+ outwards for 2 K+ into the cell. As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is polarised.

The electrical potential difference across the resting plasma membrane is called as the resting potential. You might be curious to know about the mechanisms of generation of nerve impulse and its conduction along an axon. When a stimulus is applied at a site on the polarised membrane, the membrane at the site A becomes freely permeable to Na+. This leads to a rapid influx of Na+ followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged. The polarity of the membrane at the site A is thus reversed and hence depolarised. The electrical potential difference across the plasma membrane at the site A is called the action potential, which is in fact termed as a nerve impulse. At sites immediately ahead, the axon (e.g., site B) membrane has a positive charge on the outer surface and a negative charge on its inner surface. As a result, a current flows on the inner surface from site A to site B. On the outer surface current flows from site B to site A to complete the circuit of current flow. Hence, the polarity at the site is reversed, and an action potential is generated at site B. Thus, the impulse (action potential) generated at site A arrives at site B. The sequence is repeated along the length of the axon and consequently the impulse is conducted. The rise in the stimulus-induced permeability to Na+ is extremely shortlived. It is quickly followed by a rise in permeability to K+. Within a fraction of a second, K+ diffuses outside the membrane and restores the resting potential of the membrane at the site of excitation and the fibre becomes once more responsive to further stimulation.

Transmission of Impulses through synapse

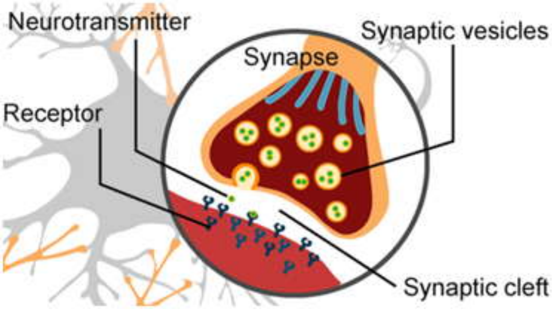


Fig : Transmission of Impulses

A nerve impulse is transmitted from one neuron to another through junctions called synapses. A synapse is formed by the membranes of a pre-synaptic neuron and a post-synaptic neuron, which may or may not be separated by a gap called synaptic cleft. There are two types of synapses, namely, electrical synapses and chemical synapses. At electrical synapses, the membranes of pre- and post-synaptic neurons are in very close proximity. Electrical current can flow directly from one neuron to the other across these synapses. Transmission of an impulse across electrical synapses is very similar to impulse conduction along a single axon. Impulse transmission across an electrical synapse is always faster than that across a chemical synapse. Electrical synapses are rare in our system. At a chemical synapse, the membranes of the pre- and post-synaptic neurons are separated by a fluid-filled space called synaptic cleft Do you know how the pre-synaptic neuron transmits an impulse (action potential) across the synaptic cleft to the post-synaptic neuron? Chemicals called neurotransmitters are involved in the transmission of impulses at these synapses. The axon terminals contain vesicles filled with these neurotransmitters. When an impulse (action potential) arrives at the axon terminal, it stimulates the movement of the synaptic vesicles towards the membrane where they fuse with the plasma membrane and release their neurotransmitters in the synaptic cleft. The released neurotransmitters bind to their specific receptors, present on the post-synaptic membrane. This binding opens ion channels allowing the entry of ions which can generate a new potential in the post-synaptic neuron. The new potential developed may be either excitatory or inhibitory.

Reflex Action and Reflex Arc

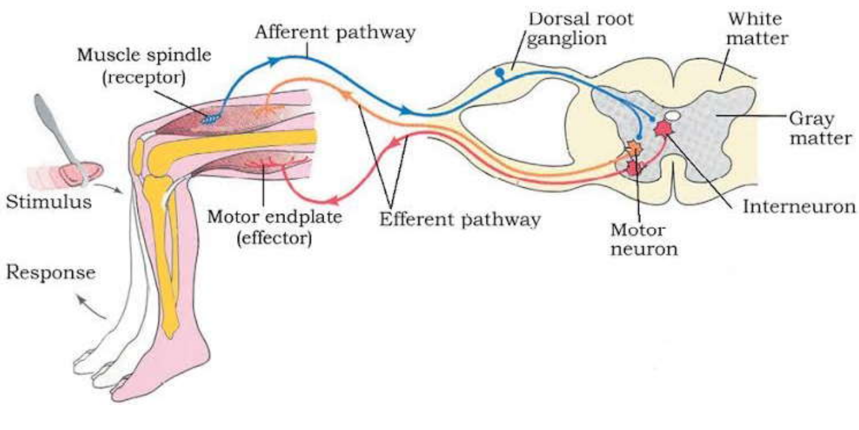


Fig: Reflex Action and Reflex Arc

An automatic, involuntary, instantaneous and unconscious action brought about by the involvement of the central nervous system is called a reflex action. The reflex action is mediated by the 'neuronal components', which constitute the 'reflex arc'. A reflex arc is the 'route' followed by a nerve impulse in the production of a reflex action (the neural pathway involved in a reflex action). The neural (reflex) pathway comprises at least one afferent neuron (receptor), one internuncial neuron and one efferent (effector) neuron arranged in series. The afferent neuron receives signal from a sense organ and transmits the impulse via the dorsal root of a spinal nerve to the CNS (at the level of the spinal cord). The efferent neuron then carries signals from the CNS to the effector through the ventral root of the spinal nerve. The stimulus and response thus forms a reflex action as shown in the diagram showing knee jerk reflex.

Sensory Reception and Processing

In human body, the different types of receptors detect of changes in the environment and send appropriate signals to the CNS, where all the inputs are processed and analysed. Then the different controlling centres of the brain send 'motor impulses' to the 'effectors' through motor nerves. The following sections, you will be introduced to some of the important receptors of human body.

1) **Exteroceptors**: They are located at or near the surface of the body, and sensitive to external stimuli like hearing, vision, touch, taste and pain etc.

2) **Interoceptors (visceroceptors):** They are located in the visceral organs and blood vessels and sensitive to internal stimuli.

3) **Proprioceptors:** They are also a kind of interoceptors and they provide information about body position and movement and are located in muscles, tendons, joints and the internal ear.

4) **Thermoreceptors:** They respond to heat (caloreceptors) and cold (frigidoreceptors).

Eye

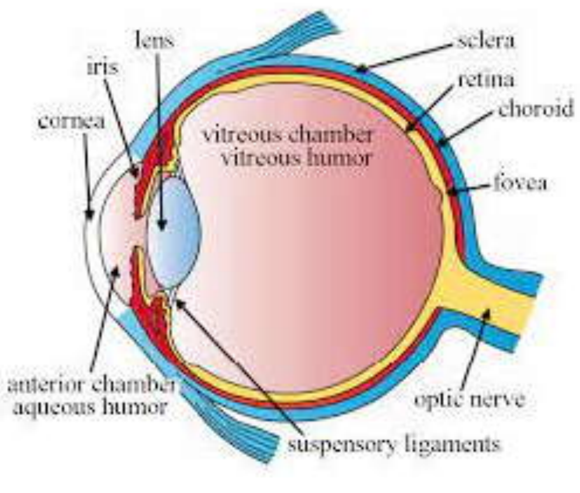


Fig : Diagramme showing parts of Eye

Our paired eyes are located in sockets of the skull called orbits. A brief account of structure and functions of the human eye is given in the following sections.

Parts of an eye

The adult human eye ball is nearly a spherical structure. The wall of the eye ball is composed of three layers . The external layer is composed of a dense connective tissue and is called the sclera. The anterior portion of this layer is called the cornea. The middle layer, choroid, contains many blood vessels and looks bluish in colour. The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the ciliary body. The ciliary body, itself continues forward to form a pigmented and opaque structure called the iris which is the visible coloured portion of the eye. The eye ball contains a transparent crystalline lens which is held in place by ligaments attached to the ciliary body. In front of the lens, the aperture surrounded by the iris is called the pupil. The diameter of the pupil is regulated by the muscle fibres of iris.

The inner layer is retina and it contains three layers of neural cells- from inside to outside-ganglion cells, bipolar cells and photoreceptor cells. There are two types of photoreceptor cells, namely, rods and cones. These cells contain the light-sensitive proteins called the photopigments. The daylight (photopic) vision and colour vision are functions of cones and the twilight (scotopic) vision is the function of the rods. The rods contain a purplish-red protein called the rhodopsin or visual purple, which contains a derivative of Vitamin A. In the human eye, there are three types of cones which possess their own characteristic photopigments that respond to red, green and blue lights. The sensations of different colours are produced by various combinations of these cones and their photopigments. When these cones are stimulated equally, a sensation of white light is produced.

The optic nerves leave the eye and the retinal blood vessels enter it at a point medial to and slightly above the posterior pole of the eye ball. Photoreceptor cells are not present in that region and hence it is called the blind spot. At the posterior pole of the eye lateral to the blind spot, there is a yellowish pigmented spot called macula lutea with a central pit called the fovea. The fovea is a thinned-out portion of the retina where only the cones are densely packed. It is the point where the visual acuity (resolution) is the greatest.

The space between the cornea and the lens is called the aqueous chamber and contains a thin watery fluid called aqueous humor. The space between the lens and the retina is called the vitreous chamber and is filled with a transparent gel called vitreous humor.

Mechanism of Vision

The light rays in visible wavelength focussed on the retina through the cornea and lens generate potentials (impulses) in rods and cones. As mentioned earlier, the photosensitive compounds (photopigments) in the human eyes is composed of opsin (a protein) and retinal (an aldehyde of vitamin A). Light induces dissociation of the retinal from opsin resulting in changes in the structure of the opsin. This causes membrane permeability changes. As a result, potential differences are generated in the photoreceptor cells. This produces a signal that generates action potentials in the ganglion cells through the bipolar cells. These action potentials (impulses) are transmitted by the optic nerves to the visual cortex area of the brain, where the neural impulses are analysed and the image formed on the retina is recognised based on earlier memory and experience.

The Ear

The ears perform two sensory functions, hearing and maintenance of body balance. Anatomically, the ear can be divided into three major sections called the outer ear, the middle ear and the inner ear The outer ear consists of the pinna and external auditory meatus (canal). The pinna collects the vibrations in the air which produce sound. The external auditory meatus leads inwards and extends up to the tympanic membrane (the ear drum). There are very fine hairs and wax-secreting glands in the skin of the pinna and the meatus. The tympanic membrane is composed of connective tissues covered. with skin outside and with mucus membrane inside. The middle ear contains three ossicles called malleus, incus and stapes which are attached to one another in a chain-like fashion. The malleus is attached

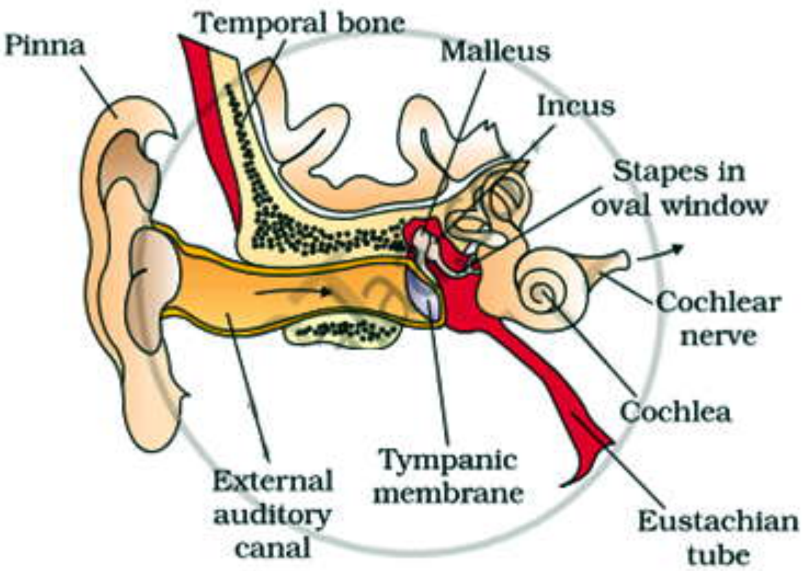


Fig : Diagrammatic view of ear

to the tympanic membrane and the stapes is attached to the oval window of the cochlea. The ear ossicles increase the efficiency of transmission of sound waves to the inner ear. An Eustachian tube connects the middle ear cavity with the pharynx. The Eustachian tube helps in equalising the pressures on either sides of the ear drum.

The fluid-filled inner ear called labyrinth consists of two parts, the bony and the membranous labyrinths. The bony labyrinth is a series of channels. Inside these channels lies the membranous labyrinth, which is surrounded by a fluid called perilymph. The membranous labyrinth is filled with a fluid called endolymph. The coiled portion of the labyrinth is called cochlea. The membranes constituting cochlea, the reissner's and basilar, divide the surounding perilymph filled bony labyrinth into an upper scala vestibuli and a lower scala tympani The space ear. within cochlea called scala media is filled with endolymph. At the base of the cochlea, the scala vestibuli ends at the oval window, while the scala tympani terminates at the round window which opens to the middle

The organ of corti is a structure located on the basilar membrane which contains hair cells that act as auditory receptors. The hair cells are present in rows on the internal side of the organ of corti. The basal end of the hair cell is in close contact with the afferent nerve fibres. A large number of processes called stereo cilia are projected from the apical part of each hair cell. Above the rows of the hair cells is a thin elastic membrane called tectorial membrane.

The inner ear also contains a complex system called vestibular apparatus, located above the cochlea. The vestibular apparatus is composed of three semi-circular canals and the otolith (macula is the sensory part of saccule and utricle). Each semi-circular canal lies in a different plane at right angles to each other. The membranous canals are suspended in the perilymph of the bony canals. The base of canals is swollen and is called ampulla, which contains a projecting ridge called crista ampullaris which has hair cells. The saccule and utricle contain a projecting ridge called macula. The crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

Mechanism of Hearing

How does ear convert sound waves into neural impulses, which are sensed and processed by the brain enabling us to recognise a sound? The external ear receives sound waves and directs them to the ear drum.. The ear drum vibrates in response to the sound waves and these vibrations are transmitted through the ear ossicles (malleus, incus and stapes) to the oval window. The vibrations are passed through the oval window on to the fluid of the cochlea, where they generate waves in the lymphs. The waves in the lymphs induce a ripple in the basilar membrane. These movements of the basilar membrane bend the hair cells, pressing them against the tectorial membrane. As a result, nerve impulses are generated in the associated afferent neurons. These impulses are transmitted by the afferent fibres via auditory nerves to the auditory cortex of the brain, where the impulses are analysed and the sound is recognised.

INTEXT QUESTIONS

1. Write a short note on the following
   a) Exteroceptors
   b) Interoceptors (visceroceptors)
   c) Proprioceptors
   d) Thermoreceptors
   e) Mechanism of vision
   f) Mechanism of hearing

Disorders of Human Neural system

1. **Alzheimer's disease (AD):** It is the most common form of dementia (Senile Dementia of the Alzheimer) in people above 65 years of age. It is a progressive neurologic disease of the brain, leading to the loss of neurons and the loss of intellectual abilities, including memory. It worsens with age and eventually leads to death..

2. **Meningitis**: It is the inflammation of the protective membranes (meninges) covering the brain and the spinal cord. The inflammation may be caused by infection with viruses, bacteria and rarely by certain drugs.

3. **Parkinson's disease**: It is a progressive disorder of a certain region in the brain. It affects movements producing motor symptoms, which include autonomic dysfunction, neuropsychiatric problems, and sleep difficulties, and uncontrolled movements of other body parts.

4. **Stroke or Cerebro-Vascular Accident (CVA):** It is the rapid loss of brain functions due to disturbance in the blood supply to the brain. This can be due to

ischemia (reduced blood flow) caused by partial blockage, or hemorrhage. As a result, the affected area of the brain cannot function, and it might cause inability to move one or more limbs on one side of the body, and the inability to understand or speak.

INTEXT QUESTIONS

1. Explain the Structure and functions of Brain ?
2. Explain the transmission of nerve impulse through a nerve fibre with the help of suitable diagrams?
3. What is corpus collasum?
4. What do you know about arbor vitae?
5. Distinguish between blind spot and the yellow spot?
6. What is organ of Corti ?
7. Draw a labeled diagram of the T.S of the spinal cord of man ?
8. Distinguish between somatic and autonomic neural systems ?
9. Give an Account of synaptic transmission ?
10. List out the differences between sympathetic and parasympethetic neural system?
11. Mention the disorders of the human neural system?

Chemical Coordination and Integration

You have already learnt that the neural system provides a point-to-point rapid coordination among organs. The neural coordination is fast but short-lived. As the nerve fibres do not innervate all cells of the body and the cellular functions need to be continuously regulated; a special kind of coordination and integration has to be provided. This function is carried out by hormones. The neural system and the endocrine system jointly coordinate and regulate the physiological functions in the body.

Objectives

After completing this lesson, you will be able to :

- List various endocrine glands and locate their position in human body
- Identify properties of hormones and mention their nature and manner of functioning

- Name the various endocrine glands and their functions
- relate the hormonal imbalance with disorders
- State the effects of over functioning (hyperactivity) and hypoactivity (under functioning) of pituitary and thyroid
- Mechanism of hormonal action.

Endocrine Glands and Hormones

Endocrine glands lack ducts and are hence, called ductless glands. Their secretions are called hormones. Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts. The new definition covers a number of new molecules in addition to the hormones secreted by the organised endocrine glands. Invertebrates possess very simple endocrine systems with few hormones whereas a large number of chemicals act as hormones and provide coordination in the vertebrates.

General Properties of Hormones

1. Hormones are secreted from their source directly into the blood (and not into lymph).
2. They regulate the physiological processes by chemical means.
3. They act on target organs or cells usually away from their source.
4. They are produced in very small quantities but biologically very active.
5. Chemically, some hormones are peptides (proteins such as insulin) which are water soluble, some are amines (derived from amino acids such as adrenaline) again water-soluble and some are steroids derived from cholesterol such as testosterone which are lipid-soluble.
6. Their excess (hypersecretion) or deficiency (hyposecretion), both may lead to serious consequences.

Human Endocrine System

The endocrine glands and hormone producing tissues/cells located in different parts of our body constitute the endocrine system. Pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus and gonads are the organized endocrine bodies in our body In addition, some other organs, Ex., gastrointestinal tract liver, kidney, heart also produce hormones. A brief account of the structure and functions of all major endocrine glands of the human body is given in the following sections.

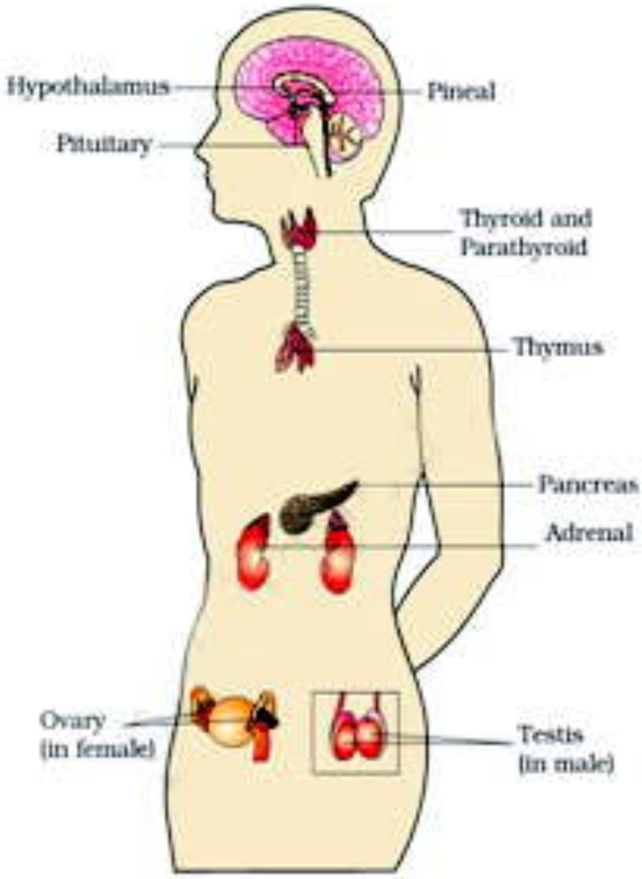


Fig : Location of endocrine glands

INTEXT QUESTIONS

1. Define the following
   a) Endocrine glands
   b) Hormone
2. List out the Endocrine glands and their location

The Hypothalamus

As you know, the hypothalamus is the basal part of diencephalon, forebrain and it regulates a wide spectrum of body functions. It contains several groups of neurosecretory cells called nuclei which produce hormones. These hormones regulate the synthesis and secretion of pituitary hormones. However, the hormones produced by hypothalamus are of two types, the releasing hormones (which stimulate secretion of pituitary hormones) and the inhibiting hormones (which inhibit secretions of pituitary hormones). For example, Gonadotrophin releasing hormone (GnRH) stimulates the pituitary synthesis and release of gonadotrophins. On the other hand, somatostatin from the hypothalamus inhibits the release of growth hormone from the pituitary. These hormones originating in the hypothalamic neurons, pass through axons and are released from their nerve endings. These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.

INTEXT QUESTIONS

1. List of hormones secreted by hypothelomus

The Pituitary Gland

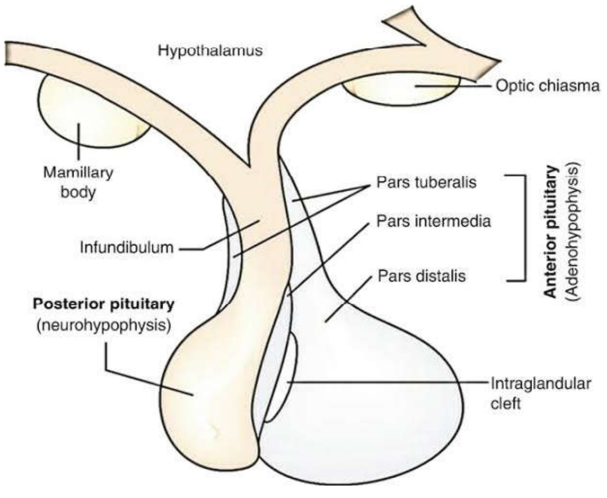


Fig : Pituitary Gland

The pituitary gland is located in a bony cavity called sella tursica and is attached to hypothalamus by a stalk. It is divided anatomically into an adenohypophysis and neurohypophysis. Adenohypophysis consists of two portions, pars distalis and pars intermedia. The pars distalis region of pituitary, commonly called anterior pituitary, produces growth hormone (GH), prolactin (PRL), thyroid stimulating hormone (TSH), adrenocorticotrophic hormone (ACTH), luteinizing hormone (LH) and follicle stimulating hormone (FSH). Pars intermedia secretes only one hormone called melanocyte stimulating hormone (MSH). However, in humans, the pars intermedia is almost merged with pars distalis. Neurohypophysis (parsnervosa) also known as posterior pituitary, stores and releases two hormones called oxytocin and vasopressin, which are actually synthesised by the hypothalamus and are transported axonally to neurohypophysis. Over-secretion of GH stimulates abnormal growth of the body leading to Gigantism and low secretion of GH results in stunted growth resulting in pituitary Dwarfism. Excess secretion of growth hormone in adults especially in middle age can result in severe disfigurement (especially of the face) called Acromegaly. Prolactin regulates the growth of the mammary glands and formation of milk in them. TSH stimulates the synthesis and secretion of thyroid hormones from the thyroid gland. ACTH stimulates the synthesis and secretion of steroid hormones called glucocorticoids from the adrenal cortex. LH and FSH stimulate gonadal activity and hence are called gonadotrophins. In males, LH stimulates the synthesis and secretion of hormones called androgens from testis. FSH and androgens regulate spermatogenesis. In females, LH induces ovulation of fully mature follicles (graafian follicles) and maintains the corpus luteum, formed from the remnants of the graafian follicles after ovulation. FSH stimulates growth and development of the ovarian follicles in females. MSH acts on the melanocytes (melanin containing cells) and regulates pigmentation of the skin. Oxytocin acts on the smooth muscles of our body and stimulates their contraction. In females, it stimulates a vigorous contraction of uterus at the time of child birth, and milk ejection from the mammary gland. Vasopressin acts mainly at the kidney and stimulates resorption of water and electrolytes by the distal tubules and thereby reduces loss of water through urine (diuresis). Hence, it is also called as antidiuretic hormone (ADH). An impairment affecting synthesis or release of ADH results in a diminished ability of the kidney to conserve water leading to water loss and dehydration. This condition is known as Diabetes Insipidus

INTEXT QUESTIONS

1. What is acromegali? Which hormone responsible for this disorder ?
2. Which hormone is called Anti-Diuretic hormone ?
3. Give an account of Secretions of pituitary glands?
4. What is Diabetes Insipidus?

The Pineal Gland

The pineal gland is located on the dorsal side of forebrain and secretes a hormone called melatonin. Melatonin plays a very important role in the regulation of a 24-hour (diurnal) rhythm of our body. For example, it helps in maintaining the normal rhythms of sleep-wake cycle, body temperature. In addition, melatonin also influences metabolism, pigmentation, the menstrual cycle as well as our defense capability.

INTEXT QUESTIONS

1. Name the hormone secreted by the pineal gland and its importance ?

Thyroid Gland

The thyroid gland is composed of two lobes which are located on either side of the Trachea both the lobes are interconnected with a thin flap of connective tissue called isthmus. The thyroid gland is composed of follicles and stromal tissues. Each thyroid follicle is composed of follicular cells, enclosing a cavity. These follicular cells synthesise two hormones, tetraiodothyronine or thyroxine (T4) and triiodothyronine (T3). Iodine is essential for the normal rate of hormone synthesis in the thyroid. Deficiency of iodine in our diet results in hypothyroidism and enlargement of the thyroid gland, commonly called goitre. Hypothyroidism during pregnancy causes defective development and maturation of the growing baby leading to stunted growth (cretinism), mental. retardation, low intelligence quotient, abnormal skin, deaf-mutism, etc. In adult women, hypothyroidism may cause menstrual cycle to become irregular. Due to cancer of the thyroid gland or due to development of nodules of the thyroid glands, the rate of synthesis and secretion of the thyroid hormones is increased to abnormal high levels leading to a condition called hyperthyroidism which adversely affects the body physiology. Exopthalmic goitre is a form of hyperthyroidism, characterised by enlargement of the thyroid gland, protrusion of the eyeballs, increased basal metabolic rate, and weight loss is called Graves' disease. Thyroid hormones play an important role in the regulation of the basal metabolic rate. Thyroid hormones control the metabolism of carbohydrates, proteins and fats. Maintenance of water and electrolyte balance is influenced by thyroid hormones. Thyroid gland also secretes a protein hormone called thyrocalcitonin (TCT), which regulates the blood calcium levels.

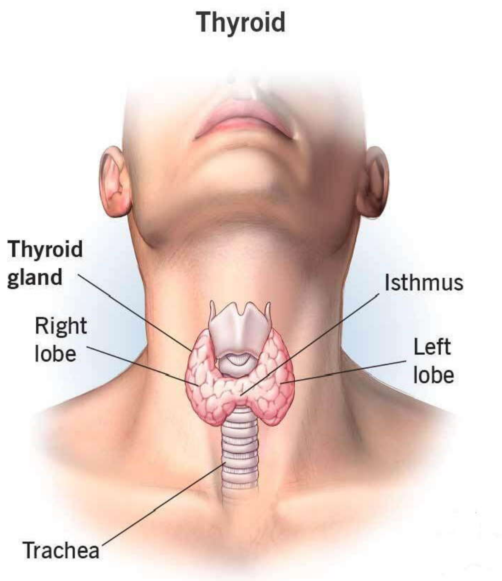


Fig. : Thyroid Gland

INTEXT QUESTIONS

1. Name the hormone secreted by the thyroid gland?
2. Explain how hypo thyroidism and hyperthyroidism can effect the body?

Parathyroid gland

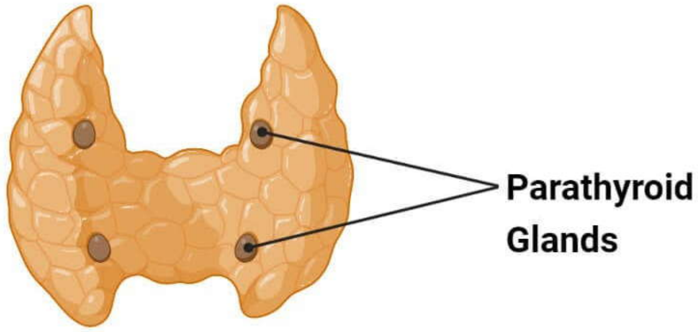


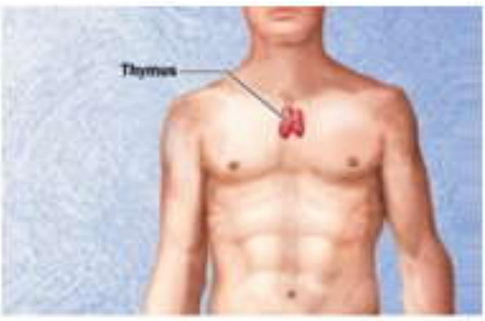
Fig. : Parathyroid Gland

In humans, four parathyroid glands are present on the back side of the thyroid gland, one pair each in the two lobes of the thyroid gland The parathyroid glands secrete a peptide hormone called parathyroid hormone (PTH). The secretion of PTH is regulated by the circulating levels of calcium ions. Parathyroid hormone (PTH) increases the Ca2+ levels in the blood. PTH acts on bones and stimulates the process of bone resorption (dissolution/ demineralisation). PTH also stimulates reabsorption of Ca2+ by the renal tubules and increases Ca2+ absorption from the digested food. It is, thus, clear that PTH is a hypercalcemic hormone, i.e., it increases the blood Ca2+ levels. Along with TCT, it plays a significant role in calcium balance in the body.

INTEXT QUESTIONS

1. Where is the parathyroid located in the body?
2. What are the hormone secreted by the parathyroid gland and its functions?

Thymus



The thymus gland is a lobular structure located between lungs behind sternum on the ventral side of aorta. The thymus plays a major role in the development of the immune system. This gland secretes the peptide hormones called thymosin. Thymosins play a major role in the differentiation of T-lymphocytes, which provide cell-mediated immunity. In addition, thymosin also promote production of antibodies to provide humoral immunity. Thymus is degenerated in old individuals resulting in a decreased production of thymosin. As a result, the immune responses of old persons become weak.

INTEXT QUESTIONS

1. Name the hormone secreted by the thymus gland ?

Adrenal Gland

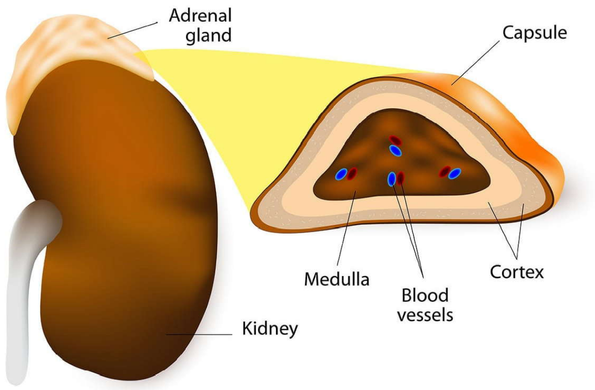


Fig. : Adrenal Gland

Our body has one pair of adrenal glands, one at the anterior part of each kidney The gland is composed of two types of tissues. The centrally located tissue is called the adrenal medulla, and outside this lies the adrenal cortex Underproduction of hormones by the adrenal cortex alters carbohydrate metabolism causing acute weakness and fatigue leading to a disease called Addison's disease. The adrenal medulla secretes two hormones called adrenaline or epinephrine and noradrenaline or norepinephrine. These are commonly called as catecholamines. Adrenaline and noradrenaline are rapidly secreted in response to stress of any kind and during emergency situations and are called emergency hormones or hormones of Fight or Flight. These hormones increase alertness, pupilary dilation, piloerection (raising of hairs), sweating etc. Both the hormones increase the heart beat, the strength of heart contraction and the rate of respiration. Catecholamines also stimulate the breakdown of glycogen resulting in an increased concentration of glucose in blood. In addition, they also stimulate the breakdown of lipids and proteins. The adrenal cortex can be divided into three layers, called zona reticularis (inner layer), zona fasciculata (middle layer) and zona glomerulosa (outer layer). The adrenal cortex secretes many hormones, commonly called as corticoids. The corticoids, which are involved in carbohydrate metabolism are called glucocorticoids. In our body, cortisol is the main glucocorticoid. Corticoids, which regulate the balance of water and electrolytes in our body are called mineralocorticoids. Aldosterone is the main mineralocorticoid in our body. Glucocorticoids stimulate gluconeogenesis, lipolysis and proteolysis; and inhibit cellular uptake and utilisation of amino acids. Cortisol is also involved in maintaining the cardio-vascular system as well as the kidney functions. Glucocorticoids, particularly cortisol, produces anti-inflammatory reactions and suppresses the immune response. Cortisol stimulates the RBC production. Aldosterone acts mainly at the renal tubules and stimulates the reabsorption of Na+ and water and excretion of K+ and phosphate ions. Thus, aldosterone helps in the maintenance of electrolytes, body fluid volume, osmotic pressure and blood pressure. Small amounts of androgenic steroids are also secreted by the adrenal cortex which play a role in the growth of axial hair, pubic hair and facial hair during puberty.

INTEXT QUESTIONS

1. Which hormone is commonly is known as fight and flight hormone?
2. Write a note on Addison's disease?

Pancreas

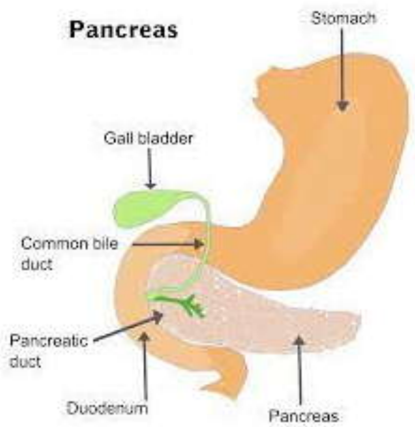


Fig. : Pancreas

Pancreas is a composite gland which acts as both exocrine and endocrine gland. The endocrine pancreas consists of 'Islets of Langerhans'. There are about 1 to 2 million Islets of Langerhans in a normal human pancreas representing only 1 to 2 per cent of the pancreatic tissue. The two main types of cells in the Islet of Langerhans are called α-cells and β-cells.

The α-cells secrete a hormone called glucagon, while the b-cells secrete insulin. Glucagon is a peptide hormone, and plays an important role in maintaining the normal blood glucose levels. Glucagon acts mainly on the liver cells (hepatocytes) and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). In addition, this hormone stimulates the process of gluconeogenesis which also contributes to hyperglycemia. Glucagon reduces the cellular glucose uptake and utilisation. Thus, glucagon is a hyperglycemic hormone. Insulin is a peptide hormone, which plays a major role in the regulation of glucose homeostasis. Insulin acts mainly on hepatocytes and adipocytes (cells of adipose tissue), and enhances cellular glucose uptake and utilisation. As a result, there is a rapid movement of glucose from blood to hepatocytes and adipocytes resulting in decreased blood glucose levels (hypoglycemia). Insulin also stimulates conversion of glucose to glycogen (glycogenesis) in the target cells. The glucose homeostasis in blood is thus maintained jointly by the two – insulin and glucagons. Prolonged hyperglycemia leads to a complex disorder called diabetes mellitus which is associated with loss of glucose through urine and formation of harmful compounds known as ketone bodies.

INTEXT QUESTIONS

1. What are Islets of Langerhans?
2. Name the hormone secreted by the pancreas?
3. What is diabetise mellitus?

Testis

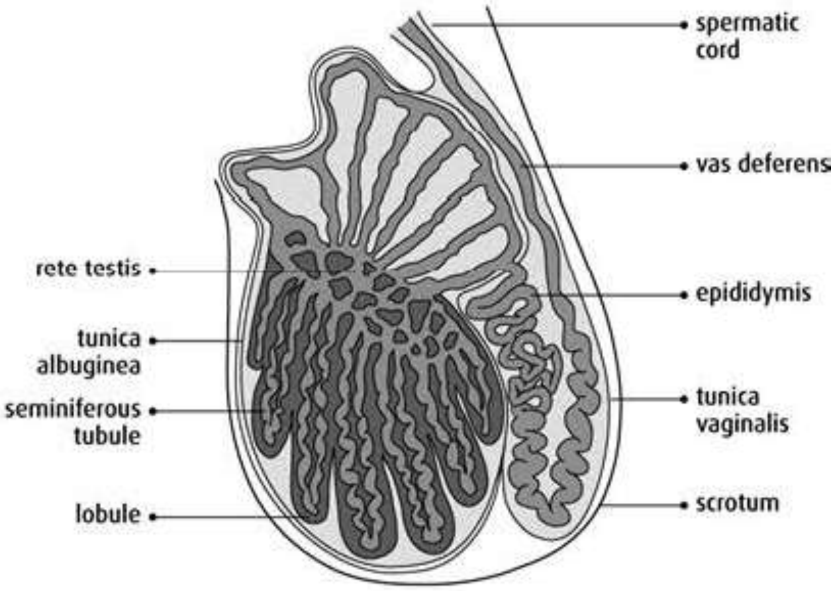


Fig.: Testis

A pair of testis is present in the scrotal sac (outside abdomen) of male individuals and performs dual functions as a primary sex organ as well as an endocrine gland. Testis is composed of seminiferous tubules and stromal or interstitial tissue. The Leydig cells or interstitial cells, which are present in the intertubular spaces produce a group of hormones called androgens mainly testosterone. Androgens regulate the development, maturation and functions of the male accessory sex organs like epididymis, vas deferens, seminal vesicles, prostate gland, urethra etc. These hormones stimulate muscular growth, growth of facial and axillary hair, aggressiveness, low pitch of voice etc. Androgens play a major stimulatory role in the process of spermatogenesis (formation of spermatozoa). Androgens act on the central neural system and influence the male sexual behaviour (libido). These hormones produce anabolic (synthetic) effects on protein and carbohydrate metabolism.

INTEXT QUESTIONS

1. What are androgens ? Which cells secret them?
2. Describe the male hormone and their action?

Ovary

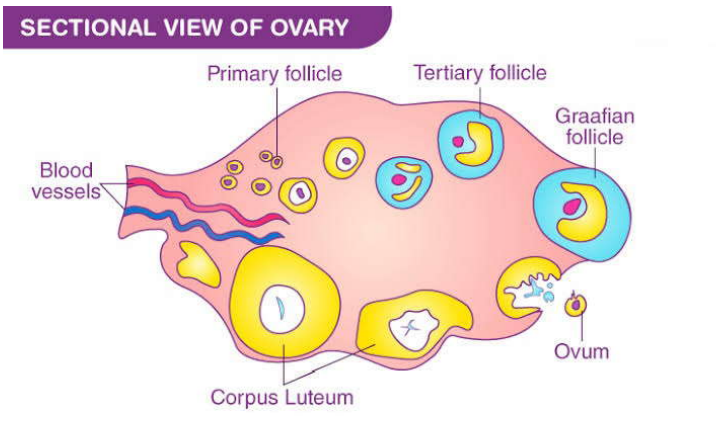


Fig. : Ovary

Females have a pair of ovaries located in the abdomen Ovary is the primary female sex organ which produces one ovum during each menstrual cycle. In addition, ovary also produces two groups of steroid hormones called estrogen and progesterone. Ovary is composed of ovarian follicles and stromal tissues. The estrogen is synthesised and secreted mainly by the growing ovarian follicles. After ovulation, the ruptured follicle is converted to a structure called corpus luteum, which secretes mainly progesterone.

Estrogens produce wide ranging actions such as stimulation of growth and activities of female secondary sex organs, development of growing. ovarian follicles, appearance of female secondary sex characters (e.g., high pitch of voice, etc.), mammary gland development. Estrogens also regulate female sexual behaviour. Progesterone supports pregnancy and acts on the mammary glands, stimulates the formation of alveoli (sac-like structures which store milk) and milk secretion.

INTEXT QUESTIONS

1. Name the hormones secreted by the Ovary and their actions?

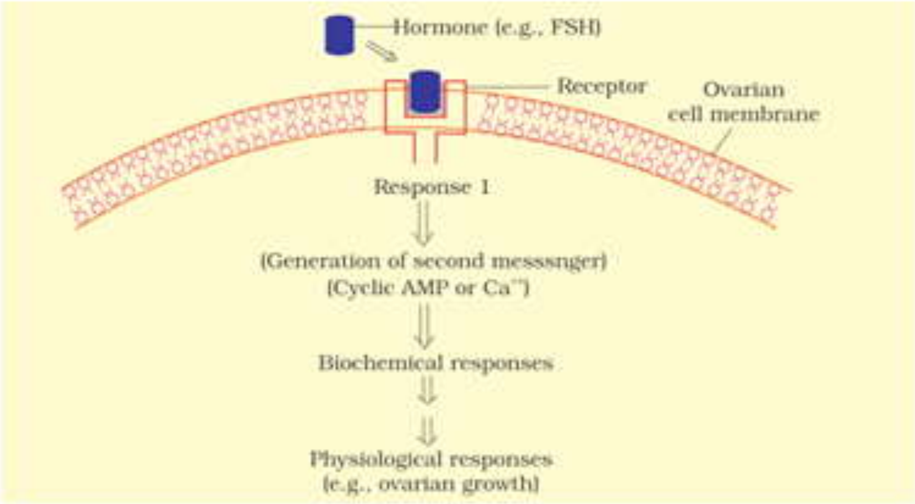
Hormones of Heart, Kidney and Gastrointestinal Tract

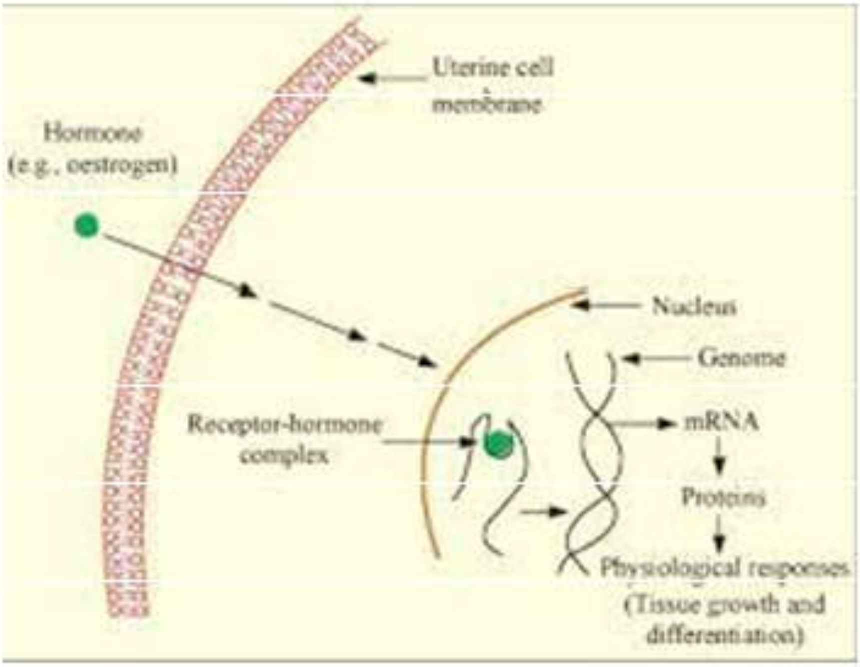
Now you know about the endocrine glands and their hormones. However, as mentioned earlier, hormones are also secreted by some tissues which are not endocrine glands. For example, the atrial wall of our heart secretes a very important peptide hormone called atrial natriuretic factor (ANF), which decreases blood pressure. When blood pressure is increased, ANF is secreted which causes dilation of the blood vessels. This reduces the blood pressure. The juxtaglomerular cells of kidney produce a peptide hormone called erythropoietin which stimulates erythropoiesis (formation of RBC). Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones, namely gastrin, secretin, cholecystokinin (CCK) and gastric inhibitory peptide (GIP). Gastrin acts on the gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen. Secretin acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions. CCK acts on both pancreas and gall bladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively. GIP inhibits gastric secretion and motility. Several other non-endocrine tissues secrete hormones called growth factors. These factors are essential for the normal growth of tissues and their repair/regeneration.

INTEXT QUESTIONS

1. Name the hormones secreted by the following
   a) Heart
   b) Kidney
   c) Gastrointestinal tract

MECHANISM OF HORMONE ACTION





Hormones produce their effects on target tissues by binding to specific proteins called hormone receptors located in the target tissues only. Hormone receptors present on the cell membrane of the target cells are called membrane-bound receptors and the receptors present inside the target cell are called intracellular receptors, mostly nuclear receptors (present in the nucleus). Binding of a hormone to its receptor leads to the formation of a hormone-receptor complex. Each receptor is specific to one hormone only and hence receptors are specific. Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue, target tissue metabolism and hence physiological functions are regulated by hormones. On the basis of their chemical nature, hormones can be divided into following groups :

(i) Peptide, polypeptide, protein hormones

(e.g., insulin, glucagon, pituitary hormones, hypothalamic hormones, etc.)

(ii) Steroids (e.g., cortisol, testosterone, estradiol and progesterone)

(iii) Iodothyronines (thyroid hormones)

(iv) Amino-acid derivatives (e.g., epinephrine).

Hormones which interact with membrane-bound receptors normally do not enter the target cell, but generate second messengers (e.g., cyclic AMP, IP3, Ca++ etc) which in turn regulate cellular metabolism . Hormones which interact with intracellular receptors (e.g., steroid hormones, iodothyronines, etc.) mostly regulate gene expression or chromosome function by the interaction of hormone-receptor complex with the genome.

INTEXT QUESTIONS

1. Explain the mechanism of hormone action?
2. Classify hormones on the basis of their chemical nature?

17 HOMEOSTASIS

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 occurs 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 completing this lesson, you will be able to:

- 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.

Concepts of Homeostasis

Homeostasis (homeo : same/steady, stasis : state) is a phenomenon in which the body regulates its processes 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, inside the cell the presence of proper concentration of chemicals, proper temperature, and a suitable pH (degree of salinity or acidity), etc. 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) a little better, consider the following five (5) 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 normal percentage 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 are taking 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 are consuming 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 are 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 of red blood corpuscles (RBCs) per cubic millimeter 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 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. Then, there is the reverse of it i.e. cold winter. Inspite of wearing thick warm clothesyou still you 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 is to maintain a steady state of warmth inside your body. In both the above situations, you are trying to regulate your internal body temperature, called thermoregulation. You will study more about thermoregulation in subsequent sections of this lesson.

INTEXT QUESTIONS

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?

   ____

THERMOREGULATION — WHY IS IT NECESSARY

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 Are Denatured,
- Plasma Membrane Breaks Down, And
- Cells Suffer Lack Of Oxygen.

B. Below 0°C. (45^0 - 0^0C)

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.

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 respectto the 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

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?

   ____

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

Endotherms and Ectotherms

A. **ENDOTHERMS** (*endo* : inside, *therm* : heat) : Endotherms are the 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 **Poikilotherms** or **Warm-blooded** means animals which are felt warm whenever touched. If you held a pigeon in your hand or feel a rabbit by touch even when it is intensely cold, you will find them warm. Ex: All birds, Mammals.

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*** means animals which are felt 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.

Characteristics of Endotherms

1. With a **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 maintaining 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.

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.

Some ectotherms and how they cope unfavorable temperatures

Consider the following examples

Frogs hibernate under the ground in cold winters and aestivate during hot summers to avoid heat and escape from cold.

Fishes live in water. But the water seldom undergoes extreme temperaturechanges 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

1. Classify the following animals as endotherms or ectotherms:

   Camel, Bat, Earthworm, Cockroach, Fish, Wall lizard, Polar bear, sparrow

   Endotherms:

   ____

   Ectothrms :

   ____

2. Explain the following terms and give one or more synonymous terms for each:

   (i) Poikilotherms ______________________

   (ii) Homiotherms ______________________

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 ____________________

MECHANISM OF HOMEOSTASIS OF BODY TEMPERATURE (THERMOREGULATION) IN HUMANS

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.

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. 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

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.

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

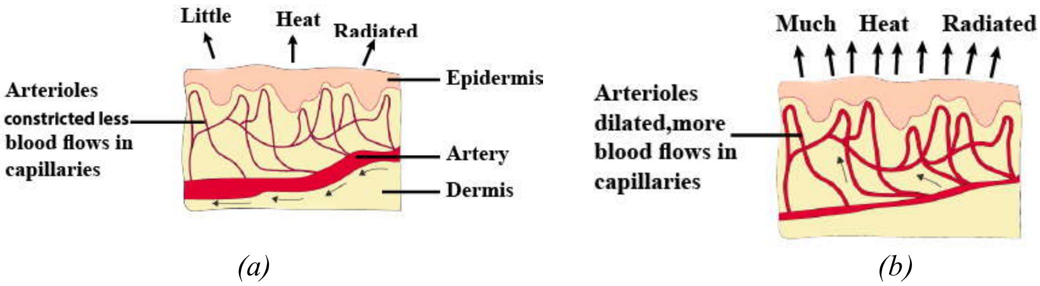


Fig : *Blood vessels in the skin during temperature regulation.*

Fig : (a) Vasoconstriction for cutting down heat loss (b) Vasodilation to increase heat loss

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 37o C (with 0.5o 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.

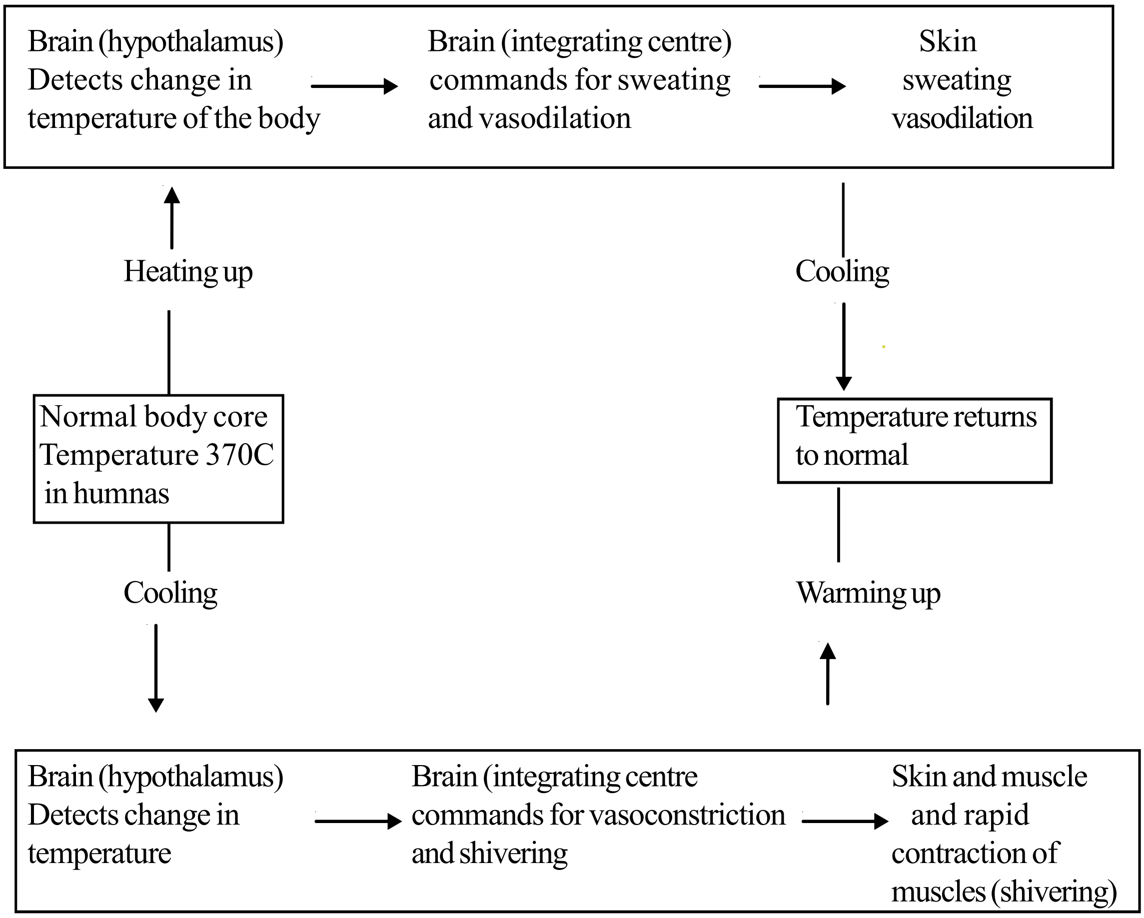
4. **Effectors -** The effectors are the agencies, which act to restore the set point.

   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 is given below explains the different steps in thermoregulation in humans.



The 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 the arms or both arms and legs tightly close to the body (to reduce heat radiation).

INTEXT QUESTIONS

1. Rearrange the following in their correct sequence in a homeostasis:
   Effector, Set point, Integrating centre, Sensor.

   ____

2. State in one word or sentence :
   (i) The normal body core temperature of human.

   ____

   (ii) The function of feathers in bird and the hairs of rabbit.

   ____

   (iii) Effect of shivering.

   ____

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

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, nsects, etc.

- The endotherms have a variety of heat regulating systems such as sweating and vasodilatation 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 coding?
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.