TEACHING / TRAINING MODULE
BOTANY

CLASS-XI & XII

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September 2018

FOREWORD

The ST and SC Development Department, Government of Odisha, has initiated an innovative effort by setting up an ***Academic Performance Monitoring Cell*** (APMC) in Scheduled Castes and Scheduled Tribes Research and Training Institute (SCSTRTI) to monitor the Training and Capacity Building of teachers of SSD Higher Secondary Schools and Ekalabya Model Residential Schools (EMRS) under the administrative control of the ST & SC Development Departme. This innovative program is intended to ensure quality education in the Higher Secondary Level of the schools of the ST & SC Development Department.

The modules and lesson plans are prepared for the +2 Science and Commerce stream' in all the subjects such as Physics, Chemistry, Botany, Zoology, Mathematics, Information Technology, Odia, English and Commerce for both the years in line with the syllabus of Council of Higher Secondary Education (CHSE).

These modules/lesson plans are self contained. The subiect experts who are the best in their respective subjects in the State have been roped in for the exercise. They have given their precious time to make the module as activity based as possible.

I hope, this material will be extremely useful for the subject teachers in effective class room transactions and will be helpful in improving the quality education at the Higher Secondary Level. I also take this opportunity to thank all the subject experts of different subjects for rendering help and assistance to prepare the modules/lesson notes and lesson plans within a record time.

Prof. (Dr.) A.B.Ota
Director and Special Secretary,
SCSTRTI

CONTENTS

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LESSON PLAN

Higher Secondary (Science), BOTANY

(1st Year) - Approx. 50 Classes/Year

Unit	Lecture No.	TOPIC	Date of Completion	Signature
I	**DIVERSITY OF LIVING WORLD :**			
	1	Introduction and future prospects of Plant Science		
	2	5-Kingdom system of classification Monera, Protista, Fungi-Salient features		
	3	Lichens, Viruses, Viroids - Features -		
	4	Classification of plants into major groups - Algal groups with examples		
	5	Salient features of Bryophytes, Pteridophytes and Gymnosperms - Examples		
	6	Salient features of Angiosperms major classes, Systems of classification		
II	**STRUCTURAL ORGANIZATION OF PLANTS :**			
	7	Morphology and modification of roots		
	8	Morphology and modification of stems		
	9	Leaf, inflorescence, morphology		
	10	Flower structure and function		
	11	Fruit development, different types of fruit		
	12	Meristematic and permanent tissues		
	13	Tissue and Tissue system		
	14	Root anatomy (dicot & monocot)		
	15	Stem anatomy (dicot and monocot) & secondary growth.		
	16	Leaf anatomy (Dorsivental and isobilateral)		
III	**CELL STRUCTURE AND FUNCTION :**			
	17	Cell-basic unit of life and cell theories		
	18	Prokaryotic and Eukaryotic Cell		
	19	Plant Cell and Animal Cell		
	20	Cell envelope, structure and function (Cell Wall)		
	21	Cell Membrane - Structure, Models and Function		
	22	Endomembrane systems - endoplasmic reticulum, golgi bodies, lysosome, vacuole		
	23	Endomembrane System II - Mitochondria and Chloroplast		
	24	Ribosomes, microbodies, cytoskeleton - Cilia and flagella, centrioles		
	25	Nucleus, nuclear membrane, chromatin, nucleolus		
	26	Chemical composition of living cells - Biomolecules, carbohydrates, lipids and proteins - structure and function		
	27	Nucleic acid - DNA and RNA - Structure and function		
	28	Enzymes - Types, properties and enzyme action		
	29	Cell Division - Cell cycle Mitosis and its significance		
	30	Meosis and its significance		

IV	PLANT PHYSIOLOGY :			
	31	Transport in Plants - Movement of water, gases and nutrients. Diffusion - facilitated and a Active Transport Diffusion of gases		
	32	Plant - Water relations - Imbibition, water potential, Osmosis, Plasmolysis		
	33	Long distance Transport of water - Absorption, apoplast, symplast, transpiration pull, root pressure and guttation		
	34	Transpiration - Mechanism of opening and closing of stomata		
	35	Uptake and translocation of mineral nutrients		
	36	Essential mineral nutrients - Macro and Micronutrients and their role. Deficiency symptoms		
	37	Mineral toxicity, Hydroponics (Elementary Idea), Nitrogen metabolism		
	38	Nitrogen cycle and Biological Nitrogen fixation		
	39	Photosynthesis and Photosynthetic pigment		
	40	Photochemical reactions in Photosynthesis Cyclic and Non-Cyclic Photosphorylation		
	41	Biosynthetic phases of Photosynthesis - C3, C4 and other pathways		
	42	Photorespiration and factors affecting Photosynthesis		
	43	Chemiosmotic hypothesis		
	44	Respiration process - Exchange of gases		
	45	Glycolysis, Fermnetation		
	46	TCA Cycle -		
	47	Electron Transport system and ATP synthesis		
	48	Amphibolic pathway and Respiratory quotient		
	49	Plant growth and development - Phases of plant growth and plant growth rate, differentiation, dedifferentiation and redifferentiation		
	50	Sequence of development process in plant cell, growth regulators - Auxins, Gibberellin, Cytokinins, Ethylene, Abscisic acid		
	51	Seed dormancy, vernalization and photoperiodism		

N.B. : (a) Unit-1 - Lecture 1-3, Unit-III - Lecture - 17-27, Unit-IV to be covered before First Unit Test.
(b) Unit-I - Lecture 4-6, Unit-II (Whole), Unit-(IV) 28-30, to be completed before second Unit Test.
(c) Unit-IV - 31-51 to be completed before third Unit Test.

Module-1

5 - KINGDOM SYSTEM OF CLASSIFICATION

We see non-living things and living beings all around us. Nonliving things comprise of air, water, light, soil, rocks and many other such things. These factors always influence the type of life that will exist at a particular place. Besides, the existence of the varieties of living beings which abounds this planet, is more perplexing. It varies from invisible microorganisms to giant sequoias or monstrous whales. But all have same DNA, same RNA, same genetic code that make them living. In order to know them better and in systematic manner, one intends to keep them in different groups on the basis of their similarities and dissimilarities in structure, physiology, habitat etc.

Man instinctively classified all the living organisms into plants and animals from prehistoric time. Simple outward characters were taken into consideration since science was not so much advanced at that stage. Linnaeus, the father of taxonomy first made scientific attempt to classify the living world into two kingdoms - Plantae and Animalia. These included plants and animals, respectively. It was much in vogue, for a long time. Even a layman today knows the existence of plants and animals only in this world. He does not take into consideration inconspicuous, invisible microorganisms, unicellular plants and animals. With development of techniques, the huge world of microbes became more and more apparent, 3-Kingdom, 4-Kingdom Systems were proposed in the course of time. Yet, certain drawbacks in them prompted R.H. Whittaker (1969) to propose. 5-Kingdom System of Classification of the living world. The kingdoms established by him were named Monera, Protista, Fungi, Plantae and Animalia. The main criteria of classification used by him include. 1. Cell structure 2. Body organization and 3. Mode of nutrition.

In this module, we will consider the main characteristics of this classification.

I. Kingdom Monera

Bacteria are the sole members of the Kingdom-Monera. They are present everywhere but quite invisible to the naked eye. A drop of rain water contains hundreds of bacteria. They can survive in very adverse environmental conditions like hot springs, snowy mountains, marine and marshy soil. They are thought to be the most primitive life forms.

Bacteria are called the prokaryotes. They have a very simple cell structure. True nucleus and nuclear membrane, all cell organelles excepting ribosome, are absent. No membrane bound compartments are seen among bacteria (Fig.1). The major component of bacterial cell wall is peptidoglycan.

Bacteria are unicellular prokaryotes. They possess only a single circular DNA as the genetic material. They may be autotrophic or heterotrophic. Autotrophic bacteria are of two types - Chemosynthetic or Photosynthetic. Heterotrophs may live as saprophytes or parasites or symbionts.

Examples - *Blue green algae* - *methanogens*, etc.

Bacteria mainly reproduce by fission. Under adverse conditions, they adopt to sexual method which is very primitive type. It may be called genetic recombination.

II. **Kingdom Protista**

All unicellular eukaryotes are included under Protista. But their cell boundaries are not well defined, i.e. Cell Wall may or may not be present. They include protozoans, slime molds, Euglenoids etc. Members of this group are primarily aquatic. Cell body contains nucleus, nuclear membrane, cell organelles with membrane bound compartments (Fig. 2).

These organisms may be autotrophic or heterotrophic. They possess motile organelles like cilia or flagella. Protists reproduce asexually and sexually. Sexual reproduction involves cell fusion and zygote formation.

III. **Kingdom Fungi**

Fungi form the characteristic kingdom of heterotrophs. Very few fungi are unicellular but most of them are multicellular, coenocytic, filamentous. True nuclei and cell organelles are present in each cell. The fungal thallus is called mycelia. Individual branches of mycelia are hyphae. The cell wall is composed mainly of chitin in true fungi.

Fungi may live as saprophytes or parasites or symbionts. Their mode of nutrition is absorptive. Fungi reproduce asexually or sexually. The asexual reproductive units are called zoospores or conidia. These are respectively borne endogenously or exogenously. Sexual reproduction involves plasmogamy, karyogamy and meiosis like other higher plants and animals.

Fungi are ubiquitous in nature. They appear wherever a trace of organic substance is available.

Examples - Yeast (unicellular), Mucor, Rhizopus, Pencillium etc. (Fig.3)

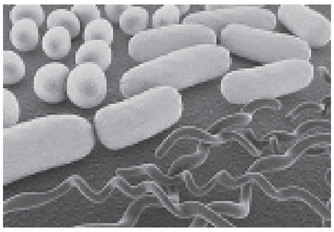

Fig. 1 : Bacteria Cells

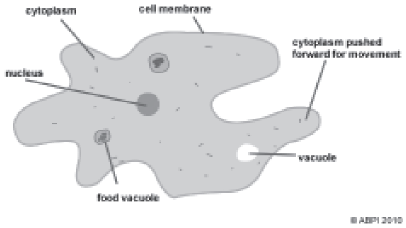

Fig. 2 : Protozoa Cells

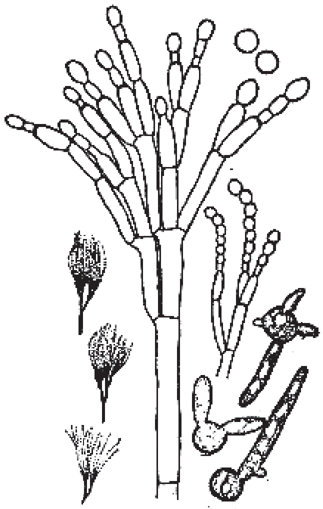

Fig. 3 : Penicillium-mycelium with conidia

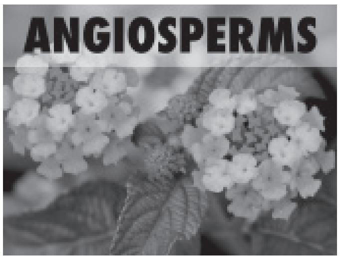

Fig. 4 : A Plant

Fig. 5 : An Animal

Table - 1

Characteristics of 5- Kingdoms

Characteristics	**Five Kingdoms**				
	Monera	Protista	Fungi	Plantae	Animalia
Cell Type	Prokaryote Unicellular	Eukaryote unicellular	Eukaryote multicellular	Eukaryote multicellular	Eukaryote multicellular
Nucleus	Primitive	Well organized	Well organized	Well organized	Well organized
Cell wall	Present	Present or absent	Present	Present	Absent
Chloroplast	Present or absent	Present or absent	Absent	Present	Absent
Tissue system	Absent	Absent	Absent	Present	Present
Nutrition	Auto or Heterotrophic	Auto or Heterotrophic	Heterotrophic & Absorptive	Autotrophic	Heterotrophic
Ecological role	Producer or decompser	Producer or decomposer	Heterotroph or decomposer	Producer	Heterotroph
Sexual reproduction	Absent	Present	Present	Present	Present

IV. Kingdom Plantae

Kingdom Plantae includes multicellular, eukaryotic chlorophyll containing organisms. The plant cells contain nucleus, cell orgnelles, Cell walls etc. The major component of cell wall is cellulose. Matured plant cells contain few large vacuoles. The green plants are called producers. The reserve food materials are mainly composed of starch. The growth of the higher plants is always terminal. Reproduction is vegetative, asexual and sexual. Plantae include algae, bryophytes pterido-phytes, Gymnosperms and angiosperms. Angiosperms predominate the present form of land plants (Fig.4).

V. **Kingdom Animalia**

The Kingdom is represented by heterotrophic, eukaryotic organisms. They are multicellular and lack cell walls. They are dependent on plants for their food, hence are heterotrophic. The reserve food material of the animals is glycogen. The mode of nutrition is holozoic and they ingest food materials which are digested internally. All parts of animals grow equally and they show locomotion. The sexual reproduction normally takes place in all higher form of animals. (Fig.5)

In spite of many advantages of the 5- Kingdom system of classification, it has certain drawbacks which are pointed below.

Demerits

1. The classification is very complex one. For example, Organisms belonging to algae were spread among monera, protista and plantae.
2. Origin of all the groups were from different lines, i.e. polyphyletic and they were not monophyletic.
3. Protists were heterogenous group containing walled and organisms with no cell walls. Again, organisms may be photosynthetic and nonphotosynthetic.
4. No place was assigned to viruses.

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MODEL QUESTIONS

1. Choose the correct answers from the choices given in the brackets of each bit :

   a) The major component of cell wall of bacteria is

      (Peptidoglycan, Chitin, Cellulose, Lipoprotein)

   b) The mode of nutrition in fungi is

      (Ingestive, autotrophic, holozoic, absorptive)

   c) Major reserve food material of animals is

      (Starch, cellulose, glycogen, lipopolysaccharide)

   d) Which one is present in the bacterial cells?

      (Chloroplast, Mitochondria, Ribosomes, Nucleus)

   e) Unicellular eukaryotes are classified under

      (Monera, Protista, Fungi, Plantae)

   f) Fungal thallus is called

      (Sporophyte, Gamete, Mycelium, Sporangium)

   g) The cell wall is altogether absent in

      (Monera, Protista, Fungi, Animalia)

   h) Which one has coenocytic cells?

      (Fungi, Protista, Plantae, Animalia)

2. Write notes on the following with 2 to 3 valid points :

   a) Bacterial cell

   b) Protista

   c) Fungi

   d) Demerits of 5-kingdom classification

   e) Nutrition in Fungi

3. Differentiate between the following with 2 to 3 valid points :

   a) Protista & Monera

   b) Fungi & Animalia

   c) Plantae & Animalia

   d) Protista & Fungi

4. Give an account of 5-kingdom system of classification.

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Module-2

SALIENT FEATURES AND CLASSIFICATION OF PLANTS INTO MAJOR GROUPS

Because of the presence of cell walls, earlier Fungi, Monera and even some protists were kept under the plant kingdom. We have visualized this anomaly which has been adequately met with the 5-kingdom system of classification. Thus, our understanding of the various groups of plant kingdom has been changed. Now, Algae, Bryophytes, Pteridophytes, Gymnosperms and - Angiosperms are kept under the plant kingdom. Salient features of each group is given below.

A. **Algae**

Algae are thallose, chlorophyll bearing, eukaryotic organisms. Plant body here, is a gametopyte. They flourish in aquatic habitats, it may be fresh water or marine.

Thallus structure is very much variable. Right from the colonial, filametous forms to multi-cellular thallus structure with division of labour in different parts is seen among the algae. The major component of cell wall is cellulose and the reserve food material among algae is starch (Fig. 1).

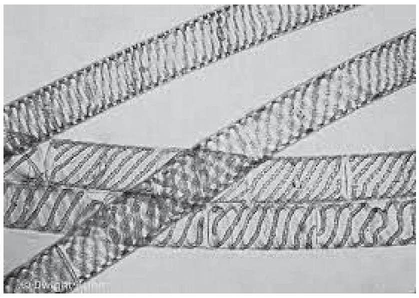

Fig. 1 : Spirogyra-thallus

Asexual reproduction normally takes place by motile zoospores. However, nonmotile aplanospores and hypnospores may develop under unsuitable conditions.

Although sexual reproduction takes place among algae, the sex organs are unicellular and never a sterile jacket layer develops around such gametes. The post-fertilized product zygote never develops into an embryo. It immediately undergoes meiosis to regenerate the gametophytic generation.

True alternation of generations never occurs among the algal members.

Example - *Spirogyra, Chara, Fucus*

B. **Bryophytes**

Byophytes and Pteridophytes form the plant groups which have sharply defined heteromorphic alternation of generation in which sporophytic generation is very short lived and completely dependent on the gametophytes.

Bryophytes are amphibious plants which flourish in marshy, swampy, moist, shady places, barks of the trees etc.

It is thallus like and may be called foliose. From the prostrate, thick, multicellular plant body, certain root like structures called scales and rhizoids develop (Fig. 2). Motile asexual spores are absent. Sexual reproduction is oogamous. Sex organs are enclosed by a sterile jacket layer.

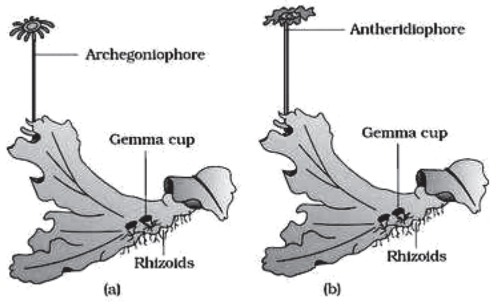

Fig. 2 : Marchantia-thallus with sex organs

Zygote formed as a result of sexual reproduction develops into the sporophyte. It is multicellular and always possesses a tendency to differentiate into different zones. Sporogonium is partially autotrophic and always depend upon the gametophyte. It is never an independent plant at maturity.

III. **Pteridophytes**

Pteridophytes are the vascular cryptogams which are the pioneers to become terrestrial in habit. The main plant body is a sporophyte and differentiated into root, stem and leaf like structures (Fig.3).


Fig. 3 : Fern Plants

The pteridophytes, similar to bryophytes have sharply defined alternation of generation. But unlike bryophytes, gametophytes are short lived structures and ends with the formation of zygote and sporophyte. The male and female sex organs are called antheridia and archegonia. These are borne in multicellular gametophytes called prothallus. Antheridia and archegonia are multicellular with a sterile jacket layer.

The sporophytes bear sporophylls (a type of specialized leaf which bears spores). The sporophylls form distinct compact stobili. Inside these, spore mother cells and ultimately pores develop. These spores are the first cells of female gametophytic generation.

Examples - *Lycopodium, Selaginella, Ferns.*

IV. **Gymnosperms**

The gymnosperms are naked seeded plants, i.e. the ovules are not protected by ovary wall before and after fertilization. Plants are medium sized trees. But giant sequoias belong to Gymnosperms. These are among the tallest trees of the world.

Plant body is differentiated into true roots, stems and leaves (Fig. 4). It is a sporophyte and gametophyte is very much reduced and completely dependent upon the sporophyte.

Fig. 4 : Pinus Plants

The leaves of the gymnosperms are compound and the fertile leaves are known as sporophylls. These aggregate to form stobili. Microsporangia and megasporangia develop within the sporophylls. These ultimately form the respective gametes. Pollination is anemophilous.

The vascular system is well developed and often secondary growth is seen.

Examples - *Cycas, Pinus, Ginkgo*

V. **Angiosperms**

These are diploid plants. Plant body is differentiated into true root, stem and leaves. The reproductive units are borne in specialized structures called flowers. These flowers bear male and female reproductive units, respectively called stamens and carpels. Here, reproduction is highly developed.

Fig. 5 : Maize Plant

Angiosperms are seen all around us. They are land forms. Representatives of it, are also seen in water. The sexual reproduction here is called double fertilization and triple fusion. Fusion products are called zygote and primary endosperm nucleus.

Fig. 6 : Banyan Tree

Endosperm formed here is a triploid structure. The angiosperms are divided into two subkingdoms. Monocotyledons and dicotyledons (Fig. 5 & 6). It is based on certain features given below :

Table - 2
Morphological Difference between dicots and Monocots

Character	Dicotyledons	Monocotyledons
Number of cotyledons in seed	Two	One
Leaf exposure	Dorsivental	Isobilateral
Leaf Venation	Reticulate	Parallel
Flower symmetry	Pentamerous	Trimerous
Root system	Taproot	Taproot gets modified

Angiosperms are the predominating flora of the present day plant forms. In order to have a systematic study of such vast number of plants, it was felt necessary to keep similar plants together and dissimilar ones, apart. Hence, people tried to classify the plants in various ways. First of all, Linnaeus attempted it on the basis of certain vegetative and floral structures. This is called artificial system of classification. Since classification based on vegetative features can be easily affected by environment, Another system developed out of it. It is called Natural system of classification and primarily developed on natural affinities among the plants. Hence, it was not only based on morphological characters but anatomy, embryology, and physiological characters were taken into consideration. This was proposed by Bentham and Hooker and hence, called as Bentham and Hooker’s system of classification.

At present phylogenetic system of classification envisaged by Engler and Prantl is accepted. Here, the origin and evolution among the plants are considered in the method of classification.

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MODEL QUESTIONS

1. Answer the questions choosing appropriate answers given under each bit :

   a) Thallose structure are seen among :
   (Pterdophytes, algae, Gymnosperms, Angiosperms)

   b) What is the major component of cell wall of plants ?
   (Cellulose, Chitn, Pectin, Peptidoglycan)

   c) Which of the following feature of Gymnosperms is similar to lower plants?
   (seed, flower, anchegonia, flower)

   d) Which are called vascular cryptogams?
   (Gymnosperms, Angiosperms, Bryophytes, Pteridophytes)

   e) What the gametophyte structure of Bryophytes?
   (Thallose, foliose, erect, filamentous)

   f) Which is completely aquatic in habit?
   (Bryophytes, Pteridophytes, Gymnosperms, Algae)

   g) Which one is amphibous in habit?
   (Algae, Pteridophytes, Gymnosperms, Bryophytes)

2. Write notes on the following with 2 to 3 valid points :

   a) Reproduction in algae
   b) Sporophytes of Bryophytes
   c) Vascular cryptogams
   d) Gymnosperms
   e) Systems of classification

3. Differentiate between the following with 2 to 3 valid points.

   a) Algae & Fungi
   b) Gymnosperms & Angiosperms
   c) Dicotyledons & Monocotyledons
   d) Phylogenetic system of classification & Natural system of classification
   e) Artificial system of classification & Natural system of classification

4. Give the salient features of different groups under plant kingdom with examples.

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Module -3

TISSUES AND TISSUE SYSTEM

Plants possess cells which are called basic units of life. After their origin, the cells tend to differentiate and even, similar cells associate themselves to carry out specific functions. These cells having similar origin, when associate together to carry out a definite function, then, it is called tissue. Plants have different organs like roots, stems, leaves, flowers etc. In these organs, tissues get organized in various ways forming tissue systems.

In this module, we will have a basic idea on tissues, their classification and the tissue systems, generally utilized in the internal organization of the plant parts.

PLANT TISSUE

Plant tissues may be classified in different ways. It can be based on structural and functional aspects or on the basis of the stages of development. Fundamentally, there are two types of tissues - Meristematic and Permanent tissues.

Meristematic tissues : Unlike the animals, big plants always grow terminally, i.e. they divide only at the shoot and root apex. Meristematic tissues or meristems are present in these regions. Hence, meristematic tissues comprise of young, undifferentiated mass of thin walled living cells. When the tissue get fully differentiated, get organized themselves together carry out specific function, it is called permanent tissue. Permanent tissues have no power of further division. First we will discuss the classification of meristems.

Classification of Meristems

Table - I shows the classification of meristems based on different characteristics.

Table-1

Meristematic tissue

Criteria of Classification

(I) Development	(II) Origin	(III) Position	(IV) Plane of division	(V) Function
Promeristem	Primary	Apical	Mass or block	Protoderm
	Secondary	Intercalary	Plate	Protambium
		Lateral	Rib	Ground

I. **Based on method of stage of development**

Promeristem : These are young initials present on root and shoot apices. The derivatives of it develop as true meristems. Hence, these are called as primordial or embryonic meristems (Fig. 1).

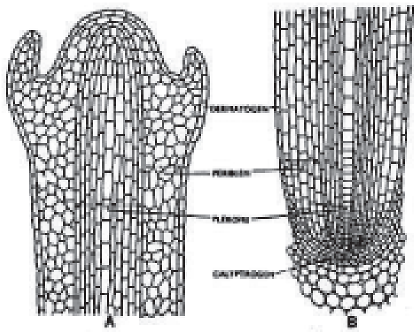


Fig. 1 : Meristem :
(A) Shoot Apex (B) Root Apex

II. **Based on Origin :** On the basis of origin, meristems are of two types : Primary and Secondary meristem. Primary meristems develop directly from promeristems. It divides and its derivatives form permanent tissues.

Secondary meristems : These develop from the tissues which have lost their power of division and hence called primary permanent tissues. However, they become meristematic at later stage. Cambium and Cork Cambium are the examples of secondary meristems.

III. **Meristems based on Position**

Position of the meristems may be apical, intercalary or lateral in a plant body and hence, these are of 3 types (Fig. 2).

Apical meristem : Its position is at the apex of root, stem and leaves. Plants or its organs grow in length because of its presence.

Intercalary meristem : This is placed between two permanent tissues. Due to uneven growth in the plant body, portions of the apical meristems get separated and function as intercalary meristem.

Example - monocot stems and leaf sheaths.

Lateral Meristems : They are present laterally in the plant organs and add thickness to the plant body. Example - Cambium and Cork Cambium.

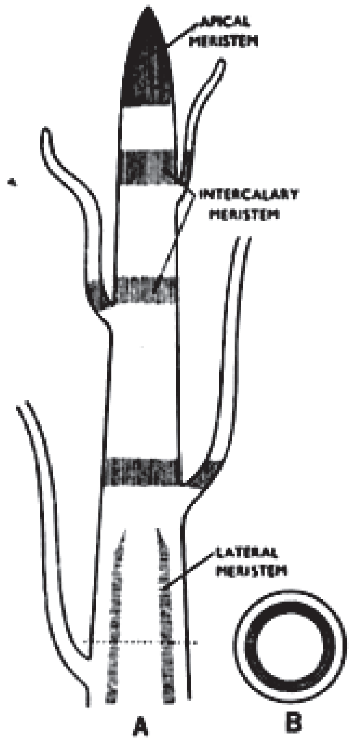


Fig. 2 : Meristems based on position
A. Vertical Section
B. Transverse Section

IV. **Meristems based on function**

There are three types of meristems on the basis of physiological function. The primary meristem gets differentiated into three zones, Protoderm, Procambium and Ground meristem.

Protoderm : It is the outermost zone and only divides radially to form epidermis.

Procamblum : This produces primary vascular tissues like Xylem, phloem and cambium. Procambium strands are scattered in monocot stems but arranged in a ring in dicot stems.

Fundamental or Ground tissue system

The meristematic tissues left between protoderm and procambium form the ground tissue system. It forms tissues between the epidermis and vascular bundle.

V. **Meristems based on plane of division**

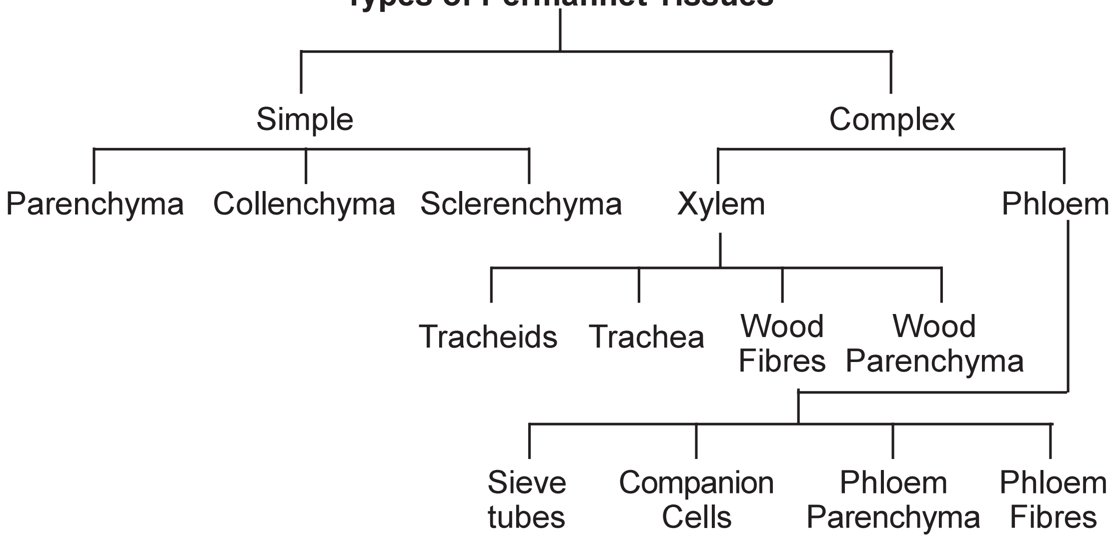
When meristematic cells have no definite plane of division and form irregular masses, then it is called mass or block meristem. Example- pith and cortex. On the other hand, the plate meristems divide at two planes, (periclinal or anticlinal) to form leaf blades. Rib meristems divide anticlincally to form columns of cells like cortex or pith.

Permanent Tissues

The cells of the permanent tissues are fully matured and do not divide further. These cells achieve definite size and shape. They can be categorized as per the following table II.

Table - II

Types of Permannet Tissues



Parenchyma :

It is the major component of living tissues. The cells of parenchyma are isodiametric, oval, spherical, round or may be elongated. The cell walls are thin, made of cellulose. Occurrence of intercellular spaces is the identifying feature of this tissue. The parenchyma tissue is responsible for photosynthesis, storage and other vital functions. It is found in the cortex, pith, mesophyll of leaf and softer regions of the plant (Fig.3). Parenchyma with Chloroplasts are called Chlorenchyma. Chlorenchyma are seen in mesophyll tissues of the leaves. Similarly, parenchyma with lot of air spaces are called aerenchyma. It is a characteristic feature of hydrophytes. It helps in floating.

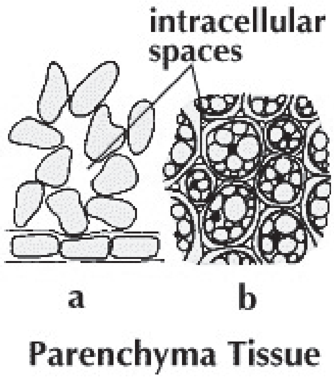


Fig.3

Collenchyma :

Like parenchyma, these are also living tissues. Collenchyma tissues are oval, spherical or polygonal, often contain chloroplasts. Cell walls are thin walled. Only difference from parenchyma is the deposition of cellulose or pectin in the intercellular spaces.

Hence, it provides some amount of support to the growing parts of the plants such as young stems, petioles of leaves, even to herbaceous stems. Besides, it carries out some amount of photosynthesis for the plants (Fig. 4).

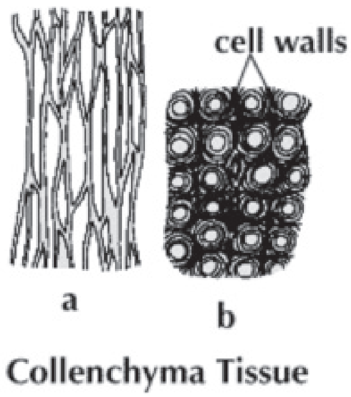


Fig. 4

Sclerenchyma :

Sclerenchyma tissues are made of dead cells. The cells may be long, narrow of short. There is deposition of lignin on cell walls. On the basis of variation in form sclerenchyma are of two types, such as fibres and sclereids. The fibres are elongated cells pronted at both ends. The sclereids are spherical, oval or cylindrical with a very narrow cavity. It provides strength and rigidity to the plant (Fig. 5).

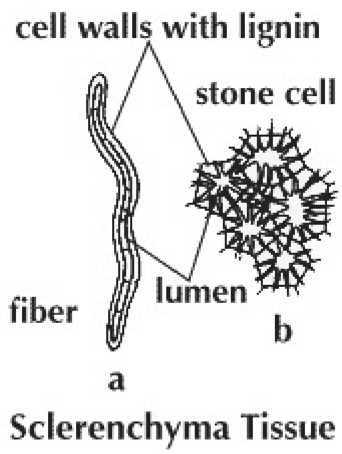


Fig. 5

Complex tissues made of two or more types of cells performing a common function. These tissues are xylem and phloem.

Xylem

The constituents of xylem are tracheids, trachea (vessels), wood or xylem fibres and wood (xylem) parenchyma (Fig. 6) Out of these, wood parenchyma is living and the rest are dead. Xylem tissues are responsible for providing mechanical support and absorbed water transport from the root system of the plants. The first formed xylem elements are called protoxylem and the later formed ones are metaxylem. When protoxylems are formed towards the pith and metaxylem towards the periphery, the type is called endarch. When the reverse happens, i.e. metaxylem towards the centre and protoxylem towards the periphery, the formation is exarch.

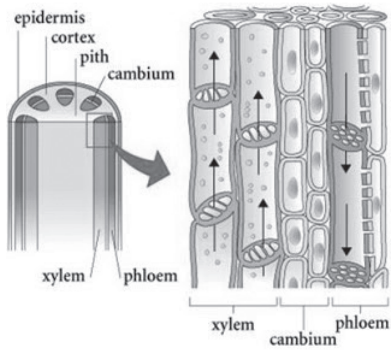


Fig. 6 : Xylem

Phloem

Phloem tissues are formed by combination of four types of tissues (I) sieve tubes (ii) Companion cells (iii) Phloem parenchyma (iv) Bast fibres (Fig.7). Out of these four, only bast fibres are made of dead cells. The main function of phloem in plants is transportation of nutrients synthesized in leaves.

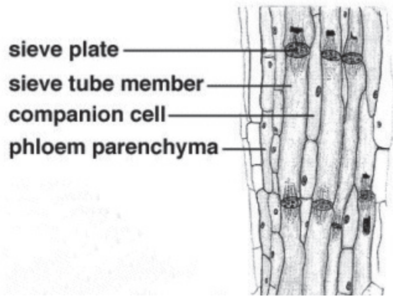


Fig. 7 : Phloem

Tissue system

On the basis of their structure and location, there are three types of tissue systems. These are epidermal tissue system, ground or fundamental tissue system and vascular or conducting tissue system (Fig.8).

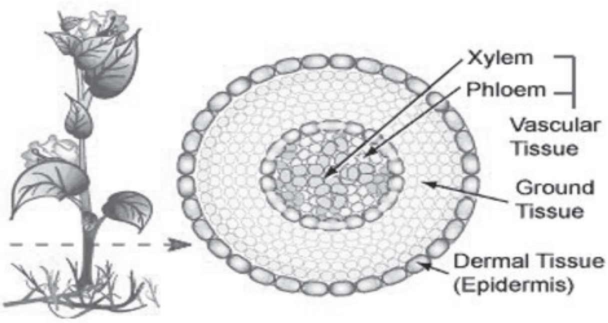


Fig. 8 : Tissue System

I. **Epidermal Tissue System**

It comprises mainly of single layered epidermis, stomata, epidermal appendages, root hairs etc. and some may be covered with a cuticle. These are elongated parenchymatous cells with no intercellular spaces and little amount of protoplasm.

It provides protection to the inner tissues. The stomata are responsible for transpiration and exchange of gases. Root hairs help in absorption of water from the soil.

II. **Ground or Fundamental Tissue System**

It is present between the epidermis and vascular tissues. It is comprised of cortex, pericycle, pith and medullary rays in the primary stems or roots. It forms the bulk of leaves and are called mesophylls. It is made of simple tissues like parenchyma, collenchyma and sclerenchyma.

Its main function is storage of food and it also helps in secretion, excretion, mechanical strength etc.

III. **Vascular Tissue System**

The components of vascular tissue system are xylem and phloem. Xylem and phloem together form vascular bundle. In dicotyledonous stems, a cambium is present between xylem and phloem. Such vascular bundles are open. When no cambium is present, it is closed. When xylem and phloem bundles are present in alternate manner, it is radial arrangement (roots). In stems they are present adjacent to each other and is called conjoint (Fig. 9). All tissues such as pericycle, vascular bundles and pith present at the inner side of endodermis form stele.

The function of the vascular bundles are mechanical support and transport of water and nutrients to different parts of the plant.

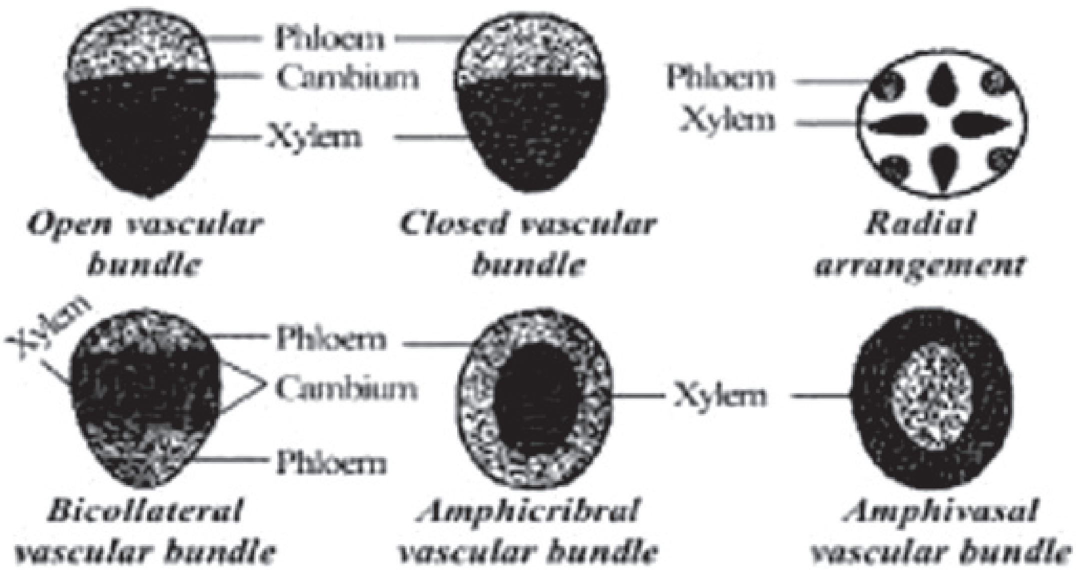


Fig. Various types of vascular bundles

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MODEL QUESTIONS

1. Write the appropriate answers from each bit from the choices given under each bit :

   (a) In which part of the plant are meristems not seen?
   (root tip, stem tip, leaf tip, wood tip)

   (b) Which is an example of secondary meristem?
   (Xylem, Phloem, Cambium, Endodermis)

   (c) Which part of the meristems does develop into intercalary meristems?
   (Primary, Lateral, Secondary, Apical)

   (d) As per the meristems based on plane of division, which are responsible for pith and cortex?
   (Rib meristem, Mass meristem, Plate meristem, Procambium)

   (e) Which one is simple but dead permanent tissue?
   (Parenchyma, Collenchyma, Sclerenchyma, Chlorenchyma)

   (f) Which one is a living tissue with intercellular spaces?
   (Collenchyma, Sclerenchyma, Tracheids, Parenchyma)

   (g) Which one is a living tissue in xylem ?
   (Trachea, Tracheids, Xylem parenchyma, Phloem Parenchyma)

   (h) Which one is a dead tissue is phloem?
   (Bast fibres, Sieve tubes, Companion Cells, Phloem Parenchyma)

   (i) From which tissue system do vascular bundles arise?
   (Epidermal, Vascular, Fundamental, Peripheral)

2. Write notes on the following with 2 to 3 valid points :

   (a) Ground tissue system
   (b) Phloem
   (c) Xylem
   (d) Parenchyma
   (e) Sclerenchyma
   (f) Lateral meristem
   (g) Promeristem

3. Differentiate between the following with 2 to 3 valid points :

   (a) Permanent tissue & Meristematic tissue
   (b) Xylem & Phloem
   (c) Parenchyma & Sclerenchyma
   (d) Primary Meristem & Secondary Meristem
   (e) Epidermal Tissue System & Ground Tissue System.
   (f) Ground Tissue System & Vascular Tissue System.

4. Give an account of different types of permanent tissues.

5. What is meristem? Discuss the classification of meristems.

6. Describe the organization of tissue system in plants.

***

Module - 4

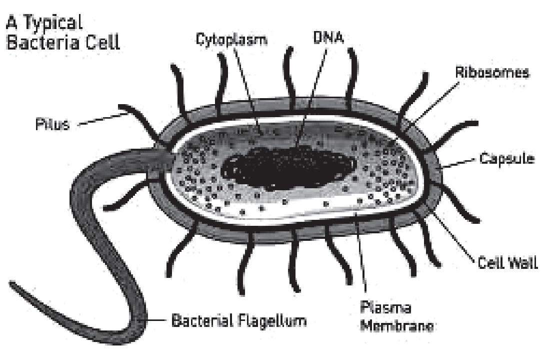
STRUCTURE OF CELL

The term cell was coined by Robert Hooke in 1665, while observing the box-like cavities in their slices of commercial cork under the microscope. On the basis of presence or absence of well-organized nucleus, cells may be differentiated as i) prokaryotic and ii) eukaryotic. All higher organisms are composed of cells with well organized nucleus. The cell is a self-contained unit, capable of all functions including regeneration and reproduction. Cells are structural and functional units of life. New cells arise from pre-existing ones.

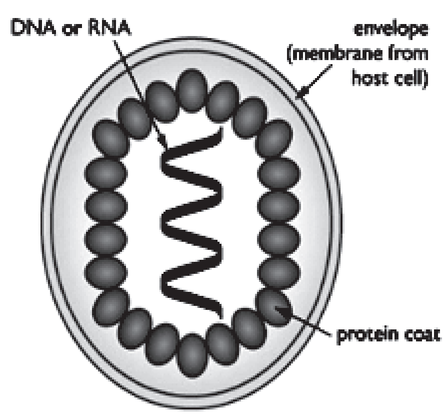
Prokaryotic Cell - These are the simplest kind of cells. These are smaller in size, consisting of cytoplasm surrounded by a cell membrane and a rigid cell wall. The nuclear material is a naked DNA without any protein and not enclosed in an envelope. The prokaryotic cell contains 70s ribosomes for protein synthesis. There is no membrane bound cell organelle like mitochondria, endoplasmic reticulum, golgi complex, lysosomes etc. True vacuoles are absent.

The group "prokaryotes" comes under Monera. This includes eubacteria archaebacteria, green bacteria, purple bacteria, virus, prochlorophyta, cyanophyta and mycoplasma.

Bacteria - Bacteria have a protective covering called cell wall. Beneath this, there is plasma membrane which encloses protoplasm containing various types of RNA, DNA, proteins and organic molecules. Though simple in structure, they are the most abundant of all life forms on earth to day.



Viruses - Viruses are on the borderline of life between non-living and the living organisms. They have some characteristics of living organisms such as ability to reproduce while some non-living characters like ability to crystallize and absence of metabolic processes make them unique. They have a very simple structure with a circular nucleic acid (either DNA or RNA)



surrounded by a protein coat. Viruses live only as parasites and can reproduce themselves only in a plant / animal / bacterium host cell at the expense of metabolic machinery of the host cell.

Eukaryotic Cell - Eukaryotic cells found in plants and animals are more complex structures. They have a membrane-bound organized nucleus enclosing the genetic material and an extensive endomebrane system. The exterior of the cell in bound by a plasma membrane. The plant cells have rigid cell walls external to plasma membrane. Cell wall is absent in animal cells. The cytoplasm contains a number of membrane bound organells like mitochondria, endoplasmic reticulum, Golgi Complex, lysosomes and plastids (only in plant cells) among other reserve materials.

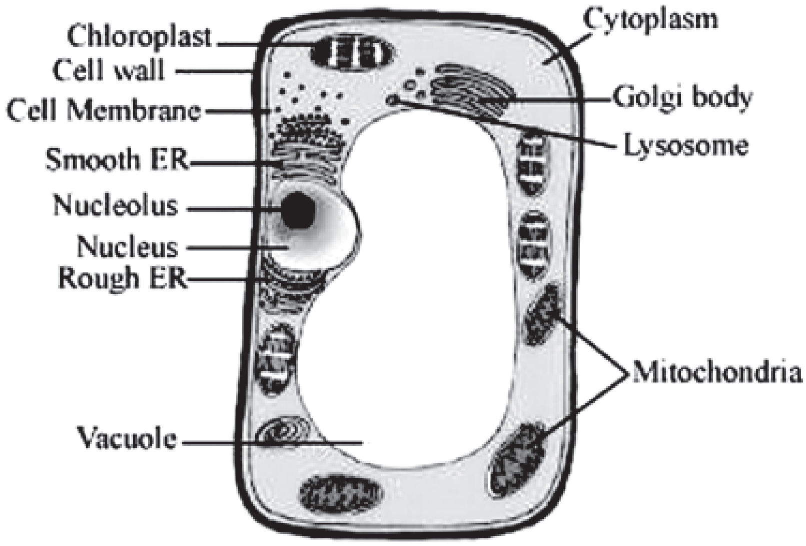
Difference between Prokaryotic Cell and Eukaryotic Cell

Characters	*Prokaryotic Cell*	*Eukaryotic Cell*
1. **Size**	0.5–5 μm diameter.	Diameter 1 μm–40 μm.
2. **Nucleus**	No true nucleus, single chromosome, nuclear membrane absent.	True nucleus, nuclear membrane is present, more than one chromosome is present.
3. **Organelles**	Membrane-bound organelles are absent.	Membrane-bound organelles are present.
4. **Ribosomes**	Ribosomes are 70s and randomly scattered.	Ribosomes are 80s, can be free or attached to ER.
5. **Cell division**	Cell divides by simple fission.	Cell divides by mitosis or by meosis.

Ultrastructure

i) **Cell Wall -** It is a fairly rigid, protective and supportive layer surrounding the cell external to plasma membrane. Plant cell walls are made of cellulose. It consists of middle lamella, primary wall and secondary wall. Middle lamella is the layer between two adjacent cells. Primary wall is deposited inner to middle lamella. It is thin and elastic in younger cells, but rigidity comes with cell enlargement. Major structural components are cellulose, hemicellulose and pectin. Most abundant structural proteins are glycoproteins. In some plants after the maximum growth is reached, a secondary wall is laid down inner to the primary wall. Secondary wall is multilayered and is strengthened by the deposit of lignin. Cell wall protects the cell and gives a definite shape to it.

ii) **Cell membrane -** Cell membrane or plasma membrane and other subcellular membranes, together constitute the biological membranes. Biomembranes are dynamic, selectively permeable and around 75A^0 in



A Typical Plant Cell

thickness. The membranes are composed of lipids and proteins with small amounts of carbohydrates as glycolipids or glycoproteins. Lipids are mostly in the form of phospholipids. Phospholipids are amphipathic molecules with both polar (hydrophyllic) and non-polar (hydrophobic) region. Proteins can be structural proteins, carrier proteins, receptor proteins and enzyme proteins. Chemical organization of plasma membrane is explained by a) Unit membrane concept proposed by David Robertson in 1959, and b) Fluid Mosaic model proposed by S. Singer & G. Nicolson in 1972.

Unit Membrane Concept

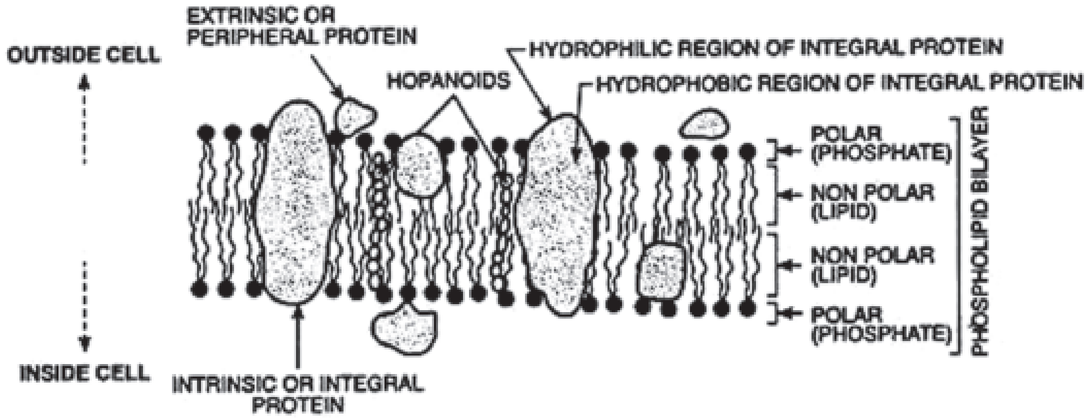
According to this concept, the unit membrane consists of a bimolecular lipid layer sandwiched between outer and inner layers of protein.

High resolution electro micrograph of plasma membrane shows a 'dense-light-dense' three-layered structure.

Fluid-Mosaic Model

According to this model, the membrane contains a biomolecular lipid layer the surface of which is interspersed with proteins individually. This arrangement views membrane as a mosaic of protein molecules bubbling in a fluid bi-layer of lipids. The protein molecules act as channels and pumps that move different molecules into and out of the cell. Membrane surface also contains receptor proteins that allow cells to detect external signaling molecules like hormones. Fluid mosaic model of cell membrane structure is widely accepted.

Fluid Mosaic Model of Cell Membrane



iii) **Cytoskeleton -** All eukaryotic cells have a cytoskeleton made up of a network of protein filaments. It is composed of micro filaments, intermediate filaments and microtubules. Microfilaments form a network close to the cell membrane and are made up of actin. They are the smallest of the cytoplasmic filamentous structure. They perform both cytoskeletal and contractile function and help in cellular motion.

Tubules are the most prominent structural component of cytoskeleton. They are long, hollow cylinders which are polymers of protein tubulin. They help to maintain cell shape and important for intercellular movement.

Microtubules form structures such as asters and spindles during cell division and complex organelles such as centrioles, basal budies, cilia and flagella (wherever they are found). During cell division, the microtubules radiate out from the microtubule organizing centre, located near the nucleus.

In addition to the microfilaments and microtubules there is another component called intermediate filament. Their average diameter is between the microfilaments and microtubules and they are said to help the cell organelles in anchorage.

iv) **Cell organelles -** The eukaryotic cell has a number of organelles such as endoplasmic reticulum, Golgi apparatus, mitochondria, lysosomes, peroxisomes and the nucleus. In plant cells, in addition to the above, a large membrane-bound vacuole filled with liquid and plastids are also seen. The remaining cytoplasm is referred to as cytosol. The intracellular membrane system of a eukaryotic cell is much larger in size than that of a prokaryotic cell. It provides enough surface area for the exchange of materials and other cellular reactions.

a) ***Endoplasmic Reticulum (ER)***

Cytoplasm was known to have no structure until the discovery of electron microscope. That cytoplasm is permeated by a membranous network called endoplasmic reticulum (ER), was revealed only after the introduction of electron microscope. Endoplasmic reticulum is a three dimensional network of membrane channels which constitutes more than half of the total membrane of the cell. ER is a highly folded and convoluted structure and forms a single continuous sheet enclosing one continuous sac. The interior of the sac is called "cisternal space" or "ER lumen". This is separated from the cytoplasm by a single membrane which mediates the communication between these two compartments. ER provides the cell with a compartment for storage of substances to be kept separate from cytosol. In addition, it has a key role in the biosynthesis of macromolecules.

ER is a double membranous organelle which consists of interconnecting flattened sacs called cisternae or interconnected tubules or vesicles. Cisternae are temporary storage sites for nutrients.

Rough and Smooth Endoplasmic Reticulum (RER and SER) : ER is differentiated into two regions, granular or rough endoplasmic reticulum (RER) and agranular or smooth endoplasmic reticulum (SER). These two regions also differ considerably in shape : rough ER is organized in stacks of flatteded sacs called cisternae and smooth ER consists of a mesh work of fine tubules. In RER, the outer surface in the cytoplasmic site of the membrane is studded with small particles called ribosomes whereas in SER, the ribosomes are absent. Ribosomes are the sites of protein synthesis. ER (both RER and SER) performs many mechanical functions of the cell by providing mechanical support. Large surface area of ER helps in the exchange of materials across the membrane by diffusion and active transport. ER may act as a kind of circulatory system for the distribution of various substances in the cell.

b) ***Golgi Apparatus***

Camillo Golgi in 1898 discovered a reticular structure in the cytoplasm of nerve cells, for which he received the Nobel prize. This structure was named as Golgi complex after him. Golgi complex is located near the cell nucleus.

Golgi complex is structurally similar in both plant and animal cells, but in plant cells it is more evident and is called as dictyosomes which are stack-like or plate-like bodies. Animal cells contain comparatively much smaller number of Golgi bodies than plant cells.

The Golgi complex consists of (a) stack of flattened sacs or cisternae (b) small rounded transport vesicles (c) larger vacuoles filled with amorphous or granular material.

The transformation of membrane from one type to another is a step which leads to the formation of a vesicle. The chemical composition of Golgi complex is intermediary between ER and the plasma membrane.

Golgi apparatus performs many functions in the cell such as processing of the molecules secreted by the ER, and packaging of the molecules according to their final destination. Golgi apparatus functions in recycling of the membrane components.

c) ***Microbodies -*** These are single unit membrane bound small spherical bodies such as Lysomes, Peroxisomes & Glyoxysomes etc.

Lysomes

These particles were called lysosomes (lysis = dissolution, soma = body) due to their hydrolytic activity. A lysosome is a single membrane bound vesicle that either buds off from the releasing face of Golgi apparatus or arises directly from ER. The lysosomes are rich in hydrolases, specially acid phosphatase.

Polymorphism in Lysosomes

Polymorphism, i.e. existence of a structure in more than one form , is an important feature of lysosomes. Several different forms of lysosomes have been identified within the cell as primary lysosomes, secondary lysosomes, residual bodies and autophagic vacuoles.

Lysosomes are responsible for the intracellular digestion of a variety of substances such as food molecules, disease causing organisms, etc.

Lysosomes are also responsible for digestion of cell's own cytoplasmic constituents. This process is called autophagy.

Peroxisomes and glyoxysomes

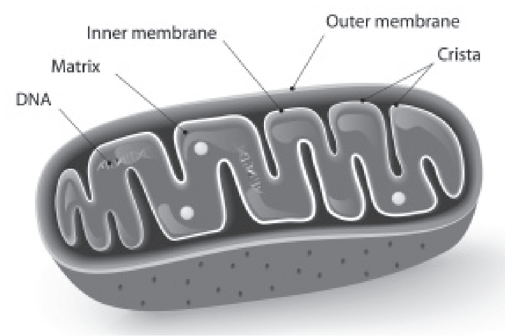
Peroxisomes and glyoxysomes are microbdies formed from ER which superficially resemble the lysosomes. Peroxisomes are spherical bodies limited by a single membrane. The centre of peroxisome is occupied by a fine granular core called 'nucleoid'.

Peroxisomes contain oxidizing enzymes which are synthesized by ribosomes. These enzymes which produce hydrogen peroxide on oxidation, while peroxisomal catalase, the enzyme found in lysosomes, destroys hydrogen peroxide, toxic to the cell.

Glyoxysomes are a form of peroxisome which contain enzymes like isocitrate lyase, and malate synthetase which are specific to gloxylate cycle. They also have several Krebs cycle enzymes. Glyoxysomes are the essential components of plant cell.

d) **Mitochndria**

Mitochondria (mito-thread, chondrion-granules) are generally rod shaped elongated structures. They are commonly known as the "power house" of the cell, as they are the sites of ATP (energy currency) production in the cell.



A mitochondrion consists of two membranes (outer and inner) and two compartments (outer and inner). The outer three layered membrane is separated by a space of 6-8 nm from the inner membrane. The inner membrane has a number of infoldings which are called cristae or mitochondrial crests. Cristae vary in number and shape. Mitochondria themselves are often found concentrated in regions of high metabolic activity.

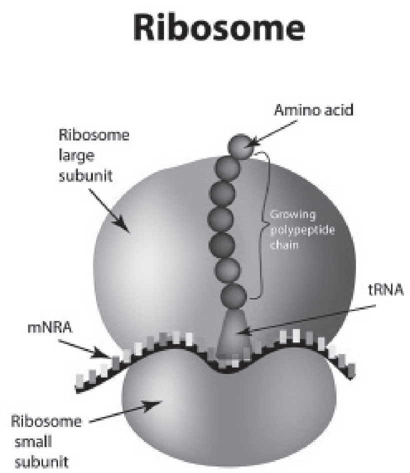
The fluid filled space between the outer and inner membrane is called the intermembrane space. The space surrounded by inner membrane is called mitochondrial matrix. It is dense and is made-up of proteinaceous material. The matrix is generally homogeneous but sometimes, may contain a fine filamentous material or small dense granules. Matrix is continuous within the mitochondria. Matrix contains ribosomes, RNA and one or more molecules of circular DNA, an important characteristic of mitochondria. It is because of the presence of DNA, RNA and ribosomes that mitochondria are self replicating and can synthesise some of their own proteins and membrane material. The enzymes involved in TCA cycle and fatty acid oxidation are found in the matrix.

Cristae appear to be covered with mushroom-like particles, called F_1 particles, elementary particles or oxysomes. These particles are small stalked sphere-like structures containing an enzyme, ATPase that is involved in oxidative phosporylation.

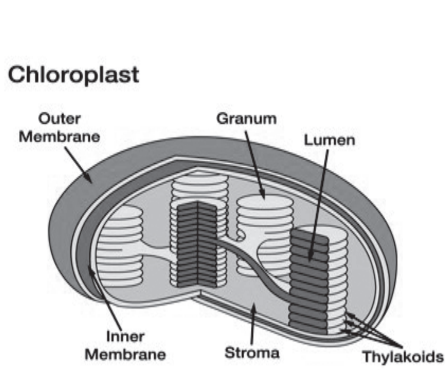
Since the inner membrane of the mitochondria is the site of ATP production in the cell, greater the number of cristae, the larger the surface area for ATP production.

e) ***Ribosome***

Ribosomes are non-membranous particles made up of rRNA and proteins. They occur freely in the cytoplasm or attached to the endoplasmic reticulum. Each ribosome has two subunits, a smaller one and a larger one. Prokaryotic cells have 70s ribosomes (s=sedimentation coefficient) and eukaryotes have 80s ribosomes. It is the site of protein synthesis.



f) ***Chloroplast***



Plastids are the organelles found in plant cells only. Like mitochondria they are bound by two membranes. Plastids self replicate as they contain their own genetic material, i.e. DNA, RNA and ribosomes. There are many types of plastids such as chloroplasts, chromoplasts and leucoplasts depending on the colour pigment they contain.

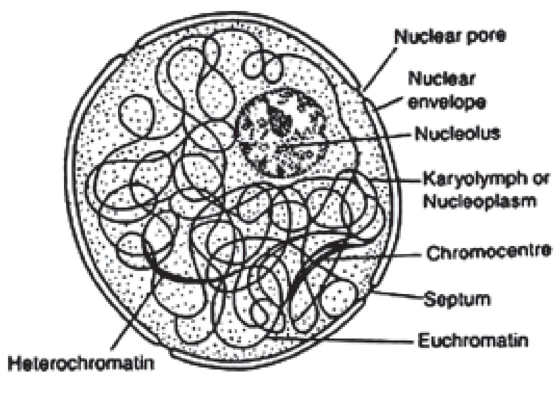
Chloroplasts, that are mainly found in the cells of leaves of green plants and the most common ones are biologically important plastids. Chloroplasts are limited by a smooth outer membrane which regulates the transport of materials between the cytoplasm and the interior of the organelle. The inner membrane runs parallel to the outer membrane and is provided with extensive folding. The inner membrane gives rise to a series of internal parallel membranous sheets called lamellae. Lamellae are suspended in a fluid-like matrix called stroma. Stroma contains about 50% of soluble protein, ribosomes, DNA and the machinery for protein synthesis.

Most of the lamellae in the chloroplasts are organized to form sac like structures called thylakoids. They are flattened vesicles arranged as a membranous network within the stroma. Thylakoids may be stacked like a pile of coins forming the 'grana'.

The pigments, chlorophyll, carotenoids and plastiquinone are present in the thylakoid membranes involved in photosynthesis. Chlorophyll is the green coloured pigment present in chloroplasts. The function of chlorophyll is to trap the light energy required for the formation of two products : ATP and NADPH essential for the reactions involved in CO_2-assimilation.

g) **Nucleus**

Nucleus is the dominant organelle controlling all the activities of the eukaryotic cell. The prokaryotes have nuclear regions in the cytoplasm as opposed to eucaryotes, that have a prominent well defined nucleus. There are variations in the size and shape of the nucleus. However, some cells lack nucleus at maturity such as RBCs and sieve tube cells (transport cells in vascular plants).



Nucleus is composed of two membranes known as 'nuclear envelope'. The outer and inner membranes are separated by a narrow space called the perinuclear space. The outer membrane remains in contact with endoplasmic reticulum and the inner membrane surrounds the nuclear contents. At certain places, the nuclear envelope is interrupted by the presence of small structures called "pores". The pores are enclosed by circular structures called annuli. The pores and annuli together constitute the pore complex. Both the membranes of the envelope are in continuity around these pores. The pores help in the exchange of material between nucleoplasm (nuclear fluid) and cytoplasm. The nuclear envelope is a dynamic structure. It is not just a physical barrier but regulates the passage of ions and small molecules. During the cell division, the nuclear envelope disappears and reappears during nuclear reorganization.

Nuceoplasm contains a number of structures like nucleolus, chromatin and chromatin network (chromosomes). The nucleolus is a spherical structure which is not separated from the rest of the nucleoplasm by a membrane. It is produced from and is associated with a specific nucleolar organizing region (NOR) on a chromosome. In the nucleolus rRNA is synthesized and the ribosomal subunits and proteins are partially assembled.

During the resting stage of the cell, the chromosomes are uncoiled in a loose, indistinct network called "chromatin". Chromosome contains DNA, RNA and protein.

Chromosomes

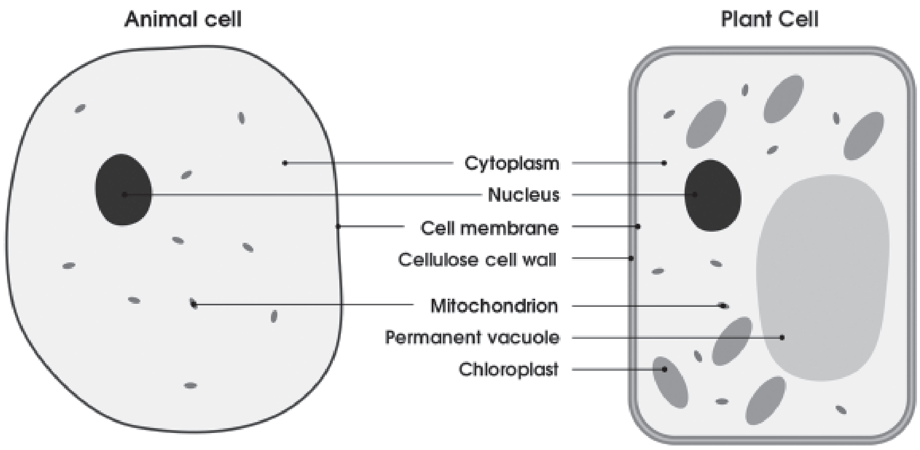
The chromosomes in their true sense are found only in eukaryotic cells as complexes of DNA and histone protein. During interphase (phase in between two cell divisions), chromosomes remain as fine threads without any distinct shape. However, during cell division they get condensed to shorter and thicker structures and are distinctly visible. DNAs in eukaryotic cells are very large molecules. However, packaging of DNAs in the chromosomes is such that not only they remain compact, they also remain functional. This is achieved by formation of repeating units of nucleosomes, as proposed by Kornberg in 1974.

h) **Vacuole**

Vacuole is a non-cytoplasmic area bound by a membrane bilayer. Growing plant cells contain many vacuoles, which coalesce to form a large central vacuole in matured cells. The aqueous solution inside is called cell sap and the sorrounding membrane is called the tonoplast. Vacuole provides turgidity to the cell.

Plant and Animal Cells

The internal structural organisaton and information related with hereditary characters and metabolic pathways are more or less similar in all eukaryotic cells. However, plant and animal cells differ in some respects. Cell wall is unique to plant cells. Plant cells also contain pigment-containing organelles called plastids, more specifically chloroplasts as found in green plants. Chloroplasts help the plants to prepare their own food in presence of sunlight (autotrophs). Presence of a large vacuole distinguishes the plant cell from the animal cell. Endoplasmic Reticulum (ER) plays a significant role in the formation of vacuoles. Glyoxysomes, found in some plant cells are involved in lipid metabolism.



The animal cells often contain flagella and cilia for movement and centrioles for cell division. These are absent in plants.

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MODEL QUESTIONS

1. Select the correct answer from the choices under each bit :

   (a) Plasma membrane is principally composed of :
   - i) Starch
   - ii) DNA and ATP
   - iii) Lipids & Proteins
   - iv) Nucleotides and aminoacids

   (b) Cell sap is present in :
   - i) Mitochondria
   - ii) Chloroplast
   - iii) Nucleolus
   - iv) Vacuole

   (c) The chemical substance that provides energy in the cell is :
   - i) RNA
   - ii) DNA
   - ii) ATP
   - iv) ADP

   (d) Mitochondria are primarily associated with
   - i) excretion
   - ii) cellular respiration
   - iii) protein synthesis
   - iv) transmission of hereditary characters.

   (e) Protein synthesis takes place at :
   - i) Chloroplast
   - ii) Golgi buddies
   - iii) Lysosome
   - iv) Ribosomes

   (f) Chloroplast is essential for :
   - i) photosynthesis
   - ii) respiration
   - iii) transpiration
   - iv) protein synthesis

   (g) Genetic material of a cell is
   - i) protein
   - ii) mRNA
   - iii) tRNA
   - iv) DNA

2. Write short notes on the following with 2 to 3 valid point :
   - a) Plasma membrane
   - b) Ribosomes
   - c) Nucleus
   - d) Endoplasmic reticulum
   - e) Chromosomes

3. Draw a labelled diagram depicting the ultrastructure of a typical plant cell.

4. Describe the structure and function of mitochondria and chloroplasts.

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Module - 5

BIOMOLECULES

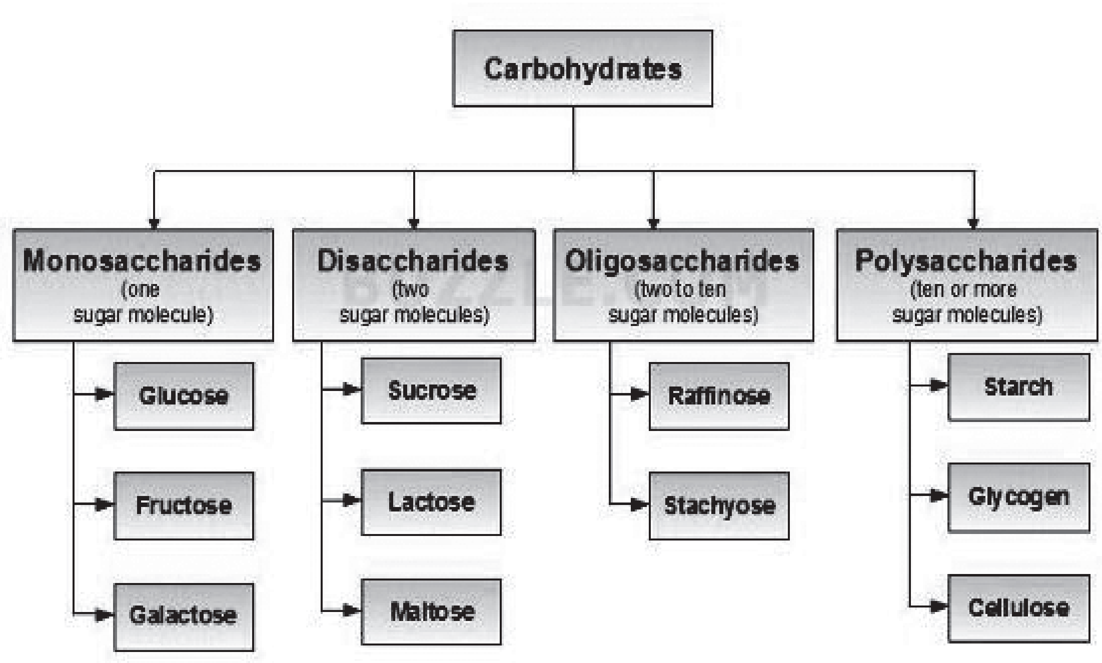
Biomolecules are organic compounds that are normally present as essential components of organisms. Besides water, important biomolecules of life are : (1) Carbohydrates, (2) Proteins, (3) Lipids, (4) Nucleic acids and (5) Enzymes etc.

CARBOHYDRATES

Carbohydrates are long chains of sugars and therefore are called polysaccharides. They are good sources of energy. Monosaccharides are simple sugars that are composed of 3-7 carbon atoms. They have a free aldehyde/keto group, which acts as reducing agent and therefore they are known as reducing sugars. Disaccharides are made of two monosaccharides, joined by a glycosidic bond. Mono and disaccharides are sweet, crystalline and water soluble substances. Polysaccharides are polymers of monosaccharides. They are complex carbohydrates, not sweet and insoluble the water. They are also not in crystalline form.

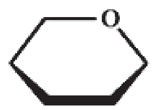
They are compounds of carbon, hydrogen and oxygen atoms. The simplest form has the empirical formula $C_n(H_2O)_n$. The formula indicates that carbohydrates are hydrates of carbon and hence the name carbohydrate.

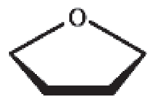
Classification



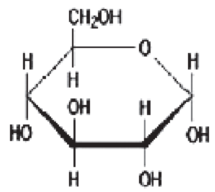
1. **Monosaccharides -** These are the simplest carbohydrates with single poly hydroxy aldehyde or keto units. The minimum number of carbons in a monosaccharide is three and it can go upto seven.

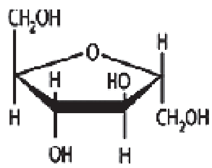
Pentose and hexose sugars can exist in open chain or ring structure. The ring structure may be pyranose or a furanose.


Pyranose


Furanose

Pyranose has a six-membered ring with five carbon atoms and one oxygen atom. Furanose form has five-membered ring with four carbon atoms and one oxygen atom. The rest of the carbon atoms remain outside the ring. In solution, the pyranose forms of sugars are more stable than furanose forms.


Glucopyranose


Fructofuranose

Classification of Monosaccharides

No. of Carbon	Type of sugar	Aldoses	Ketoses
3	TRIOSES	Glyceraldehydes	Dihydroxyacetone
4	TETROSES	Erythrose	Erythrulose
5	PENTOSES	Ribose, Xylose	Ribulose, xylulose
6	HEXOSES	Glucose, Galactose	Fructose
7	HEPTOSES	Glucoheptose	Sedoheptulose

2. **Oligosaccharides -** These are carbohydrates formed by condensation of 2 to 9 monosaccharides, joined by glycosidic bonds. When hydroxyl groups attached to two monosaccharides react and eliminate a molecule of water, a C-O-C bond is formed. The oligo saccharides can be di-(2-monosaccharides), tri (3-mono) tetra (4-mono) and so on.

3. **Polysaccharides :**

Polysaccharides are polymers of 10 or more monosaccharides or their derivatives.

a) **Homopolysaccharides -** It contains a single type of monosaccharides.

Example - Starch, Glycogen & cellulose.

i) **Starch -** Natural starch consists of two components - (a) amylose and (b) amylopectin. Amylose is a long unbranched straight chain of α-D-glucose and amylopectin is a branched chain of α-D-glucose. Starch is a storage polyacchanoide and an important reserve food material of plants.

ii) **Glycogen -** It is a branched chain polymer of α-D-glucose resembling amylopectin. However, the molecule is more compact compared to starch. It is the major reserve food of animals and fungi.

iii) **Cellulose -** It is the most abundant biomolecule in the biosphere and is the structural component of cell wall in higher plants. It is composed of β-D-glucose.

b) **Heteroplysaccharides :**

It contains different types of monosaccharides.

Example - Pectin, Hyaluronic acid

i) **Pectin -** It is a structural heteropolysaccharide contained in the primary cell walls of terrestrial plants. Major component is D-galacturonic acid.

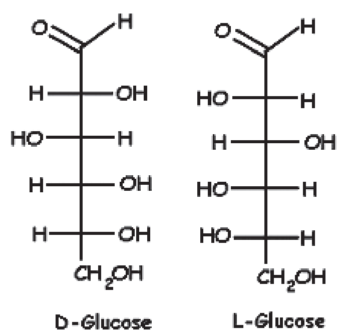
ii) **Hyaluronic acid -** It is a heteropolysaccharide formed by thousands of N-acetyl glucosamine and glucoronic acid units.

Reducing Sugars

All monosaccharides and some disaccharides like lactose, maltose etc. are reducing sugars. Reducing sugars have free aldehyde or Keto groups.

Isomerism :

Monosaccharides show isomerism. Isomers are compounds having same molecular formulae but different molecular structures. The presence of an asymetric carbon atom (carbon atom with different groups) make possible the formation of isomers of a compound.



There are several types of classification of isomerism like

1. D & L (dextrorotatory & levorototary) - can rotate plane of polirized light to right (D, dextrorotatory, +) or to left (L, levoratatory, -)
2. α & β anomers - mutarotation
3. Epimers - interchange of -OH and -H groups in carbon 2, 3 & 4 of glucose.
4. Pyranose and Furanose ring structure.
5. Aldose - Ketose isomerism

But simply they can be classified as (a) Structural and (b) Stereoisomers.

Optical isomerism -

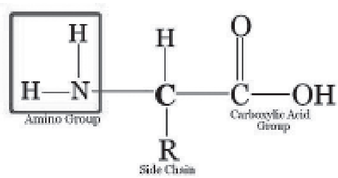
Optical isomers are one type of stereo isomers where they appear as mirror images of each other around asymetric carbon atom.

PROTEINS

Proteins are polymers of amino acids. Amino acids undergo condensation reactions and are joined by peptide bonds. A polypeptide chain containing more than 30 amino acids is conventionally accepted as a protein molecule. To be able to perform their biological function, proteins fold into one or more spatial conformations driven by non-covalent interactions, hydrogen bonding, ionic interactions, hydrophobic packing and Van der Waals forces. This three dimensional structure is very important as it determines its function.

Amino acids

Amino acids contain an amino (-NH2) group and a carboxyl (-COOH) group. Only about twenty amino acids occur naturally as the building blocks of proteins. These are all α-amino acids meaning thereby that the amino group is attached to the carbon atom next to the -COOH group i.e. in the α-position.



Essential and non-essential amino acids

Plants can synthesize all the amino acids from simpler substances. The ones which animals cannot synthesize, but must obtain in their diet, are known as essential amino acids.

The essential amino acids are : i) lysine, ii) tryptophan, iii) histidine, iv) leucine, v) phenylalanine, vi) iso-leucine, vii) threonine, viii) methionine, ix) valine and x) arginine.

Non-essential amino acids are those which can be synthesized in the body in adequate amount. They need not be supplied from outside.

Classification of amino acids

Basing on the chemical nature of the side chain (R), the naturally occurring amino acids are categorized into three main groups, the neutral, basic and acidic amino acids.

The standard twenty amino acids found in proteins are grouped into seven different categories :

i) Aliphatic amino acids - The side chain (R group) is neutral, non-polar.
Ex. - glycine, alanine

ii) Hydroxy amino acids - the side chain has -OH group
Ex. - serine, threonine

iii) Sulphur-containing amino acids - The side chain has sulphur group.
Ex. - cystine, methionine

iv) Dicarboxylic amino acids and amides - The side chain has extra carboxylic group.
Ex . - glutamic acid, aspartic acid. They exist in amide forms like glutamine & asparagine.

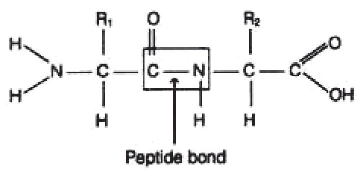
v) Basic amino acid - They have an additional amino group without forming amides.
Ex. - lysine, arginine

vi) Aromatic amino acids - They have a cyclic structure with a straight chain bearing carboxylic and amino groups.
Ex. - phenylanine, tyrosine

vii) Heterocyclic amino acid - Here the nitrogen group is in the ring structure.
Ex. - proline

Besides these there are about 300 additional natural amino acids which are not constituents of protein, but take part in different metabolic pathways.

Peptide bond - When the carboxylic group (-COOH) of one amino acid reacts with the amino group (-NH2) of another amino acid with the elimination of a water molecule, a peptide is formed. Since only two amino acids are involved, it is called a dipeptide.



The linkage, -CO-NH-, by which the above two aminoacids are joined together is called peptide bond. A long chain with a large number of amino acid residues is called a polypeptide chain.

Function of amino acids

1. They are the building blocks of proteins.
2. They serve as storage of nitrogen in the form of amides.
3. They participate in formation of vitamins and coenzymes.
4. Surplus aminoacids are deaminated to form organic acids, which may be converted to glucose (gluconeogenesis).

Protein structures

Proteins have four levels of structure : Primary, Secondary, Tertiary and Quaternary structures.

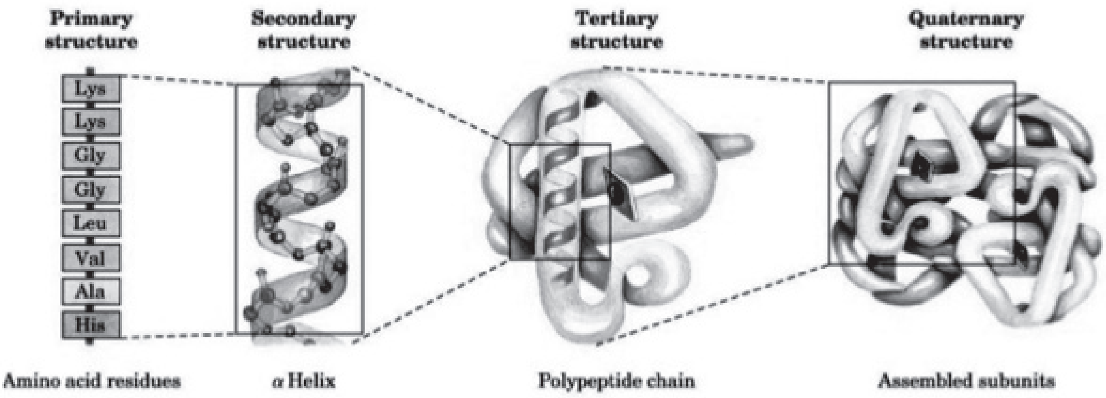
Primary Structure - It is a linear sequence of amino acid residues making up a polypeptide chain. Only peptide bonds are associated with the primary structure.

Secondary Structure- Secondary structure results from hydrogen bonding between the polypeptide chains or within the same polypeptide. We get a α-helix or a β-sheet.

Tertiary Structure - Extensive folding of polypeptide chain results in a complex, rigid and globular structure. Ionic bonds, hydrogen bonds, hydrophobic interactions and disulfide linkage come into play.

Quaternary Structure - When two or more polypeptide chains associate to form a functional protein, that is called the quaternary structure.

Ex. - Hemoglobin has four subunits. Loss of activity in one submit can have profound effect on the protein's functioning.



Types of proteins- Based on shape, they can be 1) globular proteins and 2) fibrous proteins.

Globular proteins - Almost all enzymes, protein hormones, antibodies etc. are globular proteins.

Fibrous proteins - They are structural or protective proteins and come from animal sources. There are three different conformations like a) α-Keratin, b) β-Keratin and c) Collagen.

Based on composition, they can be 1) simple, 2) conjugate.

Simple Proteins - Proteins made up of amino acids only.

Conjugate proteins - Functional proteins with non-protein components come under this category. Many of the regulatory enzymes are conjugate proteins.

Function of Proteins -

1. Structural proteins constitute the body of living organisms.
2. They are constituents of biological membranes.
3. Participate in tissue formation.
4. Act as signal receptors and as hormones.
5. Involved in antigen-antibody reactions, Ex. - immunoglobin.
6. As enzymes they catalyze biochemical reactions.
7. Histone proteins are responsible for packaging of DNA.

LIPIDS

Lipids are the esters of fatty acids with alcohol. A variety of lipids occur in plant cells, which can be classified as :

a) Simple lipids : (i) Fats and oils & (ii) Waxes

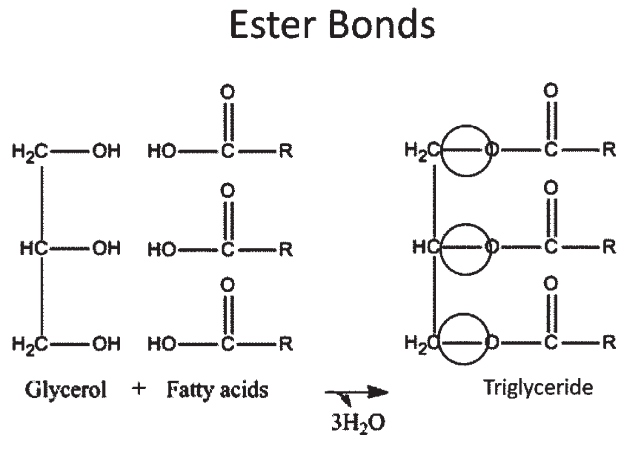
b) Compound lipids : (i) Phospholipids & (ii) Glycolipids

c) Derived lipids : (i) Sterols & Steroids

Fats and Oils : They occur in all plant and animal cells. At normal temperature and pressure, fats are semisolid and oils liquid. Chemically they are called triglycerides, formed by the esterification of some fatty acids and glycerol (a trihydric alcohol).

Formation of ester bond

-OH group of alcohol reacts with -COOH group of a fatty acids to form an ester linkage. A molecule of H_2O is released. This reaction is reversible. Lipase enzymes control the speed of this reaction. Fatty acids can be of one



type or many types. That is why many different types of fats are found in plants. They are insoluble is water but soluble in organic solvents such as ether, alcohol & Chloroform.

Waxes - In many plants waxy substances occur as a surface layer on the epidermis of leaves, fruits & stems. They are impermeable to water and are formed by esterification of a higher fatty acid with an aliphatic or aromatic monohydric alcohol.

Phospholipids - They contain phosphate groups. Out of the three -OH groups in glycerol, one (1st or 3rd) is esterified by phosphoric acid and rest two by fatty acids.

Glycolipids - They are conjugate lipids containing some carbohydrate molecules.

Sterols - These are derived from compounds with a central "phenanthrene" ring. Sterols occurring in plants are called phytosterols. Steroids are manufactured from sterols in the cells. They are very important biological compounds.

Fatty acids - Fatty acids are long chains of carbon atoms with a -COOH group at one end. They can be i) Saturated and ii) Unsaturated.

Saturated fatty acids - Fatty acids are said to be saturated when they do not possess any double bond. The carbon atoms are always with even numbers and are filled with hydrogen atoms. Ex. - Palmitic acid (16 carbon atoms).

Unsaturated fatty acids - Fatty acids with one or more double bonds are called unsaturated. A major fraction of fatty acids in plants are polyunsaturated. They are good for health because they seem to lower cholesterol in the blood. Ex. - Linolenic acid, Linoleic acid.

Function of Lipids -

1. They provide structural framework of living tissues.
2. They serve as prime fuel reserve for metabolism
3. They are deposited as reserve food in seeds and serve as a source of energy during germination and growth.
4. Oils are used by human beings for various purposes. They are of great medicinal value.
5. Oils are used for preparation of soaps and margarin.

NUCLEIC ACIDS

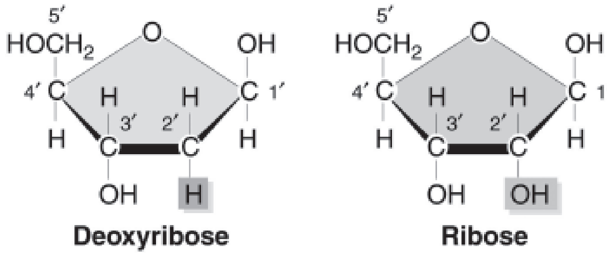
Friedrich Miescher isolated a new class of substance in 1869 from the nuclei of pus cells and called it "nuclein". Subsequent research revealed that this substance is rich in phosphorus, and contained carbon, hydrogen, oxygen and nitrogen and was called nucleic acid. Now, we know that there are two types of nucleic acids. (i) deoxyribonucleic acid (DNA) and ii) ribonucleic acid (RNA). DNA is ordinarily double stranded and is present in all plants, animals, prokaryotes and viruses. RNA is single stranded except in certain viruses.

Chemical Composition

Nucleic acid is a polymer of nucleotides, therefore primarily a polynucleotide. Each nucleotide is composed of three units, (a) a pentose sugar, (b) one of the four/five nitrogenous bases and (c) a phosphate group.

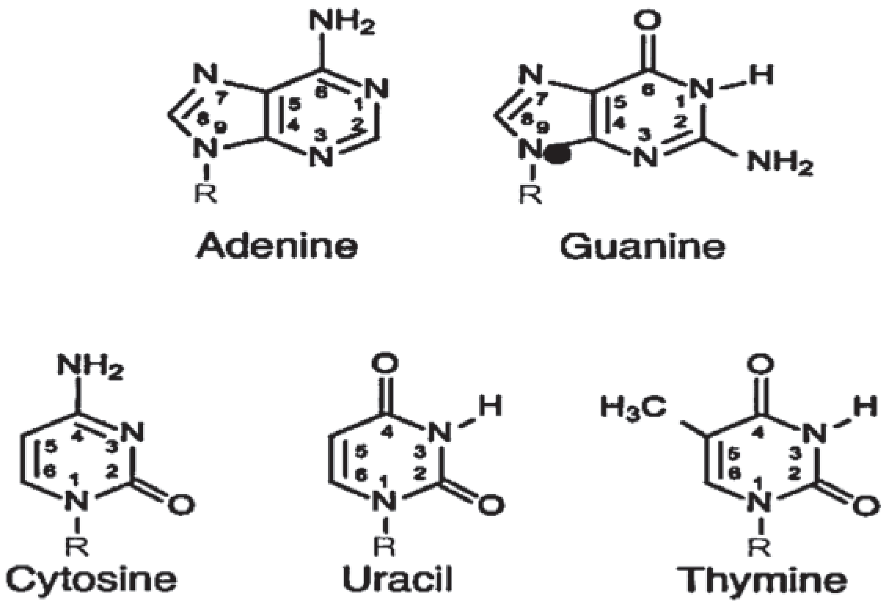
Pentose Sugar

In case of DNA, it is a deoxyribose sugar and in case of RNA it is a ribose surgar.



Nitrogenous bases

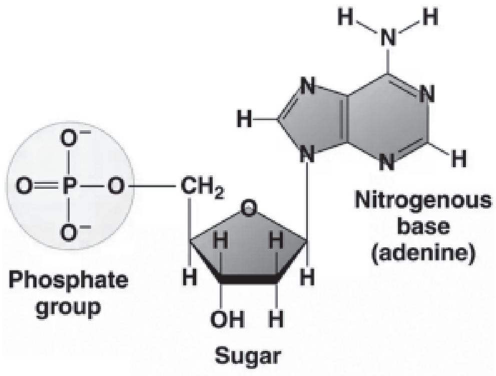
Nitrogenous bases are of two types, (i) Purines and (ii) Pyrimidines. Purines, are heterocyclic aromatic organic compounds with two - carbon nitrogen ring bases, adenine and guanine. Pyriamidines are one-carbon nitrogen ring bases, thymine and cytosine. While these four nitrogen bases are present in DNA with linkage of A-T and G-C, RNA has another base uracil in place of Thymine.



Nucleotide & Nucleoside

Nucleoside = Pentose sugar + nitrogenous base

Nucleotide = nucleoside + phosphate



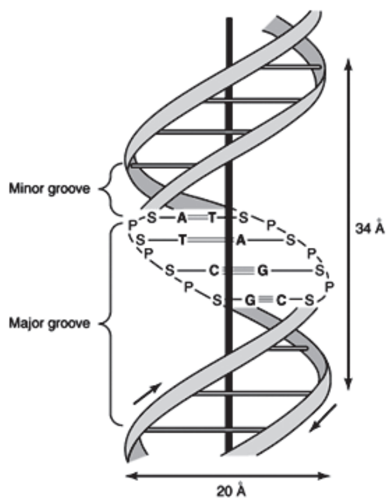
Nucleosides are formed by the linkage of carbon 1 of pentose with nitrogen 9 of purine-base or nitrogen I of pyrimidine base. Nucleotides are phosphoric esters of nucleosides. Depending on the nature of pentose sugar, one can have ribonucleotides or deoxyribonucleotides. Phosphorylation can take place at carbon 2', 3' & 5' positions of a ribonucleoside and 3' & 5' positions of a deoxyribonucleoside.

Primary Structure of DNA

Primary structure of DNA is formed by the covalent backbone consisting of deoxy ribocleotides linked to each other by phosphodiester, therefore consists of alternating deoxyribose and phosphate residues.

Secondary structure of DNA

Watson & Crick proposed the secondary structure of DNA in 1953, for which they shared the nobel prize with Wilkins in 1962. A double helical structure of DNA as proposed by them has the following main features.



i) The DNA molecule consists of two polydeoxyribonucleotide strands, helically twisted (double helix) and connected together by hydrogen bonds between nitrogen bases (A-T, G-C).

ii) The diameter of the DNA molecule is $20A^0$ and one complete turn of DNA measures $34A^0$, incorporating 10 base pairs.

iii) Both the strands have sugar-phosphate backbone, but are antiparallel to one another.

iv) The strands are complementary to each other with purine base of one strand linked to the pyrimidine base of other strand.

RNA - Like DNA, RNA is a polynucleotide made of ribose sugar, nitrogen bases (adenine, guanine, cytosine & uracil in place of thymine) and phosphoric acid, but is single stranded. Cellular RNAs are non-genetic and are of three types, mRNA, rRNA and tRNA.

Messenger RNA (mRNA)

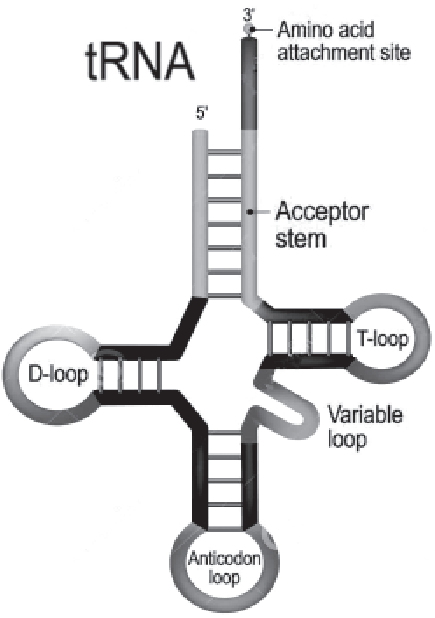
5 to 10% of cellular RNA is of this type. It is short-lived and formed during protein synthesis. DNA transfers the genetic information through this for synthesis of particular proteins.

Ribosomal RNA (rRNA)

Almost 80% of total cellular RNA is of this type. It acts as a structural component of ribosome and helps in polypeptide synthesis.

Transfer RNA (tRNA)

It is the smallest of three types and may be composed of 75 to 100 nucleotides. It is also called soluble RNA. The clover leaf model of tRNA was proposed by Holley in 1964. It has three loops and a small variable arm or extra loop. The anticodon loop has the complementary base sequence with respect to a particular triplet codon of mRNA. The 3'-end of tRNA acts as the amino acids attachment site. It transfers aminoacids from the cytoplasm to the ribosome, the site of protein synthesis.



Circular DNA

In prokaryotes or cells without nucleus, the chromosome is represented by circular DNA containing the entire genome. Ex-plasmids.

Biological Significance of DNA

1. It is the genetic material for eukaryotes.
2. It contains all the biologically useful informations in a stable form.
3. It is able to replicate and is transmitted to the next generation.
4. It is capable of variations i.e. mutation and recombination, which are stable and inheritable.
5. Genes are composed of DNA and are located within the chromosomes.
6. The unit of genetic information is a codon, a group of three adjacent nueleotides that specify a single amino acid in polypeptide chain. Therefore the genetic code is a 'triplet code'.

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MODEL QUESTIONS

1. Select the correct answers from the choices given under each bit :

   (a) Which of the following elements is not present in a nitrogenous base :

   i) nitrogen ii) hydrogen

   iii) carbon iv) phosphorus

   (b) Which of the following is the smallest RNA :

   i) mRNA ii) r-RNA

   iii) t-RNA iv) Chromosomal RNA

   (c) A nucleoside is :

   i) base + sugar ii) base + phosphate

   ii) sugar + phosphate iv) base + sugar + phosphate

   (d) Which one is not a reducing sugar :

   i) glucose ii) sucrose

   iii) lactose iv) maltose

   (e) Unsaturated fatty acids contain one or more :

   i) double bond(s) ii) hydrogen bonds

   iii) ionic bonds iv) single bonds

   (f) Nucleic acid is a polymer of :

   i) nucleosides ii) nitrogenous bases

   iii) sugar phosphates iv) nucleotides

   (g) Which one has a clover leaf shape :

   i) m-RNA ii) r-RNA

   iii) t-RNA iv) mt DNA

   (h) Cellulose is made up of ubaranched chain of :

   i) glucose ii) fructose

   iii) galactose iv) glucosamne

2. Write short notes on the following with 2 to 3 valid points.

   a) Nucleotide

   b) Peptide bond

   c) Essential amino acids

   d) Fatty acids

   e) Oligosaccharides

   f) Reducing sugars

3. Give an account of structure of proteins.

4. Describe the double helical structure of DNA.

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Module - 6

ENZYMES

Enzymes are biological catalysts that accelerate rate of biochemical reactions in living cells. They do not get altered, destroyed or used up in the course of reaction. Most enzymes are proteins but a few RNA molecules, called ribozymes are also reported to have catalytic properties. They may function inside or outside the cell. Exoenzymes or Extroacellular enzymes are widely prevalent in bacteria, fungi & some insectivorous plants like *Drosera* and *Nepenthes.* Being proteins, they are produced through the process of translation and are concerned with expression of genetic information. Enzymes accelerate the reaction rate by lowering the activation energy. Almost all enzyme-catalysed reactions are reversible, but there are certain exceptions.

Chemical nature :

Although enzymes are proteins, many of them depend for their activity on the presence of small non-protein molecules termed as cofactors. The enzyme plus cofactor is called *holoenzyme.* When the cofactor is removed, it becomes inactive and is called *apoenzyme.*

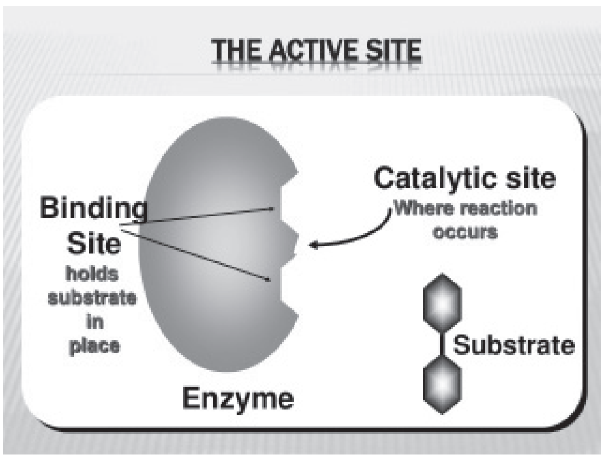
Apoenzyme + Cofactor = Holo-enzyme
(Inactive) (Active)

Cofactors can be either *metal ions,* called activators or small organic molecules, called *coenzymes.* Coenzymes can be transiently associated or tightly bound called *prosthetic groups* (FAD in succinate dehydrogenase).

Structurally, enzymes are fairly large molecules with many functional *active sites.* These are three dimensional sites where specific substrate molecules get attached to form enzyme-substrate complex. The process of activation and reaction of the substrates occurs at these centres.

$$E + S \rightleftharpoons ES \rightarrow P$$

enzyme plus the substrate — enzyme-substrate complex — product



Types of Enzymes :

A scheme for nomenclature of enzmes and its classification was adopted in 1961 by the Enzyme Commission set up under the International Union of Biochemistry (IUB). The commission has recognized six major classes basing on the biochemical reactions they catalyze :

1. **Oxidoreductases -** They catalyse oxidation - reduction reactions.

   Ex-Catalase, Peroxidase.

2. **Transferases -** They are involved with transfer of chemical groups like methyl, aldehyde, ketonic & phosphoryl groups. Ex- Hexokinase.

3. **Hydrolases -** They catalyze hydrolytic cleavage. Ex. - Phosphatase, Urease.

4. **Lyases -** They catalyze addition of groups to double bonds and vice-versa.

   Ex. - Aldolases, Decarboxylases

5. **Isomerases -** They calalyze reactions involving formation of isomeric forms of substrates.

   Ex. - Triose phosphate isomerase.

6. **Ligases -** They catalyze joining or ligation of two substrates coupled wih breakdown of ATP or other triphosphate.

   Ex - Thiokinase.

Properties -

1. **Catalytc Power**

   Enzymes are very effective even in minute quantites. Therefore they are far superior to ordinary chemical catalysts. They sometimes increase the rate of reactions by 10^6 to 10^{12} times.

2. **Specificity**

   Enzymes are highly substrate-specific. When it is specific to only one substrate, the speciciticity is called absolute. When it is specific to a group of substrates with some common functional groups, the enzyme is said to exhibit group specificity -

   Absolute specificity -

   Ex.- $\text{Sucrose} + H_2O \xrightarrow{\text{Sucrase}} \text{Glucose} + \text{Fructose}$

Group Specificity -

$$\text{Glucose} + \text{ATP} \xrightarrow{\text{hexokinase}} \text{Glucose} - 6 - \text{phosphate} + \text{ADP}$$

Some Enzymes also exibit stereo chemical and bond specifities.

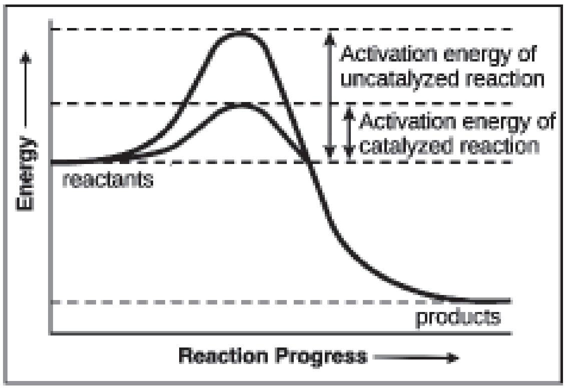
3. **Regulation**

   Enzymes can either be activated or inhibited by other molecules. When the end products of a metabolic pathway inhibit the function of one of the first enzymes, it is called ***feed back inhibition.*** This helps in regulation of metabolites and energy conservation of the cell.

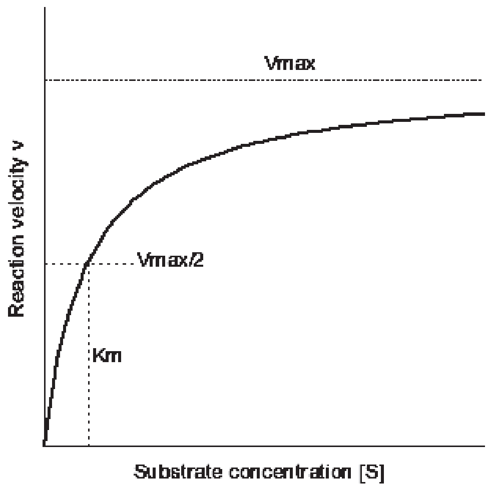
4. **Reversibility :**

   Most of the enzyme-catalysed reactions are reversible.

Mechanism of Enzyme Action



All biochemical reactions are energy dependant. Enzymes, however, lower the activation energy of the reactions so that reactants can be possible with available supply of energy. Activation energy is the energy required to activate the reactions, so as to move them from the ground state to the transition state. Higher the activation energy, slower is the reaction rate. An enzyme lowers the activation energy of the substrates by forming enzyme-substrate complex. Michaelis & Menten in 1913, while explaining the velocity of enzymatic reactions proposed an equation popularly, called the Michaelis - Menten's equation.



$$v = \frac{v_{max}[S]}{[S] + K_m}$$

Where v - initial velocity,

Vmax - maximum velocity,

Km - Michaelis constant

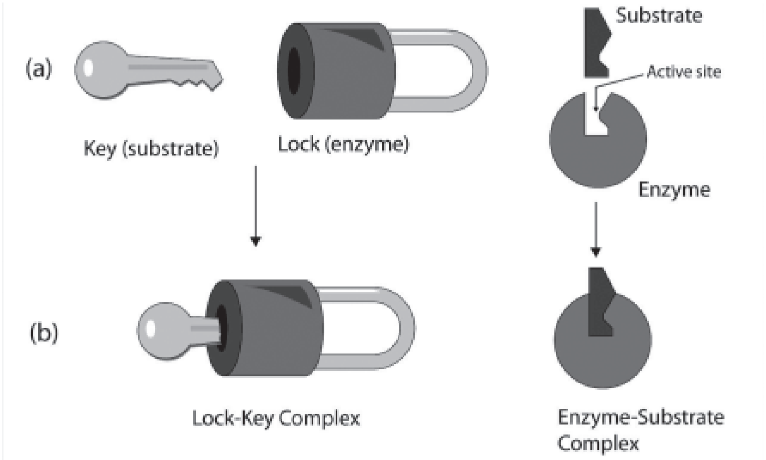
[S] - substrate concentration.

Km is the Michaelis - Menten constant which shows the concentration of the substrate when the reaction velocity is equal to one half of the maximal velocity of the reaction.

Models

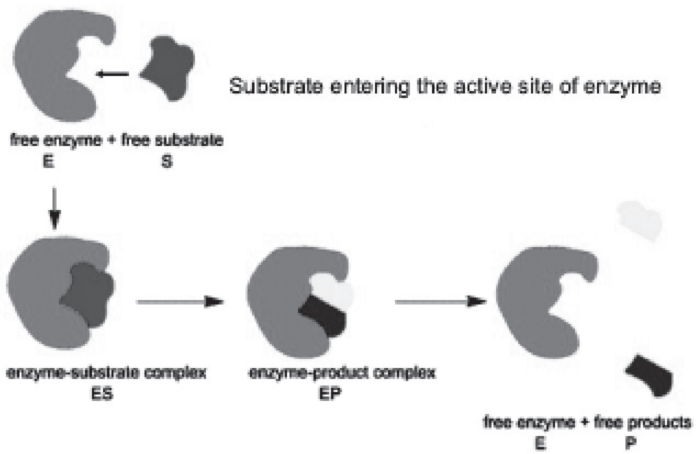
1) ***Lock & key hypothesis -***

Lock-and-key mechanism was proposed by Emil Fischer in 1890. It explains the binding between the active site of an enzyme and a substrate molecule. The active site is thought to have a fixed structure (the lock) which exactly matches the structure of a specific substrate (the key).



2) ***Induced - Fit hypothesis -***

Induced - Fit hypothesis was proposed by Daniel Koshland in 1958. It attempts to explain that when the active site comes in contact with the proper substrate, the enzyme moulds itself to the shape of the molecule so as to enhance or inhibit its activity.



Factors that affect enzymatic reactions

1) Enzyme Concentration
2) Substrate Concentration
3) pH
4) Temperature
5) Inhibitors/Activators

***

MODEL QUESTIONS

1. Select the correct answer from the choices under each bit :

(a) Which one is a coenzyme :

i) Magnsium   ii) Iron

iii) NAD   iv) Manganese

(b) Holoenzyme consists of

i) Apoenzyme and substrate

ii) Protein and fat

iii) Prosthetic group and coenzyme

iv) Apoenzyme and coenzyme

(c) Enzymes are composed of :

i) Carbohydrates   ii) Proteins

ii) Lipids   iv) Nucleic acids

(d) Peroxidase belongs to which class of enzyme :

i) Trnasferases   ii) Oxidoreductase

iii) Hydrolases   iv) Ligases

(e) Enzymes are useful to plants becase they :

i) help in their movements

ii) enhance absorption of water

iii) are the building block of chlorophyll

iv) are essential for their metabolic process

(f) Enzymes acceterate biochemical reaction in the cell by :

i) lowering the energy of activation

ii) raising the energy of activation

iii) raising the energy level of products

iv) lowering the energy level of products

2. Write short notes on the following with 2 to 3 valid points :

a) Specificity of enzymes

b) Lock & Key hypothesis

c) Michaelis & Menten equation

d) Classification of enzymes

3. Discuss the mechanism of enzyme action.

***

Module - 7

DIFFUSION, OSMOSIS AND IMBIBITION

In higher plants, water, mineral nutrients, organic substances etc. are transported from the part of absorption of substances to the part of utilization. All these are carried out by the cellular organization of the plants. The cells organise themselves to carry out all the functions as per the genetic information of the organism. They are the ultimate structural and functional unit of any living organism.

In living cells, water constitutes more than 70%. Water regularly moves in or out of the living cell through certain processes like diffusion, osmosis and imbibition to keep it functioning and for maintaining the water balance of the cell. We will discuss these three processes in this module.

DIFFUSION

Diffusion is a physical phenomenon in which solid, liquid or gases move from higher concentration to lower concentration. No energy is consumed in the process. In diffusion, molecules move in a random fashion. It is a slow process. The process is very important for the plants for the movement of gases within the plant body.

Diffusion is affected by gradient of concentration, the permeability of cell membranes, temperature and pressure (Fig. 1).

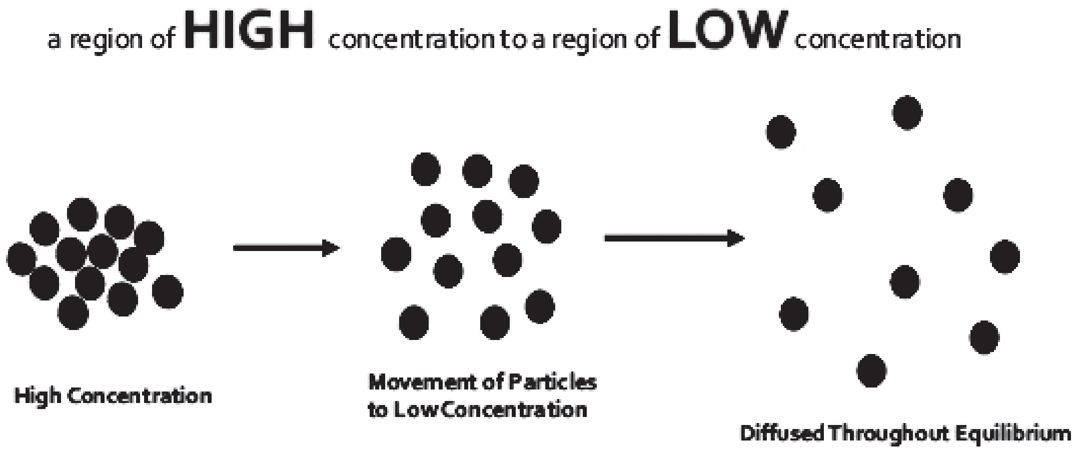


Fig. 1 : Diffusion

Facilitated diffusion

Normally, living cells have membranes. Membranes are made of lipoprotein bilayer. For the substances with hydrophilic composition, it becomes difficult to diffuse across the membrane. Hence, it needs certain carriers to facilitate its transport across the membranes. Membrane proteins serve this purpose and provide sites to bind molecules for transport across the membrane. Such diffusion is called facilitated diffusion. It does not take place against the concentration gradient, because there is no expenditure of energy (Fig.2)

The proteins form channels in the membrane to carry the molecules. Such protein molecules are called 'porins'. These porins sometime, make channels across the membranes (Fig. 3). When transport is only in one direction, then it is called uniport. When, on the other hand, the molecules move in both directions, the facilitated diffusion is antiport. Sometimes, protein molecules accommodate two types of molecules to be transported simultaneously. It is then, called symport.

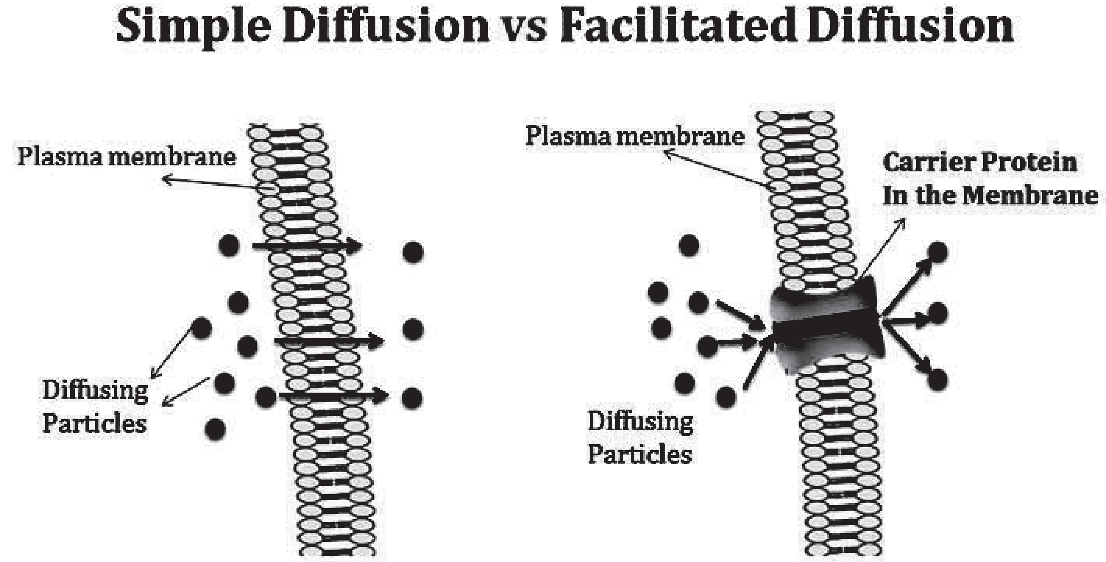


Fig. 2

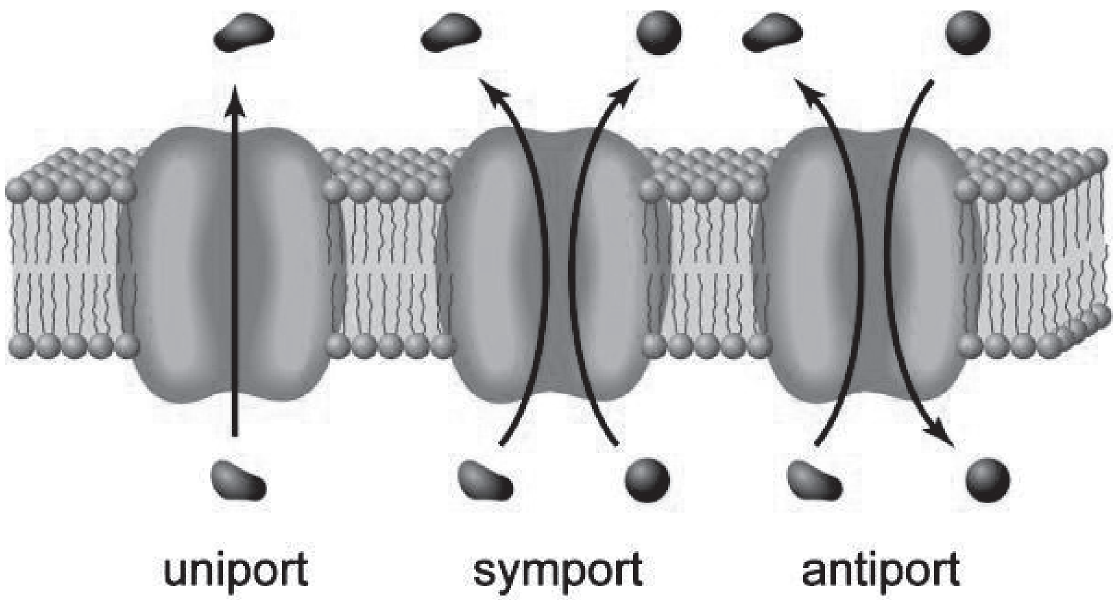


Fig. 3 : Transport through membrane channels

OSMOSIS

Osmosis is a process by which solvent (generally water) molecules move from a solution of lower concentration to a solution of higher concentration across a semipermeable membrane.

Plant cells are surrounded by a living cell membrane and nonliving cell wall. Cell wall is freely permeable to water and substances soluble in it. Hence, it doesnot stand as the barrier. Mature cells in plants contain 2 to 3 large vacuoles whose membranes are called vacuolar membrane or tonoplast. The vacuolar fluid is the tonoplasm and that develops the solute potential of the cell. The cell membrane and vacuole membranes are semipermeable and determines the movement of the molecules into and out of the cell. Certain terminologies are used in connection with osmosis. These are given below :

I. **Water Potential :** Like all other molecules, water molecules do have kinetic energy. In liquid or gaseous form, they are in rapid and constant random motion. Pure water has the highest kinetic energy. This is called the water potential. If we add a solute to it, its water potential will decrease. If we keep two systems adjacent to each other, net movement of water will be from higher water potential to the lower water potential. It is denoted by Ψ. The water potential of pure water at standard temperature and no pressure is taken as 0.

II. **Solute potential :** By addition of solute, the water potential decreases and the concentration of water decreases. The amount of decrease of water potential due to the solute is called solute potential or W_S. It is always negative.

III. **Semipermeable membrane :** This type of membrane allows only passage of solvent (water) molecules and does not allow the solutes to pass through it. Examples - Parchment paper, white membrane of the eggs, fish bladder etc.

IV. **Osmotic Pressure :** It is the actual pressure which may be applied to a solution, when the solution is separated from its pure solvent (water) by means of a semi permeable membrane. As a result, inflow of the solvent to the solution is prevented. It is denoted by symbol π.

V. **Endosmosis and Exosmosis :** Generally root systems of the plants absorbs water by their root hairs. Here, the osmotic pressure of the cell sap is higher than outside root hair zone in the soil. This type of solution is called hypotonic. As a result, the net movement of water will be into the plant cell. This process is called endosmosis. On the other hand, when plant cell is placed in hypertonic solution, water outflows from the cells. Here, osmotic pressure of the outside solution is higher than the cell sap. This is called exosmosis. When the cell is placed in a solution whose osmotic pressure is equal to the pressure of the outside solution, it is called isotonic condition. There will be no net movement of water.

VI. **Turgor Pressure and Wall Pressure :** When a cell is placed in water, it enters into the cell. Pressure develops inside the cell contents and ultimately on the cell wall. This pressure which develops in the cell wall because of the osmotic entry of the water is called turgor pressure. The turgor pressure depends on the amount of water entered. It is the maximum when the cell is fully enlarged or frugal and there can not be no net entry of the water into the cell. The reverse case happens, when the cell can accumulate the maximum amount of water. This the flaccid condition.

Due to the increase in the turgor pressure, the cell wall stretches. The cell wall provides definite shape to the cell and is elastic in nature. This also exerts pressure on the cell sap in opposite direction. So, this pressure which is exerted by cell wall on the cell sap is called wall pressure.

VII. **Diffusion Pressure Deficit (DPD) :** A pure solvent like water has the maximum diffusion pressure. When a little bit of solute is added to the solvent, the diffusion pressure of it gets reduced. The amount by which the diffusion pressure of molecules of solvent in a solution is decreased is called Diffusion Pressure Deficit (DPD).

The DPD of any cell is the measure of its absorbing capacity. It is also called the suction pressure. Each cell has TP, OP and DPD. When the cell is fully turgid, DPD becomes zero as it can not absorb water. DPD = OP-TP. When cell is placed in hypertonic solution OP of the cytoplasm increases and TP decreases. When cell has no TP or it is fully flaccid, DPD becomes equal to OP, i.e. DPD=OP (Fig. 4).

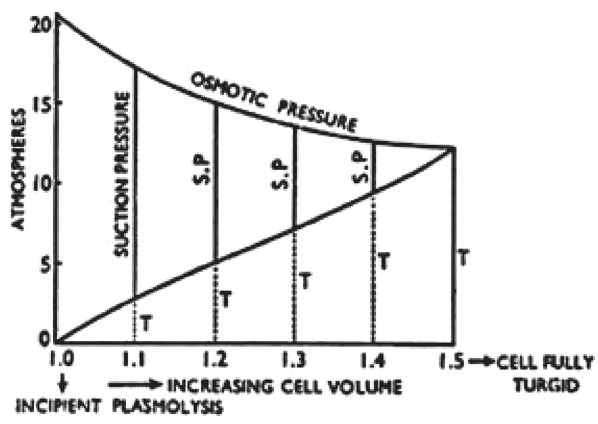


FIG. 666. Interrelationship of osmotic quantities of plant cells. S. P. Suction pressure. T. Turgour pressure.

Fig. 4

VIII. **Plasmolysis :** Plasmolysis occurs when water moves out of the cell and cell membrane, thereby shrinkage of protoplasm occurs. It happens when a cell is placed in hypertonic solution, water moves out of the cell. The cell loses its original form. The exosmosis starts causing slight shrinkage of the protoplasm and the cell is said to be plasmolysed.

IMBIBITION

Imbibition is a physical process. It is a special type of diffusion when water is absorbed by the solids causing its increase in volume. Seeds, even dry woods absorb water and swells up. It is the process of adsorption of hydrophilic colloids. These are submicroscopic capillaries present on the surface of such particles. Imbibing particle is called imbibant (Fig. 5).

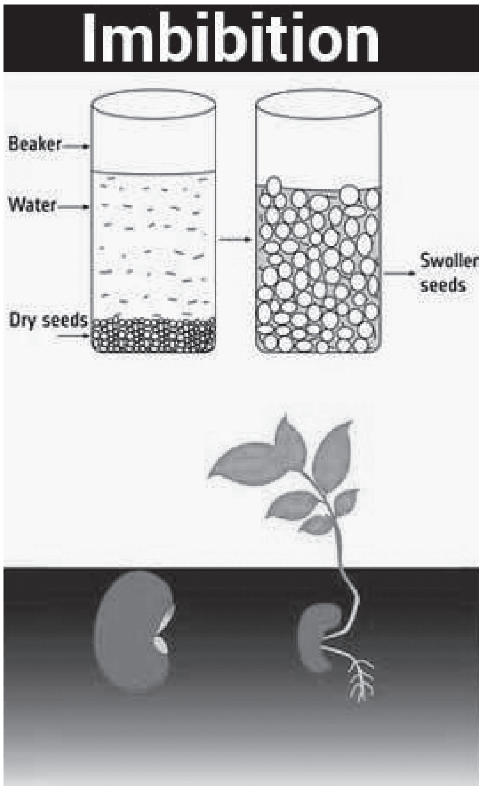


Fig. 5 :

Conductions of Imbibition

1. Diffusion Pressure gradient exists between imbibant and the substance imbibed.
2. Affinity between the imbibant and imbibing substance.

***

MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

a) Which is the factor that does not affect diffusion?
(Concentration, Temperature, Semipermeability, Permeability)

b) Which one acts as carrier in facilitated diffusion across the cell membrane?
(Protein, Carbohydrates, Fat, Vitamins)

c) Which type of diffusion is responsible for transport of two types of molecules ?
(Active, Symport, Uniport, Antiport)

d) What is the water potential of pure water ?
(0, -1, 1, -2)

e) When net movement of water is outside the cell, we have then placed it in which type of solution ?
(isotonic, hypotonic, hypertonic, balanced)

f) When NaCl is dissolved in water, its water potential
(becomes O, increases, decreases, not effected)

g) What does exist for diffusion ?
(Turgor pressure, diffusion pressure gradient, Osmotic pressure, Semipermeable membrane)

2. Write notes on the following with 2 to 3 valid points :

a) Diffusion
b) Facilitated diffusion
c) Osmotic Pressure
d) Turgor pressure
e) DPD
f) Plasmolysis
g) Imbibition

3. Differentiate between the following with 2 to 3 valid points :

a) Imbition & Diffusion
b) Diffusion & Osmosis
c) Diffusion & Facilitated diffusion
d) Wall pressure & Turgor Pressure
e) Osmosis & Plasmolysis

4. Give a detailed account of osmosis phenomenon.

***

Module - 8

CYCLIC AND NON-CYCLIC PHOTOPHOSPHORYLATION

Phosphorylation is an important energy yielding (ATP) process in cells. In this process, a phosphoryl group (phosphate) is added to ADP, so that ATP is formed in the presence of enzyme, kinases. Photophosphorylation refers to use of light energy from photosynthesis to ultimately provide the energy to convert ADP to ATP. So, this process replenishes the universal energy currency in the living cells. Only two sources of energy are available to living organisms : Solar energy and oxidation - reduction energy (respiration energy). Commonly in photosynthesis, this involves photolysis or photodissociation of water and a continuous unidirectional flow of electrons from water to PS II.

CYCLIC AND NON-CYCLIC PHOTOPHOSPHORYLATION

There are two types of photophosphorylation. Cyclic photophosphorylation occurs in the thylakoid membrane. The high energy electron released from P700 or PSI flow down the cyclic pathway. Cyclic phosphorylation starts from a pigment complex called PSI, passes the released electrons to plastoquinone, then to cytochrome b_6f system and then to plastocyanin before returning to chlorophyll. This transport of electrons through various carriers creates a proton-motive force, pumping H^+ ions across membrane. This concentration gradient across the membrane is sufficient to generate ATP molecules by ATP synthase enzyme. This is the cyclic pathway. Here, only ATP is synthesized, neither O_2 nor NADPH are formed (Fig.1).

The other pathway is noncyclic photophosphorylation. It is a two stage process involving 2 different chlrophyll systems. It occurs in the stroma lamellae. First water molecule is broken down into $2H^+ + {}^1/_2\, O_2 + 2e^-$ by the process called photolysis of water. Then, a photon absorbed by chlorophyll pigments surounding the core centre of the photosystem. The light excites the electrons of each pigment, causing a series of reactions that eventually transfers the energy to core of the photosystem II, exciting two electrons that are transferred to the primary electron acceptor, pheophytin. The deficit of electrons are replenished by accepting another molecule of water. The electrons are transferred from pheophytin to plastoquinene. This takes $2e^-$ from Pheophytin and two H^+ atoms from stroma and forms PQH_2. This later breaks and $2e^-$ are released to cytochrome b_6f complex and the two H^+ ions are released into the thylakoid lumen. Then electrons pass through Cyt b_6 and Cyt f. After this, they are passed to plastocyanin providing the energy for hydrogen ions (H^+) to be pumped into the thylakoid space. This creates gradient of H^+ ions and when they tend to come back into stroma ATP is generated.

The photosystem II complex replaces its lost electrons from external source. However, two other electrons are not returned to the system. Instead, the excited electrons are transfered to photosystem I complex, which boosts their energy level to higher level using second solar photon. The highly excited electrons are transferred to the acceptor molecule, but this time passed to an enzyme molecule called Ferredoxin-NADP - reductase. This catalyzes following reaction :

$$NADP^+ + 2H^+ + 2e^- \rightarrow NADPH + H^+$$

This consumes H^+ ions produced by splitting of water, leading to a net production of $^1/_2O_2e$, ATP and NADH + H^+.

The molecule of ATP synthesis in the thylakoid membrane of chloroplasts can be explained through chemiosmotic hypothehsis. The light driven electron transfer (Figure - 1 & 2) creates a proton-motive-force or proton gradient across the thylakoid membrane. This gradient drives the synthesis of ATP when the protons force their way into the stroma through an enzyme complex called ATP synthase : The complex is also described as CF_O-CF, particle (Coupling factors). It has been estimated that 4 protons are transported by ATP synthase for one ATP synthesis.

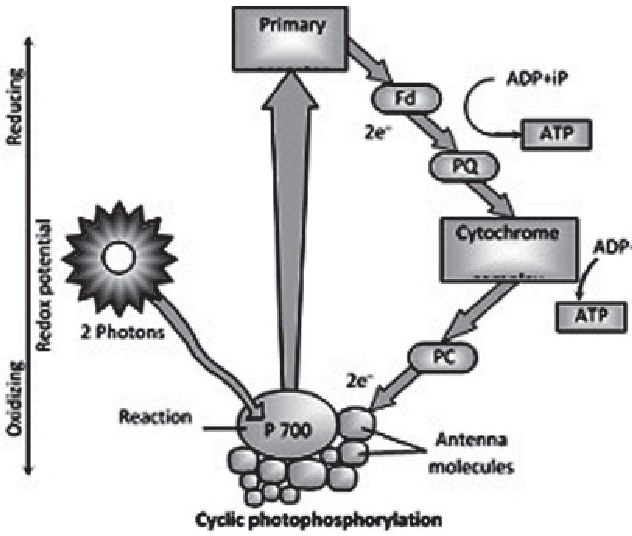


Fig. 1

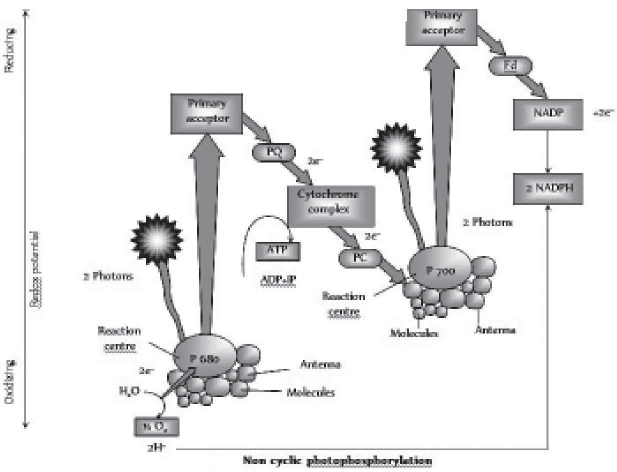
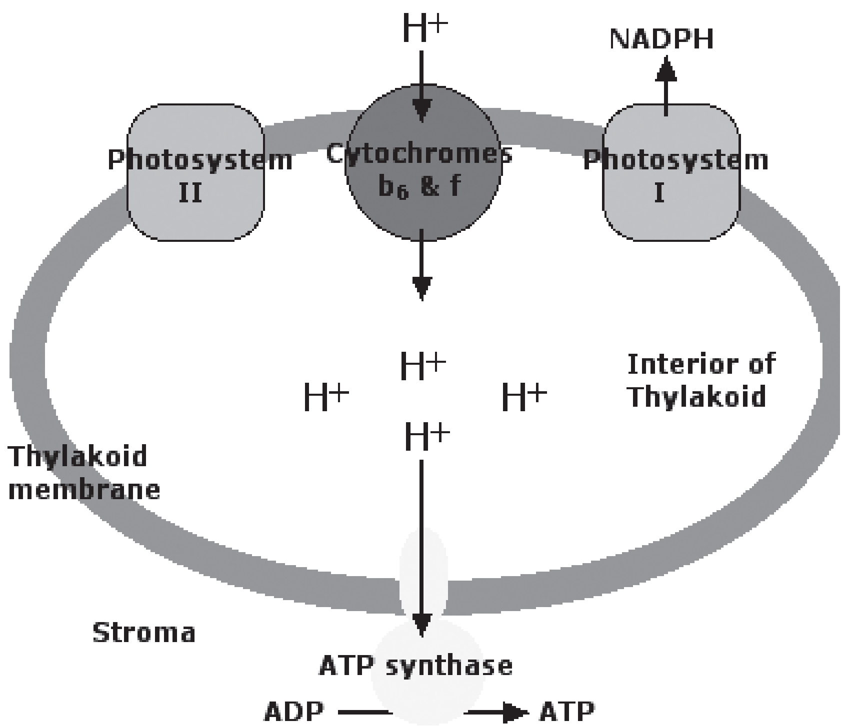


Fig. 2

The proton gradient is caused because (i) splitting of water molecules takes place in the inner side of the membrane. The protons or hydrogen that are produced by splitting of water accumulate in the lumen of thylakoids (ii) As electrons pass through photosystems, protons are transported across the membrane. This happens as the primary acceptor of electron located towards the outer side of the membrane, transfers its electrons not to an elctron carrier but to a H carrier. Hence, the molecule removes a proton from stroma while transporting electron. When this molecule passes on its electron to the electron carrier at the inner side of the membrane, the proton is released to the inner side of the lumen. (iii) NADP reductase enzyme is located on the stroma side of the membrane. Along with electrons of PSI, protons are necessary for reduction of $NADP^+$ to $NADPH^+H^+$. These protons are removed from the stroma (Fig. 3).



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MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

a) What is the end product of Cyclic photphosporylation ?

(NADPH, ADP, ATP, O_2)

b) ATP in chloroplasts is synthesized at

(Stroma, Outer membrane of Chloroplast, thylakoid luman, Cytoplasm)

c) Where from the Photosynthetic O_2 is liberated ?

(CO_2, H_2O, Sunlight, ATP)

d) Which one is the immediate electron donor to PS_1 ?

(Cyt-b, Cyt b_6, Plastocyanin, Plastoquinone)

e) Which one does receive excited electrons from P_{680} ?

(Cyt b_6, Pheo, Fd, Cyt b)

f) Which one is the reaction centre of PSI ?

(P_{680}, P_{700}, P_{450}, P_{800})

g) Which one is the first reaction in Photophosphorylation ?

(CO_2 fixation, ATP formation, NADPH formulation, Photolysis of Water)

2. Write notes on the following with 2 to 3 valid plants.

   a) Photophosphorylation
   b) Cyclic Photophosphorylation
   c) Photolysis of water
   d) Photosystem
   e) Chemiosmotic hypothesis

3. Differentiate the following with 2 to 3 valid points :

   a) Phosphorylation and Photophosphorylation
   b) P_{700} and P_{680}
   c) Cyclic photosphorylaton and Noncyclic Photophosphorylation
   d) Storma and Grana

4. Describe the Non-Cyclic Photophosphorylation with a Z - Scheme.

***

Module - 9

C_3 AND C_4 PATHWAYS

In light reactions of Photosynthesis, the products are ATP, NADPH and O_2. O_2 diffuses out of chloroplasts. ATP and NADPH are utilized in the next reaction system leading to the formation of carbohydrates. This phase does not need any direct light energy and hence, called dark reactions. Here CO_2 is reduced to synthesize sugar molecules and therefore, called biosynthetic phase.

In this stepwise orderly process, CO_2 reduction is completed in definite manner. In the process, the first stable product of CO_2 fixation is C_3- 3 phosphoglyceric acid (PGA) acid. Hence, it is called C_3 cycle. Again, the cycle was first demonstrated in algal photosynthesis by Melvin Calvin. Therefore, it is also known as Calvin Cycle (Figure-1).

Experimentation over wide groups of plants led to the discovery of another cycle independent of PGA and here Oxaloacetic acid (OAA) was the first stable product. Hence, it is called C_4 pathway. We will discuss two pathways below.

C_3 - PATHWAY OR CALVIN CYCLE

Studies with green plant cells have shown that 5-Carbon ketose sugar - Ribulose bisphosphate accepts the molecule of CO_2 to form PGA. This cycle is conviniently divided into 3 stages. Carboxylaton, reduction and regeneration.

I. **Carboxylation :** Ribulose -1-5-bisposphate (RUBP) reacts with CO_2 to form two molecules of 3-Phosphoglyceric acid (3-PGA). This carboxylation process is catalyzed by an enzyme ribulose-5 bisphosphate carboxylase oxygenase (rubisco). As 3-PGA is a 3-Carbon compound, the cycle is known as C_3 cycle.

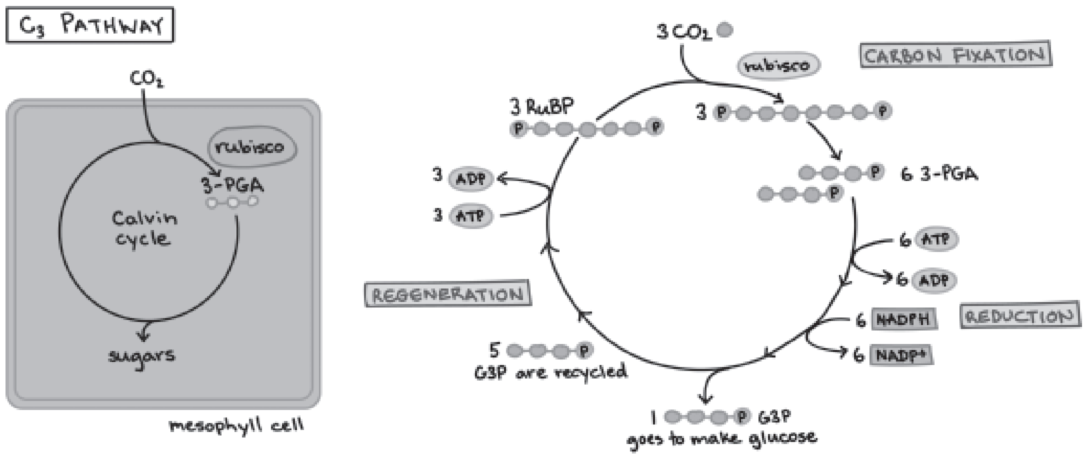


Fig. 1 : C_3 Pathway

II. **Reduction :** A series of reactions continuously occur leading to the final formation of glucose. 2 molecules of ATP are used for phosphosylation and 2 NADH for reduction of CO_2 molecule. Hence, six molecules of CO_2 are reqired for the removal of one molecle of glucose from the pathway.

III. **Regeneration :** Regeneration means formation of RUBP molecule whcih is required for the initiation of another such cycle.

The cycle is depicted in Figure-I. Every CO_2 entering the Calvin Cycle, 3 molecules of ATP and 2NADPH are required. The overall reaction can be shown :

$$6CO_2 + 11H_2O + 12NADPH + 18ATP \rightarrow Hexose\text{-}6\text{-}PO_4 + 12NADP^+ + 6H^+ + 18ADP + 17\ Pi$$

C_4 PATHWAY - HATCH - SLACK CYCLE

Tropical plants like maize, sugar cane, Sorghum etc. assimilate CO_2 in the dark reaction and convert it to oxaloacetic acid (OAA), a 4-carbon compound. The experiments were perfomed by M.D. Hatch and H.P. Kortschack to establish this cycle. Therefore, it is called Hatch-slack cycle.

C_4 plants have certain unique characteristics. They have a special type of leaf anatomy. They can tolerate high tmperature. Under high light intensities, these plants lack photorespiration (a wasteful process) and have greater productivity.

Leaf anatomy of C_4 plants is interesting. Around the vascular bundles, tightly fitted bundle sheath cells are present here instead of normal endodermal cells. These bundle sheaths form several layers around the vascular bundle. Large cells of these layers possess large number of chlroplasts. Around these, loosely arranged chlorophyllose mesopyll cells exist. This type of anatomy is called 'kranz' (Wreath) anatomy.

C_4 Cycle Consists of 4 phases (Fig. 2)

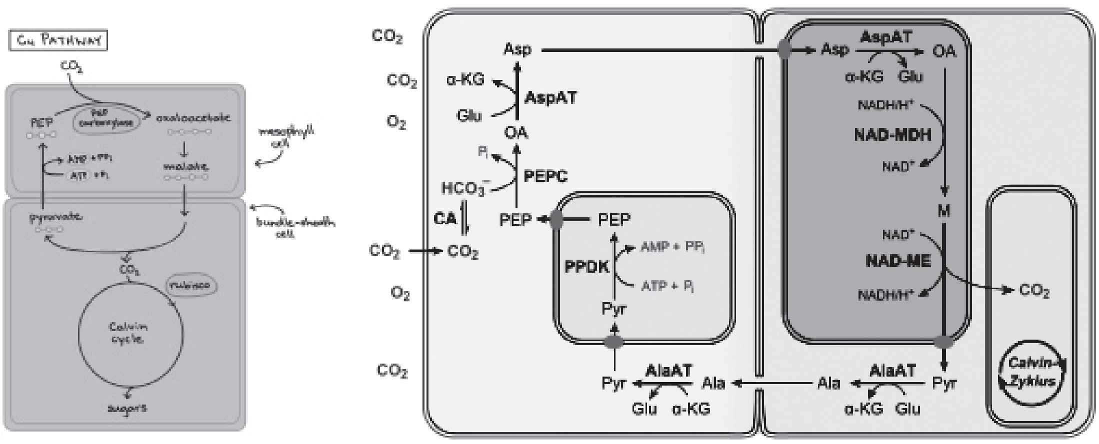


Fig. 2 : C_4 Pathway

I. **Carboxylation Phase :** In the mesophyll cells, the acceptor of CO_2 is a 3-carbon molecle, called phospoenol pyruvate (PEP) and the enzyme responsible for this fixation is Phosphoenol-Pyruvate Carboxylase (PEP-Carboxylase). The product is a 4-Carbon Compound, Oxaloacetic Acid (OAA).

II. **Transport Phase :** It then forms 4-Carbon Compounds like malic acid or aspartic acid depending on the plant species. These are transported to bundle sheath cells.

III. **Decarboxylation Phase :** In the bundle sheath cells, these C_4 acids are broken down to release CO_2 and a 3-Carbon molecule.

IV. **Transport and regeneration phase :** 3 - carbon compounds formed in the decarboxylation is transported back to mesophyll and it is converted to PEP again. This molecule is now ready to accept another molecle of CO_2 to form OAA and thus, the C_4 Cycle is carried on.

The bundle sheath cells are rich in RUBISCO enzyme but lack PEP Carboxylase. Here, Calvin Pathway is operated to synthesize sugar molecules. In contrast to C_3 plants, C_4 plants, lack RUBISCO enzyme in their mesophyll cells. Hence, C_3 cycle here does not take place in mesophyll cells but in endodermal cells in a cyclic manner. Hence, this is called C_4 cycle.

***

MODEL QUESTIONS

1. Choose the correct answers from the alternatives given under each bit :

a) Which is the primary fixation product in C_3 plants ?
(OAA, PGA, RUBP, PEP)

b) Which is molecule that receives CO_2 in mesophyll tissues in C_4 plants ?
(RUBP, PEP, PGA, OAA)

c) In which type of cells C_3 cycle does not occur ?
(Palisade Parenchyma, Spongy Parenchyma, Mesophyll, Sclerenchyma)

d) What is the number of carbons present in primary fixation product of C_4 plants ?
(2, 3, 4, 5)

e) Which is the primary CO_2 acceptor in C_3 plants ?
(RUBP, PEP, PGA, OAA)

f) In which step of C_3 cycle are NADPH utilized ?
(carboxylation, reduction, transport, regeneration)

2. Write notes on the following with 2 to 3 valid plants :
   a) Kranz anatomy
   b) Carboxylation reaction
   c) Regeneration reaction
   d) Transport phase

3. Distinguish between the following with 2 to 3 valid points :
   a) Anatomy of C_3 and C_4 plants
   b) C_3 patway and C_4 pathway
   c) RUBISCO and PEP Carboxylase
   d) C_3-plants and C_4 plants

4. Enumerate the steps of C_3 cycle.

5. Describe the C_4 cycle and its advantages.

***

Module - 10

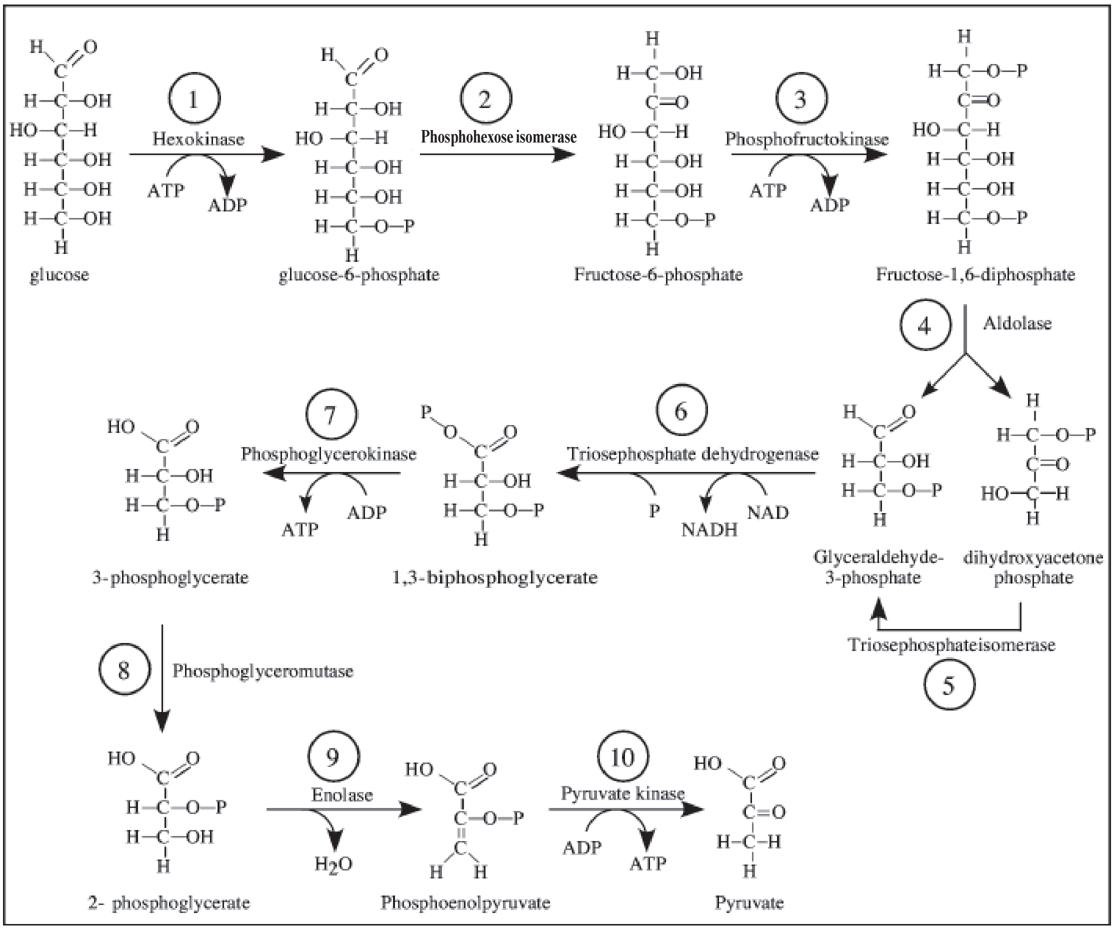
GLYCOLYSIS

Respiration is an oxidation-reduction process in which respirable substrates like carbohydrates (sometimes proteins & fats also) are oxidized to CO_2 with the release of energy. Most energy so released is lost as heat, but a part of it is utilized in the formation of ATP. Breakdown of carbohydrate is accomplished in three steps, the first one of which is called Glycolysis. It consists of a series of steps resulting in the oxidation of carbohydrates (sugars) to Pyruvic acid. The entire set of reactions operates in the cytoplasm and is common to both aerobic & anaerobic respiration. It is also known as Embden-Meyerhoff-Parnass (EMP) Pathway, named after the three Scientists who worked out the steps.

Glycolysis is completed in two phases and does not require molecular oxygen at any level.

Phase-I : This is called *glucose activation phase* and is also known as Preparatory Phase. In this phase hexose (6-carbon) is cleaved into two triose (3-carbon) phosphates. Phosphroylation of glucose and its conversion to Glyceraldehyde - 3- phosphate takes place in five steps.

Phase - II : This is called the *Payoff phase*. During this phase, Glyceraldehyde-3-phosphate is converted to Pyruvate coupled with formation of ATP. This is accomplished in another five steps.



Phase - I : Glucose activation phase

Step-1 : ***Phosphorylation of Glucose -***

The reaction is catalysed by the enzyme hexokinase in the presence of Mg++. It is a regulatory step in glycolysis and the reaction is irreversible.

Step-2 : ***Isomerization of Glucose - 6-P to Fructose - 6 -P -***

This reacton involves aldose - ketose isomerisation catalysed by phosphohexose isomerase.

Step-3 : ***Phosphorylation of Fructose - 6-P to Fructose 1,6 - Bisphosphate-***

The enzyme phosphofructokinase-1 catalyzes transfer of a phosphate group from ATP to fructose 6-Phosphate to form fructose 1,6-bisphosphate. The reaction is irreversible.

Step-4 : ***Cleavage of Fructose 1, 6- Bisphosphate -***

This is a key reaction where the 6-Carbon Fructose 1,6 - bisphosphate is cleaved into two three carbon units, one glyceraldehyde-3-phosphate (GAP) and another dihydroxy acetone phosphate (DHAP) in presence of enzyme aldolase. The reaction is reversible.

Step-5 : ***Interconversion of Triose Phosphates -***

This reaction enables DHAP to come to the main pathway through GAP. Triosephosphate isomerase converts DHAP to GAP. The reaction is rapid and reversible.

Phase - II : Pay off phase

Step -6 : ***Oxidative phosphorylation of GAP to 1, 3 - bisphosphoglycerate-***

This reaction is catalysed by glyceraldehyde-3-phosphate dehydrogenase. This is an energy-yielding reaction. Aldehyde group is oxidized to an acid. In the process NAD+ is reduced to NADH. This is a reversible reaction.

Step-7 : ***Conversion of 1,3-bisphospho glycerate to 3-P glycerate -***

The high energy phosphoryl group is transferred from carboxyl group of 1, 3-bisphosphoglycerate to ADP forming ATP. This is an example of substrate level phosphorylation without participation of electron transport chain. The reaction is catalyzed by phosphoglycero kinase.

Step - 8 : ***Conversion of 3-P-Glycerate to 2-P Glycerate -***

Here the phosphate group is shifted from 3rd to 2nd carbon atom in the presence of enzyme phosphoglycero mutase and Mg^{++}. This is a reversible reaction.

Step - 9 : ***Dehydration of 2-P-glycerate to phosphoenol pyrurate -***

2-phosphoglycerate is converted to phospho enol pyruvate in the presence of enzyme enolase and Mg^{++}. A molecule of H_2O is removed.

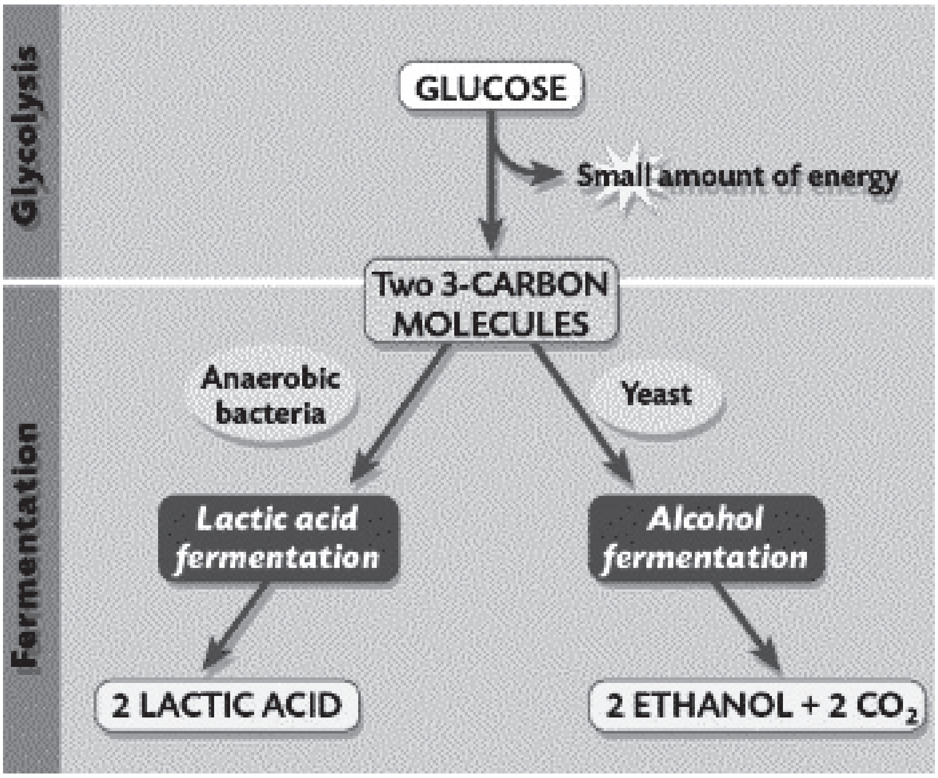
Step - 10 : ***Conversion of PEP to Pryruvate -***

This is another example of substrate level phosphorylation producing ATP. PEP is dephosphorylated to pyruvate by the enzyme pyruvate kinase in the presence of Mg^{++} and K^{+}.

Pyruvate, thus formed, is a key intermedicate in several metabolic pathways. It can be converted back to gluclose through gluconeogenesis or to fatty acids through a reaction with acetyl CoA. However, it undergoes complete oxidation in the TCA cycle incourse of *aerobic respiration* to yield CO_2 and a lot of usable energy. In the absence of oxygen or during anaerobic respiration, the end product is an organic acid like lactic acid and low yield of energy.

Anaerobic Respiration

There are two major types of anaerobic respiration—lactic acid fermentation and alcoholic fermentation—both of which occur in the cytoplasm of the cell.



Alcoholic Fermentation

The anaerobic pathway carried out by yeasts in which glucose is converted to ethanol & CO_2 with low energy output.

$$\text{glucose} \xrightarrow{\text{yeast}} \text{ethanol} + \text{carbon dioxide}$$

$$C_6H_{12}O_{6(aq)} \xrightarrow{\text{yeast}} 2C_2H_5OH_{(aq)} + 2CO_{2(aq)}$$

Energy yield in Glycolysis

Aerobic

i)	Hexokinase (6C)	→	- 1 ATP
ii)	Phosphofructokinase	→	- 1 ATP
iii)	Glyceraldehyde - 3-P dehydrogenase (3c)	→	NADH (2 x 2) = + 4 ATP
iv)	Phosphoglycerate Kinase (3C)	→	ATP (x 2) = + 2 ATP
v)	Pyruvate Kinase (3C)		ATP (x 2) = +2 ATP
			Net - 6 ATP Molecues

Anaerobic

i)	Hexokinase (6C)	→	- 1 ATP
ii)	Phosphofructokinase	→	- 1 ATP
iii)	Phosphoglycerate Kinase (3C)	→	ATP (x 2) = + 2 ATP
v)	Pyruvate Kinase (3C)		ATP (x 2) = +2 ATP
			Net - 2 ATP Molecues

Significance of glycolysis

1. It takes place in all the cells.
2. It is the preliminary step for complete oxidation of glucose.
3. It provides carbon skeleton for many other metabolic pathways.
4. Most of the reactions are reversible, hence used for gluconeogenesis.

***

MODEL QUESTIONS

1. Select the correct answer from the choices under each bit :

   (a) Glycolysis operates in :

   i) Mitochondria ii) Golgi apparatus

   iii) Endoplasma reticulum iv) Cytoplasm

   (b) Glycolysis converts :

   i) Protein to glucose ii) fats to glucose

   iii) glucose to fructose iv) glucose to pyruvate

   (c) ATP is produced in the mitochondria by the process of :

   i) photophosphorylation ii) oxidative phosphorylation

   ii) gluconeogensis iv) endocytosis

   (d) The 1st reaction step of glycolysis that produces ATP is catalyzed by the enzyme :

   i) hexokinase ii) pyrvate kinase

   ii) phosphoglycerate kinases iv) phosphofructo kinase

2. Write short notes on the following with 2 to 3 valid point :

   a) Alcoholic fermentation

   b) Anaerobic respiration

   c) Substrate level phosphorylation

   d) Preparatory phase

   e) Pay off phase

3. Describe the reaction steps of glycolysis.

***

Module - 11

TCA CYCLE

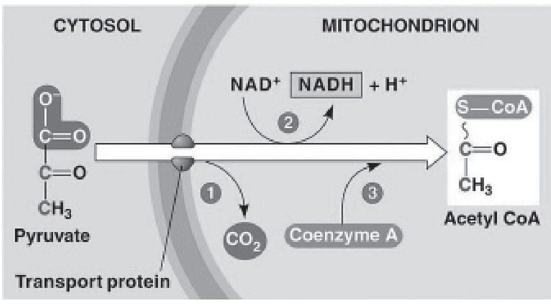
The tricarboxylic acid cycle (TCA cycle) is a series of enzyme-catalyzed chemical reactions that form a key part in aerobic respiration. This cycle is also called the 'Krebs Cycle' and the 'Citric acid cycle'. Hans A. Krebs in 1937 discovered the citric acid cycle which occurs in the mitochondria of the cell. Pyruric acid is oxidized in this process to form CO_2 and H_2O. A tricarboxylic acid such as citric acid is the earliest product of this cycle and is therefore, called the TCA Cycle or citric acid cycle. Under aerobic conditions, pyruvate enters the mitochondrial matrix where it is decaroxylated, oxidized and the resultant acetyl group is transferred to CoA to form acetyl CoA.

Acetyl CoA is the starting point for the TCA Cycle and the connecting link between Glycolysis and the TCA Cycle.

Reactions :

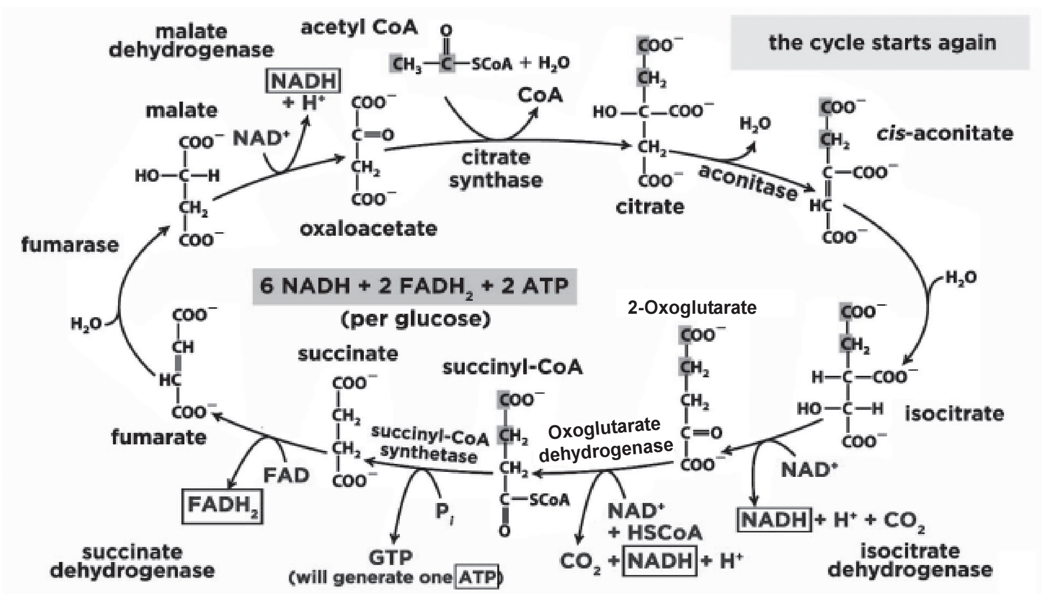
Formation of acetyl CoA

It is an irreversible oxidative decarboxylation reaction in which one molecule of CO_2 is removed from Pyruvate in the presence of Pyruvate dehydrogenase.



In this process NAD^+ is reduced to generate a molecule of NADH.

Tricarboxylic Acid Cycle



1. **Formation of Citrate**

   It is a condensation reaction in which acetyl CoA (2C) condenses with Oxaloacetate (4C) to form Citrate (6C) in the presence of enzyme citrate synthase. At the end of the cycle a molecule of oxaloacetate is regenerated.

2. **Isomerization of Citrate to Isocitrate**

   This reaction occurs in two steps.

   In the presence of enxyme aconitase, citrate first undergoes dehydration to form an intermediate called cis-aconitate and then cis-aconitate is hydrated to form isocitrate. Both these steps are reversible.

3. **Formaton of 2-Oxoglutarate :**

   In the presence of enzyme isocitrate dehydrogenase and Mn^{++}, isocitrate is oxidized to form oxalosuccinic acid. Subsequently oxalosuccinate is decarboxylated to form 2-oxoglutarate. This is a very important intermediate compound in the TCA Cycle, because if participates in the synthesis of amino acids. It is an irreversible reaction.

4. **Formation of Succinyl - CoA**

   This is an oxidative decarboxylation reaction catalyzed by oxoglutarate dehydrogenase enzyme forming succinyl CoA and CO_2 from a molecule of 2-oxoglutarate. CoA serves as a carrier of succinyl group and NAD^+ as an electron acceptor to form NADH.

5. **Formation of Succinate :**

   This is a substrate-level phosphorylation reaction in which the high energy thioester bond of succinyl CoA transfers energy to ADP and Pi to form ATP (GDP to GTP in animals/human beings).

6. **Formation of fumarate :**

   In the presence of enzyme succinate dehydrogenase, succinate undergoes dehydrogenation to form fumarate. FAD is reduced to form a molecule of $FADH_2$. This reaction is reversible.

7. **Formation of malate :**

   In this reaction fumarate gains a molecule of H_2O and produces malate in the presence of enzyme fumarase. The reaction is reversible.

8. **Regeneration of Oxaloacctate :**

Malate is oxidized to oxaloacetate in the presence of enzyme malate dehydrogenase. In the process, NAD^+ is reduced to form NADH. Oxaloacetate, so regenerated combines, with acetyl CoA again & the cycle continues. This is a reversible reaction.

Significance of TCA Cycle

1. It is a common metabolic pathway of carbohydrates, fatty acids and aminoacids.
2. This cycles oxidize acetyl CoA completely into CO_2 & H_2O releasing a large amount of energy.
3. Many of the intremediates like citrate, 2-oxoglutarate, succinyl CoA & Oxaloacetate also act as precursors for biosynthesis of molecules like purines, pyrimidines, fatty acids, and steroids.
4. Electron acceptors like NAD^+ and FAD accept electrons during oxidation reactions of the cycle. These reduced molecules like NADH and $FADH_2$ finally transfer electrons to O_2 during the flow of electrons in ETS to produce energy in the form of ATP.

Summary of Energy Calculation

Complete oxidation of Glucose during aerobic respiration :

1.	*Oxidation of Pyruvate*	(3x2)	=	6 ATP
2.	*Krebs Cycle :*			
	a) Direct substrate level phosphorylation		=	2 ATP
	b) Three NADH from each cycle	(3x3x2)	=	18 ATP
	c) One $FADH_2$ form each cycle	(2x2)	=	4 ATP
				--------------
				30 ATP
3.	*From aerobic Glycolysis (net)*		=	6 ATP
				=======
				36 ATP

***

MODEL QUESTIONS

1. Select the correct answer from the choices given under each bit.

(a) The reaction of Krebs Cycle take place inside :

i) mitochondria ii) ribosome

iii) lysosome iv) vacuoles

(b) First-reaction of Krebs Cycle produces a 6-C organic acid called :

i) Oxaloacotate ii) Fumarate

iii) Malate iv) Citrate

(c) Oxidation of one molecule of pyruvate inside mitochondria produces :

i) $3CO_2$ ii) $2CO_2$

ii) $4CO_2$ iv) $1CO_2$

(d) The key molecule that links glycolysis with Krebs Cycle during aerobic respiraton is :

i) pyruvate ii) oxaloautate

iii) acetyl CoA iv) citrate

2. Write notes on the following with 2 to 3 valid points :

a) Acetyl CoA

b) Substrate level phosphorylation

c) F_0 - F_1 ATPase

d) Enzymes in TCA.

3. Describe the reaction steps of Krebs Cycle.

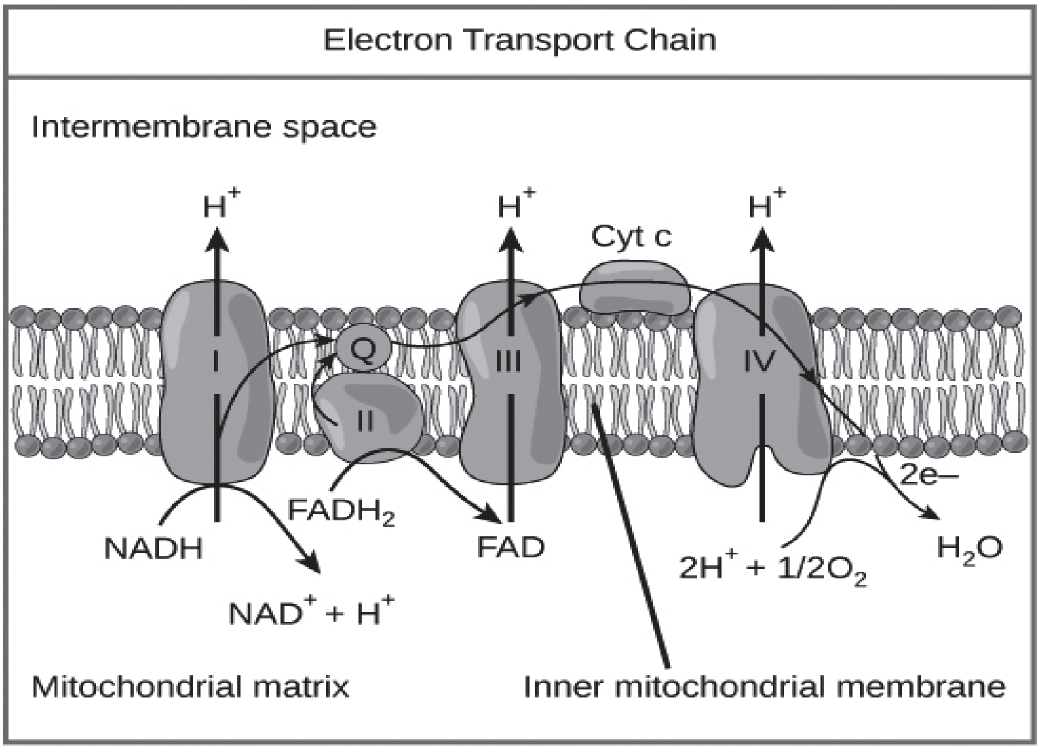
***

Module - 12

ELECTRON TRANSPORT CHAIN AND OXIDATIVE PHOSPHORYLATION

The electron transport chain is located in the inner memberane of the mitochondrion in eukaryotes. The transfer of electrons from NADH and $FADH_2$ to oxygen involves a sequence of electron carriers. The electron carriers with their assocaited enzymes are organised into four large complexes-complex (I) to (IV), and two mobile carriers.

NADH ubiquinone oxidoreductase is the Complex-I which accepts electrons from NADH and passes them to coenzyme Q (ubiquinone). This complex has a tightly bound flavin mononucleotide (FMN). Ubiquinone also receives electrons from Complex-II. Succinate dehydrogenase oxidizes succinate to fumarate and the reducing equivalents are transferred to ubiquinone via $FADH_2$, which is bound to Complex-II. Ubiquinol (reduced form of ubiquinone) transfers electrons to Complex-III, known as cytochrome-c reductase. It contains cytochorme-b, cytochrome-c_1 and iron-sulphur protein. Complex-III passes electrons to cytochrome-c, a mobile electron carrier located on the outer surface facing inter-membrane space. Cytochrome-c in turn transfers electrons to Complex-IV, known as cytochrome-c oxidase. This complex also contains copper ion, cytochrome-a and cytochrome-a_3. Electrons are finally transferred to molecular oxygen, which is the terminal electron acceptor.



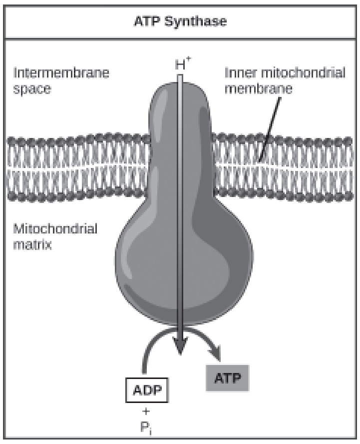
These four membrane-bound complexes are transmembrane structures embedded in the inner membrane and are electrically connected by lipid and water soluble electron carriers.

The inner membrane is arranged into folds (cristae) which increases the surface area available for the transport chain. The electron transport chain releases the energy stored within the reduced hydrogen carriers to synthesize ATP. It is therefore called oxidative phosphorylation. The entire process is completed in three distinct steps.

Step - I : Generating Proton Motive Force :

The hydrogen carriers (NADH & $FADH_2$) when oxidised, release high energy electons and protons. The electrons pass through the chain, lose energy, which is used to pump protons (H^+ ions) from the matrix to the intermembrane space. Accumulation of H^+ ions within the intermembrane space creates an electrochemical gradient or Proton Motive Force.

Step - 2 : ATP Synthesis via Chemiosmosis :



The proton motive force causes H^+ ions to move down their electrochemical gradient and diffuse back into matrix. This diffusion is called chemiosmosis. It is facilitated by the transmembrane enzyme ATP synthase. As the H^+ ions move through the enzyme, ATP synthase, ATP is synthesized, from ADP and Pi.

Step - 3 : Oxygen as final electron acceptor

In order for the electron transport chain to continue functioning, the de-energised electrons must be removed. Oxygen acts as the final electron acceptor, removing the de-energised electrons to prevent the chain from being blocked. Oxygen binds with the free protons in the matrix to form water. Removing matrix protons maintains the hydrogen gradient. In the absence of oxygen, hydrogen carriers can not transfer eneregised electrons to the chain and ATP production is halted.

Oxidative Phosphorylation

Passage of an electron pair down the electron transport chain release free energy which is used to phophorylate ADP molecules with inorganic Pi to form ATP. Formation of ATP molecules coupled with the transfer of electrons, derived from the oxidation of organic compounds through the mitochandrian electron transport chain is called oxidative phosphorylation. The molecular mechanism of ATP synthesis, as explained in Step - 1-3 through ‘Chemiosmotic hypothesis was proposed by Peter Mitchell in 1961. For this Mitchell was awarded Nobel Prize in Chemistry in 1978.

A total of 10 protons are transferred when two electrons are transported from NADH to oxygen molecule via ETS. For the transport of electrons coming from succinate via $FADH_2$ which bypasses complex-I, 6 protons are transported per two electrons transferred. It is estimated that for three protons transported through ATP synthase (Step-2), one ATP is formed. Because 10 protons are transported for each pair of electrons, transferred through the ET chain, a total of 3 ATP molecules are synthesized for each molecule of NADH and 2 ATP molecules are formed per $FADH_2$ molecule.

Summary

1. The electron transport chain only operates when oxygen is available.
2. The process is a stepwise movement of electrons form high energy to low energy carriers that makes the proton gradient.
3. The proton gradient powers ATP production, not the flow of electrons.
4. The ETS is responsible for producing H_2O and upto 34 ATP molecules for one glucose molecule.
5. NAD^+ & FAD are recycled to be again used in the TCA cycle and glycolysis.
6. ETS operates in the mitrochondia of eukoryotes & cell membrane of prokaryotes.

***

MODEL QUESTIONS

1. Select the correct answer from the choices under each bit :

   (a) When two electrons are transported from NADH to Oxygen how many protons are transferred ?

i) 6	ii) 10
iii) 8	iv) 12

   (b) In the mitochondrial electron transport chain the terminal electron accepter is :

i) Ubiquinone	ii) Cytochrome c
iii) Cytochrome b	iv) Molecular Oxygen

   (c) Chemiosmotic hypothesis was proposed by :

i) Hans Krebs	ii) Peter Mitchell
ii) C. R. Slack	iv) Gustav Embden

   (d) Which one does get reduce by the protons and electrons of succinate?

i) NAD	ii) FAD
ii) NADP	iv) ADP

2. Write short notes on the following with 2 to 3 valid points :

   a) Proton motive force

   b) oxydative phosphorylation

   c) Chemiosmotic hypothesis

   d) Mitochondria

3. Describe respiratory electron transport chain and the mechanism of ATP synthesis.

***

Class - XII
BOTANY

CONTENTS

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LESSON PLAN

Higher Secondary (Science), BOTANY

(2nd Year) – Approx. 40 Classes / Year

Unit	Lecture Number	Topic	Date of Completion	Signature
I	**Reproduction**			
	1.	Reproduction, a characteristic feature of all organisms for continuation of species		
	2.	Asexual reproduction – Modes of asexual reproduction – Binary fission, Sporulation, budding		
	3.	Gemmule formation, fragmentation and vegetative propagation in plants		
	4.	Sexual reproduction in flowering plants – flower structure		
	5.	Development of male and female gametophytes.		
	6.	Outbreeding devices, Pollen pistil interaction.		
	7.	Double fertilization, post fertilization events, Development and formation of embryo endosperm.		
	8.	Seed and fruit development special modes-apomixes, parthenocarpy, polyembryony, significance of seed and fruit formation.		
II.	**Genetics and Evolution**			
	9.	Mendelian inheritance		
	10.	Deviation from Mendelism-I – Incomplete dominance, co-dominance, Multiple allels and inheritance of blood groups.		
	11.	Deviation from Mendelism-II, Pleiotropy, Elementary idea on Polygenic inheritance		
	12.	Chromosome theory of inheritance chromosomes and genes, linkage and crossing over.		
	13.	Molecular basis of inheritance : Search for genetic material and DNA as the genetic material.		
	14.	Structure of DNA and RNA DNA packaging		
	15.	DNA replication		
	16.	Central dogma, Transcription		
	17.	Genetic Code		
	18.	Translation		
	19.	Gene expression and regulation, Lac Operon		
	20.	Genome and Human genome project, DNA fingerprinting		

III	**Biology and Human Welfare**			
	21.	Plant breeding, Biofortification		
	22.	Tissue Culture, Single Cell Protein		
	23.	Microbes in Human Welfare in food processing and Industrial Production		
	24.	Microbes in energy production and Bicontrol agents and Biofertilizers		
IV	**Ecology and Environment**			
	25.	**Organisms and Environment :** Habitat, Niche, Population and Ecological adaptations		
	26.	Adaptations of hydrophytes and xerophytes		
	27.	Population interactions – mutualism, Competition, Predation, Parasitism.		
	28.	Population attributes – growth, birth rate and death rate, Age distribution		
	29.	Ecosystems : Patterns, Components, Productivity and decomposition.		
	30.	Energy flow, Pyramid of number, biomass and energy.		
	31.	Nutrient cycling (carbon and phosphate) Ecological Succession I Hydrosere.		
	32.	Ecological Succession-II – Xerosere, Ecological Services – Carbon fixation, Pollination, Oxygen release.		
	33.	Biodiversity and its conservation : Concept of biodiversity, Patterns of Biodiversity, Importance of Biodiversity.		
	34.	Loss of Biodiversity, Conservation, Hotspots, endangered Organisms, extinction, Red Data Book.		
	35.	Biosphere Reserves, National Parks and Sanctuaries		
	36.	Environmental issues – Air Pollution and Control		
	37.	Water Pollution and Control		
	38.	Agrochemicals and their effects, Solid waste management, Radioactive Waste Management.		
	39.	Green house effect and Global Warming, Ozone depletion.		
	40.	Deforestation – Any three Case studies as success stories addressing Environmental issues.		

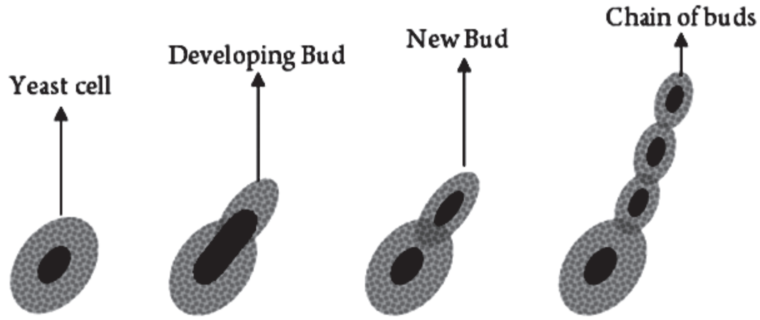
N.B. : 1. First Unit Test – Lecture No. 1-15 to be completed.
2. Second Unit Test – Lecture No. 16-28 to be completed
3. Third Unit Test – Lecture No. 29-40 to be completed.

Module - 1

ASEXUAL REPRODUCTION IN PLANTS

Asexual reproduction is common among lower group of plants. It produces new individuals genetically identical to the parent plants without fusion of gametes. It may happen through budding, fragmentation, fission, spore formation and vegetative propagation.

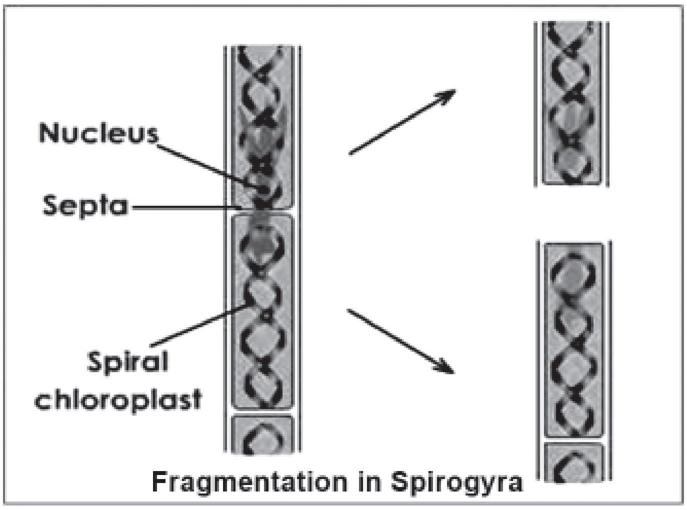
Budding :



Yeast Budding

The unicellular fungus, yeast (Saccharomyces) propagates by this method. It is a type of asexual reproduction in which the new organism develops from an outgrowth or *bud* due to cell division at one particular site. The small bulb like projection remains attached to the parent yeast cell till it is mature. The new organism is genetically identical to the parent.

Some Animals like *hydra* and *sponges* also asexually reproduce by external and internal type of budding.

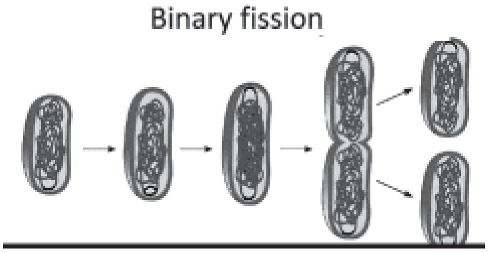


Fragmentation in Spirogyra

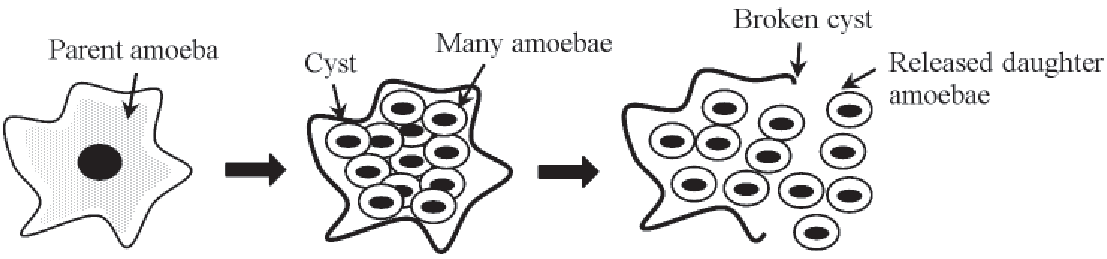
Fragmentation : Here the organism is spilt into fragments and each of these fragments develops into mature fully grown individual. The new organism is a clone of the parent. Fragmentation may occur naturally or by external factors. This type of asexual reproduction is seen in filamentous algae, molds, lichens and many other plants. In animals, like sponges, some annelids and coral colonies, natural fragmentation is prevalent.

Fission : This is a very simple method of asexual reproduction seen in unicellular organisms. The fission may be *binary fission* in which a single cell produces two parts or *multiple fission*, in which a single entity produces multiple parts.

Bacteria reproduce by binary fission. First, the bacterial DNA is replicated. The replicated DNA copies move to opposite poles. The cell lengthens and divides along the equatorial plane. The new cells get separated after the cell walls fully develop in the daughter cells. Binary fission is very fast at suitable temperature (around 37^0C). Bacterial growth is, however, limited by nutrient factors and availability of space.



Besides binary fission, certain algae and amoeba spp. undergo multiple divisions to produce new organisms. That is called multiple fission. The nucleus of the parent cell divides several times by amitosis, producing several nuclei. The cytoplasm then separates producing several daughter cells. Amoeba reproduces by multiple fission under unfavourable conditions. *Plasmodium*, which causes malaria also reproduces by multiple fission.



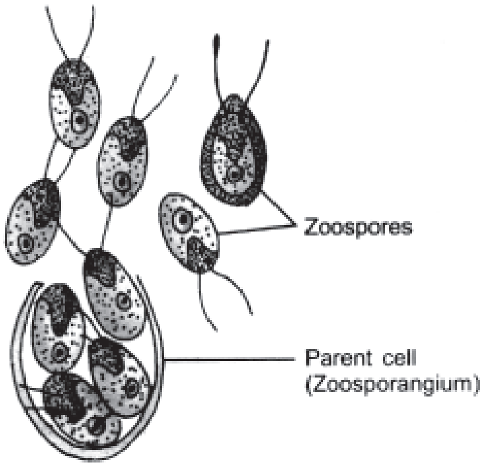
Multiple fission in amoeba

Spore formation :

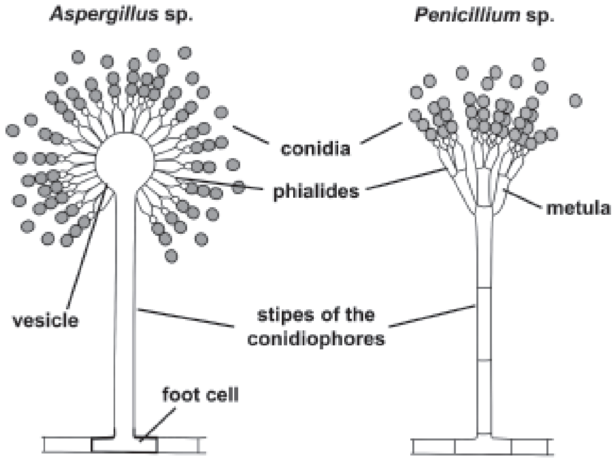
Spores are reproductive cells formed by certain algae & fungi. Unlike gametes in sexual reproduction, spores do not need to fuse and therefore are asexual in nature.

Chlamydomonas a green alga reproduces asexually by producing zoospores, which are motile and by aplanospores, which are non motile. Lower fungi like *Saprolegnia* reproduce by zoospores but higher fungi like *Aspergillus*, *Penicillium* develop naked conidia, which are borne exogenously. Endogenous spores in unicellular or multicellular spore sacs, called sporangia (um) are seen in many fungi, bryophytes, pteridophytes and also is higher plants. The spores get released when mature and germinate to form adult plants.

Zoospores of Chlamydomonas



Conidia



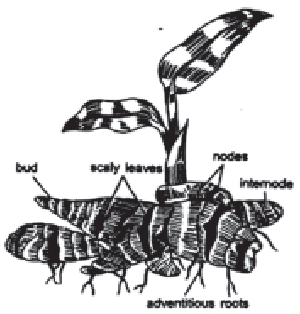
Vegetative Propagation in Plants :

Here specialized reproductive structures are not produced. Vegetative parts like root, stem or leaf may get separated from the mother plant and grow into new individuals. Several types of vegetative propagation are seen in flowering plants.

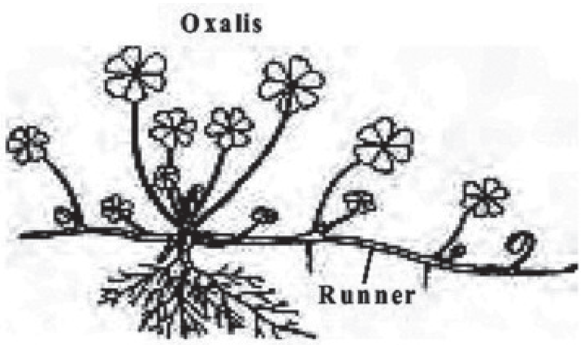
i) ***Natural :*** It involves structural modifications of stem, root or leaf, which can contribute to vegetative reproduction in many herbaceous or woody perrennial plants.

  a) ***Rhizomes -*** These are stem-like structures that grow horizontally and develop into new plants. Ex. - ginger, lilies

  b) ***Runners -*** These are modified stems also called stolons. Buds develop on these modified stems which produce new stems and roots. These buds get separated to form new plants. Ex. - *Oxalis*.

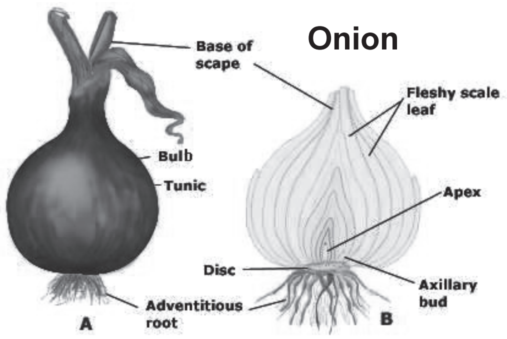


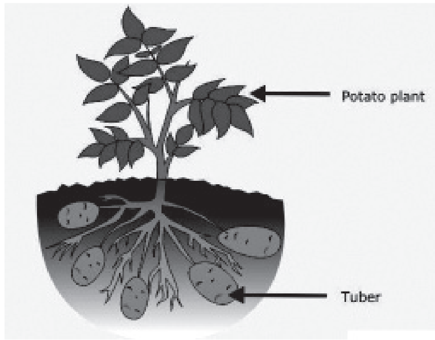
Rhizome of ginger.



  c) ***Bulbs -*** These are inflated parts of stem which grow underground. Ex.- Onion.

  d) ***Tubers -*** Tubers can grow from either stems or roots. Example of stem tuber is potato, whereas sweet potato and dahlia develop from root tubers.

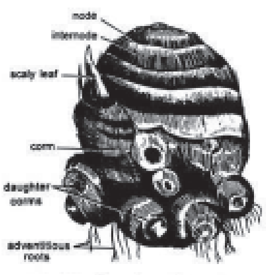




e) ***Corms -*** These are solid and fleshy enlarged underground stems. Ex. - Colocasia.

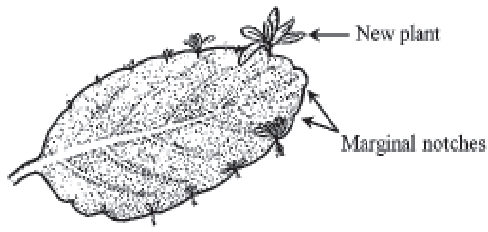
f) ***Suckers -*** These are root sprouts, that develop on the base of parent plant stems or on roots. Ex. - banana

g) ***Plantlets -*** Miniature structures that arise from leaf margins called adventitious buds develop into small plants. Ex. - Bryophyllum.



Corm of taro (Colocasia).

Banana Plant

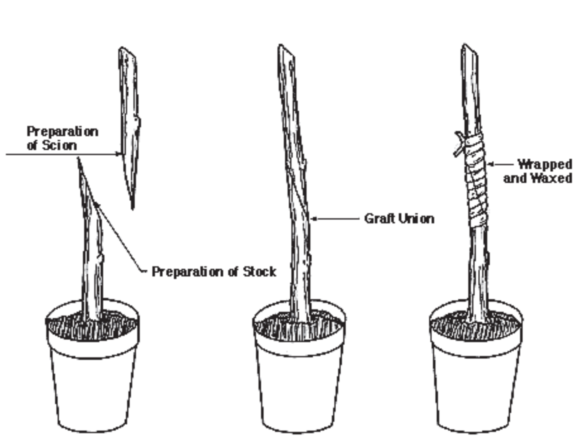


Vegetative propagation by leaves in Bryophyllum

ii. ***Artificial :*** These are methods used by farmers / horticulturists to produce better desirable crops.

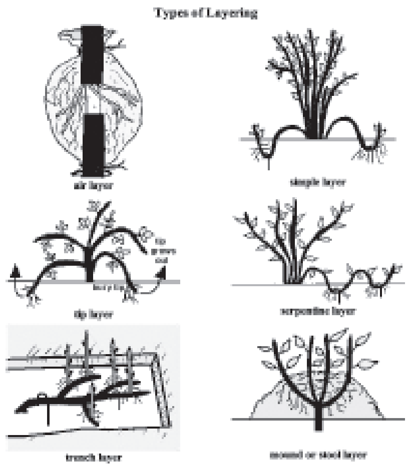
a) ***Cutting -*** A small plant part either a stem or leaf portion is cut off and planted. Hormones are mostly used to induce rooting and further growth. China rose and Bougainvillea can be grown by this method.

b) ***Grafting -*** A detached part of one plant, a twig or bud (scion) is inserted into the stem or root system of another plant (stock). The grafted portion is covered. A new plant develops from the scion. Mango, orange, rose are propagated by grafting.

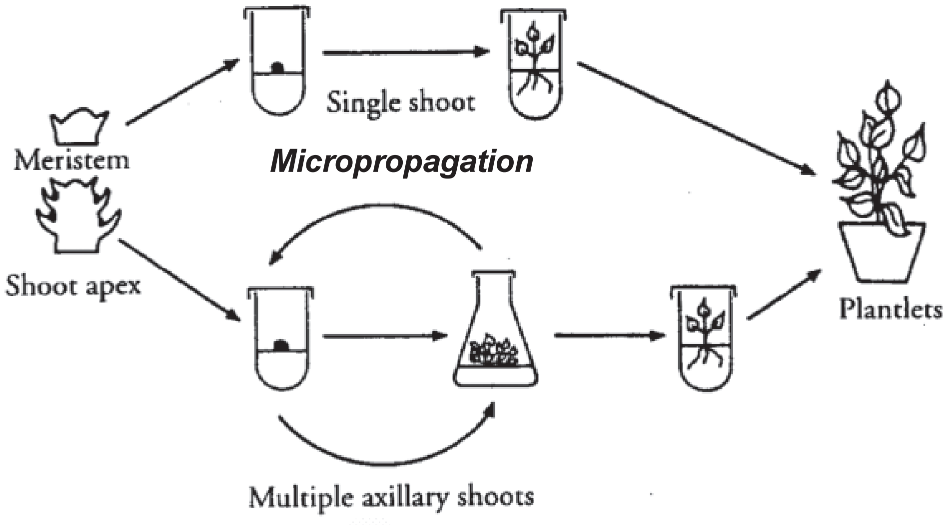


Grafting

c) ***Layering -*** Here roots are artificially induced to grow on branches. The rooted twig is detached from the mother plant and made to grow as a new plant. There are several types of layering.



d) ***Micropropagation -*** It is a method of vegetative propagation using artificial nutrient medium under aseptic conditions.



This method is extremely useful because

i) rapid rate of multiplication can be achieved within a short period.

ii) the plant variety with the desired traits can be maintained in a small space.

iii) pathogen free plants can be obtained quickly.

iv) it is the only reliable method of regenerating genetically modified cells.

v) it helps to multiply plants which do not produce viable seeds or when seeds can not be stored.

There are several disadvantages of micropropagation also. Micropropagation through tissue culture method will be discussed separately.

***

MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

   a. Yeast generally reproduces by :

   i) fission ii) budding

   iii) sporulation iv) gamete formation

   b. Naked spores which help *Penicillium* in asexual reproduction are called:

   i) conidia ii) cones

   iii) sporangia iv) mycelia

   c. Bacteria generally reproduce through :

   i) gametogenesis ii) fusion

   iii) binary fission iv) budding

   d. In grafting the rooted plant is called the :

   i) transplant ii) scion

   iii) graft material iv) stock

   e. Dahlia propagates by :

   i) root ii) stem

   iii) leaf iv) bud

2. Write notes on the following with 2 to 3 valid points :

   a) Budding b) Micropropagation

   c) Fragmentation d) Grafting

3. Differentiate between the following with 2 to 3 valid points :

   a) Zoospores and conidia

   b) budding and fission

   c) Stem tuber and root tuber

4. Give an account of various types of asexual reproduction seen in plants.

***

Module - 2

DEVELOPMENT OF MALE AND FEMALE GAMETOPHYTES IN ANGIOSPERMS

In angiosperms, plant body is a sporophyte and it is differentiated into root and shoot systems. On the shoot system, vegetative and reproductive parts are borne. The flowers are the important constituents of the reproductive shoot. A typical flower comprises of calyx, corolla, androecium and gynoecium. Calyx and Corolla are the inessential or accessory whorls. But, andrdoecium and gynoecium respectively form male and female reproductive parts. The individual members of androecium are called stamens. Each stamen, generally, is divided into two parts, such as filament and anther. Similarly individual components of gynoecium are carpels. The carpels are made of ovary, style and stigma. The male and female gametophytes of angiosperms develop inside the anthers and ovaries, respectively.

Inside the anthers, primary sporogenous tissue gets differentiated, it divides and redivides and ultimately forms the microspore mother cells. Microspore mother cells divide reductionally forming microspore tetrads. These microspores are the first cells of male gametophytic generation.

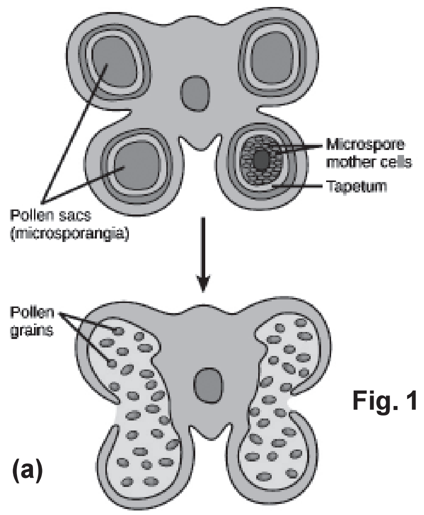
Ovules are borne inside the ovaries in various manners. The ovules bear archesporial cells which are larger in size, prominent nuclei and dense cytoplasm. Division and redivision of these archespirial cells, lead to form finally the megaspore mother cells. These cells divide reductionally and a linear tetrad of megaspores develop. These megaspores are the first cells of female gametophytic generation.

Development of male gametophyte

Microspores are, otherwise, called pollen grains. A mature microspore is predominantly oval or ellipsoidal structure. It has well defined 2 layered wall, the outer one is exine and inner called intine. Exine is thick walled, discontinuous and sporopollenin is the major constituent of it. Intine encloses the cytoplasm, thin walled and continuous. It is made of cellulose material (Fig.1).

At certain patches, the exine remains thin. These areas are called germ pores and through these, intine can protrude outside and forms pollen tube.

Once male gametes or microspores are formed, then these develop into male gametophytes. The development of male gametophytes may be divided into two stages, such as pre-pollination and post-pollination stages.



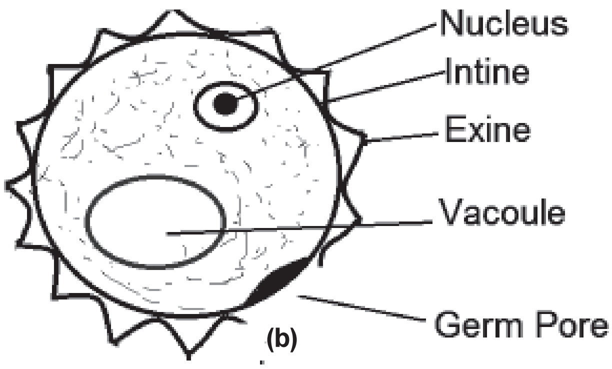


Fig. 1 : (a) Microspore formation and (b) its structure

Pre-pollination development

When male gamete or microspores are still inside the anthers, cell division occurs forming two unequal cells, the longer vegetative cell and smaller generative cell. No distinct wall formation takes place between the two. Cytoplasm of vegetative cells are rich in stored food but generative cells are hyaline. At this 2 celled stage, pollination occurs (Fig.2)

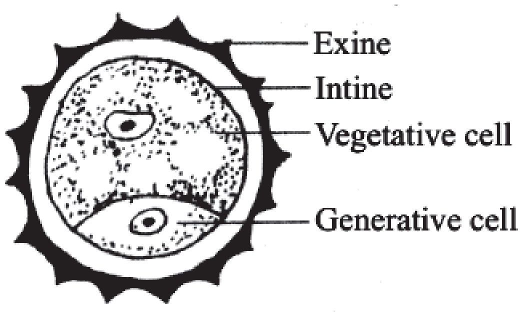


Fig. 2 : Two-celled pollen

Post-pollination development

At two celled stage, transference of pollen grains occur from the stamens to the complementary carpels. The receptive portions of the carpels are stigma. Here, the 2 celled male gametophytes absorb nutrients and water available at the surface of the stigma. Through the germ pores, fine narrow tubes are formed by the extensions of intine. These are called the pollen tubes (Fig. 3). The pollen tube penetrates the stigmatic wall and passes through the style to reach the ovary. Tube cell nucleus followed by generative nucleus migrate through it. Generative nucleus divides once mitotically but without wall formation and these are called sperms or male gametes. Now, this 3-celled stage represents the male gametophyte of angiosperms.

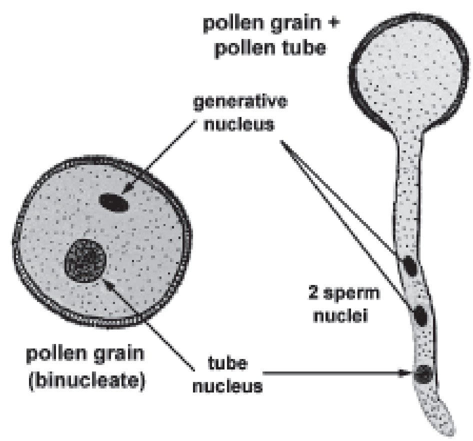


Fig. 3 : Pollen with Pollen Tube

Development of female gametophyte

Megasporogenesis occurs inside the ovule. As result, 4 megaspores are formed in linear tetrad. Out of these, only the lowermost survives and the rest get disintegrated. Only this functional gamete develops into the female gametophyte.

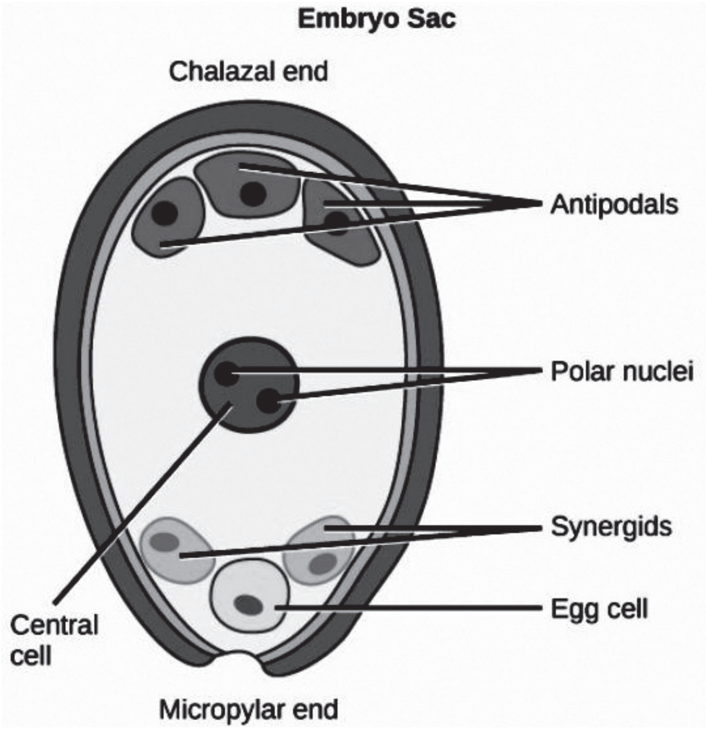


Fig. 4 : Embryo sac

Initially, the megaspore increases in size and many small vacuoles appear. The nucleus of this functional gamete divides thrice forming eight nuclei. Generally, four nuclei are seen at the microphylar end and four at the chalazal end of the ovule. The ovule enlarges in size. Out of the four nuclei at the microphylar end, one migrates to the centre and other three make egg apparatus. The central one of the egg apparatus is the egg cell and the other two at its both sides are known as synergids. Similarly, one nucleus from the chalazal tetrad moves towards the centre and other three form the antipodal cells. Two nuclei that migrate to the centre fuse together forming central cell or polar nuclei. This 8-nucleate and 7-celled female gametophyte form the embryo sac (Fig.4). It remains surrounded by the nutritive tissue of the ovule called nucellus.

***

MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

   a. Which is not a female reproductive part ?

      (ovary, style, anther, stigma)

   b. At how many celled stage normally pollination does occur ?

      (1, 2, 3, 4)

   c. How many types of cells are seen in embryo sac ?

      (1, 2, 3, 4)

   d. How many cells are present in embryo sac ?

      (2, 4, 7, 8)

   e. Which is the first cell of male gametophytic generation ?

      (Microspore, Microspore mother cell, Megaspore, Megaspore mother cell)

   f. What is the chromosome number of embryo sac cells except definite nucleus ?

      (n, 2n, 3n, 4n)

   g. How many nuclei make male gametophyte ?

      (1, 2, 3, 4)

   h. Where does pollen grains fall due to pollination ?

      (Ovary, Style, Stigma, Ovule)

2. Write notes on the following with 2 to 3 valid points :

   a) Microspore

   b) Embryo sac

   c) Post-pollination changes in microspore

   d) Megaspore

3. Differentiate between the following with 2 or 3 valid points :

   a) Microspore and megaspore

   b) Exine and Intine

   c) Embryo sac and Mature male gametophytes

   d) Egg apparatus and Synergids.

4. Give an account of development of male and female gametophytes of angiosperms.

***

Module - 3

DOUBLE FERTILIZATION IN ANGIOSPERMS

Sexual reproduction is a process in which male and female gametes come together, fuse and develop the fusion products called zygotes. Zygotes are the first cells of sporophytic generation. This sexual reproduction has advantage above the asexual process. By this process, the genetic recombination occurs as the two gametes are dissimilar in certain aspects. Normally, sexual reproduction occurs in three stages, i.e. Plasmogamy, Karyogamy and Meiosis. In lower plants where plant body is a gametophyte, the plasmogamy occurs first followed by karyogamy, development of sporophyte and ultimately meiosis. The latter again, restores the gametophytic phase. But in angiosperms the plant body is a sporophyte. Here, meiosis occurs first and then the gametophytes develop to ultimately effect the fertilization. This, again, restores sporophytic generation.

In angiosperms, fertilization takes place inside the embryo sac (Fig. 1). As a result of pollination, the compatible pollen grains are received by stigma, then they germinate by the production of germ tube. The pollen tube carries the male nuclei

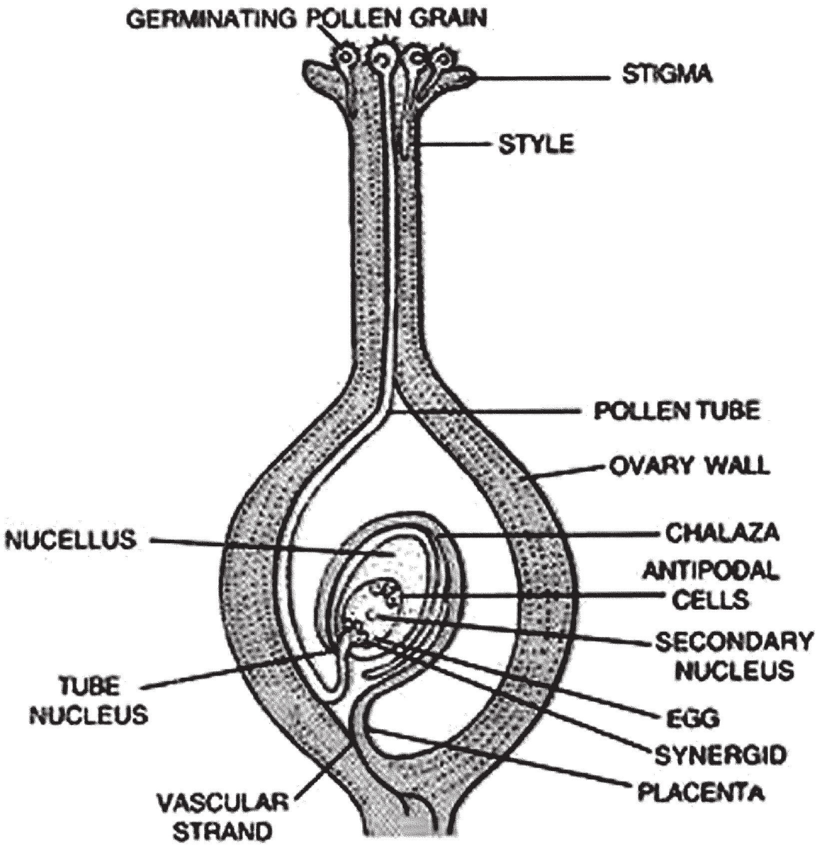


Fig. 1 : Double Fertilization in Angiosperms

into the embryo sac. When pollen tube enters through the microphylar opening of the ovule, it is called porogamy. But sometimes, it enters through the chalaza and the process is known as chalazogamy. Rarely, pollen tube may enter through the integuments of the ovule, then, it is called mesogamy.

Normally, in the sugary liquid of the stigma, the pollen grains get entangled. A mass of cytoplasm accumulates at tip of pollen tube which also contains the male nuclei. The tube nucleus gets disorganized, since it is a short lived structure. The pollen tube pierces through the style and reach the embryo sac.

One of the two male gametes fuses with the egg of egg apparatus and a diploid (2n) zygote is formed. The process is called syngamy or true fertilization. The other male gamete moves still further in the embryo sac and fuses with the polar nuclei. This results in the formation of primary endosperm nuclei (3n). As two separate fusions take place within the emryo sac by two male gametes, the process is called double fertilization and triple fusion. As soon as the fertilization is over, the cells other than the fusion products i.e. zygote and primary endosperm nucleus, get disorganized. Antipodals disappear even before fertilization. After the fertilization, the mature ovule develops into a seed and the matured ovary develops into the fruit.

***

MODEL QUESTIONS

1. Choose the correct answers from the choices given in the brackets of each bit :

   a) Sexual reproductive units are called :

      (zoospores, gametes, zygotes, parthenospores)

   b) How many nuclei or sperms take part in the sexual reproduction ?

      (4, 3, 2, 1)

   c) From which cell of the embryo sac do zygotes develop ?

      (Antipodal, Synergid, Definite nuclei, Egg Cell)

   d) From which cell of the embryo sac does primary endosperm nucleus develop ?

      (Egg, Antipodal, Polar, Egg)

   e) The entry of the pollen tube through the micropylar opening of the ovule is called :

      (Porogamy, Chalazogamy, Mesogamy, Herkogamy)

   f) What is the Chromosome number of primary endosperm nucleus ?

      (n, 2n, 3n, 4n)

2. Write notes on the following with 2 to 3 valid points.

   a) Embryo sac

   b) Primary endosperm nucleus

   c) Male gametes of angiosperms

   d) Double fertilization and Triple fusion.

3. Differentiate between the following with 2 to 3 valid points :

   a) Embryo sac and pollen grains

   b) Zygote and endosperm

   c) Gamete and Zygote

   d) Pollination and Fertilization

4. Give an account of double fertilization and triple fusion in angiosperms.

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Module - 4

MENDELIAN INHERITANCE

Mendelian Inheritance is a type of biological inheritance which states the laws originally proposed by G.J. Mendel in 1865 and 1866. It was rediscovered in 1900 by Hugo de Vries, Carl Correns and E.V. Tschermark. The laws originally created a lot of controversy. But when Mendel's Principles were integrated by Sutton - Boveri's chromosome theory by T.H. Morgan in 1915, it became the cornerstone of classical genetics. Because of his pioneering work in the field of genetics, he is rightly called the 'Father of genetics'. He performed the experiments on garden pea plants (*Pisum sativum*). Mendelian inheritance may be discussed under following headings;

1. Working Methods

Mendel performed the experiments in 2 acres of land between 1856 to 1863.

i. His experimental material was pea plants which bears bisexual flowers. It can be self pollinated and cross pollinated. Its life cycle could be completed within months so that he could observe the inheritance of characters of 3 to 4 generations in a year.

ii. He considered only one or few contrasting characters at a time and ignored a number of differences in his experimental material.

iii. He kept statistical records of his findings.

iv. At the outset, he took special care to choose pure lines of pea plants. For example, when he chose to take tallness and dwarfness in the original parental generation, he observed for generations, these are producing tall and dwarf progenies. This is called true breeding or pure line plants.

v. He took these pure parents as the parental generation, P. Then, he cross pollinated the flowers of these two plants and intentionally avoided the self pollination. This type of crossing is called hybridization. For example, he transferred pollens from tall pea plant to the stigma of dwarf plant or vice-versa. The off-springs are called first filial generation of F_1.

vi. In the final stage, he performed the self pollination or selfing between the flowers obtained as first filial generation. The progenies were named as F_2 or second filial generation.

Medel's Experiments

Initially, Mendel selected 7 pairs of contrasting characters in Pea plant, such as seed shape (round and wrinkled), seed colour (yellow or green), flower colour (violet or white), pod shape (full or constricted), pod colour (green or yellow), flower position (axial or terminal) and plant height (tall or dwarf).

He considered only one pair of contrasting characters or alleles and ignored the rest. Hence, the cross in which only a pair of alternative characters are taken is called monohybrid cross. Then, his experiments proceeded with two pairs of contrasting characters. This type of cross is called dihybrid cross.

Monohybrid Cross

When Mendel performed his experiments with true breeding tall plant with a true breeding dwarf plant, all the F_1 plants were tall. F_1 tall plants when self pollinated, the ratio of tall to dwarf was 3:1. Again, F_2 plants were self pollinated to obtain F3 generation. It was observed that all the dwarf plants were producing only dwarf plants. But, two thirds of the tall plants upon selfing produced tall and dwarf plants in 3:1 ratio. Hence, two thirds of tall plants are not true breeding. The rest one third tall plants are producing only tall plants and hence, those were true breeding.

It can be concluded from the above that the dominant characters express itself in the F_1 generation. In F_2, dominant and recessive characters reappear due to selfing and obtained ratio was 3:1. In this recessive one was homozygous or contain only the character for dwarfness. From among the three talls, one was homozygous but other two were heterozygous, i.e. possess contrasting pair of characters. The visible characters or the morphological expression of the characters are called phenotype but the internal factors responsible for expression of characters in the subsequent generations are known as genotype. If tallness and dwarfness are represented by TT and tt, respectively, a phenotypic tall may have genotype TT or Tt. The dwarfness is represented only by tt. It can be shown in the following :

P TT tt

Tall x Dwarf

Gametes (T) (t)

F_1 Tt Monohybrid

Tall (Selfing)

Gametes (T) (t)

F_2	T	t
T	TT	Tt
t	Tt	tt

TT - 1 Homozygous tall

Tt - 2 Heterozygous tall

tt - 1 Dwarf

Tall : Dwarf = 3:1

Fig. 1 : Monohybrid Cross

Dihybrid Cross

Mendel, then took two pairs of contrasting characters and observed their pattern of production of off-springs. He called it dihybrid cross. In the first filial generation, similar to the monohybrid cross, he found only dominant characters expressed themselves. Selfing it, in the F_2 generation, he observed 4 types of phenotypic characters being expressed independently.

For example, round (R) seeds were dominated over wrinkled (r) seeds and yellow (Y) seed colours were dominant over green (y) seed. He took true breeding round yellow (RRYY) and wrinkled green (rryy) seeds and observed the expression of characters in two filial generation as shown below.

In this dihyrbid cross, 4 types of plants were produced.

R-Y	-	Round yellow seeds	-	9
R-yy	-	Round green seeds	-	3
rrY	-	Wrinkled yellow seeds	-	3
rryy	-	Wrinkled green	-	1

The factor for round (R) was dominant over wrinkled (r). Similarly, factor for yellow (Y) was dominant over green (y). In the F_2 generation of dihybrid cross each pair of recessive and dominant characters assorted independently. Thus, it seemed that other pair of characters is non-existent. This can be shown in the following.

Number of plants with round seeds	= 9 + 3 = 12
Number of plants with wrinkled seeds	= 3 + 1 = 4
Hence, F_2 ratio of round : wrinkled	= 12:4 = 3:1
Number of plants with yellow seeds	= 9 + 3 = 12
Number of plants with green seeds	= 3 + 1 = 4
Hence F_2 ratio of yellow : green seeds	= 12:4 = 3: 1

This shows that although the factors for both the characters were present together, the ratio was exactly similar to monohybrid cross which shows their independent assortment.

Based on his experiments, Mendel proposed three laws which became the guiding principle of Mendelian inheritance.

1) **Principle of dominance:**

   Performing experiments with one pair of contrasting characters, he observed that one character becomes evident and other is masked. This character, which is not seen phenotypically in F_1 generation, is recessive one and the one which expresses itself is called dominant character. This is the Mendel's law of dominance.

2) **Principle of segregation:**

   F_1 plants with phenotypic dominant characters when selfed, the recessive characters reappeared in the subsequent generation. This shows that the characters were not actually mixed in the F_1 generation but genotypically, they were maintaining their identity. Thus, they were segregating in F_2 generation.

3) **Principle of independent assortment:**

   As shown, law of independent assortment expresses that a cross between parents with two contrasting characters, the inheritance of each pair of characters is independent of the other. Hence, characters for round seeds or wrinkled seeds and characters of yellow seed or green seed got inherited independently in F_2 generation. This experiment is given below in a checker board (Fig. 2).

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Round/Yellow: 9

Round/green: 3

wrinkled/Yellow: 3

wrinkled/green: 1

9:3:3:1 phenotypic ratio

Fig. 2 : Dihybrid Cross

Back cross and Test cross:

Back cross denotes a cross between F_1 hybrid and either of the homozygous parents. It can be shown by the following;

Parents TT x tt

Gametes T x t

F_1 Tt x TT (Back cross)

Gametes (T) (t) (T)

F_2

	T	t
T	TT	Tt

All are tall

F_1 Tt x tt (Test cross)

Gametes (T) (t) (t)

F_2

	T	t
t	Tt	tt

Tall : Dwarf = 1: 1

The above results shows that, if F_1 hybrid is crossed with homozygous dominant parent, then only dominant character will be expressed in F_2 generation. But if the back cross is made with the recessive parent, F_2 hybrid will show 1:1 ratio of contrasting characters.

Back cross is defined as the cross between F_1 hybrid and either of the parents. But test cross is done between F_1 hybrid and the recessive parent only. If a dominant phenotype with unknown genotype is crossed with recessive parent, then the cross is a test cross. If F_2 formed is in equal proportion of dominant and recessive phenotypes, then the test plant is heterozygous dominant. This was used effectively by Mendel to ascertain the genotypes of dominant phenotypes.

***

MODEL QUESTIONS

1. Answer the questions in each bit choosing correct answers from the alternatives given in the brackets.

    a) Who is known as the father of genetics?
    (Morgan, De Vries, Mendel, Darwin)

    b) In which plant did Mendel perform his experiments?
    (Pea, Maize, Potato, Snapdragon)

    c) What is phenotypic ratio of monohybrid cross in pea plants in F_2 generation?
    (1:2:1, 3:1, 2:1, 1:1)

    d) The cross between F_1 hybrid and double recessive parent is called;
    (Test cross, Back cross, Multiple cross, Complementary cross)

    e) F_1 plants of monohybrid cross are;
    (Homozygous, Heterozygous, Hoterologus, Heterogynous)

    f) Which was the law proposed by Mendel from dihybrid cross?
    (Law of Segregation, Law of purity of gametes, Law of dominance, Law of independent assortment)

    g) The phenotypic ratio in dihybrid cross is;
    (3:1, 9:3:3:1, 1:1:1:1, 1:2:1)

    h) In which of the crosses, will half of the off-springs be recessive?
    (Tt x tt, Tt x TT, tt x tt, TT x TT)

2. Write notes on the following with 2 to 3 valid points.
    a) Allele
    b) Law of dominance
    c) Law of segregation
    d) Test cross
    e) Back cross
    f) Reason for Mendel's success

3. Differentiate between the following with 2 to 3 valid point.
    a) Genotype & Phenotype
    b) Heterozygosity & Homozygosity
    c) Monohybrid cross & Dihybrid cross
    d) Law of dominance & Law of segregation
    e) Parental generation & Filial generation.

4. Give an account of Mendel's monohybrid cross.

5. With a checker board, describe Mendel's dihybrid cross experiment.

***

Module - 5

STRUCTURE OF DNA

Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are two types of nucleic acids found in the living organisms. DNA acts as the genetic material in all the organisms excepting certain viruses. In these viruses, called RNA viruses, RNA is the genetic material. Generally, RNA acts as the messenger of genetic informations. Besides, in certain cases, RNA also acts as the adapter, structural and catalytic molecule.

Chromosomes are made of DNA molecules. This is the bearer of hereditary material of all living beings. Therefore, in recent years, attempts have been to determine the entire genetic make up called genome of the organisms. This means the study of genetic make up or DNA structure and its arrangement in an organism. In 2003, complete nucleotide sequence of human genetic composition has been determined. This has heralded new era in molecular biology. In this module we will examine the structures of this important molecule.

DNAs are found in the chromosomes present in plant, animal and all eukaryotic cells. In prokaryotic cells, a single circular DNA molecule makes the genetic make up. Some viruses, usually animal viruses have DNA as the genetic material. Again, small amount of DNA is found in the chloroplast cells of photosynthetic organisms.

DNA is a polymer of nucleotides. Nucleotides have three components : a nitrogenous base, a pentose sugar and a phosphate group. There are two types of nitrogenous bases - purines and Pyrimidines (Fig. 1). Adenine and guanine make purines. Pyrimidines made of Cytosine, thymine and Uracil. Cytosine is common in DNA and RNA. But, Uracil is present in RNA only and DNA has thymine is place of uracil.

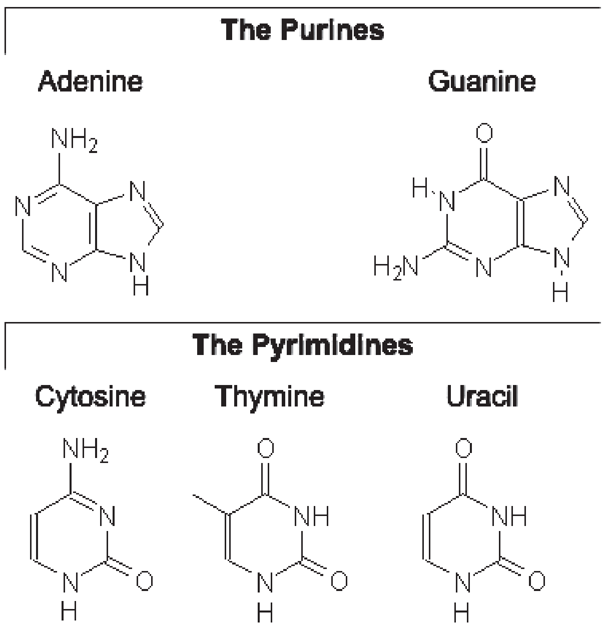

Fig.1 : Constituents of Purines and Pyrimidines

A nitrogenous base is linked to the pentose sugar through N-glycoside linkage to form a nucleoside. Nomenclature of nucleoside varies with the nitrogenous base (Table-1).

Table-1

Different nucleosides of DNA and RNA

Base	Ribonucleoside	Deoxyribonucleoside
Adenine	Adenosine	Deoxyadenosine
Guanine	Guanosine	Deoxyguanosine
Cytosine	Cytidine	Deoxycytidne
Thymine	Ribothymidine	Deoxythymidine
Uracil	Uridine	Deoxyuridine

Again, in case of RNA formation, the pentose sugar is a ribose but DNA sugars are deoxyribose (Fig. 2). Phosporic esters of nucleosides are nucleotides (Fig. 3). A ribonucleotide has 3 positions such as 2, 3 and 5 which may be esterified but a DNA can be esterified at 3 and 5 positions. When a phosphate group is linked to 5'-OH of nucleoside through phosphoester linkage a corresponding nucleotide is formed (Fig. 3). Two nucleotides linked through 3' -5' phosphodiester linkage to form dinucleotide. When more and more nucleotides are joined a polynucleotide chain will be formed.

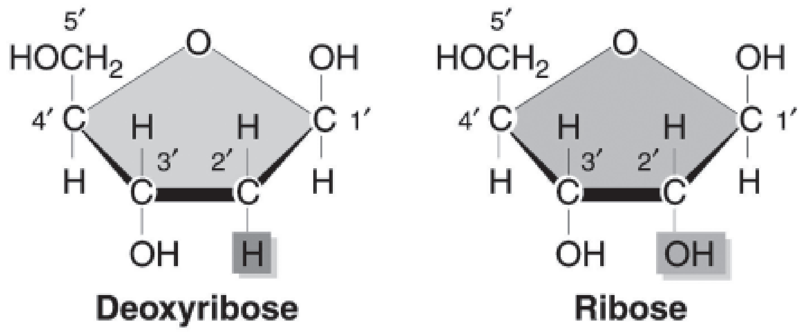

Fig. 2 : Pentose sugars

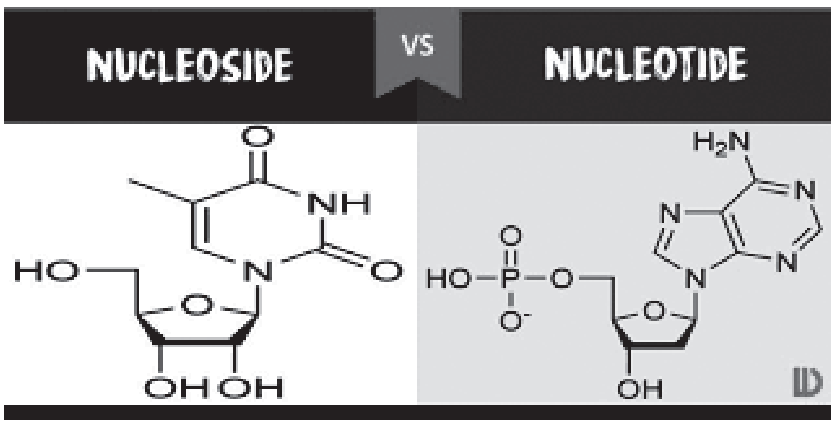

Fig. 3

Primary structure of DNA

DNA is an acidic substance found in the nucleus. It was observed by Fredrich Meischer, 1869. He named it 'nuclein'. In 1953, James Watson and Francis Crick proposed the DNA structure. It was based on X-ray diffraction data produced by Maurice Wilkins and Rosalind Franklin.

As stated earlier, only 3'-5' ends of pentose sugar gets esterified to form a DNA polynucleotide. Esterification occurs in such a way that 3' end of one nucleotide is followed by 5' end of the next nucleotide. Therefore, the polydeoxyribonucleotide chain consists of alternating deoxyribose and phosphate residues. (Fig. 4).

Secondary structure of DNA

Watson and Crick's double helical structure of DNA is actually the secondary structure of DNA (Fig.5).

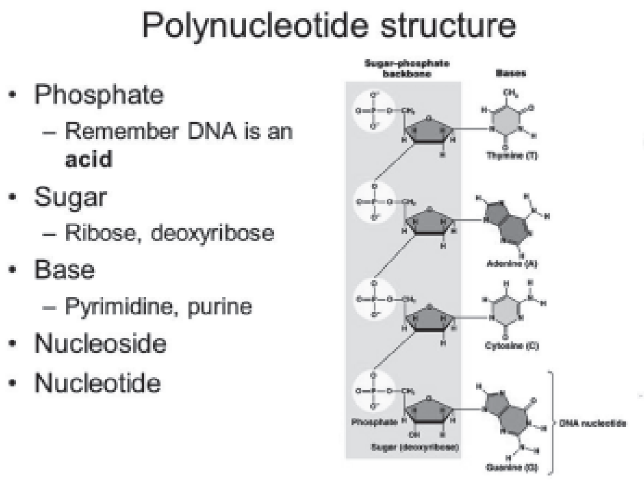

Fig. 4

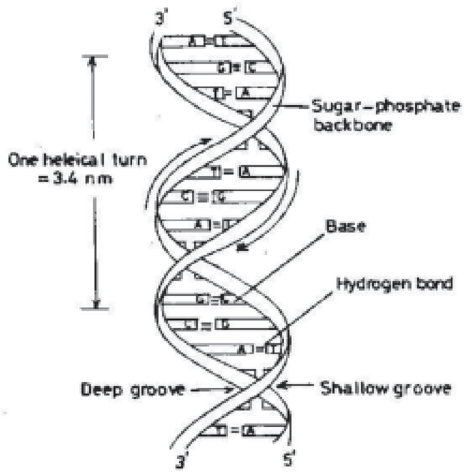

Fig. 5 : Watson and Crick's double helical structure of DNA

According to this model, DNA has a double stranded structure where two polydeoxyribonucleotide chain get twisted around each other. Here, a purine always pairs with pyrimidine and Vice Versa. For example, adenine (A) of one polynucleotide chain pair with thymine (T) of the other chain. Similarly guanine (G) of one chain pairs with Cytosine (C) of other; so that the sum of purines and pyrinmidines (A + G = C + T) is equal. This is called Chargaff's rule.

This shows that the base pairing of DNA chains are very unique. They show complementarity with each other. Once the composition of one strand is known, then the composition of other strand can be predicted.

The main features of DNA double helix are

(1) DNA molecules are made of two polynucleotide chains where the backbone is sugar-phosphate and bases form the core.

(2) Two chains have antiparallel polarity, i.e. 5'-3' polarity of one chain is complemented by 3'-5' of the other.

(3) The bases of each chain are paired by hydrogen bonds.

(4) Two chains are coiled in right hand direction. The pitch of the helix is 3.4 nm and there are 10 base pairs in each turn. Consequently, the distance between each base pair is 0.34 nm.

Structural forms of DNA double helix

Watson and Crick proposed the structure of the B- form DNA. B - form is a right handed helix with ten residues per 360^0 turn and the planes of bases are perpendicular to the axis. The chromosomal DNA consists of B-DNA.

If B-DNA is moderately hydrated, it will be A-form DNA. It shows right hand helix but there are II base pairs per each 360^0 turn. The planes of bases are tilted 20^0 away from the perpendicular helical axes.

Z-DNA have Zig-zag backbone. It is a left handed helix containing 12 base pairs.

Besides these 3-form of DNA, there may be C-DNA with 9 base pairs and D-DNA with 8 base pairs in each turn.

***

MODEL QUESTIONS

1. Write the correct answers of each bit selecting from the choices given in the brackets.

   a) Which is the base absent in DNA ?

      (adenine, cytosine, thymine, uracil)

   b) Where are DNA molecules not seen ?

      (Chloroplast, Vacuoles, Mitochondria, Nucleus)

   c) Which is present in RNA but not in DNA?

      (adenine, guanine, uracil, cytosine)

   d) The example of purine is :

      (adenine, cytosine, thymine, uracil)

   e) Which does constitute nucleotides ?

      (Sugar + nitrogenous base, Sugar + phosphate, Nucleoside + phosphates, Nitrogenous base + phosphates)

   f) In DNA double helix adenine is paired with.

      (guanine, uracil, thymine, cytosine)

   g) How many base pairs are present in each turn of double helix ?

      (5, 8, 10, 20)

   h) Watson and Crick proposed the structure of

      (A-DNA, B-DNA, C-DNA, Z-DNA)

2. Write notes on the following with 2 to 3 valid points.

   a) Nucleoside
   b) Nucleotide
   c) Polynucleotide
   d) Chargaff's rule
   e) B-DNA
   f) A-DNA

3. Differentiate between the following with 2 to 3 valid points :

   a) Purine and Pyrimidine
   b) DNA and RNA
   c) B-DNA and A -DNA
   d) Nucleoside and nucleotide

4. Give the secondary structure DNA molecule.

***

Module - 6

DNA REPLICATION

DNA replication is the biological process that occurs in all living organisms and copies their DNA; it is the basis for biological inheritance. In molecular biology, DNA replication process involves production of two identical replicas of DNA from one original DNA molecule.

While proposing the double helical structure for DNA molecule, Watson and Crick suggested that the basis for copying the genetic material is base complementarity : two strands, in the process of replication would separate and would act as a template for the synthesis of new complementary strands. After the completion of replication, each DNA double helix would have one parental and a newly synthesized strand. Hence, in every DNA, one parental strand is conserved and one new strand synthesized, the mode of replication is known as semiconservative replication (Fig. 1).

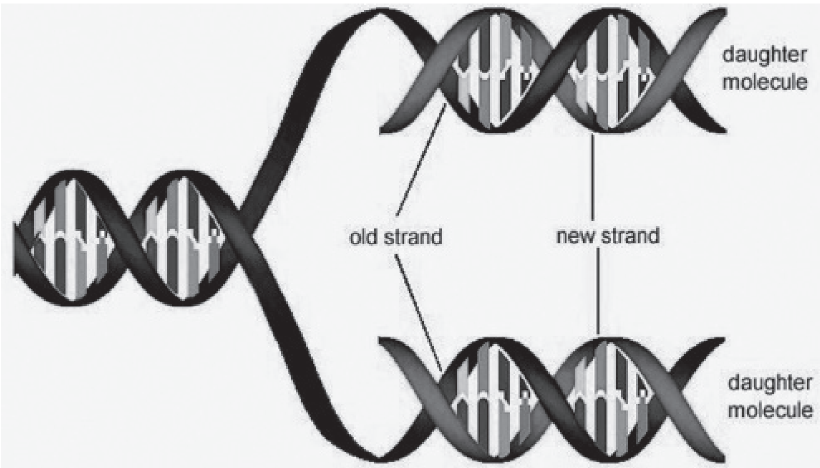

Fig. 1 : Semiconservative replication model

Experimental Proof

It is now well established that DNA replicates semiconservatively. It was first shown in *Escherichia Coli* and subsequently in higher organisms like plant and human cells. Mathew Meselson and Franklin Stahl proved it by the following experiment in 1958 :

i) *E.Coli* cells were grown in the medium containing $^{15}NH_4Cl$ as only source of nitrogen for many generations. The result was that ^{15}N was incorporated into the newly synthesized DNA as well as other nitrogen containing comounds. In a cesium chloride (CsCl) density gradient centrifugation, the heavy DNA molecule could be distinguished from the normal DNA.

ii) The cells were transferred into a medium with normal $^{14}NH_4Cl$. The samples were taken at various definite intervals as cells multiplied and extracted the DNA that remained as double stranded helices. The samples were separated at various intervals on the basis of CsCl gradients to measure the densities of DNA (Fig. 2).

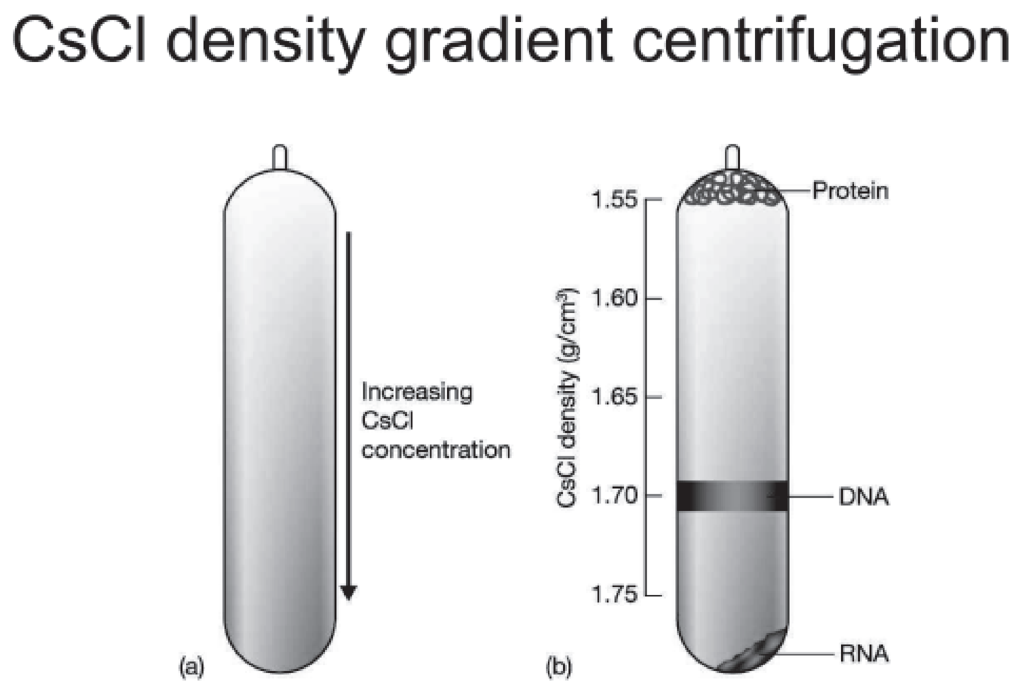

Fig. 2

iii) It was observed that DNA extracted from the culture one generation after the transfer from ^{15}N to ^{14}N medium had a hybrid of intermediate density. DNA extracted from the culture after another generation composed equal amount of hybrid DNA (^{15}N DNA) and normal DNA (^{14}N DNA).

Semiconservative mode of replication of DNA molecules in bacteria was demonstrated by J. Cairns using autoradiography. J. H. Taylor and his coworkers established semiconservative mode of replication in *Vicia faba*. Semiconservative replication of chromosomes can be visualized through an examination of chromosomes using fluorescent dye and Giemsa. The Chromosomes are allowed two rounds of replication in a medium containing bromodeoxyuridine. The newly synthesized strand of each DNA stain differently from old strand. Such chromosomes where the two strands of DNA are stained differently are called harlequin chromosomes. Presence of harlequin chromosomes confirm semiconservative replications.

Requirements and DNA replication steps

The process of DNA replication is fast, accurate and complex. It requires several enzymes and protein factors for completion. The basic steps are :

1. Unwinding and separation of two parental strands of DNA.
2. Each parental strand then serves as the template for synthesis of new strand on the basis of complementarity of nucleotide sequences of the template strand.
3. One parental strand and one new strand will wind around each other to form a new double helix.

DNA replication originates at specific sites called replication origin and then proceeds in one or both the directions. In *E. Coli,* the origin is a unique sequence of DNA of about 245 base pair long and known as Ori C. It is A-T rich so that two stands easily separate at the origin. The origin is characteristically recognised by a replication initiator protein which binds to the origin to begin replication. In Yeast, the origin is known as Autonomous Replicating Sequence (ARS) and 150 base pair long. ARS is the binding site for Origin Recognition Complex (ORC). The replication initiated from the origin proceeds along the replication fork. So, each origin has two terminii. This is called replicon. But eukaryotes have larger DNA and have several origins for DNA.

DNA Polymerase

Replication process requires a series of enzymes and protein complexes. The main enzyme is referred to as DNA dependent DNA polymerase or DNA polymerase. This enzyme polymerises deoxyribonucleotides.

Arthur Kornberg and his colleagues in Washington University in 1956 isolated this enzyme from *E. Coli*. Hence, it is called Kornberg enzyme. Later, this was called DNA Polymerase I as other DNA polymerase like DNA Polymerase II and Polymerase III were discovered. DNA Polymerase III is the major polymerase invovled in DNA replication. Polymrase I and Polymerase II are used in DNA repair and proof reading in prokaryotes. DNA polymerase requires a template for synthesis of new strand. They can synthesize in 5'-3' direction. This enzyme does not synthesize DNA but can only add to an existing primer strand. A primer is a small strand of DNA or RNA which is hydrogen bonded to template. During DNA synthesis, new nucleotides are added to open 3' OH end of the primer of growing polynucleotide so that synthesis is always 5'-3' direction. Polymerase III has exonuclease property.

It can remove 3' end of the growing DNA strand. It helps in proof reading so that wrong nucleotides added at 3' end can be removed. Polymerase I has 5'-3' exocuclease function.

Mechanism of replication

Entire set of enzymes and protein factors involved in DNA replication are called replicase system.

1. The initiator protein recognises the unique sequence of origin and build to it.
2. DNA helicase unwinds the double stranded DNA by breaking the hydrogen bonds between nitrogenous bases.
3. Single strand binding proteins bind to the separated strands to keep them in extended position. It also prevents rewinding and attack by single stranded nuclease.
4. As a result, replication fork is created (Fig. 3).

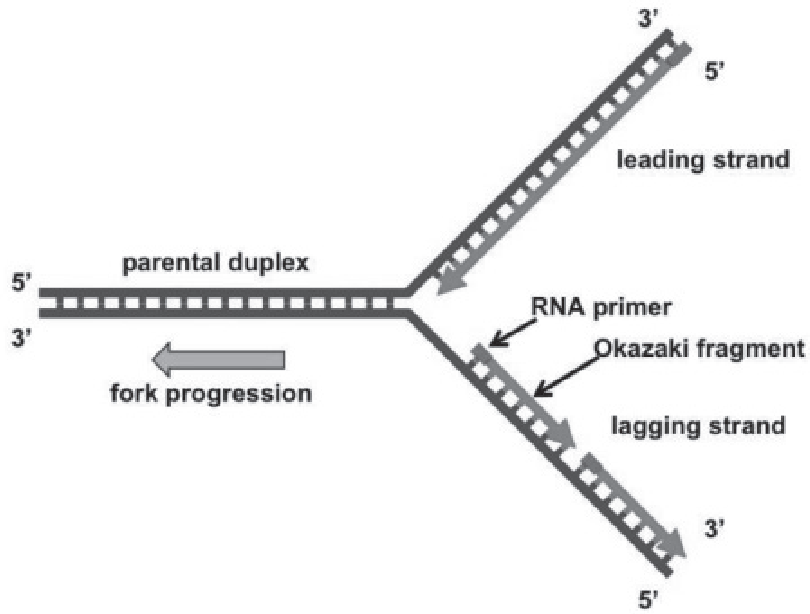

Fig. 3 : DNA Replication Fork

5. DNA Polymerase requires a primer strand for addition of nucleotides. Enzyme primase synthesizes a primer complementary to 3' end of templates.
6. The replication fork moves by unwinding of double stranded DNA. As a result, one template strand is continuous with the movement of fork along 3' to 5' direction of the template strand.
7. In the same replication fork, other strand is not continuous with the movement of the fork.

8. The template strand whose 3'-5' direction coincides with the movement of the fork is known as leading template strand or leading strand. This strand need a single initiation event at the start of the replication and the new strand synthesis takes place continuously.

9. The other strand whose 3'-5' direction is opposite to the direction of movement of replication fork is known as lagging strand.

10. In this case, continuous DNA synthesis is not possible. Short strands of DNA are synthesized here discontinuously and later join to form a new strand.

11. The small DNA fragments of lagging strand are called Okazaki fragments. These fragments are 1000-2000 nucleotide long in prokaryotes and 100-200 nucleotides in eukaryotes.

12. Each Okazaki fragment on lagging strand has its own primer. The primsome protein complex moves along the lagging strand and forms RNA primers at intervals on which Okazaki fragments are synthesized.

13. DNA Polymerase I enzyme removes the RNA primers from the lagging strand through its 5'-3' exonuclease activity. Then it fills the resulting gaps by adding nucleotides complementary to these portions of lagging strand.

14. Finally, ligases join the Okazaki fragments to form continuous DNA strand complementary to lagging strand.

***

MODEL QUESTIONS

1. Answer the questions in each bit selecting appropriate answers from the alternatives given in the brackets :

   (a) Which is referred to as Kornberg enzyme ?
   (DNA Polymerase, RNA Polymerase, Ligase, Helicase)

   (b) Which enzyme does remove DNA strands ?
   (Ligase, Helicase, Isomerase, Polymerase)

   (c) Which enzyme does join DNA fragments ?
   (Isomerase, Polymerse, Ligase, Helicase)

   (d) RNA primers are removed by
   (DNA Polymerse III, RNA Polymerse, Helicase, DNA Polymerse I)

   (e) DNA synthesis from another DNA molecules is called :
   (Translation, Transformation, Replication, Transcription)

   (f) Which is the enzyme that synthesize RNA primers ?
   (Polymerase, Helicase, Ligase, Primase)

2. Write notes on the following within 2 to 3 valid points :

   (a) Semiconservative replication
   (b) DNA Polymerase
   (c) Replication fork
   (d) Okazaki fragments
   (e) RNA primer
   (f) Template strand

3. Differentiate between the following with 2 to 3 valid points :

   (a) Leading strand and Lagging strand.
   (b) DNA Polymerase I and DNA Polymerase III.
   (c) Helicase and Ligase.

4. Give an account of DNA replication in Prokaryotes.

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Module - 7

PLANT BREEDING, TISSUE CULTURE, SINGLE CELL PROTEIN AND BIOFORTIFICATION

PLANT BREEDING

Plant breeding is the science of evolving new varieties of plants that can grow better under varied climatic conditions, be resistant to diseases and produce superior quality yield. Plant breeding has been practiced in some form or the other from the very beginning of human civilization. Mendel's experiments using plant hybridization formed the basis of the science of genetics or inheritance. As the knowledge in the field of genetics, molecular biology and tissue culture advanced significantly, plant breeding is increasingly being carried out using tools of molecular genetics and biotechnology.

In the breeding process two genetically dissimilar varieties are purposely crossed to produce a new hybrid variety. Characteristics or traits from both parents are obtained in the new variety. In order to introduce a new variety in the field with desired characters like, resistance to specific diseases, resistance to drought or salinity, better productivity etc., various steps involving the breeding protocol are required to be gone through.

a) Collection of germplasm : Genetic variability from various wild and relatives of the cultivated species are collected and maintained. This is known as germplasm collection.

b) Evaluation of germplasm and selection of parents : The germplasm is evaluated for desirable genes. Seeds of the selected plants are sown and cultivated repeatedly to see that the desired characters are transmitted successfully to subsequent generations.

c) Hybridization between selected parents : The hybridization may be of different types like :

  i) inter-varietal = between two varieties
  ii) intra-varietal = between different genotypes of same variety
  iii) intra-generic = between two species of the same genus
  iv) inter-generic = between two genera

d) Selection of superior hybrids : The hybrids with the desired characteristics are selected scientifically and are then self pollinated for several generations to ensure homozygosity.

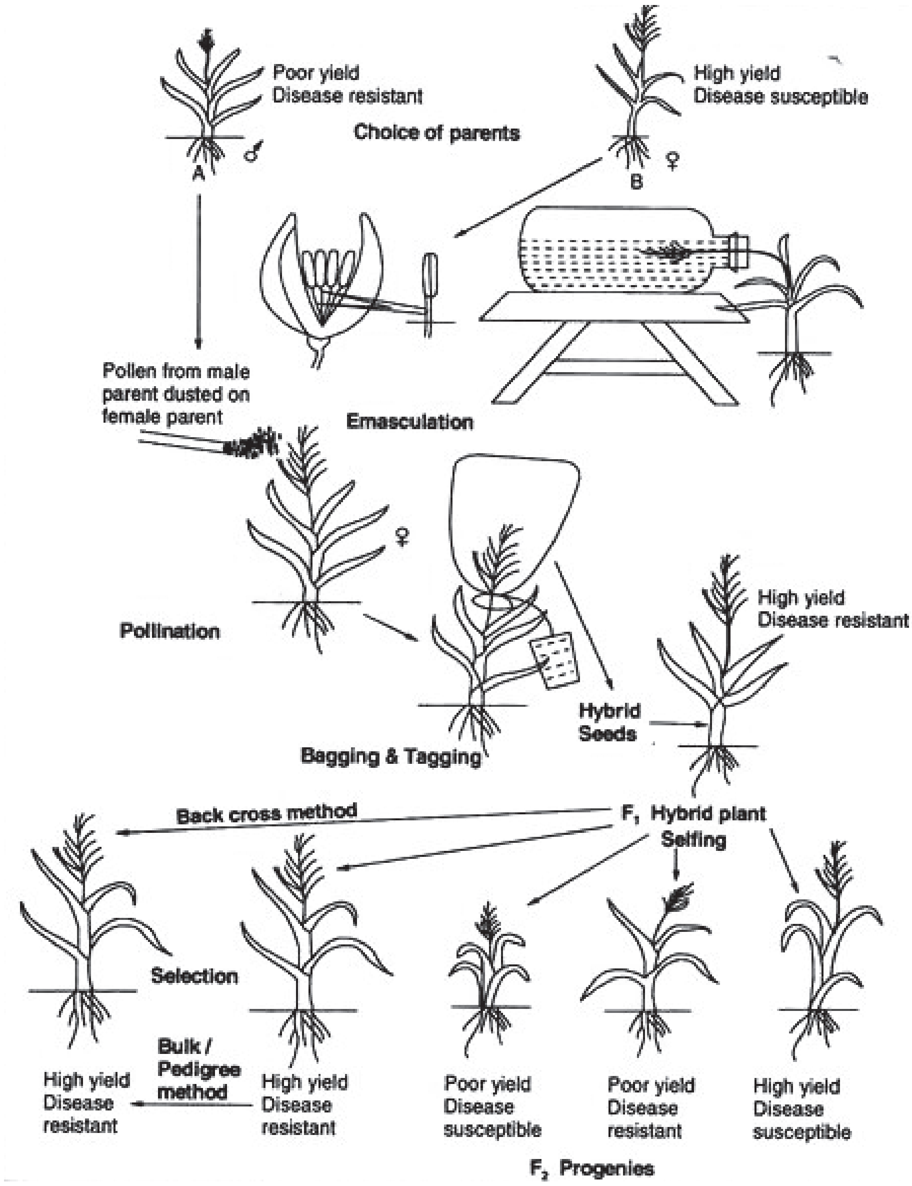
e) Testing and release of new cultivars - After thorough testing and evaluation in research fields for at least three seasons, the selected varieties are released to the farmers for large scale production.

Techniques of hybridization :

a) ***Emasculation -*** In this process anthers are physically removed in self pollinated plants. It is done before the anthers are mature.

b) ***Bagging -*** The emasculated flowers are covered with a bag to prevent contamination of stigma with unwanted pollen from other sources.

c) ***Tagging -*** The emasculated flowers are tagged just after bagging. The information on the tag should be very brief may include a number (field test), date of emasculation and date of crossing.



Steps in Hybridization Technique

Artificial Pollination :

Pollens from selected male parents are collected and then dusted with a fine brush on the stigma of the female plant. The female plant is sincerely sealed in a bag till the time of seed production.

Selection of superior hybrids :

Seeds from the F_1 generation are self pollinated for obtaining homozygous plants with desired superior characters, so that they can breed true with the desired character. Examples of improved high yielding varieties.

Rice - IR8, Taichung and their derivatives - Jaya & Ratna. These varieties were responsible for the green revolution.

Wheat - Kalyan sona, and Sonalika. Plant breeding aims at improving the food quality along with food production. The quality may include colour, flavor, size, nutrient levels and other food safety requirements in a variety of crop plants.

Plant breeding for Crop improvement :

World's population is predicted to reach over 9 billion (900 crores) by 2050. Therefore, there is continuing need to produce improved varieties of crop plants for a balanced and healthy diet. Land available for crop production has stayed at 660 million hectares for the last 50 years and world's best agricultural land have already been used. The choice, therefore, before the scientific community is to strive for production of more food, fibre, fuel and forage per unit of land. Plant breeders therefore need to priorities the following :

a) To access the genetic variation in crop species and quickly respond to new situations by making use of advanced breeding techniques,

b) To see that increase in yield and yield stability remains the top priority,

c) To ensure that strategies for facing the new challenges of climate variation arising out of global warming is formulated futuristically for next one or two decades.

Important facets of modern day agriculture is to replace the conventional method of using large quantities of chemical fertilizer and chemical pesticides with use of pest-resistant and disease-resistant varieties and organic fertilizers etc. Therefore, introduction of desired resistant genes in the susceptible crop varieties can be achieved by the breeders by employing advanced molecular and mutation breeding tools.

BIOFORTIFICATION

Biofortification is a process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding and modern biotechnology. Several successful projects of biofortification include :

a) iron-biofortification of rice, beans etc.

b) zinc-biofortification of wheat, rice, maize, beans etc.

c) carotenoid (pro vitamin A) - biofertification of sweet potato, maize etc.

d) amino acid and proteins - biofortification of sorghum and cassava etc.

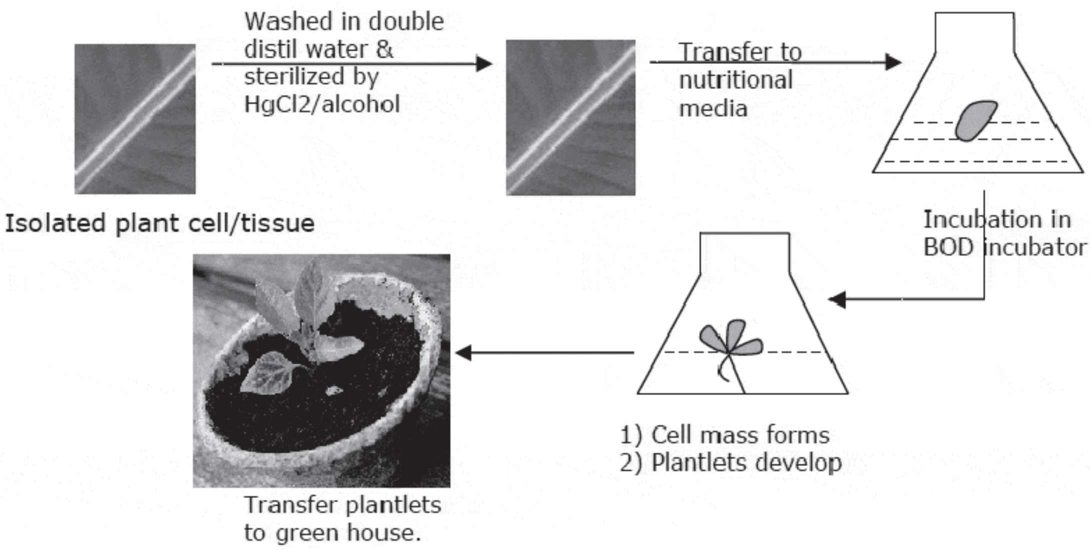
Biofortification represents a promising strategy to enhance the availability of vitamins and minerals for people whose diets are deficient with micronutrients.

TISSUE CULTURE

Tissue Culture is the growth of tissues or cells in a liquid, semisolid or solid growth medium separate from the organism. Here we will only discuss about plant tissue culture. Plant tissue culture technique is based on the unique property of plant cells known as totipotency. Totipotency, originally called as "totipotentiality" by Gottlieb Haberlandt in 1902 is based on the dictum that theoretically all plant cells are able to give rise to a complete plant.

Tissue culture Technique

There can be various types of plant tissue culture such as (i) seed culture, (ii) embryo culture, (iii) callus culture, (iv) organ culture, (v) protoplast culture and (vi) anther culture.



Tissue culture Technique

Procedure :

Selection of explants - It is the plant part used for culture. Healthy and young tissues from stem and root tips, leaves respond quickly to culture condition.

Sterilization - The entire culture process has to be gone through under total aseptic conditions. The explants are surface sterilized by repeated washing in sterile water and by using disinfectants such as hydrogen peroxide, mercuric chloride etc. The glass wares and culture media are sterilized with steam in autoclave under high pressure.

Culture Medium - Since the explants are cultured in vitro, the nutrient medium should cater to fulfill their nutritional requirement like :

Macronutrients - It includes elements like Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Sulphur (S).

Micronutrients - Elements like iron (Fe), Manganese, Zinc (Zn) etc.

Carbon Source - Sucrose is the most widely used carbon or energy source.

Vitamins and growth hormones - Vitamins like pyridoxine-HCl and several growth hormones like 2, 4-D, Cytokinins, Myoinositol, IAA and NAA are used. When a solid medium is used suitable quantities of agar agar is added to the medium.

Standard culture media - White's medium is one of the earliest plant tissue medium developed for root culture. But the medium developed by Murashige and Skoog (MS) to induce organogenesis is widely used in plant tissue culture work due to its success with several plant species. Other specialised media are - B5 medium - for suspension culture and protoplast culture, N6 medium for cereal anther culture and Nitsch's medium - for anther culture.

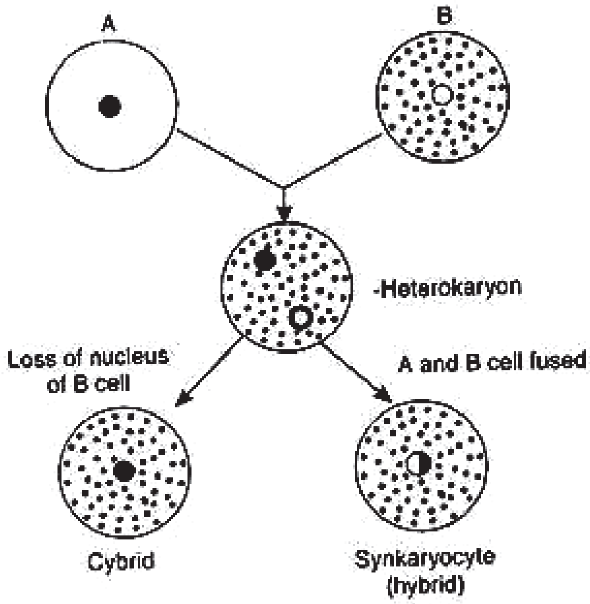
Inoculation - Inoculation is the process of transfer of explants to suitable nutrient medium under sterile condition. Special inoculation chamber or Laminar Flow (a sterile air flow platform) is used for inoculation. After inoculation, the culture tubes/vessels are transferred to growth chambers with controlled temperature (18-25^{0}C) and light.

Callus formation and its culture - Callus is an amorphous mass of loosely arranged thin parenchyma cells developing from the parent tissue. The callus has the potential to develop normal shoots, root and the whole plant. Callus culture can be maintained for a long period of time by suitable manipulation of growth hormones.

Organogenesis - The development of organs like root, shoot and leaves from the callus is known as organogenesis. A high ratio of auxin : cytokinin stimulates root formation, while a low ratio of the same induces shoot formation from the callus.

Somatic Embryogenesis - This is the process of inducing embryo formation from somatic cells of cultured plant tissue. The embryos, so developed are known as embryoids. By manipulating the culture medium the embryoids develop into plantlets. The embryonic cells pass through three stages like - globular stage, heart stage and torpedo stage before forming plantlets. This process has been successfully introduced in *Brassica oleacea, Carica papaya, Citrus cinensis* etc. Somatic embryos/embryoids, when encapsulated, behave like true seeds, if grown in soil and are called artificial seeds or synthetic seeds.

Protoplast culture and somatic hybridization - When the cell wall of the plant cell is mechanically or enzymatically removed, it is called a protoplast. These protoplasts are biologically active and can be induced by polyethylene glycol (PEG) or by high voltage of electric current to fuse. When potoplasts of two different cell lines are induced to fuse, the nuclei may or may not fuse even after fusion of the cytoplasm. The resulting binucleate cells are called heterocytes or heterokaryons. When the two nuclei are fused, it is called a somatic hybrid, whereas when one of the nuclei is lost it is called a cybrid or cytoplasmic hybrid or heteroplast. Both somatic hybrids and cybrids can be exploited for crop improvement.



Protoplast fusion

Somaclonal variation - The genetic variability developed during tissue culture is known as somaclonal variation. This is seen is cultures maintained for a very long period due to spontaneous mutation or transposition of genetic material activated by the culture medium.

Application of Plant Tissue Culture

1. Commercial production of plants normally propagated through meristem & shoot culture.
2. Screening of cells for certain desired traits to be used for breeding purpose.
3. Conservation of rare and endangered species.
4. Large-scale commercial production of secondary metabolites and biopharmaceuticals through bioreactors.
5. Regeneration of new hybrids through protoplast fusion.
6. In vitro study of important physiological and biochemical processes of select plants for their future application.
7. For chromosome doubling and induction of polyploidy by using antimitotic agents like colchicines.
8. Propagation of transgenic plants.
9. For producing virus-free stocks of important crop plants like sugarcane, potato etc.
10. Large scale production of artificial seeds through somatic embryogenesis.
11. Embryo rescue in certain specific plants where embryo viability is a major hindrance in mass propagation.

SINGLE CELL PROTEIN

Single Cell Proteins (SCP) are dried cells of micro organisms which can be used as dietary protein supplement. They can be used as animal feed or dieting protein supplement for human beings. They can be obtained from uni or multicellular micro organisms such as algae, fungi and bacteria.

Organisms - *Chlorella, Spirulina* etc.

Spirulina tablets are commercially available now, which contain nearly 60% protein. Edible mushrooms, Yeasts, Chaetomium are good sources of SCP.

However the organisms must be,

i) non-pathogenic

ii) source of good nutritional value

iii) free from other toxic compounds and

iv) cheaper in production cost.

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MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

   a. Physical removal of anthers is called :

      i) hybridization ii) mutation

      iii) emasculation iv) variation

   b. Single Cell Protein is obtained from an autotrough known as :

      i) *Sacharomyces* ii) *Pseudomonas*

      iii) *Chaetomium* iv) *Spirulina*

   c. Polyploidy is induced by :

      i) irradiation ii) mutagenic chemicals

      iii) ethylene iv) colchicine

   d. Somatic hybridization is achieved through :

      i) protoplast fusion ii) canjugation

      iii) grafting iv) recombinant DNA technology

   e. Breeding crops for improved nutritional quality is called :

      i) biomagnification ii) biofortification

      iii) bioremediation iv) biomining

2. Write notes on the following with 2 to 3 valid points :

   a) Emasculation

   b) Artificial seed

   c) Biofortification

   d) Somaclonal variation

   e) *Spirulina*

3. Differentiate between the following with 2 to 3 valid points :

   a) Bagging and Tagging

   b) Hybrid and Cybrid

   c) Callus and Protoplast

4. Give an account of techniques of plant tissue culture.

5. Write a note on application of plant tissue culture.

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Module - 8

MICROBES IN HUMAN WELFARE

Microbes are very small living organisms, which are not-visible to our naked eyes. Prokaryotes and primitive eukaryotes together constitute the microbes. They include-bacteria, cyanobacteria, algae, fungi, protozoans and many infectious agents like virus etc. They are one of the most dominant life forms on earth.

They are present everywhere in nature - the soil, water and air. They are also present inside and outside the surface of most plants and animals. They can exist in extreme habitat conditions like polar regions, hot sulphur springs where no other life form can exist. Microbes have multifarious uses is various fields for human welfare.

Household Products

1) ***Dairy Products :*** Lactic acid bacteria (LAB) like lactobacillus, when added to milk, convert lactose sugar to lactic acid. Lactic acid causes coagulation and partial digestion of milk protein casein thereby forming curd. Curd is more nutritious than milk as it contains a number of organic acids and vitamins including Vitamin B12. LAB present in curd also checks growth of disease causing microbes in the digestive tract. Other products like yoghurt, butter milk, sour cream and cheese are prepared from the milk and its products using one or more combination of microbes and enzymes with specific protocols.

2) **Bread :** Baker's yeast is harvested by growing *Sacchromyces cerevisiae* on molasses. A small quantity of Baker's yeast is added to the wheat flour, kneaded and kept at warm temperature for a few hours. Leavening or swelling up of the dough is caused by the enzymes amylase, maltase & zymase secreted by the yeast. The leavened dough is baked to prepare a porous and soft bread.

3) **Dosa, Upma & Idli :** Black gram and rice in their suitable proportions are allowed to ferment by air-borne Streptococcus and Leuconostoc spp. CO_2 production during the fermentation causes puffing up of the dough.

4) **Jalebi :** This is a speciality sweet prepared by fermenting wheat flour/black gram dough and dipping the fried coils in sugar syrup. Several soyabean products like Tofu and Soya sauce are prepared by the fermentation process.

   Tender bamboo shoots, and sausages from fish/meat are subjected to fermentation before they are used as food.

5) **Toddy :** It is a traditional drink prepared in southern and eastern India from coconut, palm/datepalm flowers (tapping of unopened spadix) using the natural process of fermentation. It is a healthy beverage containing around 6% alcohol and vitamins.

6) **Single Cell Protein (SCP) :** SCP is rich in high quality proteins, vitamins and minerals prepared from *Spirulina*, yeast etc.

Industrial products

1) **Alcoholic beverages :** Yeast species are used for the fermentation process for alcohol production using different nutrient media.

Barley malt	-	Beer	Rye malt-gin
Rice	-	Sake (rice wine)	Cashew apple - fenny
Potato	-	Vodka	Cereals - whisky
Molasses	-	Rum	Grape juice - Wine / brandy

For industrial production of the alcoholic beverages, fermentation is done either by batch process, continuous process or fed batch process. Both beer and wine are filtered, pasteurized and bottled. Distillation of the fermented broth is carried out in all other cases. A number of other chemicals can be produced just by changing the nutrient medium.

2. **Antibiotics :** Certain bacteria and fungi produce antibiotics which kill pathogenic bacteria. The first antibiotic, penicillin was extracted by Sir Alexander Fleming from the fungus *Penicillium notatum*. The second one, known as streptomycin was produced from the bacterium, *Streptomyces griseus*. Since then a number of antibiotics have been developed and industrially produced from microbes like fungi, bacteria and actinomycetes. These antibiotics are used to cure many killer diseases like cholera, plague, tuberculosis, typhoid etc.

Over 7000 antibiotics are known and every year 300 new antibiotics are being discovered from different micro organisms.

A good antibiotic should have no side effect, be harmless to normal microflora, quick to act and be effective against all strains of the pathogen.

Important Antibiotics with their source and action

Antibiotic	*Source*	*Action*
Penicillin	*Penicillium chrysogenum, P. notatum* + Phenyl Acetic Acid.	Tonsilitis, Sore Throat, Gonorrhoea, Rheumatic Fever, some Pneumonia types.
Griseofulvin	*Penicillium griseofulvum*	Antifungal, especially for Ringworm.
Nystatin	*Streptomyces noursei*	Antifungal for Candidiasis and overgrowth of Intestinal Fungi during escessive antibiotic treatment.
Neomycin	*Streptomyces fradiae*	Antibacterial against Gram negative bacilli and some Gram (+) bacteria.
Viridin	*Gliocladium virens*	Antifungal.
Hamycin	*Streptomyces pimprei*	Antifungal for Thrush.
Fumagillin	*Aspergillus fumigatus*	Broad spectrum antibacterial especially against *Salmonella* and *Shigella*.
Bacitracin	*Bacillus licheniformis*	Syphilis, Lymphonema or Reticulosis.
Streptomycin	*Streptomyces griseus*	Meningitis, Pneumonia, Tuberculosis and Local Infections. Toxic in some through eighth cranial nerve.
Chloramphenicol/ Chloromycetin	*Streptomyces venezuelae, S. lavendulae*, Now synthetic	Typhoid, Typhus, Whooping Cough, Atypical Pneumonia, Bacterial Urinary Infections.
Tetracyclines/ Aureomycin	*Streptomyces aureofaciens* Chlorotetracycline → Hydrogenation	Viral Pneumonia, Osteomyelitis, Whooping Cough, Eye Infections.
Oxytetracycline/ Terramycin	*Streptomyces rimosus*	Intestinal and Urinary Infections (Spirochaetes, Rickettsiae, Viruses)
Erythromycin	*Streptomyces erythreus* (= *S. erythraeus*)	Typhoid, Common Pneumonia, Diphtheria, Whooping Cough, etc.
Gentamycin	*Micromonospora purpurea*	Effective against Gram (+) bacteria
Polymixin	*Bacillus polymyxa*	Antifungal.

3. **Chemicals, enzymes and other bioactive molecules :**

a) ***Organic acids and alcohols :*** A number of organic acids such as acetic acid, citric acid, Lactic acid, Gluconic acid, Butyric acid and alcohols such as ethanol, methanol, propanol and butanol are being produced commercially through fermentation using various microbes. Alocholic fermentation is an anaerobic process, but the conversion of alcohol to acetic acid is an aerobic process. Once 10-13% of acetic acid is formed in the fermentation, it is removed and after ripening used as *Vinegar*.

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} C_2H_5OH$$

$$\underset{\text{ethyl alcohol}}{C_2H_5OH} + O_2 \xrightarrow{\text{Acetobacter}} \underset{\text{acetic acid}}{CH_3COOH} + H_2O$$

The organic acids have wider uses and are employed in dyeing, medicines, flavoring, preservation of foods. Alcohols are important industrial solvents.

b) **Enzymes :** These are macromolecules with specific three-dimensional structures. About 300 enzymes are being used in food, textile and pharmaceutical industries. Most of them are obtained from microbes. Important enzymes like proteases, amylases, lactases, streptokinase, pectinases, lipases etc. are commercially produced.

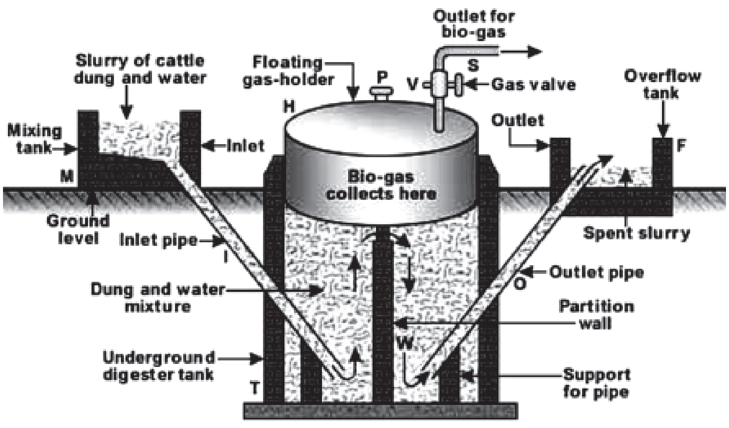
Microbes (*Trichoderma polysporum*) also produces bioactive molecules like cyclosporin A, which is used to suppress the immune system during organ transplant procedures. Similarly *Monascus purpureus* produces statins which help to lower blood cholesterol levels.

Sewage Treatment

As human population increases, human settlements in the form of cities, towns, urban centres are coming up in large numbers. The waste water generated from these locations are called sewage. This large amount of sewage (waste water) is treated in Sewage Treatment Plants (STPs) before being released into natural water bodies. Microbes present in these STPs make the waste water less harmful, so that they can be discharged to natural water bodies. Ganga Action Plan and Yamuna Action Plan have been started by the Central Government to clean these two rivers, which are severely polluted due to discharge of untreated sewage and industrial effluents from the nearby urban centres.

Biogas Production

Anaerobic bacteria feed on cellulose and generate large amounts of methane along with CO_2 and H_2. These methanogenic bacteria are present plentily in cattle dung. Cattle dung is used to generate biogas. A typical biogas plant has the following parts:



Floating gas-holder type bio-gas plant.

i) Concrete tank in which slurry of dung and biowastes are fed.
ii) Floating cover on the slurry, which rises as the microbes form gas.
iii) An outlet for supply of gas
iv) Another outlet to remove spent slurry.

In India biogas is popularly known as "Gobar Gas". Biogas can also be produced from municipal sewage, and form agricultural and urban wastes. The sludge is used as biofertilizer and the gas can be used to generate electricity.

Biocontrol Agents

Overuse of chemical pesticides and insecticides have created havoc not only in the agricultural fields, but their residue have started appearing in increasing concentrations in different trophic levels of the food chains. Therefore, farmers are now turning to use of biocontrol agents. The bacterium, *Bacillus thuringiensis* is such a biocontrol agent, which is toxic to butterfly caterpillars, but does not harm others. Genetic engineering scientists have successfully introduced the toxin 'gene' from the bacteria into plants, making them resistant to attack of pests. Ex. - Bt-cotton, Bt-brinjal. A free living fungus, *Trichoderma* is another biocontrol agent, that works against several fungal pathogens in plants. Baculoviruses are also excellent biocontrol agents as they only attack harmful pests without negatively impacting plants and beneficial insects. The viruses are obligate parasites and host specific. They infect mostly larval stages of insects belonging to order Lepidoptera, Diptera, Hymenoptera etc. A number of enzyme inhibitors transferred to target plants from the microbes are now being used as biocontrol agents.

Biofertilizers :

Biofertilizer is a substance which contains living micro organisms. When applied to seeds, plant surfaces, or soil, they colonize the area (rhizopsphere/interior of the plants) and promote growth. The microorganisms in the biofertilizer restore the soil's natural cycle and build soil organic matter. Several groups of microbes are selected for commercial use of biofertilizers. Those include (i) *Rhizobium*, (ii) *Azospirillum*, (iii) *Azotobacter*, (iv) Blue green algae, (v) Micorrhiza, (vi) Acetobacteria and (vii) Phosphobateria. They are mostly free-living or symbiotic nitrogen-fixing bacteria or those producing essential nutrients to the crop plants. Symbiotic nitrogen fixing bacteria form nodules in association with roots of legumes and mycorrhiza is a symbiotic association of certain types of soil fungi with root system of forest trees. They fix nitrogen from the atmosphere. The term "plant-growth promoting rhizobacteria" (PGPR) is also used by scientific communities to identify this group.

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MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

   a. The bacteria that grow on milk and convert it to curd are

   (i) *Clostridium* (ii) *Lactobacillus*
   (iii) *Nitrosomonas* (iv) Acetobacter

   b. The excreta of cattle, commonly called 'gobar' is rich in

   (i) *Rhizobium* (ii) *Spirulina*
   (iii) *Pseudomonas* (iv) Methanogenic bacteria

   c. The free living fungus, used as a biological control agent against fungal diseases in plants is

   (i) *Trichoderma* (ii) *Penicillium*
   (iii) *Rhizopus* (iv) *Saccharomyces*

   d. The commercial name of acetic acid is

   (i) Vinegar (ii) Pencillin
   (iii) Butter milk (iv) Curd

2. Write notes on the following with 2 to 3 valid points :

   a) Biogas
   b) Biopesticides
   c) Biofertilizers
   d) Antibiotics
   e) Bt cotton
   f) PGPR

3. Differentiate between the following with 2 or 3 valid points :

   a) Chemical pesticides and biopesticides
   b) Chemical fertilizers and biofertilizers
   c) Bakery and brewery

4. Describe how microbes play an important role in human welfare.

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Module - 9

ECOSYSTEM

Plants, animals and human beings live in association with a wide variety of other plants and animals. Those communities represent highly ordered dynamic and complex organisation. Such complex natural organisations with their living and nonliving environments that controls them and from which living organisms derive their sustenance are called as 'Ecosystem' or 'Ecological System'.

The interaction between the living organisms and their environment is very much a two way process : Organisms affect and in turn, affected by their surroundings. Professor Arthur Tansley, a British Botanist, in 1935 proposed the term ecosystem. He defined it as, "system resulting from the integration of all living and nonliving factors of the environment."

Components of Ecosystem

Any complete definition of an ecosystem includes physical environment and biological components and interaction between the two. The biotic components of ecosystem are :-

(i) Organism, mostly green plants and certain bacteria which can synthesize their own food in the presence of sunlight. These are autotrophs or producers.

(ii) All other organisms that do not make their own food but depend on other organisms to obtain energy for their survival are the heterotrophs or consumers.

Among consumers some animals like cow, goat, deer, rabbit or certain insects which eat only green plants are the primary consumers or herbivores. As per their feeding habit, they are in one trophic level. Organisms which eat only herbivores are called Secondary consumers. Examples - Frog eats grass hopper, small fishes are eaten by big fishes. They are at another trophic level. Organisms which eat only secondary consumers are the tertiary consumers and they are in a trophic level. Example - Frog is eaten by snakes, big fishes are eaten by seabirds. Animals like lions and vultures which are not killed or eaten by other animals are called top carnivores. Top carnivores form a trophic level. Thus, an ecosystem may be considered as a natural community which obtain their food from the plants through one, two, three or four steps and called first, second, third and fourth trophic levels or food levels.

Both these consumers and producers complete their life-cycles and new generations of populations develop while older ones die. There is continuous breaking up or decomposition of the dead organic matter in the ecosystem. Certain fungi and bacteria which are responsible for decomposition are called decomposers. Water, carbon dioxide, phosphates and a number of organic compounds are largely the by-products of organisms activity or death of the organisms.

The other important components of ecosystem are abiotic or non living components. These are basically inorganic elements and compounds such as carbon dioxide, and water, nitrogen, phosphates etc. and a number of organic compounds like amino acids, simple carbohydrates and physical factors including temperature, moisture, solar radiation etc. In this abiotic background, biotic components i.e. plants, animals and microbes interact to form sustainable units.

Functional components of an ecosystem

Let us look, how the above cited components affect each other and act in a more integrated manner and see how the flow of energy takes place within these components of ecosystem. These are called the functional aspects of the ecosystem and it can be studied under the following;

- Energy flow
- Food chain and food web
- Diversity pattern in time and space
- Nutrient or biogeochemical cycles
- Development and evolution
- Control or cybernetic

Figure-1, shows the functional aspects or interactions of various components which involves flow of energy and cycling of material. In this system, autotroph to heterotroph, producer to consumer or producer to herbivore to carnivore relationship is the direction of energy movement through ecosystem. In the process, solar energy is converted to chemical energy through photosynthesis by green plants. Here, they also incorporate into the protoplasm a number of inorganic elements and compounds. These green plants are grazed subsequently by herbivores. This shows that not only the chemical energy in the form of carbohydrates, fats and proteins are transferred into herbivores but a number of other nutrients also. This process continues upto the decomposer level.

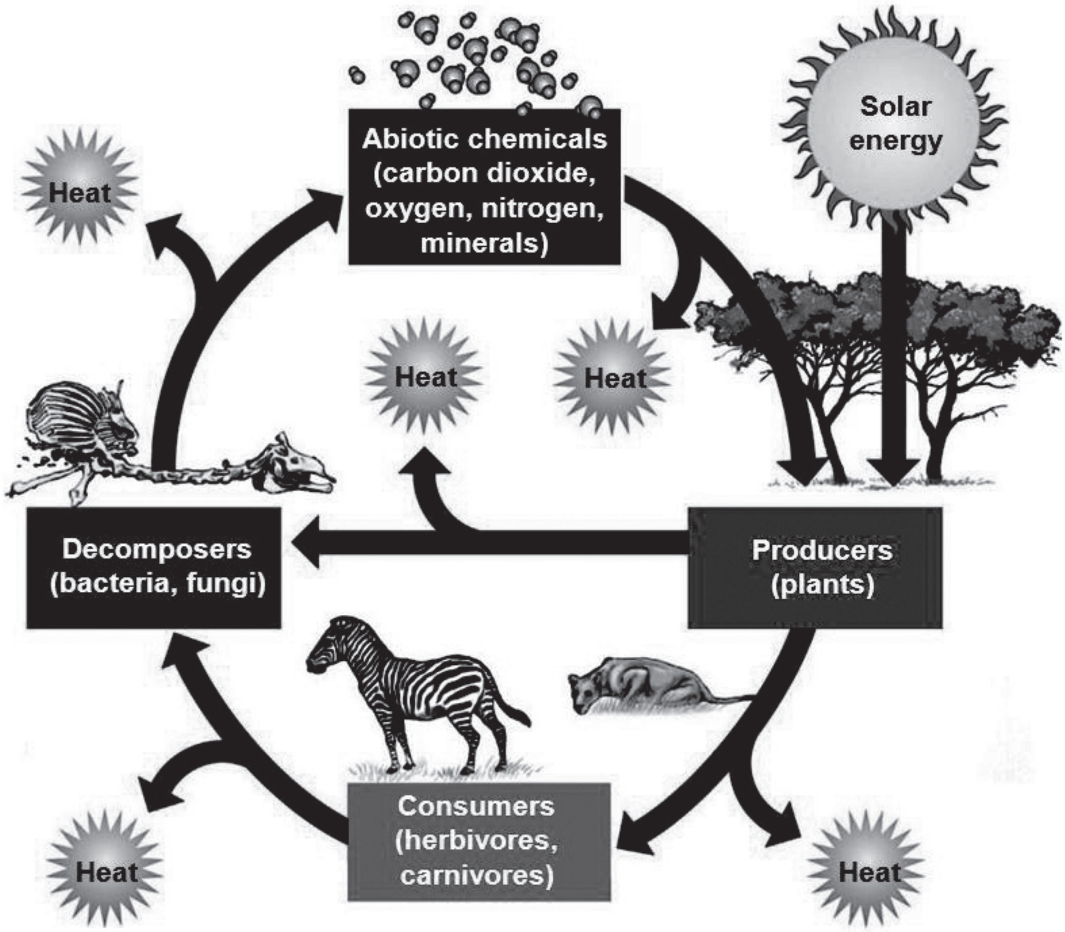

Fig. 1 : A Natural Ecosystem

Another feature of the process is that the energy trapped by green plants when transferred from one trophic level to another, there occurs its loss at each transfer along the chain (Figure-2).

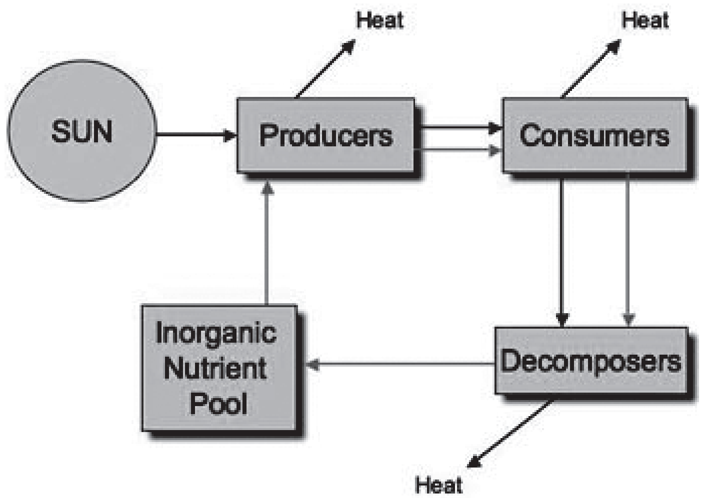

Fig. 2 : Flow of Energy in Ecosystem

From the Figure-2, it can be concluded that.

- Energy flow is unidirectional unlike nutrients/materials which moves in a cyclic manner.
- Energy that passes from herbivore to carnivore does not pass back to herbivore from carnivore. As a result of this, unidirectional and continuous flow of energy the ecosystem maintains its entity and prevents collapse of the system.

In the functioning of the ecosystem, the transfer of energy from one trophic level to another, i.e. from Sun to autotrophs, from autotrophs to heterotrophs denotes accumulation of new organic materials in the system. These accumulated organic materials may be broken down by the decomposers. Thus, recycling of materials occur. During the process, the biomass is broken down into the components, which becomes the raw materials for the autotrophs.

For balanced condition, the ecosystem must have self sufficient and self regulating structural systems. Abiotic and biotic components of an ecosystem invariably indicate a natural tendency to maintain the functional balance within a certain range of environmental variations. In all ecosystems, there is a self regulatory mechanism or control of check and balance the ecosystem.

Food chain and Food web:

The sequence of organisms through which the energy flows is called food chain. For example, plants are eaten by grass hoppers, who are eaten by frogs and frogs are eaten by snakes, snakes are eaten by owls.

Flow of energy in ecosystems, from sunlight through photosynthetic organisms or producers, to tissues of herbivores, the primary consumers, determines the number and biomass of organisms at each level in the ecosystem. Flow of energy is greatly reduced at each successive level of nutrition because of the energy utilization by the organisms and heat losses at each step in transformation of energy. This largely accounts for the decrease of biomass at each successive level (Fig.-3).

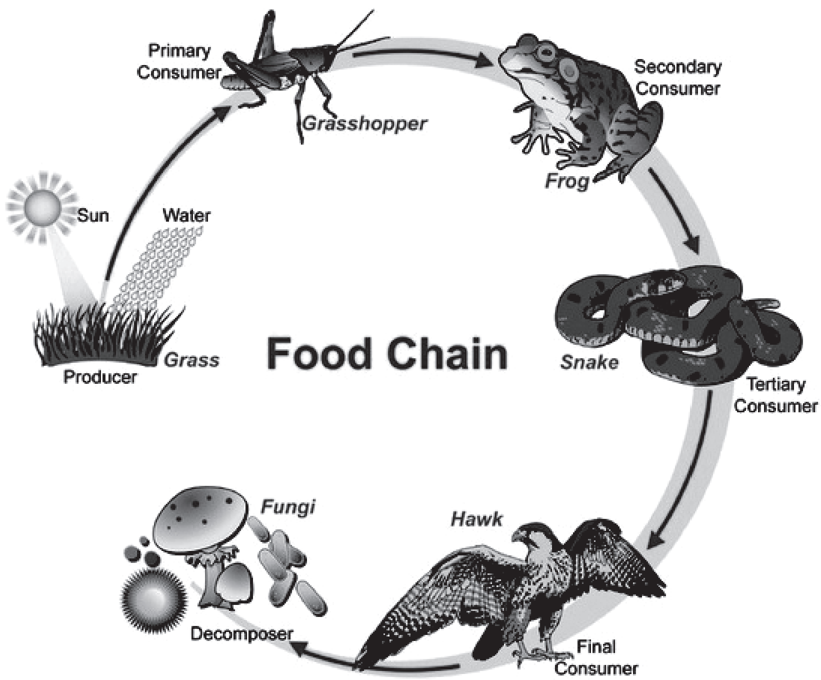

Fig. 3 : Food Chain

Some animals eat only one kind of food and therefore, are members of single food chain. Other animals may eat many kinds of food, so they may be members of different food chains and may occupy different positions in separate food chains so that the species can survive. The animals may be primary consumers in one chain, eating one plants but secondary or tertiary consumer in other food chains, eating herbivorous animals or other carnivores.

In nature, there are 3 types of food chain occurs (1) Grazing food chain-Grass - Grass hopper-bird-hawk, (2) Parasitic food chain-Grass-Cow-Nematodes-Bacteria, (3) Detritus food chain- Dead plant or animal remains - microorganisms - predators.

Food Web

A food chain represents only one part of the energy flow through an ecosystem and an ecosystem may be composed of several interrelated food chains. Food chain exhibits simple, isolated relationships which seldom occurs in an ecosystem. Very often, the same food resource is part of more than one chain, especially when that resource is at one of lower trophic level. Thus there are interconnected network of feeding relationship that form the food web (Fig. 4).

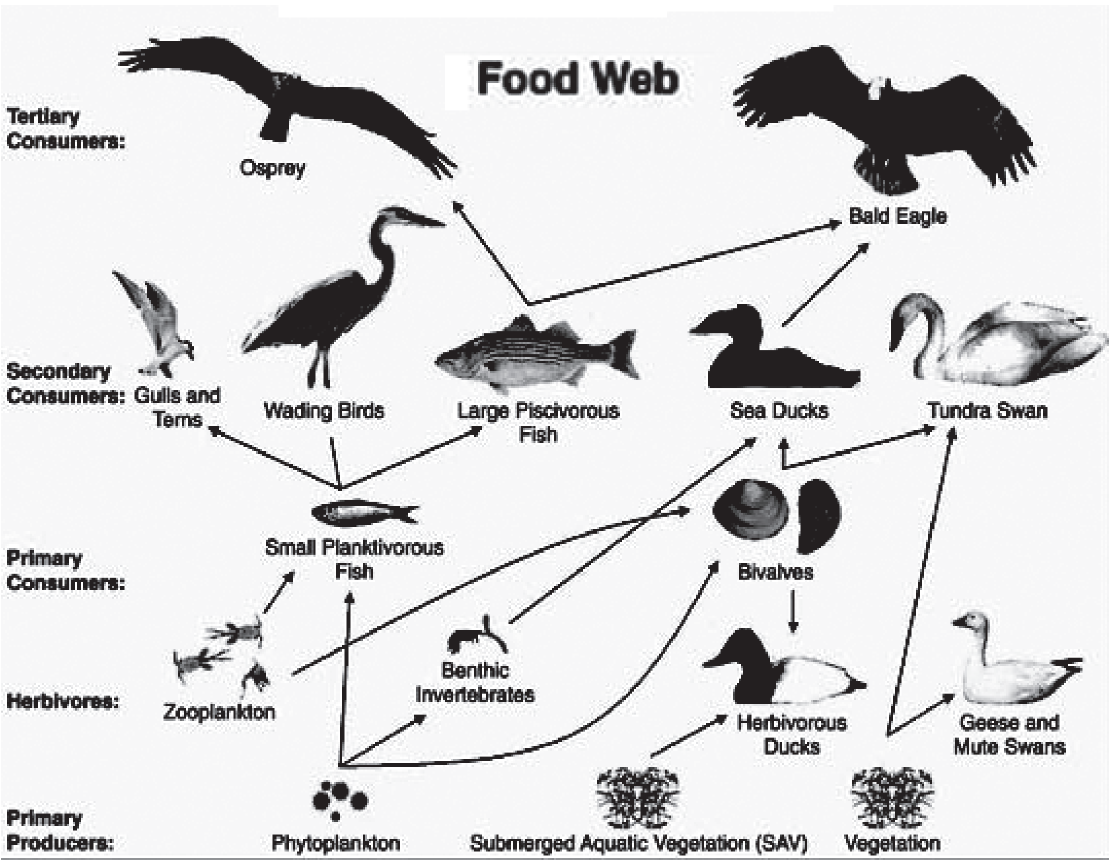

Fig. 4 : Food Web

Pyramids

There are different trophic levels in an ecosystem. These can be represented diagrammatically and form pyramids. Producers form the base of the pyramid and the top carnivore the apex. The ecological pyramids are of 3 types:- (i) Pyramid of number, (ii) Pyramid of biomass, (iii) Pyramid of energy. This classification is respectively based on the number, organic weight and energy content of each trophic level in an ecosystem. The pyramid of number and pyramid of biomass may be upright or inverted. But the pyramid of energy is always upright (Fig.-5).

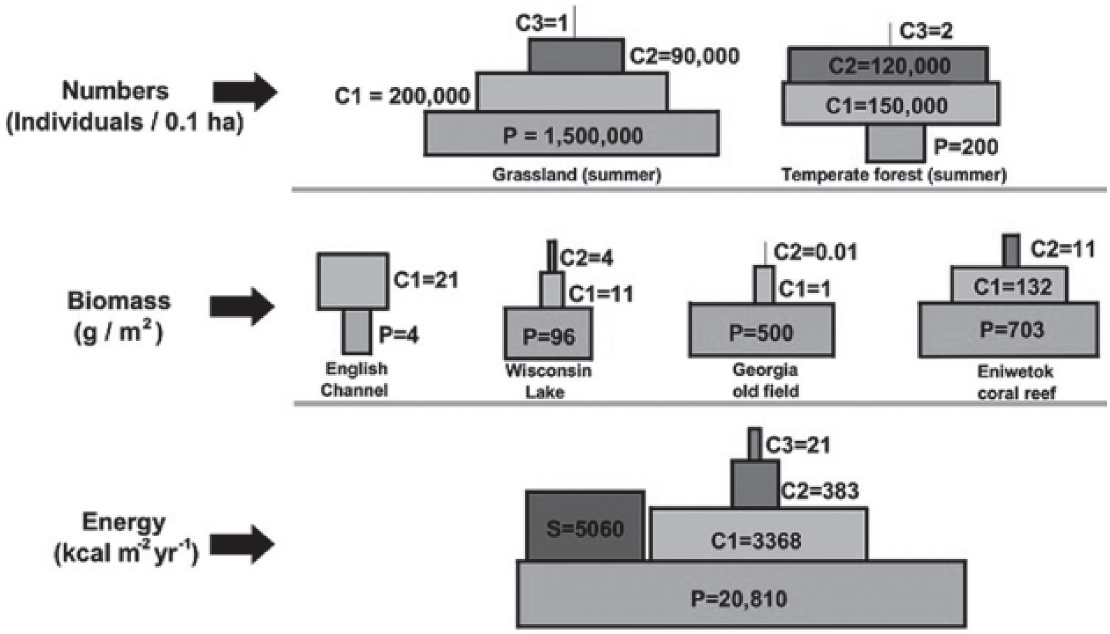

Fig.-5 : Ecological Pyramids

Productivity

A constant flow of energy is the basic requirement for any ecosystem to function. Primary production is the amount of biomass per unit area over a fixed time period by green plants due to photosynthesis. The rate of biomass production is called productivity (expressed in g^{-2} yr^{-1} or Kcal $m^{-2}yr^{-1}$). It is divided into gross primary productivity (GPP) and net primary productivity (NPP). GPP is the rate of production of organic matter due to photosynthesis. NPP is the excess retained by the plants after their metabolic uses like respiration. NPP = GPP - R. Secondary productivity is the rate of formation of new organic matter by consumers.

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MODEL QUESTIONS

1. Write the correct answers selecting appropriate ones from the choices given under each bit :

a) Decomposers are generally
(green plants, animals, microorganisms, insects)

b) In which trophic level can herbivores be kept?
(first, second, third, fourth)

c) Herbivores are always
(primary consumers, secondary consumers, tertiary consumers, decomposers)

d) Energy enters an ecosystem by:
(producers, consumers, detrivores, decomposers)

e) About how much chemical energy in the producer turns does become chemical energy in herbivore tissues ?
(1%, 10%, 30%, 40%)

f) In food chain, the maximum energy is available to :
(Producers, Herbivores, Secondary Consumer, Decomposers)

2. Write notes on the following with 2 to 3 valid points :

   a) Ecosystem
   b) Producers
   c) Consumers
   d) Productivity
   e) Food Chain
   f) Food Web

3. Differentiate between the following with 2 to 3 valid points :

   a) Producers & Consumers
   b) Food Chain & Food Web
   c) Pyramid of Biomass & Pyramid of Numbers
   d) GPP & NPP

4. Give an account of structural and functional aspects of an ecosystems.

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Module - 10

BIODIVERSITY

Pattern, Importance and Loss of Biodiversity

The degree of variation of life forms or biological organisms is referred to as biological diversity or biodiversity. The diversity occurs at all possible levels such as *species, populations* and *communities*. Biologists most often define biodiversity as the "totality of genes, species and ecosystems of a region”. It seems to describe most circumstances. The three levels at which biodiversity can be identified is called the hierarchy of biodiversity and they are :

(i) Genetic diversity - within species

(ii) Organismal diversity - among species or populations

(iii) Ecological diversity among communities.

Genetic diversity : Genetic diversity means the variation in genetic material among individuals within species. It arises through genetic recombination during sexual reproduction and mutation. It leads to origin of new species. Therefore, diversity within a species is necessary to maintain diversity among species.

Organismal diversity : It is the diversity among species and is measured by species richness (number of species in a given area), species composition (list of species) and their relative abundance (number of individuals of different species). IUCN recognizes three types of species diversity such as alpha, beta and gamma diversity.

Alpha diversity : It refers to the variety of species within a community - species richness.

Beta diversity : It is the diversity of species among communities.

Gamma diversity : It is the diversity of species across wider geographical range.

Ecological diversity : Ecological diversity refers to the community diversity and is about the presence of different types of ecosystems present in the biosphere.

Patterns of biodiversity : It is observed that species diversity decreases as one moves from the equator towards the pole. In fact, the tropical region is very rich in species diversity. Tropical rain forests contain 70% of the species of world in 7% of earth's land surface.

India which is situated north of the equator is one among the seventeen mega biodiversity countries of the world. The country harbours about 7% of the world's species of animals and plants with arount 40,000 species of plants and 90,000 species of animals. Eastern Himalayas, Western Ghats and Indo-Burma Region are the three large biodiversity hotsports present in this country.

Importance of biodiversity

A healthy biodiversity provides a number of natural services for everyone :

a) ***Ecosystem services :***

i) protection of water resources

ii) protection of soil formation

iii) storage and recycling of nutrients

iv) breakdown and absorption of pollutants

v) contributing to climate stability

vi) maintenance of ecosystems.

b) ***As biological resources :***

i) food, medicinal resources and clothing

ii) valuable timber and other products for shelter

iii) diversity of genes, species and ecosystems

iv) ornamental plants

v) raw material for industrial products

vi) biological control of pests & diseases

c) ***Social benefits :***

i) education and research

ii) recreation and eco tourism

iii) cultural values

Loss of biodiversity

Physical environment changes with time. Loss of adaptability with the changing physical environment causes species extinction. To date there are five episodes of mass extinction. However, human intervention is going to be the most important cause for any future mass extinction of species. As per IUCN estimates some 12259 species have become extinct since the origin of life on earth. The factors that contribute to loss of biodiversity are :

i) ***Habitat loss and Fragmentation -*** Deforstation, fire, over-use and urbanization are major factors for habitat loss. Frequenting of elephants into human habitats in recent years is the consequence of fragmentation of habitats.

ii) ***Over exploitation and commercialization -*** Over exploitation of resources has caused severe environmental degradation in comparison to economic benefits. Shrimp farming in coastal waters of India, Thailand, Indonesia and other countries in that region has severely polluted the coastal water and degradation of coastal fisheries.

iii) ***Introduction of invasive species -*** These alien or exotic species when introduced accidentally or intentionally get established in the new environment and become a threat to the local biodiversity. This is said to be the second greatest threat to biodiversity after habitat loss.

iv) ***Pollution :*** Pollution is a major threat to biodiversity. It does not recognize international boundaries and may impact biodiversity in regions other than its place of origin.

v) ***Climate change :*** It is believed that green house effect is likely to raise world temperature by 2^0C by 2030 and rise of sea levels around 30-50 cm by that time. Vast areas may be inundated causing loss of life and ecosystems.

vi) ***Population Growth :*** From a modest population of one billion (100 crores) at the beginning of 19th century, we have reached numbers more than seven billion. Added to this 25 percent of the population consume about 75 percent of world's natural sources. This over consumption and growth has become unsustainable and cause for loss of biodiversity.

vii) ***Illegal Wildlife Trade :*** International trade of wild plants and animals for the purpose of food, medicines and pet trade has wider ramifications on the stability of ecosystems.

viii) ***Species extinction :*** Current rate of species extinction due to increased anthropogenic activities is far greater than the natural process. This man-made extinction results in severe depletion of biodiversity and may bring in the sixth extinction sooner than the expectations. IUCN Red list of 2004 has recorded a total loss of 784 species in the last 500 years. This Red list of threatened species was founded in 1964 and is the most comprehensive inventory of global conservation status of biological species.

Red Data Book : The Red Data Book contains the complete list of threatened species. The book contains colour-coded information sheets arranged according to the level of danger. The main aim behind this documentation is to provide complete information for research and analysis. IUCN recognizes several categories in the Red List. These are :

Extinct - The last individual has died. Ex. - Indian Cheetah

Critically Endangered : Species, facing extremely high rate of extinction in the wild in near future. Ex. - One-horned Rhinoceros.

Endangered : Species, facing high risk of extinction in the wild in near future. Ex. - Giant Panda, Polar Bear

Vulnerable : Species, facing high risk of extinction in the wild in the medium-term future. Ex. - Sparrow.

Hot Spots of Biodiversity : A biodiversity hot spot is a biogeographic region with significant levels of biodiversity that is threatened with destruction. It must meet two strict criteria.

a) It must contain at last 0.5% or 1500 species of vascular plants as endemics.

b) It has to have lost at least 70 percent of its primary vegetation.

There are 34 hot-spots around the world that qualify under the above definition. These sites support nearly 75% of the world's most threatened mammals, birds and amphibians, 50% of all plants and 42% land vertebrates. Four regions that satisfy the criteria of hotspots (two major and two in part) are in India.

i) *Western Ghats and Srilanka :* The Indian region has a chain of hills, along the western border of peninsular India, with moist deciduous forest and rain forest. The region shows high species diversity as well as high level of endemism. 77% of amphibians and 62% of the reptile species, found here are found nowhere else. Out of the 6000 vascular plants, 3000 are endemic. Species such as black pepper and cardamom have their origin in the Western Ghats.

ii) *The Eastern Himalayas :* It has nearly 163 globally threatened species including one-horned Rhinoceros, the Wild Asian Water Buffalo. These Himalayan mountains are the highest in the World which include the Mount Everest.

iii) *Indo-Burma :* This region includes only the North-eastern India (South of Brahmaputra) and the rest includes countries like Thailand, Cambodia, Southern part of Yunnan province of China etc.

iv) *Sundaland :* The South-East Asian countries come under this region. Nicobar Island represents India.

***

MODEL QUESTIONS

1. Choose the correct answers from the choices given in the brackets of each bit :

   a) Red data book contains data of

      i) all plant species ii) all animal speices

      iii) economically important spcies iv) threatened species

   b) Hot spots are regions of high :

      i) pollution ii) endemism

      iii) critically endangered population iv) diversity

   c) Which one of the following is a biodiversity hotspot in Indic ?

      i) Sundarbans ii) Western Ghats

      iii) Eastern Ghats iv) Gangetic Plain

   d) The term Alpha diversity refers to :

      a) Genetic diversity

      b) Community and ecosystem diversity

      c) Species diversity

      d) Diversity among plants

   e) Which is an extinct speices

      a) Indian Cheetah b) One horned Rhinoceros

      c) Polar Bear d) Sparrow

2. Write notes on the following with 2 to 3 valid points.

   a) Red Data Book b) Biodiversity hotspot

   c) Species diversity d) Ecosystem diversity

3. Differentiate between the following with 2 to 3 valid points.

   a) Extinct and Endangered Species

   b) Beta diversity and Gamma diversity

   c) Mass extinction and Anthropogenic extinction

4. Describe the causes of loss of bio-diversity.

5. Write a note on importance of biodiversity.

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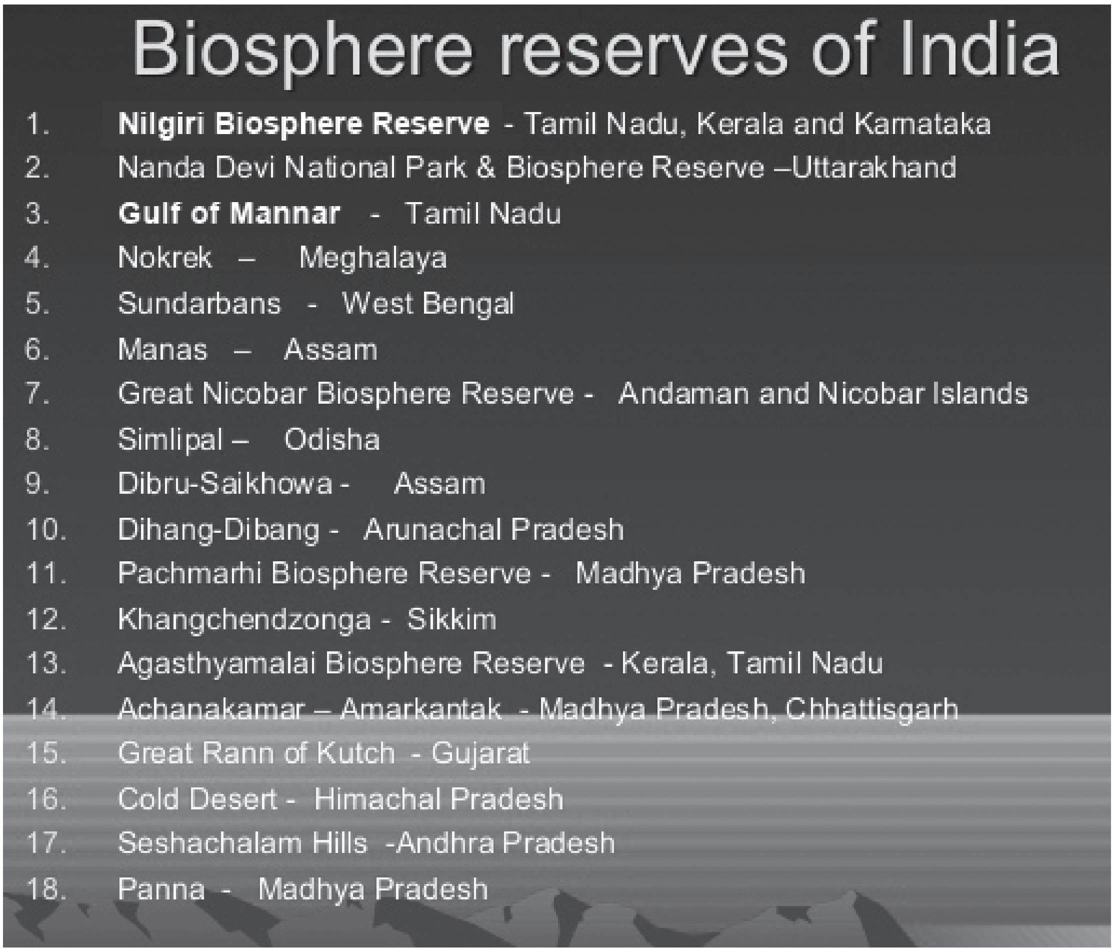
Module - 11

BIOSPHERE RESERVES, NATIONAL PARKS AND SANCTUARIES

Biosphere Reserve

The International union for conservation of Nature and Natural Resources (IUCN), also known as World Conservation Union and other world bodies evolved a conservation strategy in 1980 for conservation and sustainable use of biological resources. IUCN has designated six different categories of land as protected areas for conservation of all the ecosystems operating there. A biosphere reserve comes under category v of the protected areas. The world network of biosphere reserves went up to 669 in 120 countries which includes 16 trans-boundary sites as on 2016. The total number has undergone changes in 2017 as the U.S withdrew some sites from the network. There are 18 biosphere reserves in India and Odisha has the lone biosphere reserve in Similipal.



Man and Biosphere Programme

Man and Biosphere Programme (MAB) is an intergovernmental scientific programme launched by UNESCO in 1971. The MAB programme provides a unique platform for cooperation on research and development, capacity building and networking to shared information, knowledge, and experience on three interlinked issues - biodiversity loss, climate change and sustainable development.

Biosphere Reserves are, therefore, special sites for testing inter disciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including prevention and management of biodiversity.

The biosphere reserve integrates human activities with conservation of biodiversity. It has four zones (i) core zone, (ii) buffer zone, (iii) transition zone and (iv) Zone of human encroachment.

(i) ***Core zone -*** This zone is strictly protected to maintain ecological diversity and integrity.

(ii) ***Buffer zone -*** This zone concentrically surrounds the core zone. Recreational activities and sustainable utilization of natural resources are allowed in this zone.

(iii) ***Transitional zone -*** This zone is ecologically least sensitive and hence anthropogenic activities, research and sustainable development work are permitted.

(iv) ***Human encroachment zone -*** It is the outermost area, where normal anthropogenic activities are allowed.

Wildlife Sanctuary

It comes under category - iv of the IUCN protected areas. India has 543 wildlife sanctuaries which include 50 tiger reserves and "Project Tiger" programme. The state of Odisha has 10 wildlife sanctuaries. A naturally occurring wildlife sanctuary is a protected area under which wildlife is protected from hunting, predation and poaching. It is also a place of refuge, where abused, injured and abandoned captive wildlife may live in peace and dignity. Unlike national parks, wildlife sanctuaries do not have properly marked boundaries. Rann of Kutch is the largest wildlife sanctuary in India. It is also known as the Indian Wild Ass Sanctuary.

National Park

It is a category-II type of IUCN protected area. National park is an area set aside by a national Government for preservation of the natural environment. It is established by a special statute of the central Government. From the date of notification, all rights and privileges including forestry operations and grazing of domestic animals are completely stopped or withdrawn. However, general public may enter into it with valid permission. As per the definition adopted by IUCN in 1969, a National Park is a large area with:

a) one or more ecosystems not much altered by humans. It should have plant and animal species and important geological sites and habitats, which should be of special scientific, educative and recreative interest and contain a natural landscape of great beauty.

b) the country has taken steps to prevent or eliminate exploitation or occupation in the area and to enforce conservation measures in respect of ecological, geomorphological and aesthetic features.

c) visitors are allowed to enter, under special conditions, for inspirational, educative, cultural and recreative purposes.

d) there is statutory / legal protection with adequate budget and staff.

e) no exploitation of natural resources of the area.

Corbett National Park (Hailey's - earlier name) in Uttarakhand is the first national park in India established in 1935. There are 103 national parks in India. Bhitarkanika and Similipal are the two national parks in Odisha.

***

MODEL QUESTIONS

1. Choose the correct answers from the choices given in the brackets of each bit :

   a) Corbett National park is situated in

      i) Uttar Pradesh

      ii) Himachal Pradesh

      iii) Jharkhand

      iv) Uttarakhand

   b) MAB stands for

      i) Man and Biotechnology

      ii) Man and Biology

      iii) Man and Biosphere

      iv) Material and Biology

   c) IUCN is also called as

      i) Man and Biosphere Programme

      ii) World Conservation Union

      iii) World Conservation Consortium

      iv) World Wide Conservation Union.

2. Write notes on the following with 2 to 3 valid points.

   a) MAB Programme

   b) National Park

   c) Sanctuary

   d) Biosphere Reserve

3. Give an account of the important features of Wildlife Sanatuary and National Park.

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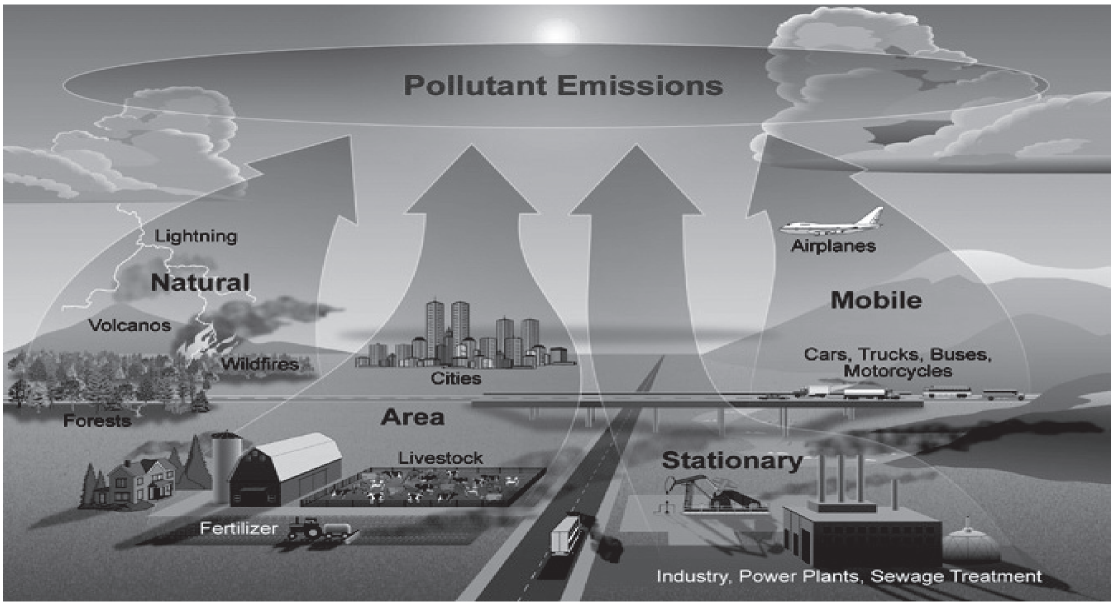
Module - 12

POLLUTION AND ITS CONTROL

AIR POLLUTION

Air is a mixture of several gases. The major constituents are nitrogen (78.09%), oxygen (20.94%) and water vapour (0.1 -5%). Carbon dioxide is a minor constituent with approx 0.04%. There are many other gases in very small quantities. Air is never found clean in the atmosphere due to natural and anthropogenic activities. Natural causes are volcanic activity, forest fire, vegetation decay, and wind storm etc. Except episodal volcanic eruptions pollution due to natural factors are within accepted levels. However, pollutions due to anthropogenic factors is high and has reached alarming proportions in certain urban centres. The activities are burning of fossil fuels and industrial activities. Air pollution can therefore be defined as the presence of harmful substances (pollutants) above the accepted levels. Accepted level of air pollutants varies from one another and is expressed by the "Threshold Limit Value".



Types of Air pollutants

Air pollutants can be categorized as (i) primary pollutants and (ii) secondary pollutants. Primary pollutants are those which are directly released into the atmosphere by the natural or manmade sources, whereas secondary pollutants are the ones which are produced by atmospheric reactions of primary pollutants.

Primary pollutants :

Five primary pollutants together constitute more than 90% of the global air pollution.

They are :

a) Suspended particulate matter (SPM)

b) Carbon monoxide (CO)

c) Oxides of nitrogen (NO_x)

d) Oxides of sulphur (SO_x)

e) Hydrocarbons (HC)

Other primary pollutants which occur in lesser proportions are

f) Ammonia

g) Chlorofluorocarbons (CFCs)

h) Carbondioxide (CO_2)

i) Hydrogen sulphide (H_2S)

j) Hydrogen fiuoride (HF)

k) Volatie organic carbon compounds (VOC)

l) Hydrogen sulphide (H_2S)

and

m) Radioactive elements

Suspended Particulate Matters (SPM) :

Small solid particles and liquid droplets are collectively called "Particulates" or "suspended particulate matters". Their size determine their role in the environment. The size may vary from 0.5 to 500 mì . The residence time of a particle in the atmosphere depends on the settling rate, which again depends on particle size and density, turbulence of air and humidity. Besides the natural sources, anthropogenic (manmade) sources mostly include vehicular emission and road dust, cement kilns, incinerators and industrial activities. Larger particles when inhaled get filtered by nasal hairs and nasal-throat tracts containing slimy fluid. But particles having aerodynamic diameter equal to or less than 10 micrometer escape the nasal filters and get into the lungs causing serious respiratory diseases. These particulate are known as Respirable suspended particulate matters (RSPM). When a particulate matter remains suspended in the atmosphere for a long time "aerosol" is formed, the common example of which is "smog". In ill-ventilated kitchens where fire wood and other agro products are used as fuel, the rural women folk are exposed to another organic particulate air pollutant called Polycyclic Aromatic Hydrocarbons (PAH). This particulate air pollutant is carcigenic in nature. Workers at stone quarries, asbestos factories and coal mines are also exposed to severe air pollutants and suffer from occupational diseases like silicosis, asbestosis, black lungs disease etc.

Carbon monoxide - It is a poisonous gas which interferes with the oxygen intake of hemoglobin in the respiratory system. In high doses it can be fatal. Carbon monoxide (CO) is formed by (i) incomplete combustion of coal, hydrocarbon and biomass, (ii) reaction between CO_2 and carbon at elevated temperatures and (iii) dissociation of CO_2 at very high temperature. Emissions from motor vehicles, air crafts, rail engines and industrial processes contribute the maximum amount of CO as a pollutant.

Oxides of nitrogen - Pollution due to oxides of nitrogen is an urban phenomenon. The mixture of all oxides of nitrogen is referred to as NOx. NOx is mostly formed through natural processes like lightning, volcano and bacterial decay. A small amount is also formed by anthropogenic activities. Nitric oxide (NO) is a colour less gas. Its residence time in the atmosphere is 3-4 hours and thereafter it is converted to brown coloured nitrogen dioxide (NO_2) gas in the presence of air. Nitrous oxide (N_2O) is produced by denitrifying bacteria in the soil. Higher concentrations of NO_x i.e. above 50 ppm by volume causes inflammation of lungs in human beings. Most adverse effects of NO_x are, however, by formation of secondary pollutants like "photochemical smog", formed by a series of complicated atmospheric reactions involving NOx, hydrocarbons and air.

Oxides of sulphur (SO_x) : A mixture of sulphur dioxide (SO_2) and sulphur trioxide (SO_3) is represented as SO_x. SO_2 is a colourless gas with pungent odour. It is released to the atmosphere mostly by volcanic eruptions, but a small portion is contributed by thermal power plants, petroleum refineries and smelters of Copper, Zinc and Lead. Transportation sector also contribute some SO_2 to the atmosphere. SO_2 is converted to SO_3 in the atmosphere and under humid conditions may be converted to sulphuric acid (H_2SO_4) or remain as "aerosol". SO_x is toxic to the respiratory tract and at a level above 5 ppm may cause severe bronchial spasm in human beings and may be fatal above 500 ppm. These gases cause acid rain when washed away by rain water. SO_x also affects plant life and may cause leaf necrosis and chronic exposure may lead to chlorosis (yellowing of leaves).

Hydrocarbons : Auto-exhausts (unburnt gasoline) constitute the main source of hydrocarbons in the urban atmosphere. Methane is a product of decomposition of organic matters. Rotting rice fields and intestines of bovine population are the main sources of methane. Methane is a green house gas. Hydrocarbons also participate in the formation of photochemical smog in the urban atmosphere.

Secondary Pollutants :

Atmospheric pollutants are mostly confined to the troposphere. Although a part of those pollutants are removed by rain and fog, a major portion gets trapped in the cloud and atmospheric water vapours. Atmospheric reactions with these pollutants lead to formation of secondary pollutants.

Acid Rain : Pollutants in the atmosphere are exposed to intense sunlight and excess oxygen. This results in their oxidation.

a) $CO/CO_2 \xrightarrow[H_2O]{O_2} H_2CO_3$ (Carbonic acid)

b) Hydrocarbon $\xrightarrow{O_2}$ (Carboxylic acid)

c) $H_2S/SO_2 \xrightarrow[H_2O_2]{O_2} H_2SO_4$ (Sulphuric acid)

d) $N_2O/NO/NO_2 \xrightarrow[H_2O_2]{O_2} HNO_2/HNO_3$ (Nitrous / Nitric acid)

e) $SiF_4 \xrightarrow{HF} H_2SiF_6$ (Fluorosilicic acid)

The oxidized products get washed by rain or are absorbed by water vapour producing acids. When the pH of rain water falls below 5.4, the rain is said to be acid. Movement of clouds carry the acid to far away places from their places of origin.

Photochemical Smog : Atmospheric reactions are very complex and are photo-chemically induced. The secondary pollutants generated in 'NO_x- hydrocarbon-air' reactions produce photochemical smog. This is a common phenomenon in urban atmosphere during winter. One of the secondary pollutants present in the photochemical smog is Peroxy Acetyl Nitrate (PAN), which is a strong eye irritant.

Greenhouse Effect and Global Warming : Carbon dioxide helps to keep the atmosphere warm by absorbing the scattered sunlight from the earth's surface. In cold countries green houses are used to grow plants inside chambers with elevated temperatures. This analogy is used to explain the green house gas effect of certain gases, which are responsible for raising the atmospheric temperature steadily and cause Global Warming. CO_2 is the primary green house gas. Others include methane, nitrous oxide, nitrogen dioxide, CFCs, halons - used in fire extinguishers, and tropospheric ozone etc.

CO_2 is generated from burning of fossil fuels, solid waste and wood. Industrial activities also substantially contribute towards rise of CO_2 concentration in the atmosphere. It has increased from 315ppm in 1958 to355ppm in 1992, 389 in 2010 and currently at a level of around 400ppm. This evidently causes rise in global temperature to unsustainable levels and triggers climatic and meteorological changes. Phenomena of extreme precipitation, could bursts, drought and melting of glaciers and ice caps result in flooding of coastal regions and loss of livelihood options of a large section of the population.

The World Meteorological Organization and United Nations Environment Programme (UNEP) jointly set up an Intergovernmental Panel on Climate Change (IPCC) in 1988, to monitor and suggest measures to be taken by the world community. This task force so far has produced five assessment reports, based on which several landmark international protocols like Kyoto Protocol (1997) and Paris Climate Agreement (2017) have been signed. These protocols/ agreements seek to reduce the rate of emission of GHG by the member countries.

Control of Air Pollution

Air pollution control methods can be discussed under five heads : i) Pollution control at source, ii) Installation of control devices, iii) Plantation and creation of green belt, iv) Zoning and v) Construction of high stacks/ chimneys.

Source Control : Here pollution is minimized by improving process design, changing raw materials and prescribing tougher emission standards.

Control Devices : Particulates can be controlled by settling chambers, cyclones, bag filters and electrostatic precipitators (ESP). There are also wet collection devices like ventury scrubber. Gas-pollutants are controlled by absorption in suitable liquids, adsorption on solid surfaces like activated carbon, silica gel etc. and chemical alteration (ex-direct combustion or flaring).

Plantation : Plantation and development of a green belt around industrial clusters/plants act as barriers for pollutants and noise.

Zoning : Zoning means promoting, prohibiting and regulating establishment of industries in specific areas.

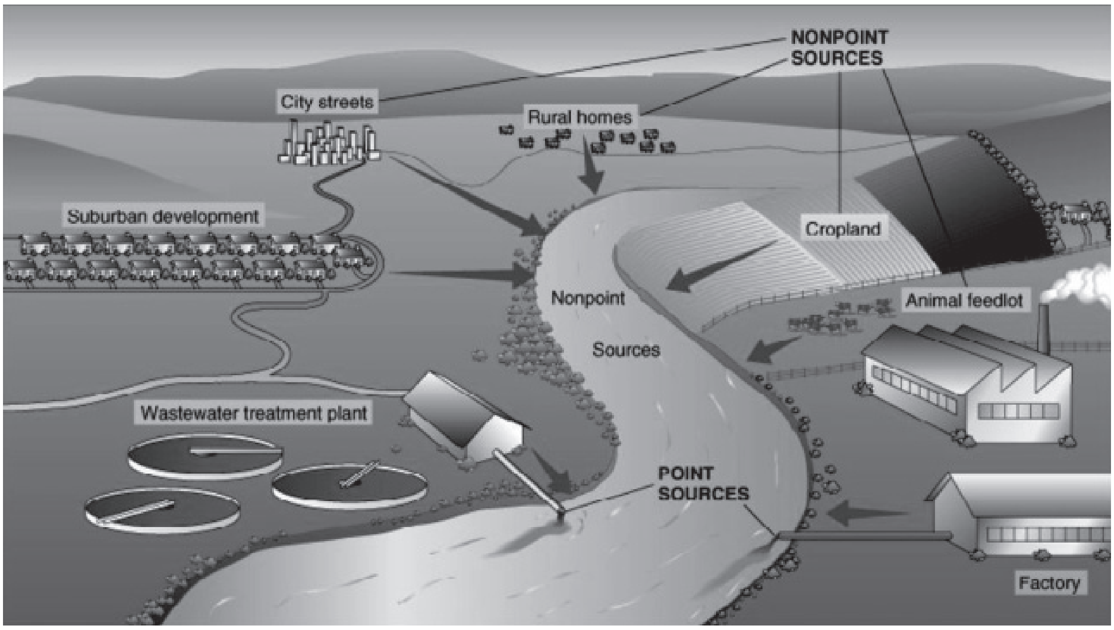
High stacks/chimneys : With all the control devices in place it is sometimes not possible to effectively remove pollutants from the source. By raising the height and diameter of the stacks it is possible to disperse the emissions in a large area, there by diluting its impact in the immediate vicinity.

Dispersion of pollutants is largely controlled by prevailing meteorological conditions in any area and the degree of stability/turbulence in the atmosphere. Prevention and control of air pollution is a matter of serious concern and it can be achieved by seriously enforcing the provisions of the Air (Prevention and Control of Pollution) Act, 1981.

WATER POLLUTION

Water is a good solvent. Therefore it is rarely found free from impurities. Depending on its designated uses, water pollution can be perceived differently at different sources. Thus, water pollution can be defined as the presence of deleterious matter in such quantities to make the water unsuitable for its designated use.

Water Polluction Source



Types of Pollutants and their effects

The pollutant may be of chemical or biological origin in surface water pollution.

i) ***Toxic Chemicals :*** Any toxic chemical present in the aqueous environment, if not degraded in nature, enters the food chain and tends to bioaccumulate. They disturb the biological processes, leading in some cases to fatality. While some chemicals are useful to body metabolism when present in trace quantities, they tend to be harmful beyond a tolerant limit. For example, fluoride at levels of 1.0 mg/L prevents tooth decay, but at levels above 1.5 mg/L, it becomes toxic and may cause fluorosis. Well-known toxic elements like arsenic, lead and cadmium are very much required in trace quantities for growth of animals. Some of the other toxic trace elements found in industrial waste water are boron, chromium, copper, manganese, mercury, molybdenum and zinc. Mercury poisoning of Minamata bay in Japan due to dumping of industrial waste by one, Chisso Corporation, Japan in the 2nd half of Twentieth Century is recorded as one of the worst global industrial disasters, the world has witnessed. Other toxic chemicals sourced from industrial effluents and agricultural run-off could be ammonia, cyanides, phenol, nitrates, polyaromatic hydrocarbons, oil and grease, acids and alkalis and organic halogen compounds.

ii) ***Persistent Organic Pollutants (POPs) :*** Many organic pollutants released to the environment by virtue of their stability and persistence pose a serious threat to human and wildlife health. Some twelve have been identified by the UNEP for urgent action. Some of them are DDT, aldrin, endrin, hexachlorobenzene (HCB) etc. Nine of the above twelve are pesticides / insecticides used in agriculture or for control of public health vectors. These are not easily biodegradable, as they resist photolytic, chemical and biological actions. POPs are not confined to the areas of use. They are easily transported to any part of the globe through evaporation and rainfall.

iii) ***Oxygen demanding Chemicals :*** Aerobic bacteria present in water use dissolved oxygen to oxidize and bio-degrade chemicals that are discharged through industrial effluents and urban sewage to the surface water. Depletion in oxygen level hampers the life cycle of aquatic organisms. Dissolved oxygen below 4.0 mg/L is considered dangerous to aquatic life.

iv) ***Plant nutrients :*** Heavy doses of nitrogenous and phosphatic fertilizers are being used now a days in agriculture. Agricultural run-off and sewage water carry a lot of nitrates & phosphates to the water bodies. These promote growth of algae. Decaying algal blooms reduce oxygen level in water and lead to "eutrophication", a phenomenon by which water bodies are gradually converted to swamps and finally to land mass.

Urban waste water also contains considerable quantities of detergents. These detergents contain polyphosphates and surfactants. Polyphosphates undergo hydrolysis to produce monophosphates, which also help ultimately for entrophication of the waterbody.

v) ***Biological Pollutants :*** The degree of microbial pollution with pathogenic bacteria can be assessed by the presence of *Escherichia coli*. Highly polluted water has faecal coliform count of more than 10,000/liter, indicating open defecation by humans in the nearby areas.

vi) ***Heat and Radioactive Wastes :*** Many industries use a lot of water for cooling purpose and discharge the hot water to lakes and rivers. The life of aquatic flora & fauna gets severely affected by this *thermal pollution*, because many essential enzymes get denatured, thereby causing death of the organisms.

Radioactive pollution may occur due to discharge, leakage or accidents of radioactive elements into water. Exposure to radioactive substances may cause cancer.

vii) ***Suspended and Total Dissolved Solids :*** Waste water contain many dissolved solids. Although they are not toxic *per se*, but they make the water unsuitable for drinking and may other uses. Suspended solids & floating materials affect the photosynthetic process of aquatic plants and also make the water unsuitable for drinking and many other uses.

Sources of Pollution

Maximum volume of waste water entering our lakes and rivers are from *non-point sources* i.e. sources without any definite outfall. Non-point sources are linked to our cultural and agricultural practice and are difficult to control.

However, *point sources* are those, which can be identified and linked to the problem of pollution in a given area. More than 15,000 MLD (million liters per day) of sewage is generated in Indian cities, most of which are discharged untreated into major rivers and lakes, causing severe water pollution. Industrial waste water, although not too large in volume, contains toxic substances. The industrial effluents and urban sewage can be properly treated to control the level of pollution. Similarly mine drainage water is mostly acidic and contains heavy metals. Treatment is expensive because of its large volume.

Ground Water Pollution

About one third of World's population depends on ground water for their daily requirement. Arsenic and Fluoride pollution of ground water has been reported from certain areas of West Bengal, Rajasthan and many other states. Prolonged use of arsenic contaminated water lead to skin ulcers and finally to formation of gangrenes and then cancer. Fluoride pollution has been reported from many parts of Odisha. Use of fluoride contaminated water leads to deformities of bone and teeth, a disease known as Fluorosis. These contaminations are mostly due to leaching from sediments present near the aquifers. Pollutants from septic tanks, waste dumps, landfills may sometimes sip into the ground water. Treatment of pollutants in the ground water aquifer is very expensive and time consuming process.

Marine Pollution

All wastes generated on lands unless rapidly biodegraded, reach the sea. Marine pollution is a serious threat to biodiversity in the sea. Industrial effluents, agricultural run-off containing fertilizer and pesticides regularly reach the ocean. Similarly oil spill is a major contributor of marine pollution. Now a days, plastics and packaging materials in very large proportions are reaching the sea. It has posed a serious threat to the marine aquatic life.

Control of Water Pollution

Waste water from the sewers, industrial and agricultural sources are subjected to stage wise treatment called (i) Primary, (ii) Secondary and (iii) Tertiary treatment. In the primary treatment, suspended solids are removed by sedimentation in large sedimentation tanks. Secondary treatment is carried out to treat dissolved and colloidal organic matters. This involves biological oxidation using aerobic or anaerobic microorganisms. Activated Sludge Process is a common biological oxidation process using aerobic microorganisms. This treatment is carried out in large oxidation ponds. The organic matter is converted to activated sludge. This activated sludge is subjected to sedimentation and digestion by anaerobic microorganisms. Tertiary treatment is used to disinfect the sludge. Sludge from the sewage water is used as organic manure, while sludge from industrial effluents containing toxic substances are disposed off safely.

Purification of water for domestic use may be done by boiling, UV treatment and reverse osmosis. But the practice of bulk cleaning is done by chemical treatment, filtering and use of disinfectants. Prevention and control of Water Pollution is a responsibility of the State and Central Pollution Control Boards and they do it by enforcing the provisions made under the Water (Prevention and Control of Pollution) Act, 1974.

Biomonitoring

Assessing the pollution status of an environment by bioindicators is called biomonitoring. While determining the physical and chemical characteristics of water is useful in detecting the level of pollution and to control it, biomonitoring helps in assessing the overall health of the water body.

When pollution of water creates a stressed condition, only the resistant species thrive. As a consequence, the biodiversity of the environment decreases. One of the means of checking biodiversity in a still-water ecosystem is to measure the Plankton (both phytoplankton and zooplankton) abundance and their diversity.

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MODEL QUESTIONS

1. Write the correct answers from the choices given under each bit :

   a. Which one is not a green house gas ?

      i) CO_2 ii) Methane

      iii) Oxygen iv) CFC

   b. Wich one is a secondary air pollutnat ?

      i) CO ii) Sulphuric acid

      iii) NH_3 iv) SO_2

   c. Which one is not a source of particulate matter emission ?

      i) Volcano ii) Burning of fosil fuel

      iii) Cement industry iv) Acid rain

   d. Fluorosis is caused due to

      i) Fluoride contamination of ground water

      ii) Use of water contaminated with faecal coliform bacteria

      iii) Exposure of workers to polluted air in stone crusher units.

      iv) Exposure to UV radiation.

   e. Which one is a persistent organic pollutant ?

      i) NH_3 ii) DDT

      iii) Mercury iv) Ozone

2. Write notes on the following :

   a) Marine pollution b) Biomonitoring

   c) Acid rain d) Green house effect

   e) Eutrophication

3. Differentiate between the following with 2 to 3 valid points :

   a) SPM and RSPM

   b) Primary air pollutants and Secondary air pollutnats.

   c) Point sources and non-point sources of water pollution

4. Describe different types of primary air pollutants and their effect on environment.

5. Describe the types of surface water pollutants and their effects on environment.

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