GOVERNMENT OF TAMIL NADU

BIOLOGY
BOTANY

HIGHER SECONDARY SECOND YEAR

Untouchability is Inhuman and a Crime

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HOW TO USE THE BOOK

Career corner	List of professions related to the subject
Learning Objectives:	Learning objectives are brief statements that describe what students will be expected to learn by the end of school year, course, unit, lesson or class period.
Chapter Outline	Illustrate the complete overview of chapter
DO YOU KNOW?	Amazing facts, Rhetorical questions to lead students to biological inquiry
Activity	Directions are provided to students to conduct activities in order to explore, enrich the concept.
Infographics	Visual representation of the lesson to enrich learning .
Evaluation	Assess students to pause, think and check their understanding
	To motivate the students to further explore the content digitally and take them in to virtual world
ICT	To enhance digital Science skills among students
Concept Map	Conceptual diagram that depicts relationships between concepts to enable students to learn the content schematically
Glossary	Explanation of scientific terms
English - Tamil Terminology	Tamil terminology for Botanical terms given for easy understanding
References	List of related books for further details of the topic
Web links	List of digital resources
Competitive Exam questions	Model questions to face various competitive exams

Scope of Botany
Higher Studies and Career Opportunities

List of Medical Courses

1. **M. B. B. S. (Bachelor of Medicine and Bachelor of Surgery) – 5.5 years**

   MBBS is the bachelor degree in medical field for cure & diagnose, awarded in many countries.

2. **B. D. S. (Bachelor of Dental Surgery) – 4 years**

   BDS is a professional degree programme in dentistry.

3. **B. H. M. S. (Bachelor of Homeopathic Medicine & Surgery) – 5.5 years**

   BHMS is a bachelor degree in Homeopathic Education in India regulated by the National Institute of Homeopathy.

4. **B. A. M. S. (Bachelor of Ayurvedic Medicine and Surgery) – 5.5 years**

   BAMS is a bachelor degree in ayurvedic system of medical field. In India, the Ayurvedic Education is regulated by the Central Council of Indian Medicine (CCIM).

5. **B.Pharm (Bachelor of Pharmacy) – 4 years**

   This degree involves the knowledge of pharmacy.

6. **B.Sc Nursing – 4 years**

   The motive of B.Sc. Nursing programme is to produce the qualified nurses, as a member of the health care team.

7. **B.P.T (Physiotherapy) – 4.5 years**

   Physiotherapy helps the temporary disabled people in their rehabilitation.

8. **B.O.T (Occupational Therapy) – 3 years**

   The Occupational Therapy helps the people to enable in their everyday life and treats the emotionally and physically challenged people.

9. **B.U.M.S (Unani Medicine) – 5.5 years**

   BUMS degree is equivalent to the BAMS, but in Unani medicines.

   Naturopathy & Yogic Science is one of the trusted fields after Allopathy in India. Duration: 4 Years

10. **D.Pharm (Ayurvedic, Siddha Medicine) – 2 years**

    It is a medical diploma course in pharmacy of ayurvedic medicines.

11. **BMLT (Bachelor of Medical Lab Technicians) – 3 year**

    It is a bachelor degree of medical laboratory technology, contains the entire laboratory practices of the medical system. Various institutions are offering the B.Sc. programme in medical laboratory technology in India.

12. **DMLT (Diploma of Medical Lab Technicians) – 1 year**

    It is a medical diploma course of medical laboratory technology, contains the laboratory practices of the medical field. Candidate must have cleared the 10+2 exam with PCB.

Agricultural Courses

- B.Sc in Agriculture
- B.Sc in Genetics and Plant Breeding
- B.Sc in Agriculture Economics and Farm Management
- B.Sc in Animal Husbandry
- B.Sc in Fisheries
- B.Sc in Forestry
- B.Sc Soil and water management
- B.Sc in Horticulture
- B.Sc Agriculture and Food Business
- M.Sc in Agronomy
- M.Sc Agricultural Economics
- M.Sc Seed science and Technology
- M.Sc Agricultural Entomology
- M.Sc Agricultural Statistics
- Diploma in Agriculture

Various Botany courses

- Bachelor of Science in Botany
- Bachelor of Science (Hons) in Botany
- Master of Science in Botany
- Master of Science in Botany and Forestry
- Master of Science in Applied Botany
- Master of Science in Herbal Science
- Post Graduate Diploma in Medico botany
- Post Graduate Diploma in Plant Biodiversity

Specializations available for botany are:

- Cytology
- Lichenology
- Palynology
- Bryology
- Phycology
- Forestry
- Phytopathology
- Plant physiology
- Agronomy
- Plant ecology
- Genetics
- Economic botany
- Palaeobotany
- Ethnobotany
- Phytochemistry
- Plant morphology
- Plant anatomy
- Plant genetics
- Horticulture
- Plant systematic

Veterinary Science

Bachelor of Veterinary Science or B.V.Sc. is an undergraduate program in veterinary

Botany Career Opportunities and Job Prospects

The amount of diversity in the field of Botany gives it students to choose their specializations as per their choice, aptitude and interests. One can be a part of any reputed organization as a

Plant explorer: Botanist with a passion for plants who could be a photographer, writer, expeditioner, etc

Conservationist: Is an individual who works for the conservation of the environment and is often linked to organisations working for the cause.

Ecologist: A person who works for the eco-system and a balanced environment.

Environment consultant: Some botanists qualify to work as environmental consultants, providing inputs and advice for the conservation of the environment.

Horticulturist: A horticulturist knows the science behind different plants, flowers, and greenery. They conduct research in gardening and landscaping, plant propagation, crop production, plant breeding, genetic engineering, plant biochemistry, and plant physiology.

Plant biochemist: Biochemists study the chemical and physical principles of living things and of biological processes, such as cell development, growth, heredity, and disease.

Molecular biologist: Molecular biologists conduct research and academic activities. The research component involves the study of biological structures in well-equipped laboratories with advanced technology to help them explore complex molecular structures and their particular functions. The equipment may include microscopes, lab centrifuges, computers with specific software that allows them to analyze obtained data, and many more.

Chapter 1

UNIT VI: Reproduction in Plants

Asexual and Sexual Reproduction in Plants

Learning Objectives

The learner will be able to

- Recall various types of reproduction in lower and higher organisms.
- Discuss different methods of vegetative reproduction in plants.
- Recognise modern methods of reproduction.
- Recall the parts of a flower.
- Recognise the structure of mature anther.
- Describe the structure and types of ovules.
- Discuss the structure of embryo sac.
- Recognise different types of pollination.
- Identify the types of endosperms.
- Differentiate the structure of Dicot and Monocot seed.

Chapter outline

4ATHKN

One of the essential features of all living things on the earth is reproduction. Reproduction is a vital process for the existence of a species and it also brings suitable changes through variation in the offsprings for their survival on earth. Plant reproduction is important not only for its own survival but also for the continuation and existence of all other organisms since the latter directly or indirectly depend on plants. Reproduction also plays an important role in evolution.

In this unit let us learn in detail about reproduction in plants.

Milestones in Plant Embryology

1682 - Nehemiah Grew mentioned stamens as the male organ of a flower.

1694 - R.J.Camerarius described the structure of a flower, anther, pollen and ovule

1761 - J.G. Kolreuter gave a detailed account on the importance of insects in pollination

1824 - G.B.Amici discovered the pollen tube.

1848 - Hofmeister described the structure of pollen tetrad

1870 - Hanstein described the development of embryo in *Capsella* and *Alisma*

1878 - E.Strasburger reported polyembryony

1884 - E.Strasburger discovered the process of Syngamy.

1898 & 1899 - S.G.Nawaschin and L. Guignard independently discovered Double fertilization

1904 – E.Hanning initiated embryo culture.

1950 - D.A. Johansen proposed classification for embryo development

1964 - S.Guha and S.C.Maheswari raised haploids from *Datura* pollen grains

1991 - E.S.Coen and E. M. Meyerowitz proposed the ABC model to describe the genetics of initiation and development of floral parts

2015 - K.V.Krishnamurthy summarized the molecular aspects of pre and post fertilization reproductive development in flowering plants

Panchanan Maheswari (1904-1966)

Professor P. Maheswari was an eminent Botanist who specialised in plant embryology, morphology and anatomy. In 1934, he became the Fellow of Indian Academy of Science. He published the book titled "An introduction to the Embryology of Angiosperms"in 1950. He established the International Society for Plant Morphologists, in 1951.

Basically reproduction occurring in organisms fall under two major categories

1. Asexual reproduction
2. Sexual reproduction.

1.1 Asexual Reproduction

The reproduction method which helps to perpetuate its own species without the involvement of gametes is referred to as asexual reproduction. From Unit I of Class XI we know that reproduction is one of the attributes of living things and the different types of reproduction have also been discussed. Lower plants, fungi and animals show different methods of asexual reproduction. Some of the methods include, formation of Conidia (*Aspergillus* and *Penicillium*); Budding (*Yeast* and *Hydra*); Fragmentation (*Spirogyra*); production of Gemma (*Marchantia*); Regeneration (*Planaria*) and Binary fission (Bacteria) (Refer chapter 1 of Unit I of class XI). The individuals formed by this method is morphologically and genetically identical and are called **clones**. Higher plants also reproduce asexually by different methods which are given below:

1.2 Vegetative reproduction

1.2.1 Natural methods

Natural vegetative reproduction is a form of asexual reproduction in which a bud grows and develops into a new plant. The buds may be formed in organs such as root, stem and leaf. At some stage, the new plant gets detached from the parent plant and starts to develop into a new plant. Some of the organs involved in the vegetative reproduction also serve as the organs of storage and perennation. The unit of reproductive structure used in propagation is called **reproductive propagules** or **diaspores.** Some of the organs that help in vegetative reproduction are given in Figure 1.1.

A. Vegetative reproduction in root

The roots of some plants develop vegetative or adventitious buds on them. Example *Murraya, Dalbergia* and *Millingtonia.* Some tuberous adventitious roots apart from developing buds also store food. Example *Ipomoea batatus* and *Dahlia.* Roots possessing buds become detached from the parent plant and grow into independent plant under suitable condition.

Scourge of water bodies / Water hyacinth (*Eichhornia crassipes)* is an invasive weed on water bodies like ponds, lakes and reservoirs. It is popularly called "Terror of Bengal". It spreads rapidly through offset all over the water body and depletes the dissolved oxygen and causes death of other aquatic organisms.

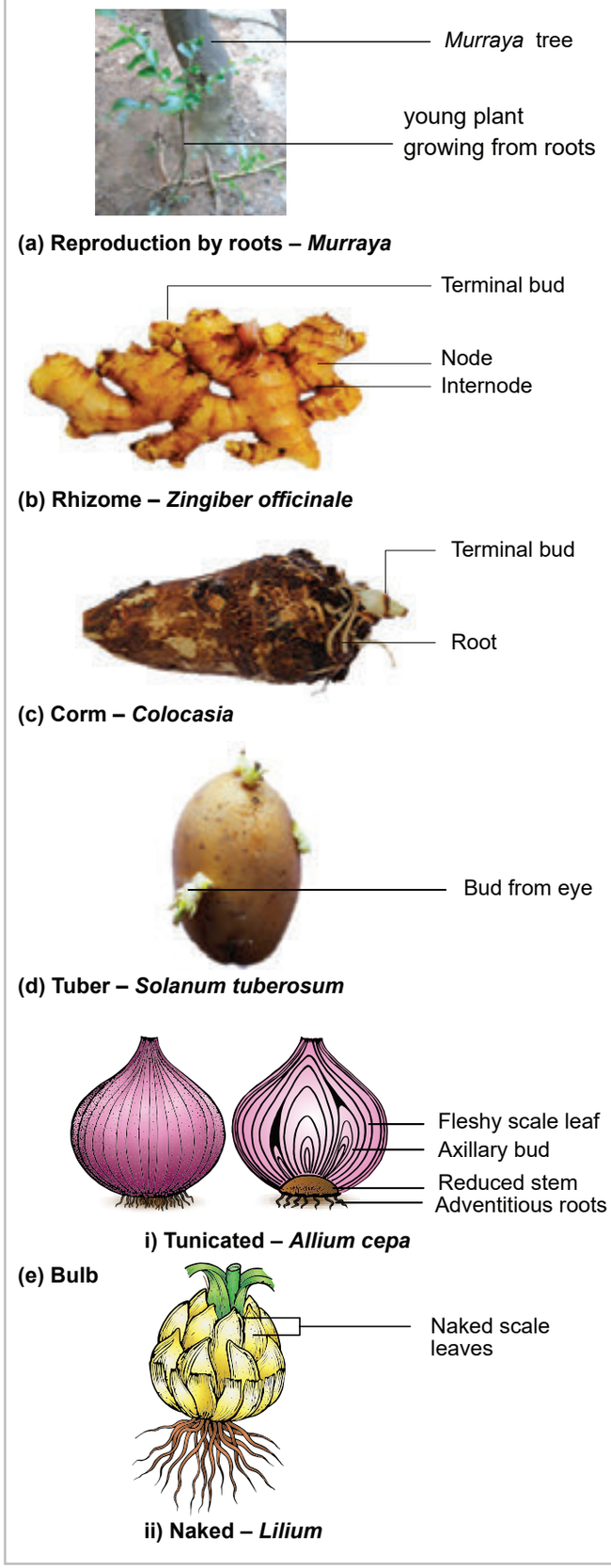


Figure 1.1 a-k: Natural methods of vegetative reproduction in plants.

Activity

Visit to a vegetable market and classify the vegetables into root, stem or leaf based on their utility and identify how many of them can be propagated through asexual methods.

B. Vegetative reproduction in stem

From the Unit 3 of class XI (Vegetative morphology) you are familiar with the structure of various underground stem and sub aerial stem modifications. These include rhizome (*Musa paradisiaca*, *Zingiber officinale* and *Curcuma longa*); corm (*Amorphophallus* and *Colocasia*); tuber (*Solanum tuberosum*); bulb(*Allium cepa* and *Lilium*) runner (*Centella asiatica*); stolon (*Mentha,* and *Fragaria*); offset (*Pistia,* and *Eichhornia*); sucker (*Chrysanthemum*) and bulbils (*Dioscorea* and *Agave*). The axillary buds from the nodes of rhizome and eyes of tuber give rise to new plants.

C. Vegetative reproduction in leaf

In some plants adventitious buds are developed on their leaves. When they are detached from the parent plant they grow into new individual plants. Examples: *Bryophyllum, Scilla,* and *Begonia*. In *Bryophyllum*, the leaf is succulent and notched on its margin. Adventious buds develop at these notches and are called **epiphyllous buds**. They develop into new plants forming a root system and become independent plants when the leaf gets decayed. *Scilla* is a bulbous plant and grows in sandy soils. The foliage leaves are long and narrow and epiphyllous buds develop at their tips. These buds develop into new plants when they touch the soil.

Advantages of natural vegetative reproduction

- Only one parent is required for propagation.
- The new individual plants produced are genetically identical.
- In some plants, this enables to spread rapidly. Example: *Spinifex*
- Horticulturists and farmers utilize these organs of natural vegetative reproduction for cultivation and to harvest plants in large scale.

Disadvantage of natural vegetative reproduction

- New plants produced have no genetic variation.

1.2.2 Artificial Methods

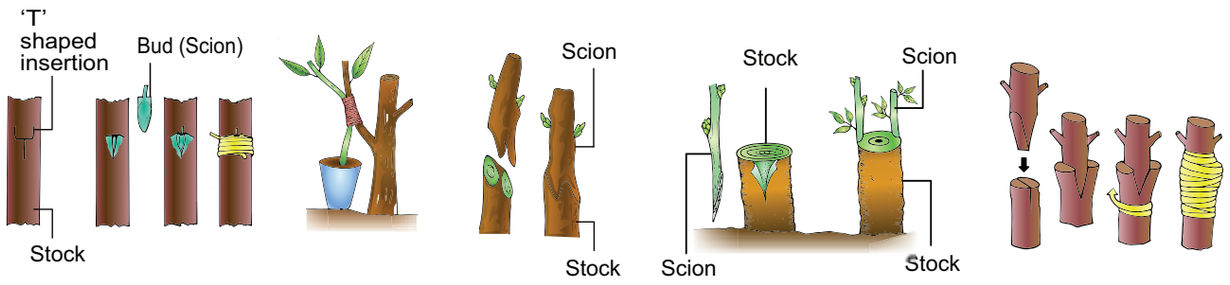
Apart from the above mentioned natural methods of vegetative reproduction, a number of methods are used in agriculture and horticulture to propagate plants from their parts. Such methods are said to be artificial propagation. Some of the artificial propagation methods have been used by man for a long time and are called **conventional methods**. Now-a-days, technology is being used for propagation to produce large number of plants in a short period of time. Such methods are said to be **modern methods**.

A. Conventional methods

The common methods of conventional propagation are cutting, grafting and layering.

a. Cutting: It is the method of producing a new plant by cutting the plant parts such as root, stem and leaf from the parent plant. The cut part is placed in a suitable medium for growth. It produces root and grows into a new plant. Depending upon the part used it is called as root cutting (*Malus*), stem cutting (*Hibiscus, Bougainvillea* and *Moringa*) and leaf cutting (*Begonia, Bryophyllum*). Stem cutting is widely used for propagation.

b.Grafting: In this, parts of two different plants are joined so that they continue to grow as one plant. Of the two plants, the plant which is in contact with the soil is called **stock** and the plant used for grafting is called **scion** (Figure 1.2 a). Examples are Citrus, Mango and Apple. There are different types of grafting based on the method of uniting the scion and stock. They are bud grafting, approach grafting, tongue grafting, crown grafting and wedge grafting.



a) Types of Grafting

Figure 1.2(a): Artificial methods of vegetative reproduction in plants

i. Bud grafting: A T- shaped incision is made in the stock and the bark is lifted. The scion bud with little wood is placed in the incision beneath the bark and properly bandaged with a tape.

ii. Approach grafting: In this method both the scion and stock remain rooted. The stock is grown in a pot and it is brought close to the scion. Both of them should have the same thickness. A small slice is cut from both and the cut surfaces are brought near and tied together and held by a tape. After 1-4 weeks the tip of the stock and base of the scion are cut off and detached and grown in a separate pot.

iii. Tongue grafting

A scion and stock having the same thickness is cut obliquely and the scion is fit into the stock and bound with a tape.

iv. Crown grafting.

When the stock is large in size scions are cut into wedge shape and are inserted on the slits or clefts of the stock and fixed in position using graft wax.

v. Wedge grafting

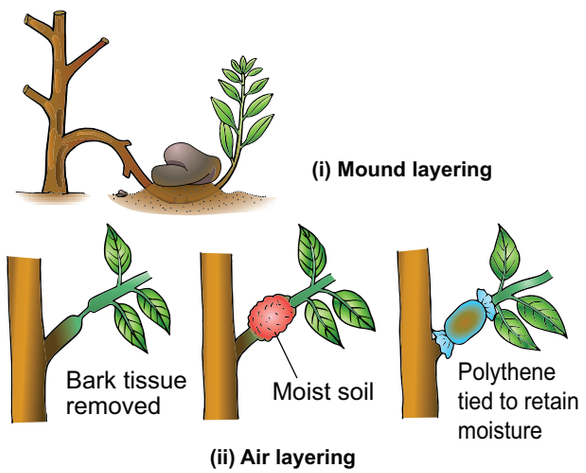
In this method a slit is made in the stock or the bark is cut. A twig of scion is inserted and tightly bound so that the cambium of the two is joined.

Activity

Visit a nursery, observe the method of grafting, layering and do these techniques with plants growing in your school or home

c. Layering: In this method, the stem of a parent plant is allowed to develop roots while still intact. When the root develops, the rooted part is cut and planted to grow as a new plant. Examples: *Ixora* and *Jasminum*. Mound layering and Air layering are few types of layering (Figure 1.2 b).

i. Mound layering: This method is applied for the plants having flexible branches. The lower branch with leaves is bent to the ground and part of the stem is buried in the soil and tip of the branch is exposed above the soil. After the roots emerge from the part of the stem buried in the soil, a cut is made in parent plant so that the buried part grow into a new plant.



b) Types of Layering

Figure 1.2(b): Artificial methods of vegetative reproduction in plants

ii. Air layering: In this method the stem is girdled at nodal region and hormones are applied to this region which promotes rooting. This portion is covered with damp or moist soil using a polythene sheet. Roots emerge in these branches after 2-4 months. Such branches are removed from the parent plant and grown in a separate pot or ground.

Advantages of conventional methods

- The plants produced are genetically uniform.
- Many plants can be produced quickly by this method.
- Some plants produce little or no seeds; in others, the seeds produced do not germinate. In such cases, plants can be produced in a short period by this method.
- Some plants can be propagated more economically by vegetative propagation. Example: *Solanum tuberosum.*
- Two different plants with desirable characters such as disease resistant and high yield can be grafted and grown as a new plant with the same desirable characters.

Disadvantages of conventional methods

- Use of virus infected plants as parents produces viral infected new plants.
- Vegetative structures used for propagation are bulky and so they are difficult to handle and store.

B. Modern Method

Professor F.C. Steward(1932) of Cornell University showed that the mature phloem parenchyma cells removed from the carrot were placed in a suitable medium under controlled conditions, could be stimulated to start dividing again to produce a new carrot plant. These cells were described as **totipotent**. The genetic ability of a plant cell to produce the entire plant under suitable conditions is said to be totipotency. This characteristic feature of a cell is utilized in horticulture, forestry and industries to propagate plants. The growth of plant tissue in special culture medium under suitable controlled conditions is known as **tissue culture**.

Micropropagation

The regeneration of a whole plant from single cell, tissue or small pieces of vegetative structures through tissue culture is called **micropropagation**. This is one of the modern methods used to propagate plants. The detailed steps involved in the micropropagation are given in Unit VIII.

Advantages of modern methods

- Plants with desired characteristics can be multiplied rapidly in a short duration.
- Plants produced are genetically identical.
- Tissue culture can be carried out in any season to produce plants.
- Plants which do not produce viable seeds and seeds that are difficult to germinate can be propagated by tissue culture.
- Rare and **endangered** plants can be propagated.
- Disease free plants can be produced by **meristem culture**.
- Cells can be genetically modified and transformed using tissue culture.

Disadvantages of modern methods

- It is labour intensive and requires skilled workers.
- Sterile condition must be maintained which adds to the cost.
- Since the clones are genetically identical, the entire crop is susceptible to new diseases or changes in environmental conditions will wipe out the species.

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- Sometimes, **callus** undergoes genetical changes which are undesirable for commercial use.

1.3 Sexual Reproduction

In previous classes reproduction in lower plants like algae and bryophytes was discussed in detail. Sexual reproduction involves the production and fusion of male and female gametes. The former is called gametogenesis and the latter is the process of fertilization. Let us recall the sexual reproduction in algae and bryophytes. They reproduce by the production of gametes which may be motile or non motile depending upon the species. The gametic fusion is of three types (Isogamy, Anisogamy and Oogamy). In algae external fertilization takes place whereas in higher plants internal fertilization occurs.

Flower

A flower is viewed in multidimensional perspectives from time immemorial. It is an inspirational tool for the poets. It is a decorative material for all the celebrations. In Tamil literature the five lands are denoted by different flowers. The flags of some countries are embedded with flowers. Flowers are used in the preparation of perfumes. For a Morphologist, a flower is a highly condensed shoot meant for reproduction. As you have already learned about the parts of a flower in Unit II of Class XI, let us recall the parts of a flower. A Flower possesses four whorls- Calyx, Corolla, Androecium and Gynoecium. Androecium and Gynoecium are essential organs(Figure 1.3). The process or changes involved in sexual reproduction of higher plants include three stages .They are Pre-fertilization, Fertilization and Post fertilization changes. Let us discuss these events in detail.

1.4 Pre-fertilization structure and events

The hormonal and structural changes in plant lead to the differentiation and development of floral primordium. The structures and events involved in pre-fertilization are given below

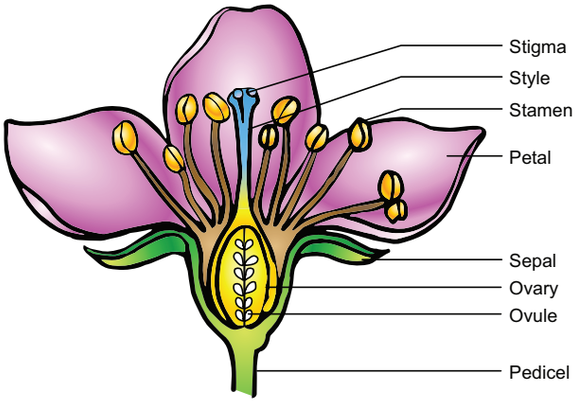


Figure 1.3 Parts of a Flower

1.4.1 Male Reproductive part - Androecium

Androecium is made up of stamens. Each stamen possesses an anther and a filament. Anther bears pollen grains which represent the male gametophyte. In this chapter we shall discuss the structure and development of anther in detail.

Development of anther: A very young anther develops as a homogenous mass of cells surrounded by an epidermis. During its development, the anther assumes a four-lobed structure. In each lobe, a row or a few rows of hypodermal cells becomes enlarged with conspicuous nuclei. This functions as archesporium. The archesporial cells divide by periclinal divisions to form primary parietal cells towards the epidermis and primary sporogenous cells towards the inner side of the anther. The primary parietal cells undergo a series of periclinal and anticlinal division and form 2-5 layers of anther walls composed of endothecium, middle layers and tapetum, from periphery to centre.

Microsporogenesis: The stages involved in the formation of haploid microspores from diploid microspore mother cell through meiosis is called **Microsporogenesis**. The primary sporogeneous cells directly, or may undergo a few mitotic divisions to form **sporogenous**

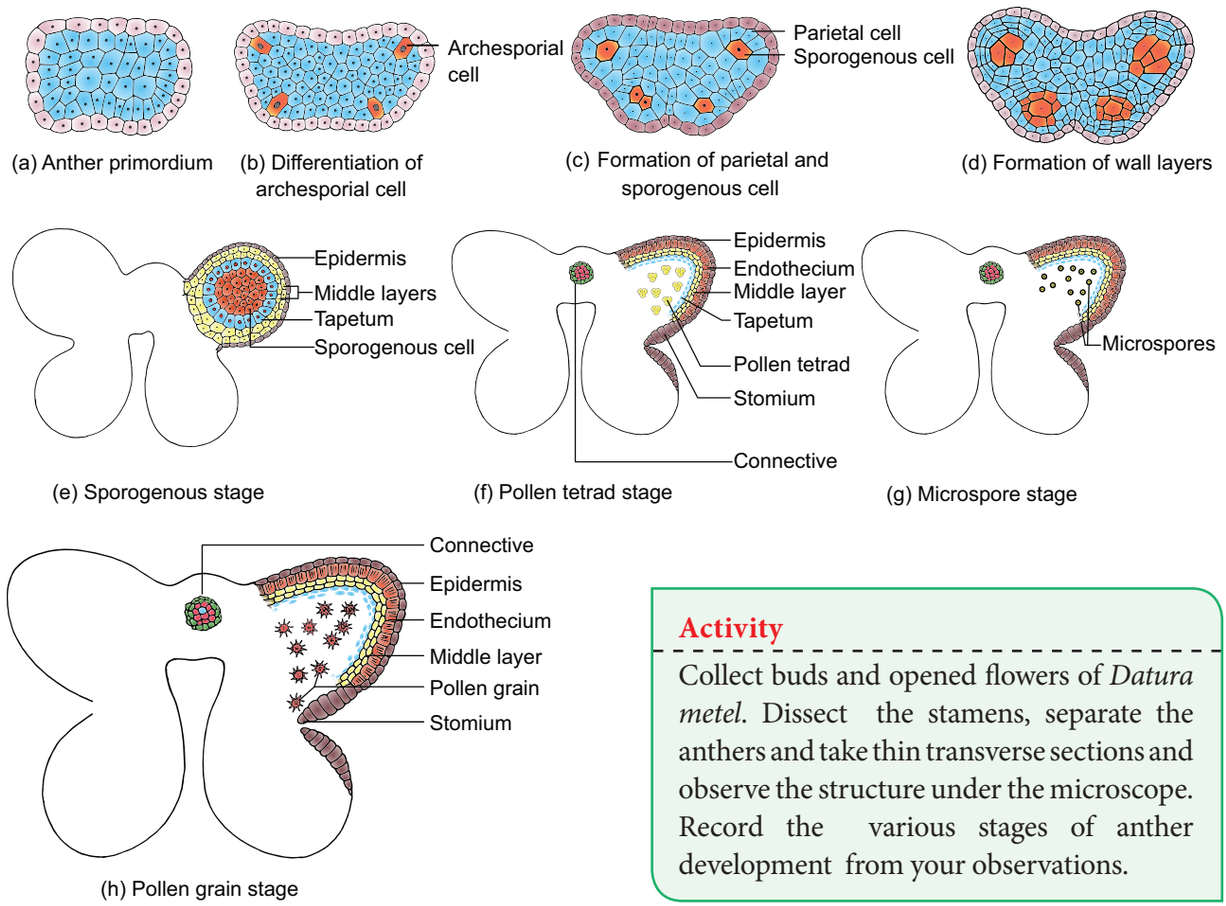


Figure 1.4 Stages in the development of anther

tissue. The last generation of sporogenous tissue functions as microspore mother cells. Each microspore mother cell divides meiotically to form a tetrad of four haploid microspores (microspore tetrad). Microspores soon separate from one another and remain free in the anther locule and develop into pollen grains. The stages in the development of microsporangia is given in Figure 1.4. In some plants, all the microspores in a microsporangium remain held together called **pollinium**. Example: *Calotropis*. Pollinia are attached to a clamp or clip like sticky structure called **corpusculum**. The filamentous or thread like part arising from each pollinium is called **retinaculum**. The whole structure looks like inverted letter 'Y' and is called **translator**

T.S. of Mature anther

Transverse section of mature anther reveals the presence of anther cavity surrounded by an anther wall. It is bilobed, each lobe having 2 theca (dithecous). A typical anther is tetrasporangiate. The T.S. of Mature anther is given in Figure 1.5.

Activity

Collect buds and opened flowers of *Datura metel*. Dissect the stamens, separate the anthers and take thin transverse sections and observe the structure under the microscope. Record the various stages of anther development from your observations.

1. Anther wall

The mature anther wall consists of the following layers **a. Epidermis b. Endothecium c. Middle layers d. Tapetum.**

a. Epidermis: It is single layered and protective in function. The cells undergo repeated anticlinal divisions to cope up with the rapidly enlarging internal tissues.

b.Endothecium: It is generally a single layer of radially elongated cells found below the epidermis. The inner tangential wall develops bands (sometimes radial walls also) of α cellulose (sometimes also slightly lignified). The cells are **hygroscopic**. In the anthers of aquatic plants, saprophytes, cleistogamous flowers and extreme parasites endothecial differentiation is absent. The cells along the junction of the two sporangia of an anther lobe lack these thickenings. This

region is called **stomium**. This region along with the hygroscopic nature of endothecium helps in the dehiscence of anther at maturity.

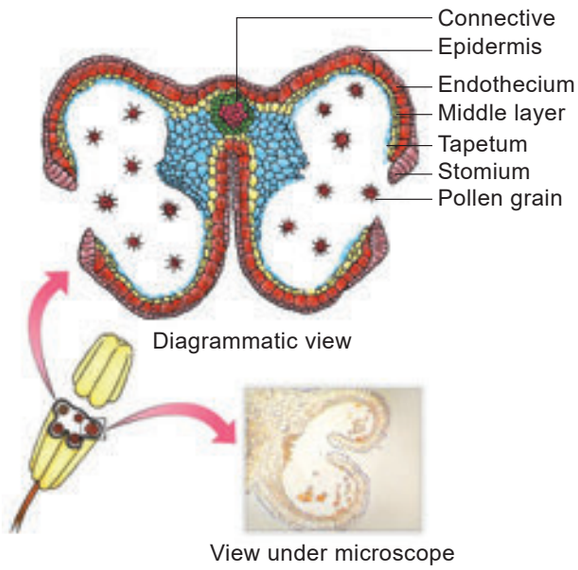


Figure 1.5 T.S of Mature anther

c. Middle layers: Two to three layers of cells next to endothecium constitute middle layers. They are generally ephemeral. They disintegrate or get crushed during maturity.

d. Tapetum: It is the innermost layer of anther wall and attains its maximum development at the tetrad stage of microsporogenesis. It is derived partly from the peripheral wall layer and partly from the connective tissue of the anther lining the anther locule. Thus, the tapetum is dual in origin. It nourishes the developing sporogenous tissue, microspore mother cells and microspores. The cells of the tapetum may remain uninucleate or may contain more than one nucleus or the nucleus may become polyploid. It also contributes to the wall materials, sporopollenin, pollenkitt, tryphine and number of proteins that control incompatibility reaction .Tapetum also controls the fertility or sterility of the microspores or pollen grains.

There are two types of tapetum based on its behaviour. They are:

Secretory tapetum (parietal/glandular/cellular): The tapetum retains the original position and cellular integrity and nourishes the developing microspores.

Invasive tapetum (periplasmodial): The cells loose their inner tangential and radial walls and the protoplast of all tapetal cells coalesces to form a periplasmodium.

Functions of Tapetum:

- It supplies nutrition to the developing microspores.
- It contributes sporopollenin through **ubisch bodies** thus plays an important role in pollen wall formation.
- The pollenkitt material is contributed by tapetal cells and is later transferred to the pollen surface.
- Exine proteins responsible for '**rejection reaction**' of the stigma are present in the cavities of the exine. These proteins are derived from tapetal cells.

Many botanists speak of a third type of tapetum called amoeboid, where the cell wall is not lost. The cells protrude into the anther cavity through an amoeboid movement. This type is often associated with male sterility and should not be confused with periplasmodial type.

2. Anther Cavity : The anther cavity is filled with microspores in young stages or with pollen grains at maturity. The meiotic division of microspore mother cells gives rise to microspores which are haploid in nature.

3. Connective: It is the column of sterile tissue surrounded by the anther lobe. It possesses vascular tissues. It also contributes to the inner tapetum.

Microspores and pollen grains

Microspores are the immediate product of meiosis of the microspore mother cell whereas the pollen grain is derived from the microspore. The microspores have protoplast surrounded by a wall which is yet to be fully developed. The pollen protoplast consists of dense cytoplasm with a centrally located nucleus. The wall is

differentiated into two layers, namely, inner layer called **intine** and outer layer called **exine**. Intine is thin, uniform and is made up of pectin, hemicellulose, cellulose and callose together with proteins. Exine is thick and is made up of cellulose, sporopollenin and pollenkitt. The exine is not uniform and is thin at certain areas. When these thin areas are small and round it is called germ pores or when elongated it is called furrows. It is associated with germination of pollen grains. The sporopollenin is generally absent in germ pores.The surface of the exine is either smooth or sculptured in various patterns (rod like, grooved, warty, punctuate etc.) The sculpturing pattern is used in the plant identification and classification.

Shape of a pollen grain varies from species to species. It may be globose, ellipsoid, fusiform, lobed, angular or crescent shaped. The size of the pollen varies from 10 micrometers in *Myosotis* to 200 micrometers in members of the family Cucurbitaceae and Nyctaginaceae

DO YOU KNOW?

Palynology is the study of pollen grains.It helps to identify the distribution of coal and to locate oil fields. Pollen grains reflect the vegetation of an area.

Liquid nitrogen (-196^{0}C) is used to preserve pollen in viable condition for prolonged duration. This technique is called **cryopreservation** and is used to store pollen grains (pollen banks) of economically important crops for breeding programmes..

The wall material sporopollenin is contributed by both pollen cytoplasm and tapetum. It is derived from carotenoids. It is resistant to physical and biological decomposition. It helps to withstand high temperature and is resistant to strong acid, alkali and enzyme action. Hence, it preserves the pollen for long periods in fossil deposits, and it also protects pollen during its journey from anther to stigma.

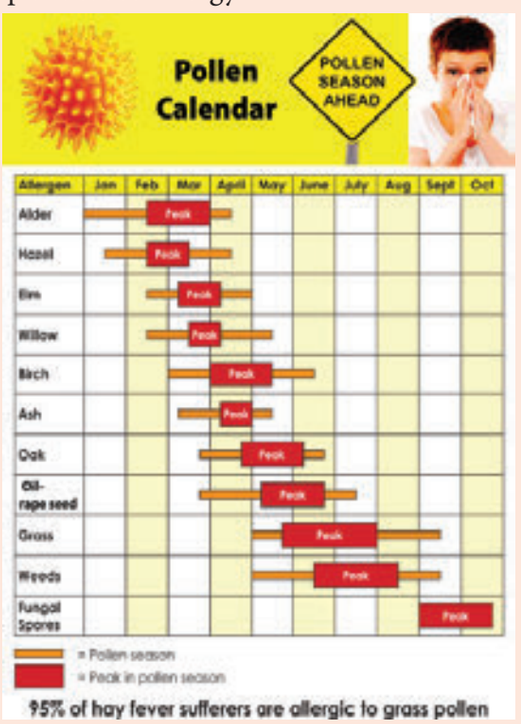
DO YOU KNOW?

Bee pollen is a natural substance and contains high protein, carbohydrate, trace amount of minerals and vitamins. Therefore, it is used as dietary supplement and is sold as pollen tablets and syrups. Further , it increases the performance of athletes, race horses and also heals the wounds caused by burns . The study of honey pollen is called Mellitopalynology.

DO YOU KNOW?

Pollen calendar shows the production of pollen by plants during different seasons. This benefits the allergic persons. Pollen grains cause allergic reactions like asthma, bronchitis, hay fever, allergic rhinitis etc.,

Parthenium hysterophorus L. (Family-Asteraceae) is commonly called Carrot grass is a native of tropical America and was introduced into India as a contaminant along with cereal wheat. The pollen of this plant cause Allergy.



Pollenkitt is contributed by the tapetum and coloured yellow or orange and is chiefly made of carotenoids or flavonoids. It is an oily layer forming a thick viscous coating over pollen surface. It attracts insects and protects damage from UV radiation.

Development of Male gametophyte:

The microspore is the first cell of the male gametophyte and is haploid. The development of male gametophyte takes place while they are still in the microsporangium. The nucleus of the microspore divides to form a **vegetative** and a **generative** nucleus. A wall is laid around the generative nucleus resulting in the formation of two unequal cells, a large irregular nucleus bearing with abundant food reserve called vegetative cell and a small generative cell. At this 2 celled stage, the pollens are liberated from the anther. In some plants the generative cell again undergoes a division to form two male gametes. In these plants, the pollen is liberated at 3 celled stage. In 60% of the angiosperms pollen is liberated in 2 celled stage. Further, the growth of the male gametophyte occurs only if the pollen reaches the right stigma. The pollen on reaching the stigma absorbs moisture and swells.

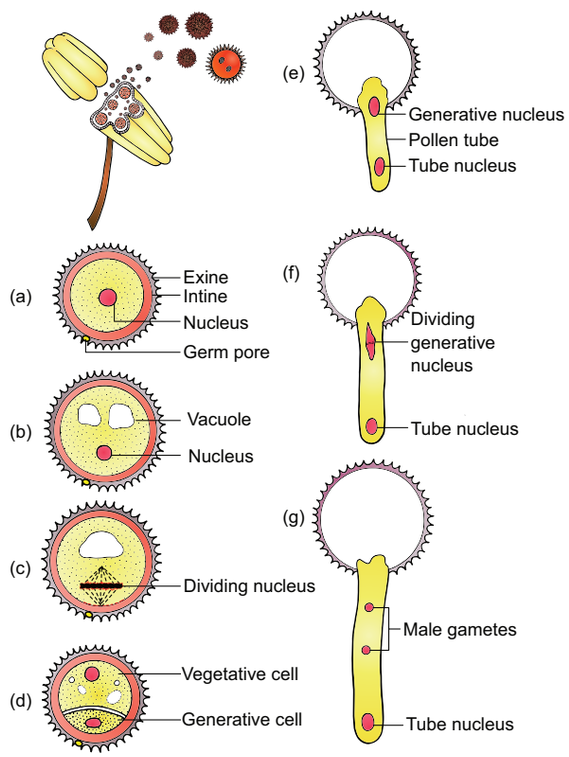


Figure 1.6 Development of male gametophyte

The intine grows as pollen tube through the germ pore. In case the pollen is liberated at 2 celled stage the generative cell divides in the pollen into 2 male cells (sperms) after reaching the stigma or in the pollen tube before reaching the embryo sac. The stages in the development of male gametophyte is given in Figure 1.6.

1.4.2 Female reproductive part - Gynoecium

The **gynoecium** represents the female reproductive part of the flower. The word gynoecium represents one or more pistils of a flower. The word pistil refers to the ovary, style and stigma. A pistil is derived from a carpel. The word ovary represents the part that contains the ovules. The stigma serves as a landing platform for pollen grains. The style is an elongated slender part beneath the stigma. The basal swollen part of the pistil is the ovary. The ovules are present inside the ovary cavity (locule)on the placenta .Gynoecium (carpel) arises as a small papillate outgrowth of meristematic tissue from the growing tip of the floral primordium. It grows actively and soon gets differentiated into ovary, style and stigma. The ovules or megasporangia arise from the placenta. The number of ovules in an ovary may be one (paddy, wheat and mango) or many (papaya, water melon and orchids).

Structure of ovule(Megasporangium):

Ovule is also called megasporangium and is protected by one or two covering called **integuments**. A mature ovule consists of a stalk and a body. The stalk or the **funiculus** (also called funicle) is present at the base and it attaches the ovule to the placenta. The point of attachment of funicle to the body of the ovule is known as **hilum**. It represents the junction between ovule and funicle. In an inverted ovule, the funicle is adnate to the body of the ovule forming a ridge called **raphe**. The body of the ovule is made up of a central mass of parenchymatous tissue called **nucellus** which has large reserve food materials. The nucellus is enveloped by one or two protective

coverings called **integuments**. Integument encloses the nucellus completely except at the top where it is free and forms a pore called micropyle. The ovule with one or two integuments are said to be **unitegmic** or **bitegmic** ovules respectively. The basal region of the body of the ovule where the nucellus, the integument and the funicle meet or merge is called as **chalaza**. There is a large,

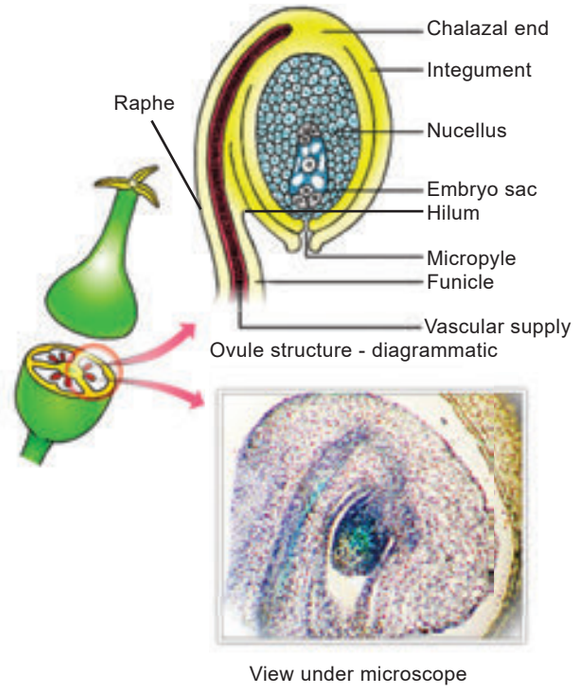


Figure 1.7 Structure of an ovule

oval, sac-like structure in the nucellus toward the micropylar end called **embryo sac** or female gametophyte. It develops from the functional megaspore formed within the nucellus. In some species(unitegmic tenuinucellate) the inner layer of the integument may become specialized to perform the nutritive function for the embryo sac and is called as **endothelium** or **integumentary tapetum** (Example : Asteraceae). There are two types of ovule based on the position of the sporogenous cell. If the sporogenous cell is hypodermal with a single layer of nucellar tissue around it is called **tenuinucellate** type. Normally tenuinucellate ovules have very small nucellus. Ovules with subhypodermal sporogenous cell is called **crassinucellate** type. Normally these ovules have fairly large nucellus. Group of cells found at the base of the ovule between the chalaza and embryo sac is called **hypostase** and the thick -walled cells found above the micropylar end above the embryo sac is called **epistase**. The structure of ovule is given in Figure 1.7.

Types of Ovules

The ovules are classified into six main types based on the orientation, form and position of the micropyle with respect to funicle and chalaza. Most important ovule types are orthotropous, anatropous, hemianatropous and campylotropous. The types of ovule is given in Figure 1.8.

Orthotropous: In this type of ovule, the micropyle is at the distal end and the micropyle, the funicle and the chalaza lie in one straight verticalline. Examples: Piperaceae, Polygonaceae

Anatropous: The body of the ovule becomes completely inverted so that the micropyle and funiculus come to lie very close to each other. This is the common type of ovules found in dicots and monocots.

Hemianatropous: In this, the body of the ovule is placed transversely and at right angles to the funicle. Example: Primulaceae.

Campylotropous: The body of the ovule at the micropylar end is curved and more or less bean

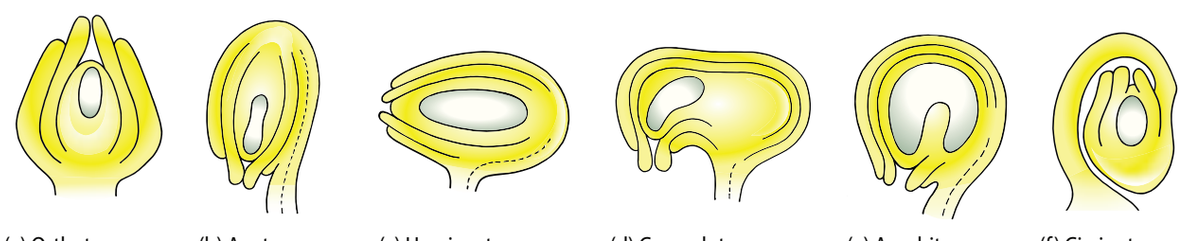


Figure 1.8 Types of ovule

shaped. The embryo sac is slightly curved. All the three, hilum, micropyle and chalaza are adjacent to one another, with the micropyle oriented towards the placenta. Example: Leguminosae

In addition to the above main types there are two more types of ovules they are,

Amphitropous: The distance between hilum and chalaza is less. The curvature of the ovule leads to horse-shoe shaped nucellus. Example: some Alismataceae.

Circinotropous: Funiculus is very long and surrounds the ovule. Example: Cactaceae

Megasporogenesis

The process of development of a megaspore from a megaspore mother cell is called **megasporogenesis**.

As the ovule develops, a single hypodermal cell in the nucellus becomes enlarged and functions as **archesporium**. In some plants, the archesporial cell may directly function as megaspore mother cell. In others, it may undergo a transverse division to form outer primary parietal cell and inner primary sporogenous cell. The parietal cell may remain undivided or divide by few periclinal and anticlinal divisions to embed the primary sporogenous cell deep into the nucellus. The primary sporogenous cell functions as a megaspore mother cell. The megaspore mother cell undergoes meiotic division to form four haploid megaspores. Based on the number of megaspores that develop into the Embryo sac, we have three basic types of development: **monosporic, bisporic** and **tetrasporic**. The megaspores are usually arranged in a linear tetrad. Of the four megaspores formed, usually the chalazal one is functional and other three megaspores degenerate. The functional megaspore forms the female gametophyte or embryo sac. This type of development is called **monosporic** development (Example: *Polygonum*). Of the four megaspores formed if two are involved in Embryo sac formation the development is called **bisporic** (Example: *Allium*). If all the four megaspores are involved in Embryo sac formation the development is called **tetrasporic** (Example: *Peperomia*). An ovule generally has a single embryo sac. The development of monosporic embryo sac (*Polygonum* type) is given in Figure 1.9.

Development of Monosporic embryo sac.

To describe the stages in embryo sac development and organization the simplest monosporic type of development is given below.

The functional megaspore is the first cell of the embryo sac or female gametophyte. The megaspore elongates along micropylar-chalazal axis. The nucleus undergoes a mitotic division. Wall formation does not follow the nuclear division. A large central vacuole now appears between the two daughter nuclei. The vacuole expands and pushes the nuclei towards the opposite poles of the embryo sac. Both the nuclei divide twice mitotically, forming four nuclei at each pole. At this stage all the eight nuclei are present in a common cytoplasm (free nuclear division). After the last nuclear division the cell undergoes appreciable elongation, assuming a sac-like appearance. This is followed by cellular organization of the embryo sac. Of

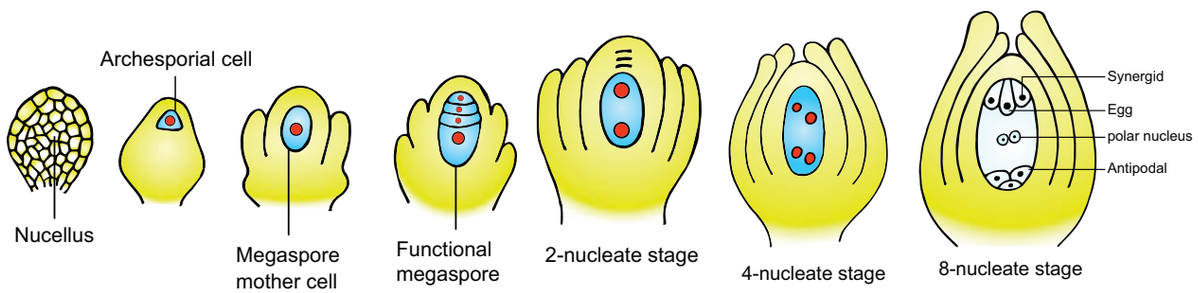


Figure 1.9 Development of ovule and embryo sac (*Polygonum type*).

the four nuclei at the micropylar end of the embryo sac, three organize into an **egg apparatus**, the fourth one is left free in the cytoplasm of the central cell as the upper polar nucleus. Three nuclei of the chalazal end form three **antipodal cells** whereas the fourth one functions as the lower polar nucleus. Depending on the plant the **2 polar nuclei** may remain free or may fuse to form a **secondary nucleus** (central cell). The egg apparatus is made up of a central egg cell and two synergids, one on each side of the egg cell. Synergids secrete chemotropic substances that help to attract the pollen tube. The special cellular thickening called filiform apparatus of synergids help in the absorption, conduction of nutrients from the nucellus to embryo sac. It also guides the pollen tube into the egg. Thus, a 7 celled with 8 nucleated embryo sac is formed. The structure of embryo sac is given in Figure 1.10.

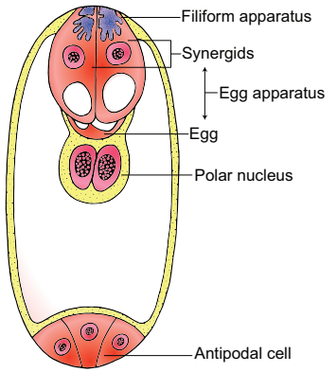


Figure 1.10 Structure of Embryo sac

1.4.3 Pollination

Pollination is a wonderful mechanism which provides food, shelter etc., for the pollinating animals. Many plants are pollinated by a particular animal species and the flowers are modified accordingly and thus there exists a co-evolution between plants and animals. Let us imagine if pollination fails. Do you think there will be any seed and fruit formation? If not what happens to pollinating organisms and those that depend on these pollinating organism for the food? Here lies the significance of the process of pollination.

The pollen grains produced in the anther will germinate only when they reach the stigma of the pistil. The reproductive organs, stamens and pistil of the flower are spatially separated, a mechanism which is essential for pollen grains to reach the stigma is needed. This process of transfer of pollen grains from the anther to a stigma of a flower is called **pollination.**

Pollination is a characteristic feature of spermatophyte (Gymnosperms and Angiosperms). Pollination in gymnosperms is said to be direct as the pollens are deposited directly on the exposed ovules, whereas in angiosperms it is said to be indirect, as the pollens are deposited on the stigma of the pistil. In majority of angiosperms, the flower opens and exposes its mature anthers and stigma for pollination. Such flowers are called **chasmogamous** and the phenomenon is **chasmogamy.** In other plants, pollination occurs without opening and exposing their sex organs. Such flowers are called **cleistogamous** and the phenomenon is **cleistogamy.**

Based upon the flower on which the pollen of a flower reaches, the pollination is classified into two kinds, namely, **self-pollination (Autogamy) and cross-pollination (Allogamy).**

A. Self-pollination or Autogamy (Greek Auto = self, gamos = marriage):

According to a majority of Botanists, the transfer of pollen on the stigma of the same flower is called **self-pollination or Autogamy**. Self-pollination is possible only in those plants which bear bisexual flowers. In order to promote self- pollination the flowers of the plants have several adaptations or mechanisms. They are:

1. Cleistogamy: In cleistogamy (Greek Kleisto = closed. Gamos = marriage) flowers never open and expose the reproductive organs and thus the

pollination is carried out within the closed flower. *Commelina, Viola*, *Oxalis* are some examples for cleistogamous flowers. In *Commelina benghalensis,* two types of flowers are produced- aerial and underground flowers. The aerial flowers are brightly coloured, chasmogamous and insect pollinated. The underground flowers are borne on the subterranean branches of the rhizome that are dull, cleistogamous and self pollinated and are not depended on pollinators for pollination.(Figure 1.11).

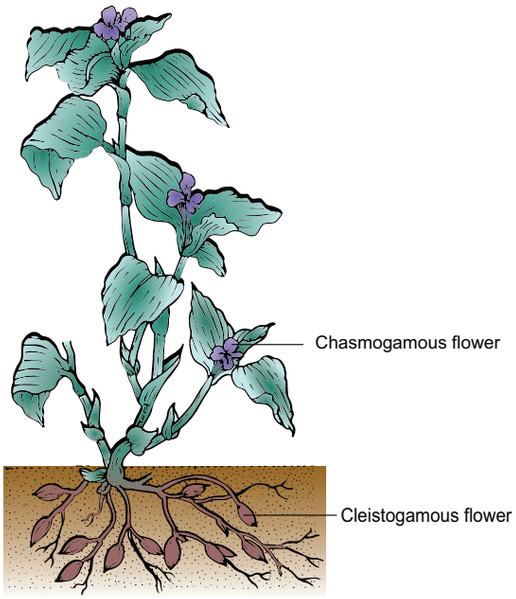


Figure 1.11 *Commelina* with Cleistogamous and Chasmogamous flowers

2. Homogamy: When the stamens and stigma of a flower mature at the same time it is said to be homogamy. It favours self-pollination to occur. Example: *Mirabilis jalapa, Catharanthus roseus*

3. Incomplete dichogamy: In dichogamous flowers the stamen and stigma of a flower mature at different time. Sometimes , the time of maturation of these essential organs overlap so that it becomes favourable for self-pollination.

B. Cross - pollination

It refers to the transfer of pollens on the stigma of another flower. The cross-pollination is of two types:

i. Geitonogamy: When the pollen deposits on another flower of the same individual plant, it is said to be geitonogamy. It usually occurs in plants which show monoecious condition. It is functionally cross-pollination but is similar to autogamy because the pollen comes from same plant.

ii. Xenogamy: When the pollen (genetically different) deposits on another flower of a different plant of the same species , it is called as xenogamy.

Contrivances of cross-pollination

The flowers of the plants have also several mechanisms that promote cross-pollination which are also called **contrivances of cross-pollination or outbreeding** devices. It includes the following.

1. Dicliny or Unisexuality

When the flowers are unisexual only cross-pollination is possible. There are two types.

i. **Monoecious**: Male and female flowers on the same plant. Coconut, Bitter gourd. In plants like castor and maize, autogamy is prevented but geitonogamy takes place.

ii. **Dioecious** : Male and female flowers on different plants. *Borassus*, *Carica papaya* and date palm. Here both autogamy and geitonogamy are prevented.

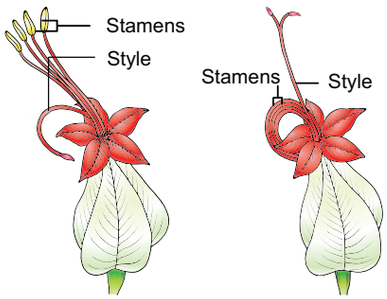
2. Monocliny or Bisexuality

Flowers are bisexual and the special adaptation of the flowers prevents self-pollination.

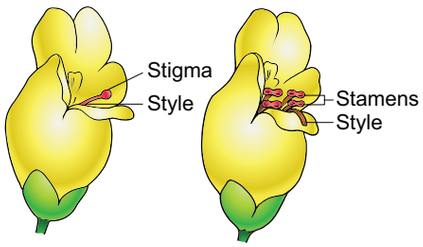
i. Dichogamy: In bisexual flowers anthers and stigmas mature at different times, thus checking self-pollination. It is of two types.

a. Protandry: The stamens mature earlier than the stigmas of the flowers. Examples: *Helianthus, Clerodendrum* (Figure 1.12 a).

b. Protogyny: The stigmas mature earlier than the stamens of the flower. Examples: *Scrophularia nodosa* and *Aristolochia bracteata* (Figure 1.12 b).



(a) Protandry - *Clerodendrum*



(b) Protogyny - *Scrophularia*

Figure 1.12 Dichogamy

ii. Herkogamy: In bisexual flowers the essential organs, the stamens and stigmas, are arranged in such a way that self-pollination becomes impossible. For example in *Gloriosa superba,* the style is reflexed away from the stamens and in *Hibiscus* the stigmas project far above the stamens (Figure 1.13).

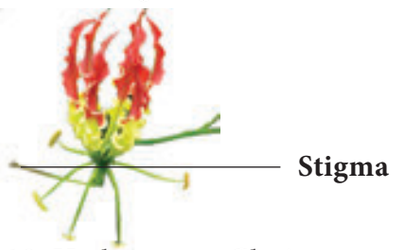
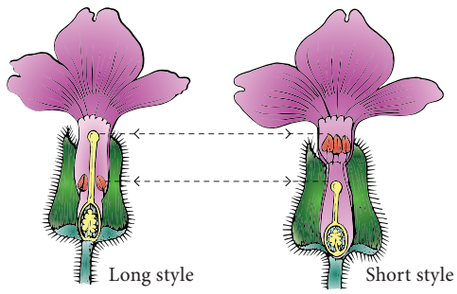


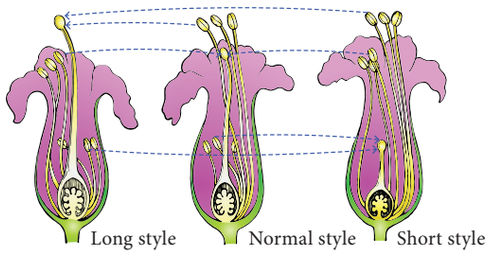
Figure 1.13 Herkogamy - *Gloriosa*

iii. Heterostyly: Some plants produce two or three different forms of flowers that are different in their length of stamens and style. Pollination will take place only between organs of the same length.(Figure 1.14)

a. Distyly: The plant produces two forms of flowers, Pin or long style, long stigmatic papillae, short stamens and small pollen grains; Thrum-eyed or short style, small stigmatic papillae, long stamens and large pollen grains. Example: *Primula* (Figure 1.14a). The stigma of the Thrum-eyed flowers and the anther of the pin lie in same level to bring out pollination. Similarly the anther of Thrum-eyed and stigma of pin ones is found in same height. This helps in effective pollination.



a) Distyly - *Primula*



b) Tristyly - *Lythrum*

Figure 1.14 Heterostyly

b. Tristyly: The plant produces three kinds of flowers, with respect to the length of the style and stamens. Here,the pollen from flowers of one type can pollinate only the other two types but not their own type. Example : *Lythrum* (Figure 1.14b).

iv. Self sterility/ Self- incompatibility: In some plants, when the pollen grain of a flower reaches the stigma of the same, it is unable to germinate or prevented to germinate on its own stigma. Examples: *Abutilon*, *Passiflora.* It is a genetic mechanism.

Agents of pollination

Pollination is effected by many agents like wind, water, insects etc. On the basis of the agents that bring about pollination, the mode of pollination is divided into abiotic and biotic. The latter type is used by majority of plants.

Abiotic agents

1. Anemophily - pollination by Wind
2. Hydrophily - pollination by Water

Biotic agents

3. Zoophily

Zoophily refers to pollination through animals and pollination through insects is called Entomophily.

1. Anemophily: Pollination by wind. The wind pollinated flowers are called **anemophilous**. The wind pollinated plants are generally situated in wind exposed regions. Anemophily is a chance event. Therefore, the pollen may not reach the target flower effectively and are wasted during the transit from one flower to another. The common examples of wind pollinated flowers are - grasses, sugarcane, bamboo, coconut, palm, maize etc.,

Anemophilous plants have the following characteristic features:

- The flowers are produced in pendulous, catkin-like or spike inflorescence.
- The axis of inflorescence elongates so that the flowers are brought well above the leaves.
- The perianth is absent or highly reduced.
- The flowers are small, inconspicuous, colourless, not scented, do not secrete nectar.
- The stamens are numerous, filaments are long, exerted and versatile.
- Anthers produce enormous quantities of pollen grains compared to number of ovules available for pollination. They are minute, light and dry so that they can be carried to long distances by wind.
- In some plants anthers burst violently and release the pollen into the air. Example: *Urtica.*
- Stigmas are comparatively large, protruding, sometimes branched and feathery, adapted to catch the pollen grains. Generally single ovule is present.
- Plant produces flowers before the new leaves appear, so the pollen can be carried without hindrance of leaves.

Pollination in Maize (*Zea mays*): The maize is monoecious and unisexual. The male inflorescence (tassel) is borne terminally and female inflorescence (cob) laterally at lower levels. Maize pollens are large and heavy and cannot be carried by light breeze. However, the mild wind shakes the male inflorescence to release the pollen which falls vertically below. The female inflorescence has long stigma (silk) measuring upto 23 cm in length, which projects beyond leaves. The pollens drop from the tassel is caught by the stigma (Figure 1.15).

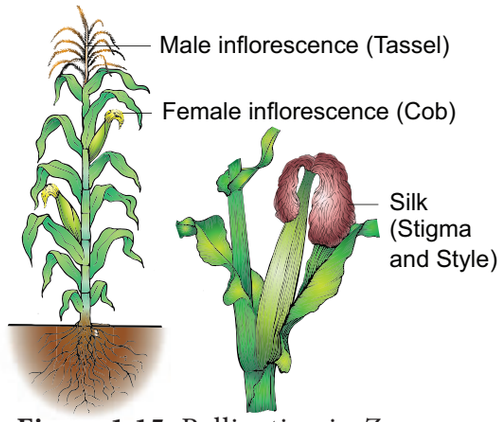


Figure 1.15 Pollination in *Zea mays*

2. Hydrophily: Pollination by water is called hydrophily and the flowers pollinated by water are said to be **hydrophilous** (Example: *Vallisneria, Hydrilla*). Though there are a number of aquatic plants, only in few plants pollination takes place by water. The floral envelop of hydrophilous plants are reduced or absent. In water plants like *Eichhornia* and water lilly pollination takes place through wind or by insects. There are two types of hydrophily, Epihydrophily and Hypohydrophily. In most of the hydrophilous flowers, the pollen grains possesses mucilage covering which protects them from wetting.

a. Epihydrophily: Pollination occurs at the water level. Examples: *Vallisneria spiralis, Elodea.*

Pollination in *Vallisneria spiralis*: It is a dioecious, submerged and rooted hydrophyte. The female plant bears solitary flowers which rise to the surface of water level using a long coiled

stalk at the time of pollination. A small cup shaped depression is formed around the female flower on the surface of the water. The male plant produces male flowers which get detached and float on the surface of the water. As soon as a male flower comes in closer to a female flower, it gets settled in the depression and contacts with the stigma thus bringing out pollination. Later the stalk of the female flower coils and brings back the flower from surface to under water where fruits are produced. (Figure 1.16).

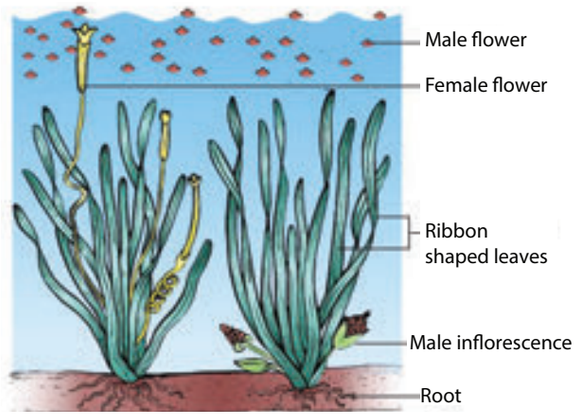


Figure 1.16 Pollination in *Vallisneria*

Activity

Visit to a nearby park and observe the different flowers. Record the adaptations or modifications found in the flowers for different types of pollination.

b. Hypohydrophily: Pollination occurs inside the water. Examples: *Zostera marina and Ceratophyllum.*

3. Zoophily: Pollination by the agency of animals is called zoophily and flowers are said to be zoophilous. Animals that bring about pollination may be birds, bats, snails and insects. Of these, insects are well adapted to bring pollination. Larger animals like primates (lemurs), arboreal rodents, reptiles (gecko lizard and garden lizard) have also been reported as pollinators.

A. Ornithophily: Pollination by birds is called Ornithophily. Some common plants that are pollinated by birds are *Erythrina, Bombax, Syzygium, Bignonia, Sterlitzia* etc., Humming birds, sun birds, and honey eaters are some of the birds which regularly visit flowers and bring about pollination.

The ornithophilous flowers have the following characteristic features:

- The flowers are usually large in size.
- The flowers are tubular, cup shaped or urn-shaped.
- The flowers are brightly coloured, red, scarlet, pink, orange, blue and yellow which attracts the birds.
- The flowers are scentless and produce nectar in large quantities. Pollen and nectar form the floral rewards for the birds visiting the flowers.
- The floral parts are tough and leathery to withstand the powerful impact of the visitors.

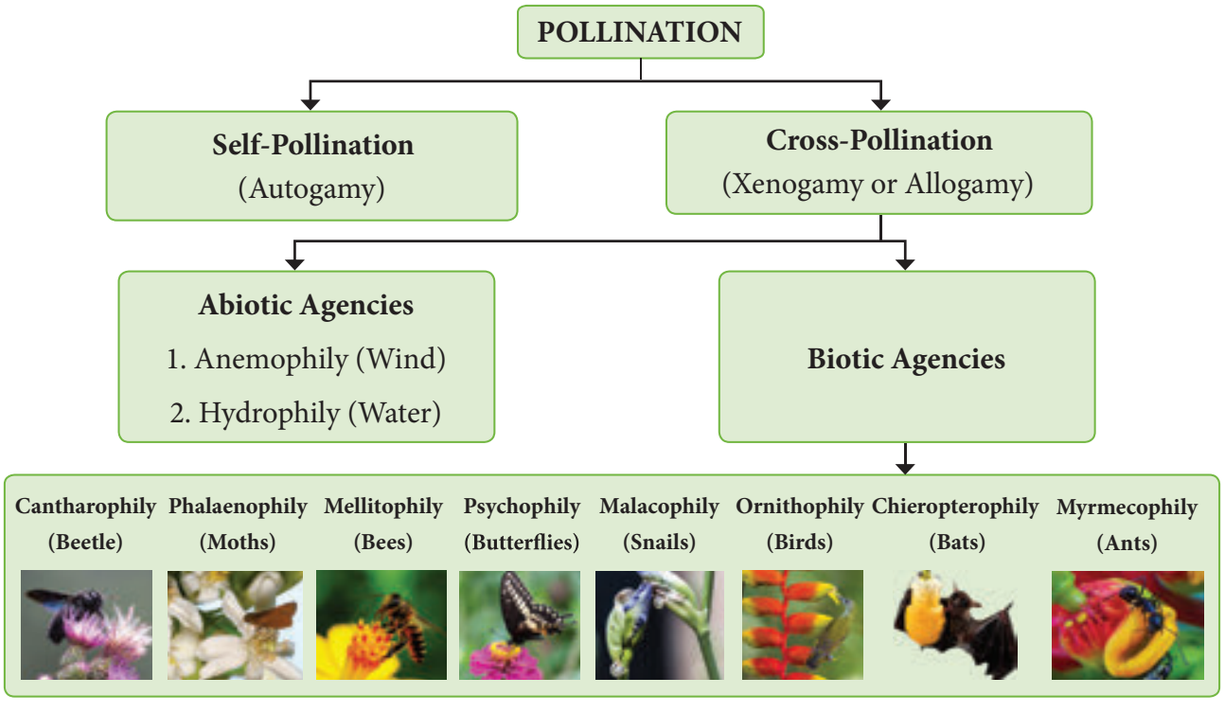
B. Cheiropterophily: Pollination carried out by bats is called cheiropterophily. Some of the common cheiropterophilous plants are *Kigelia africana*, *Adansonia digitata*, etc.,

C. Malacophily: Pollination by slugs and snails is called malacophily. Some plants of Araceae are pollinated by snails. Water snails crawling among *Lemna* pollinate them.

D. Entomophily: Pollination by insects is called **Entomophily**. Pollination by ant is called **myrmecophily**. Insects that are well adapted to bring pollination are bees, moths, butterflies, flies, wasps and beetles. Of the insects, bees are the main flower visitors and dominant pollinators. Insects are chief pollinating agents and majority of angiosperms are adapted for insect pollination. It is the most common type of pollination.

The characteristic features of entomophilous flowers are as follows:

- Flowers are generally large or if small they are aggregated in dense inflorescence. Example: Asteraceae flowers.



- Flowers are brightly coloured. The adjacent parts of the flowers may also be brightly coloured to attract insect. For example in *Poinsettia* and *Bougainvillea* the bracts become coloured.
- Flowers are scented and produce nectar.
- Flowers in which there is no secretion of nectar, the pollen is either consumed as food or used in building up of its hive by the honeybees. Pollen and nectar are the floral rewards for the visitors.
- Flowers pollinated by flies and beetles produce foul odour to attract pollinators.
- In some flowers juicy cells are present which are pierced and the contents are sucked by the insects.

Pollination in *Salvia* (Lever mechanism):

The flower of *Salvia* is adapted for Bee pollination. The flower is protandrous and the corolla is bilabiate with 2 stamens. A lever mechanism helps in pollination. Each anther has an upper fertile lobe and lower sterile lobe which is separated by a long connective which helps the anthers to swing freely. When a bee visits a flower, it sits on the lower lip which acts as a platform. It enters the flower to suck the nectar by pushing its head into the corolla. During the entry of the bee into the flower the body strikes against the sterile end of the connective. This makes the fertile part of the stamen to descend and strike at the back of the bee. The pollen gets deposited on the back of the bee. When it visits another flower, the pollen gets rubbed against the stigma and completes the act of pollination in *Salvia* (Figure 1.17).

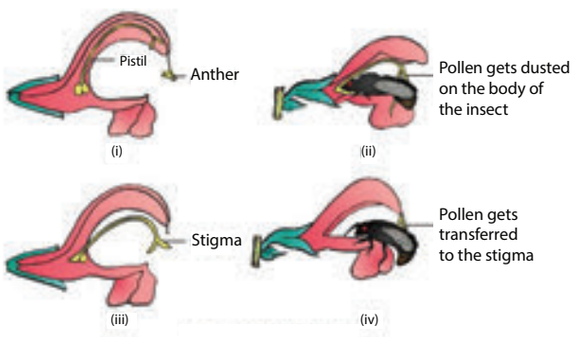


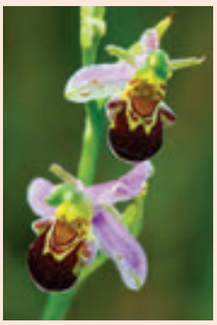
Figure 1.17 Pollination in *Salvia* - Lever mechanism

Some of the other interesting pollination mechanisms found in plants are a) Trap mechanism (*Aristolochia*);Pit fall mechanism (*Arum*);Clip or translator mechanism (*Asclepiadaceae*) and Piston mechanism (*Papilionaceae*).

Pollination – A composite event

Pollination provides information about evolution, ecology, animal learning and foraging behaviour. Flowers not only supply nectar but also provide microclimate, site and shelter for egg laying insects. The association of insects benefits the flower by getting pollinated and ensures the propagation of its own progeny. The floral parts are well modified in shape, size to attract the pollinators to accomplish pollination .

The relationship between *Yucca* and moth (*Tegeticula yuccasella*) is an example for obligate mutualism. The moth bores a hole in the ovary of the flower and lays eggs in it. Then it collects pollen and pushes it in the form of balls down the hollow end of the stigma. Fertilization takes place and seeds develop. Larvae feed on developing seeds. Some seeds remain unconsumed for the propagation of the plant species. It is interesting that the moth cannot survive without *Yucca* flowers and the plant fails to reproduce sexually without the moth.



Bee Orchid

Similarly in *Amorphophallus*, flowers apart from providing floral rewards, also forms safe site for laying eggs. Many visitors consume pollen and nectar and do not help in pollination. They are called pollen / nectar robbers.

In Bee orchid (*Ophyrus*) the morphology of the flower mimics that of female wasp (*Colpa*). The male wasp mistakes the flowers for a female wasp and tries to copulate. This act of pseudocopulation helps in polli nation.

The pollination in Fig (*Ficus carica*) by the Wasp (*Blastophaga psenes*) is also an example for similar Plant – insect interaction.

Advantages of self-pollination:

- Pollination is almost certain in bisexual flowers.
- When the members of the species are uncommon and are separated by large distances, the plant has to depend on self-pollination.
- If all the chances of cross-pollination fails, self-pollination will take place and prevent the extinction of the species.

Disadvantages of self-pollination:

- Continuous self-pollination, generation after generation results in weaker progeny.
- Chances of producing new species and varieties are meager.

Advantages of cross-pollination:

- It always results in bringing out much healthier offsprings.
- Germination capacity is much better.
- New varieties may be produced.
- The adaptability of the plants to their environment is better.

Disadvantages of cross-pollination:

- Depend on external agencies for the pollination and the process is uncertain.
- Various devices have to be adopted to attract pollinating agents.

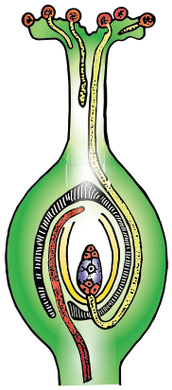
Significance of Pollination

- Pollination is a pre-requisite for the process of fertilisation. Fertilisation helps in the formation of fruits and seeds.
- It brings the male and female gametes closer for the process of fertilisation.
- Cross-pollination introduces variations in plants due to the mixing up of different genes. These variations help the plants to adapt to the environment and results in speciation.

1.5 Fertilization

The fusion of male and female gamete is called **fertilization**. Fertilization in angiosperms is **double fertilization** type.

Events of fertilization



The stages involved in double fertilization are:- germination of pollen to form pollen tube in the stigma; growth of pollen tube in the style; direction of pollen tube towards the micropyle of the ovule; entry of the pollen tube into one of the synergids of the embryo sac, discharge of male gametes; syngamy and triple fusion. The events from pollen deposition on the stigma to the entry of pollen tube in to the ovule is called **pollen- pistil interaction.** It is a dynamic process which involves recognition of pollen and to promote or inhibit its germination and growth.

Pollen on the stigma

In nature, a variety of pollens fall on the receptive stigma, but all of them do not germinate and bring out fertilization. The receptive surface of the stigma receives the pollen. If the pollen is compatible with the stigma it germinates to form a tube. This is facilitated by the stigmatic fluid in **wet stigma** and pellicle in **dry stigma**. These two also decide the incompatibility and compatibility of the pollen through **recognition-rejection protein reaction** between the pollen and stigma surface. Sexual incompatibility may exist between different species (interspecific) or between members of the same species (intraspecific).The latter is called self-incompatibility. The first visible change in the pollen, soon after it lands on stigma is hydration. The pollen wall proteins are released from the surface. During the germination of pollen its entire content moves into the pollen tube. The growth is restricted to the tip of the tube and all the cytoplasmic contents move to the tip region. The remaining part of the pollen tube is occupied by a vacuole which is cut off from the tip by callose plug. The extreme tip of pollen tube appears hemispherical and transparent when viewed through the microscope. This is called **cap block**. As soon as the cap block disappear the growth of the pollen tube stops.

Pollen tube in the style

After the germination the pollen tube enters into the style from the stigma. The growth of the pollen tube in the style depends on the type of style.

Types of style

There are three types of style a) Hollow or open style b)solid style or closed style c) semi-solid or half closed style.

Hollow style (Open style): It is common among monocots. A hollow canal running from the stigma to the base of the style is present. The canal is lined by a single layer of glandular canal cells (Transmitting tissue).They secrete mucilaginous substances. The pollen tube grows on the surface of the cells lining the stylar canal. The canal is filled with secretions which serve as nutrition for growing pollen tubes and also controlling incompatibility reaction between the style and pollen tube. The secretions contain carbohydrates, lipids and some enzymes like esterases, acid phosphatases as well as compatibility controlling proteins.

Solid style (Closed type): It is common among dicots. It is characterized by the presence of central core of elongated, highly specialised cells called transmitting tissue.This is equivalent to the lining cells of hollow style and does the same function. Its contents are also similar to the content of those cells. The pollen tube grows through the intercellular spaces of the transmitting tissue.

Semi-solid style (half closed type): This is intermediate between solid and open type.

There is a difference of opinion on the nature of transmitting tissue. Some authors consider that it is found only in solid styles while others consider the lining cells of hollow style also has transmitting tissue.

Entry of pollen tube into the ovule: There are three types of pollen tube entry into the ovule(Figure 1.18).

Porogamy: when the pollen tube enters through the micropyle.

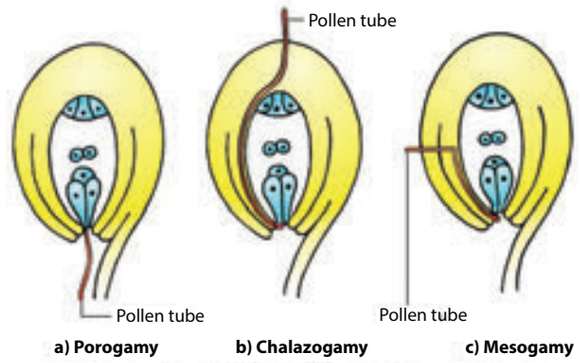


Figure 1.18 Path of pollen tube entry into the ovule

Chalazogamy: when the pollen tube enters through the chalaza.

Mesogamy: when the pollen tube enters through the integument.

Entry of pollen tube into embryo sac: Irrespective of the place of entry of pollen tube into ovule, it enters the embryo sac at the micropylar end. The pollen enters into embryo sac directly into one of the synergids.

The growth of pollen tube towards the ovary, ovule and embryo sac is due to the presence of chemotropic substances. The pollen tube after travelling the whole length of the style enters into the ovary locule where it is guided towards the micropyle of the ovule by a structure called **obturator** (See Do you know). After reaching the embryo sac, a pore is formed in pollen tube wall at its apex or just behind the apex. The content of the pollen tube (two male gametes, vegetative nucleus and cytoplasm) are discharged into the synergids into which pollen tube enters. The pollen tube does not grow beyond it, in the embryo sac. The tube nucleus disorganizes.

1.5.1 Double fertilization and triple fusion

S.G. Nawaschin and L.Guignard in 1898 and 1899, observed in *Lilium* and *Fritillaria* that both the male gametes released from a male gametophyte are involved in the fertilization. They fertilize two different components of the embryo sac. Since both the male gametes are involved in fertilization, the phenomenon is called **double fertilization** and is unique to angiosperms. One of the male gametes fuses with the egg nucleus (syngamy) to form **Zygote.** (Figure 1.19)

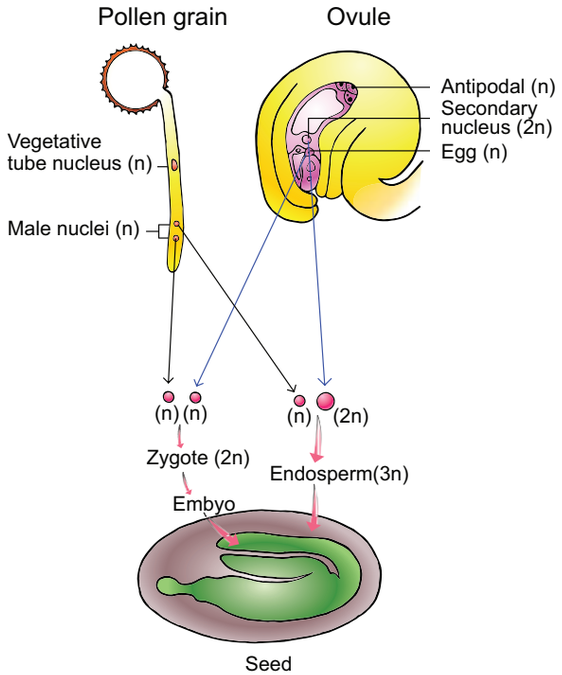


Figure 1.19 Fertilization in Angiosperms

The second gamete migrates to the central cell where it fuses with the **polar nuclei** or their fusion product, the secondary nucleus and forms the **primary endosperm nucleus (PEN)**. Since this involves the fusion of three nuclei, this phenomenon is called **triple fusion**. This act results in endosperm formation which forms the nutritive tissue for the embryo.

1.6 Post Fertilization structure and events

After fertilization, several changes take place in the floral parts up to the formation of the seed (Figure 1.20).

The events after fertilization (endosperm, embryo development, formation of seed, fruits) are called post fertilization changes.

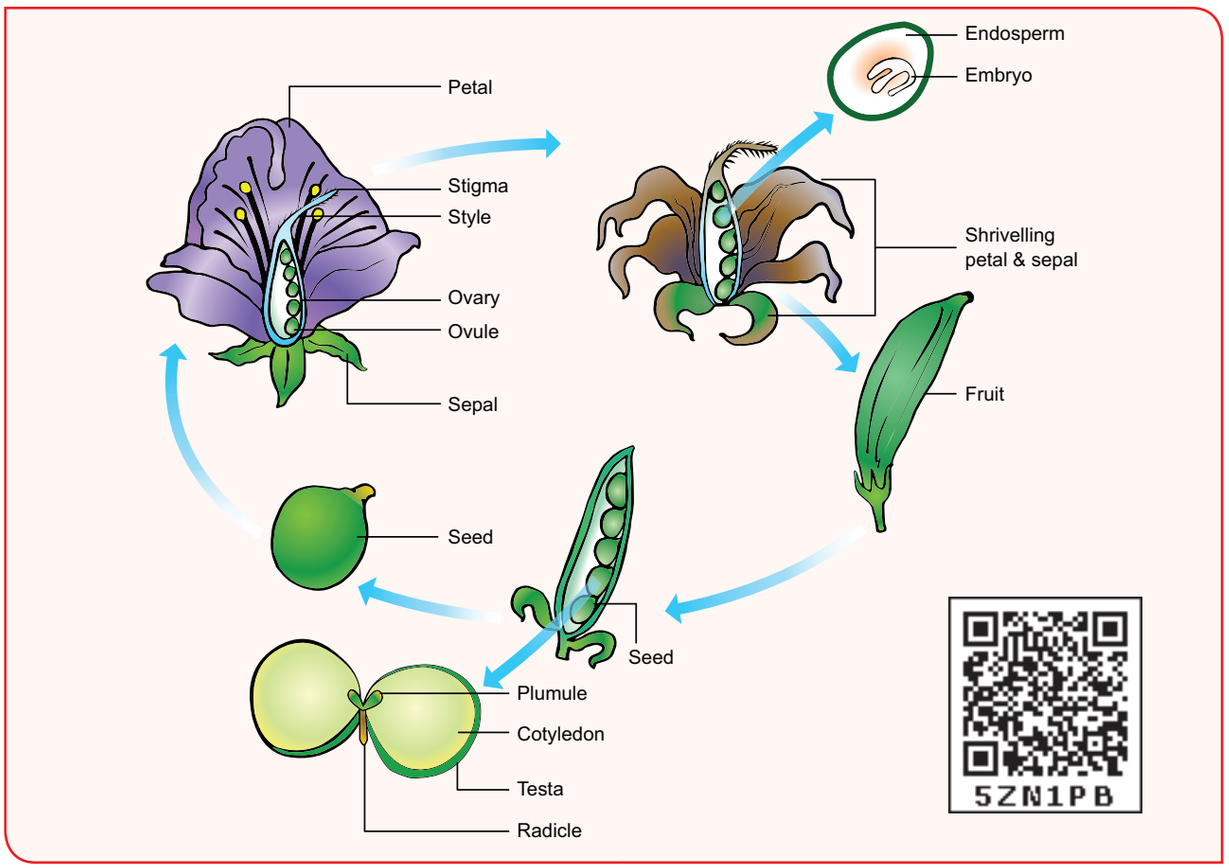


Figure 1.20 Post Ferilization changes in the flower of an angiosperms

More to Know

- The receptacle becomes fleshy and edible around the fruit enclosing the seeds as in *Pyrus malus* (apple)
- The calyx may persist and enlarge (*Solanum melongena)* or may cover the fruit *(Physalis minima*)

Physalis - Persistent calyx

- The flower stalk or axis below the gynoecium enlarges into a juicy pear shaped body which is edible (*Anacardium occidentale).* The Perianth becomes fleshy as in Jack fruit.

Anacardium - pedicel (edible)

- The cells present at the tip of the outer integument around the micropyle develop into a fleshy structure called **caruncle**. (*Ricinus communis).*

Ricinus - Caruncle

- The funiculus develops into a fleshy structure which is often very colourful and called **aril**. (*Myristica and Pithecellobium*)

Aril

Myristica *Pithecellobium*

- The nucellar tissue is either absorbed completely by the developing embryo sac and embryo or small portion may remain as storage tissue. Thus the remnant of nucellar tissue in the seed is called **perisperm**. Example: Black pepper and beet root

Parts before fertilization	Transformation after fertilization
Sepals, petals, stamens, style and stigma	Usually wither and fall off
Ovary	Fruit
Ovule	Seed
Egg	Zygote
Funicle	Stalk of the seed
Micropyle (ovule)	Micropyle of the seed(facilitates O_2 and water uptake)
Nucellus	Perisperm
Outer integument of ovule	Testa (outer seed coat)
Inner integument	Tegmen (inner seed coat)
Synergid cells	Degenerate
Secondary nucleus	Endosperm
Antipodal cells	Degenerate

Endosperm

The primary endosperm nucleus (PEN) divides immediately after fertilization but before the zygote starts to divide, into an endosperm. The primary endosperm nucleus is the result of triple fusion (two polar nuclei and one sperm nucleus) and thus has 3n number of chromosomes. It is a nutritive tissue and regulatory structure that nourishes the developing embryo. Depending upon the mode of development three types of endosperm are recognized in angiosperms. They are nuclear endosperm, cellular endosperm and helobial endosperm (Figure 1.21).

Nuclear endosperm: Primary Endosperm Nucleus undergoes several mitotic divisions without cell wall formation thus a free nuclear condition exists in the endosperm. Examples: *Coccinia*, *Capsella* and *Arachis*

Cellular endosperm: Primary endosperm nucleus divides into 2 nuclei and it is immediately followed by wall formation. Subsequent divisions also follow cell wall formation. Examples: *Adoxa, Helianthus* and *Scoparia*

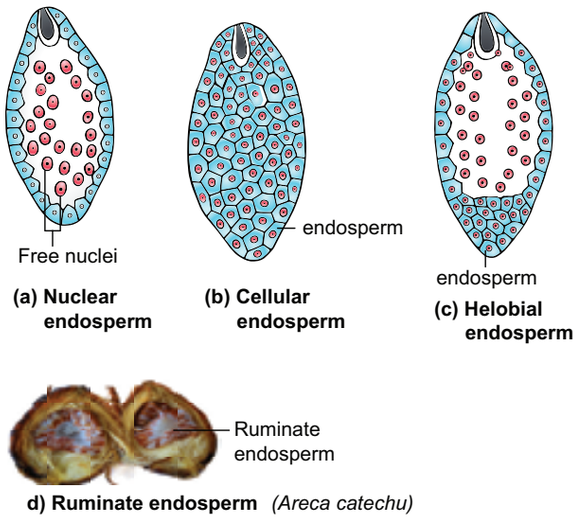


Figure 1.21 Types of Endosperm

Helobial endosperm: Primary Endosperm Nucleus moves towards base of embryo sac and divides into two nuclei. Cell wall formation takes place leading to the formation of a large micropylar and small chalazal chamber. The nucleus of the micropylar chamber undergoes several free nuclear division whereas that of chalazal chamber may or may not divide. Examples : *Hydrilla* and *Vallisneria*.

The endosperms may either be completely consumed by the developing embryo or it may persist in the mature seeds. Those seeds without endosperms are called non- endospermous or ex- albuminous seeds. Examples: Pea, Groundnut and Beans. Those seeds with endosperms are called endospermous or albuminous seeds. The endosperms in these seeds supply nutrition to the embryo during seed germination. Examples: Paddy, Coconut and Castor.

Aleurone tissue consists of highly specialised cells of one or few layers which are found around the endosperm of cereals (barley and maize). Aleurone grain contains sphaerosomes. During seed germination cells secrete certain hydrolytic enzymes like amylases, proteases which digest reserved food material present in the endosperm cells.

Ruminate endosperm: The endosperm with irregularity and unevenness in its surface forms ruminate endosperm. Examples :*Areca catechu, Passiflora* and *Myristica*

Functions of endosperm:

- It is the nutritive tissue for the developing embryo.
- In majority of angiosperms, the zygote divides only after the development of endosperm.
- Endosperm regulates the precise mode of embryo development.

Coconut milk is a basic nutrient medium which induces the differentiation of embryo (embryoids) and plantlets from various plant tissues. Coconut water from tender coconut is free-nuclear endosperm and white kernel part is cellular.

Development of Dicot embryo

The Stages involved in the development of Dicot embryo (*Capsella bursa-pastoris* – Onagrad or crucifer type) is given in Figure 1.22. The embryo develops at micropylar end of embryo sac. The zygote undergoes transverse division to form upper or terminal cell and lower or basal cell. Further divisions in the zygote during the development lead to the formation of embryo. Embryo undergoes globular, heart shaped stages before reaching a mature stage. The mature embryo has a **radicle,** two **cotyledons** and a **plumule**.

Activity

Collect the fruits of *Tridax* (Cypsella). Using a needle dissect out the content, separate the embryo and observe different stages of dicot embryo – globular, torpedo, heart shaped under a dissection microscope.

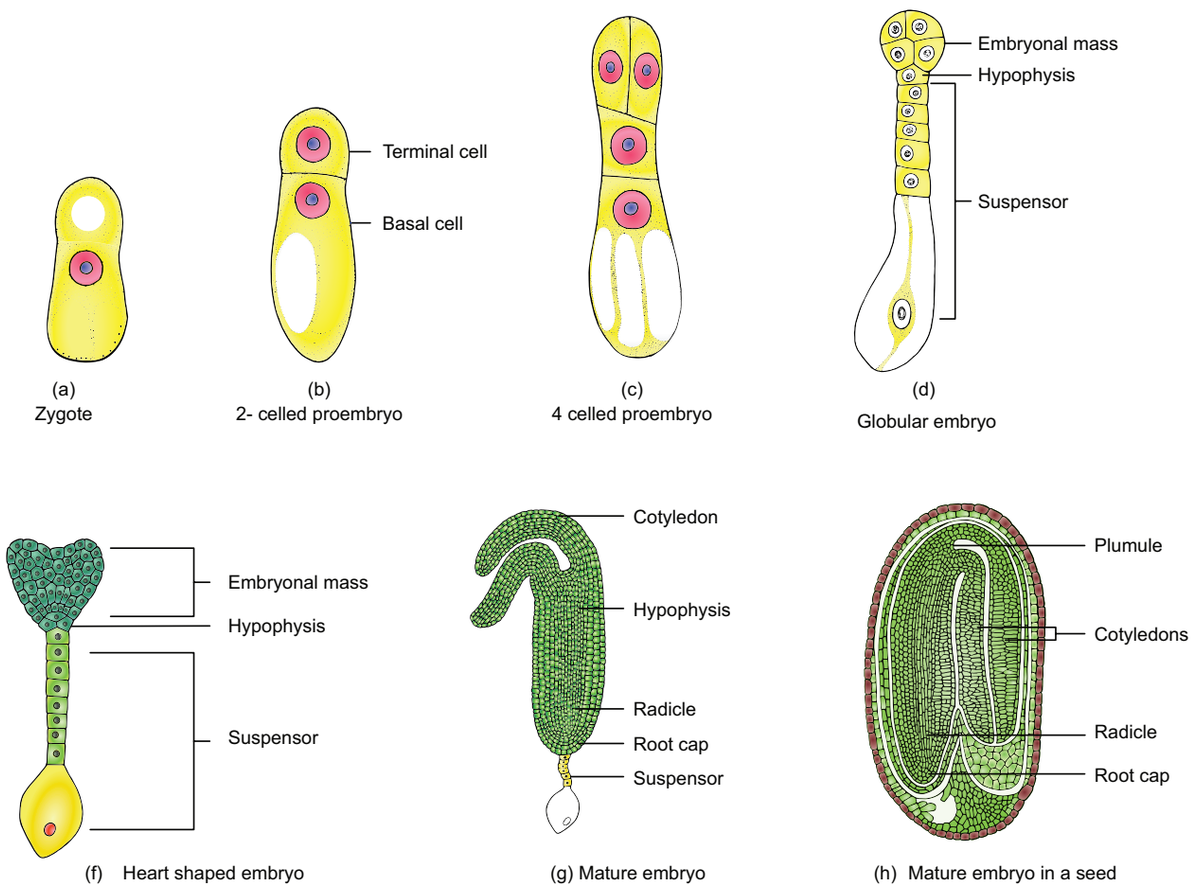


Figure 1.22 Development of Dicot embryo (*Capsella bursa-pastoris*)

Seed

The fertilized ovule is called seed and possesses an embryo, endosperm and a protective coat. Seeds may be endospermous (wheat, maize, barley and sunflower) or non endospermous. (Bean, Mango, Orchids and cucurbits).

Fresh weight of an orchid seed may be 20.33 microgram and that of double coconut (*Lodoicea maldivica*) is about 6 kg.

Structure of a *Cicer* seed as an example for Dicot seed

The mature seeds are attached to the fruit wall by a stalk called **funiculus**. The funiculus disappears leaving a scar called **hilum**. Below the hilum a small pore called **micropyle** is present. It facilitates entry of oxygen and water into the seeds during germination. Each seed has a thick outer covering called seed coat. The seed coat is developed from integuments of the ovule. The outer coat is called **testa** and is hard whereas the inner coat is thin, membranous and is called **tegmen**. In Pea plant the tegmen and testa are fused. Two cotyledons laterally attached to the embryonic axis are present. It stores the food materials in pea whereas in other seeds like castor the endosperm contains reserve food and the cotyledons are thin. The portion of embryonal axis projecting beyond the cotyledons is called **radicle** or embryonic root. The other end of the axis called embryonic shoot is the **plumule**. Embryonal axis above the level of cotyledon is called **epicotyl** whereas the cylindrical region between the level of cotyledon is called **hypocotyl**(Figure 1.23 a). The epicotyl terminates in plumule whereas the hypocotyl ends in radicle.

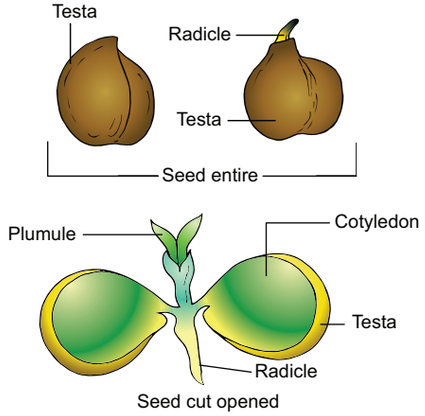


Figure 1.23(a) Dicot seed - *Cicer arientinum*

Structure of *Oryza* seed as an example for Monocot seed

The seed of paddy is one seeded and is called **Caryopsis**. Each seed remains enclosed by a brownish husk which consists of glumes arranged in two rows. The seed coat is a brownish, membranous layer closely adhered to the grain. Endosperm forms the bulk of the grain and is the storage tissue. It is separated from embryo by a definite layer called **epithelium**. The embryo is small and consists of one shield-shaped cotyledon known as **scutellum** present towards lateral side of embryonal axis.

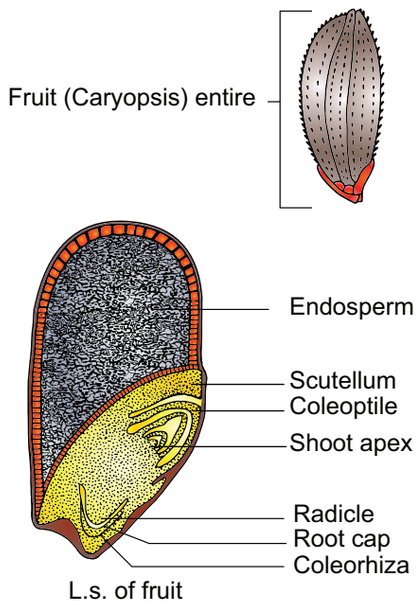


Figure 1.23(b) Monocot seed - *Oryza sativa*

A short axis with plumule and radicle protected by the **root cap** is present. The plumule is surrounded by a protective sheath called **coleoptile**. The radicle including root cap is also covered by a protective sheath called

coleorhiza. The scutellum supplies the growing embryo with food material absorbed from the endosperm with the help of the epithelium (Figure 1.23 b).

Activity

Soak seeds of green gram for three hours. Drain the water and place few seeds in a clean tray containing moist cotton or filter paper. Allow the seeds to sprout. Collect the sprouted seeds, cut open and observe the parts. Record your observation.

1.7 Apomixis

Reproduction involving fertilization in flowering plants is called amphimixis and wherever reproduction does not involve union of male and female gametes is called apomixis.

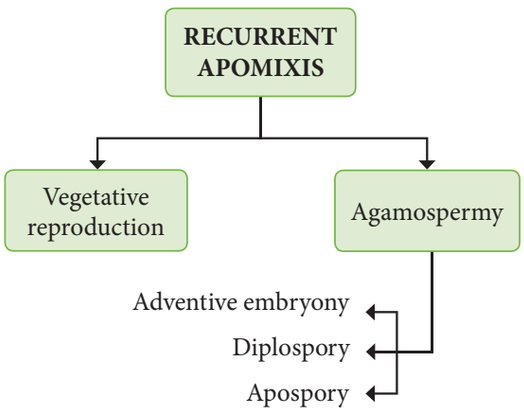
The term Apomixis was introduced by Winkler in the year 1908. It is defined as the substitution of the usual sexual system (Amphimixis) by a form of reproduction which does not involve meiosis and syngamy.

Maheswari (1950) classified Apomixis into two types - Recurrent and Non recurrent

Recurrent apomixis: It includes vegetative reproduction and agamospermy

Non recurrent apomixis: Haploid embryo sac developed after meiosis, develops into a embryo without fertilization.

The outline classification of Recurrent apomixis is given below.



Vegetative reproduction: Plants propagate by any part other than seeds

Bulbils – *Fritillaria imperialis*; Bulbs – *Allium*; Runner – *Mentha arvensis*; Sucker - *Chrysanthemum*

Agamospermy: It refers to processes by which Embryos are formed by eliminating meiosis and syngamy.

Adventive embryony

An Embryo arises directly from the diploid sporophytic cells either from nucellus or integument. It is also called **sporophytic budding** because gametophytic phase is completely absent. Adventive embryos are found in *Citrus* and *Mangifera*

Diplospory (Generative apospory): A diploid embryo sac is formed from megaspore mother cell without a regular meiotic division Examples. *Eupatorium* and *Aerva.*

Apospory: Megaspore mother cell undergoes the normal meiosis and four megaspores formed gradually disappear. A nucellar cell becomes activated and develops into a diploid embryo sac. This type of apospory is also called somatic apospory. Examples *Hieracium* and *Parthenium.*

1.8 Polyembryony

Occurrence of more than one embryo in a seed is called polyembryony (Figure 1.24). The first case of polyembryony was reported in certain oranges by Anton van Leeuwenhoek in the year 1719. Polyembryony is divided into four categories based on its origin.

a. **Cleavage polyembryony** (Example: Orchids)

b. **Formation of embryo by cells of the Embryo sac other than egg** (Synergids – *Aristolochia*; antipodals – *Ulmus* and endosperm – *Balanophora*)

c. **Development of more than one Embryo sac within the same ovule.** (Derivatives of same MMC, derivatives of two or more MMC – *Casuarina*)

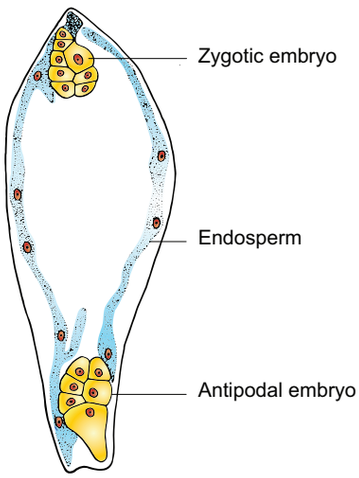


Figure 1.24 : Polyembryony – Embryo sac of *Ulmus glabra* showing zygotic and antipodal embryo

d. **Activation of some sporophytic cells of the ovule** (Nucellus/ integuments-*Citrus and Syzygium*).

Practical applications

The seedlings formed from the nucellar tissue in *Citrus* are found better clones for Orchards. Embryos derived through polyembryony are found virus free.

1.9 Parthenocarpy

As mentioned earlier, the ovary becomes the fruit and the ovule becomes the seed after fertilization. However in a number of cases, fruit like structures may develop from the ovary without the act of fertilization. Such fruits are called **parthenocarpic fruits**. Invariably they will not have true seeds. Many commercial fruits are made seedless. Examples: Banana, Grapes and Papaya.

Nitsch in 1963 classified the parthenocarpy into following types:

Genetic Parthenocarpy: Parthenocarpy arises due to hybridization or mutation Examples: *Citrus,Cucurbita*.

Environmental Parthenocarpy:

Environmental conditions like frost, fog, low temperature, high temperature etc., induce Parthenocarpy. For example, low temperature for 3-19 hours induces parthenocarpy in Pear.

Chemically induced Parthenocarpy: Application of growth promoting substances like Auxins and Gibberellins induces parthenocarpy.

Significance

- The seedless fruits have great significance in horticulture.
- The seedless fruits have great commercial importance.
- Seedless fruits are useful for the preparation of jams, jellies, sauces, fruit drinks etc.
- High proportion of edible part is available in parthenocarpic fruits due to the absence of seeds.

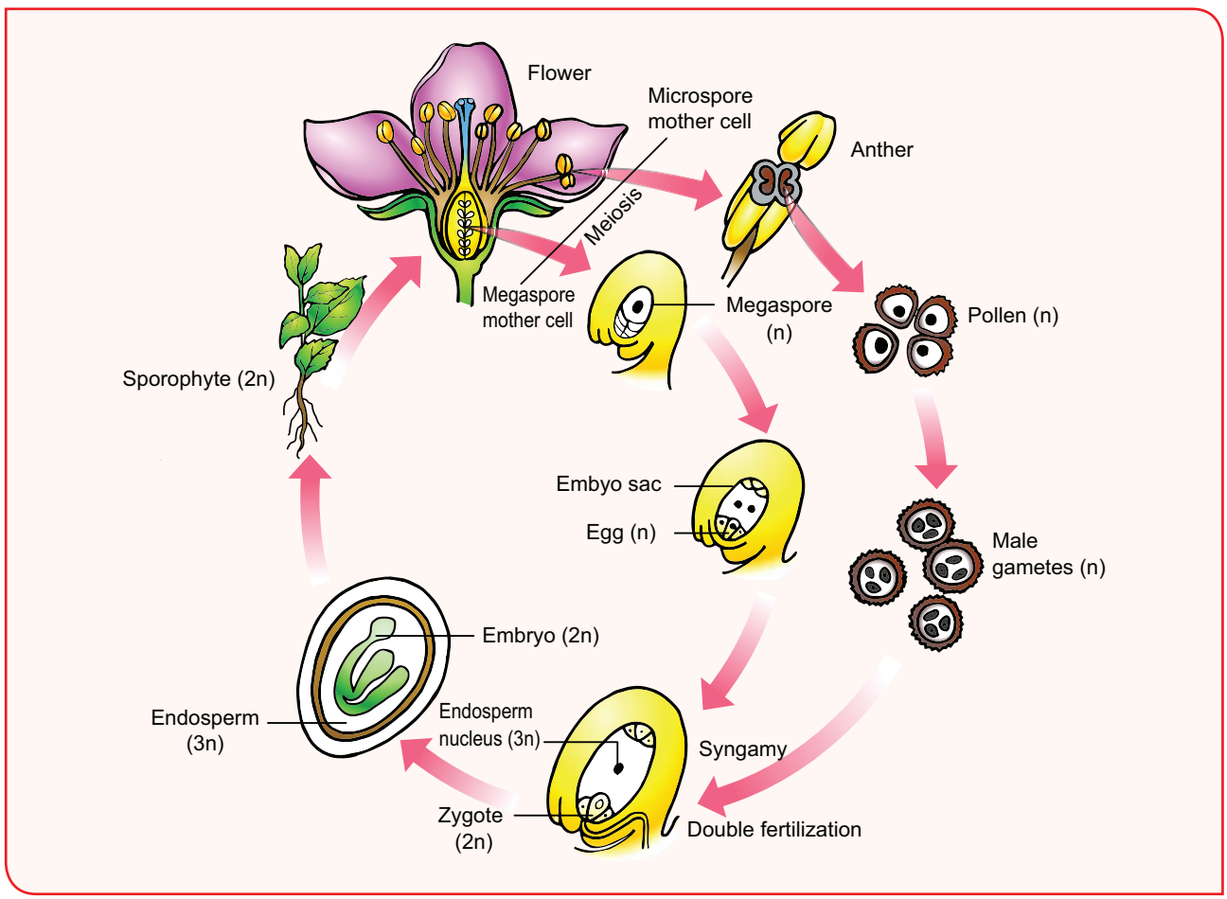
Summary

Reproduction is one of the attributes of living things. Lower plants, microbes and animals reproduce by different methods (fragmentation, gemma, binary fission, budding, regeneration). Organisms reproduce through asexual and sexual methods. Asexual methods in angiosperms occur through natural or artificial methods. The natural methods take place through vegetative propagules or diaspores. Artificial method of reproduction involves cutting, layering and grafting. Micropropagation is a modern method used to raise new plants.

Sexual reproduction includes gametogenesis and fertilization. External fertilization occurs in lower plants like algae but in higher plants internal fertilization takes place. A flower is a modified shoot meant for reproduction. Stamen is the male reproductive part and produces pollen grains. The development of microspore is called microsporogenesis. The microspore mother cell undergoes meiotic division to produce four haploid microspores. In majority of Angiosperms the anther is dithecous and are tetrasporangiate. It possesses epidermis,

endothecium, middle layers and tapetum. The hygroscopic nature of endothecial cell along with thin walled stomium helps in the dehiscence of anther. Tapetum nourishes the microspores and also contributes to the wall materials of the pollen grain. Pollen grain is derived from the microspore and possesses thin inner intine and thick outer exine. Sporopollenin is present in exine and is resistant to physiological and biological decomposition. Microspore is the first cell of male gametophyte. The nucleus of the microspore divides to form a vegetative nucleus and a generative nucleus. The generative nucleus divides to form two male nuclei. Gynoecium is the female reproductive part of a flower and it represents one or more pistils. The ovary bears ovules which are attached to the placenta. There are six major types of ovules. The development of megaspore from megaspore mother cell is called megasporogenesis. A monosporic embryo sac (*Polygonum* type) possesses three antipodals in chalazal end, Three cells in the micropylar end constituting egg apparatus(1 egg and 2 Synergids) and two polar nucleus fused to form secondary nucleus. Thus, a 7 celled 8 nucleated Embryo sac is present.

The transfer of pollen grains to the stigma of a flower is called pollination. Self-pollination and cross-pollination are two types of pollination. Double fertilization and triple fusion are characteristic features of angiosperms. After fertilization the ovary transforms into a fruit and the ovule becomes a seed. Endosperm is triploid in angiosperms and is of three types – Nuclear, cellular, helobial. Reproduction which doesn't involve meiosis and syngamy is called apomixis. Occurrence of more than one embryo in a seed is called polyembryony. Formation of fruit without the act of fertilization is called parthenocarpy.



Evaluation

6UFUQB

1. Choose the correct statement from the following
   a) Gametes are involved in asexual reproduction
   b) Bacteria reproduce asexually by budding
   c) Conidia formation is a method of sexual reproduction
   d) Yeast reproduce by budding
2. An eminent Indian embryologist is
   a) S.R.Kashyap b) P.Maheswari
   c) M.S. Swaminathan d) K.C.Mehta
3. Identify the correctly matched pair
   a) Tuber - *Allium cepa*
   b) Sucker - *Pistia*
   c) Rhizome - *Musa*
   d) Stolon - *Zingiber*
4. Pollen tube was discovered by
   a) J.G.Kolreuter b) G.B.Amici
   c) E.Strasburger d) E.Hanning
5. Size of pollen grain in *Myosotis*
   a) 10 micrometer b) 20 micrometer
   c) 200 micrometer d) 2000 micrometer
6. First cell of male gametophyte in angiosperm is
   a) Microspore b) megaspore
   c) Nucleus d) Primary Endosperm Nucleus
7. Match the following

I) External fertilization	i) pollen grain
II) Androecium	ii)anther wall
III) Male gametophyte	iii)algae
IV) Primary parietal layer	iv)stamens

   a)I-iv;II-i;III-ii;IV-iii
   b)I-iii;II-iv;III-i;IV-ii
   c)I-iii;II-iv;III-ii,IV-i
   d)I-iii;II-i;III-iv;IV-ii
8. Arrange the layers of anther wall from locus to periphery
   a) Epidermis,middle layers, tapetum, endothecium
   b) Tapetum, middle layers, epidermis, endothecium
   c) Endothecium, epidermis, middle layers, tapetum
   d) Tapetum, middle layers endothecium epidermis
9. Identify the incorrect pair
   a) sporopollenin - exine of pollen grain
   b) tapetum – nutritive tissue for developing microspores
   c) Nucellus – nutritive tissue for developing embryo
   d) obturator – directs the pollen tube into micropyle
10. Assertion : Sporopollenin preserves pollen in fossil deposits
    Reason : Sporopollenin is resistant to physical and biological decomposition
    a) assertion is true; reason is false
    b) assertion is false; reason is true
    c) Both Assertion and reason are not true
    d) Both Assertion and reason are true.
11. Choose the correct statement(s) about tenuinucellate ovule
    a) Sporogenous cell is hypodermal
    b) Ovules have fairly large nucellus
    c) sporogenous cell is epidermal
    d) ovules have single layer of nucellus tissue
12. Which of the following represent megagametophyte
    a) Ovule b)Embryo sac
    c)Nucellus d)Endosperm
13. In *Haplopappus gracilis*, number of chromosomes in cells of nucellus is 4. What will be the chromosome number in Primary endosperm cell?
    a)8 b)12 c)6 d)2

14. Transmitting tissue is found in
    a) Micropylar region of ovule
    b) Pollen tube wall
    c) Stylar region of gynoecium
    d) Integument

15. The scar left by funiculus in the seed is
    a)tegmen b)radicle
    c)epicotyl d)hilum

16. A Plant called X possesses small flower with reduced perianth and versatile anther. The probable agent for pollination would be
    a)water b)air
    c)butterflies d)beetles

17. Consider the following statement(s)
    i) In Protandrous flowers pistil matures earlier
    ii) In Protogynous flowers pistil matures earlier
    iii) Herkogamy is noticed in unisexual flowers
    iv) Distyly is present in *Primula*
    a) i and ii are correct
    b) ii and iv are correct
    c) ii and iii are correct
    d) i and iv are correct

18. Coelorhiza is found in
    a)Paddy b)Bean
    c)Pea d)Tridax

19. Parthenocarpic fruits lack
    a)Endocarp b)Epicarp
    c)Mesocarp d) seed

20. In majority of plants pollen is liberated at
    a) 1 celled stage b) 2 celled stage
    c) 3 celled stage d) 4 celled stage

21. What is reproduction?
22. Mention the contribution of Hofmeister towards Embryology.
23. List out two sub-aerial stem modifications with example.
24. What is layering?
25. What are clones?
26. A detached leaf of *Bryophyllum* produces new plants. How?
27. Differentiate Grafting and Layering.
28. "Tissue culture is the best method for propagating rare and endangered plant species"- Discuss.
29. Distinguish mound layering and air layering.
30. Explain the conventional methods adopted in vegetative propagation of higher plants.
31. Highlight the milestones from the history of plant embryology.
32. Discuss the importance of Modern methods in reproduction of plants.
33. What is Cantharophily.
34. List any two strategy adopted by bisexual flowers to prevent self-pollination.
35. What is endothelium.
36. "The endosperm of angiosperm is different from gymnosperm". Do you agree. Justify your answer.
37. Define the term Diplospory.
38. What is polyembryony. How it can commercially exploited.
39. Why does the zygote divides only after the division of Primary endosperm cell.
40. What is Mellitophily?
41. "Endothecium is associated with dehiscence of anther" Justify the statement.
42. List out the functions of tapetum.
43. Write short note on Pollen kitt.
44. Distinguish tenuinucellate and crassinucellate ovules.
45. 'Pollination in Gymnosperms is different from Angiosperms' – Give reasons.
46. Write short note on Heterostyly.
47. Enumerate the characteristic features of Entomophilous flowers

48. Discuss the steps involved in Microsporogenesis.
49. With a suitable diagram explain the structure of an ovule.
50. Give a concise account on steps involved in fertilization of an angiosperm plant.
51. What is endosperm. Explain the types.
52. Differentiate the structure of Dicot and Monocot seed.
53. Give a detailed account on parthenocarpy. Add a note on its significance.

Glossary

Apospory: The process of embryo sac formation from diploid cells of nucellus as a result of mitosis

Budding: A method of asexual reproduction where small outgrowth(Bud) from a parent cell are produced

Callus: Undifferentiated mass of cells obtained through tissue culture.

Clone: Genetically identical individuals.

Endothecium: A single layer of hygroscopic, radially elongated cells found below the epidermis of anther which helps in dehiscence of anther.

Fertilization: The act of fusion of male and female gamete

Grafting: Conventional method of reproduction where stock and scion are joined to produce new plant.

Horticulture: Branch of plant science that deals with the art of growing fruits, vegetables, flowers and ornamental plants.

Nucellus: The diploid tissue found on the inner part of ovule next to the integuments.

Pollenkitt: A sticky covering found on the surface of the pollen that helps to attract insects.

Regeneration: Ability of organisms to replace or restore the lost parts.

Sporopollenin: Pollen wall material derived from carotenoids and is resistant to physical and biological decomposition.

Tapetum: Nutritive tissue for the developing sporogenous tissue

Transmitting tissue: A single layer of glandular canal cells lining the inner part of style.

Chapter

2

UNIT VII: Genetics

Classical Genetics

Learning Objectives

The Learner will be able to

- Differentiate classical and modern genetics.
- Understand the concepts of principles of inheritance.
- Describe the extensions of Mendelism.
- Explain polygenic inheritance and Pleiotropy.
- Analyze extra chromosomal inheritance in cytoplasmic organelles.

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Chapter outline

2.1 Heredity and Variation

2.2 Mendelism

2.3 Laws of Mendelian Inheritance

2.4 Monohybrid, Dihybrid, Trihybrid cross, Backcross and Testcross

2.5 Interaction of Genes -Intragenic and Intergenic Incomplete dominance, Lethal genes, Epistasis

2.6 Polygenic inheritance in Wheat kernel colour, Pleiotropy – *Pisum sativum*

2.7 Extra chromosomal inheritance-Cytoplasmic inheritance in Mitochondria and Chloroplast.

Genetics is the study of how living things receive common traits from previous generations. No field of science has changed the world more, in the past 50 years than genetics. The scientific and technological advances in genetics have transformed agriculture, medicine and forensic science etc.

Genetics – The Science of heredity (Inheritance) - "Genetics" is the branch of biological science which deals with the mechanism of transmission of characters from parents to offsprings. The term **Genetics** was introduced by **W. Bateson** in 1906.

The four major subdisciplines of genetics are

1. **Transmission Genetics / Classical Genetics** – Deals with the transmission of genes from parents to offsprings. The foundation of classical genetics came from the study of hereditary behaviour of seven genes by Gregor Mendel.
2. **Molecular Genetics** – Deals with the structure and function of a gene at molecular level.
3. **Population Genetics** – Deals with heredity in groups of individuals for traits which is determined by a few genes.
4. **Quantitative Genetics** – Deals with heredity of traits in groups of individuals where the traits are governed by many genes simultaneously.

What is the reason for similarities, differences of appearance and skipping of generations?

Genes – Functional Units of inheritance: The basic unit of heredity (biological information) which transmits biochemical, anatomical and behavioural traits from parents to offsprings.

2.1 Heredity and variation

Genetics is often described as a science which deals with heredity and variation.

Heredity: Heredity is the transmission of characters from parents to offsprings.

Variation: The organisms belonging to the same natural population or species that shows a difference in the characteristics is called variation. Variation is of two types (i) Discontinuous variation and (ii) Continuous variation

1. Discontinuous Variation:

Within a population there are some characteristics which show a limited form of variation. Example: Style length in *Primula*, plant height of garden pea. In discontinuous variation, the characteristics are controlled by one or two major genes which may have two or more allelic forms. These variations are genetically determined by inheritance factors. Individuals produced by this variation show differences without any intermediate form between them and there is no overlapping between the two phenotypes. The phenotypic expression is unaffected by environmental conditions. This is also called as qualitative inheritance.

2. Continuous Variation:

This variation may be due to the combining effects of environmental and genetic factors. In a population most of the characteristics exhibit a complete gradation, from one extreme to the other without any break. Inheritance of phenotype is determined by the combined effects of many genes, (polygenes) and environmental factors. This is also known as quantitative inheritance. Example: Human height and skin color.

Importance of variations

- Variations make some individuals better fitted in the struggle for existence.
- They help the individuals to adapt themselves to the changing environment.
- It provides the genetic material for natural selection
- Variations allow breeders to improve better yield, quicker growth, increased resistance and lesser input.
- They constitute the raw materials for evolution.

2.2 Mendelism

The contribution of Mendel to Genetics is called Mendelism. It includes all concepts brought out by Mendel through his original research on plant hybridization. Mendelian genetic concepts are basic to modern genetics. Therefore, Mendel is called as **Father of Genetics.**

2.2.1 Father of Genetics – Gregor Johann Mendel (1822 – 1884)

Figure 2.1: Gregor Johann Mendel

The first Geneticist, Gregor Johann Mendel unraveled the mystery of heredity. He was born on 22nd July 1822 in Heinzendorf Silesia (now Hyncice, Czechoslovakia), Austria. After school education, later he studied botany, physics and mathematics at the University of Vienna.He then entered a monastery of St.Thomas at Brunn in Austria and continued his interest in plant hybridization.In 1849 Mendel got a temporary position in a school as a teacher and he performed a series of elegant experiments with pea plants in his garden. In 1856, he started his historic studies on pea plants. 1856 to 1863 was the period of Mendel's hybridization experiments on pea plants. Mendel discovered the principles of heredity by studying the inheritance of seven pairs of contrasting traits of pea plant in his garden. Mendel crossed and catalogued 24,034

plants through many generations. His paper entitled **"Experiments on Plant Hybrids"** was presented and published in The Proceedings of the Brunn Society of Natural History in 1866. Mendel was the first systematic researcher in the field of genetics.

Mendel was successful because:

- He applied mathematics and statistical methods to biology and laws of probability to his breeding experiments.
- He followed scientific methods and kept accurate and detailed records that include quantitative data of the outcome of his crosses.
- His experiments were carefully planned and he used large samples.
- The pairs of contrasting characters which were controlled by factor (genes)were present on separate chromosomes.
- The parents selected by Mendel were pure breed lines and the purity was tested by self crossing the progeny for many generations.

Mendel's Experimental System – The Garden pea.

He chose pea plant because,

- It is an annual plant and has clear contrasting characters that are controlled by a single gene separately.
- Self-fertilization occurred under normal conditions in garden pea plants. Mendel used both self-fertilization and cross-fertilization.
- The flowers are large hence emasculation and pollination are very easy for hybridization.

2.2.2 Mendel's experiments on pea plant

Mendel's theory of inheritance, known as the Particulate theory, establishes the existence of minute particles or hereditary units or factors, which are now called as **genes**. He performed artificial pollination or cross pollination experiments with several true-breeding lines of pea plants. A true breeding lines (Pure-breeding strains) means it has undergone continuous self pollination having stable trait inheritance from parent to offspring. Matings within pure breeding lines produce offsprings having specific parental traits that are constant in inheritance and expression for many generations. Pure line breed refers to homozygosity only. Fusion of male and female gametes produced by the same individual i.e pollen and egg are

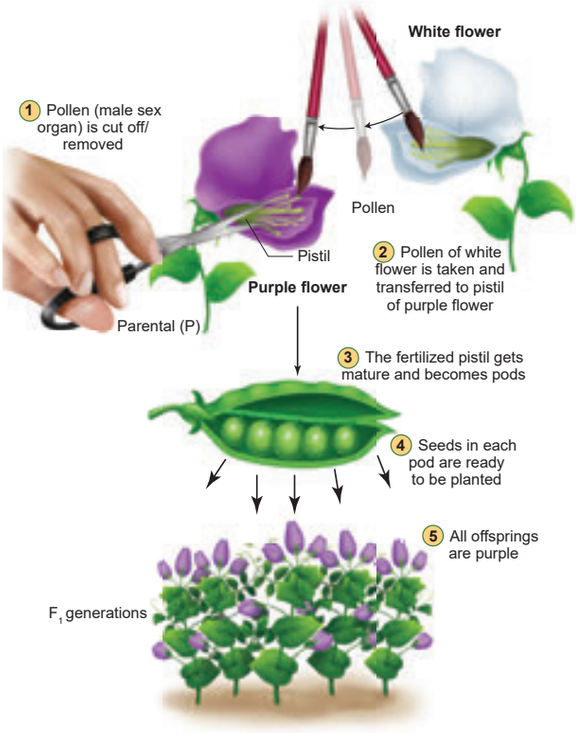


Figure 2.2: Steps in cross pollination of pea flowers

derived from the same plant is known as self-fertilization. Self pollination takes place in Mendel's peas. The experimenter can remove the anthers (Emasculation) before fertilization and transfer the pollen from another variety of pea to the stigma of flowers where the anthers are removed. This results in cross-fertilization, which leads to the creation of hybrid varieties with different traits. Mendel's work on the study of the pattern of inheritance and the principles or laws formulated, now constitute the Mendelian Genetics.

The First Model Organism in Genetics – Garden Peas (*Pisum sativum*) – Seven characters studied by Mendel.

Character	Dominant Trait	Recessive Trait
Stem length	Tall	Dwarf
Pod shape	Inflated	Constricted
Seed shape	Round	Wrinkled
Seed colour	Yellow	Green
Flower position	Axial	Terminal
Flower colour	Purple	White
Pod colour	Green	Yellow

Figure 2.3: Seven characters of *Pisum sativum* studied by Mendel.

Character	Gene	Dominant Trait	Recessive Trait
Plant Height	Le	Tall	Dwarf
Seed Shape	R	Round	Wrinkled
Cotyledon colour	I	Yellow	Green
Flower colour	A	Purple	White
Pod colour	GP	Green	Yellow
Pod form	V	Inflated	Constricted
Flower position	Fa	Axial	Terminal

Table 2.1 Seven characters of *Pisum sativum* with genes

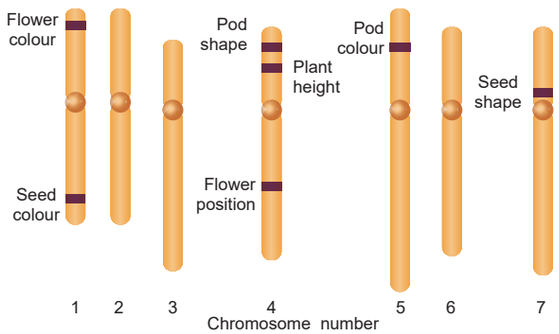


Figure 2.4: Mendel's seven characters in Garden Peas, shown on the plant's seven chromosomes

Can you identify Mendel's gene for **regulating white colour** in peas? Let us find the **molecular answer** to understand the gene function. Now the **genetic mystery of Mendel's white flowers is solved**.

Figure 2.5: Purple flower of Pea with Pea Gene A and White flower of Pea

It is quite fascinating to trace the Mendel's genes. In 2010, the gene responsible for regulating flower colour in peas were identified by an international team of researchers. It was called **Pea Gene A** which encodes a **protein** that functions as a transcription factor which is responsible for the production of **anthocyanin pigment**. So the flowers are purple. Pea plants with white flowers do not have anthocyanin, even though they have the gene that encodes the enzyme involved in anthocyanin synthesis.

Researchers delivered normal copies of gene A into the cells of the petals of white flowers by the gene gun method. When Gene A entered in a small percentage of cells of white flowers it is expressed in those particular cells, accumulated anthocyanin pigments and became purple.

In white flowers the gene A sequence showed a single-nucleotide change that makes the transcription factor inactive. So the mutant form of gene A do not accumulate anthocyanin and hence they are white.

Mendel worked at the rules of inheritance and arrived at the correct mechanism before any knowledge of cellular mechanism, DNA, genes, chromosomes became available. Mendel insights and meticulous work into the mechanism of inheritance played an important role which led

to the development of improved crop varieties and a revolution in crop hybridization.

Mendel died in 1884. In 1900 the work of Mendel's experiments were rediscovered by three biologists, **Hugo de Vries** of Holland, **Carl Correns** of Germany and **Erich von Tschermak** of Austria.

2.2.3 Terminology related to Mendelism

Mendel noticed two different expressions of a trait – Example: Tall and dwarf. Traits are expressed in different ways due to the fact that a gene can exist in alternate forms (versions) for the same trait is called **alleles.**

If an individual has two identical alleles of a gene, it is called as **homozygous(TT)**. An individual with two different alleles is called **heterozygous(Tt)**. Mendels non-true breeding plants are heterozygous, called as **hybrids**.

When the gene has two alleles the dominant allele is symbolized with capital letter and the recessive with small letter. When both alleles are recessive the individual is called **homozygous recessive** (tt) dwarf pea plants. An individual with two dominant alleles is called **homozygous dominant** (TT) tall pea plants. One dominant allele and one recessive allele (Tt) denotes non-true breeding tall pea plants **heterozygous tall.**

2.2.4 Mendelian inheritance – Mendel's Laws of Heredity

Mendel proposed two rules based on his observations on monohybrid cross, today these rules are called laws of inheritance The first law is The Law of Dominance and the second law is The Law of Segregation. These scientific laws play an important role in the history of evolution.

The Law of Dominance: The characters are controlled by discrete units called factors which occur in pairs. In a dissimilar pair of factors one member of the pair is dominant and the other is recessive. This law gives an explanation to the monohybrid cross (a) the expression of only one of the parental characters in F_1 generation and (b) the expression of both in the F_2 generation. It also explains the proportion of 3:1 obtained at the F_2

The Law of Segregation (Law of Purity of gametes): Alleles do not show any blending, both characters are seen as such in the F_2 generation although one of the characters is not seen in the F_1 generation. During the formation of gametes, the factors or alleles of a pair separate and segregate from each other such that each gamete receives only one of the two factors. A homozygous parent produces similar gametes and a heterozygous parent produces two kinds of gametes each having one allele with equal proportion. **Gametes are never hybrid.**

2.3 Monohybrid cross

Monohybrid inheritance is the inheritance of a single character i.e. plant height.It involves the inheritance of two alleles of a single gene. When the F_1 generation was selfed Mendel noticed that 787 of 1064 F_2 plants were tall, while 277 of 1064 were dwarf. The dwarf trait disappeared in the F_1 generation only to reappear in the F_2 generation. The term **genotype** is the genetic constitution of an individual. The term **phenotype** refers to the observable characteristic of an organism. In a genetic cross the genotypes and phenotypes of offspring, resulting from combining gametes during fertilization can be easily understood with the help of a diagram called Punnett's Square named after a British Geneticist Reginald C.Punnett. It is a graphical representation to calculate the probability of all possible genotypes of offsprings in a genetic cross.The Law of Dominance and the Law of Segregation give suitable explanation to Mendel's monohybrid cross.

Reciprocal cross – In one experiment, the tall pea plants were pollinated with the pollens from a true-breeding dwarf plants, the result was all tall plants. When the parental types were reversed, the pollen from a tall plant was used to pollinate a dwarf pea plant which gave only tall plants. The result was the same - All tall plants.

Tall (♀) x Dwarf (♂) and Tall (♂) x Dwarf (♀) matings are done in both ways which are called reciprocal crosses.The results of the reciprocal crosses are the same. So it was concluded that the trait is not sex dependent. The results of Mendel's monohybrid crosses were not sex dependent.

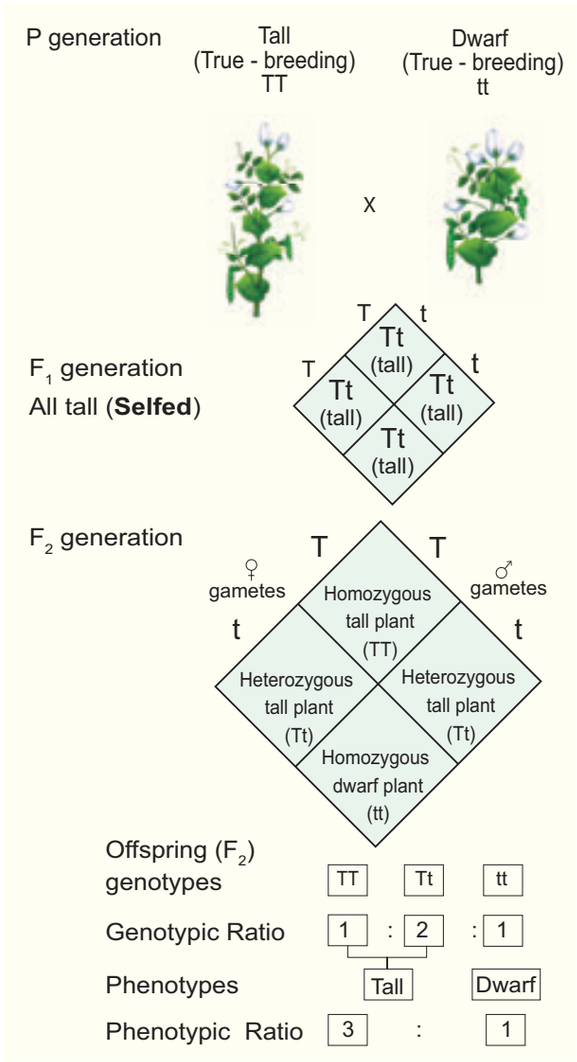


Figure 2.6: Monohybrid Cross

The gene for plant height has two alleles: Tall (T) x Dwarf (t). The phenotypic and genotypic analysis of the crosses has been shown by Checker board method or by Forkline method.

2.3.1 Mendel's analytical and empirical approach

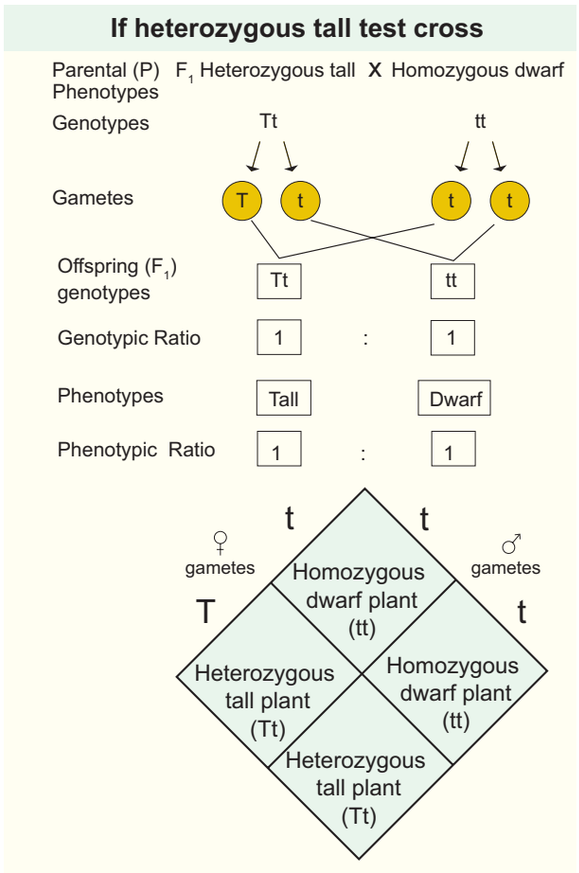
Mendel chose two contrasting traits for each character. So it seemed logical that two distinct factors exist. In F_1 the recessive trait and its factors do not disappear and they are hidden or masked only to reappear in ¼ of the F_2 generation. He concluded that tall and dwarf alleles of F_1 heterozygote segregate randomly into gametes. Mendel got 3:1 ratio in F_2 between the dominant and recessive trait. He was the first scientist to use this type of quantitative analysis in a biological experiment. Mendel's data is concerned with the proportions of offspring.

Mendel's analytical approach is truly an outstanding scientific achievement. His meticulous work and precisely executed breeding experiments proposed that discrete particulate units of heredity are present and they are transmitted from one generation to the other. Now they are called as genes. Mendel's experiments were well planned to determine the relationships which govern hereditary traits. This rationale is called an empirical approach. Laws that were arrived from an empirical approach is known as empirical laws.

2. 3.2 Test cross

Test cross is crossing an individual of unknown genotype with a homozygous recessive.

In Mendel's monohybrid cross all the plants are tall in F_1 generation. In F_2 tall and dwarf plants were in the ratio of 3:1.Mendel self pollinated dwarf F_2 plants and got dwarf plants in F_3 and F_4 generations. So he concluded that the genotype of dwarf was homozygous (tt). The genotypes of tall plants TT or Tt from $F_1$and F_2 cannot be predicted. But how we can tell if a tall plant is homozygous or heterozygous? To determine the genotype of a tall plant Mendel crossed the plants from F_2 with the homozygous recessive dwarf plant. This he called a test cross. The progenies of the test cross can be easily analysed to predict the genotype of the plant or the test organism. Thus in a typical test cross an organism (pea plants) showing dominant phenotype (whose genotype is to be determined) is crossed with the recessive parent instead of self crossing. Test cross is used to identify whether an individual is homozygous or heterozygous for dominant character.



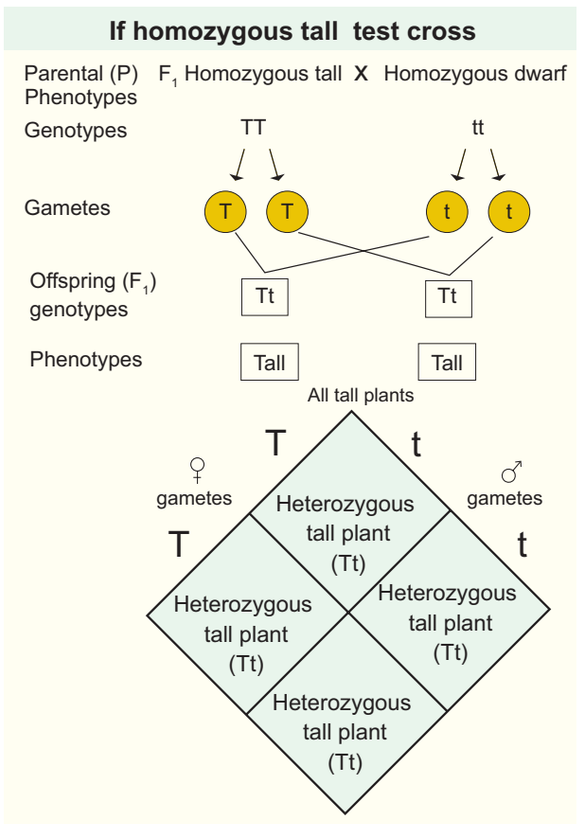


Figure 2.7: Test cross

Why Mendel's pea plants are tall and dwarf? Find out the molecular explanation.

Molecular characterization of Mendel's gene for plant height.

The plant height is controlled by a single gene with two alleles. The reason for this difference in plant height is due to the following facts: (i) the cells of the pea plant have the ability to convert a precursor molecule of gibberellins into an active form (GA1) (ii) Tall pea plants have one allele (Le) that codes for a protein (functional enzyme) which functions normally in the gibberellin-synthesis pathway and catalyzes the formation of gibberellins (GA1). The allele is dominant even if it is two (Le Le) or single (Le le), it produces gibberellins and the pea plants are tall. Dwarf pea plants have two recessive alleles (le le) which code for non-functional protein, hence they are dwarf.

Gene for plant height in Peas

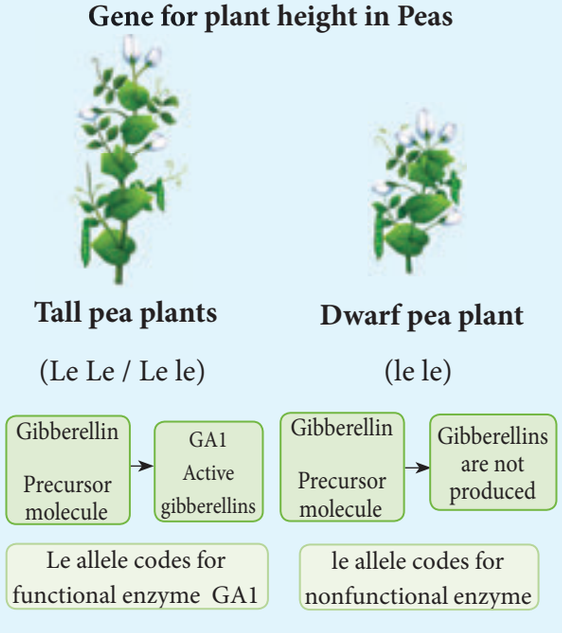


Figure 2.8: Gene for plant height in Peas

2.3.3 Back cross

- Back cross is a cross of F_1 hybrid with any one of the parental genotypes. The back cross is of two types; they are dominant back cross and recessive back cross.
- It involves the cross between the F_1 offspring with either of the two parents.

- When the F_1offsprings are crossed with the dominant parents all the F_2 develop dominant character and no recessive individuals are obtained in the progeny.
- If the F_1 hybrid is crossed with the recessive parent individuals of both the phenotypes appear in equal proportion and this cross is specified as test cross.
- The recessive back cross helps to identify the heterozygosity of the hybrid.

2.3.4 Dihybrid cross

It is a genetic cross which involves individuals differing in two characters. Dihybrid inheritance is the inheritance of two separate genes each with two alleles.

Law of Independent Assortment – When two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent to the other pair of characters. Genes that are located in different chromosomes assort independently during meiosis. Many possible combinations of factors can occur in the gametes.

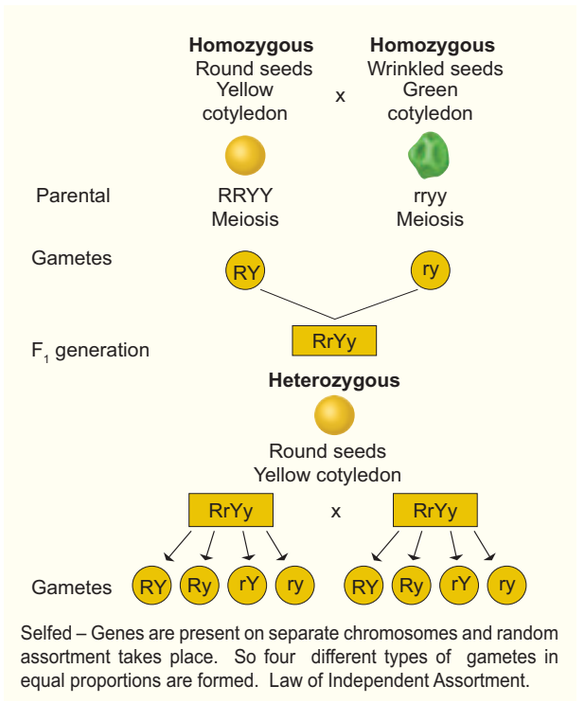


Figure 2.9: Dihybrid cross – Segregation of gametes

Independent assortment leads to genetic diversity. If an individual produces genetically dissimilar gametes it is the consequence of independent assortment. Through independent assortment, the maternal and paternal members of all pairs were distributed to gametes, so all possible chromosomal combinations were produced leading to genetic variation. In sexually reproducing plants / organisms, due to independent assortment, genetic variation takes place which is important in the process of evolution. The Law of Segregation is concerned with alleles of one gene but the Law of Independent Assortment deals with the relationship between genes.

The crossing of two plants differing in two pairs of contrasting traits is called dihybrid cross. In dihybrid cross, two characters (colour and shape) are considered at a time. Mendel considered the seed shape (round and wrinkled) and cotyledon colour (yellow & green) as the two characters. In seed shape round (R) is dominant over wrinkled (r) ; in cotyledon colour yellow (Y) is dominant over green (y). Hence the pure breeding round yellow parent is represented by the genotype RRYY and the pure breeding green wrinkled parent is represented by the genotype rryy. During gamete formation the paired genes of a character assort out independently of the other pair. During the F_1 x F_1 fertilization each zygote with an equal probability receives one of the four combinations from each parent. The resultant gametes thus will be genetically different and they are of the following four types:

1) Yellow round (YR) - 9/16
2) Yellow wrinkled (Yr) - 3/16
3) Green round (yR) - 3/16
4) Green wrinkled (yr) - 1/16

These four types of gametes of F_1 dihybrids unite randomly in the process of fertilization and produce sixteen types of individuals in F_2 in the ratio of 9:3:3:1 as shown in the figure. Mendel's 9:3:3:1 dihybrid ratio is an ideal ratio based on the probability including segregation, independent assortment and random

fertilization. In sexually reproducing organism / plants from the garden peas to human beings, Mendel's findings laid the foundation for understanding inheritance and revolutionized the field of biology. The dihybrid cross and its result led Mendel to propose a second set of generalisations that we called Mendel's Law of independent assortment.

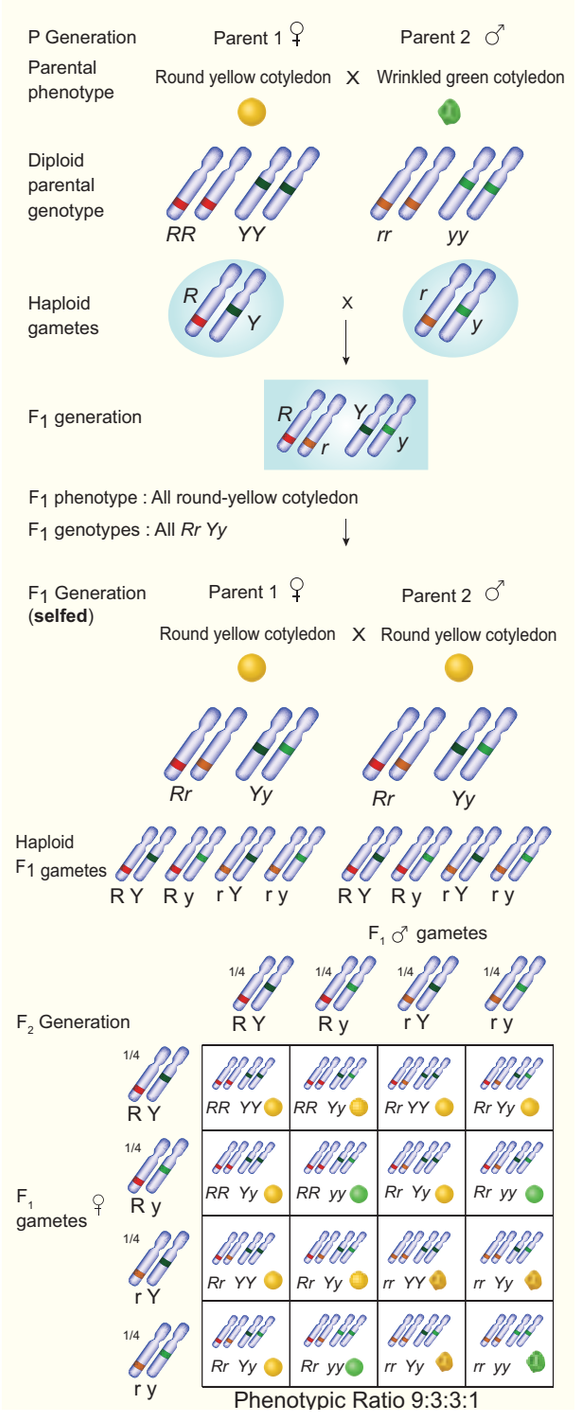
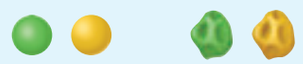


Figure 2.10: Dihybrid Cross in Garden peas

How does the wrinkled gene make Mendel's peas wrinkled? Find out the molecular explanation.

The protein called starch branching enzyme (SBEI) is encoded by the wild-type allele of the gene (RR) which is dominant. When the seed matures, this enzyme SBEI catalyzes the formation of highly branched starch molecules. Normal gene (R) has become interrupted by the insertion of extra piece of DNA (0.8 kb) into the gene, resulting in r allele. In the homozygous mutant form of the gene (rr) which is recessive, the activity of the enzyme SBEI is lost resulting in wrinkled peas. The wrinkled seed accumulates more sucrose and high water content. Hence the osmotic pressure inside the seed rises. As a result, the seed absorbs more water and when it matures it loses water as it dries. So it becomes wrinkled at maturation. When the seed has atleast one copy of normal dominant gene heterozygous, the dominant allele helps to synthesize starch, amylopectin an insoluble carbohydrate, with the osmotic balance which minimises the loss of water resulting in smooth structured round seed.

The wrinkled gene make Mendel's peas wrinkled



Round Peas & Wrinkled Peas

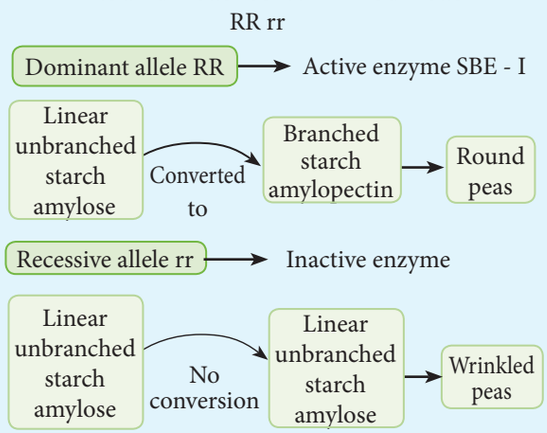


Figure 2.11: Molecular explanation of round and wrinkled peas.

2.3.5 The Dihybrid test cross

The Dihybrid test cross

The F_1 hybrid plant (round yellow peas) is crossed with homozygous double recessive genotype, wrinkled green peas (rryy). This is called dihybrid test cross with the ratio of 1:1:1:1.

Parental (P) Phenotypes F_1: Heterozygous round peas (Yellow cotyledon) x Homozygous Wrinkled peas (Green cotyledon)

Genotypes: RrYy x rryy

Gametes: RY, Ry, rY, ry x ry, ry, ry, ry

Gametes	RY	Ry	rY	ry
all ry	RrYy Round Yellow	Rryy Round Green	rrYy Wrinkled Yellow	rryy Wrinkled Green

Genotypes	RrYy		Rryy		rrYy		rryy
Genotypic ratio	1	:	1	:	1	:	1
Phenotypes	round Yellow		round Green		Wrinkled Yellow		Wrinkled Green
Phenotypic ratio	25%		25%		25%		25%

Figure 2.12: Dihybrid test cross

2.3.6. Trihybrid cross

The trihybrid cross demonstrates that Mendel's laws are applicable to the inheritance of multiple traits. Mendel Laws of segregation and independent assortment are also applicable to three pairs of contrasting characteristic traits called trihybrid cross.

A cross between homozygous parents that differ in three gene pairs (i.e. producing trihybrids) is called trihybrid cross. A self fertilizing trihybrid plant forms 8 different gametes and 64 different zygotes. In this a combination of three single pair crosses operating together. The three contrasting characters of a trihybrid cross are

Tall, Yellow, Round x Dwarf, Green, Wrinkled
TTYYRR ↓ ttyyrr
F_1 Tall, Yellow, Round (Selfed)
TtYyRr
F_2 Phenotypic ratio - 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1

2.3.7 Extensions of Mendelian Genetics

Apart from monohybrid, dihybrid and trihybrid crosses, there are exceptions to Mendelian principles, i.e. the occurrence of different phenotypic ratios. The more complex patterns of inheritance are the extensions of Mendelian Genetics. There are examples where phenotype of the organism is the result of the interactions among genes.

Gene interaction – A single phenotype is controlled by more than one set of genes, each of which has two or more alleles. This phenomenon is called Gene Interaction. Many characteristics of the organism including structural and chemical which constitute the phenotype are the result of interaction between two or more genes.

9TL2WA

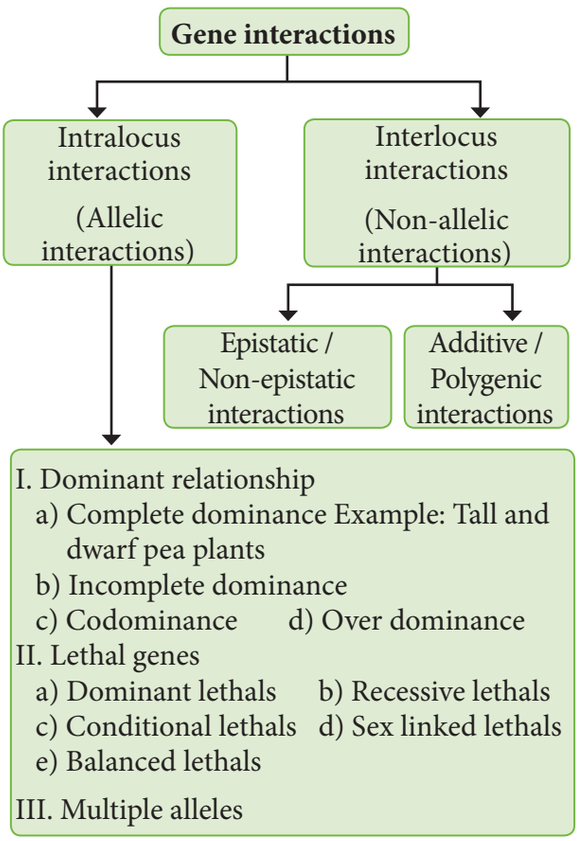


Figure 2.13: Gene Interaction

Mendelian experiments prove that a single gene controls one character. But in the post Mendelian findings, various exception have been noticed, in which different types of interactions are possible between the genes. This gene interaction concept was introduced and explained by W. Bateson. This concept is otherwise known as Factor hypothesis or Bateson's factor hypothesis. According to Bateson's factor hypothesis, the gene interactions can be classified as

- Intragenic gene interactions or Intra allelic or allelic interactions
- Intergenic gene interactions or inter allelic or non-allelic interactions

2.4 Intragenic gene interactions

Interactions take place between the alleles of the same gene i.e., alleles at the same locus is called intragenic or intralocus gene interaction. It includes the following:
1) Incomplete dominance (2) Codominance (3) Multiple alleles (4) Pleiotropic genes are common examples for intragenic interaction.

2.4.1. Incomplete dominance – No blending of genes

The German Botanist Carl Correns's (1905) Experiment - In 4 O' clock plant, *Mirabilis jalapa* when the pure breeding homozygous red (R^1R^1) parent is crossed with homozygous white (R^2R^2), the phenotype of the F_1 hybrid is heterozygous pink (R^1R^2). The F_1 heterozygous phenotype differs from both the parental homozygous phenotype. This cross did not exhibit the character of the dominant parent but an intermediate colour pink. When one allele is not completely dominant to another allele it shows incomplete dominance. Such allelic interaction is known as incomplete dominance. F_1 generation produces intermediate phenotype pink coloured flower. When pink coloured plants of F_1 generation were interbred in F_2 both phenotypic and genotypic ratios were found to be identical as 1 : 2 : 1(1 red : 2 pink : 1 white). Genotypic ratio is 1 R^1R^1 : 2 R^1R^2 : 1 R^2R^2.From this we conclude that the alleles themselves remain discrete and unaltered proving the Mendel's Law of Segregation. The phenotypic and genotypic ratios are the same. There is no blending of genes. In the F_2 generation R^1 and R^2 genes segregate and recombine to produce red, pink and white in the ratio of 1 : 2 : 1. R^1 allele codes for an enzyme responsible for the formation of red pigment. R^2 allele codes for defective enzyme. R^1 and R^2 genotypes produce only enough red pigments to make the flower pink. Two R^1R^1 are needed for producing red flowers. Two R^2R^2 genes are needed for white flowers. If blending had taken place, the original pure traits would not have appeared and all F_2 plants would have pink flowers. It is very clear that Mendel's particulate inheritance takes place in this cross which is confirmed by the reappearance of original phenotype in F_2.

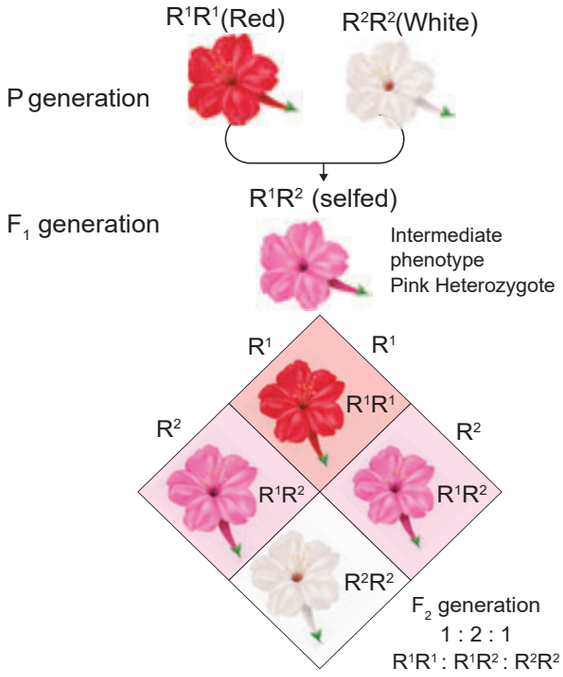


Figure 2.14: Incomplete dominance in 4 O' clock plant

How are we going to interpret the lack of dominance and give explanation to the intermediate heterozygote phenotype?

How will you explain incomplete dominance at the molecular level?

Gene expression is explained in a quantitative way. Wild-type allele which is a functional allele when present in two copies (R^1 R^1) produces an functional enzyme which synthesizes red pigments. The mutant allele which is a defective allele in two copies (R^2 R^2) produces an enzyme which cannot synthesize necessary red pigments. The white flower is due to the mutation causing complete loss of function. The F_1 intermediate phenotype heterozygote (R^1R^2) has one copy of the allele R^1. R^1 produces 50% of the functional protein resulting in half of the pigment of red flowered plant and so it is pink. The intermediate phenotype pink heterogyzote with 50% of functional protein is not enough to create the red phenotype homozygous, which makes 100% of the functional protein.

2.4.2. Codominance (1 : 2 : 1)

This pattern occurs due to simultaneous (joint) expression of both alleles in the heterozygote - The phenomenon in which two alleles are both expressed in the heterozygous individual is known as codominance. Example: Red and white flowers of *Camellia*, inheritance of sickle cell haemoglobin, ABO blood group system in humanbeings. In humanbeings, I^A and I^B alleles of I gene are codominant which follows Mendels law of segregation. The codominance was demonstrated in plants with the help of electrophoresis or chromatography for protein or flavonoid substance. Example: *Gossypium hirsutum* and *Gossypium sturtianum*, their F_1 hybrid (amphiploid) was tested for seed proteins by electrophoresis. Both the parents have different banding patterns for their seed proteins. In hybrids, additive banding pattern was noticed. Their hybrid shows the presence of both the types of proteins similar to their parents.

The heterozygote genotype gives rise to a phenotype distinctly different from either of the homozygous genotypes. The F_1 heterozygotes produce a F_2 progeny in a phenotypic and genotypic ratios of 1 : 2 : 1.

2.4.3. Lethal genes

An allele which has the potential to cause the death of an organism is called a "Lethal Allele". In 1907, E. Baur reported a lethal gene in snapdragon (*Antirrhinum sp.*). It is an example for recessive lethality. In snapdragon there are three kinds of plants.

1. Green plants with chlorophyll. (CC)
2. Yellowish green plants with carotenoids are referred to as pale green, golden or aurea plants (Cc)
3. White plants without any chlorophyll. (cc)

The genotype of the homozygous green plants is CC. The genotype of the homozygous white plant is cc.

The aurea plants have the genotype Cc because they are heterozygous of green and white plants. When two such aurea plants are crossed the F_1 progeny has identical phenotypic and genotypic ratio of 1 : 2 : 1 (viz. 1 Green (CC) : 2 Aurea (Cc) : 1 White (cc))

Since the white plants lack chlorophyll pigment, they will not survive. So the F_2 ratio is modified into 1 : 2. In this case the homozygous recessive genotype (cc) is lethal.

F_1	Heterozygote	Antirrhinum aurea	x	Antirrhinum aurea		
		Cc	x	Cc		
F_2		1CC	:	2 Cc	:	1 cc
		Green		Aurea		White (lethal)

Figure: 2.15: Lethal genes

The term "lethal" is applied to those changes in the genome of an organism which produces effects severe enough to cause death. Lethality is a condition in which the death of certain genotype occurs prematurely. The fully dominant or fully recessive lethal allele kills the carrier individual only in its homozygous condition. So the F_2 genotypic ratio will be 2 : 1 or 1 : 2 respectively.

2.4.4. Pleiotropy – A single gene affects multiple traits

In Pleiotropy, the single gene affects multiple traits and alter the phenotype of the organism. The Pleiotropic gene influences a number of characters simultaneously and such genes are called pleiotropic gene. Mendel noticed pleiotropy while performing breeding experiment with peas (*Pisum sativum*). Peas with purple flowers, brown seeds and dark spot on the axils of the leaves were crossed with a variety of peas having white flowers, light coloured seeds and no spot on the axils of the leaves, the three traits for flower colour, seed colour and a leaf axil spot all were inherited together as a single unit. This is due to the pattern of inheritance where the three traits were controlled by a single gene with dominant and recessive alleles. Example: sickle cell anemia.

2.5 Intergenic gene interactions

Interlocus interactions take place between the alleles at different loci i.e between alleles of different genes.It includes the following:

26G4FP

Dominant Epistasis – It is a gene interaction in which two alleles of a gene at one locus interfere and suppress or mask the phenotypic expression of a different pair of alleles of another gene at another locus. The gene that suppresses or masks the phenotypic expression of a gene at another locus is known as **epistatic**. The gene whose expression is interfered by non-allelic genes and prevents from exhibiting its character is known as **hypostatic**. When both the genes are present together, the phenotype is determined by the epistatic gene and not by the hypostatic gene.

In the summer squash the fruit colour locus has a dominant allele 'W' for white colour and a recessive allele 'w' for coloured fruit. 'W' allele is dominant that masks the expression of any colour. In another locus hypostatic allele 'G' is for yellow fruit and its recessive allele 'g' for green fruit. In the first locus the white is dominant to colour where as in the second locus yellow is dominant to green. When the white fruit with genotype WWgg is crossed with yellow fruit with genotype wwGG, the F_1 plants have white fruit and are heterozygous (WwGg). When F_1 heterozygous plants are crossed they give rise to F_2 with the phenotypic ratio of 12 white : 3 yellow : 1 green.

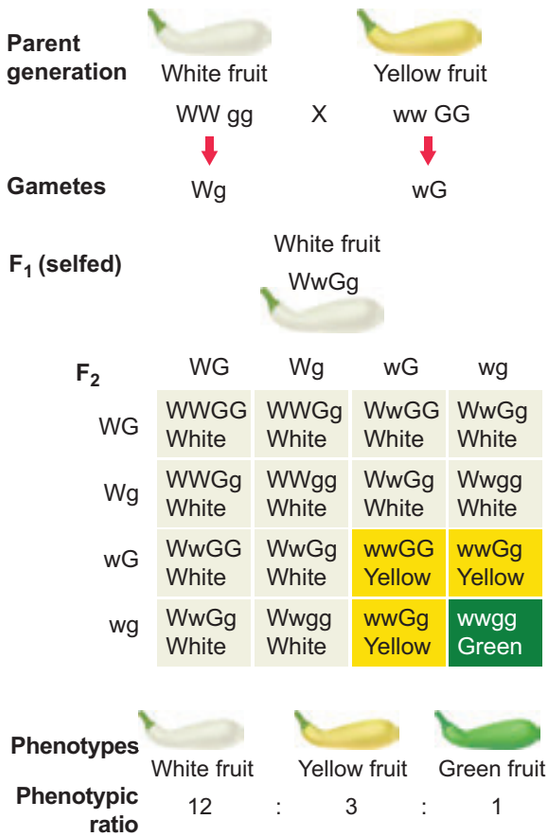


Figure 2.16: Dominant epistasis in summer squash

Since W is epistatic to the alleles 'G' and 'g', the white which is dominant, masks the effect of yellow or green. Homozygous

recessive ww genotypes only can give the coloured fruits (4/16). Double recessive 'wwgg' will give green fruit (1/16). The Plants having only 'G' in its genotype (wwGg or wwGG) will give the yellow fruit(3/16).

Intra –genic or allelic interaction

S. No.	Gene interaction	Example	F_2 Phenotypic ratio
1	Incomplete Dominance	Flower colour in *Mirabilis jalapa.* Flower colour in snapdragon *(Antirrhinum* spp.)	1 : 2 : 1 1 : 2 : 1
2	Codominance	ABO Blood group system in humans	1 : 2 : 1

Table 2.2: Intra- genic interaction

Inter-genic or non-allelic interaction

S. No.	Epistatic interaction	Example	F_2 Ratio Phenotypic ratio
1	Dominant epistasis	Fruit colour in summer squash	12 : 3 : 1
2	Recessive epistasis	Flower colour of *Antirrhinum* spp.	9 : 3 : 4
3	Duplicate genes with cumulative effect	Fruit shape in summer squash	9 : 6 : 1
4	Complementary genes	Flower colour in sweet peas	9 : 7
5	Supplementary genes	Grain colour in Maize	9 : 3 : 4
6	Inhibitor genes	Leaf colour in rice plants	13 : 3
7	Duplicate genes	Seed capsule shape (fruit shape) in shepherd's purse Bursa bursa-pastoris	15 : 1

Table 2.3: Inter-genic interaction

2.6 Polygenic Inheritance in Wheat (Kernel colour)

Polygenic inheritance - Several genes combine to affect a single trait.

A group of genes that together determine (contribute) a characteristic of an organism is called polygenic inheritance. It gives explanations to the inheritance of continuous traits which are compatible with Mendel's Law.

The first experiment on polygenic inheritance was demonstrated by Swedish Geneticist H. Nilsson - Ehle (1909) in wheat kernels. Kernel colour is controlled by two genes each with two alleles, one with red kernel colour was dominant to white. He crossed the two pure breeding wheat varieties dark red and a white. Dark red genotypes $R_1R_1R_2R_2$ and white genotypes are $r_1r_1r_2r_2$. In the F_1 generation medium red were obtained with the genotype $R_1r_1R_2r_2$. F_1 wheat plant produces four types of gametes R_1R_2, R_1r_2, r_1R_2, r_1r_2. The intensity of the red colour is determined by the number of R genes in the F_2 generation.

Four R genes: A dark red kernel colour is obtained.**Three R genes:** Medium - dark red kernel colour is obtained.**Two R genes:** Medium-red kernel colour is obtained.**One R gene:** Light red kernel colour is obtained. **Absence of R gene:**Results in White kernel colour.

The R gene in an additive manner produces the red kernel colour. The number of each phenotype is plotted against the intensity of red kernel colour which produces a bell shaped curve. This represents the distribution of phenotype. Other example: Height and skin colour in humans are controlled by three pairs of genes.

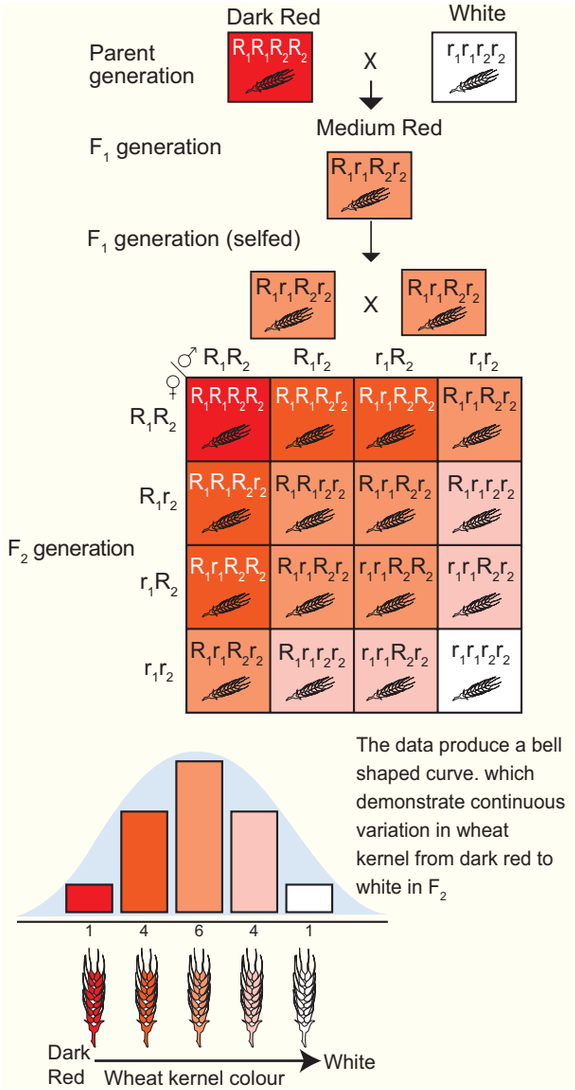


Figure 2.17 (a): Polygenic inheritance in wheat kernel colour

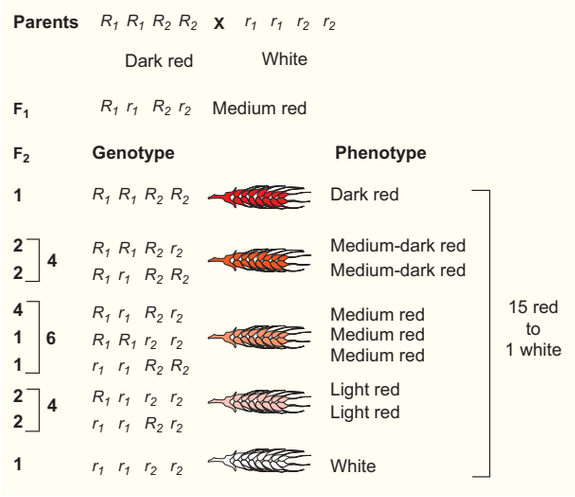


Figure 2.17 (b) : The genetic control of colour in wheat kernels.

Conclusion:

Finally the loci that was studied by Nilsson – Ehle were not linked and the genes assorted independently.

Later, researchers discovered the third gene that also affect the kernel colour of wheat. The three independent pairs of alleles were involved in wheat kernel colour. Nilsson – Ehle found the ratio of 63 red : 1 white in F_2 generation – 1 : 6 : 15 : 20 : 15 : 6 : 1 in F_2 generation.

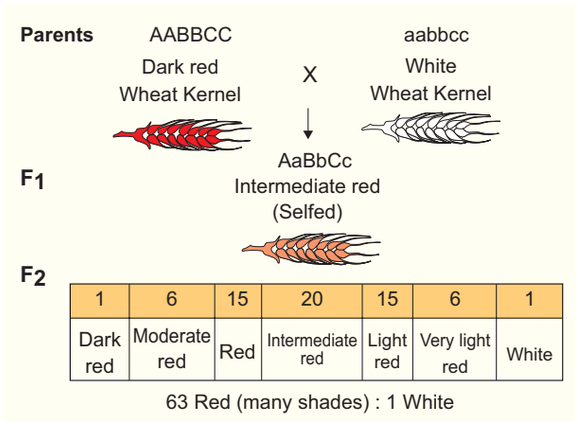


Figure 2.18: Polygenic inheritance in Wheat kernel

From the above results Nilsson – Ehle showed that the blending inheritance was not taking place in the kernel of wheat. In F_2 generation plants have kernels with wide range of colour variation. This is due to the fact that the genes are segregating and recombination takes place. Another evidence for the absence of blending inheritance is that the parental phenotypes dark red and white appear again in F_2. There is no blending of genes, only the phenotype. The cumulative effect of several pairs of gene interaction gives rise to many shades of kernel colour. He hypothesized that the two loci must contribute additively to the kernel colour of wheat. The contribution of each red allele to the kernel colour of wheat is additive.

2.7 Extra Chromosomal Inheritance or Extra Nuclear Inheritance (Cytoplasmic Inheritance)

DNA is the universal genetic material. Genes located in nuclear chromosomes follow Mendelian inheritance. But certain traits are governed either by the chloroplast or mitochondrial genes. This phenomenon is known as extra nuclear inheritance. It is a kind of Non-Mendelian inheritance. Since it involves cytoplasmic organelles such as chloroplast and mitochondrion that act as inheritance vectors, it is also called Cytoplasmic inheritance. It is based on independent, self-replicating extra chromosomal unit called plasmogene located in the cytoplasmic organelles, chloroplast and mitochondrion.

Chloroplast Inheritance

It is found in 4 O' Clock plant (*Mirabilis jalapa*). In this, there are two types of variegated leaves namely dark green leaved plants and pale green leaved plants. When the pollen of dark green leaved plant (male) is transferred to the stigma of pale green leaved plant (female) and pollen of pale green leaved plant is transferred to the stigma of dark green leaved plant, the F_1 generation of both the crosses must be identical as per Mendelian inheritance. But in the reciprocal cross the F_1 plant differs from each other. In each cross, the F_1 plant reveals the character of the plant which is used as female plant.

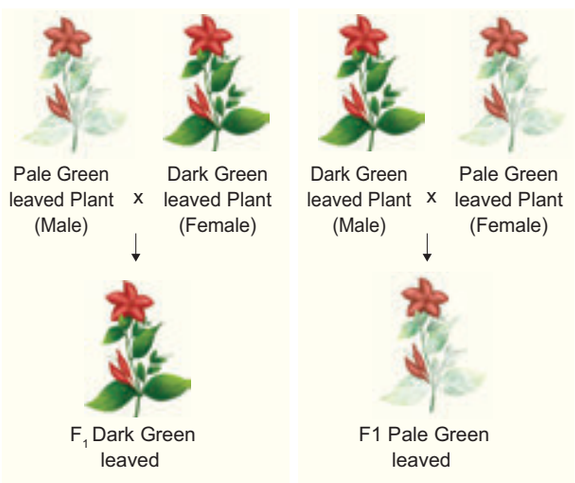


Figure 2.19: Chloroplast inheritance

This inheritance is not through nuclear gene. It is due to the chloroplast gene found in the ovum of the female plant which contributes the cytoplasm during fertilization since the male gamete contribute only the nucleus but not cytoplasm.

Mitochondrial Inheritance

Male sterility found in pearl maize (*Sorgum vulgare*) is the best example for mitochondrial cytoplasmic inheritance. So it is called **cytoplasmic male sterility**. In this, male sterility is inherited maternally. The gene for cytoplasmic male sterility is found in the mitochondrial DNA.

In this plant there are two types, one with normal cytoplasm (N) which is male fertile and the other one with aberrant cytoplasm (S) which is male sterile. These types also exhibit reciprocal differences as found in *Mirabilis jalapa*.

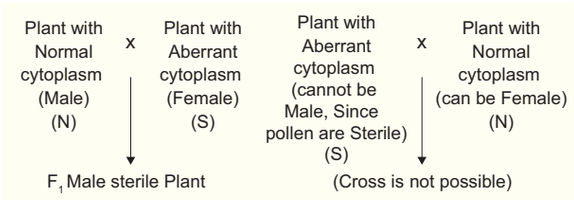


Figure 2.20: Mitochondrial Inheritance

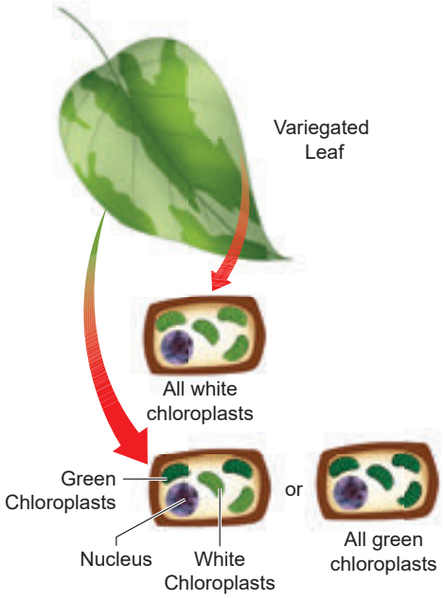


Figure 2.21: A cellular explanation of the variegated phenotype of the leaves in *Mirabilis jalapa*

Recently it has been discovered that cytoplasmic genetic male sterility is common in many plant species. This sterility is maintained by the influence of both nuclear and cytoplasmic genes. There are commonly two types of cytoplasm N (normal) and S (sterile). The genes for these are found in mitochondrion. There are also restores of fertility (Rf) genes. Even though these genes are nuclear genes, they are distinct from genetic male sterility genes of other plants. Because the Rf genes do not have any expression of their own, unless the sterile cytoplasm is present. Rf genes are required to restore fertility in S cytoplasm which is responsible for sterility.

So the combination of N cytoplasm with rfrf and S cytoplasm with RfRf produces plants with fertile pollens, while S cytoplasm with rfrf produces only male sterile plants.

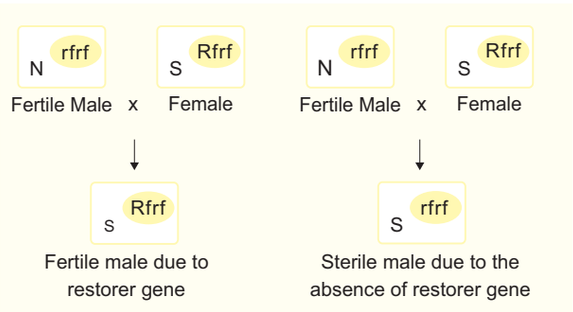


Figure 2.22: Cytoplasmic genetic male sterility

Atavism

Atavism is a modification of a biological structure whereby an ancestral trait reappears after having been lost through evolutionary changes in the previous generations. Evolutionary traits that have disappeared phenotypically do not necessarily disappear from an organism's DNA. The gene sequence often remains, but is inactive. Such an unused gene may remain in the genome for many generations. As long as the gene remains intact, a fault in the genetic control suppressing the gene can lead to the reappearance of that character again. Reemergence of sexual reproduction in the flowering plant *Hieracium pilosella* is the best example for Atavism in plants.

Summary

Gregor Johann Mendel, father of Genetics unraveled the mystery of heredity through his experiments on garden peas. Mendel's laws, analytical and empirical reasoning endure till now guiding geneticists to study variation. The monohybrid cross of Mendel proved his particulate theory of inheritance. In F_2 the alternative traits were expressed in the ratio of 3 dominant and 1 recessive. The characteristic 3 : 1 segregation is referred to as Mendelian ratio. Parents transmit discrete information about the traits to their offspring which Mendel called it as "factors". To test his experimental results Mendel devised a powerful procedure called the test cross. Test cross is used to determine the genotype of an individual when two genes are involved. In Mendel's dihyrbid cross, the two pairs of factors were inherited independently. From the results of dihybrid cross Mendel gave the Law of Independent Assortment. Mendel's dihybrid ratio of 9 : 3 : 3 : 1 with the representation of two new recombinations appeared in the progeny, i.e. round green peas or wrinkled yellow peas. Molecular explanation of Mendel's gene for monohybrid cross, dihybrid cross were explained. Extension of Mendelian Genetics was dealt with examples for interaction among genes. Incomplete dominance is not an example for blending inheritance. Incomplete dominance exhibits a phenotypic heterozygote intermediate between the two homozygous. In plants codominance can be demonstrated by the methods of electrophoresis or chromatography for protein or flavonoid substances. Lethal genes with an example are explained. Pleiotropy a single gene which affects multiple traits was explained with an example of Pisum sativum. Dominant epistatis in summer squash with 12 : 3 : 1 ratio was discussed. Polygenic inheritance is an example for inheritance of continuous traits which is compatible with Mendel's laws. The inheritance of mitochondrial and chloroplast genes were explained with examples which does not follow the rules of nuclear genes.

Evaluation

31HTIC

1. Extra nuclear inheritance is a consequence of presence of genes in
   a) Mitrochondria and chloroplasts
   b) Endoplasmic reticulum and mitrochondria
   c) Ribosomes and chloroplast
   d) Lysososmes and ribosomes
2. In order to find out the different types of gametes produced by a pea plant having the genotype AaBb, it should be crossed to a plant with the genotype
   a) aaBB b) AaBB
   c) AABB d) aabb
3. How many different kinds of gametes will be produced by a plant having the genotype AABbCC?
   a) Three b) Four
   c) Nine d) Two
4. Which one of the following is an example of polygenic inheritance?
   a) Flower colour in *Mirabilis Jalapa*
   b) Production of male honey bee
   c) Pod shape in garden pea
   d) Skin Colour in humans
5. In Mendel's experiments with garden pea, round seed shape (RR) was dominant over wrinkled seeds (rr), yellow cotyledon (YY) was dominant over green cotyledon (yy). What are the expected phenotypes in the F_2 generation of the cross RRYY x rryy?
   a) Only round seeds with green cotyledons
   b) Only wrinkled seeds with yellow cotyledons
   c) Only wrinkled seeds with green cotyledons
   d) Round seeds with yellow cotyledons an wrinkled seeds with yellow cotyledons
6. Test cross involves
   a) Crossing between two genotypes with recessive trait
   b) Crossing between two F_1 hybrids
   c) Crossing the F_1 hybrid with a double recessive genotype
   d) Crossing between two genotypes with dominant trait
7. In pea plants, yellow seeds are dominant to green. If a heterozygous yellow seed pant is crossed with a green seeded plant, what ratio of yellow and green seeded plants would you expect in F_1 generation?
   a) 9:1 b) 1:3
   b) 3:1 d) 50:50
8. The genotype of a plant showing the dominant phenotype can be determined by
   a) Back cross b) Test cross
   c) Dihybrid corss d) Pedigree analysis
9. Select the correct statement from the ones given below with respect to dihydrid cross
   a) Tightly linked genes on the same chromosomes show very few combinations
   b) Tightly linked genes on the same chromosomes show higher combinations
   c) Genes far apart on the same chromosomes show very few recombinations
   d) Genes loosely linked on the same chromosomes show similar recombinations as the tightly linked ones
10. Which Mendelian idea is depicted by a cross in which the F_1 generation resembles both the parents
    a) Incomplete dominance

b) Law of dominance

c) Inheritance of one gene

d) Co-dominance

11. Fruit colour in squash is an example of

a) Recessive epistatsis

b) Dominant epistasis

c) Complementary genes

d) Inhibitory genes

12. In his classic experiments on Pea plants, Mendel did not use

a)Flowering position b) Seed colour

c) Pod length d) Seed shape

13. The epistatic effect, in which the dihybrid cross 9:3:3:1 between AaBb Aabb is modified as

a) Dominance of one allele on another allele of both loci

b) Interaction between two alleles of different loci

c) Dominance of one allele to another alleles of same loci

d) Interaction between two alleles of some loci

14. In a test cross involving F_1 dihybrid flies, more parental type offspring were produced than the recombination type offspring. This indicates

a) The two genes are located on two different chromosomes

b) Chromosomes failed to separate during meiosis

c) The two genes are linked and present on the some chromosome

d) Both of the characters are controlled by more than one gene

15. The genes controlling the seven pea characters studied by Mendel are known to be located on how many different chromosomes?

a) Seven b) Six

c) Five d) Four

16. Which of the following explains how progeny can posses the combinations of traits that none of the parent possessed?

a) Law of segregation

b) Chromosome theory

c) Law of independent assortment

d) Polygenic inheritance

17. "Gametes are never hybrid". This is a statement of

a) Law of dominance

b) Law of independent assortment

c) Law of segregation

d) Law of random fertilization

18. Gene which suppresses other genes activity but does not lie on the same locus is called as

a) Epistatic b) Supplement only

c) Hypostatic d) Codominant

19. Pure tall plants are crossed with pure dwarf plants. In the F_1 generation, all plants were tall. These tall plants of F_1 generation were selfed and the ratio of tall to dwarf plants obtained was 3:1. This is called

a) Dominance b) Inheritance

c) Codominance d) Heredity

20. The dominant epistatis ratio is

a) 9:3:3:1 b) 12:3:1

c) 9:3:4 d) 9:6:1

21. Select the period for Mendel's hybridization experiments

a) 1856 - 1863 b) 1850 - 1870

c) 1857 - 1869 d) 1870 - 1877

22. Among the following characters which one was not considered by Mendel in his experimentation pea?

a) Stem – Tall or dwarf

b) Trichomal glandular or non-glandular

c) Seed – Green or yellow

d) Pod – Inflated or constricted

23. Name the seven contrasting traits of Mendel.
24. What is meant by true breeding or pure breeding lines / strain?
25. Give the names of the scientists who rediscovered Mendelism.
26. What is back cross?
27. Define Genetics.
28. What are multiple alleles
29. What are the reasons for Mendel's successes in his breeding experiment?
30. Explain the law of dominance in monohybrid cross.
31. Differentiate incomplete dominance and codominance.
32. What is meant by cytoplasmic inheritance
33. Describe dominant epistasis with an example.
34. Explain polygenic inheritance with an example.
35. Differentiate continuous variation with discontinuous variation.
36. Explain with an example how single genes affect multiple traits and alleles the phenotype of an organism.
37. Bring out the inheritance of chloroplast gene with an example.

Glossary

Alleles: Alternative forms of a gene.

Back Cross: Crosses between F_1 off-springs with either of the two parents (hybrid) are known as back cross

F_1 / First Filial Generation: The second stage of Mendel's experiment is called F_1 generation

Gene: The determinant of a characteristic of an organism (Mendelian factor). Gene symbols are underlined or italicized.

Genetic Code: The set of 64 triplets of bases (codons) corresponding to the twenty amino acids in proteins and the signals for initiation and termination of polypeptide synthesis.

Genotype: The types of alleles in a single individual is called genotype

Genome: The total complement of genes contained in a cell.

Heterozygous: Diploid organisms that have two different allels at a specific gene locus are said to be heterozygous.

Homozygous: A diploid organism in which both alleles are the same at a given gene locus is said to be homozygous.

Hybrid Vigour or Heterosis: The superiority of hybrid over either of its parents in one or more traits.

Locus: The site or position of a particular gene on a chromosome.

Phenotype: The physical expression of an individuals gene. The physical observable characteristics of an organism.

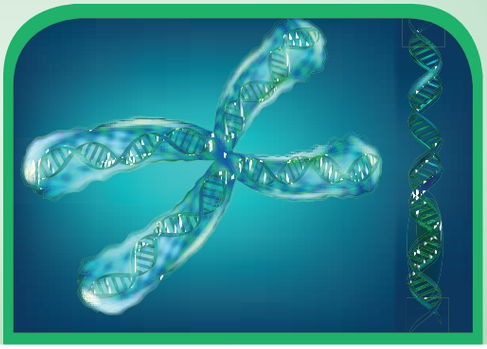
Punnett Square / Checkerboard: A sort of cross-multiplication matrix used in the prediction of the outcome of a genetic cross, in which male and female gametes and their frequencies are arranged along the edges.

Chapter

3

UNIT VII: Genetics

Chromosomal Basis of Inheritance



Learning Objectives

The Learner will be able to

- Understand chromosomal theory of inheritance.
- Analyze the three-point test crosses and appreciate results in linkage map construction.
- Describe the sex determination in plants.
- Observe and calculate recombination frequency.
- Differentiate mutation types with examples.

55LBLN

Chapter outline

3.1 Chromosomal theory of Inheritance

3.2 Linkage - Eye colour in *Drosophila* and Seed colour in Maize

3.3 Crossing over, Recombination and Gene mapping

3.4 Multiple alleles

3.5 Sex determination in plants.

3.6 Mutation-types, mutagenic agents and their significance.

In the previous chapter you have learned about Mendelian genetics, now you are going to be study with deviations of concepts related to Mendelian genetics and chromosomal theory of inheritance. You must recall the structure of chromosome and cell division from eleventh standard.

3.1 Chromosomal Theory of Inheritance

G. J. Mendel (1865) studied the inheritance of well-defined characters of pea plant but for several reasons it was unrecognized till 1900. Three scientists (de Vries, Correns and Tschermak) independently rediscovered Mendel's results on the inheritance of characters. Various cytologists also observed cell division due to advancements in microscopy. This led to the discovery of structures inside nucleus. In eukaryotic cells, worm-shaped structures formed during cell division are called **chromosomes** (colored bodies, visualized by staining). An organism which possesses two complete basic sets of chromosomes are known as diploid. A chromosome consists of long, continuous coiled piece of DNA in which genes are arranged in linear order. Each gene has a definite position (locus) on a chromosome. These genes are hereditary units. Chromosomal theory of inheritance states that Mendelian factors (genes) have specific locus (position) on chromosomes and they carry information from one generation to the next generation.

3.1.1 Historical development of chromosome theory

The important cytological findings related to the chromosome theory of inheritance are given below.

- **Wilhelm Roux (1883)** postulated that the chromosomes of a cell are responsible for transferring heredity.

- **Montgomery (1901)** was first to suggest occurrence of distinct pairs of chromosomes and he also concluded that maternal chromosomes pair with paternal chromosomes only during meiosis.
- **T. Boveri (1902)** supported the idea that the chromosomes contain genetic determiners, and he was largely responsible for developing the chromosomal theory of inheritance.
- **W.S. Sutton (1902),** a young American student independently recognized a parallelism (similarity) between the behaviour of chromosomes and Mendelian factors during gamete formation.

Sutton and **Boveri (1903)** independently proposed the chromosome theory of inheritance. Sutton united the knowledge of chromosomal segregation with Mendelian principles and called it chromosomal theory of inheritance.

3.1.2 Salient features of the Chromosomal theory of inheritance

- Somatic cells of organisms are derived from the zygote by repeated cell division (mitosis). These consist of two identical sets of chromosomes. One set is received from female parent (maternal) and the other from male parent (paternal). These two chromosomes constitute the homologous pair.
- Chromosomes retain their structural uniqueness and individuality throughout the life cycle of an organism.
- Each chromosome carries specific determiners or Mendelian factors which are now termed as genes.
- The behaviour of chromosomes during the gamete formation (meiosis) provides evidence to the fact that genes or factors are located on chromosomes.

3.1.3 Support for chromosomal theory of heredity

This theory was widely discussed and controversies by scientists around the world. However, this debate has been finally cleared by the works of **Thomas Hunt Morgan** (1910) on the fruit fly *Drosophila melanogaster* (2n=8). This fruit fly completed their life cycle within two weeks. The alleles for red or white eye colour are present on the X chromosome but there is no counterpart for this gene on the Y chromosome. Thus, females have two alleles for this gene, whereas males have only one (Figure 3.1). The genetic results were completely based on meiotic behaviour of the X and Y chromosomes. Similarly, the genes for yellow body colour and miniature wings are also carried on the X chromosome. This study strongly supports the idea that genes are located on chromosomes. The linked genes connected together on sex chromosome is called **sex linkage.**

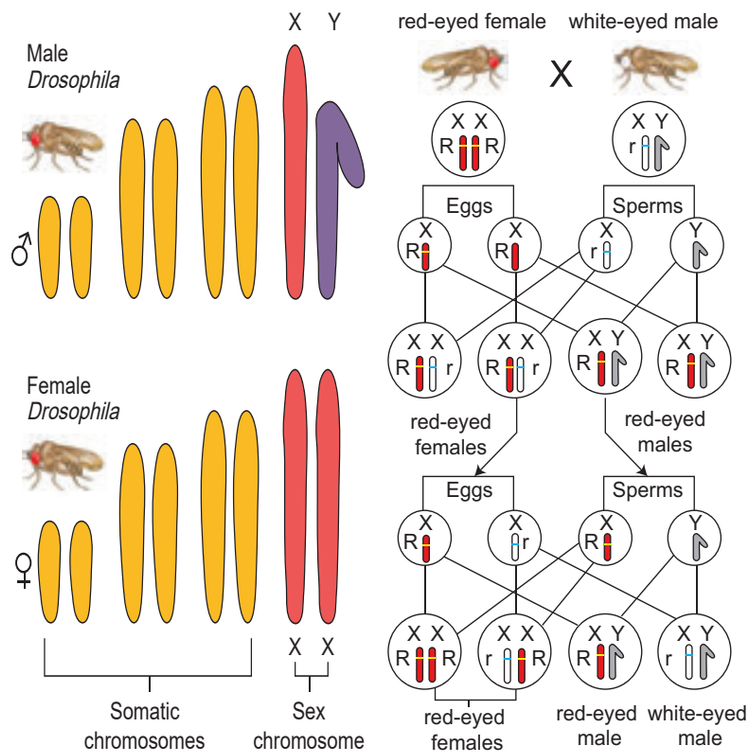


Figure 3.1: Structure of somatic and sex chromosomes in *Drosophila* and sex linkage

3.1.4 Comparison between gene and chromosome behaviour

Around twentieth century cytologists established that, generally the total number of chromosomes is constant in all cells of a species. A diploid eukaryotic cell has two haploid sets of chromosomes, one set from each parent. All somatic cells of an organism carry the same genetic complement. The behaviour of chromosomes during meiosis not only explains Mendel's principles but leads to new and different approaches to study about heredity.

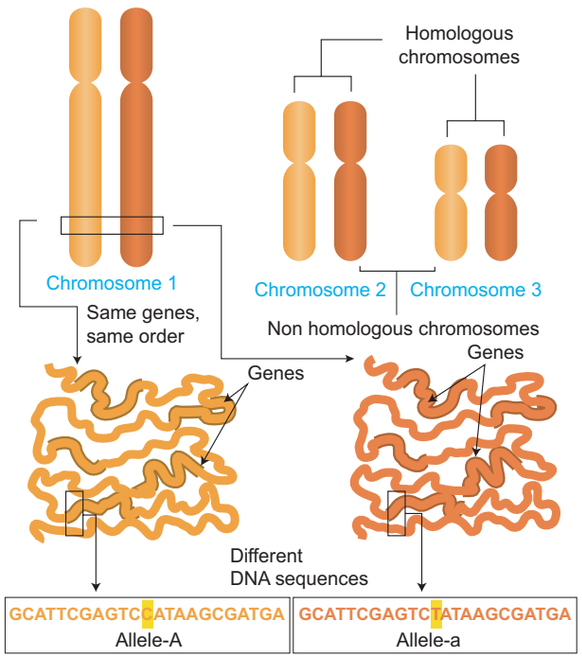


Figure 3.2: Comparison of chromosome and gene behaviour

Mendelian factors	Chromosomes behaviour
1. Alleles of a factor occur in pair	Chromosomes occur in pairs
2. Similar or dissimilar alleles of a factor separate during the gamete formation	The homologous chromosomes separate during meiosis
3. Mendelian factors can assort independently	The paired chromosomes can separate independently during meiosis but the linked genes in the same chromosome normally do not assort independently.

Table 3.1: Parallelism between Mendelian factors and chromosomal behaviour.

The important aspects to be remembered about the chromosome behaviour during cell division (meiosis) are as follows.

- The alleles of a genotype are found in the same locus of a homologous chromosome (A/a) (Figure 3.2).
- In the S phase of meiotic interphase each chromosome replicates forming two copies of each allele (AA/aa), one on each chromatid.
- The homologous chromosomes segregate in anaphase I, thereby separating two different alleles (AA) and (aa).
- In anaphase II of meiosis, separation of sister chromatids of homologous chromosomes takes place. Therefore, each daughter cell (gamete) carries only a single allele (gene) of a character (A), (A), (a) and (a).

Organism	Number of chromosomes (2n)
Adder's tongue fern (*Ophioglossum*)	1262
Horsetail *(Equisetum)*	216
Giant sequoia	22
Arabidopsis	10
Sugarcane	80
Apple	34
Rice	24
Potato	48
Maize	20
Onion	16
Haplopappus gracilis	4

Table 3.2 : Number of Chromosomes

Thomas Hunt Morgan (1933) received Nobel Prize in Physiology or Medicine for his discoveries concerning the role played by chromosomes in heredity.

Fossil Genes: Some of the junk DNA is made up of pseudo genes, the sequences presence in that was once working genes. They lost their ability to make proteins. They tell the story of evolution through fossilized parts.

3.2 Linkage

The genes which determine the character of an individual are carried by the chromosomes. The genes for different characters may be present either in the same chromosome or in different chromosomes. When the genes are present in different chromosomes, they assort independently according to Mendel's Law of Independent Assortment. Biologists came across certain genetic characteristics that did not assort out independently in other organisms after Mendel's work. One such case was reported in Sweet pea ***(Lathyrus odoratus)*** by **Willium Bateson** and **Reginald C. Punnet** in 1906. They crossed one homozygous strain of sweet peas having **purple flowers** and **long pollen grains** with another homozygous strain having **red flowers** and **round pollen grains.** All the F_1 progenies had purple flower and long pollen grains indicating purple flower long pollen **(PL/PL)** was dominant over red flower round pollen **(pl/pl).** When they crossed the F_1 with double recessive parent (test cross) in results, F_2 progenies did not exhibit in 1:1:1:1 ratio as expected with independent assortment. A greater number of F_2 plants had purple flowers and long pollen or red flowers and round pollen. So they concluded that genes for purple colour and long pollen grain and the genes for red colour and round pollen grain were found close together in the same homologous pair of chromosomes. These genes do not allow themselves to be separated. So they do not assort independently. This type of tendency of genes to stay together during separation of chromosomes is called **Linkage.**

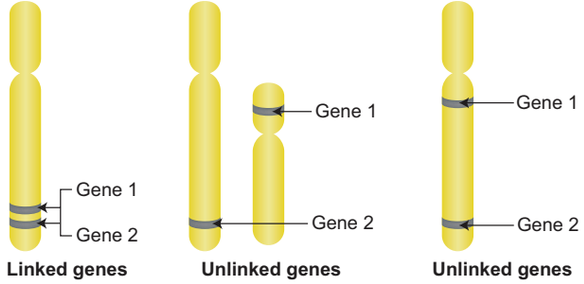


Figure 3.3: Arrangement of linked and unlinked genes on chromosome

Genes located close together on the same chromosome and inherited together are called **linked genes.** But the two genes that are sufficiently far apart on the same chromosome are called **unlinked genes or syntenic genes** (Figure 3.3). Such condition is known as **synteny**. It is to be differentiated by the value of recombination frequency. If the recombination frequency value is more than 50 % the two genes show unlinked. when the recombination frequency value is less than 50 %, they show linked. Closely located genes show strong linkage, while genes widely located show weak linkages.

3.2.1 Coupling and Repulsion theory

The two dominant alleles or recessive alleles occur in the same homologous chromosomes, tend to inherit together into same gamete are called **coupling or *cis* configuration** (Figure: 3.5). If dominant or recessive alleles are present on two different, but homologous chromosomes they inherit apart into different gamete are called **repulsion or *trans* configuration** (Figure: 3. 6)**.**

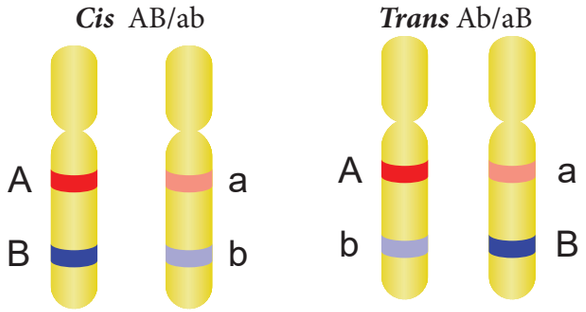


Figure 3.4: *Cis-Trans* arrangement of genes

3.2.2 Kinds of Linkage

T.H. Morgan found two types of linkage. They are complete linkage and incomplete linkage depending upon the absence or presence of new combination of linked genes.

Complete Linkage

If the chances of separation of two linked genes are not possible those genes always remain

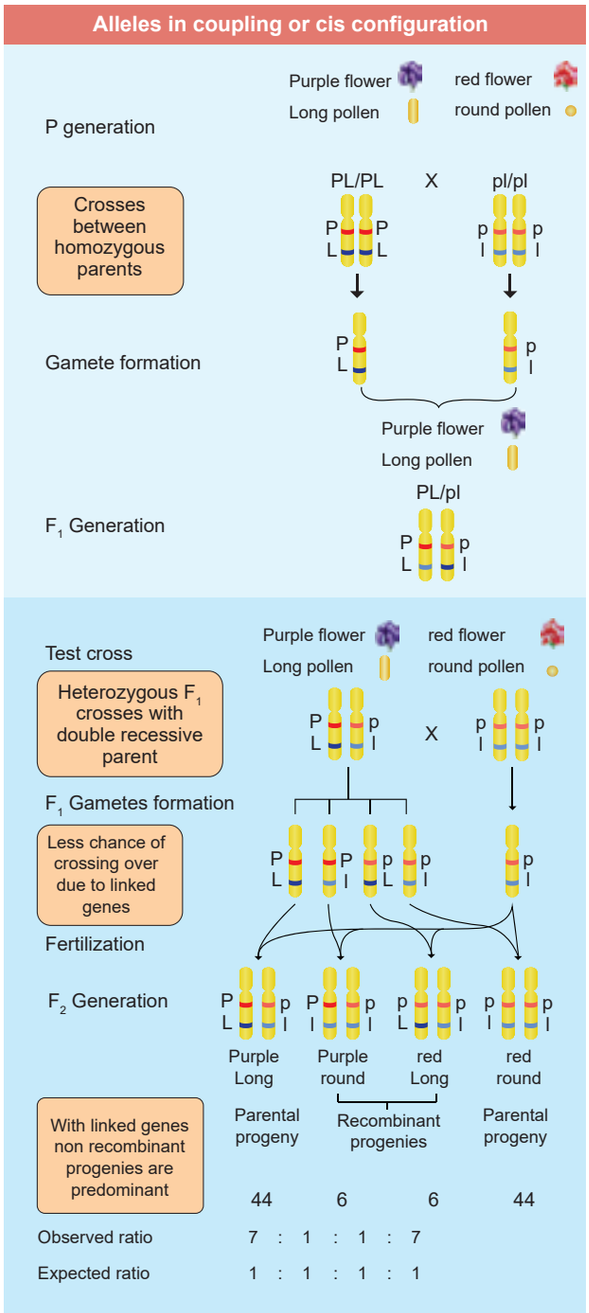


Figure 3.5: Alleles in coupling or cis configuration

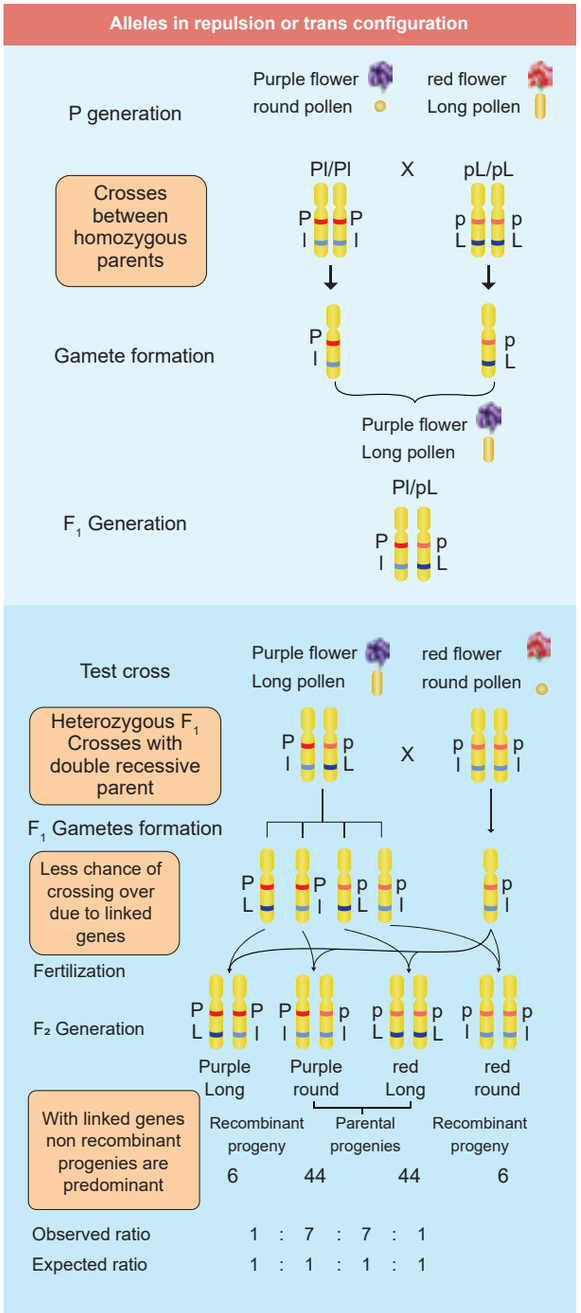


Figure 3.6: Alleles in repulsion or trans configuration

together as a result, only parental combinations are observed. The linked genes are located very close together on the same chromosome such genes do not exhibit crossing over. This phenomenon is called **complete linkage**. It is rare but has been reported in male ***Drosophila*** (Figure 3.7)**. C.B Bridges** (1919) discovered that crossing over is completely absent in some species of male ***Drosophila***.

Incomplete Linkage

If two linked genes are sufficiently apart, the chances of their separation are possible. As a result, parental and non-parental combinations are observed. The linked genes exhibit some crossing over. This phenomenon is called **incomplete linkage**. This was observed in maize. (Figure 3.8) It was reported by Hutchinson.

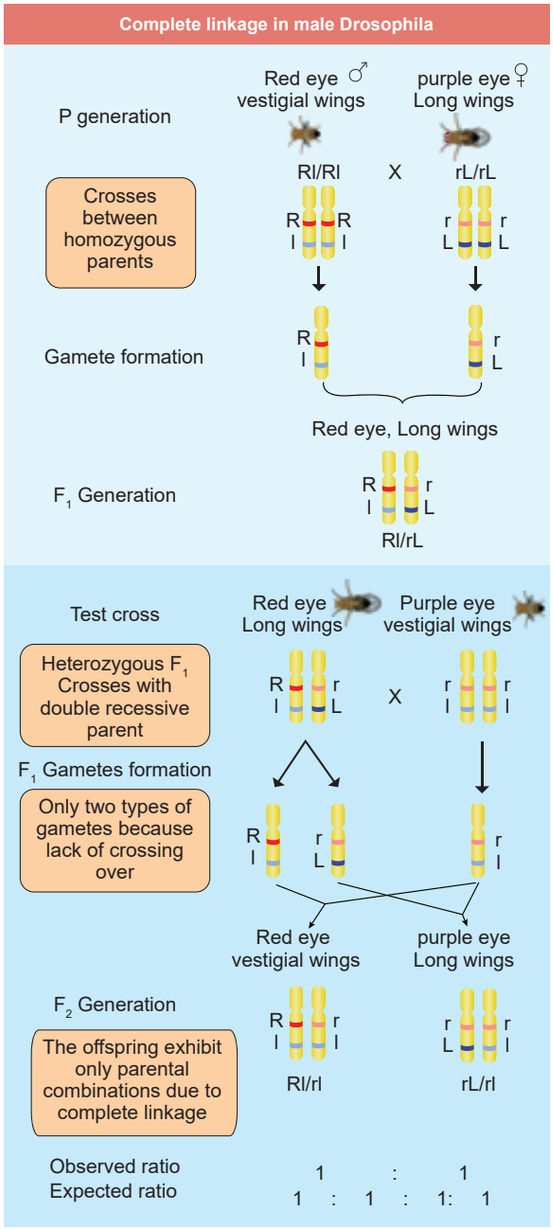


Figure 3.7: Complete linkage in male *Drosophila*

3.2.3 Linkage Groups

The groups of linearly arranged linked genes on a chromosome are called **Linkage groups**. In any species the number of linkage groups corresponds to the number haploid set of chromosomes. Example:

Name of organism	Linkage groups
Mucor	2
Drosophila	4
Sweet pea	7
Neurospora	7
Maize	10

Table 3.3 : Linkage groups in some organisms

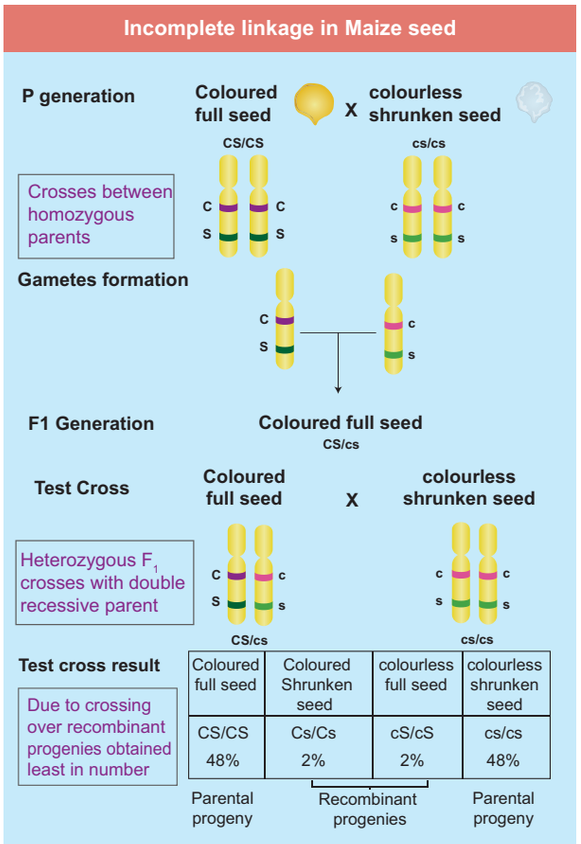


Figure 3.8: Incomplete linkage in Maize seed

Linkage and crossing over are two processes that have opposite effects. Linkage keeps particular genes together but crossing over mixes them. The differences are given below.

Linkage	Crossing over
1. The genes present on chromosome stay close together	It leads to separation of linked genes
2. It involves same chromosome of homologous chromosome	It involves exchange of segments between non-sister chromatids of homologous chromosome.
3. It reduces new gene combinations	It increases variability by forming new gene combinations. lead to formation of new organism

Table 3.4: Differences between linkage and crossing over

3.3 Crossing Over

Crossing over is a biological process that produces new combination of genes by inter-changing the corresponding segments between non-sister chromatids of homologous pair of chromosomes. The term 'crossing over' was coined by **Morgan (1912).** It takes place during pachytene stage of prophase I of meiosis. Usually crossing over occurs in germinal cells during gametogenesis. It is called meiotic or germinal crossing over. It has universal occurrence and has great significance. Rarely, crossing over occurs in somatic cells during mitosis. It is called somatic or mitotic crossing over.

3.3.1 Mechanism of Crossing Over

Crossing over is a precise process that includes stages like synapsis, tetrad formation, cross over and terminalization.

(i) Synapsis

Intimate pairing between two homologous chromosomes is initiated during zygotene stage of prophase I of meiosis I. Homologous chromosomes are aligned side by side resulting in a pair of homologous chromosomes called **bivalents**. This pairing phenomenon is called **synapsis or syndesis.** It is of three types,

1. **Procentric synapsis:** Pairing starts from middle of the chromosome.
2. **Proterminal synapsis:** Pairing starts from the telomeres.
3. **Random synapsis:** Pairing may start from anywhere.

(ii) Tetrad Formation

Each homologous chromosome of a bivalent begin to form two identical sister chromatids, which remain held together by a centromere. At this stage each bivalent has four chromatids. This stage is called **tetrad stage**.

(iii) Cross Over

After tetrad formation, crossing over occurs in pachytene stage. The non-sister chromatids of homologous pair make a contact at one or more points. These points of contact between non-sister chromatids of homologous chromosomes are called **Chiasmata** (singular-Chiasma). At chiasma, cross-shaped or X-shaped structures are formed, where breaking and rejoining of two chromatids occur. This results in reciprocal exchange of equal and corresponding segments between them. A recent study reveals that synapsis and chiasma formation are facilitated by a highly organised structure of filaments called **Synaptonemal Complex (SC)** (Figure 3.9). This synaptonemal complex formation is absent in some species of male ***Drosophila*** hence crossing over does not takes place.

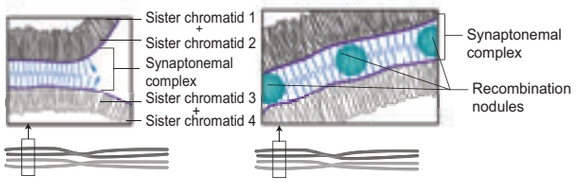


Figure 3.9: Structure of Synaptonemal Complex

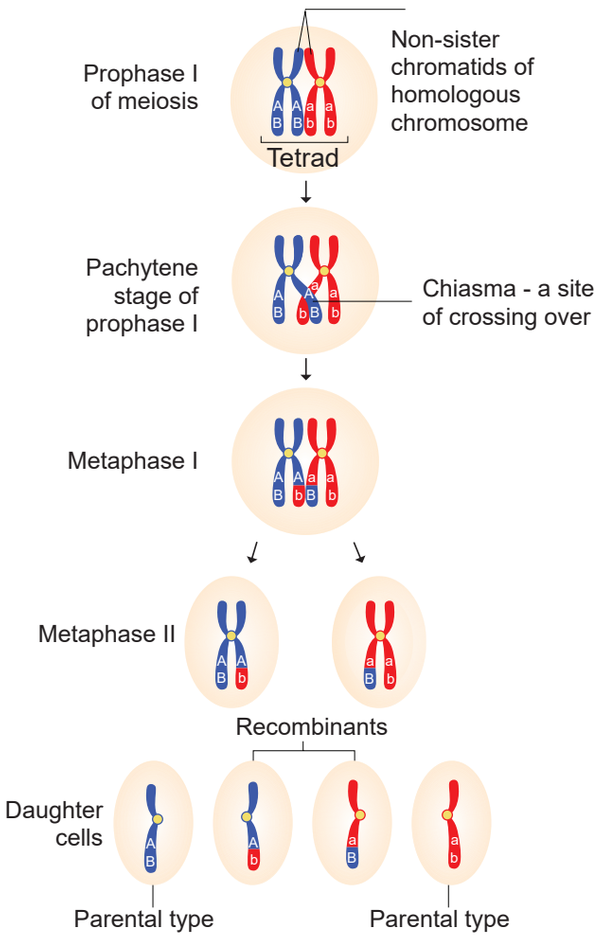


Figure 3.10: Mechanism of crossing over

(iv) Terminalisation

After crossing over, chiasma starts to move towards the terminal end of chromatids. This is known as **terminalisation**. As a result, complete separation of homologous chromosomes occurs. (Figure 4.10)

3.3.2 Types of Crossing Over

Depending upon the number of chiasmata formed crossing over may be classified into three types. (Figure 3.11)

1. **Single cross over**: Formation of single chiasma and involves only two chromatids out of four.

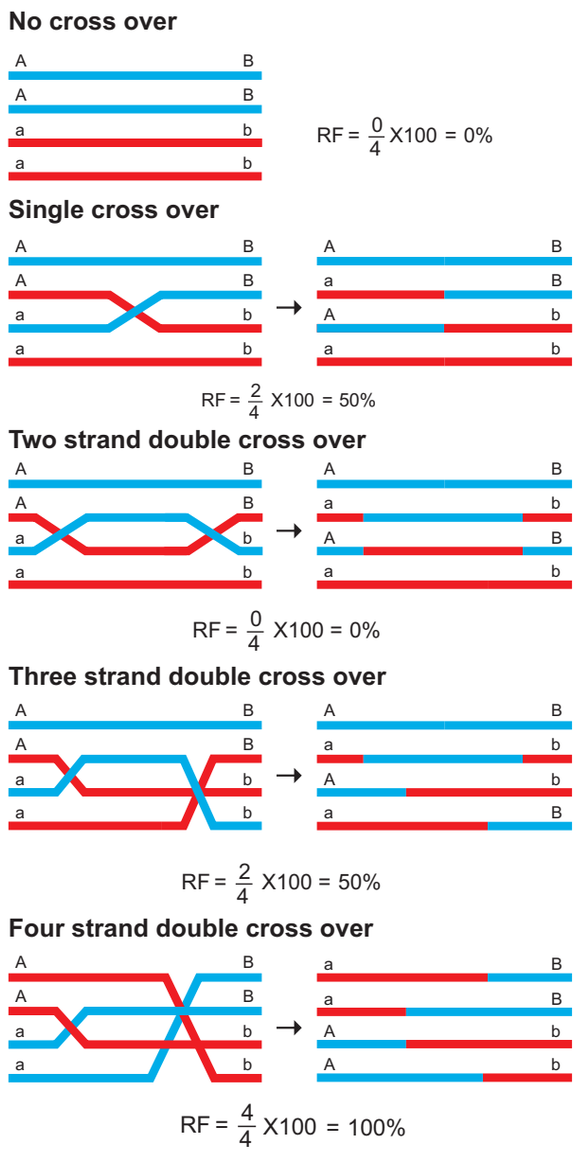


Figure 3.11: Types of crossing over and its Recombination Frequency (RF)

Activity: Solve this

Consider two hypothetical recessive autosomal genes a and b, where a heterozygote is testcrossed to a double homozygous mutant. Predict the phenotypic ratios under the following conditions:

(a) a and b are located on separate autosomes.

(b) a and b are linked on the same autosome but are so far apart that a crossover occurs between them.

(c) a and b are linked on the same autosome but are so close together that a crossover almost never occurs.

2. **Double cross over:** Formation of two chiasmata and involves two or three or all four strands
3. **Multiple cross over**: Formation of more than two chiasmata and crossing over frequency is extremely low.

3.3.3 Importance of Crossing Over

Crossing over occurs in all organisms like bacteria, yeast, fungi, higher plants and animals. Its importance is

- Exchange of segments leads to new gene combinations which plays an important role in evolution.
- Studies of crossing over reveal that genes are arranged linearly on the chromosomes.
- Genetic maps are made based on the frequency of crossing over.
- Crossing over helps to understand the nature and mechanism of gene action.
- If a useful new combination is formed it can be used in plant breeding.

3.3.4 Recombination

Crossing over results in the formation of new combination of characters in an organism called recombinants. In this, segments of DNA are broken and recombined to produce new combinations of alleles. This process is called **Recombination.** (Figure 3.12)

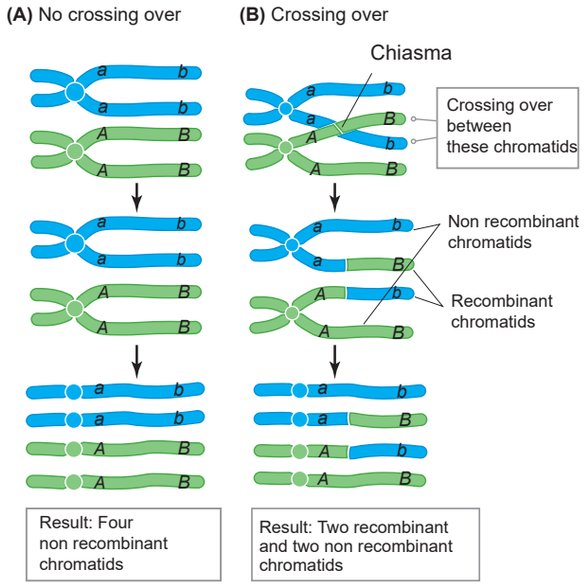


Figure 3.12 : Recombination

The widely accepted model of DNA recombination during crossing over is **Holliday's hybrid DNA model**. It was first proposed by **Robin Holliday** in 1964. It involves several steps. (Figure 3.13)

1. Homologous DNA molecules are paired side by side with their duplicated copies of DNAs
2. One strand of both DNAs cut in one place by the enzyme **endonuclease**.
3. The cut strands cross and join the homologous strands forming the **Holliday structure** or **Holliday junction**.
4. The Holliday junction migrates away from the original site, a process called **branch migration,** as a result heteroduplex region is formed.
5. DNA strands may cut along through the vertical (V) line or horizontal (H) line.
6. The vertical cut will result in heteroduplexes with recombinants.
7. The horizontal cut will result in heteroduplex with non recombinants.

Calculation of Recombination Frequency (RF)

The percentage of recombinant progeny in a cross is called recombination frequency. The recombination frequency (cross over frequency) (RF) is calculated by using the following formula. The data is obtained from alleles in coupling configuration (Figure 3.14)

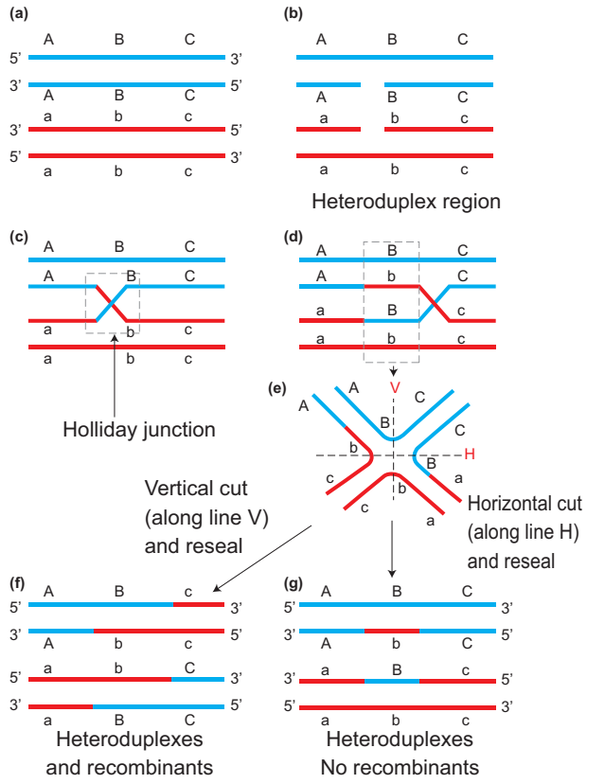


Figure 3.13: Holliday model showing Recombination

$$RF = \frac{\text{Number of recombinants}}{\text{Number of off springs}} \times 100$$

$$= \frac{6+6}{44+6+6+44} \times 100$$

$$= \frac{12}{100} \times 100$$

RF = 12%

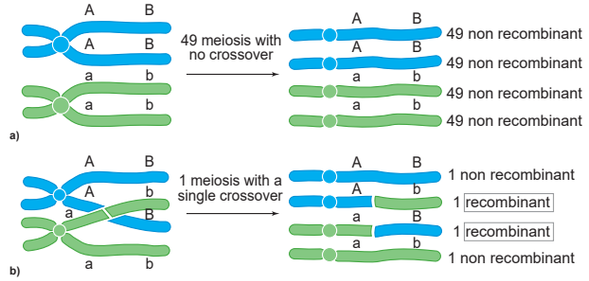


Figure 3.14 Recombination frequency observation

Check your Grasp

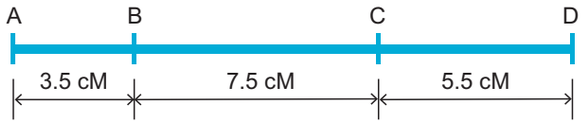
Find out Recombination frequency value from the above figure.

3.3.5 Genetic Mapping

Genes are present in a linear order along the chromosome. They are present in a specific location called **locus** (plural: loci). The diagrammatic representation of position of genes and related distances between the adjacent genes is called **genetic mapping**. It is directly proportional to the frequency of recombination between them. It is also called as **linkage map**. The concept of gene mapping was first developed by Morgan's student **Alfred H Sturtevant** in 1913. It provides clues about where the genes lies on that chromosome.

Map distance

The unit of distance in a genetic map is called a **map unit** (m.u). One map unit is equivalent to one percent of crossing over (Figure 4.). One map unit is also called a centimorgan (cM) in honour of **T.H. Morgan**. 100 centimorgan is equal to one Morgan (M). For example: A distance between A and B genes is estimated to be 3.5 map units. It is equal to 3.5 centimorgans or 3.5 % or 0.035 recombination frequency between the genes.



Genetic maps can be constructed from a series of test crosses for pairs of genes called **two point crosses**. But this is not efficient because double cross over is missed.

Three point test cross

A more efficient mapping technique is to construct based on the results of **three-point test cross**. It refers to analyzing the inheritance patterns of three alleles by test crossing a triple recessive heterozygote with a triple recessive homozygote. It enables to determine the distance between the three alleles and the order in which they are located on the chromosome. Double cross overs can be detected which will provide more accurate map distances.

Three-point test cross can be best understood by considering following an example.

In maize (corn), the three recessive alleles are

1. l for lazy or prostrate growth habit
2. g for glossy leaf
3. s for sugary endosperm

These three recessive alleles (l g s) are crossed with wild type dominant alleles (L G S).

Parents	LGS / LGS	x	lgs / lgs
Gametes	LGS	x	lgs
F_1 trihybrid	LGS / lgs		
Test cross			
(Heterozygous F_1 crosses with triple recessive alleles)			
	LGS / lgs	x	lgs / lgs

This trihybrid test cross produces 8 different types (2^3=8) of gametes in which 740 progenies are observed. The following table shows the result obtained from a test cross of corn with three linked genes.

The analysis of a three-point cross:

S. no	Phenotype of test cross progeny	Gamete types	Number of progenies
1.	Normal (wild type)	L G S	286
2.	Lazy	l G S	33
3.	Glossy	L g S	59
4.	Sugary	L G s	4
5.	Lazy, glossy	l g S	2
6.	Lazy, sugary	l G s	44
7.	Glossy, sugary	L g s	40
8.	Lazy, glossy, sugary	l g s	272
	Total		**740**

From the above result, we must be careful to observe parental (P) and recombinant (R) types. First note that parental genotypes for the triple homozygotes are L G S and l g s, then analyse two recombinant loci at a time orderly L G/ l g, L S/ l s and G S/ g s. In this any combination other than these two constitutes a recombinant (R).

Let's analyse the loci of two alleles at a time starting with L and G Since the L G and l g parental genotypes the recombinants will be L g and l G. The Recombinant frequency (RF) for these two alleles can be calculated as follows

S.no	Phenotype of test cross progeny	Gamete types	Number of progenies	Recombinant for loci		
				L and G	L and S	G and S
1.	Normal (wild type)	L G S	286			
2.	Lazy	l G S	33	R	R	
3.	Glossy	L g S	59	R		R
4.	Sugary	L G s	4		R	R
5.	Lazy, glossy	l g S	2		R	R
6.	Lazy, sugary	l G s	44	R		R
7.	Glossy, sugary	L g s	40	R	R	
8.	Lazy, glossy, sugary	l g s	272			
	Total		**740**	**176**	**79**	**109**

$$RF = \frac{\text{Total number of recombinants}}{\text{Total number of progenies}} \times 100$$

$$RF = \frac{33 + 59 + 44 + 40}{740} \times 100$$

$$RF = \frac{176}{740} \times 100$$

RF = 23.7%

For L and S loci, the recombinants are L s and l S. The Recombinant frequency (RF) will be as follows

$$RF = \frac{33 + 4 + 2 + 40}{740} \times 100$$

$$RF = \frac{79}{740} \times 100$$

RF = 10.7%

For G and S loci, the recombinants are G s and g S. The Recombinant frequency (RF) will be as follows

$$RF = \frac{59 + 4 + 2 + 44}{740} \times 100$$

$$RF = \frac{109}{740} \times 100$$

RF = 14.7%

All the loci are linked, because all the RF values are considerably less than 50%. In this L G loci show highest RF value, they must be farthest apart. Therefore, the S locus must lie between them. The order of genes should be l s g. A genetic map can be drawn as follows: (Figure 3.15)

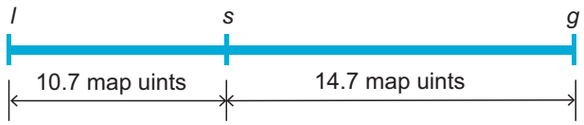


Figure: 3.15 Gene mapping

A final point note that two smaller map distances, 10.7 m.u and 14.7., is add up to 25.4 m.u., which is greater than 23.7 m.u., the distance calculated for l and g. we must identify the two least number of progenies (totaling 8) in relation to recombination of L and G. These two least progenies are double recombinants arising from double cross over. The two least progenies not only counted once should have counted each of them twice because each represents a double recombinant progeny. Hence, we can correct the value adding the numbers 33+59+44+40+4+4+2+2=188. Of the total of 740, this number exactly 25.4 %, which is identical with the sum of two component values.

The test cross parental combination can be re written as follows:

LSG / lsg x lsg / lsg

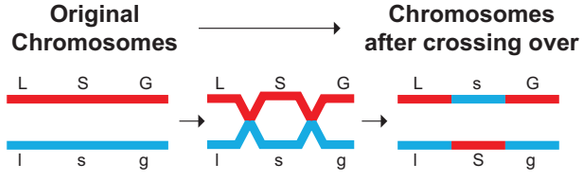


Figure: 3. 16 Gene order showing double recombinant

Uses of genetic mapping

- It is used to determine gene order, identify the locus of a gene and calculate the distances between genes.
- They are useful in predicting results of dihybrid and trihybrid crosses.
- It allows the geneticists to understand the overall genetic complexity of particular organism.

3.4 Multiple alleles

A given phenotypic trait of an individual depends on a single pair of genes, each of which occupies a specific position called the locus on homologous chromosome. When any of the three or more allelic forms of a gene occupy the same locus in a given pair of homologous chromosomes, they are said to be called **multiple alleles**.

Check your Grasp

There may be multiple alleles within the population, but individuals have only two of those alleles. Why?

3.4.1 Characteristics of multiple alleles

- Multiple alleles of a series always occupy the same locus in the homologous chromosome. Therefore, no crossing over occurs within the alleles of a series.
- Multiple alleles are always responsible for the same character.
- The wild type alleles of a series exhibit dominant character whereas mutant type will influence dominance or an intermediate phenotypic effect.
- When any two of the mutant multiple alleles are crossed the phenotype is always mutant type and not the wild type

3.4.2 Self-sterility in *Nicotiana*

In plants, multiple alleles have been reported in association with self-sterility or self-incompatibility. Self-sterility means that the pollen from a plant is unable to germinate on its own stigma and will not be able to bring about fertilization in the ovules of the same plant. **East (1925)** observed multiple alleles in ***Nicotiana*** which are responsible for self-incompatibility or self-sterility. The gene for self-incompatibility can be designated as S, which has allelic series S_1, S_2, S_3, S_4 and S_5 (Figure 3.17).

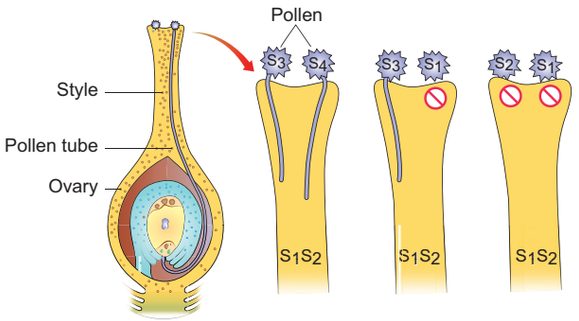


Figure: 3.17 The self-incompatibility in relation to its genotype in tobacco

The cross-fertilizing tobacco plants were not always homozygous as S_1S_1 or S_2S_2, but all plants were heterozygous as S_1S_2, S_3S_4, S_5S_6. When crosses were made between different S_1S_2 plants, the pollen tube did not develop normally. But effective pollen tube development was observed when crossing was made with other than S_1S_2 for example S_3S_4.

Female parent (Stigma spot)	**Male parent (Pollen source)**		
	S_1S_2	S_2S_3	S_3S_4
S_1S_2	Self Sterile	S_3S_2 S_3S_1	S_3S_1 S_3S_2 S_4S_1 S_4S_2
S_2S_3	S_1S_2 S_1S_3	Self Sterile	S_4S_2 S_4S_3
S_3S_4	S_1S_3 S_1S_4 S_2S_3 S_2S_4	S_2S_3 S_2S_4	Self Sterile

Table: 3.5. Different combinations of progeny in self-incompatibility

When crosses were made between seed parents with S_1S_2 and pollen parents with S_2S_3, two kinds of pollen tubes were distinguished. Pollen grains carrying S_2 were not effective, but the pollen grains carrying S_3 were capable of fertilization. Thus, from the cross $S_1S_2XS_3S_4$, all the pollens were effective and four kinds of progeny resulted: S_1S_3, S_1S_4, S_2S_3 and S_2S_4. Some combinations are showed in the table-3.5.

3.5 Sex determination in plants

About 94% of all flowering plants have only one type of individual, which produces flowers with male organs (the stamens) and female organs (the carpels). Such plants are termed as sexually **monomorphic**. Some 6% of flowering plants which have two separate sexes are called **dimorphic**. Male plants produce flowers with stamens and female plants produce flowers with carpels only. Researchers are interested to study the mechanism of sex determination in plants.**C.E. Allen (1917)** discovered sex determination in plants. Sex determination is a complex process determined by genes, the environment and hormones.

Sex determination in *Silene latifolia* (*Melandrium album*) is of controlled by three distinct regions in a sex chromosome.

1. Y chromosome determines maleness
2. X specifies femaleness
3. X and Y show different segments (I II III IV and V)

Does environment play a role on sex determination in plants?

Yes. Horsetail plant (***Equisetum***) grown under good conditions develop as female and those grown under stress condition develop into males.

3.5.1 Sex determination in papaya

Recently researchers in Hawaii discovered sex chromosomes in Papaya (***Carica papaya***, 2n=36). Papaya has 17 pairs of autosomes and one pair of sex chromosomes. Male papaya plants have XY and female plants have XX. Unlike human sex chromosomes, papaya sex chromosomes look like autosomes and it is evolved from autosome. The sex chromosomes are functionally distinct because the Y chromosome carries the genes for male organ development and X bears the female organ developmental genes (Figure 3.18).

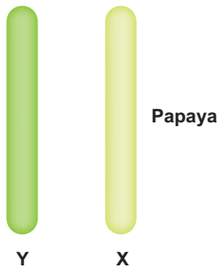


Figure 3.18 : Sex chromosome of papaya

In papaya sex determination is controlled by three alleles. They are m, M_1 and M_2 of a single gene.

Genotype	Dominant/ recessive	Modification	Sex
mm	Homozygous recessive	Restrict maleness	Female
M_1m	Heterozygous	Induces maleness	Male
M_2m	Heterozygous	Induces both the sex	Bisexual (rare)
M_1M_1 or M_2M_2 or M_1M_2	Homozygous/ Heterozygous dominant	Inviable plants	Sterile

Table 3.6 : Sex determination in Papaya

3.5.2 Sex Determination in *Sphaerocarpos*

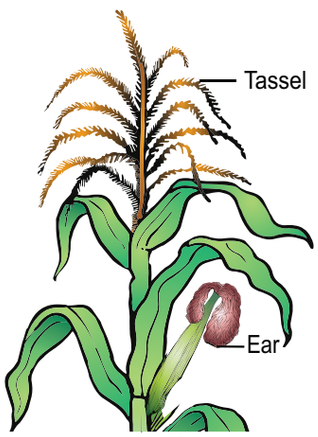
Sex determination was first described in the bryophyte ***Sphaerocarpos donnellii*** which has heteromorphic chromosomes. The gametophyte is haploid and heteromorphic. The male gametophyte as well as the female gametophyte is an haploid organism

Bottle liverwort-*Sphaerocarpus*

with 8 chromosome (n=8). The diploid sporophyte is always heterogametic. Seven autosomes are similar in both male and female gametophyte. But the eighth chromosome of female is X which is larger than the seven autosomes. The eighth chromosome of male is Y which is comparatively smaller than autosomes. The sporophyte containing XY combination produces two types of meiospores, that is some with X and others with Y chromosomes. The meiospores with X chromosomes produce female gametophyte and those with Y chromosome produces male gametophyte.

3.5.3 Sex determination in maize

Zea mays (maize) is an example for monoecious, which means male and female flowers are present on the same plant. There are two types of inflorescence. The terminal inflorescence which bears staminate florets develops from shoot apical meristem called **tassel.** The lateral inflorescence which develop pistillate florets from axillary bud is called **ear or cob.** Unisexuality in maize occurs through the selective abortion of stamens in ear florets and pistils in tassel florets. A substitution of two single gene pairs '**ba**' for barren plant and '**ts**' for tassel seed makes the difference between monoecious and dioecious (rare) maize plants. The allele for barren plant (ba) when homozygous makes the stalk staminate by eliminating silk and ears. The allele for tassel seed (ts) transforms tassel into a pistillate structure that produce no pollen. The table-3.7 is the resultant sex expression based on the combination of these alleles. Most of these mutations are shown to be defects in gibberellin biosynthesis. Gibberellins play an important role in the suppression of stamens in florets on the ears.



Inflorescence of *Zea mays*

Genotype	Dominant/ recessive	Modification	Sex
ba/ba ts/ts	Double recessive	Lacks silk on the stalk, but transformed tassel to pistil	Rudimentary female
ba/ba ts^+/ts^+	Recessive and dominant	Lacks silk and have tassel	Male
ba^+/ba^+ ts^+/ts^+	Double dominant	Have both tassel and cob	Monoecious
ba^+/ba^+ ts/ts	Dominant and recessive	Bears cob and lacks tassel	Normal female

Table 3.7: Sex determination in Maize
(Superscript (+) denotes dominant character)

3.6 Mutation

Genetic variation among individuals provides the raw material for the ultimate source of evolutionary changes. Mutation and recombination are the two major processes responsible for genetic variation. A sudden change in the genetic material of an organisms is called **mutation**. The term mutation was introduced by **Hugo de Vries** (1901) while he has studying on the plant, evening primrose (***Oenothera lamarkiana***) and proposed **'Mutation theory'**. There are two broad types of changes in genetic material. They are point mutation and chromosomal mutations.


Mutant Leaf

84RISM

Mutational events that take place within individual genes are called gene mutations or point mutation, whereas the changes occur in structure and number of chromosomes is called chromosomal mutation. Agents which are responsible for mutation are called **mutagens,** that increase the rate of mutation. Mutations can occur either spontaneously or induced. The production of mutants through exposure of mutagens is called mutagenesis, and the organism is said to be ***mutagenized.***

S.No	Basis of classification	Major types of mutations	Major features
1.	Origin	Spontaneous	Occurs in the absence of known mutagen
		Induced	Occurs in the presence of known mutagen
2.	Cell type	Somatic	Occurs in non-reproductive cells
		Germ-line	Occurs in reproductive cells
3.	Effect on function	Loss-of-function (knockout, null)	Eliminates normal function
		Hypomorphic(leaky)	Reduces normal function
		Hypermorphic	Increases normal function
		Gain-of-function (ectopic expression)	Expressed at incorrect time or inappropriate cells
4.	Molecular change	**Nucleotide substitution** • Transition	A base pair in DNA duplex is replaced with a different base pair Purine to purine(A⟶G)or pyrimidine to pyrimidine(T⟶C)
		• Transversion	Purine to pyrimidine(A⟶T) or pyrimidine to purine(C⟶G)
		• Insertion	One or more extra nucleotides are present
		• Deletion	One or more nucleotides are missing
5.	Effect on translation	• Silent (synonymous)	No change in amino acid encoded
		• Missense (non-synonymous)	Change in amino acid encoded
		• Nonsense(termination)	Creates translational termination codon (UAA, UAG, or UGA)
		• Frameshift	Shifts triplet reading of codons out of correct phase

Table 3.8: Major types of mutations

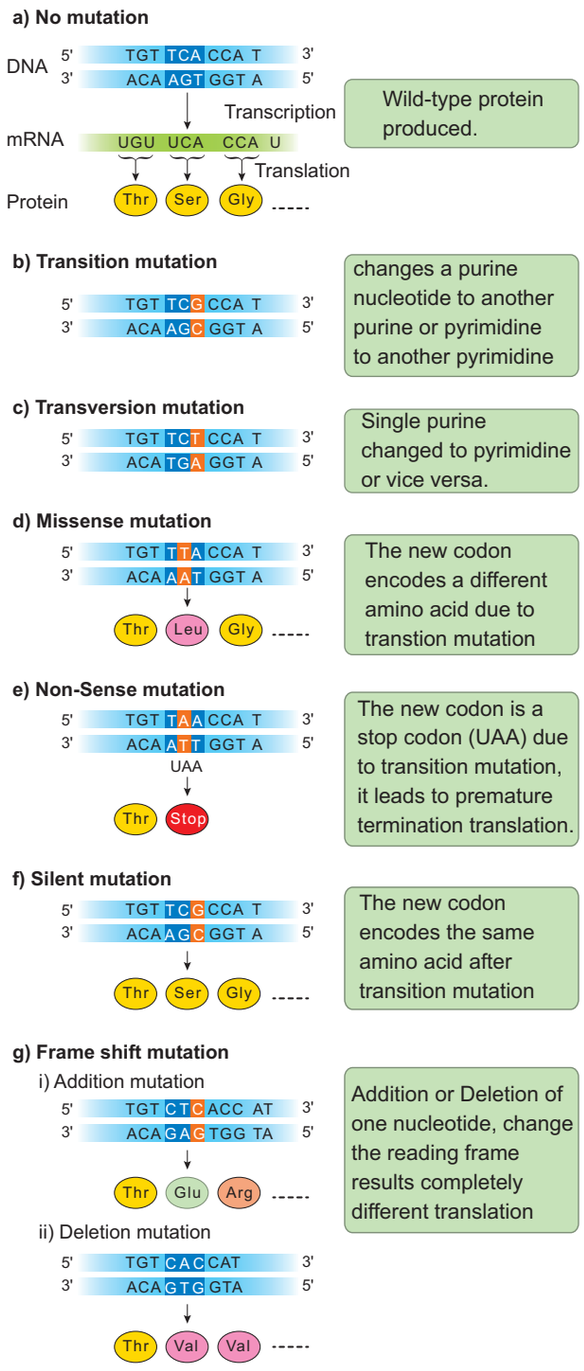


Figure: 3.19 Types of point mutation

3.6.1 Types of mutation

Let us see the two general classes of gene mutation:

- Mutations affecting single base or base pair of DNA are called point mutation
- Mutations altering the number of copies of a small repeated nucleotide sequence within a gene

Point mutation

It refers to alterations of single base pairs of DNA or of a small number of adjacent base pairs

Types of point mutations

Point mutation in DNA are categorised into two main types. They are base pair substitutions and base pair insertions or deletions. Base substitutions are mutations in which there is a change in the DNA such that one base pair is replaced by another (Figure: 3.17). It can be divided into two subtypes: transitions and transversions. Addition or deletion mutations are actually additions or deletions of nucleotide pairs and also called base pair addition or deletions. Collectively, they are termed **indel mutations** (for insertion-deletion).

Substitution mutations or indel mutations affect translation. Based on these different types of mutations are given below.

The mutation that changes one codon for an amino acid into another codon for that same amino acid are called **Synonymous or silent mutations.** The mutation where the codon for one amino acid is changed into a codon for another amino acid is called **Missense or non-synonymous mutations**. The mutations where codon for one amino acid is changed into a termination or stop codon is called **Nonsense mutation**. Mutations that result in the addition or deletion of a single base pair of DNA that changes the reading frame for the translation process as a result of which there is complete loss of normal protein structure and function are called **Frameshift mutations** (Figure: 3.19).

3.6.2 Mutagenic agents

The factors which cause genetic mutation are called **mutagenic agents or mutagens**. Mutagens are of two types, physical mutagen and chemical mutagen. **Muller** (1927) was the first to find out physical mutagen in *Drosophila*.

Physical mutagens:

Scientists are using temperature and radiations such as X rays, gamma rays, alfa rays, beta rays, neutron, cosmic rays, radioactive isotopes, ultraviolet rays as physical mutagen to produce mutation in various plants and animals.

Temperature: Increase in temperature increases the rate of mutation. While rise in temperature, breaks the hydrogen bonds between two DNA nucleotides which affects the process of replication and transcription.

Radiation: The electromagnetic spectrum contains shorter and longer wave length rays than the visible spectrum. These are classified into ionizing and non-ionizing radiation. Ionizing radiation are short wave length and carry enough higher energy to ionize electrons from atom. X rays, gamma rays, alfa rays, beta rays and cosmic rays which breaks the chromosomes (chromosomal mutation) and chromatids in irradiated cells. Non-ionizing radiation, UV rays have longer wavelengths and carry lower energy, so they have lower penetrating power than the ionizing radiations. It is used to treat unicellular microorganisms, spores, pollen grains which possess nuclei located near surface membrane.

Sharbati Sonora

Sharbati Sonora is a mutant variety of wheat, which is developed from Mexican variety (Sonora 64) by irradiating of gamma rays. It is the work of Dr. **M.S.Swaminathan** who is known as **'Father of Indian green revolution'** and his team.

Castor Aruna

Castor Aruna is mutant variety of castor which is developed by treatment of seeds with thermal neutrons in order to induce very early maturity (120 days instead of 270 days as original variety).

Chemical mutagens:

Chemicals which induce mutation are called chemical mutagens. Some chemical mutagens are mustard gas, nitrous acid, ethyl and methyl methane sulphonate (EMS and MMS), ethyl urethane, magnous salt, formaldehyde, eosin and enthrosine. Example: Nitrous oxide alters the nitrogen bases of DNA and disturb the replication and transcription that leads to the formation of incomplete and defective polypeptide during translation.

Comutagens

The compounds which are not having own mutagenic properties but can enhance the effects of known mutagens are called comutagens.

Example: Ascorbic acid increase the damage caused by hydrogen peroxide.

Caffeine increase the toxicity of methotrexate

Mustard gas (Dichloro ethyl sulphide) used as chemical weapon in world war I.

H J Muller (1928) first time used X rays to induce mutations in fruit fly.

L J Stadler reported induced mutations in plants by using X rays and gamma rays.

Chemical mutagenesis was first reported by C. Auerback (1944).

3.6.3 Chromosomal mutations

The genome can also be modified on a larger scale by altering the chromosome structure or by changing the number of chromosomes in a cell. These large-scale variations are termed as **chromosomal mutations** or **chromosomal aberrations**. Gene mutations are changes that take place within a gene, whereas chromosomal mutations are changes to a chromosome region consisting of many genes. It can be detected by microscopic examination, genetic analysis, or both. In contrast, gene mutations are never detectable microscopically. Chromosomal mutations are divided into two groups: changes in chromosome number and changes in chromosome structure.

I. Changes in chromosome number

Each cell of living organisms possesses fixed number of chromosomes. It varies in different species. Even though some species of plants and animals are having identical number of chromosomes, they will not be similar in character. Hence the number of chromosomes will not differentiate the character of species from one another but the nature of hereditary material (gene) in chromosome that determines the character of species.

Sometimes the chromosome number of somatic cells are changed due to addition or elimination of individual chromosome or basic set of chromosomes. This condition in known as **numerical chromosomal aberration** or **ploidy**. There are two types of ploidy.

(i). Ploidy involving individual chromosomes within a diploid set (**Aneuploidy**)

(ii). Ploidy involving entire sets of chromosomes (**Euploidy**) (Figure 3.20)

(i) Aneuploidy

It is a condition in which diploid number is altered either by addition or deletion of one or more chromosomes. Organisms showing aneuploidy are known as **aneuploids** or **heteroploids**. They are of two types, Hyperploidy and Hypoploidy (Figure 3.21).

1. Hyperploidy

Addition of one or more chromosomes to diploid sets are called **hyperploidy**. Diploid set of chromosomes represented as Disomy. Hyperploidy can be divided into three types. They are as follows,

(a) Trisomy

Addition of single chromosome to diploid set is called **Simple trisomy**(2n+1). Trisomics were first reported by Blackeslee (1910) in ***Datura stramonium*** (Jimson weed). But later it was reported in ***Nicotiana, Pisum*** and ***Oenothera.*** Sometimes addition of two individual chromosome from different chromosomal pairs to normal diploid sets are called **Double trisomy** (2n+1+1).

(b) Tetrasomy

Addition of a pair or two individual pairs of chromosomes to diploid set is called **tetrasomy** (2n+2) and **Double tetrasomy** (2n+2+2) respectively. All possible tetrasomics are available in Wheat.

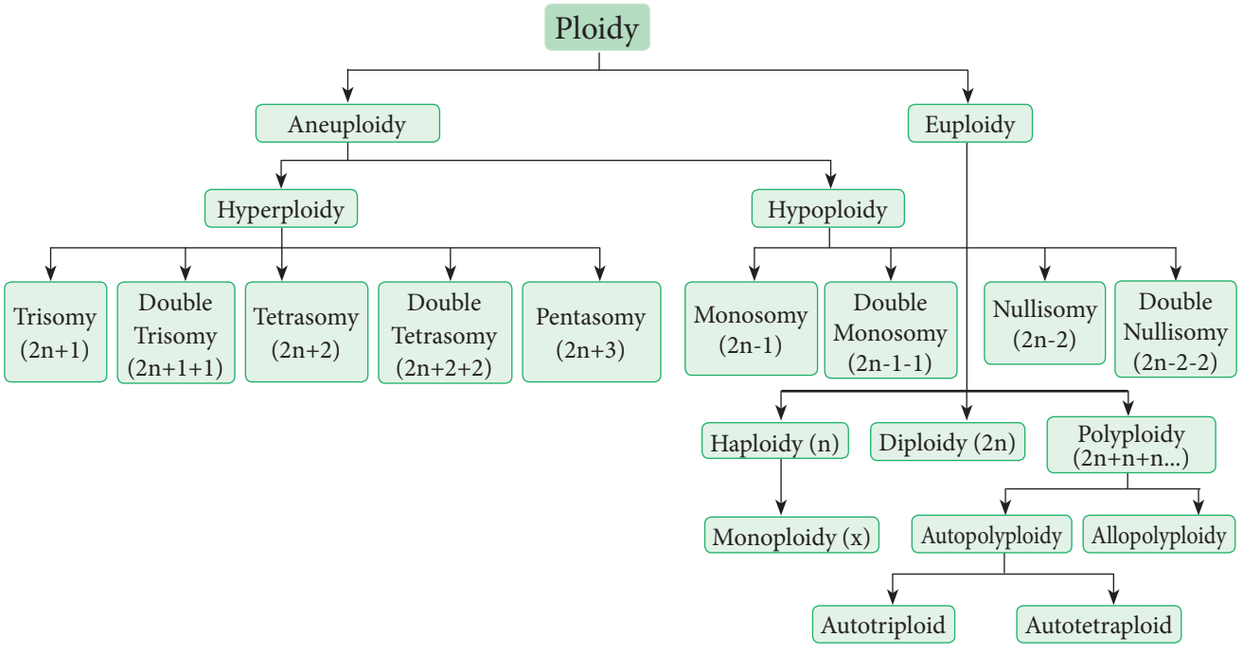


Figure 3.20 Types of Ploidy

(c) Pentasomy

Addition of three individual chromosome from different chromosomal pairs to normal diploid set are called pentasomy (2n+3).

2. Hypoploidy

Loss of one or more chromosome from the diploid set in the cell is called **hypoploidy**. It can be divided into two types. They are

(a) Monosomy

Loss of a single chromosome from the diploid set are called **monosomy**(2n-1). However loss of two individual or three individual chromosomes are called **double monosomy** (2n-1-1) and **triple monosomy** (2n-1-1-1) respectively. Double monosomics are observed in maize.

(b) Nullisomy

Loss of a pair of homologous chromosomes or two pairs of homologous chromosomes from the diploid set are called **Nullisomy** (2n-2) and **double Nullisomy** (2n-2-2) respectively. Selfing of monosomic plants produce nullisomics. They are usually lethal.

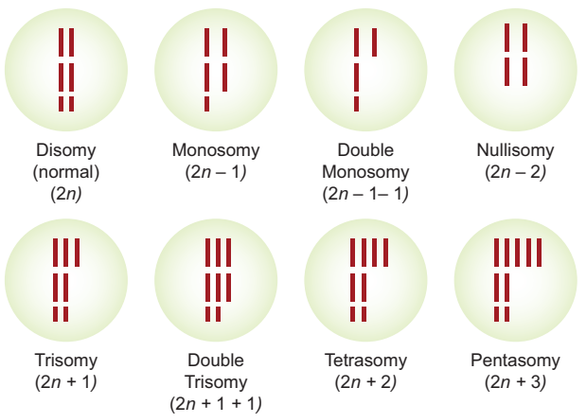


Figure 3.21 Types of aneuploidy

(ii) Euploidy

Euploidy is a condition where the organisms possess one or more basic sets of chromosomes. Euploidy is classified as monoploidy, diploidy and polyploidy. The condition where an organism or somatic cell has two sets of chromosomes are called diploid (2n). Half the number of somatic chromosomes is referred as gametic chromosome number called haploid(n). It should be noted that haploidy (n) is different from a monoploidy (x). For example, the common wheat plant is a polyploidy (hexaploidy) 2n=6x=72 chromosomes. Its haploid number (n) is 36, but its monoploidy (x) is 12. Therefore, the haploid and diploid condition came regularly one after another and the same number of chromosomes is maintained from generation to generation, but monoploidy condition occurs when an organism is under polyploidy condition. In a true diploid both the monoploid and haploid chromosome number are same. Thus a monoploid can be a haploid but all haploids cannot be a monoploid.

Polyploidy

Polyploidy is the condition where an organism possesses more than two basic sets of chromosomes. When there are three, four, five or six basic sets of chromosomes, they are called triploidy (3x) tetraploidy (4x), pentaploidy (5x) and hexaploidy (6x) respectively. Generally, polyploidy is very common in plants but rarer in animals. An increase in the number of chromosome sets has been an important factor in the origin of new plant species. But higher ploidy level leads to death. Polyploidy is of two types. They are autopolyploidy and allopolyploidy

1. Autopolyploidy

The organism which possesses more than two haploid sets of chromosomes derived from within the same species is called autopolyploid. They are divided into two types. Autotriploids and autotetraploids.

Autotriploids have three set of its own genomes. They can be produced artificially by crossing between autotetraploid and diploid species. They are highly sterile due to defective gamete formation. Example: The cultivated banana are usually triploids and are seedless having larger fruits than diploids. Triploid sugar beets have higher sugar content than diploids

and are resistant to moulds. Common doob grass (***Cyanodon dactylon***) is a natural autotriploid. Seedless watermelon, apple, sugar beet, tomato, banana are man made autotriploids.

Autotetraploids have four copies of its own genome. They may be induced by doubling the chromosomes of a diploid species. Example: rye, grapes, alfalfa, groundnut, potato and coffee.

2. Allopolyploidy

An organism which possesses two or more basic sets of chromosomes derived from two different species is called allopolyploidy. It can be developed by interspecific crosses and fertility is restored by chromosome doubling with colchicine treatment. Allopolyploids are formed between closely related species only. (Figure 3.22)

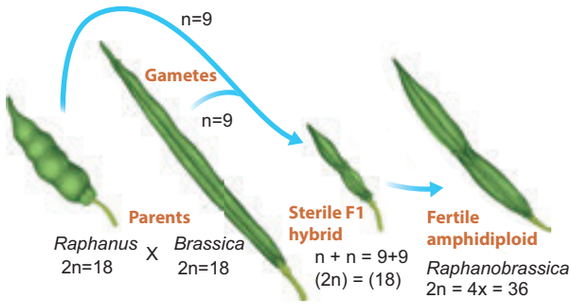


Figure 3. 22 *Rhaphanobrassica*

Example:1 ***Raphanobrassica***, **G.D. Karpechenko** (1927) a Russian geneticist, crossed the radish (***Raphanus sativus***, 2n=18) and cabbage (***Brassica oleracea***, 2n=18) to produce F_1 hybrid which was sterile. When he doubled the chromosome of F_1 hybrid he got it fertile. He expected this plant to exhibit the root of radish and the leaves like cabbage, which would make the entire plant edible, but the case was vice versa, so he was greatly disappointed.

Example: 2 **Triticale**, the successful first man made cereal. Depending on the ploidy level Triticale can be divided into three main groups.

(i). Tetraploidy: Crosses between diploid wheat and rye.

(ii). Hexaploidy: Crosses between tetraploid wheat Triticum durum (macaroni wheat) and rye

(iii). Octoploidy: Crosses between hexaploid wheat T. aestivum (bread wheat) and rye

Hexaploidy Triticale hybrid plants demonstrate characteristics of both macaroni wheat and rye. For example, they combine the high-protein content of wheat with rye's high content of the amino acid lysine, which is low in wheat. It can be explained by chart below (Figure: 3.23).

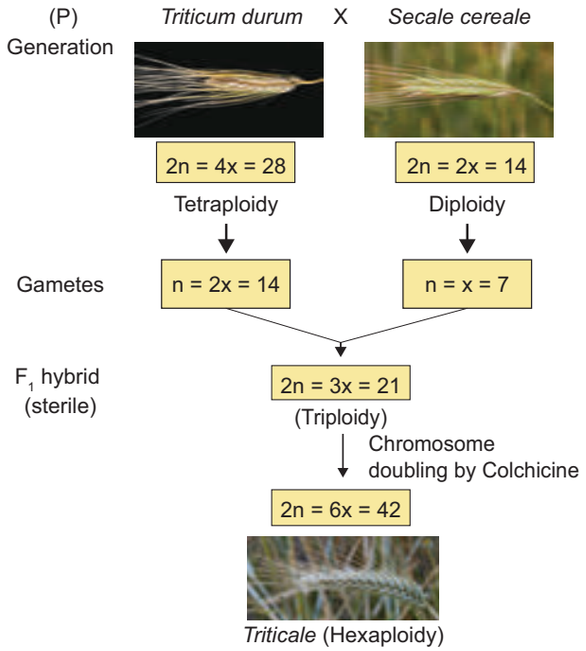


Figure 3.23 Triticale

Colchicine , an alkaloid is extracted from root and corms of ***Colchicum autumnale***, when applied in low concentration to the growing tips of the plants it will induce polyploidy. Surprisingly it does not affect the source plant *Colchicum*, due to presence of anticolchicine.

Activity: Solve this

When two plants (A and B) belonging to the same genus but different species are crossed, the F_1 hybrid is viable and has more ornate flowers. Unfortunately, this hybrid is sterile and can only be propagated by vegetative cuttings. Explain the sterility of the hybrid and what would have to occur for the sterility of this hybrid to be reversed.

Significance of Ploidy

- Many polyploids are more vigorous and more adaptable than diploids.
- Many ornamental plants are autotetraploids and have larger flower and longer flowering duration than diploids.
- Autopolyploids usually have increase in fresh weight due to more water content.
- Aneuploids are useful to determine the phenotypic effects of loss or gain of different chromosomes.
- Many angiosperms are allopolyploids and they play a role in an evolution of plants.

II Structural changes in chromosome (Structural chromosomal aberration)

Structural variations caused by addition or deletion of a part of chromosome leading to rearrangement of genes is called **structural chromosomal aberration**. It occurs due to ionizing radiation or chemical compounds. On the basis of breaks and reunion in chromosomes, there are four types of aberrations. They are classified under two groups.

A. Changes in the number of the gene loci

1. Deletion or Deficiency
2. Duplication or Repeat

B. Changes in the arrangement of gene loci

3. Inversion
4. Translocation

1. Deletion or Deficiency

Loss of a portion of chromosome is called deletion. On the basis of location of breakage on chromosome, it is divided into terminal deletion and intercalary deletion. It occurs due to chemicals, drugs and radiations. It is observed in ***Drosophila*** and Maize. (Figure 3.24)

There are two types of deletion:

i. **Terminal deletion:** Single break in any one end of the chromosome.

ii. **Intercalary deletion or interstitial deletion:** It is caused by two breaks and reunion of terminal parts leaving the middle.

Both deletions are observable during meiotic pachytene stage and polytene chromosome. The unpaired loop formed in the normal chromosomal part at the time of chromosomal pairing. Such loops are called as **deficiency loops** and it can be seen in meiotic prophase. Larger deletions may lead to lethal effect.

2. Duplication or Repeat

The process of arrangement of the same order of genes repeated more than once in the same

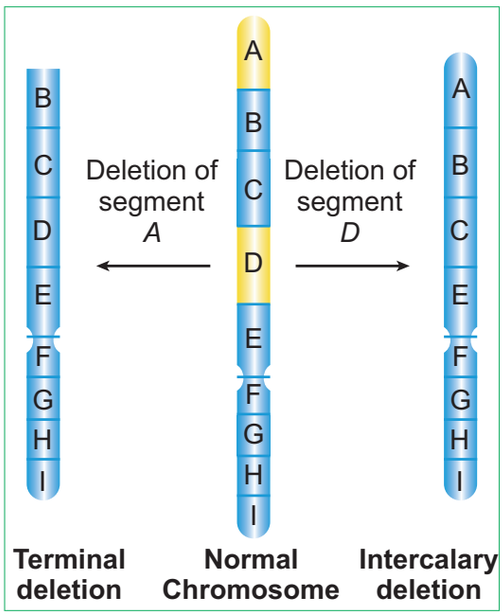


Figure 3.24 Deletion

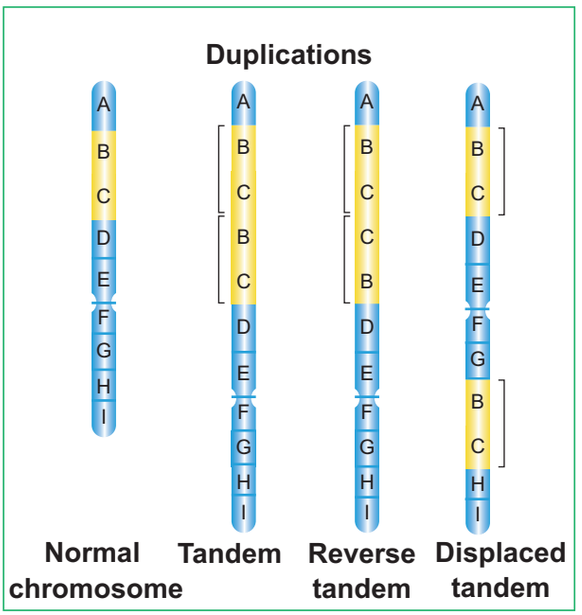


Figure 3.25 Duplication

chromosome is known as **duplication.** Due to duplication some genes are present in more than two copies. It was first reported in ***Drosophila*** by Bridges (1919) and other examples are Maize and Pea**.** It is three types.

i. Tandem duplication

The duplicated segment is located immediately after the normal segment of the chromosome in the same order.

ii. Reverse tandem duplication

The duplicated segment is located immediately after the normal segment but the gene sequence order will be reversed.

iii. Displaced duplication

The duplicated segment is located in the same chromosome, but away from the normal segment. (Figure 3.25)

Duplications play a major role in evolution.

3. Inversion

A rearrangement of order of genes in a chromosome by reversed by an angle 180^0. This involve two chromosomal breaks and reunion. During this process there is neither gain nor loss but the gene sequences is rearranged. Inversion was first reported in ***Drosophila*** by Sturtevant (1926). There are two types of inversion, paracentric and pericentric (Figure 3.26).

i. Paracentric inversion: An inversion which takes place apart from the centromere

ii. Pericentric inversion: An inversion that includes the centromere.

Inversions lead to evolution of a new species.

4. Translocation

The transfer of a segment of chromosome to a non-homologous chromosome is called translocation. Translocation should not be confused with crossing over, in which an exchange of genetic material between homologous chromosome takes place. Translocation occurs as a result of interchange of chromosome segments in non-homologous chromosomes. There are three types

i. Simple translocation

ii. Shift translocation

iii. Reciprocal translocation

i. Simple translocation

A single break is made in only one chromosome. The broken segment gets attached to one end of a non-homologous chromosome. It occurs very rarly in nature.

ii. Shift translocation

Broken segment of one chromosome gets inserted interstitially in a non-homologous chromosome.

iii. Reciprocal translocations

It involves mutual exchange of chromosomal segments between two non-homologous

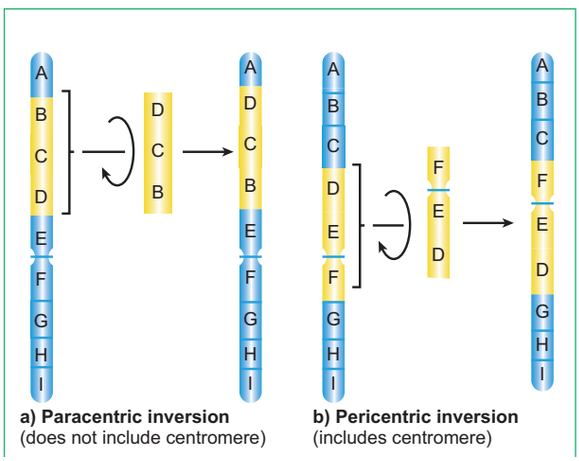


Figure 3.26 Inversion

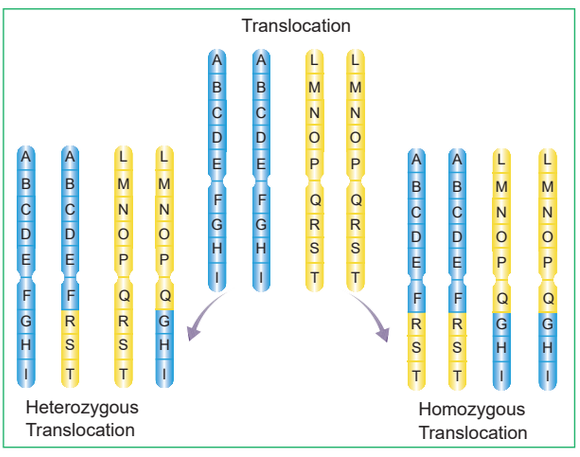


Figure: 3.27 Translocation

chromosomes. It is also called **illegitimate crossing over.** It is further divided into two types (Figure 3.27).

a. **Homozygous translocation**: Both the chromosomes of two pairs are involved in translocation. Two homologous of each translocated chromosomes are identical.

b. **Heterozygous translocation**: Only one of the chromosome from each pair of two homologous are involved in translocation, while the remaining chromosome is normal.

Translocations play a major role in the formation of species.

Summary

Chromosomal theory of inheritance states that Mendelian factors have specific locus on chromosomes and they carry information from one generation to the next generation. Genes located close together on the same chromosome and inherited together are called linked genes the phenomenon is called Linkage. Two types of linkage are complete linkage and incomplete linkage. The groups of linearly arranged linked genes are called Linkage groups. Crossing over is biological a process that produces new combination of genes by inter-changing the corresponding segments between non-sister chromatids of homologous pair of chromosomes. In this segment of DNA are broken and recombined to produce new combinations of alleles a process is called Recombination. The diagrammatic representation of distances between the adjacent genes which is directly proportional to the frequency of recombination between them is called genetic mapping. When any of the three or more allelic forms of a gene occupy the same locus in a given pair of homologous chromosomes, they are said to be multiple alleles. Papaya sex determination is controlled by three alleles. They are m, M1 and M2 of a single gene. Mutational events that take place within individual genes are called gene mutations or point mutation, whereas the changes occur in structure and number of chromosomes is called chromosomal mutation. The agents which are responsible for mutation is called mutagens.

Evaluation

B3WQYL

1. An allohexaploidy contains
   a) Six different genomes
   b) Six copies of three different genomes
   c) Two copies of three different genomes
   d) Six copies of one genome

2. The A and B genes are 10 cM apart on a chromosome. If an AB/ab heterozygote is testcrossed to ab/ab, how many of each progeny class would you expect out of 100 total progeny?
   a) 25 AB, 25 ab, 25 Ab, 25 aB
   b) 10 AB, 10 ab
   c) 45 AB, 45 ab
   d) 45 AB, 45 ab, 5 Ab, 5aB

3. Match list I with list II

List I	List II
A. A pair of chromosomes extra with diploid	i) monosomy
B. One chromosome extra to the diploid	ii) tetrasomy
C. One chromosome loses from diploid	iii) trisomy
D. Two individual chromosomes lose from diploid	iv) double monosomy

a) A-i, B-iii, C-ii, D-iv b) A-ii, B-iii, C-iv, D-i
c) A-ii, B-iii, C-i, D-iv d) A-iii, B-ii, C-i, D-iv

4. Which of the following sentences are correct?

1. The offspring exhibit only parental combinations due to incomplete linkage
2. The linked genes exhibit some crossing over in complete linkage
3. The separation of two linked genes are possible in incomplete linkage
4. Crossing over is absent in complete linkage

a) 1 and 2 b) 2 and 3
c) 3 and 4 d) 1 and 4

5. Accurate mapping of genes can be done by three point test cross because increases

a) Possibility of single cross over
b) Possibility of double cross over
c) Possibility of multiple cross over
d) Possibility of recombination frequency

6. Due to incomplete linkage in maize, the ratio of parental and recombinants are

a) 50:50 b) 7:1:1:7 c) 96.4: 3.6 d) 1:7:7:1

7. Genes **G S L H** are located on same chromosome. The recombination percentage is between L and G is 15%, S and L is 50%, H and S are 20%. The correct order of genes is

a) GHSL b) SHGL c) SGHL d) HSLG

8. The point mutation sequence for transition, transition, transversion and transversion in DNA are

a) A to T, T to A, C to G and G to C
b) A to G, C to T, C to G and T to A
c) C to G, A to G, T to A and G to A
d) G to C, A to T, T to A and C to G

9. If haploid number in a cell is 18. The double monosomic and trisomic number will be

a) 35 and 37 b) 34 and 35
c) 37 and 35 d) 17 and 19

10. Changing the codon AGC to AGA represents

a) missense mutation b) nonsense mutation
c) frameshift mutation d) deletion mutation

11. **Assertion (A):** Gamma rays are generally use to induce mutation in wheat varieties.

Reason (R): Because they carry lower energy to non-ionize electrons from atom

a) A is correct. R is correct explanation of A
b) A is correct. R is not correct explanation of A
c) A is correct. R is wrong explanation of A
d) A and R is wrong

12. How many map units separate two alleles A and B if the recombination frequency is 0.09?

a) 900 cM b) 90 cM c) 9 cM d) 0.9 cM

13. When two different genes came from same parent they tend to remain together.

i) What is the name of this phenomenon?
ii) Draw the cross with suitable example.
iii) Write the observed phenotypic ratio.

14. If you cross dominant genotype PV/PV male *Drosophila* with double recessive female and obtain F_1 hybrid. Now you cross F_1 male with double recessive female.

i) What type of linkage is seen?
ii) Draw the cross with correct genotype.
iii) What is the possible genotype in F_2 generation?

15.

S. no	Gamete types	Number of progenies
1.	ABC	349
2.	Abc	114
3.	abC	124
4.	AbC	5
5.	aBc	4
6.	aBC	116
7.	ABc	128
8.	abc	360

i) What is the name of this test cross?
ii) How will you construct gene mapping from the above given data?
iii) Find out the correct order of genes.

16. What is the difference between missense and nonsense mutation?

17. 

From the above figure identify the type of mutation and explain it.

18. Write the salient features of Sutton and Boveri concept.

19. Explain the mechanism of crossing over.

20. Write the steps involved in molecular mechanism of DNA recombination with diagram.

21. How is ***Nicotiana*** exhibit self-incompatibility. Explain its mechanism.

22. How sex is determined in monoecious plants. write their genes involved in it.

23. What is gene mapping? Write its uses.

24. Draw the diagram of different types of aneuploidy.

25. Mention the name of man-made cereal. How it is formed?

Glossary

Branch Migration: The process in which base pairs on homologous strands are consequently exchanged at a Holliday junction, moving the branch up or down the DNA sequence.

Cis configuration: The presence of dominant alleles of two or more pairs on one chromosome and the recessive alleles on the homologous chromosome.

Feminizing Masculinizing: To induce female characteristics in male To induce male characteristics in female

Heteroduplex: A double stranded molecule of nucleic acid originated through genetic recombination from different sources

Self incompatibility: A genetic mechanism which prevent self fertilization thus encourage outcross.

Synapsis: The pairing of two homologous chromosomes that occurs during meiosis.

Tassel seed: Feminization of the tassel

Trans configuration: An arrangement in which the dominant allele of one pair of genes and the recessive allele of another pair are on the same chromosome

Transesterification: A reaction that breaks and makes chemical bonds in a coordinated transfer, so that no energy is required.

Vestigial: Rudimentary organ of body become functionless in the course of evolution

Chapter

4

UNIT VIII: Biotechnology

Principles and Processes of Biotechnology

Learning Objectives

The learner will be able to

- Apply the knowledge of traditional and modern biotechnology in day to day life.
- Appreciate the uses of fermentation process.
- Acquire the knowledge on the process of genetic engineering
- Analyse the uses and limitations of genetically modified plants
- Cognize the terms of bio prospecting and bio piracy.

BIFKZX

Chapter outline

Karl Ereky

Biotechnology is the science of applied biological process. In other words it is science of development and utilization of biological processes, forms and systems for the benefit of mankind and other life forms. The term biotechnology was coined by Karl Ereky, a Hungarian Engineer in 1919. Biotechnology has been extended to include any process in which organisms, tissues, cells, organelles or isolated molecules such as enzymes are used to convert biological or other raw materials to products of greater value.

4.1 Development of Biotechnology

Biotechnology has developed by leaps and bounds during the past century. The development of the biotechnology can be well understood under two main heads namely **conventional or traditional biotechnology** and **modern biotechnology**

1. Conventional or traditional biotechnology: This is the kitchen technology developed by our ancestors, it is as old as human civilization. This technology uses bacteria and other microbes in the daily usage for preparation of dairy products like curd, ghee, cheese and in preparation of foods like idli, dosa, nan, bread and pizza. This conventional biotechnology also extends to preparation of alcoholic beverages like beer, wine, etc.

With the advancement of the science and technology during the 18th century, these kitchen technologies gained scientific validation.

2. Modern biotechnology

There are two main features of this technology, that differentiated it from the conventional technology are its i) ability to change the genetic material for getting new products with specific requirement through recombinant DNA technology ii) ownership of the newly developed technology and its social impact. Today, biotechnology is a billion dollar business around the world, pharmaceutical companies, breweries, agro industries and other biotechnology based industries apply biotechnological tools for their product improvement.

Modern biotechnology embraces all methods of genetic modification by recombinant DNA and cell fusion technology. The major focus of biotechnology are

- **Fermentation** for production of acids, enzymes, alcohols, antibiotics, fine chemicals, vitamins and toxins
- **Biomass for** bulk production of single cell protein , alcohol, and biofuel
- **Enzymes** as biosensors, in processing industry
- **Biofuels** for production of hydrogen, alcohol, methane
- **Microbial inoculants** as biofertiliser, and nitrogen fixers
- **Plant and animal cell culture** for production of secondary metabolites, monoclonal antibodies
- **Recombinant DNA technology** for production of fine chemicals, enzymes, vaccines, growth hormones, antibiotics, and interferon
- **Process engineering** – tools of biotechnology is used for effluent treatment, water recycling.

This unit will reveal the various aspects of modern biotechnology, its products and applications.

Interdisciplinarity Fields of Biotechnology

Biotechnology is one of the most important applied interdisciplinary sciences of the **21st century**. It is the trusted area that enables us to find the beneficial way of life. Biotechnology has wide applications in various sectors like agriculture, medicine, environment and commercial industries.

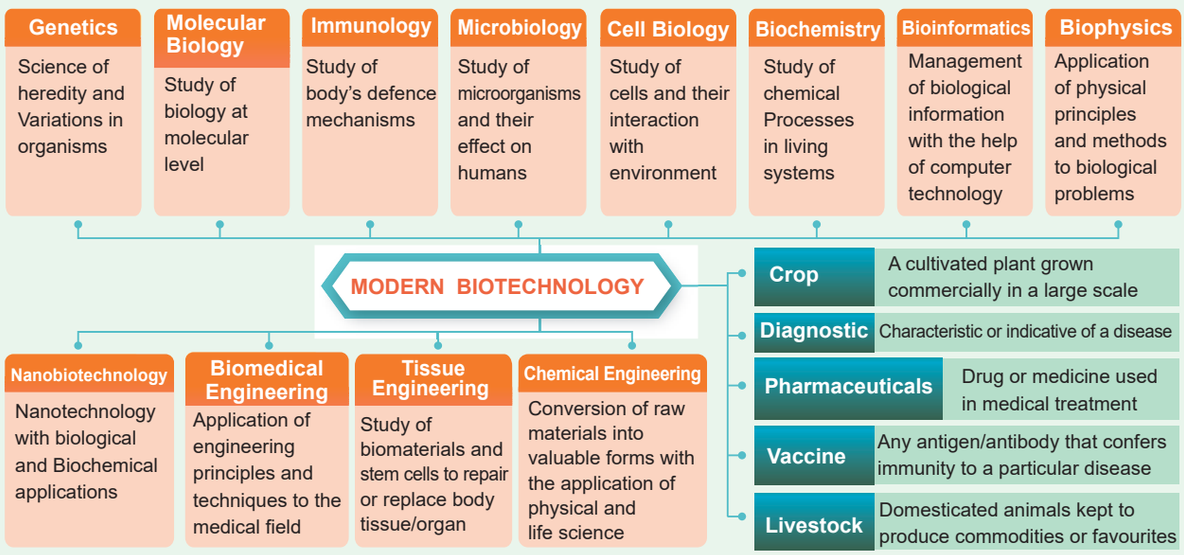


Figure 4.1: Interdisciplinarity Fields of Biotechnology

4.2 Historical Perspective

The major historical events for the development of Biotechnology, as an interdisciplinary field with multidisciplinary applications are listed below:

Before Common Era

6000 BC – 3000 BC – Bread making, fermentation of fruit juices and plant exudates to produce alcoholic beverages using yeast.

Pre – 20th Century

1770 – Antoine Lavoisier gave chemical **basis of alcoholic fermentation.**

1798 – Edward Jenner uses **first viral vaccine** to inoculate a child from smallpox.

1838 – **Protein** discovered, named and recorded by Gerardus Johannes Mulder and Jons Jacob Berzelius.

1871 – Ernst Hoppe, Seyler discovered **enzyme invertase**, which is still used for making artificial sweeteners.

1876 – Louis Pasteur identified **role of microorganisms in fermentation**.

20th Century

1919 – The **term biotechnology** was coined by Karl Ereky

1928 – **Discovery of Penicillin** by Alexander Fleming

1941 – Experiment with *Neurospora crassa* resulting in **one gene one enzyme hypothesis** by George Beadle and Edward Tatum.

1944 – Identification of **DNA as the genetic material** Avery–MacLeod–McCarty

1953 – Discovery of **double helix structure of DNA** by James Watson and Francis Crick.

1972 – Discovery of **Restriction enzymes** by Arber, Smith and Nathans.

1973 – Fragmentation of DNA-combined with Plasmid DNA, **r-DNA technology** - Genetic engineering -Modified gene by Stanley Cohen, Annie Chang, Robert Helling and Herbert Boyer.

1975 – Production of **Monoclonal antibodies** by Kohler and Milstein

1976 – Sanger and Gilbert developed **techniques to sequence DNA**

1978 – Production of **human insulin** in E.Coli

1979 – **Development of Artificial gene** – functioning within the living cells by H.G. Khorana

1982 – U.S approved **humulin** (human insulin) the first pharmaceutical product of rDNA technology, for human use.

1983 – Use of **Ti plasmids** to genetically transform plants

1986 – Development of **Polymerase Chain Reaction (PCR)** technology by Kary Mullis.

1987 – Gene transfer by **biolistic transformation**

1992 – First chromosomes of yeast is sequenced

1994 – U.S approved the first **Genetically Modified food: Flavr Savr tomato.**

1997 – The **first transgenic animal**, mammalian sheep, Dolly developed by **nuclear cloning** by Ian Wilmet.

2000 – **First plant Genome** of *Arabidopsis thaliana* sequenced

21st Century

2001 – Human genome Project creates a **draft of the human genome sequence**.

2002 – **First crop plant genome sequenced** in *Oryza sativa*

2003 – **Human genome project is completed**, providing information on the locations and sequence of human genes on all 46 chromosomes.

2010 – Sir Robert G. Edwards developed ***in vitro* fertilization in animal**.

2016 – Stem cells injected into stroke patients re-enable patient to walk – **Stem cell therapy**

2017 – **Blood stem cells** grown in lab.

2018 – James Allison and TasukuHonjo **discovered protein found in immune cells.** This found a new role in cancer therapy.

4.3. Traditional Biotechnology

As described earlier, it is the kitchen technology developed by our ancestors that was using the fermenting bacteria. Thus it includes the process that is based on the natural capabilities of organisms.

4.3.1 Fermentation

The word fermentation is derived from the Latin verb 'fervere' which means ' to boil'. Fermentation refers to the metabolic process in which organic molecules (normally glucose) are converted into acids, gases, or alcohol in the absence of oxygen or any electron transport chain. The study of fermentation, its practical uses is called zymology and originated in 1856, when French chemist Louis Pasteur demonstrated that fermentation was caused by yeast. Fermentation occurs in certain types of bacteria and fungi that require an oxygen-free environment to live. The processes of fermentation are valuable to the food and beverage industries, with the conversion of sugar into ethanol to produce alcoholic beverages, the release of CO2 by yeast used in the leavening of bread, and with the production of organic acids to preserve and flavor vegetables and dairy products.

Bioreactor (Fermentor)

Bioreactor (Fermentor) is a vessel or a container that is designed in such a way that it can provide an optimum environment in which microorganisms or their enzymes interact with a substrate to produce the required product. In the bioreactor aeration, agitation, temperature and pH are controlled. Fermentation involves two process namely upstream and downstream process.

i. Upstream process

All the process before starting of the fermenter such as sterilization of the fermenter, preparation and sterilization of culture medium and growth of the suitable inoculum are called upstream process.

ii. Downstream process

All the process after the fermentation process is known as the downstream process. This process includes distillation, centrifuging, filtration and solvent extraction. Mostly this process involves the purification of the desired product.

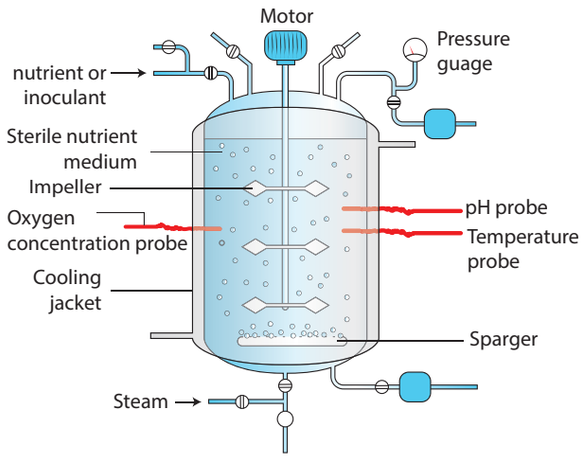


Figure 4.2: Bioreactor

Procedure of Fermentation

a. Depending upon the type of product, bioreactor is selected.

b. A suitable substrate in liquid media is added at a specific temperature, pH and then diluted.

c. The organism (microbe, animal/plant cell, sub-cellular organelle or enzyme) is added to it.

d. Then it is incubated at a specific temperature for the specified time.

e. The incubation may either be aerobic or anaerobic.

f. Withdrawal of product using downstream processing methods

Application of fermentation in industries

Fermentation has industrial application such as:

1. Microbial biomass production

Microbial cells (biomass) like algae, bacteria, yeast, fungi are grown, dried and used as source of a complete protein called

'single cell protein (SCP)' which serves as human food or animal feed.

2. Microbial metabolites

Microbes produce compounds that are very useful to man and animals. These compounds are called metabolites, can be grouped into two categories:

a. **Primary metabolites:** Metabolites produced for the maintenance of life process of microbes are known as primary metabolites Eg. Ethanol, citric, acid, lactic acid, acetic acid.

b. **Secondary metabolites:** Secondary metabolites are those which are not required for the vital life process of microbes, but have value added nature, this includes antibiotics e.g -Amphotericin-B (*Streptomyces nodosus*), Penicillin (*Penicillium chryosogenum*) Streptomycin (*S. grises*) , Tetracycline (*S. aureofacins*), alkaloids, toxic pigments, vitamins etc.

3. Microbial enzymes

When microbes are cultured, they secrete some enzymes into the growth media. These enzymes are industrially used in detergents, food processing, brewing and pharmaceuticals. Eg. protease, amylase, isomerase, and lipase.

4. Bioconversion, biotransformation or modification of the substrate

The fermenting microbes has the capacity to produce valuable products, eg. conversion of ethanol to acetic acid (vinegar), isopropanol to acetone, sorbitol to sorbose (this is used in the manufacture of vitamin C), sterols to steroids.

4.3.2 Single Cell Protein (SCP)

Single cell proteins are dried cells of microorganism that are used as protein supplement in human foods or animal feeds. Single Cell Protein (SCP) offers an unconventional but plausible solution to protein deficiency faced by the entire humanity. Although single cell protein has high nutritive value due to their higher protein, vitamin, essential amino acids and lipid content, there are doubts on whether it could replace conventional protein sources due to their high nucleic acid content and slower in digestibility. Microorganisms used for the production of Single Cell Protein are as follows:

- Bacteria - *Methylophilus methylotrophus, Cellulomonas, Alcaligenes*
- Fungi - *Agaricus campestris, Saccharomyces cerevisiae* (yeast), *Candida utilis*
- Algae - *Spirulina, Chlorella, Chlamydomonas*

The single cell proteins forms an important source of food because of their protein content, carbohydrates, fats, vitamins and minerals. It is used by Astronauts and Antarctica expedition scientists.

Spirulina can be grown easily on materials like waste water from potato processing plants (containing starch), straw, molasses, animal manure and even sewage, to produce large quantities and can serve as food rich in protein, minerals, fats, carbohydrate and vitamins. Such utilization also reduces environmental pollution. 250 g of *Methylophilus methylotrophus*, as its high rate of biomass production and growth, can be expected to produce 25 tonnes of protein.

Figure 4.3: *Spirulina* products

Applications of Single-Cell Protein

- It is used as protein supplement
- It is used in cosmetics products for healthy hair and skin
- It is used in poultry as the excellent source of proteins and other nutrients, it is widely used for feeding cattle, birds, fishes etc.

- It is used in food industry as aroma carriers, vitamin carrier, emulsifying agents to improve the nutritive value of baked products, in soups, in ready-to-serve-meals, in diet recipes
- It is used in industries like paper processing, leather processing as foam stabilizers.

4.4 Advancements in Modern Biotechnology

The modern biotechnology embraces all the genetic manipulations, protoplasmic fusion techniques and the improvements made in the old biotechnological processes. Some of the major advancements in modern biotechnology are described below.

4.4.1 Genetic Engineering

Genetic engineering or recombinant DNA technology or gene cloning is a collective term that includes different experimental protocols resulting in the modification and transfer of DNA from one organism to another.

The definition for conventional recombination was already given in Unit II. Conventional recombination involves exchange or recombination of genes between homologous chromosomes during meiosis. Recombination carried out artificially using modern technology is called recombinant DNA technology (r-DNA technology). It is also known as gene manipulation technique. This technique involves the transfer of DNA coding for a specific gene from one organism into another organism using specific agents like vectors or using instruments like electroporation, gene gun, liposome mediated, chemical mediated transfers and microinjection.

4.4.2 Steps involved in Recombinant DNA Technology

The steps involved in recombinant DNA technology are:

- Isolation of a DNA fragment containing a gene of interest that needs to be cloned. This is called an **insert**.
- Generation of recombinant DNA (rDNA) molecule by insertion of the DNA fragment into a carrier molecule called a **vector** that can self-replicate within the host cell.
- Selection of the transformed host cells that is carrying the rDNA and allowing them to multiply thereby multiplying the rDNA molecule.

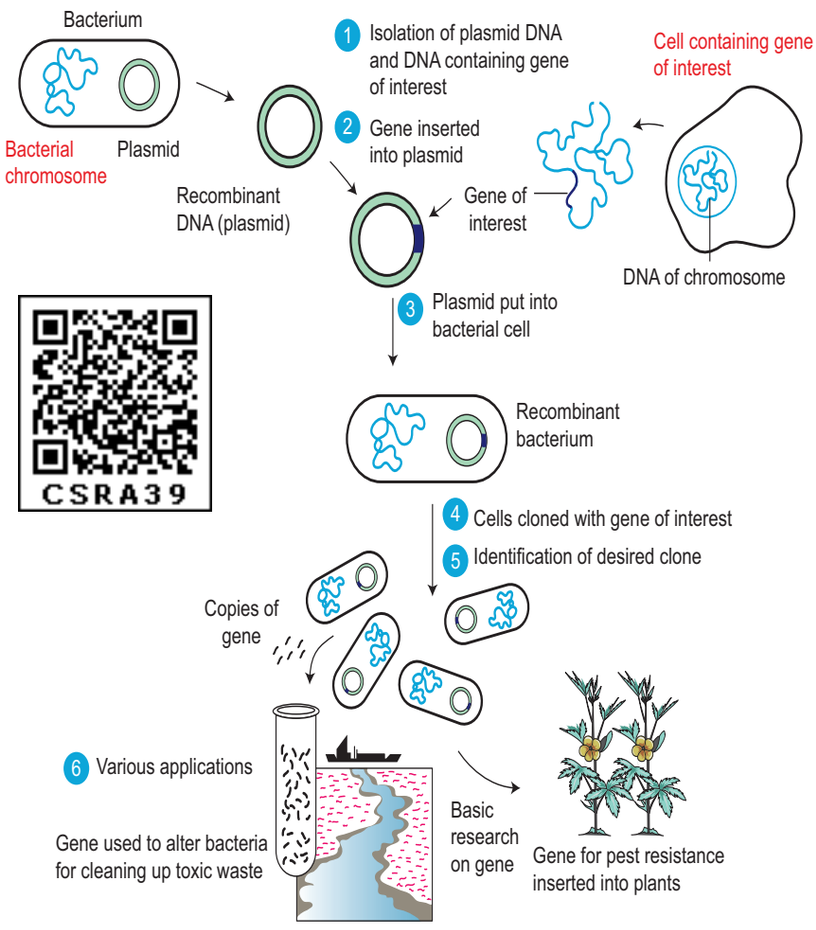


Figure 4.4: Steps involved in r-DNA Technology

- The entire process thus generates either a large amount of rDNA or a large amount of protein expressed by the insert.
- Wherever vectors are not involved the desired gene is multiplied by PCR technique. The multiple copies are injected into the host cell protoplast or it is shot into the host cell protoplast by shot gun method.

PCR: Polymerase Chain Reaction is a common laboratory technique used to make copies (millions) of a particular region of DNA.

4.5 Tools for Genetic Engineering

Now we know from the foregoing discussion that in order to generate recombinant DNA molecule, certain basic tools are necessary for the process. The basic tools are enzymes, vectors and host organisms. The most important enzymes required for genetic engineering are the restriction enzymes, DNA ligase and alkaline phosphatase.

4.5.1 Restriction Enzymes

The two enzymes responsible for restricting the growth of bacteriophage in Escherichia coli were isolated in the year 1963. One was the enzyme which added methyl groups to DNA, while the other cut DNA. The later was called restriction endonuclease. A **restriction** enzyme or **restriction endonuclease** is an enzyme that cleaves DNA into fragments at or near specific recognition sites within the molecule known as **restriction** sites. Based on their mode of action restriction enzymes are classified into Exonucleases and Endonucleases.

a. Exonucleases are enzymes which remove nucleotides one at a time from the end of a DNA molecule. e.g. Bal 31, Exonuclease III.

b. Endonucleases are enzymes which break the internal phosphodiester bonds within a DNA molecule. e.g. Hind II, EcoRI, Pvul, BamHI, TaqI.

Restriction endonuclease: Molecular scissors

The restriction enzymes are called as molecular scissors. These act as foundation of recombinant DNA technology. These enzymes exist in many bacteria where they function as a part of their defence mechanism called restriction-modification system.

There are three main classes of restriction endonuclease : Type I, Type II and Type III, which differ slightly by their mode of action. Only type II enzyme is preferred for use in recombinant DNA technology as they recognise and cut DNA within a specific sequence typically consisting of 4-8 bp. Examples of certain enzymes are given in table 5.1.

The restriction enzyme ***Hind II*** always cut DNA molecules at a point of recognising a specific sequence of six base pairs. This sequence is known s recognition sequence. Today more than 900 restriction enzymes that have been isolated from over 230 strains of bacteria with different recognition sequences.

Restriction endonucleases are named by a standard procedure. The first letter of the enzymes indicates the genus name, followed by the first two letters of the species, then comes the strain of the organism and finally a roman numeral indicating the order of discovery. For example, ***EcoRI*** is from Escherichia (**E**)

Restriction enzyme	Microbial source	Recognition sequence	Fragments
Alu I	Arthrobacter luteus	5'AG/CT3' 3'TC/GA5'	A-G C-T T-C G-A Blunt ends
BamHI	Bacillus amyloliquefaciens	5'G/GATCC3' 3'CCTAG/G5'	G G-A-T-C-C C-C-T-A-G G Sticky ends
EcoRI	Escherichia coli	5'G/AATTC3' 3'CCTAG/G5'	G A-A-T-T-C C-T-T-A-A G Sticky ends
HaeIII	Haemophilus aegyptus	5'GG/CC3' 3'CC/GG5'	G-G C-C C-C G-G Blunt ends
HindIII	Haemophilus influenza	5'A/AGCTT3' 3'TTCGA/A5'	A A-G-C-T-T T-T-C-G-A A Sticky ends

Table 4.1: Type II restriction enzyme with source, recognition and cleavage site.

coli (**co**), strain RY 13 (**R**) and first endonuclease (**I**) to be discovered.

It contains 2 different antibiotic resistance genes and recognition site for several restriction enzymes. This sequence is referred to as a restriction site and is generally –palindromic which means that the sequence in both DNA strands at this site read same in 5' – 3' direction and in the 3'-5' direction

Example: MALAYALAM: This phrase is read the same in either of the directions.

Palindromic repeats: A symmetrical repeated sequence in DNA strands

5' ... CATTATATAATG ... 3'

3' ... GTAATATATTAC ... 5'

Note: That the sequence of the base pairs in the reverse direction when compare to the first sequence.

The exact kind of cleavage produced by a restriction enzyme is important in the design of a gene cloning experiment. Some cleave both strands of DNA through the centre resulting in **blunt** or **flush end**. These are known as symmetric cuts. Some enzymes cut in a way producing protruding and recessed ends known as **sticky** or **cohesive end**. Such cut are called staggered or asymmetric cuts.

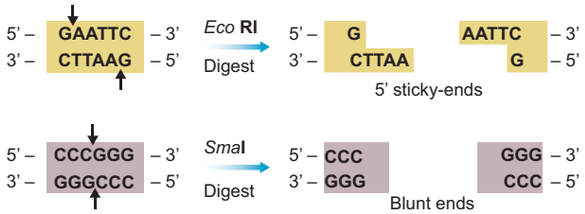


Figure 4.5: Sticky and Blunt ends

Two other enzymes that play an important role in recombinant DNA technology are DNA ligase and alkaline phosphatase

4.5.2 DNA Ligase

DNA ligase enzyme joins the sugar and phosphate molecules of double stranded DNA (dsDNA) with 5'-PO_4 and a 3'-OH in

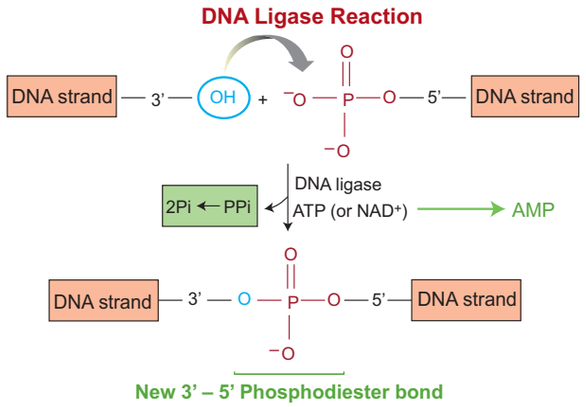


Figure 4.6: DNA ligase reaction

an Adenosine Triphosphate (ATP) dependent reaction. This is isolated from T4 phage.

4.5.3 Alkaline Phosphatase

It is a DNA modifying enzymes and adds or removes specific phosphate group at 5' terminus of double stranded DNA (dsDNA) or single stranded DNA (ssDNA) or RNA. Thus it prevents self ligation. This enzyme is purified from bacteria and calf intestine.

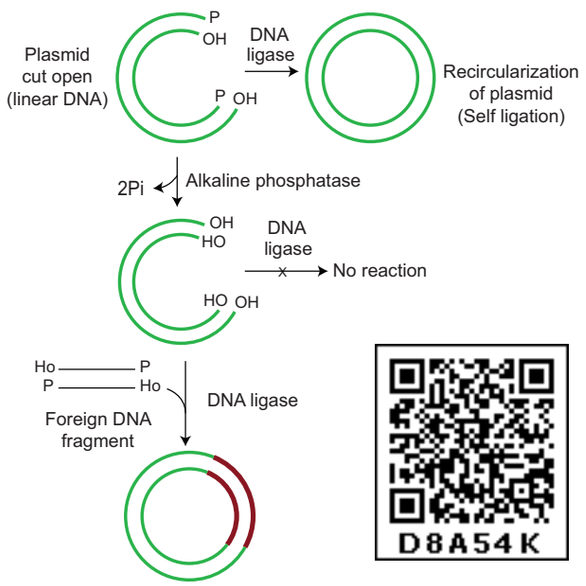
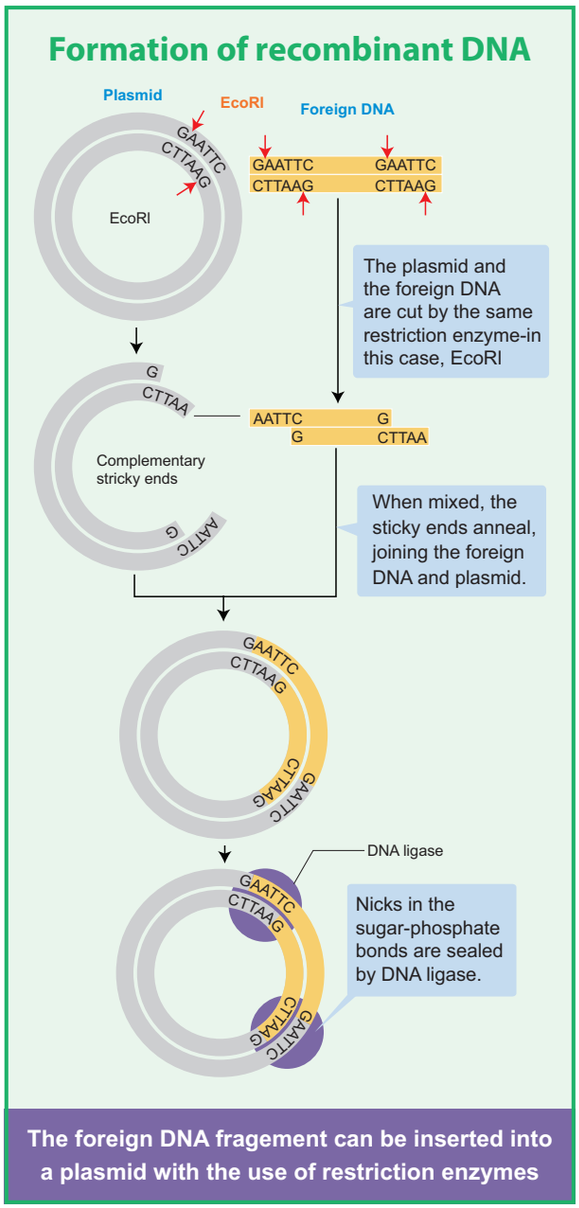


Figure 4.7: Action of Alkaline Phosphatase

4.5.4 Vectors

Another major component of a gene cloning experiment is a vector such as a plasmid. A Vector is a small DNA molecule capable of self-replication and is used as a carrier and transporter of DNA fragment which is inserted



The foreign DNA fragement can be inserted into a plasmid with the use of restriction enzymes

into it for cloning experiments. Vector is also called **cloning vehicle** or **cloning DNA**. Vectors are of two types: i) Cloning Vector, and ii) Expression Vector. Cloning vector is used for the cloning of DNA insert inside the suitable host cell. Expression vector is used to express the DNA insert for producing specific protein inside the host.

Properties of Vectors

Vectors are able to replicate autonomously to produce multiple copies of them along with their DNA insert in the host cell.

- It should be small in size and of low molecular weight, less than 10 Kb (kilo base pair) in size so that entry/transfer into host cell is easy.
- Vector must contain an origin of replication so that it can independetly replicate within the host.
- It should contain a suitable marker such as antibiotic resistance, to permit its detection in transformed host cell.
- Vector should have unique target sites for integration with DNA insert and should have the ability to integrate with DNA insert it carries into the genome of the host cell. Most of the commonly used cloning vectors have more than one restriction site. These are Multiple Cloning Site (MCS) or polylinker. Presence of MCS facilitates the use of restriction enzyme of choice.

The following are the features that are required to facilitate cloning into a vector.

1. **Origin of replication (ori):** This is a sequence from where replication starts and piece of DNA when linked to this sequence can be made to replicate within the host cells.

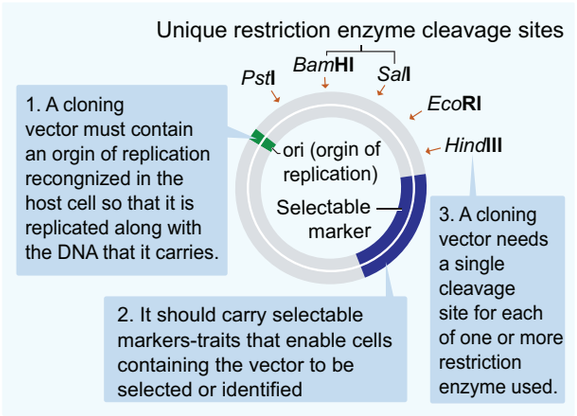


Figure 4.8: Properties of Vector

2. **Selectable marker**: In addition to **ori** the vector requires a selectable marker, which helps in identifying and eliminating non transformants and selectively permitting the growth of the transformants.
3. **Cloning sites**: In order to link the alien DNA, the vector needs to have very few, preferably single, recognition sites for the commonly used restriction enzymes.

Types of vector

Few types of vectors are discussed in detail below:

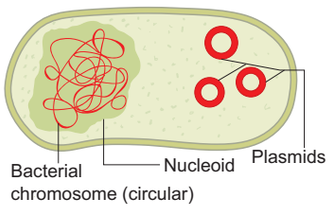


Figure 4.9: Bacterial chromosome and plasmids

Plasmid

Plasmids are extra chromosomal, self replicating ds circular DNA molecules, found in the bacterial cells in addition to the bacterial chromosome. Plasmids contain Genetic information for their own replication.

pBR 322 Plasmid

pBR 322 plasmid is a reconstructed plasmid and most widely used as cloning vector; it contains 4361 base pairs. In pBR, ***p*** denotes plasmid, ***B***and ***R*** respectively the names of scientist **B**oliver and **R**odriguez who developed this plasmid. The number **322** is the number of plasmid developed from their laboratory. It contains amp^R and tet^R two different antibiotic resistance genes and recognition sites for several restriction enzymes. (*Hind III, EcoRI, BamH I, Sal I, Pvu II, Pst I, Cla I*), ori and antibiotic resistance genes. Rop codes for the proteins involved in the replication of the plasmid.

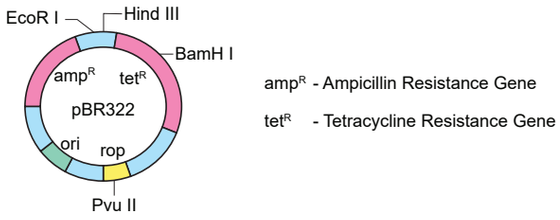


Figure 4.10: pBR 322

Ti Plasmid

Ti plasmid is found in Agrobacterium tumefaciens, a bacteria responsible for inducing tumours in several dicot plants. The plasmid carries transfer (tra) gene which help to transfer T- DNA from one bacterium to other bacterial or plant cell. It has Onc gene for oncogenecity, ori gene for origin for replication and inc gene for incompatibility. T-DNA of Ti-Plasmid is stably integrated with plant DNA. Agrobacterium plasmids have been used for introduction of genes of desirable traits into plants.

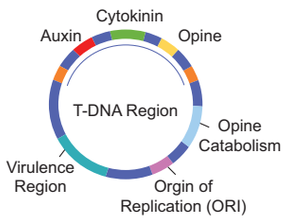


Figure 4.11: Ti Plasmid

Transposon as Vector

Transposons (Transposable elements or mobile elements) are DNA sequence able to insert itself at a new location in the genome without having any sequence relationship with the target locus and hence transposons are called **walking genes** or **jumping genes**. They are used as genetic tools for analysis of gene and protein functions, that produce new phenotype on host cell. The use of transposons is well studied in *Arabidopsis thaliana* and bacteria such as *Escherichia coli*.

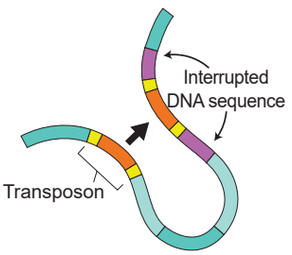


Figure 4.12: Transposon

Walking Genes - Gene walking involves the complete sequencing of large more than 1 kb stretches of DNA.

Expression vectors

Vectors which are suitable for expressing foreign proteins are called expression vectors. This vector consists of signals necessary for transcription and translation of proteins in the host. This helps the host to produce foreign protein in large amounts. Example: pUC 19.

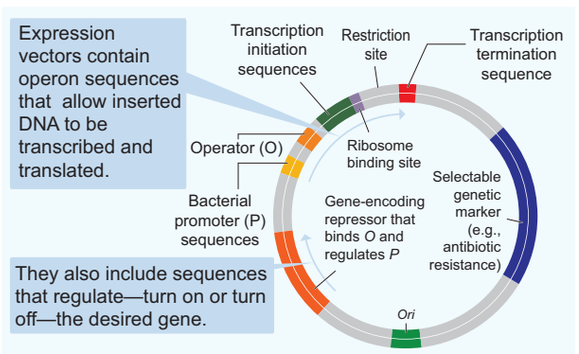
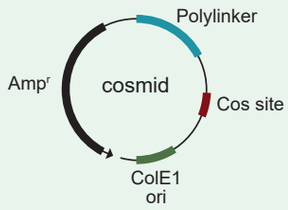


Figure 4.13: E.Coli Expression vector

More vectors to know



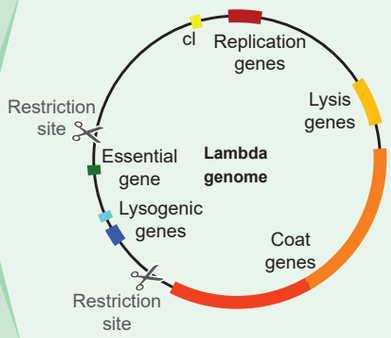
Cosmid

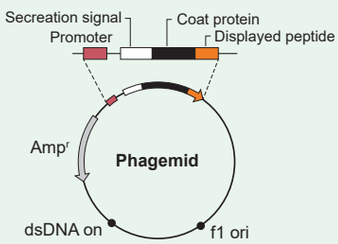
Cosmids are plasmids containing the 'cos' - Cohesive Terminus, the sequence having cohesive ends. They are hybrid vectors derived from plasmids having a fragment of lambda phage DNA with its Cos site and a bacterial plasmid.

Bacteriophage Vectors

Bacteriophages are viruses that infect bacteria. The most commonly used *E. coli* phages are l phage (Lambda phage) and M13 phage. Phage vectors are more efficient than plasmids - DNA upto 25 Kb can be inserted into phage vector.

Lambda genome: Lambda phage is a temperate bacteriophage that infects Escherichia coli. The genome of lambda-Phage is 48502 bp long, i.e. 49Kb and has 50 genes.



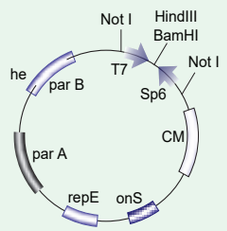


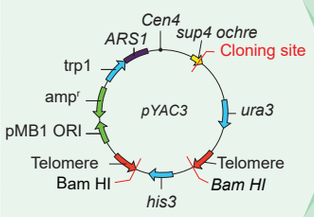
Phagemid Vectors

Phagemids are reconstructed plasmid vectors, which contain their own origin - 'ori' gene and also contain origin of replication from a phage. pBluescript SK (+/–) is an example of phagemid vector.

Bacterial Artificial Chromosome (BAC) Vector

BAC is a shuttle plasmid vector, created for cloning large-sized foreign DNA. BAC vector is one of the most useful cloning vector in r-DNA technology they can clone DNA inserts of upto 300 Kb and they are stable and more user-friendly.



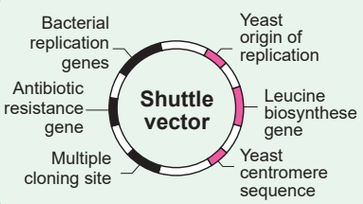


Yeast Artificial chromosome (YAC vector)

YAC plasmid vector behaves like a yeast chromosome, which occurs in two forms, i.e. circular and linear. The circular YAC multiplies in Bacteria and linear YAC multiplies in Yeast Cells.

Shuttle Vectors

The shuttle vectors are plasmids designed to replicate in cells of two different species. These vectors are created by recombinant techniques. The shuttle vectors can propagate in one host and then move into another host without any extra manipulation. Most of the Eukaryotic vectors are Shuttle Vectors.



4.5.5 Competent Host (For Transformation with Recombinant DNA)

The propagation of the recombinant DNA molecules must occur inside a living system or host. Many types of host cells are available for gene cloning which includes E.coli, yeast, animal or plant cells. The type of host cell depends upon the cloning experiment. E.coli is the most widely used organism as its genetic make-up has been extensively studied, it is easy to handle and grow, can accept a range of vectors and has also been studied for safety. One more important feature of E.coli to be preferred as a host cell is that under optimal growing conditions the cells divide every 20 minutes.

Since the DNA is a hydrophilic molecule,it cannot pass through cell membranes, In order to force bacteria to take up the plasmid, the bacterial cells must first be made competent to take up DNA. This is done by treating them with a specific concentration of a divalent cation such as calcium. Recombinant DNA can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42^0C (heatshock) and then putting them back on ice. This enables bacteria to take up the Recombinant DNA.

For the expression of eukaryotic proteins, eukaryotic cells are preferred because to produce a functionally active protein it should fold properly and post translational modifications should also occur, which is not possible by prokaryotic cell (E.coli).

4.6 Methods of Gene Transfer

The next step after a recombinant DNA molecule has been generated is to introduce it into a suitable host cell. There are many methods to introduce recombinant vectors and these are dependent on several factors such as the vector type and host cell.

For achieving genetic transformation in plants, the basic pre-requisite is the construction of a vector which carries the gene of interest flanked by the necessary controlling sequences, i.e., the promoter and terminator, and deliver the genes into the host plant. There are two kinds of gene transfer methods in plants. It includes:

- Direct or vectorless gene transfer
- Indirect or vector – mediated gene transfer

4.6.1 Direct or Vectorless Gene Transfer

In the direct gene transfer methods, the foreign gene of interest is delivered into the host plant without the help of a vector. The following are some of the common methods of direct gene transfer in plants.

a. **Chemical mediated gene transfer:** Certain chemicals like polyethylene glycol (PEG) and dextran sulphate induce DNA uptake into plant protoplasts.

b. **Microinjection:** The DNA is directly injected into the nucleus using fine tipped glass needle or micro pipette to transform plant cells. The protoplasts are immobilised on a solid support (agarose on a microscopic slide) or held with a holding pipette under suction.

c. **Electroporation Methods of Gene Transfer:** A pulse of high voltage is applied to protoplasts, cells or tissues which makes transient pores in the plasma membrane through which uptake of foreign DNA occurs.

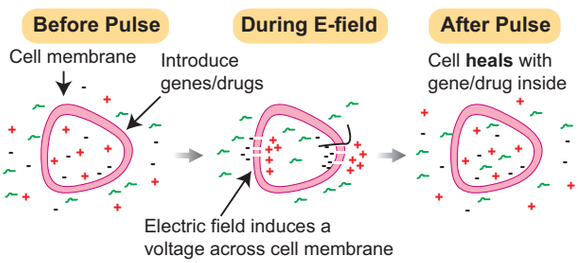


Figure 4.14: Electroporation Methods of Gene Transfer

d. **Liposome mediated method of Gene Transfer:** Liposomes the artificial phospholipid vesicles are useful in gene transfer. The gene or DNA is transferred from liposome into vacuole of plant

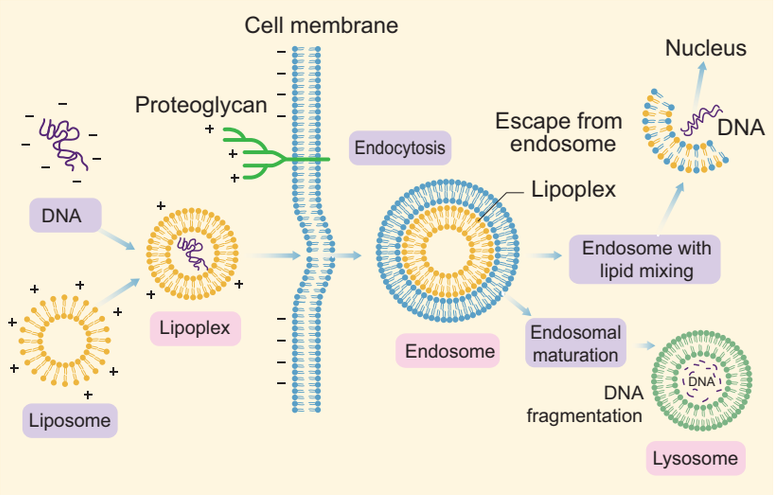


Figure 4.15: Liposome mediated method of Gene Transfer

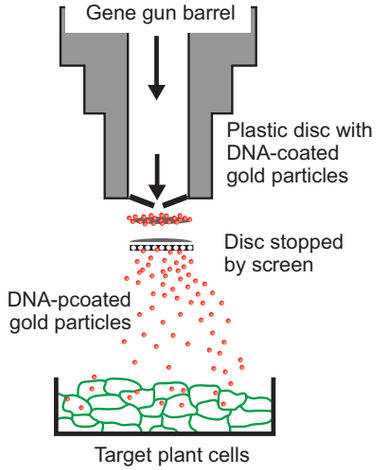


Figure 4.16: Gene gun method of Gene Transfer

cells. It is carried out by encapsulated DNA into the vacuole. This technique is advantageous because the liposome protects the introduced DNA from being damaged by the acidic pH and protease enzymes present in the vacuole. Liposome and tonoplast of vacuole fusion resulted in gene transfer. This process is called lipofection.

e. **Biolistics:** The foreign DNA is coated onto the surface of minute gold or tungsten particles (1-3 μm) and bombarded onto the target tissue or cells using a particle gun (also called as **gene gun/micro projectile gun/shotgun**). Then the bombarded cells or tissues are cultured on selected medium to regenerate plants from the transformed cells.(Figure 4.16)

4.6.2 Indirect or Vector-Mediated Gene Transfer

Gene transfer is mediated with the help of a plasmid vector is known as indirect or vector mediated gene transfer. Among the various vectors used for plant transformation, the Ti-plasmid from *Agrobacterium tumefaciens* has been used extensively. This bacterium has a large size plasmid, known as Ti plasmid (Tumor inducing) and a portion of it referred as T-DNA (transfer DNA) is transferred to plant genome in the infected cells and cause plant tumors (crown gall). Since this bacterium has the natural ability to transfer T-DNA region of its plasmid into plant genome, upon infection of cells at the wound site, it is also known as the natural genetic engineer of plants.

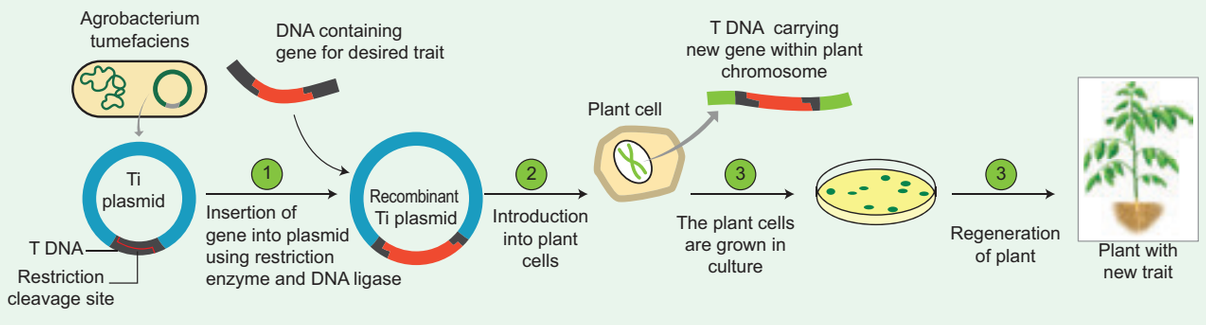


Figure 4.17: Agrobacterium mediated gene transfer in plants

The foreign gene (e.g. Bt gene for insect resistance) and plant selection marker gene, usually an antibiotic gene like *npt II* which confers resistance to antibiotic kanamycin are cloned in the T DNA region of Ti-plasmid in place of unwanted DNA sequences.(Figure 4.17)

4.7 Screening for Recombinants

After the introduction of *r*-DNA into a suitable host cell, it is essential to identify those cells which have received the r-DNA molecule. This process is called screening. The vector or foreign DNA present in recombinant cells expresses the characters, while the non-recombinants do not express the characters or traits. For this some of the methods are used and one such method is Blue-White Selection method.

4.7.1 Insertional Inactivation - Blue-White Colony Selection Method

It is a powerful method used for screening of recombinant plasmid. In this method, a reporter gene **lacZ** is inserted in the vector. The lacZ encodes the enzyme β-galactosidase and contains several recognition sites for restriction enzyme.

β-galactosidase breaks a synthetic substrates called X-gal (5-bromo-4-chloro-indolyl-β-D-galacto-pyranoside) into an insoluble blue coloured product. If a foreign gene is inserted into lacZ, this gene will be inactivated. Therefore, no-blue colour will develop (white) because β-galactosidase is not synthesized due to inactivation of lacZ. Therefore, the host cell containing r-DNA form white coloured colonies on the medium contain X-gal, whereas the other cells containing non-recombinant DNA will develop the blue coloured colonies. On the basis of colony colour, the recombinants can be selected.

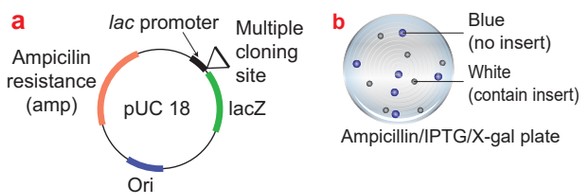


Figure 4.18: a. Plasmid vector designed for blue-white screening b. Blue-white colony selection method

4.7.2 Antibiotic resistant markers

An antibiotic resistance marker is a gene that produces a protein that provides cells with resistance to an antibiotic. Bacteria with transformed DNA can be identified by growing on a medium containing an antibiotic. Recombinants will grow on these medium as they contain genes encoding resistance to antibiotics such as ampicillin, chloro amphenicol, tetracycline or kanamycin, etc., while others may not be able to grow in these media, hence it is considered useful selectable marker.

4.7.3. Replica plating technique

A technique in which the pattern of colonies growing on a culture plate is copied. A sterile filter plate is pressed against the culture plate and then lifted. Then the filter is pressed against a second sterile culture plate. This results in the new plate being infected with cell in the same relative positions as the colonies in the original plate. Usually, the medium used in the second plate will differ from that used in the first. It may include an antibiotic or without a growth factor. In this way, transformed cells can be selected.

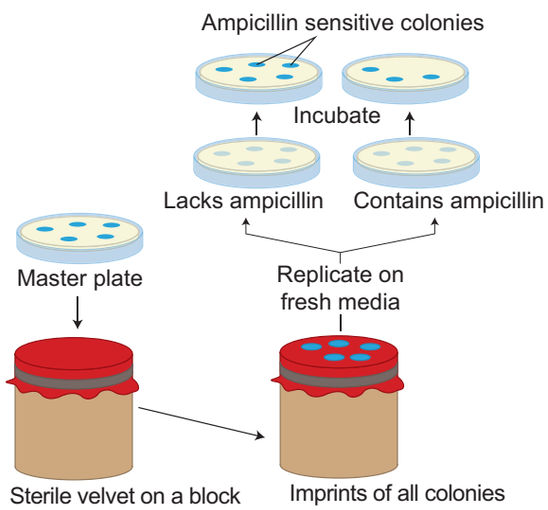


Figure 4.19: Replica plating technique

4.7.4 Molecular Techniques - Isolation of Genetic Material and Gel Electrophoresis

Electrophoresis is a separating technique used to separate different biomolecules with positive and negative charges.

Principle

By applying electricity (DC) the molecules migrate according to the type of charges they have. The electrical charges on different molecules are variable.

+ve	charged	**Cations**	will move towards	**–ve**	**Cathode**
–ve	charged	**Anions**	will move towards	**+ve**	**Anode**

Agarose GEL Electrophoresis

It is used mainly for the purification of specific DNA fragments. Agarose is convenient for separating DNA fragments ranging in size from a few hundred to about 20000 base pairs. Polyacrylamide is preferred for the purification of smaller DNA fragments. The gel is complex network of polymeric molecules. DNA molecule is negatively charged molecule - under an electric field DNA molecule migrates through the gel. The electrophoresis is frequently performed with marker DNA fragments of known size which allow accurate size determination of an unknown DNA molecule by interpolation. The advantages of agarose gel electrophoresis are that the DNA bands can be readily detected at high sensitivity. The bands of DNA in the gel are stained with the dye **Ethidium Bromide** and DNA can be detected as visible fluorescence illuminated in UV light will give orange fluorescence, which can be photographed.

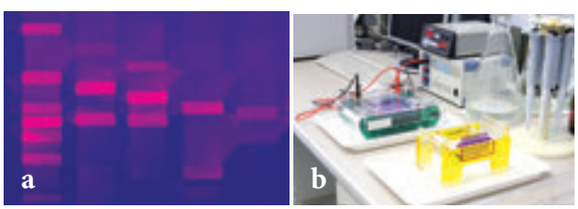


Figure 4.20: a. Bands of DNA in Agarose gel **b.** Gel Electrophoresis Instrument

Agricultural diagnostics refers to a variety of tests that are used for detection of pathogens in plant tissues. Two of the most efficient methods are

1. ELISA (Enzyme Linked Immumo Sorbent Assay)

Elisa is a diagnostic tool for identification of pathogen species by using antibodies and diagnostic agents. Use of ELISA in plant pathology especially for weeding out virus infected plants from large scale planting is well known.

2. DNA Probes

DNA Probes, isotopic and non-isotopic (Northern and Southern blotting) are popular tools for identification of viruses and other pathogens

4.7.5 Nucleic Acid Hybridization - Blotting Techniques

Blotting techniques are widely used analytical tools for the specific identification of desired DNA or RNA fragments from larger number of molecules. Blotting refers to the process of immobilization of sample nucleic acids or solid support (nitrocellulose or nylon membranes.) The blotted nucleic acids are then used as target in the hybridization experiments for their specific detection.

Types of Blotting Techniques

Southern Blotting: The transfer of DNA from agarose gels to nitrocellulose membrane.

Northern Blotting: The transfer of RNA to nitrocellulose membrane.

Western Blotting: Electrophoretic transfer of Proteins to nitrocellulose membrane.

Southern Blotting Techniques - DNA

The transfer of denatured DNA from Agarose gel to Nitrocellulose Blotting or Filter Paper technique was introduced by Southern in 1975 and this technique is called Southern Blotting Technique.

Steps

The transfer of DNA from agarose gel to nitrocellulose filter paper is achieved by Capillary Action.

A buffer Sodium Saline Citrate (SSC) is used, in which DNA is highly soluble, it can be drawn up through the gel into the Nitrocellulose membrane.

By this process ss-DNA becomes '**Trapped**' in the membrane matrix.

This DNA is hybridized with a nucleic acid and can be detected by autoradiography.

Autoradiography - A technique that captures the image formed in a photographic emulsion due to emission of light or radioactivity from a labelled component placed together with unexposed film.

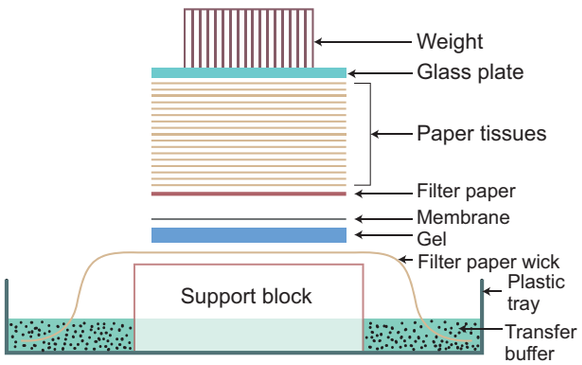


Figure 4.21: Diagrammatic representation of a typical blotting apparatus

Northern Blot

It was found that RNA is not binding to cellulose nitrate. Therefore, Alwin e*t al.* (1979) devised a procedure in which RNA bands are transferred from the agarose gel into nitrocellulose filter paper. This transfer of RNA from gel to special filter paper is called Northern Blot hybridization. The filter paper used for Northern blot is Amino Benzyloxymethyl Paper which can be prepared from Whatman 540 paper.

Western Blot

Refers to the electrophoretic transfer of proteins to blotting papers. Nitrocellulose filter paper can be used for western blot technique. A particular

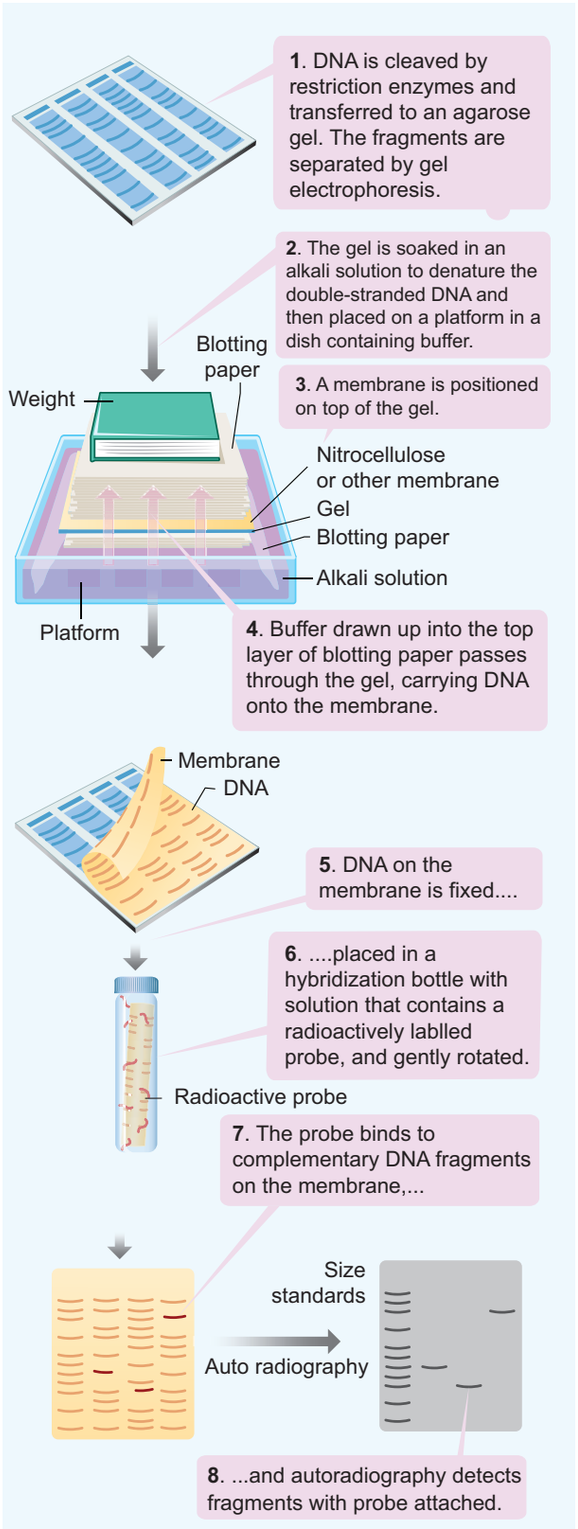


Figure 4.22: Steps involved in southern blotting technique

protein is then identified by probing the blot with a radio-labelled antibody which binds on the specific protein to which the antibody was prepared.

Differences between Blotting Techniques

	Southern blotting	Northern blotting	Western blotting
Name	Southern name of the inventor	Northern a misnomer	Western a misnomer
Separation of	DNA	RNA	Proteins
Denaturation	Needed	Not needed	Needed
Membrane	Nitrocellulose/ nylon	Amino benzyloxymethyl	Nitrocellulose
Hybridisaiton	DNA-DNA	RNA-DNA	Protein-antibody
Visualising	Autoradiogram	Autoradiogram	Dark room

Table 4.2: Difference between Blotting Techniques

4.7.6 Bioassay for Target Gene Effect

Target gene is target DNA, foreign DNA, passenger DNA, exogenous DNA, gene of interest or insert DNA that is to be either cloned or specifically mutated. Gene targeting experiments have been targeting the nuclei and this leads to 'gene knock-out'. For this purpose, two types of targeting vectors are used. They are insertion vectors and replacement or transplacement vectors.

1. Insertion vectors are entirely inserted into targeted locus as the vectors are linearized within the homology region. Initially, these vectors are circular but during insertion, become linear. It leads to duplication of sequences adjacent to selectable markers.
2 The replacement vector has the homology region and it is co-linear with target. This vector is linearized prior to transfection outside the homology region and then consequently a crossing over occurs to replace the endogenous DNA with the incoming DNA.

Transfection: Introduction of foreign nucleic acids into cells by non-viral methods.

4.7.7. Genome Sequencing and Plant Genome Projects

The whole complement of gene that determine all characteristic of an organism is called genome. The genome may be nuclear genome, mitochondrial genome or plastid genome. Genome of many plants contain both functional and non-expressive DNA proteins. Genome project refer to a project in which the whole genome of plant is analysed using sequence analysis and sequence homology with other plants. Such genome projects have so far been undertaken in *Chlamydomonas*(algae), *Arabidopsis thaliana*, rice and maize plants.

Genome content of an organism is expressed in terms of number of base pairs or in terms of the content of DNA is expressed in c-value.

Genome sequencing: The location of genes on the entire diploid chromosome of an organism.

Barcode: You might have seen in all books barcoding and also in items you buy in supermarket. This will reveal the identity of the book or item as well the details like prize. Similarily, Barcode in genetic term refer to the identify of the taxon based on its genetic makeup. In practice, it is an optical, machine-readable representation of data which describes about the characters of any plants or any objects.

4.7.8 Evolutionary pattern assessed using DNA.

In recent years the evolutionary relationship between different plant taxa is assessed using DNA content as well as the similarities and differences in the DNA sequence (sequence homology). Based on such analysis the taxa and their relationship are indicated in cladogram. Such cladogram will show the genetic distance between two taxa. It is also showed antiquity or modernity of any taxon with respect to one another (See also Unit-2, Chapter-5 of XI Std.)

4.7.9 Genome editing and CRISPR - Cas9

Genome editing or gene editing is a group of technologies that has the ability to change an organism's DNA. These technologies allow genetic material to be added, removed, or altered at particular locations in the genome. Several approaches to genome editing have been developed. A recent one is known as CRISPR-Cas9, which is short form of **Clustered Regularly Interspaced Short Palindromic Repeats** and CRISPR-associated protein 9. The CRISPR-Cas9 system has generated a lot of excitement in the scientific community because it is faster, cheaper, more accurate, and more efficient than other existing genome editing methods.

Rice, was among the first plants to be used to demonstrate the feasibility of CRISPR-mediated targeted mutagenesis and gene replacement. The gene editing tool CRISPR can be used to make hybrid rice plants that can clone their seed. Imtiyaz Khand and Venkatesan Sundaresan and colleagues reported in a new study which clearly shows one can re-engineer rice to switch it from a sexual to an asexual mode.

E32Y5K

4.7.10 RNA Interference (RNAi)

All characters of organism are the result of expression of different genes which are regions of nuclear DNA. This expression involves transcription and translation. Transcription refers to the copying of genetic information from one strand of the DNA (called sense strand) by RNA. This RNA, as soon as it formed cannot be straight away sent to the cytoplasm to undertake the process of translation. It has to be edited and made suitable for translation which brings about protein synthesis. One of the main items removed from the RNA strand are the introns. All these changes before translation normally take place whereby certain regions of DNA are silence. However, there is an (RNAi) pathway. RNA interference is a biological process in which RNA molecules inhibit gene expression or translation. This is done by neutralising targetd mRNA molecules.

A simplified model for the RNAi pathway is based on two steps, each involving ribonuclease enzyme. In the first step, the trigger RNA (either dsRNA or miRNA primary transcript) is processed into a short interfering RNA (siRNA) by the RNase II enzymes called Dicer and Drosha. In the second step, siRNAs are loaded into the effector complex RNA-induced silencing complex (RISC). The siRNA is unwound during RISC assembly and the single-stranded RNA hybridizes with mRNA target. This RNAi is seen in plant feeding nematodes.

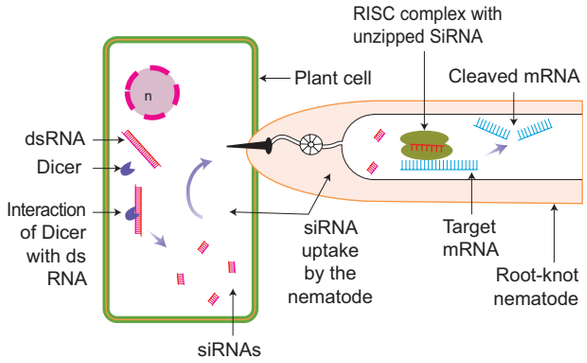


Figure 4.23: RNA Interference

4.8 Transgenic Plants / Genetically Modified Crops (Gm Crops)

4.8.1 Herbicide Tolerant – Glyphosate

Weeds are a constant problem in crop fields. Weeds not only compete with crops for sunlight, water, nutrients and space but also a carrier for insects and diseases. If left uncontrolled, weeds can reduce crop yields significantly.

Transgenic plants contain a novel DNA introduced into its genome.

Glyphosate herbicide produced by Monsanto, USA company under the trade name 'Round up' kills plants by blocking the 5-enopyruvate shikimate-3 phosphate synthase (EPSPS) enzyme, an enzyme involved in the biosynthesis of aromatic amino acids, vitamins and many secondary plant metabolites. There are several ways by which crops can be modified to be glyphosate-tolerant.

Protocol for Glyphosate tolerant Potato Plant

Introduction of 'bar' gene through vector

↓

Cell culture of potato with 'bar' gene

↓

Herbicide tolerant potato cells

↓

In vitro culture

↓

Callus → Organogenesis

↓

Development of Herbicide tolerant transgenic plants

Figure 4.24: Glyphosate Tolerant Potato Plant

One strategy is to incorporate a soil bacterium gene that produces a glyphosate tolerant form of EPSPS. Another way is to incorporate a different soil bacterium gene that produces a glyphosate degrading enzyme.

Advantages of Herbicide Tolerant Crops

- Weed control improves higher crop yields;
- Reduces spray of herbicide;
- Reduces competition between crop plant and weed;
- Use of low toxicity compounds which do not remain active in the soil; and
- The ability to conserve soil structure and microbes.

4.8.2 Herbicide Tolerant - Basta

Trade name 'Basta' refers to a non-selective herbicide containing the chemical compound phosphinothricin. Basta herbicide tolerant gene PPT (*L*-phosphinothricin) was isolated from *Medicago sativa* plant. It inhibits the enzyme glutamine synthase which is involved in ammonia assimilation. The PPT gene was introduced into tobacco and transgenic tobacco produced was resistant to PPT. Similar enzyme was also isolated from *Streptomyces hygroscopicus* with bar gene encodes for PAT (Phosphinothricin acetyl transferase) and was introduced into crop plants like potato and sugar-beet and transgenic crops have been developed.

4.8.3 Insect resistance - Bt Crops:

i. Bt Cotton

Bt cotton is a genetically modified organism (GMO) or genetically modified pest resistant plant cotton variety, which produces an insecticide activity to bollworm.

Strains of the bacterium *Bacillus thuringiensis* produce over 200 different Bt toxins, each harmful to different insects. Most Bt toxins are insecticidal to the larvae of moths and butterflies, beetles, cotton bollworms and gatflies but are harmless to other forms of life.

The genes are encoded for toxic crystals in the Cry group of endotoxin. When insects attack and eat the cotton plant the Cry toxins are dissolved in the insect's stomach.

The epithelial membranes of the gut block certain vital nutrients thereby sufficient regulation of potassium ions are lost in the insects and results in the death of epithelial cells in the intestine membrane which leads to the death of the larvae.

Figure 4.25: Bt Cotton

Advantages

The advantages of Bt cotton are:

- Yield of cotton is increased due to effective control of bollworms.
- Reduction in insecticide use in the cultivation of Bt cotton
- Potential reduction in the cost of cultivation.

Disadvantages

Bt cotton has some limitations:

- Cost of Bt cotton seed is high.
- Effectiveness up to 120 days after that efficiency is reduced
- Ineffective against sucking pests like jassids, aphids and whitefly.
- Affects pollinating insects and thus yield.

ii. Bt Brinjal

The Bt brinjal is another transgenic brinjal created by inserting a crystal protein gene (Cry1Ac) from the soil bacterium *Bacillus thuringiensis* into the genome of various brinjal cultivars. The insertion of the gene, along with other genetic elements such as promoters, terminators and an antibiotic resistance marker gene into the brinjal plant is accomplished using *Agrobacterium*-mediated genetic transformation. The Bt brinjal has been developed to give resistance against *Lepidopteron* insects, in particular the Brinjal Fruit and Shoot Borer (*Leucinodes orbonalis*).

Figure 4.26: Bt Brinjal

iii. Dhara Mustard Hybrid (DMH)

DMH -11 is transgenic mustard developed by a team of scientists Centre for Genetic Manipulation of Crop Plants at Delhi University under Government sponsored project. It is genetically modified variety of Herbicide Tolerant (HT) mustard. It was created by using "barnase/barstar" technology for genetic modification by adding genes from soil bacterium that makes mustard, a self-pollinating plant. DMH -11 contains three genes viz. Bar gene, Barnase and Barstar sourced from soil bacterium. The bar gene had made plant resistant to herbicide named Basta.

Figure 4.27: Dhara Mustard

4.8.4 Virus Resistance

Many plants are affected by virus attack resulting in series loss in yield and even death. Biotechnological intervention is used to introduce viral resistant genes into the host plant so that they can resist the attack by virus. This is by introducing genes that produce resistant enzymes which can deactivate viral DNA.

4.8.5 FlavrSavr Tomato

Agrobacterium mediated genetic engineering technique was followed to produce Flavr-Savr tomato, i.e., retaining the natural colour and flavor of tomato.

Through genetic engineering, the ripening process of the tomato is slowed down and thus prevent it from softening and to increase the shelf life. The tomato was made more resistant to rotting by *Agrobacterium* mediated gene transfer mechanism of introducing an antisense gene which interferes with the production of

Figure 4.28: FlavrSavr Tomato

the enzyme polygalacturonase, which help in delaying the ripening process of tomato during long storage and transportation.

4.8.6 Golden rice - Biofortification

Golden rice is a variety of *Oryza sativa* (rice) produced through genetic engineering of biosynthesized beta-carotene, a precursor of Vitamin-A in the edible parts of rice developed by Ingo Potrykus and his group. The aim is to produce a fortified food to be grown and consumed in areas with a shortage of dietary Vitamin-A, which kills so many children under five year age. Golden rice differs from its parental strain by the addition of three beta-carotene biosynthesis genes namely 'psy' (phytoene synthase) from daffodil plant *Narcissus pseudonarcissus* and 'crt-1' gene from the soil bacterium *Erwinia auredorora* and 'lyc' (lycopene cyclase) gene from wild-type rice endosperm.

The endosperm of normal rice, does not contain beta-carotene. Golden-rice has been genetically altered so that the endosperm now accumulates Beta-carotene. This has been done using Recombinant DNA technology. Golden rice can control childhood blindness - Xerophthalmia.

Figure 4.29: Golden rice

GM Food - Benefits

- High yield without pest
- 70% reduction of pesticide usage
- Reduce soil pollution problem
- Conserve microbial population in soil

Risks - believed to

- Affect liver, kidney function and cancer
- Hormonal imbalance and physical disorder
- Anaphylactic shock (sudden hypersensitive reaction) and allergies.
- Adverse effect in immune system because of bacterial protein.
- Loss of viability of seeds show in terminator seed technology of GM crops.

4.8.7 Polyhydroxybutyrate (PHB)

Synthetic polymers are non-degradable and pollute the soil and when burnt add dioxin in the environment which cause cancer. So, efforts were taken to provide an alternative eco-friendly biopolymers. Polyhydroxyalkanoates (PHAs) and polyhydroxybutyrate (PHB) are group of degradable biopolymers which have several medical applications such as drug delivery, scaffold and heart valves. PHAs are biological macromolecules and thermoplastics which are biodegradable and biocompatible.

Several microorganisms have been utilized to produce different types of PHAs including Gram-positive like *Bacillus megaterium*, *Bacillussubtilis* and *Corynebacterium glutamicum*, Gram-negative bacteria like group of *Pseudomonas* sp. and *Alcaligenes eutrophus*.

4.8.8 Polylactic acid (PLA)

Polylactic acid or polylactide (PLA) is a biodegradable and bioactive thermoplastic. It is an aliphatic polyester derived from renewable resources, such as corn starch, cassava root, chips or starch or sugarcane. For the production of PLA, two main monomers are used: lactic acid, and the cyclic diester, lactide. The most common route is the ring-opening polymerization of lactide with metal catalysts like tin octoate in solution. The metal-catalyzed reaction results in equal amount of *d* and polylactic acid.

Figure 4.30: Polylactic acid product

4.8.9 Green Fluorescent Protein (GFP)

The green fluorescent protein (GFP) is a protein containing 238 amino acid residues of 26.9 kDa that exhibits bright green fluorescence when exposed to blue to ultraviolet range (395 nm). GFP refers to the protein first isolated from the jellyfish *Aequorea victoria*. GFP is an excellent tool in biology due to its ability to form internal chromophore without requiring any accessory cofactors, gene products, enzymes or substrates other than molecular oxygen. In cell and molecular biology, the GFP gene is frequently used as a reporter of expression. It has been used in modified forms to make biosensors.

Protocol

Green Fluorescent Protein (GFP)

↓

Isolated from *Aequorea victoria* (jelly fish)

↓

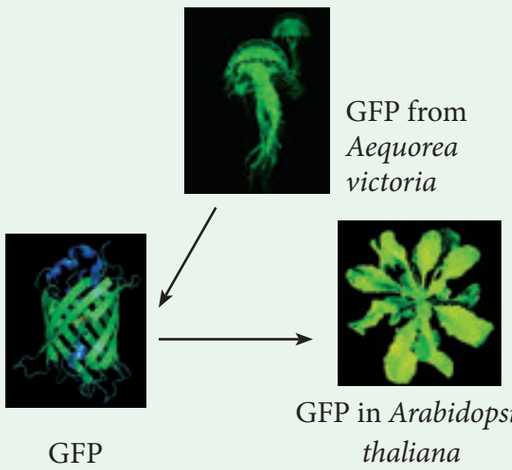
Gene splicing technique → altering the codon

↓

Introduced into *Arabidopsis thaliana* plant

↓

GFP expressed in *A. thaliana* plant



4.8.10 Biopharming

Biopharming also known as molecular pharming is the production and use of transgenic plants genetically engineered to produce pharmaceutical substances for use of human beings. This is also called "**molecular farming or pharming**". These plants are different from medicinal plants which are naturally available. The use of plant systems as bioreactors is gaining more significance in modern biotechnology. Many pharmaceutical substances can be produced using transgenic plants. Example: Golden rice

4.8.11 Bioremediation

It is defined as the use of microorganisms or plants to clean up environmental pollution. It is an approach used to treat wastes including wastewater, industrial waste and solid waste. Bioremediation process is applied to the removal of oil, petrochemical residues, pesticides or heavy metals from soil or ground water. In many cases, bioremediation is less expensive and more sustainable than other physical and chemical methods of remediation.Bioremediation process is a cheaper and eco-friendly approach and can deal with lower concentrations of contaminants more effectively. The strategies for bioremediation in soil and water can be as follows:

- Use of indigenous microbial population as indicator species for bioremediation process.
- Bioremediation with the addition of adapted or designed microbial inoculants.
- Use of plants for bioremediation - green technology.

Some examples of bioremediation technologies are:

- **Phytoremediation** - use of plants to bring about remediation of environmental pollutants.
- **Mycoremediation** - use of fungi to bring about remediation of environmental pollutants.
- **Bioventing** is the process that increases the oxygen or air flow to accelerate the

degradation of environmental pollutants.

- **Bioleaching** is the use of microorganisms in solution to recover metal pollutants from contaminated sites.
- **Bioaugmentation** is the addition of selected microbes to speed up degradation process.
- **Composting** is the process by which the solid waste is composted by the use of microbes into manure which acts as a nutrient for plant growth.
- **Rhizofiltration** is the uptake of metals or degradation of organic compounds by rhizosphere microorganisms.
- **Rhizostimulation** is the stimulation of plant growth by the rhizosphere by providing better growth condition or reduction in toxic materials.

Limitations

- Only biodegradable contaminants can be transformed using bioremediation processes.
- Bioremediation processes must be specifically made in accordance to the conditions at the contaminated site.
- Small-scale tests on a pilot scale must be performed before carrying out the procedure at the contaminated site.
- The use of genetic engineering technology to create genetically modified microorganism or a consortium of microbes for bioremediation process has great potential.

4.8.12 Biofuel: Algal Biofuel

Algal fuel, also known as algal biofuel, or algal oil is an alternative to liquid fossil fuels, the petroleum products. This use algae as a source of energy-rich oils. Also, algal fuels are an alternative to commonly known biofuel sources obtained from corn and sugarcane. The energy crisis and the world food crisis have initiated interest in algal culture (farming algae) for making biodiesel and other biofuels using land unsuitable for agriculture. *Botryococcus braunii* is normally used to produce algal biofuel.

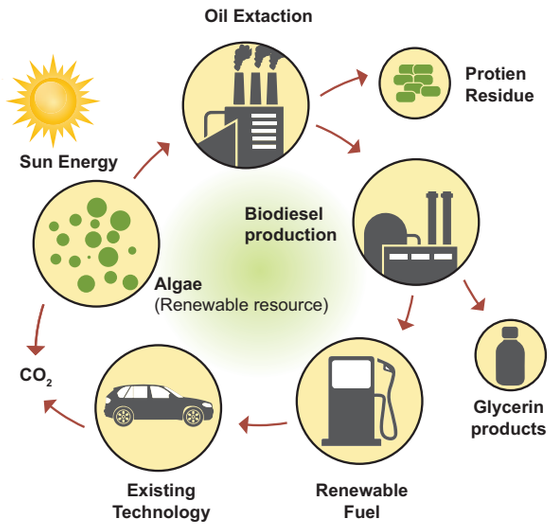


Figure 4.31: Algal Biofuel

Biological hydrogen production by algae

The biological hydrogen production with algae is a method of photo biological water splitting. In normal photosynthesis the alga, *Chlamydomonas reinhardtii* releases oxygen. When it is deprived of sulfur, it switches to the production of hydrogen during photosynthesis and the electrons are transported to ferredoxins. [Fe]-hydrogenase enzymes combine them into the production of hydrogen gas.

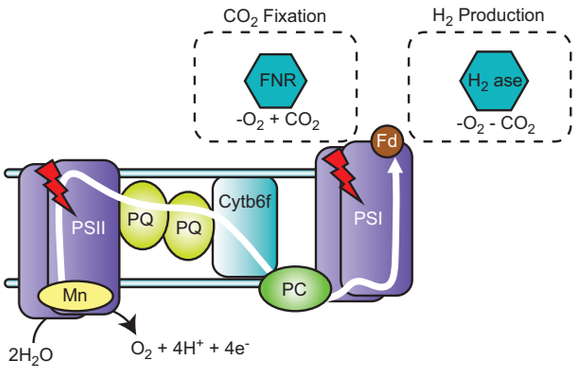


Figure 4.32: Hydrogen production by algae

4.8.13 Bioprospecting

Bioprospecting is the process of discovery and commercialization of new products obtained from biological resources. Bioprospecting may involve biopiracy, in which indigenous knowledge of nature, originating with indigenous people, is used by others for profit, without authorization or compensation to the indigenous people themselves.

Biopiracy

Biopiracy can be defined as the manipulation of intellectual property rights laws by corporations to gain exclusive control over national genetic resources, without giving adequate recognition or remuneration to the original possessors of those resources. Examples of biopiracy include recent patents granted by the U.S. Patent and Trademarks Office to American companies on turmeric, 'neem' and, most notably, 'basmati' rice. All three products are indigenous to the Indo-Pak subcontinent.

Biopiracy of Neem

The people of India used neem and its oil in many ways to controlling fungal and bacterial skin infections. Indian's have shared the knowledge of the properties of the neem with the entire world. Pirating this knowledge, the United States Department of Agriculture (USDA) and an American MNC (Multi Nation Corporation) W.R.Grace in the early 90's sought a patent from the European Patent Office (EPO) on the "method for controlling of diseases on plants by the aid of extracted hydrophobic neem oil". The patenting of the fungicidal and antibacterial properties of Neem was an example of biopiracy but the traditional knowledge of the Indians was protected in the end.

Biopiracy of Turmeric

The United States Patent and Trademark Office, in the year 1995 granted patent to the method of use of turmeric as an antiseptic agent. Turmeric has been used by the Indians as a home remedy for the quick healing of the wounds and also for purpose of healing rashes. The journal article published by the Indian Medical Association, in the year 1953 wherein this remedy was mentioned. Therefore, in this way it was proved that the use of turmeric as an antiseptic is not new to the world and is not a new invention, but formed a part of the traditional knowledge of the Indians. The objection in this case US patent and trademark office was upheld and traditional knowledge of the Indians was protected. It is another example of Biopiracy.

Biopiracy of Basmati

On September 2, 1997, the U.S. Patent and Trademarks Office granted Patent on "basmati rice lines and grains" to the Texas-based company RiceTec. This broad patent gives the company several rights, including exclusive use of the term 'basmati', as well proprietary rights on the seeds and grains from any crosses. The patent also covers the process of breeding RiceTec's novel rice lines and the method to determine the cooking properties and starch content of the rice grains.

India had periled the United States to take the matter to the WTO as an infringement of the TRIPS agreement, which could have resulted in major embarrassment for the US. Hence voluntarily and due to few decisions take by the US patent office, Rice Tec had no choice but to lose most of the claims and most importantly the right to call the rice "Basmati". In the year 2002, the final decision was taken. Rice Tec dropped down 15 claims, resulting in clearing the path of Indian Basmati rice exports to the foreign countries. The Patent Office ordered the patent name to be changed to 'Rice lines 867'.

4.9 Applications of Biotechnology

- Biotechnology is one of the most important applied interdisciplinary sciences of the **21st century**. It is the trusted area that enables us to find the beneficial way of life.
- Biotechnology has wide applications in various sectors like agriculture, medicine, environment and commercial industries.
- This science has an invaluable outcome like **transgenic varieties** of plants e.g. transgenic cotton (Bt-cotton), rice, tomato, tobacco, cauliflower, potato and banana.
- The development of transgenics as pesticide resistant, stress resistant and disease resistant varieties of agricultural crops is the immense outcome of biotechnology.
- The synthesis of **human insulin** and blood protein in *E.coli* and utilized for

insulin deficiency disorder in human is a breakthrough in biotech industries in medicine.

- The synthesis of vaccines, enzymes, antibiotics, dairy products and beverages are the products of biotech industries.
- **Biochip** based biological computer is one of the successes of biotechnology.
- Genetic engineering involves genetic manipulation, tissue culture involves aseptic cultivation of totipotent plant cell into plant clones under controlled atmospheric conditions.
- **Single cell protein** from *Spirulina* is utilized in food industries.
- Production of **secondary metabolites**, biofertilizers, biopesticides and enzymes.
- Biomass energy, biofuel, Bioremediation, phytoremediation for environmental biotechnology.

Summary

Biotechnology is the science of applied biological process in which there is a controlled use of biological agents such as microorganisms or cellular components for beneficial use. A Hungarian Engineer, Karl Ereky (1919) coined the term biotechnology. Biotechnology broadly categorized into traditional practices and modern practices. Traditional biotechnology includes our ancient practices such as fermentation. Single Cell Protein (SCP) organisms are grown in large quantities to produce goods rich in protein, minerals, fats, carbohydrates and vitamins. The modern biotechnology embraces all the genetic manipulations. The recombinant DNA technology is a technique of modern biotechnology in which transfer of DNA coding for a specific gene from one organism is introduced into another organism using specific agents like vectors or using instruments like electroporation, gene gun, liposome mediated, chemical mediated and micro injection. Other tools are enzymes and host organisms. The enzyme restriction endonuclease is a molecular scissor that cleaves DNA into fragments at or near specific recognition sites with the molecule known as restriction sites. Other enzymes are DNA ligase and alkaline phosphatase. DNA ligase enzyme joins the sugar and phosphate molecules of double stranded DNA. Alkaline phosphatase is an enzyme which adds or removes specific phosphate group of double stranded DNA.

A vector is a small DNA molecule capable of self replication and used as a carrier of DNA inserted in the host cell. Few examples of vectors are plasmid – pBR 322, cosmid – Lambda phage, M13, Phagmid , BAC, YAC, transposon, shuttle vector and expression vector.

After production of recombinant DNA molecule has been generated is introduced into a suitable host cell. Type of host cell depends upon the cloning experiment. E.coli is the most widely used host organism. There are two kinds of gene transfer methods in plants. They are direct or vectorless gene transfer and indirect or vector mediated gene transfer. Direct gene transfer includes chemical mediated gene transfer, micro injection, electroporation. Gene gun method and Liposome mediated method of gene transfer. Indirect or vector mediated gene transfer is a method of gene transfer with the help of a plasmid vector. In this method Ti-plasmid from *Agrobactirum tumefeciens* has been used extensively for vector mediated gene transfer.

After the introduction of rDNA into a host cell, it is essential to identify those cells which have received the rDNA molecule. This process is called screening. One of the method of recombinant screening is blue white selection method Replica plating technique in which the pattern of colonies growing on a culture plate is copied. Electrophoresis is a separating technique used to separate different biomolecules.

Blotting techniques are widely used tools for identification of desired DNA or RNA fragments from larger number of molecules. Some of the genetically modified crops are herbicide tolerant

– Basta, Dhara mustard, insects resistance – Bt crops, flavrSavr – Tomato, Golden rice. Biopolymers are polyhydroxybutyrate (PHB), polylactic acid (PLA) and green fluorescent protein (GFP) is used to make biosensors. Other applications are biopharming, bioprospecting, biomedication and biofuel, etc.

Evaluation

EHKT6W

1. Restriction enzymes are
   a. Not always required in genetic engineering
   b. Essential tools in genetic engineering
   c. Nucleases that cleave DNA at specific sites
   d. both b and c

2. Plasmids are
   a. circular protein molecules
   b. required by bacteria
   c. tiny bacteria
   d. confer resistance to antibiotics

3. EcoRI cleaves DNA at
   a. AGGGTT b. GTATATC
   c. GAATTC d. TATAGC

4. Genetic engineering is
   a. making artificial genes.
   b. hybridization of DNA of one organism to that of the others.
   c. production of alcohol by using micro organisms.
   d. making artificial limbs, diagnostic instruments such as ECG, EEG etc.,

5. Consider the following statements:
   I. Recombinant DNA technology is popularly known as genetic engineering is a stream of biotechnology which deals with the manipulation of genetic materials by man invitro
   II. pBR322 is the first artificial cloning vector developed in 1977 by Boliver and Rodriguez from E.coli plasmid
   III. Restriction enzymes belongs to a class of enzymes called nucleases.

   Choose the correct option regarding above statements
   a. I & II b. I & III
   c. II & III d. I,II & III

6. The process of recombinant DNA technology has the following steps
   I. amplication of the gene
   II. Insertion of recombinant DNA into the host cells
   III. Cutting of DNA at specific location using restriction enzyme .
   IV. Isolation of genetic material (DNA)
   Pick out the correct sequence of step for recombinant DNA technology.
   a. II, III, IV, I b. IV, II, III, I
   c. I, II, III, IV d. IV, III, I, II

7. Which one of the following palindromic base sequence in DNA can be easily cut at about the middle by some particular restriction enzymes?
   a. 5` CGTTCG 3` 3` ATCGTA 5`
   b. 5` GATATG 3` 3` CTACTA 5`
   c. 5` GAATTC 3` 3` CTTAAG 5`
   d. 5` CACGTA 3` 3` CTCAGT 5`

8. pBR 322, BR stands for
   a. Plasmid Bacterial Recombination
   b. Plasmid Bacterial Replication
   c. Plasmid Boliver and Rodriguez
   d. Plasmid Baltimore and Rodriguez

9. Which of the following one is used as a Biosensors?
   a. Electrophoresis b. Bioreactors
   c. Vectors d. Electroporation

10. Match the following :

Column A	Column B
1 Exonuclease	a. add or remove phosphate
2 Endonuclease	b. binding the DNA fragments
3 Alkaline Phosphatase	c. cut the DNA at terminus
4 Ligase	d. cut the DNA at middle

	1	2	3	4
A)	a	b	c	d
B)	c	d	b	a
C)	a	c	b	d
D)	c	d	a	b

11 In which techniques Ethidium Bromide is used?
a. Southern Blotting techniques
b. Western Blotting techniques
c. Polymerase Chain Reaction
d. Agrose Gel Electroporosis

12 **Assertion** : Agrobacterium tumifaciens is popular in genetic engineering because this bacteriumis associated with the root nodules of all cereals and pulse crops

Reason: A gene incorporated in the bacterial chromosomal genome gets atomatically transferred to the cross with which bacterium is associated.
a) Both assertion and reason are true. But reason is correct explanation of assertion.
b) Both assertion and reason are true. But reason is not correct explanation of assertion.
c) Assertion is true, but reason is false.
d) Assertion is false, but reason is true.
e) Both assertion and reason are false.

13 Which one of the following is not correct statement.
a) Ti plasmid causes the bunchy top disease
b) Multiple cloning site is known as Polylinker
c) Non viral method transfection of Nucleic acid in cell
d) Polylactic acid is a kind of biodegradable and bioactive thermoplastic.

14 An analysis of chromosomal DNA using the southern hybridisation technique does not use
a) Electrophoresis
b) Blotting
c) Autoradiography
d) Polymerase Chain Reaction

15 An antibiotic gene in a vector usually helps in the selection of
a) Competent cells b) Transformed cells
c) Recombinant cells d) None of the above

16 Some of the characteristics of Bt cotton are
a) Long fibre and resistant to aphids
b) Medium yield, long fibre and resistant to beetle pests
c) high yield and production of toxic protein crystals which kill dipteran pests.
d) High yield and resistant to ball worms

17. How do you use the biotechnology in modern practice?

18. What are the materials used to grow microorganism like Spirulina?

19. You are working in a biotechnology lab with a becterium namely E.coli. How will you cut the nucleotide sequence? explain it.

20. What are the enzymes you can used to cut terminal end and internal phospho di ester bond of nucleotide sequence?

21. Name the chemicals used in gene transfer.

22. What do you know about the word pBR332?

23. Mention the application of Biotechnology.

24. What are restriction enzyme. Mention their type with role in Biotechnology.

25. Is their any possibilities to transfer a suitable desirable gene to host plant without vector? Justify your answer.

26. How will you identify a vectors?

27. Compare the various types of Blotting techniques.

28. Write the advantages of herbicide tolerant crops.

29. Write the advantages and disadvantages of Bt cotton.

30. What is bioremediation? give some examples of bioremediation.

31. Write the benefits and risk of Genetically Modified Foods.

Glossary

3' Hydroxy end: The hydroxyl group attached to 3' carbon atom of sugar of the terminal nucleotide of a nucleic acid.

Bacterial artificial chromosomes (BAC): A cloning vector for isolation of genomic DNA constructed on the basis of F-factor.

Chimeric DNA: A recombinant DNA molecule containing unrelated genes.

Cleave: To break phosphodiester bonds of dsDNA, usually with a restriction enzyme.

Cloning site: A location on a cloning vector into which DNA can be inserted.

Cloning: Incorporation of a DNA molecule into a chromosomal site or a cloning vector.

Cloning Vector: A small, self-replicating DNA inserted in a cloning gene.

COS sites: The 12-base, single strand, complementary extension of phage lambda (l) DNA.

DNA Polymerase: An enzyme that catalyses the phosphodiester bond in the formation of DNA.

Endonucleases: An enzyme that catalyses the cleavage of DNA at internal position, cutting DNA at specific sites.

Genome: The entire complement of genetic material of an organism.

Insert DNA: A DNA molecule incorporated into a cloning vector.

Ligase: An enzyme used in genetic engineering experiment to join the cut ends of dsDNA.

M-13: AssDNA bacteriophage used as vector for DNA sequencing.

Phagemid: A cloning vector that contains components derived from both phage DNA and plasmid.

Plasmid: Extrachromosomal, self-replicating, circular dsDNA containing some non-essential genes.

Restriction map: A linear array of sites on DNA cleaved by various restriction enzymes.

Shuttle Vector: A plasmid cloning vector that can replicate in two different organisms due to the presence of two different origin of replication Ori^{EUK} and $Ori^{E.\ coli}$

Taq polymerase: A heat stable DNA polymerase isolated from a thermophilic bacterium *Thermus aquaticus.*

Vectors: Vehicles for transferring DNA from one cell to another.

Biofuel: Fuels like hydrogen, ethanol and methanol produced from a biological source by the action of microorganisms.

Bioleaching: Process of using microorganisms to recover metals from their ores or contaminant environment

Bioremediation: Process of using organisms to remove or reduce pollutants from the environment.

Green Technology: Pollution-free technology in which pollution is controlled at source.

Phytoremediation: Use of certain plants to remove contaminants or pollutants from the environment (soil, water or air).

Recombinant: Cell / Organism formed by a recombination of genes.

Transformation: Process of transferring a foreign DNA into a cell and changing its genome.

Vector: Agent used in recombinant DNA technique to carry new genes into foreign cells.

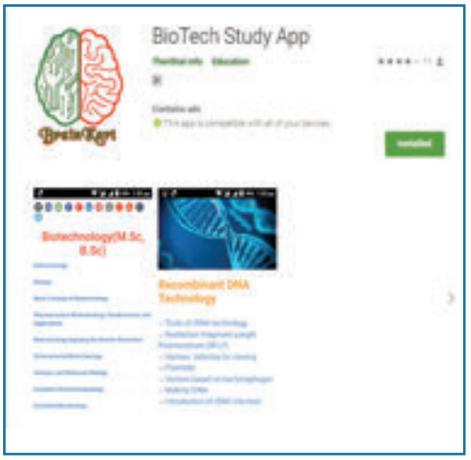
Wild Type: Natural form of organisms.

ICT Corner

Principles and Processes of Biotechnology

BIO TECH STUDY APP

Let us know about the information Bio Technology through this activity.

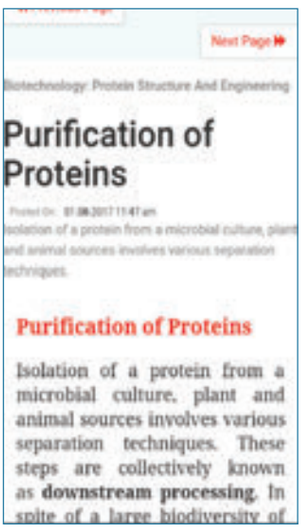


Steps

- Type the URL or scan the QR code to open the activity page.
- Click on the topic to know in detail.
- To know the sub topics in detail click on the dots in top right corner.

Step 1

Step 2



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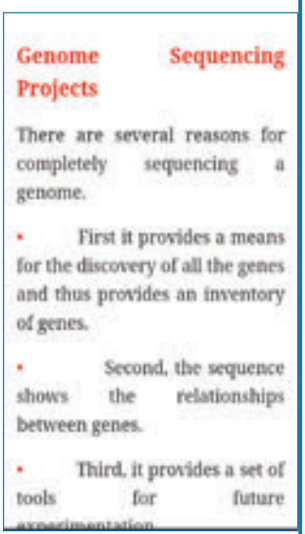

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Chapter 5

Plant Tissue Culture

Learning Objectives

The learner will be able to

- Perceive the concepts of tissue culture.
- Cognize the steps of tissue culture techniques and its types.
- Understand the protoplast culture in detail.
- Elicit the list of secondary metabolites obtained through cell suspension culture.
- Learn plant regeneration pathway.
- Appreciate the uses of micro propagation, somatic hybridization, shoot meristem culture and germplasm conservation.
- Acquire the knowledge of patenting Biosafety and Bioethics.

Chapter outline

FRWH98

Gottlieb Haberlandt

Growing plant protoplasts, cells, tissues or organs away from their natural or normal environment, under artificial condition, is known as Tissue Culture. It is also known as *in vitro* (*In vitro* is a Latin word, it means that - in glass or in test-tube) growth of plant protoplasts, cells, tissues and organs. A single explant can be multiplied into several thousand plants in short time period and space under controlled conditions.

Tissue culture techniques are often used for commercial production of plants as well as for plant research. Plant tissue culture serves as an indispensable tool for regeneration of transgenic plants. Apart from this some of the main applications of Plant tissue culture are clonal propagation of elite varieties, conservation of endangered plants, production of virus-free plants, germplasm preservation, industrial production of secondary metabolites. etc., In this chapter let us discuss the history , techniques, types , applications of plant tissue culture and get aware on ethical issues.

Gottlieb Haberlandt (1902) the German Botanist proposed the concept **Totipotency** and he was also the first person to culture plant cells in artificial conditions using the mesophyll cells of *Lamium purpureum* in culture medium and obtained cell proliferation. He is regarded as the father of tissue culture.

5.1 Milestones in Plant Tissue Culture

Haberlandt (1902)

cultured plant cells in artificial condition called in vitro (inside glass) in culture medium (Knop's salt solution) containing glucose and peptone and developed callus (unorganized growth of cells and tissue) and proposed the concept Totipotency, it means the development of whole plant from isolated cells or tissue in in vitro condition.

P.R.White (1934)

developed root cultures, used Knop's solution along with three vitamins like pyridoxine, thiamine and nicotinic acid

F.C. Steward (1948)

used coconut water in plant tissue culture work and obtained cell proliferation from carrot explants (Cellular totipotency).

Morel and **Martin** (1952, 1955)

developed virus-free *Dahlia* and potato plants using shoot meristem culture.

Murashige and **Skoog** (1962)

formulated tissue culture medium, a land mark in plant tissue culture and it is the most frequently used medium for all kinds of tissue culture work.

Kanta *et al.* (1962)

produced test-tube fertilization in flowering plants.

Yamada *et al.* (1963)

produced *calli* and free cells in tissue culture of *Tradescantia reflexa.*

Guha and **Maheshwari** (1964)

developed *in vitro* production of haploid embryos from anthers of *Datura.*

Vasil and **Hildbrandt** (1965)

achieved differentiation of tobacco plants from single, isolated cells in micro propagation.

Takebe *et al.* (1971)

regenerated tobacco plants from isolated mesophyll protoplasts.

Carlson

and co-workers obtained protoplast fusion between *Nicotiana glauca* and *Nicotiana longsdorffii* and developed first interspecific somatic hybrid in 1971.

Melchers and co-workers in 1978

developed intergenic hybrid between potato and tomato called pomato.

Chilton (1983)

produced transformed tobacco plants from single cell transformation and gene insertion.

Horsh *et al.* (1984)

developed transgenic tobacco by Agrobacterium mediated gene transfer.

Knop's solution: Nutrient solution used in growth experiments of plants which contains:

Calcium nitrate 3.0 g	Potassium nitrate 1.0 g	Sucrose 50.0 g (optimal)
Magnesium sulfate 1.0 g	Dibasic Potassium phosphate 1.0 g	Deionized water 1000.0 ml

5.2 Basic concepts of Tissue Culture

Basic concepts of plant tissue culture are totipotency, differentiation, dedifferentiation and redifferentiation.

Totipotency

The property of live plant cells that they have the genetic potential when cultured in nutrient medium to give rise to a complete individual plant.

Differentiation

The process of biochemical and structural changes by which cells become specialized in form and function.

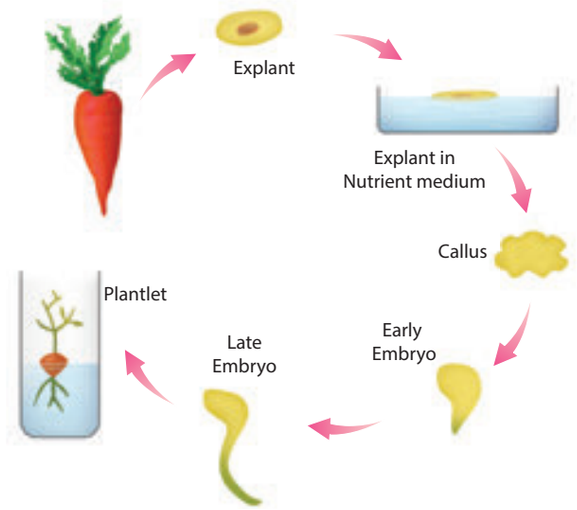


Figure 5.1: Totipotency

Redifferentiation

The further differentiation of already differentiated cell into another type of cell. For example, when the component cells of callus have the ability to form a whole plant in a nutrient medium, the phenomenon is called redifferentiation.

Dedifferentiation

The phenomenon of the reversion of mature cells to the meristematic state leading to the formation of callus is called dedifferentiation. These two phenomena of redifferentiation and dedifferentiation are the inherent capacities of living plant cells or tissue. This is described as totipotency.

5.3 Plant Tissue Culture (PTC)

Plant tissue culture is used to describe the *in vitro* and aseptic growth of any plant part on a tissue culture medium. This technology is based on three fundamental principles:

- The plant part or explant must be selected and isolated from the rest of plant body.
- The explant must be maintained in controlled physically (environmental) and chemically defined (nutrient medium) conditions.

Explant: The tissue taken from a selected plant transferred to a culture medium often to establish a new plant.

5.3.1 Laboratory Facilities for PTC

For PTC, the laboratory must have the following facilities:

Figure 5.2: Tissue culture lab

- Washing facility for glassware and ovens for drying glassware.
- Medium preparation room with autoclave, electronic balance and pH meter.
- Transfer area sterile room with laminar air-flow bench and a positive pressure ventilation unit called High Efficiency Particulate Air (HEPA) filter to maintain aseptic condition.
- Culture facility: Growing the explant inoculated into culture tubes at 22-28° C with illumination of light 2400 lux, with a photoperiod of 8-16 hours and a relative humidity of about 60%.

5.3.2 Technique Involved in PTC

1. Sterilization:

Sterilization is the technique employed to get rid of microbes such as bacteria and fungi in the culture medium, vessels and explants.

i. **Maintenance of Aseptic Environment:** During in vitro tissue culture maintenance of aseptic environmental condition should be followed, i.e., sterilization of glassware, forceps, scalpels, and all accessories in wet steam sterilization by autoclaving at 15 psi (121°C) for 15 to 30 minutes or dipping in 70% ethanol followed by flaming and cooling.

ii. **Sterilization of culture room:** Floor and walls are washed first with detergent and then with 2% sodium hypochlorite or 95% ethanol. The cabinet of laminar airflow is sterilized by clearing the work surface with 95% ethanol and then exposure of UV radiation for 15 minutes.

iii. **Sterilization of Nutrient Media:** Culture media are dispensed in glass containers, plugged with non-absorbent cotton or sealed with plastic closures and then sterilized using autoclave at 15 psi (121°C) for 15 to 30 minutes. The plant extracts, vitamins, amino acids and hormones are sterilized by passing through Millipore filter with 0.2 mm pore diameter and then added to sterilized culture medium inside Laminar Airflow Chamber under sterile condition.

iv. **Sterilization of Explants:** The plant materials to be used for tissue culture should be surface sterilized by first exposing the material in running tap water and then treating it in surface sterilization agents like 0.1% mercuric chloride, 70% ethanol under aseptic condition inside the Laminar Air Flow Chamber.

2. Media Preparation

The success of tissue culture lies in the composition of the growth medium, plant growth regulators and culture conditions such as temperature, pH, light and humidity. No single medium is capable of maintaining optimum growth of all plant tissues. Suitable nutrient medium as per the principle of tissue culture is prepared and used.

MS nutrient medium (Murashige and Skoog 1962) is commonly used. It has carbon sources, with suitable vitamins and hormones. The media formulations available for plant tissue culture other than MS are B5 medium (Gamborg.et.al 1968), White medium (white 1943), Nitsch's medium (Nitsch & Nitsch 1969). A medium may be solid or semisolid or liquid. For solidification, a gelling agent such as agar is added.

Agar: A complex mucilaginous polysaccharide obtained from marine algae (sea weeds) used as solidifying agent in media preparation.

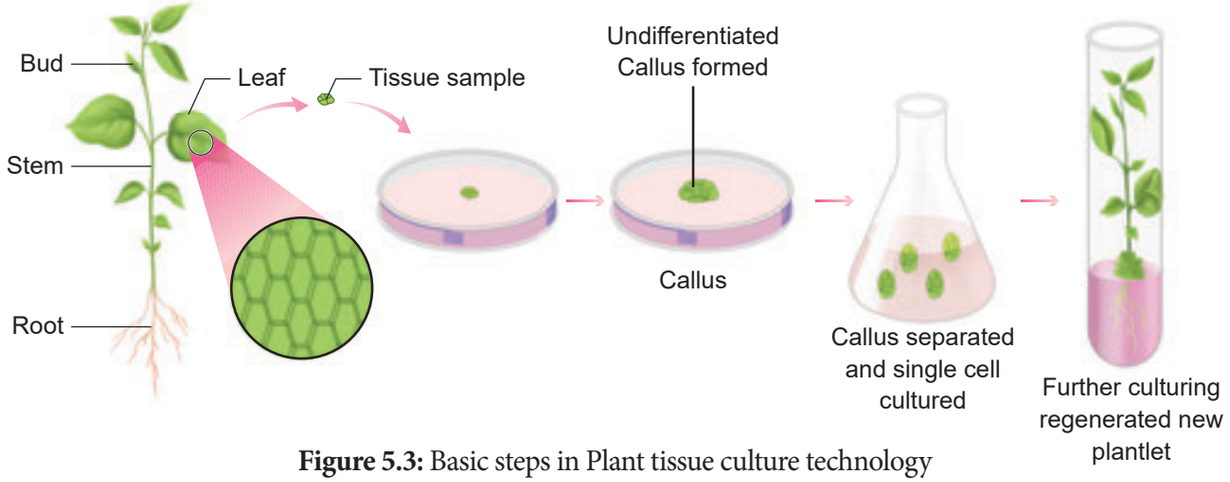


Figure 5.3: Basic steps in Plant tissue culture technology

Composition of MS (Murashige and Skoog) Medium	
Macronutrients:	
Ammonium nitrate (NH_4NO_3)	1650.0 mg/l
Potassium nitrate (KNO3)	1900.0 mg/l
Calcium chloride (CaCl2 2H2O)	440.0 mg/l
Magnesium sulphate (MgSO4 6H2O)	370.0 mg/l
Potassium dihydrogen phosphate (KH2PO4)	170.0 mg/l
Micronutrients:	
Manganese sulphate (MnSO4 4H2O)	22.3 mg/l
Zinc sulphate (ZnSO4 4H2O)	8.6 mg/l
Boric acid (H3BO3)	6.2 mg/l
Potassium iodide (KI)	0.83 mg/l
Minor nutrient:	
Sodium molybdate (Na2 MO4 2H2O)	0.250 mg/l
Cupric sulphate (CuSO4 5H2O)	0.025 mg/l
Cobaltous chloride (CoCl2 6H2O)	0.025 mg/l
Iron stock	
Na EDTA	37.25 mg/l
Ferrous Sulphate (FeSO4 7H2O)	27.85 mg/l
Vitamins	
Glycine	2.0 mg/l
Nicotinic acid	0.5 mg/l
Pyridoxin HCl	0.5 mg/l
Thaiamine HCl	0.1 mg/l
Growth Hormones	
IAA	1.30 mg/l
Kinetin	0.4–10.0 mg/l
Myo-inositol	100.0 mg/l
Sucrose	30.0 g/l
Solidifying Agent	
Agar	8.0 g/l

3. Culture condition

pH

The pH of medium is normally adjusted between 5.6 to 6.0 for the best result.

Temperature

The cultures should be incubated normally at constant temperature of 25°C ± 2°C for optimal growth.

Humidity and Light Intensity

The cultures require 50-60% relative humidity and 16 hours of photoperiod by the illumination of cool white fluorescent tubes of approximately 1000 lux.

Aeration

Aeration to the culture can be provided by shaking the flasks or tubes of liquid culture on automatic shaker or aeration of the medium by passing with filter-sterilized air.

4. Induction of Callus

Figure 5.4:
Induction of callus

Explant of 1-2 cm sterile segment selected from leaf, stem, tuber or root is inoculated (transferring the explants to sterile glass tube containing nutrient medium) in the MS nutrient medium supplemented with auxins and incubated at 25°C ± 2°C in an alternate light and dark period of 12 hours to induce cell division and soon the upper surface of explant develops into callus. Callus is a mass of unorganized growth of plant cells or tissues in *in vitro* culture medium.

5. Embryogenesis

Figure 5.5:
Embryogenesis

The callus cells undergoes differentiation and produces somatic embryos, known as **Embryoids**. The embryoids are sub-cultured to produce plantlets.

6. Hardening

The plantlets developed *in vitro* require a hardening period and so are transferred to greenhouse or hardening chamber and then to normal environmental conditions.

Hardening is the gradual exposure of *in vitro* developed plantlets in humid chambers in diffused light for acclimatization so as to enable them to grow under normal field conditions.

5.3.3 Types of Plant tissue cultures

Based on the explants some other plant tissue culture types are

1. Organ culture
2. Meristem culture
3. Protoplast culture
4. Cell culture.

1. Organ culture

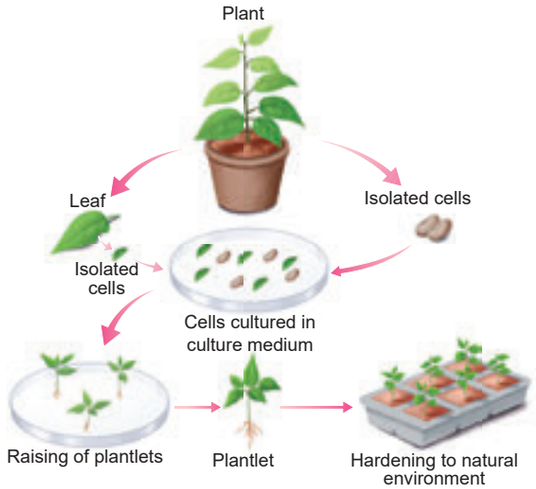


Figure 5.6: Organ Culture

The culture of embryos, anthers, ovaries, roots, shoots or other organs of plants on culture media.

2. Meristem Culture:

The culture of any plant meristematic tissue on culture media.

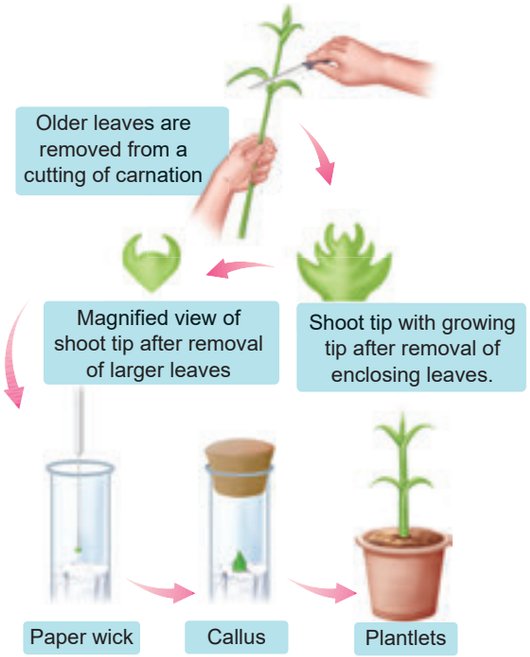


Figure 5.7: Meristem Culture

3. Protoplast Culture:

Protoplasts are cells without a cell wall, but bounded by a cell membrane or plasma membrane. Using protoplasts, it is possible to regenerate whole plants from single cells and also develop somatic hybrids. The steps involved in protoplast culture.

i. **Isolation of protoplast:** Small bits of plant tissue like leaf tissue are used for isolation of protoplast. The leaf tissue is immersed in 0.5% Macrozyme and 2% Onozuka cellulase enzymes dissolved in 13% sorbitol or mannitol at pH 5.4. It is then incubated over-night at 25°C. After a gentle teasing of cells, protoplasts are obtained, and these are then transferred to 20% sucrose solution to retain their viability. They are then centrifuged to get pure protoplasts as different from debris of cell walls.

ii. **Fusion of protoplast:** It is done through the use of a suitable fusogen. This is normally PEG (Polyethylene Glycol). The isolated protoplast are incubated in 25 to 30% concentration of PEG with Ca++ ions and the protoplast shows agglutination (the formation of clumps of cells) and fusion.

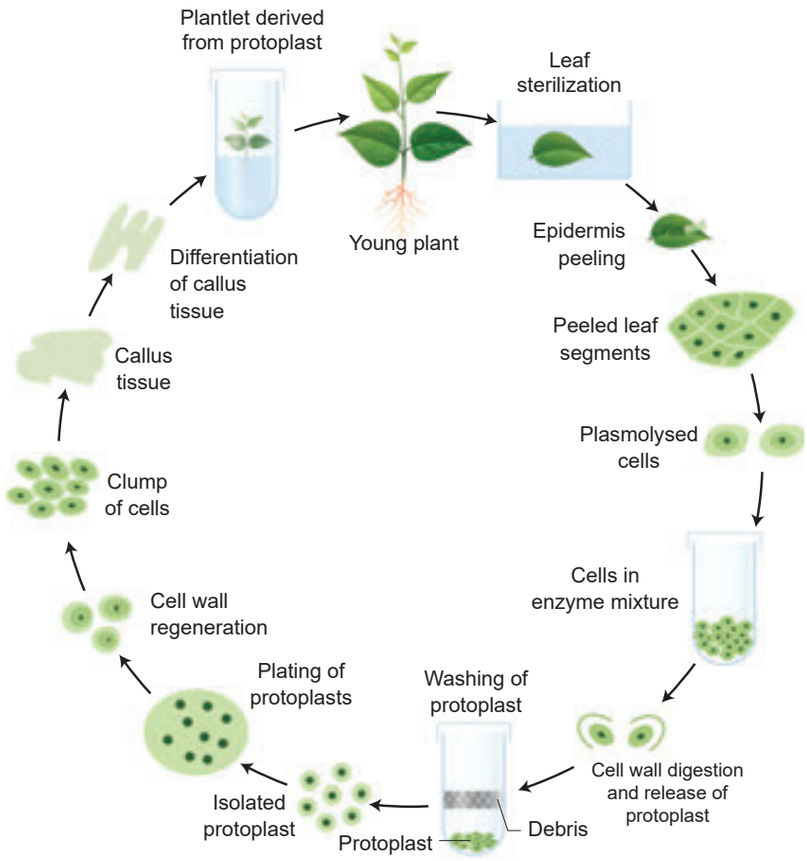


Figure 5.8: Protoplast Culture

iii. **Culture of protoplast:** MS liquid medium is used with some modification in droplet, plating or micro-drop array techniques. Protoplast viability is tested with fluorescein diacetate before the culture. The cultures are incubated in continuous light 1000-2000 lux at 25°C. The cell wall formation occurs within 24-48 hours and the first division of new cells occurs between 2-7 days of culture.

iv. **Selection of somatic hybrid cells:** The fusion product of protoplasts without nucleus of different cells is called a cybrid. Following this nuclear fusion happen. This process is called somatic hybridization.

4. Cell Suspension Culture

The growing of cells including the culture of single cells or small aggregates of cells *in vitro* in liquid medium is known as cell suspension culture. The cell suspension is prepared by transferring a portion of callus to the liquid medium and agitated using rotary shaker instrument. The cells are separated from the callus tissue and used for cell suspension culture.

Production of Secondary Metabolites

Cell suspension culture can be useful for the production of secondary metabolites like alkaloids, flavonoids, terpenoids, phenolic compounds and recombinant proteins. Secondary metabolites are chemical compounds that are not required by the plant for normal growth and development but are produced in the plant as 'byproducts' of cell metabolism. For Example: Biosynthesis and isolation of indole alkaloids from *Catharanthus roseus* plant cell culture.

The process of production of secondary metabolites can be scaled up and automated using bio-reactors for commercial production. Many strategies such as biotransformation, elicitation and immobilization have been used to make cell suspension cultures more efficient in the production of secondary metabolites. Few examples of industrially important plant secondary metabolites are listed below in the table:

Secondary metabolites	Plant source	Uses
Digoxin	*Digitalis purpuria*	Cardiac tonic
Codeine	*Papaver sominiferum*	Analgesic
Capsaicin	*Capsicum annum*	Rheumatic pain treatment
Vincristine	*Catharanthus roseus*	Anti-carcinogenic
Quinine	*Cinchona officinalis*	Antimalarial

Table 5.1: Secondary metabolites and its plant resources

5.4 Plant Regeneration Pathway

From the explants, plants can be regenerated by somatic embryogenesis or organogenesis.

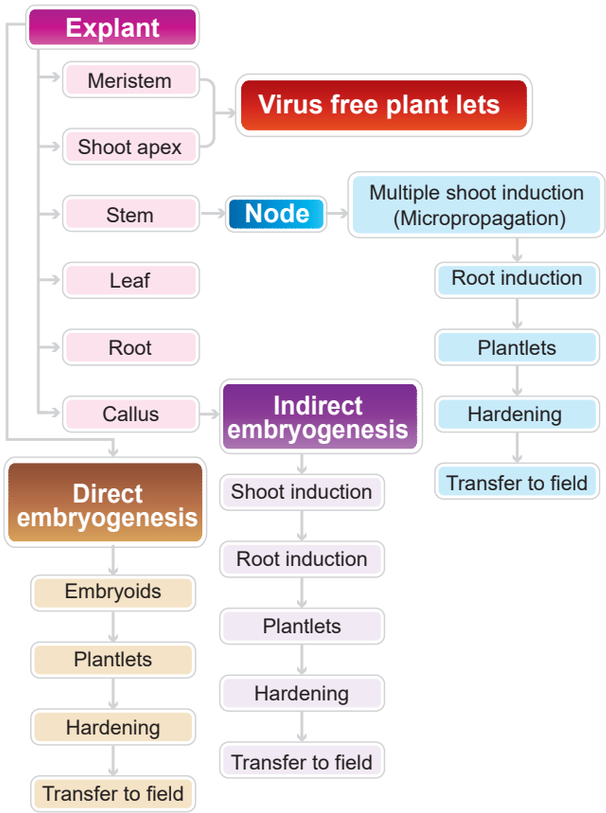


Figure 5.9: Flow chart of Plant regeneration pathway

5.4.1 Somatic Embryogenesis

Somatic embryogenesis is the formation of embryos from the callus tissue directly and these embryos are called **Embryoids** or from the *in vitro* cells directly form pre-embryonic cells which differentiate into embryoids.

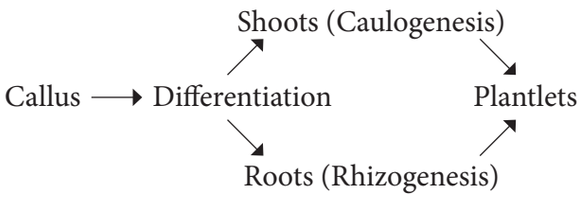
Applications

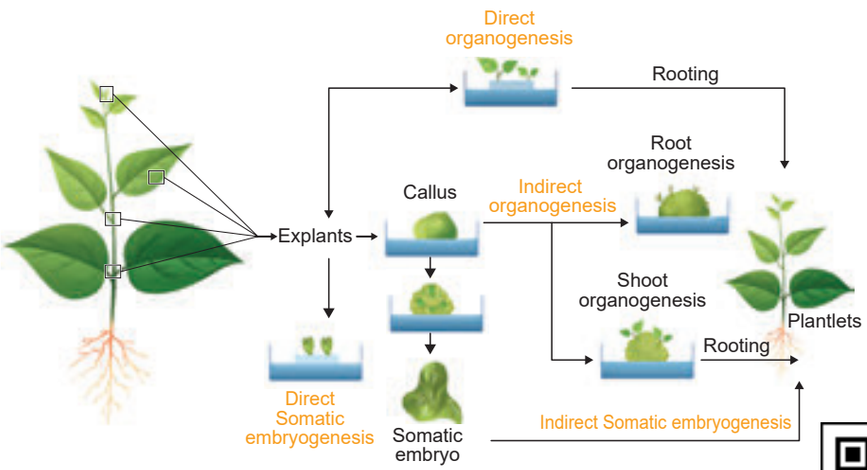
- Somatic embryogenesis provides potential plantlets which after hardening period can establish into plants.
- Somatic embryoids can be be used for the production of synthetic seeds.
- Somatic embryogenesis is now reported in many plants such as *Allium sativum*, *Hordeum vulgare, Oryza sativa, Zea mays* and this possible in any plant.

Synthetic seeds are produced by encapsulation of embryoids in agarose gel or calcium alginate.

5.4.2 Organogenesis

The morphological changes occur in the callus leading to the formation of shoot and roots is called organogenesis.





- Organogenesis can be induced *in vitro* by introducing plant growth regulators in the MS medium.
- Auxin and cytokinins induce shoot and root formation.

Figure 5.10: Plant Regeneration Pathway

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5.5 Applications of Plant Tissue Culture

Plant tissue culture techniques have several applications such as:

i. Improved hybrids production through somatic hybridization.

ii. Somatic embryoids can be encapsulated into synthetic seeds (synseeds). These encapsulated seeds or synthetic seeds help in conservation of plant biodiversity.

iii. Production of disease resistant plants through meristem and shoot tip culture.

iv. Production of stress resistant plants like herbicide tolerant, heat tolerant plants.

v. Micropropagation technique to obtain large numbers of plantlets of both crop and tree species useful in forestry within a short span of time and all through the year.

vi. Production of secondary metabolites from cell culture utilized in pharmaceutical, cosmetic and food industries.

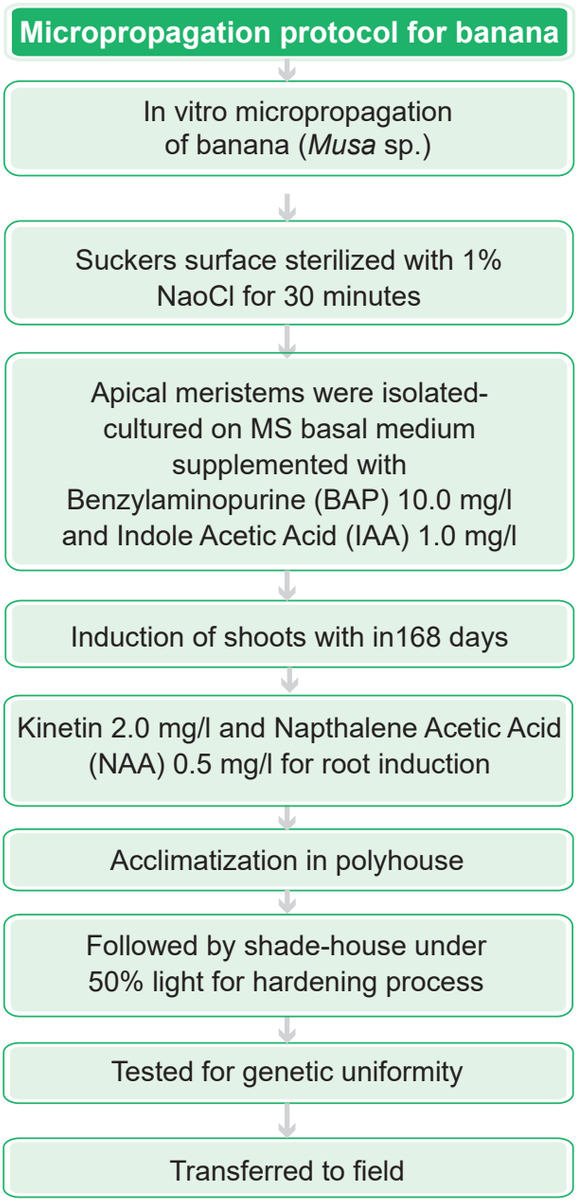
Somaclonal variations: Somatic variations found in plants regenerated in vitro (i.e. variations found in leaf, stem, root, tuber or propagule)

Gametoclonal variations: Gametophytic variations found in plants regenerated in vitro gametic origin (i.e. variations found in gametes and gametophytes)

5.5.1 Micropropagation of Banana

Micropropagation of plants at industrial level maintains high standards of homogeneity in plants like pineapple, banana, strawberry and potato.

Figure 5.11: Micropropagation of Banana



5.5.2 Artificial Seed

Artificial seeds or synthetic seeds (synseeds) are produced by using embryoids (somatic embryos) obtained through in vitro culture. They may even be derived from single cells from any part of the plant that later divide to form cell mass containing dense cytoplasm, large nuclceus, starch grains, proteins, and oils etc., To prepare the artificial seeds different inert materials are used for coating the somatic embryoids like agrose and sodium alginate.

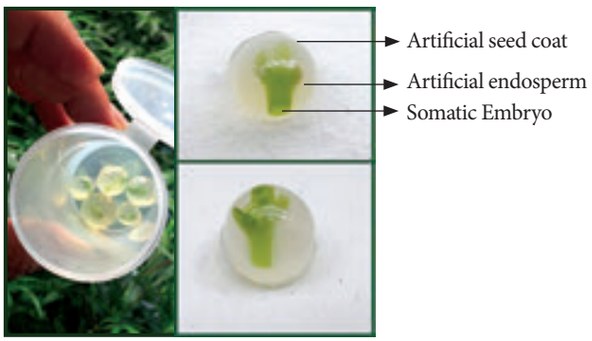


Figure 5.12: Artificial seeds

Advantages of Artificial seeds

Artificial seeds have many advantages over the true seeds

- Millions of artificial seeds can be produced at any time at low cost.
- They provide an easy method to produce genetically engineered plants with desirable traits.
- It is easy to test the genotype of plants.
- They can potentially stored for long time under cryopreservation method.
- Artificial seeds produce identical plants
- The period of dormancy of artificial seeds is greatly reduced, hence growth is faster with a shortened life cycle.

5.5.3 Virus-free plants

The field grown plants like perennial crops, usually are infected by variety of pathogens like fungi, bacteria, mycoplasma, viruses which cause considerable economic losses. Chemical methods can be used to control fungal and bacterial pathogens, but not viruses generally.

Shoot meristem tip culture is the method to produce virus-free plants, because the shoot meristem tip is always free from viruses.

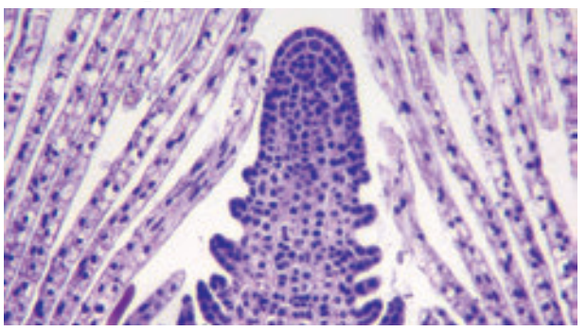


Figure 5.13: Shoot tip - Apical Meristem

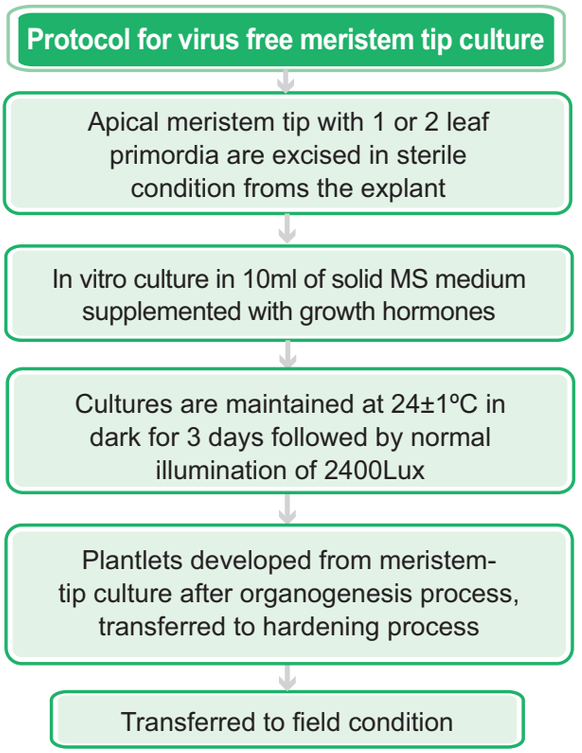


Figure 5.14: Protocol for virus free meristem culture

5.6 Conservation of plant genetic resources

5.6.1 Germplasm Conservation

Germplasm conservation refers to the conservation of living genetic resources like pollen, seeds or tissue of plant material maintained for the purpose of selective plant breeding, preservation in live condition and used for many research works.

Germplasm conservation resources is a part of collection of seeds and pollen that are stored in seed or pollen banks, so as to maintain their viability and fertility for any later use such as hybridization and crop improvement. Germplasm conservation may also involve a gene bank, DNA bank of elite breeding lines of plant resources for the maintenance of biological diversity and also for food security.

Figure 5.15: Seed bank

5.6.2 Cryopreservation (–195.C)

Figure 5.16: Cryopreservation

Cryopreservation, also known as Cryo-conservation, is a process by which protoplasts, cells, tissues, organelles, organs, extracellular matrix, enzymes or any other biological materials are subjected to preservation by cooling to very low temperature of –196°C using liquid nitrogen. At this extreme low temperature any enzymatic or chemical activity of the biological material will be totally stopped and this leads to preservation of material in dormant status. Later these materials can be activated by bringing to room temperature slowly for any experimental work.

Protective agents like dimethyl sulphoxide, glycerol or sucrose are added before cryopreservation process. These protective agents are called cryoprotectants, since they protect the cells, or tissues from the stress of freezing temperature.

5.7 Intellectual Property Right (IPR)

Intellectual property right (IPR) is a category of property that includes intangible creation of the human intellect, and primarily consists of copyrights, patents, and trademarks. It also includes other types of rights, such as trade secrets, publicity rights, moral rights, and rights against unfair competition.

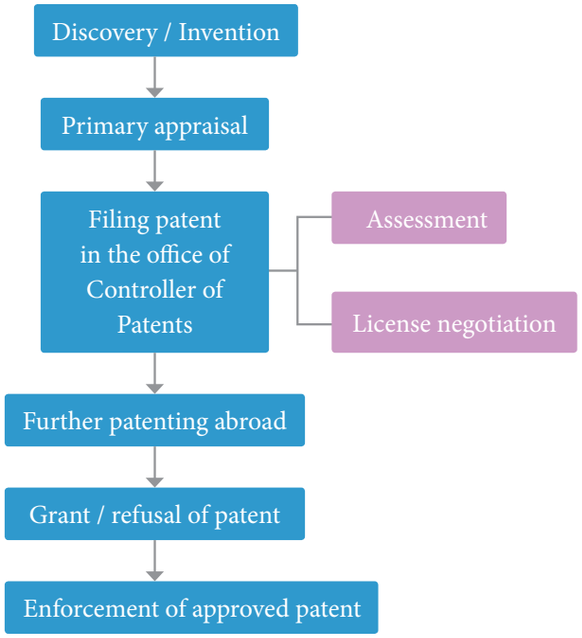
- In biotechnology, the transformed microorganisms and plants and technologies for the production of commercial products are exclusively the property of the discoverer.
- The discoverer has the full rights on his property. It should not be neglected by the others without legal permission.
- The right of discoverer must be protected and it does by certain laws framed by a country.
- The IPR is protected by different ways like patents, copyrights, trade secrets and trademarks, designs and geographical indications.

Figure 5.17: IPR in India

5.7.1 Patents

- It is a special right to the discoverer/inventor that has been granted by the government through legislation for trading new articles.
- A patent is a personal property which can be licensed or sold by the person or organisation just like any other property.
- Patent terms give the inventor the rights to exclude others from making, using or selling his invention.
- It is difficult to keep secret certain inventions and therefore, guidance should be obtained from a qualified patent attorney.
- A patent consists of three parts: the grant, specifications and claims.
- **The grant** is filled at the patent office which is not published. It is a signed document, actually the agreement that grants patent right to the inventor.
- **The specification** and claims are published as a single document which is made public from the patent office. The specification part is narrative in which the subject matter of invention is described as how the invention was carried out.
- **The claim** specifically defines the scope of the invention to be protected by the patent which the others may not practice.

General Steps in Patenting



5.7.2 Biosafety and Bioethics

Advances in biotechnology and their applications are mostly associated with controverisies. This is because the major part of the modern biotechnology deals with genetic manipulations. **ELSI** which represents **ethical**, **legal** and **social implications** of biotechnology broadly covers the relationship between biotechnology and society with particular reference to ethical and legal aspects.

Biosafety

Biosafety is the prevention of large-scale loss of biological integrity, focusing both on ecology and human health. These prevention mechanisms include conduction of regular reviews of the biosafety in laboratory settings, as well as strict guidelines to follow. Biosafety is used to protect from harmful incidents. Many laboratories handling biohazards employ an ongoing risk management assessment and enforcement process for biosafety. Failures to follow such protocols can lead to increased risk of exposure to biohazards or pathogens. Human error and poor techniques contribute to unnecessary exposure to hazards and compromise the best safeguards set into place for protection.

Potential risks and consideration for safety aspects

- Pathogenicity of living organisms and viruses - natural and genetically modified - to infect humans, animals and plants to cause diseases.
- Toxicity of allergy associated with microbial production.
- Increasing number of antibiotic resistant pathogenic microorganisms.
- Problems associated with the disposal of spent microbial biomass and purification of effluent from biotechnological process.
- Safety aspects associated with contamination, infection or mutation of process strains.
- Safety aspects associated with the industrial use of microorganisms containing *in vitro* recombinants.

Biosafety guidelines are being implemented by:

- The Institutional Bio-safety Committees (IBSCs) monitor the research activity at institutional level.
- The Review Committee on Genetic Manipulation (RCGM) functioning in the Department of Biotechnology (DBT) monitors the risky research activities in the laboratories.
- The Genetic Engineering Approval Committee (GEAC) of Ministry of Environment and Forest has the power to permit the use of Genetically Modified Organism (GMO) at commercial level and open field trials of transgenic materials including agricultural crops, industrial products and health care products.

Bioethics - Ethical, Legal and Social Implications (ELSI)

Bioethics refers to the study of ethical issues emerging from advances in biology and medicine. It is also a moral discernment as it relates to medical policy and practice. Bioethicists are concerned with the ethical questions that arise in the relationships among

life sciences, biotechnology and medicine. It includes the study of values relating to primary care and other branches of medicine.

The scope of bioethics is directly related to biotechnology, including cloning, gene therapy, life extension, human genetic engineering, astroethics life in space, and manipulation of basic biology through altered DNA, RNA and proteins. These developments in biotechnology will affect future evolution, and may require new principles, such as biotic ethics, that values life and its basic biological characters and structures.

The Ethical, Legal, and Social Implications (ELSI) program was founded in 1990 as an integral part of the Human Genome Project. The mission of the ELSI program was to identify and address issues raised by genomic research that would affect individuals, families, and society. A percentage of the Human Genome Project budget at the National Institutes of Health and the U.S. Department of Energy was devoted to ELSI research.

Ethical issues in Genomic Research

- Privacy and fairness in the use of genetic information, including the potential for genetic discrimination in employment and insurance.
- The integration of new genetic technologies, such as genetic testing, into the practice of clinical medicine.
- Ethical issues surrounding the design and conduct of genetic research with people, including the process of informed consent.

Genetic Engineering Appraisal Committee (GEAC)

GEAC is an apex body under Ministry of Environment, Forests and Climate change for regulating manufacturing, use, import, export and storage of hazardous microbes or genetically modified organisms (GMOs) and cells in the country. It was established as an apex body to accord approval of activities involving large scale use of hazardous microorganisms and recombinants in research and industrial production. The GEAC is also responsible for approval of proposals relating to release of genetically engineered organisms and products into the environment including experimental field trials (Biosafety Research Level trial-I and II known as BRL-I and BRL-II).

5.8 Future of Biotechnology

Biotechnology has become a comprehensive scientific venture from the point of academic and commercial angles, within a short time with the sequencing of human genome and genome of some important organisms. The future developments in biotechnology will be exciting. Thus the development in biotechnology will lead to a new scientific revolution that would change the lives and future of people. Like industrial and computer revolution, biotechnological revolution will also promise major changes in many aspects of modern life.

Summary

Tissue culture is the in vitro asceptic culture of cells, tissues or organs into whole plants under controlled nutritional and environmental conditions. A German physiologist Gotllieb Haberlant in 1902 for the first time attempted to culture plant cells in artificial medium, hence he was regarded as father of Tissue culture. Tissue culture mainly based on the concepts totipotency, differentiation, redifferentiation and dedifferentiation. Plant tissue culture technique involves selection of explants, sterilization, media preparation, maintaining culture condition, callus formation, embryogenesis or organgenesis and hardening. Based on the explants chosen the types of tissue culture are organ culture, meristem culture, protoplast culture and cell suspension culture. From the explants, plants can be regenerated by somatic embryogenesis or organgenesis is said to be plant regeneration pathway. Some of the main applications of tissue culture are

production of somatic hybrids, artificial seeds, disease resistant and stress resistant plants, germplasm conservation, micropropagation and production of secondary metabolites. Intellectual Property Right (IPR) is primarily aimed at patents, copyrights, trade secret and trademark given to the discoverer / inventor for the commercial production of transformed micro organisms or plants. Biosafety is the prevention mechanism to protect harmful incidents due to biohazards or pathogens. Bioethics dealt with ethical issue emerging from biotechnological advancement. ELSI program addresses issues related to genenomic research. GEAC (Genetic Engineering Appraisal Committee) is a regulatory authority for release of genetically modified products or organisms into the environment.

Evaluation

Choose the correct answer from the given option:

1. Totipotency refers to
   a) capacity to generate genetically identical plants.
   b) capacity to generate a whole plant from any plant cell / explant.
   c) capacity to generate hybrid protoplasts.
   d) recovery of healthy plants from diseased plants.
2. Micro propagation involves
   a) vegetative multiplication of plants by using micro-organisms.
   b) vegetative multiplication of plants by using small explants.
   c) vegetative multiplication of plants by using microspores.
   d) Non-vegetative multiplication of plants by using microspores and megaspores.
3. Match the following :

Column A	Column B
1) Totipotency	A) Reversion of mature cells into meristerm
2) Dedifferentiation	B) Biochemical and structural changes of cells
3) Explant	C) Properties of living cells develops into entire plant
4) Differentiation	D) Selected plant tissue transferred to culture medium

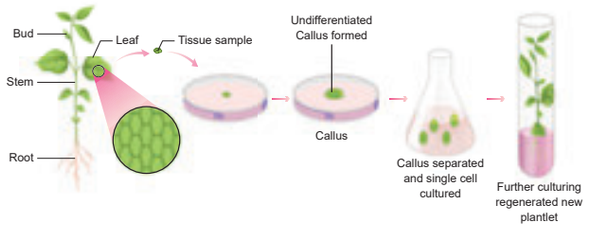
	1	2	3	4
a)	C	A	D	B
b)	A	C	B	D
c)	B	A	D	C
d)	D	B	C	A

4. The time duration for sterilization process by using autoclave is _____ minutes and the temperature is _____
   a) 10 to 30 minutes and 125° C
   b) 15 to 30 minutes and 121° C
   c) 15 to 20 minutes and 125° C
   d) 10 to 20 minutes and 121° C
5. Which of the following statement is correct
   a) Agar is not extracted from marine algae such as seaweeds.
   b) Callus undergoes differentiation and produces somatic embryoids.
   c) Surface sterilization of explants is done by using mercuric bromide
   d) P^H of the culture medium is 5.0 to 6.0
6. Select the incorrect statement from given statement
   a) A tonic used for cardiac arrest is obtained from Digitalis purpuria
   b) Medicine used to treat Rheumatic pain is extracted from Capsicum annum

c) An anti malarial drug is isolated from Cinchona officinalis.

d) Anti-cancinogenic property is not seen in Catharanthus roseus.

7. Virus free plants are developed from
   a) Organ culture
   b) Meristem culture
   c) Protoplast culture
   d) Cell suspension culture
8. The prevention of large scale loss of biological interity
   a) Biopatent b) Bioethics
   c) Biosafety d) Biofuel
9. Cryopreservation means it is a process to preserve plant cells, tissues or organs
   a) at very low temperature by using ether.
   b) at very high temperature by using liquid nitrogen
   c) at very low temperature of -196 by using liquid nitrogen
   d) at very low temperature by using liquid nitrogen
10. Solidifying agent used in plant tissue culture is
    a) Nicotinic acid
    b) Cobaltous chloride
    c) EDTA
    d) Agar
11. What is the name of the process given below? Write its 4 types.



12. How will you avoid the growing of microbes in nutrient medium during culture process? What are the techniques used to remove the microbes?
13. Write the various steps involved in cell suspension culture.
14. What do you mean Embryoids? Write its application.
15. Give the examples for micro propagation performed plants .
16. Explain the basic concepts involved in plant tissue culture.
17. Based on the material used, how will you classify the culture technology? Explain it.
18. Give an account on Cryopreservation.
19. What do you know about Germplasm conservation. Describe it.
20. Write the protocol for artificial seed preparation.

Glossary

Aseptic condition: Preparation of materials free from microbes in *in vitro* cultures.

Cell Culture: Growing of cells *in vitro*, including the culture of single cells or small aggregates of cells in a liquid medium.

Chemically defined medium: A nutritive medium used for culturing cells or tissue; each chemical of this medium is known and defined;

Cybrid: Cytoplasmic hybrid obtained by the fusion of cytoplasm of cells of different parental sources; a term applied to the fusion of cytoplasms of two different protoplasts;

Organogenesis: The process of initiation and development of shoot or root though *in vitro* culture particularly from callus

Chapter 6

Principles of Ecology

Learning Objectives

The learner will be able to

- Understand the interaction between organisms and their environment.
- Describe biotic and abiotic factors that influence the dynamics of populations.
- Describe how organisms adapt themselves to environmental changes.
- Learn the structure of various fruits and seeds related to their dispersal mechanism.

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Chapter outline

Ecology is a division of biology which deals with the study of environment in relation to organisms. It can be studied by considering individual organisms, population, community, biome or biosphere and their environment. While observing our different environments, one can ask questions like

- Why do plants or animals vary with places?
- What are the causes for variation in biological diversity of different places?
- How soil, climate and other physical features affect the flora and fauna or vice versa?

These questions can be better answered with the study of ecology.

Ecology is essentially a practical science involving experiments, continuous observations to predict how organisms react to particular environmental circumstances and understanding the principles involved in ecology.

6.1 Ecology

R. Misra

The term "ecology" (**oekologie**) is derived from two Greek words – **oikos** (meaning house or dwelling place and **logos** meaning study) It was first proposed by **Reiter** (1868). However, the most widely accepted definition of ecology was given by **Ernest Haeckel** (1869).

Alexander von Humbolt - Father of Ecology
Eugene P. Odum - Father of morden Ecology
R. Misra - Father of Indian Ecology

6.1.1 Definitions of ecology

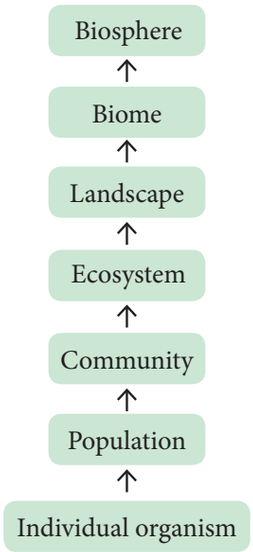
"The study of living organisms, both plants and animals, in their natural habitats or homes."

- Reiter (1885)

"Ecology is the study of the reciprocal relationship between living organisms and their environment." **- Earnest Haeckel (1889)**

6.1.2 Ecological hierarchy

The interaction of organisms with their environment results in the establishment of grouping of organisms which is called **ecological hierarchy** or ecological levels of organization. The basic unit of ecological hierarchy is an individual organism. The different hierarchy of ecological systems is illustrated below:



6.1.3 Branches of Ecology:

Ecology is mainly divided into two branches, they are autecology and synecology.

1. Autecology is the ecology of an individual species and is also called species ecology.

2. Synecology is the ecology of a population or community with one or more species and also called as community ecology.

Many advances and developments in the field ecology resulted in various new dimensions and branches. Some of the advanced fields are Molecular ecology, Eco technology, Statistical ecology and Environmental toxicology.

6.1.4 Habitat and Niche

Habitat

Habitat is a specific physical place or locality occupied by an organism or any species which has a particular combination of abiotic or environmental factors. But the environment of any community is called **Biotope**.

Niche

An ecological niche refers to an organism's place in the biotic environment and its functional role in an ecosystem. The term was coined by the naturalist **Roswell Hill Johnson** but **Grinell** (1917) was probably first to use this term. The habitat and niche of any organism is called **Ecotope**

The differences between habitat and niche are as follows.

	Habitat	Niche
1.	A specific physical space occupied by an organism (species)	A functional space occupied by an organism in the same eco-system
2.	Same habitat may be shared by many organisms (species)	A single niche is occupied by a single species
3.	Habitat specificity is exhibited by organism.	Organisms may change their niche with time and season.

Table 6.1: Difference between habitat and niche

Applied ecology or environmental technology :

Application of the Science of ecology is otherwise called as **Applied ecology or Environmental technology.** It helps us to manage and conserve natural resources, particularly ecosystems, forest and wild life conservative and management. Environmental management involves Bio-diversity conservation, Ecosystem restoration, Habitat management, Invasive species management, Protected areas management and also help us plan landscapes and environmental impact designing for the futuristic ecology.

6.1.5 Ecological equivalents

Taxonomically different species occupying similar habitats (Niches) in different geographical regions are called **Ecological equivalents.**

Examples:

- Certain species of epiphytic orchids of Western Ghats of India differ from the epiphytic orchids of South America. But they are epiphytes.
- Species of the grass lands of Western Ghats of India differ from the grass species of temperate grass lands of Steppe in North America. But they are all ecologically primary producers and fulfilling similar roles in their respective communities.

6.2 Ecological factors

Many organisms, co-exist in an environment. The environment (surrounding) includes physical, chemical and biological components. When a component surrounding an organism affects the life of an organism, it becomes a factor. All such factors together are called **environmental factors** or **ecological factors**. These factors can be classified into living (**biotic**) and non-living (**abiotic**) which make the environment of an organism. However the ecological factors are meaningfully grouped into four classes, which are as follows:

i. Climatic factors

ii. Edaphic factors

iii. Topographic factors

iv. Biotic factors

We will discuss the above factors in a concise manner.

Flowers of poppy, chicory, dog rose and many other plants, blossom before the break of dawn (4 – 5 am), evening primrose open up with the onset of dusk (5 – 6 pm) due to diurnal rhythm.

6.2.1 Climatic Factors

Climate is one of the important natural factors controlling the plant life. The climatic factors includes light, temperature, water, wind and fire.

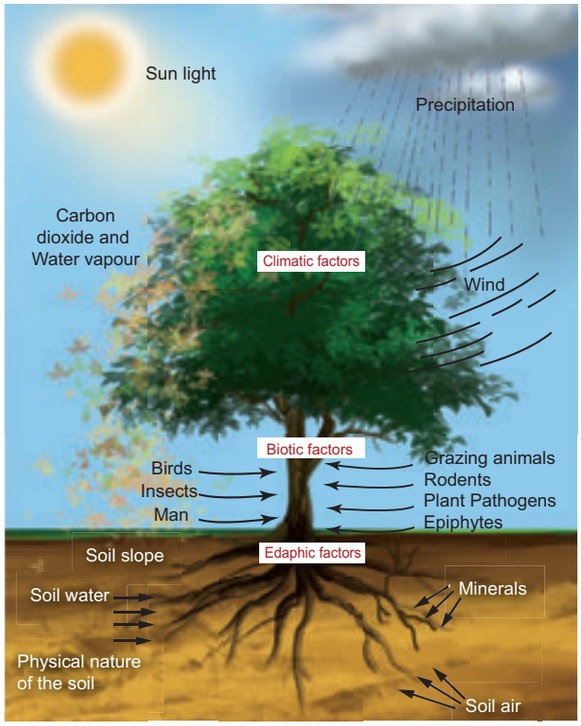


Figure 6.1: Environmental factors affecting a plant

a. Light

Light is a well known factor needed for the basic physiological processes of plants, such as photosynthesis, transpiration, seed germination and flowering. The portion of the sunlight which can be resolved by the human eye is called **visible light.** The visible part of light is made-up of wavelength from about 400 nm (**violet**) to 700 nm (**red**). The rate of photosynthesis is maximum at **blue** (400 – 500 nm) and **red** (600 – 700 nm). The **green** (500 – 600 nm) wave length of spectrum is less strongly absorbed by plants.

Effects of light on plants

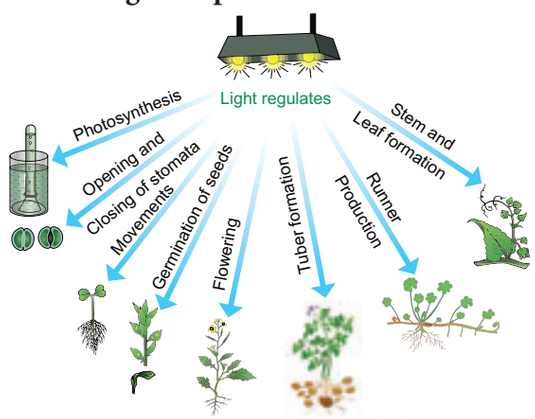


Figure 6.2: Various effects of light upon a green plant

Based on the tolerance to intensities of light, the plants are divided into two types. They are

1. **Heliophytes** - Light loving plants. Example: Angiosperms.
2. **Sciophytes** - Shade loving plants. Example: Bryophytes and Pteridophytes.

In deep sea (>500m), the environment is dark and its inhabitants are not aware of the existence of celestial source of energy called Sun. What, then is their source of energy?

Palaeoclimatology–Helps to reconstruct past climates of our planet and flora, fauna and ecosystem in which they lived. Example: Air bubbles trapped in ice for tens of thousands of years with fossilized pollen, coral, plant and animal debris.

b. Temperature

Temperature is one of the important factors which affect almost all the metabolic activities of an organism. Every physiological process in an organism requires an optimum temperature at which it shows the maximum metabolic rate. Three limits of temperature can be recognized for any organism. They are

1. **Minimum temperature** - Physiological activities are lowest.
2. **Optimum temperature** - Physiological activities are maximum.
3. **Maximum temperature** - Physiological activities will stop.

Based on the temperature prevailing in an area, **Raunkiaer** classified the world's vegetation into the following four types. They are megatherms, mesotherms, microtherms and hekistotherms. In thermal springs and deep sea hydrothermal vents where average temperature exceed 100°c.

Based on the range of **thermal tolerance**, organisms are divided into two types.

1. **Eurythermal:** Organisms which can tolerate a wide range of temperature fluctuations.

Example: *Zostera* (A marine Angiosperm) and *Artemisia tridentata*.

2. **Stenothermal:** Organisms which can tolerate only small range of temperature variations. Example: Mango and Palm (Terrestrial Angiosperms).

Mango plant donot and cannot grow in temperate countries like Canada and Germany.

Thermal Stratification

It is usually found in aquatic habitat. The change in the temperature profile with increasing depth in a water body is called **thermal stratification**. There are three kinds of thermal stratifications.

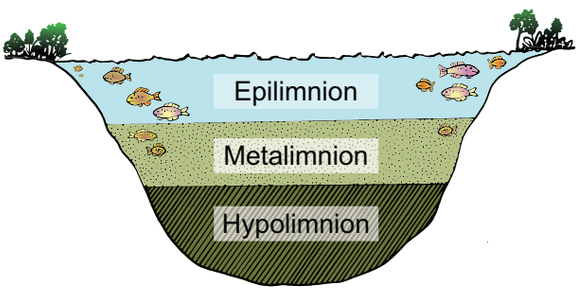


Figure 6.3: Thermal stratification of pond

1. **Epilimniotn** – The upper layer of warmer water.
2. **Metalimnion** – The middle layer with a zone of gradual decrease in temperature.
3. **Hypolimnion** - The bottom layer of colder water.

Temperature based zonation

Variations in **latitude** and **altitude** do affect the temperature and the vegetation on the earth surface. The latitudinal and altitudinal zonation of vegetation is illustrated below:

Latitude: Latitude is an angle which ranges from 0^0 at the equator to 90^0 at the poles.

Altitude: How high a place is located above the sea level is called the altitude of the place.

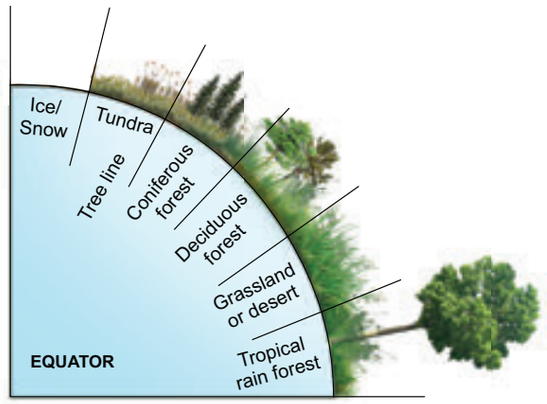


Figure 6.4: Latitudinal zonation of vegetation type

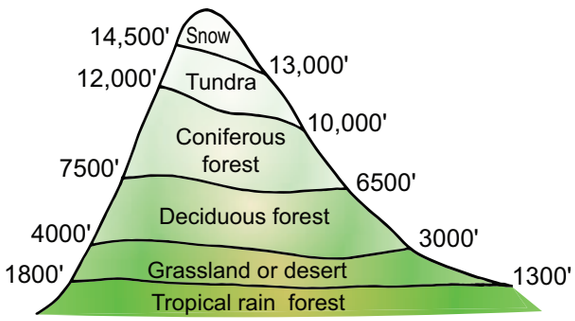


Figure 6.5: Altitudinal zonation of vegetation

Timber line / Tree line : It is an imaginary line in a mountain or higher areas of land that marks the level above which trees do not grow. The altitudinal limit of normal tree growth is about **3000** to **4000m.**

Effects of temperature

The following physiological processes are influenced by temperature:

- Temperature affects the enzymatic action of all the bio-chemical reactions in a plant body.
- It influences CO_2 and O_2 solubility in the biological systems. Increases respiration and stimulates growth of seedlings.
- Low temperature with high humidity can spread diseases to plants.
- The varying temperature with moisture determines the distribution of the vegetation types.

c. Water

Water is one of the most important climatic factors. It affects the vital processes of all living organisms. It is believed that even life had originated only in water during the evolution of Earth. Water covers more than 70% of the earth's surface. In nature, water is available to plants in three ways. They are **atmospheric moisture**, **precipitation** and **soil water**.

Evergreen forests – Found where heavy rainfall occurs throughout the year.

Sclerophyllous forests – Found where heavy rainfall occurs during winter and low rainfall during summer.

The productivity and distribution of plants depend upon the availability of water. Further the quality of water is also important especially for the aquatic organisms. The total amount of water salinity in different water bodies are :i).5% in inland water (Fresh water) ii).30 – 35% in sea water and iii). More than 100% in hypersaline water (**Lagoons**)

Based on the range of tolerance of salinity, organisms are divided into two types.

1. Euryhaline: Organisms which can live in water with wide range of salinity. Examples: Marine algae and marina angiosperms

2. Stenohaline: Organisms which can withstand only small range of salinity. Example: Plants of estuaries.

Terminology		Environmental factor
Stenothermal	Eurythermal	Temperature
Stenohaline	Euryhaline	Salinity
Stenoecious	Euryoecious	Habitat selection (niche)
Stenohydric	Euryhydric	Water
Stenophagic	Euryphagic	Food
Stenobathic	Eurybathic	Depth of water / habitat

Table 6.2: Tolerance of Environmental factor

Examples of tolerance to toxicity

i. Soyabean and tomato manage to tolerate presence of cadmium poisoning by isolating cadmium and storing into few group of cells and prevent cadmium affecting other cells .

ii. Rice and *Eichhornia* (water hyacinth) tolerate cadmium by binding it to their proteins.

These plants otherwise can also be used to remove cadmium from contaminated soil ,this is known as **Phytoremediation.**

d. Wind

Air in motion is called wind. It is also a vital ecological factor. The atmospheric air contains a number of gases, particles and other constituents. The composition of gases in atmosphere is as follows: Nitrogen -78% , Oxygen -21%, Carbon-di-oxide -0.03%, Argon and other gases - 0.93%. The other components of wind are water vapour, gaseous pollutants, dust, smoke particles, microorganisms, pollen grains, spores, etc. **Anemometer** is the instrument used to measure the speed of wind.

Green House Effect
Albedo Effect

Gases let out to atmosphere causes climatic change. Emission of dust and aerosols (small solids or liquid particles in suspension in the atmosphere) from industries, automobiles, forest fire, So_2 and DMS (dimethyl sulphur) play an important role in disturbing the temperature level of any region. Aerosols with small particles is reflecting the solar radiation entering the atmosphere. This is known as **Albedo effect**. So it reduces the temperature (cooling) limits, photosynthesis and respiration. The sulphur compounds are responsible for **acid rain** due to acidification of rain water and destroy the ozone.

Effects of wind

- Wind is an important factor for the formation of rain
- Causes wave formation in lakes and ocean, which promotes aeration of water
- Strong wind causes soil erosion and reduces soil fertility
- Increases the rate of transpiration
- Helps in pollination in anemophilous plants
- It also helps in dispersal of many fruits, seeds, spores, etc.
- Strong wind may cause up-rooting of big trees
- Unidirectional wind stimulates the development of **flag forms** in trees.

Figure 6.6: Flag form in trees

e. Fire

Fire is an exothermic factor caused due to the chemical process of combustion, releasing heat and light. It is mostly man-made and sometimes develops naturally due to the friction between the tree surfaces. Fire is generally divided into

1. **Ground fire** – Which is flameless and subterranean.
2. **Surface fire** – Which consumes the herbs and shrubs.
3. **Crown fire** – Which burns the forest canopy.

Effects of fire

- Fire has a direct lethal effect on plants
- Burning scars are the suitable places for the entry of parasitic fungi and insects
- It brings out the alteration of light, rainfall, nutrient cycle, fertility of soil, pH, soil flora and fauna
- Some fungi which grow in soil of burnt areas called pyrophilous.
  Example: *Pyronema confluens*.

Indicators of fire – *Pteris* (fern) and *Pyronema* (fungus) indicates the burnt up and fire disturbed areas. So they are called indicators of fire.

Fire break – It is a gap made in the vegetation that acts as a barrier to slow down or stop the progress of fire.

A **natural fire break** may occur when there is a lack of vegetation such as River, lake and canyon found in between vegetation may act as a natural fire break.

Rhytidome: It is the structural defense by plants against fire .The outer bark of trees which extends to the last formed periderm is called Rhytidome. It is composed of multiple layers of suberized periderm, cortical and phloem tissues. It protects the stem against fire , water loss, invasion of insects and prevents infections by microorganisms.

6.2.2 Edaphic factors

Edaphic factors, the abiotic factors related to soil, include the physical and chemical composition of the soil formed in a particular area. The study of soils is called **Pedology.**

The soil

Soil is the weathered superficial layer of the Earth in which plants can grow. It is a complex composite mass consisting of soil constituents, soil water, soil air and soil organisms, etc.

Soil formation

Soil originates from rocks and develops gradually at different rates, depending upon the ecological and climatic conditions. Soil formation is initiated by the weathering process. Biological weathering takes place when organisms like bacteria, fungi, lichens and plants help in the breakdown of rocks through the production of acids and certain chemical substances.

Soil types

Based on soil formation (**pedogenesis**), the soils are divided into

1. **Residual soils** –These are soils formed by weathering and **pedogenesis** of the rock.
2. **Transported soils** – These are transported by various agencies.

The important edaphic factors which affect vegetation are as follows:

1. Soil moisture: Plants absorbs rain water and moisture directly from the air

2. Soil water: Soil water is more important than any other ecological factors affecting the distribution of plants. Rain is the main source of soil water. Capillary water held between pore spaces of soil particles and angles between them is the most important form of water available to the plants.

3. Soil reactions: Soil may be **acidic** or **alkaline** or **neutral** in their reaction. pH value of the soil solution determines the availability of plant nutrients. The best pH range of the soil for cultivation of crop plants is **5.5 to 6.8.**

4. Soil nutrients: Soil fertility and productivity is the ability of soil to provide all essential plant nutrients such as minerals and organic nutrients in the form of ions.

5. Soil temperature: Soil temperature of an area plays an important role in determining the geographical distribution of plants. Low temperature reduces use of water and solute absorption by roots.

6. Soil atmosphere: The spaces left between soil particles are called pore spaces which contains **oxygen** and **carbon-di-oxide**.

7. Soil organisms: Many organisms existing in the soil like bacteria, fungi, algae, protozoans, nematodes, insects, earthworms, etc. are called soil organisms.

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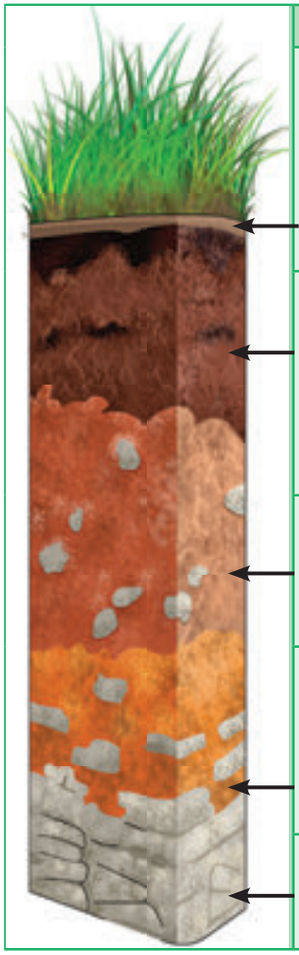


Horizon	Description
O–Horizon (Organic horizon) Humus	It consists of fresh or partially decomposed organic matter. O1 – Freshly fallen leaves, twigs, flowers and fruits O2 – Dead plants, animals and their excreta decomposed by micro-organisms. Usually absent in agricultural and deserts.
A–Horizon (Leached horizon) Topsoil - Often rich in humus and minerals.	It consists of top soil with humus, living creatures and in-organic minerals. A1 – Dark and rich in organic matter because of mixture of organic and mineral matters. A2 – Light coloured layer with large sized mineral particles.
B-Horizon (Accumulation horizon) (Subsoil-Poor in humus, rich in minerals)	It consists of iron, aluminium and silica rich clay organic compounds.
C - Horizon (Partially weathered horizon) Weathered rock Fragments - Little or no plant or animal life.	It consists of parent materials of soil, composed of little amount of organic matters without life forms.
R – Horizon (Parent material) Bedrock	It is a parent bed rock upon which underground water is found .

Figure 6.7: Soil Profile

Soil Profile

Soil is commonly stratified into horizons at different depth. These layers differ in their physical, chemical and biological properties. This succession of super-imposed horizons is called soil profile.

Types of soil particles

Based on the relative proportion of soil particles, four types of soil are recognized.

	Soil type	Size	Relative proportion
1	Clayey soil	Less than 0.002 mm	50% clay and 50% silt (cold / heavy soil)
2	Silt soil	0.002 to 0.02mm	90% silt and 10% sand
3	Loamy soil	0.002 to 2mm	70% sand and 30 % clay / silt or both (Garden soil)
4	Sandy soil	0.2 to 2 mm	85% sand and 15% clay (light soil)

Table 6.3: Types of soil particles

Loamy soil is ideal soil for cultivation. It consists of 70% sand and 30% clay or silt or both. It ensures good retention and proper drainage of water. The porosity of soil provides adequate aeration and allows the penetration of roots.

Based on the water retention, aeration and mineral contents of soil, the distribution of vegetation is divided into following types.

1. **Halophytes:** Plants living in saline soils
2. **Psammophytes:** Plants living in sandy soils
3. **Lithophytes:** Plants living on rocky surface
4. **Chasmophytes**: Plants living in rocky crevices
5. **Cryptophytes**: Plants living below the soil surface
6. **Cryophytes**: Plants living in ice surface
7. **Oxylophytes**: Plants living in acidic soil
8. **Calciphytes**: Plants living in calcium rich alkaline soil.

Hollard –Total soil water content
Chresard –Water available to plants
Echard – Water not available to plants

6.2.3 Topographic factors

The surface features of earth are called **topography**. Topographic influence on the climate of any area is determined by the interaction of solar radiation, temperature, humidity, rainfall, latitude and altitude. It affects the vegetation through climatic variations in small areas (micro climate) and even changes the soil conditions. Topographic factors include latitude, altitude, direction of mountain, steepness of mountain etc.

a. Latitudes and altitudes

Latitudes represent distance from the equator. Temperature values are maximum at the equator and decrease gradually towards poles. Different types of vegetation occur from equator to poles which are illustrated below.

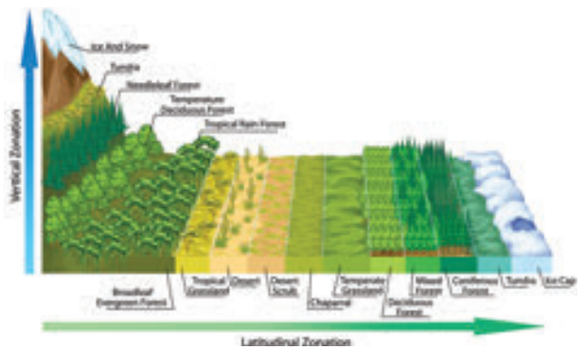


Figure 6.8: Latitudinal and Altitudinal Vegetation

Height above the sea level forms the **altitude**. At high altitudes, the velocity of wind remains high, temperature and air pressure decrease while humidity and intensity of light increases. Due to these factors, vegetation at different altitudes varies, showing distinct zonation.

b. Direction of Mountain

North and south faces of mountain or hill possess different types of flora and fauna because they differ in their humidity, rainfall, light intensity, light duration and temperature regions.

Ecotone - The transition zone between two ecosystems. Example: The border between forest and grassland.

Edge effect – Those species are found in the ecotone areas are due to the effect of environment of the two habitats. This is called edge effect. Example: Owl in the ecotone area between forest and grassland.

The two faces of the mountain or hill receive different amount of solar radiation, wind action and rain. Of these two faces, the windward region possesses good vegetation due to heavy rains and the leeward region possesses poor vegetation due to rain shadows (rain deficit).

Similarly in the soil of aquatic bodies like ponds the center and edge possess different depth of water due to soil slope and different wave actions in the water body. Therefore, different parts of the same area may possess different species of organisms.

c. Steepness of the mountain

The steepness of the mountain or hill allows the rain to run off. As a result the loss of water causes water deficit and quick erosion of the top soil resulting in **poor vegetation**. On the other hand, the plains and valley are **rich in vegetation** due to the slow drain of surface water and better retention of water in the soil.

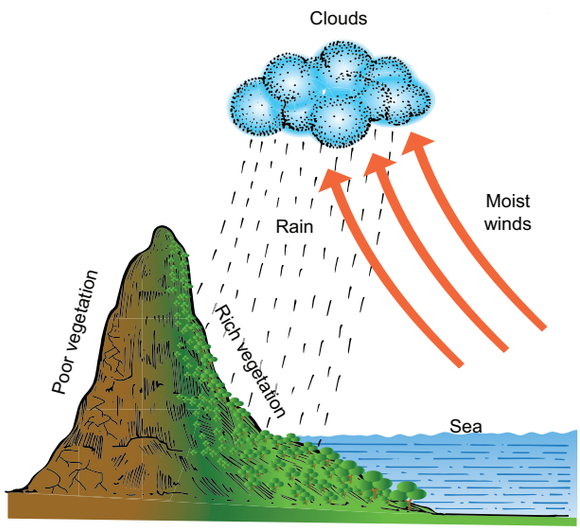


Figure 6.9: Steepness of mountain

6.2.4 Biotic factors

The interactions among living organisms such as plants and animals are called **biotic factors,** which may cause marked effects upon vegetation. The effects may be direct and indirect and modifies the environment. The plants mostly which lives together in a community and influence one another. Similarly, animals in association with plants also affect the plant life in one or several ways. The different interactions among them can be classified into following two types they are positive interaction and negative interaction

Positive interactions

When one or both the participating species are benefited, it is positive interaction. Examples; Mutualism and Commensalism.

a. Mutualism: It is an interaction between two species of organisms in which both are benefitted from the obligate association. The following are common examples of mutualism.

Nitrogen fixation

Rhizobium (Bacterium) forms nodules in the roots of leguminous plants and lives symbiotically. The *Rhizobium* obtains food from leguminous plant and in turn fixes atmospheric nitrogen into nitrate, making it available to host plants.

Other examples:

- Water fern (*Azolla*) and Nitrogen fixing Cyanobacterium *(Anabaena*).
- *Anabaena* present in coralloid roots of *Cycas*. (Gymnosperm)

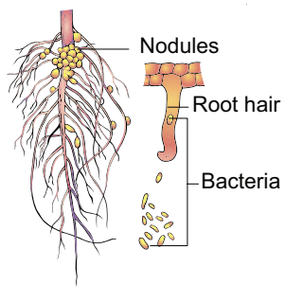


Figure 6.10: A nodulated legume plant root with bacteria

- Cyanobacterium (*Nostoc*) found in the thalloid body of *Anthoceros.*(Bryophytes)
- Wasps present in fruits of fig.
- Lichen is a mutual association of an **alga** and **a fungus**.
- Roots of terrestrial plants and fungal hyphae- **Mycorrhiza**

b. Commensalism: It is an interaction between two organisms in which one is benefitted and the other is neither benefitted nor harmed. The species that derives benefit is called the **commensal,** while the other species is called the **host**. The common examples of commensalism are listed below:

	Interaction type	Combination		Effects	Examples
1.Positive interaction					
1	**Mutualism**	(+)	(+)	Both species benefitted	Lichen, *Mycorrhiza* etc.
2	**Commensalism**	(+)	(0)	One species is benefitted and the other species is neither benefitted nor harmed	orchids, Lianas etc.
2.Negative interaction					
4	**Predation**	(+)	(-)	One species benefitted, the other species are harmed	*Drosera, Nepenthes* etc.
5	**Parasitism**	(+)	(-)	One species benefitted, the other species are harmed	*Cuscuta, Duranta, Viscum* etc.
6	**Competition**	(-)	(-)	Harmful for both	Grassland species
7	**Amensalism**	(-)	(0)	Harmful for one, but the other species are unaffected	*Penicillium* and *Staphylo coccus*

(+) Benefitted, (-) Harmed (0)Unaffected

Table 6.4: Different interactions of plant

Epiphytes

The plants which are found growing on other plants without harming them are called epiphytes. They are commonly found in tropical rain forest.

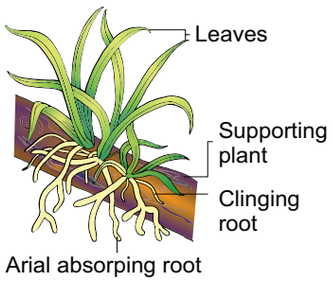


Figure 6.11: An epiphytic plant-*Vanda*

The epiphytic higher plant (**Orchids**) gets its nutrients and water from the atmosphere with the help of their hygroscopic roots which contain special type of spongy tissue called **Velamen.** So it prepares its own food and does not depend on the host. They use the host plant only for support and does not harm it in any way.

- Many orchids, ferns, lianas, hanging mosses, *Peperomia*, money plant and *Usnea* (Lichen) are some of the examples of epiphytes.
- Spanish Moss –*Tillandsia* grows on the bark of Oak and Pine trees.

Proto Cooperation

An interaction between organisms of different species in which both organisms benefit but neither is dependent on the relationship. Example: Soil bacteria / fungi and plants growing in the soil.

Negative interactions

When one of the interacting species is benefitted and the other is harmed, it is called **negative interaction** . Examples: predation, parasitism, competition and amensalism.

a. Predation: It is an interaction between two species, one of which captures, kills and eats up the other. The species which kills is called a **predator** and the species which is killed is called a **prey**. The predator is benefitted while the prey is harmed.

Examples:

- A number of plants like *Drosera* (Sun dew Plant), *Nepenthes* (Pitcher Plant), *Diaonaea* (Venus fly trap), *Utricularia* (Bladder wort) and *Sarracenia* are predators which consume insects and other small animals for their food as a source of nitrogen. They are also called as **insectivorous plants**.

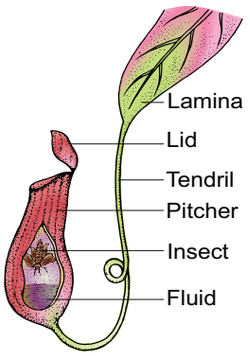


Figure 6.12: Pitcher plant – with insect

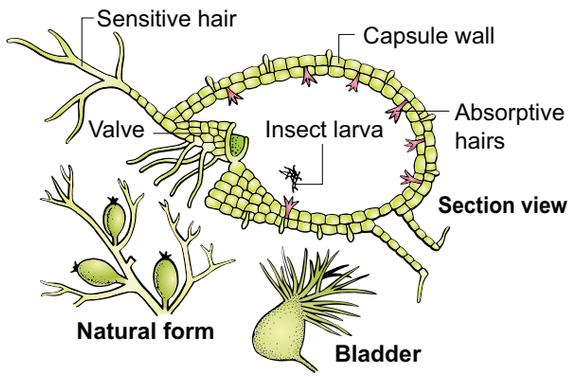


Figure 6.13: Insectivorous plant *Utricularia*

- Many herbivores are **predators**. Cattles, Camels, Goats etc., frequently browse on the tender shoots of herbs, shrubs and trees. Generally annuals suffer more than the perennials. Grazing and browsing may cause remarkable changes in vegetation. Nearly 25 percent of all insects are known as phytophagous(feeds on plant sap and other parts of plant)
- Many **defense mechanisms** are evolved to avoid their predations by plants. Examples: *Calotropis* produces highly poisonous cardiac glycosides, Tobacco produces nicotine, coffee plants produce caffeine, *Cinchona* plant produces quinine. Thorns of *Bougainvillea*, spines of *Opuntia*, and latex of cacti also protect them from predators.

b. Parasitism: It is an interaction between two different species in which the **smaller partner** (parasite) obtains food from the **larger partner** (host or plant). So the parasitic species is benefited while the host species is harmed. Based on the host-parasite relationship, parasitism is classified into two types they are holoparasite and hemiparasite.

Holoparasites

The organisms which are dependent upon the host plants for their entire nutrition are called **Holoparasites**. They are also called **total parasites**.

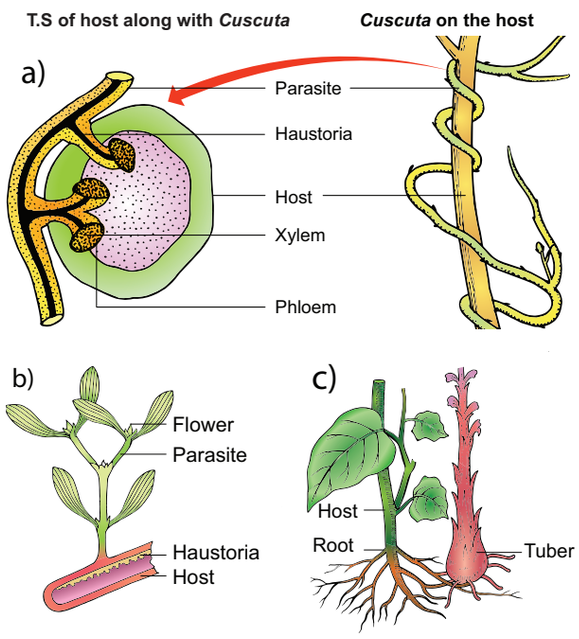


Figure 6.14: a) Holoparasite – *Cuscuta*
b) A Partial stem parasite – *Viscum*
c) Root parasite on the brinjal root *Orobanche* spp.

Examples:

- *Cuscuta* is a total stem parasite of the host plant *Acacia*, *Duranta* and many other plants. *Cuscuta* even gets flower inducing hormone from its host plant.
- *Balanophora, orobanche* and *Refflesia* are the total root parasites found on higher plants.

Hemiparasites

The organisms which derive only water and minerals from their host plant while synthesizing their own food by photosynthesis are called **Hemiparasites**. They are also called **partial parasites**.

Examples:

- *Viscum* and *Loranthus* are **partial stem parasites**.
- *Santalum* (Sandal Wood) is a **partial root parasite**.

The parasitic plants produce the **haustorial roots** inside the host plant to absorb nutrients from the vascular tissues of host plants.

c. Competition: It is an interaction between two organisms or species in which both the organisms or species are harmed. Competition is the severest in population that has irregular distribution. Competition is classified into intraspecific and interspecific.

1. **Intraspecific competition:** It is an interaction between individuals of the same species. This competition is very severe because all the members of species have similar requirements of food, habitat, pollination etc. and they also have similar adaptations to fulfill their needs.

2. **Interspecific competition:** It is an interaction between individuals of different species. In grassland, many species of grasses grow well as there is little competition when enough nutrients and water is available. During drought shortage of water occurs . A life and death competition starts among the different species of grass lands. Survival in both these competitions is determined by the quantity of nutrients, availability of water and migration to new areas. Different species of herbivores, larvae and grass hopper competing for fodder or forage plants. Trees, shrubs and herbs in a forest struggle for sunlight, water and nutrients and also for pollination and dispersal of fruits and seeds. The *Utricularia* (Bladderwort) competes with tiny fishes for small crustaceans and insects.

d. Amensalism: It is an interspecific interaction in which one species is inhibited while the other species is neither benefitted nor harmed. The inhibition is achieved by the secretion of certain chemicals called **allelopathic** substances. Amensalism is also called **antibiosis.**

- *Penicillium notatum* produces penicillin to inhibit the growth of a variety of bacteria especially *Staphylococcus*.
- *Trichoderma* inhibits the growth of fungus *Aspergillus*.
- Roots and hulls of Black Walnut *Juglans nigra* secretes an alkaloid **Junglone** which inhibits the growth of seedlings of Apple, Tomato and *Alfalfa* around it.

Interspecific interactions/ Co-evolutionary dynamics

i. Mimicry: It is a phenomenon in which living organism modifies its form, appearance, structure or behavior and looks like another living organism as a self defence and increases the chance of their survival. Floral mimicry is for usually inviting pollinators but animal mimicry is often protective. Mimicry is a result of evolutionary significance due to shape and sudden heritable mutation and preservation of natural selection.

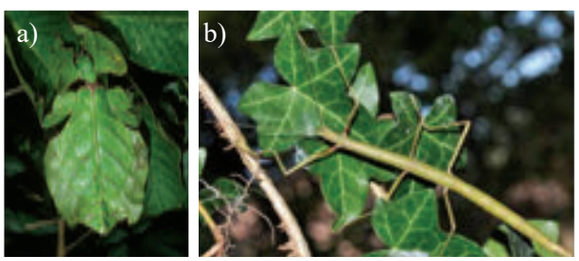


Figure 6.15: Mimicry
a) *Phyllium frondosum* b) *Carausium morosus*

Example:

- The plant, *Ophrys* an orchid, the flower looks like a female insect to attract the male insect to get pollinated by the male insect and it is otherwise called 'floral mimicry '.
- *Carausium morosus* – stick insect or walking stick. It is a protective mimicry.
- *Phyllium frondosum* – leaf insect, another example of protective mimicry.

ii. Myrmecophily: Sometimes, ants take their shelter on some trees such as Mango, Litchi, Jamun, *Acacia* etc. These ants act as body guards of the plants against any disturbing agent and the plants in turn provide food and shelter to these ants. This phenomenon is known as Myrmecophily. Example: Acacia and acacia ants.

Figure 6.16: Myrmecophily

iii. Co-evolution: The interaction between organisms, when continues for generations, involves reciprocal changes in genetic and morphological characters of both organisms. This type of evolution is called Co-evolution. It is a kind of co- adaptation and mutual change among interactive species.

Figure 6.17: Co-evolution

Examples:

- Corolla length and proboscis length of butterflies and moths (*Habenaria* and Moth).
- Bird's beak shape and flower shape and size.
- More examples: Horn bills and birds of Scrub jungles ,Slit size of pollinia of Apocynaceae members and leg size of insects.

DO YOU KNOW?

Kairomone released from *Pieris rapae* caterpillar exposed to wild Radish gets the capacity to transmit defence induced by predator to progeny of wild radish. Transmission capacity of defence induced by predator to progeny of wild radish.

6.3 Ecological adaptations

The modifications in the structure of organisms to survive successfully in an environment are called **adaptations** of organisms. Adaptations help the organisms to exist under the prevailing ecological habitat. Based on the habitats and the corresponding adaptations of plants, they are classified as hydrophytes, xerophytes, mesophytes, epiphytes and halophytes.

Hydrophytes

The plants which are living in water or wet places are called hydrophytes. According to their relation to water and air, they are sub-divided into following categories: i) Free floating hydrophytes, ii) Rooted- floating hydrophytes, iii) Submerged floating hydrophytes, iv) Rooted -submerged hydrophytes, v) Amphibious hydrophytes.

i. Free floating hydrophytes: These plants float freely on the surface of water. They remain in contact with water and air, but not with soil. Examples: *Eichhornia, Pistia and Wolffia* (smallest flowering plant).

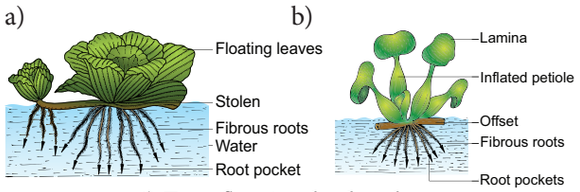
ii. Rooted floating hydrophytes: In these plants, the roots are fixed in mud, but their leaves and flowers are floating on the surface of water. These plants are in contact with soil, water and air. Examples: *Nelumbo, Nymphaea, Potomogeton* and *Marsilea.*

Lotus seeds showing highest longevity in plant kingdom.

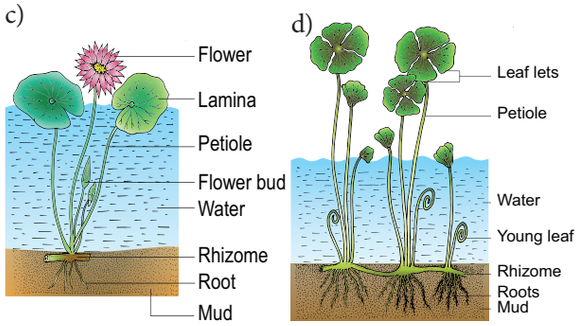
iii. Submerged floating hydrophytes: These plants are completely submerged in water and not in contact with soil and air. Examples: *Ceratophyllum* and *Utricularia.*

iv. Rooted- submerged hydrophytes: These plants are completely submerged in water and rooted in soil and not in contact with air. Examples: *Hydrilla*, *Vallisneria* and *Isoetes*.

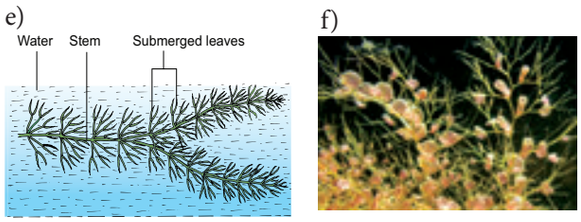
v. Amphibious hydrophytes (Rooted emergent hydrophytes)**:** These plants are adapted to both



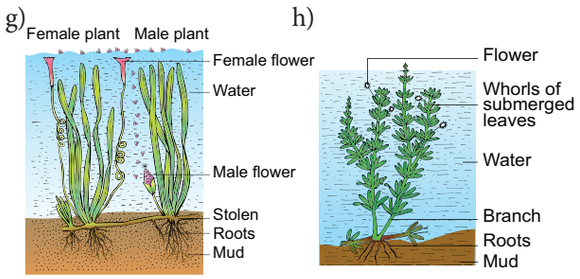
i) Free floating hydrophyte
a) *Eichhornia* b) *Pistia*



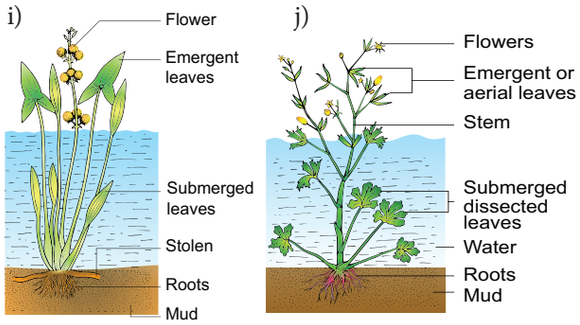
ii) Rooted floating hydrophyte
c) *Nymphaea* d) *Marsilea*



iii) Submerged floating hydrophyte
e) *Ceratophyllum* f) *Utricularia*



iv) Rooted - sumerged hydrophyte
g) *Vallisneria* h) *Hydrilla*



v) Rooted emergent hydrophyte-Heterophylly
i) *Sagittaria* j) *Ranunculus*

Figure 6.18: Hydrophytes

aquatic and terrestrial modes of life. They grow in shallow water. Examples: *Ranunculus*, *Typha* and *Sagittaria*.

Hygrophytes: The plants which can grow in moist damp and shady places are called hygrophytes. Examples: *Habenaria* (Orchid), Mosses (Bryophytes), etc.

Morphological adaptations of Hydrophytes:

In root

- Roots are totally absent in *Wolffia* and *Salvinia* or poorly developed in *Hydrilla* or well developed in *Ranunculus.*
- The root caps are replaced by **root pockets**. Example: *Eichhornia*

In stem

- The stem is long, slender, spongy and flexible in sub-merged forms.
- In free floating forms the stem is thick, short stoloniferous and spongy; and in rooted floating forms, it is a rhizome .
- Vegetative propagation is through runners, stolon, stem and root cuttings , tubers, dormant apices and offsets.

In leaves

- The leaves are thin, long and ribbon shaped in *Vallisneria* or long and linear in *Potamogeton* or finely dissected in *Ceratophyllum*
- The floating leaves are large and flat as in *Nymphaea* and *Nelumbo*. In *Eichhornia* and *Trapa* petioles become swollen and spongy.
- In emergent forms, the leaves show **heterophylly** (Submerged leaves are dissected and aerial leaves are entire). Example: *Ranunculus, Limnophila heterophylla* and *Sagittaria*

Anatomical adaptations

- Cuticle is either completely absent or if present it is thin and poorly developed
- Single layer of epidermis is present
- Cortex is well developed with aerenchyma
- Vascular tissues are poorly developed. In emergent forms vascular elements are well developed.
- Mechanical tissues are generally absent except in some emergent forms. Pith cells are sclerenchymatous.

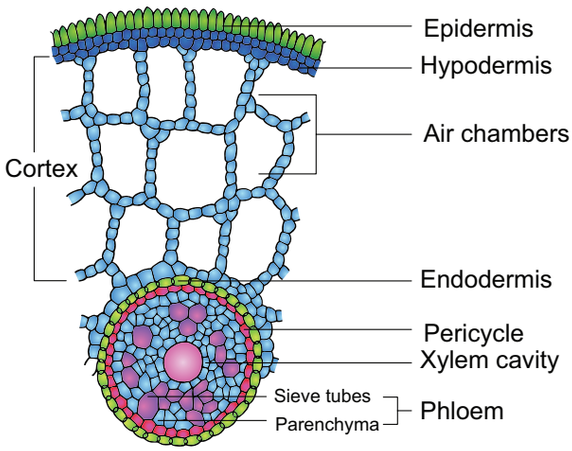


Figure 6.19: T.S. of *Hydrilla* stem

Physiological adaptations of Hydrophytes:

- Hydrophytes have the ability to withstand anaerobic conditions .
- They possess special aerating organs.

Xerophytes

The plants which are living in dry or xeric condition are known as **Xerophytes**. Xerophytic habitat can be of two different types. They are:

a. Physical dryness: In these habitats, soil has a little amount of water due to the inability of the soil to hold water because of low rainfall.

b. Physiological dryness: In these habitats, water is sufficiently present but plants are unable to absorb it because of the absence of capillary spaces. Example: Plants in salty and acidic soil.

Based on adaptive characters xerophytes are classified into three categories. They are Ephemerals, Succulents and Non succulent plants.

i. Ephemerals: These are also called **drought escapers** or **drought evaders**. These plants complete their life cycle within a short period (**single season**). These are not true xerophytes. Examples: *Argemone, Mollugo, Tribulus* and *Tephrosia*.

Figure 6.20: *Argemone mexicana*-Ephemerals

ii. Succulents: These are also called drought **enduring plants**. These plants store water in their plant parts during the dry period. These plants develop certain adaptive characters to resist extreme drought conditions. Examples: *Opuntia, Aloe, Bryophyllum* and *Begonia*.

iii. Non succulents: These are also called **drought resistant plants (true xerophytes).** They face both external and internal dryness. They have many adaptations to resist dry conditions. Examples: *Casuarina, Nerium, Zizyphus* and *Acacia.*

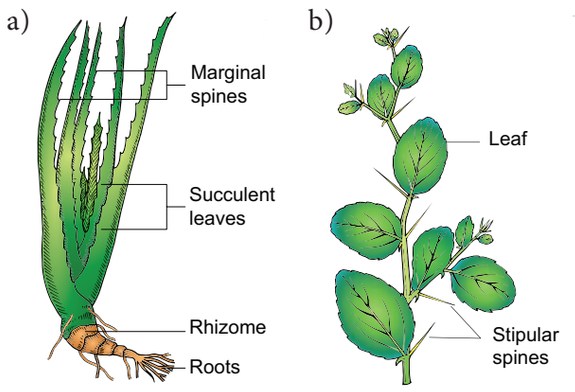


Figure 6.21: a)Succulent xerophyte – *Aloe*
b) Non succulent perennial - *Ziziphus*

Morphological Adaptations

In root

- Root system is well developed and is greater than that of shoot system.
- Root hairs and root caps are also well developed.

In Xerophytic plants with the leaves and stem are covered with hairs are called **trichophyllous plants** . Example: *Cucurbits* (*Melothria and Mukia*)

In stem

- Stems are mostly hard and woody. They may be aerial or underground
- The stems and leaves are covered with wax coating or covered with dense hairs.
- In some xerophytes all the internodes in the stem are modified into a fleshy leaf structure called **phylloclades** (*Opuntia*) .
- In some of the others single or occasionally two internodes modified into fleshy green structure called **cladode** (*Asparagus*).

  In some the petiole is modified into a fleshy leaf like structure called **phyllode** (*Acacia melanoxylon*).

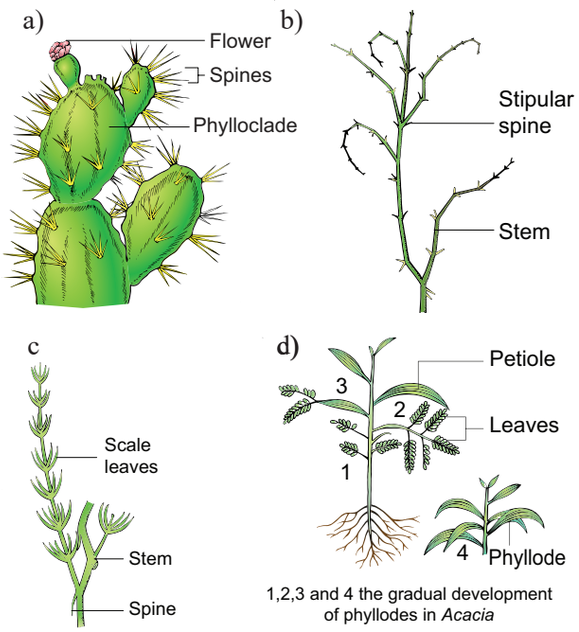


Figure 6.22: Xerophytes

a) A succulent xerophyte: Phylloclade – *opuntia*

b) Non succulent: Perennial - *Capparis*

c) Cladode of *Asparagus*

d) Phyllode – *Acacia*

In leaves

- Leaves are generally leathery and shiny to reflect light and heat.
- In some plants like *Euphorbia, Acacia, Ziziphus* and *Capparis*, the stipules are modified into spines.
- The entire leaves are modified into spines (*Opuntia*) or reduced to scales (*Asparagus*).

Anatomical adaptations

- Presence of multilayered epidermis with heavy cuticle to prevent water loss due to transpiration.
- Hypodermis is well developed with sclerenchymatous tissues.
- Sunken shaped stomata are present only in the lower epidermis with hairs in the sunken pits.
- Scotoactive type of stomata found in succulent plants .
- Vascular bundles are well developed with several layered bundle sheath.
- Mesophyll is well differentiated into palisade and spongy parenchyma.
- In succulents the stem possesses a water storage region.

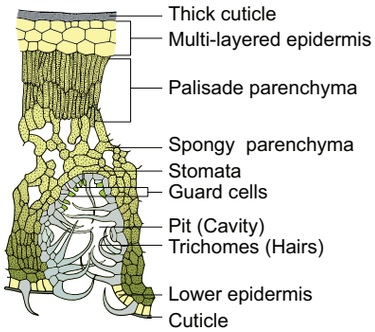


Figure 6.23: T.S. of Nerium leaf

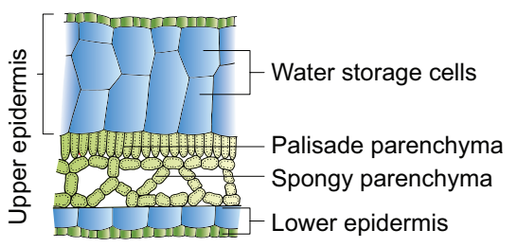


Figure 6.24: A Succulent leaf of *Pepromia* (T.S.) (lateral wing portion only)

Physiological adaptations

- Most of the physiological processes are designed to reduce transpiration.
- Life cycle is completed within a short period (Ephemerals).

Mesophytes

The plants which are living in moderate conditions (neither too wet nor too dry) are known as **mesophytes**. These are common land plants. Example: Maize and *Hibiscus.*

Morphological adaptations

- Root system is well developed with root caps and root hairs
- Stems are generally aerial, stout and highly branched.
- Leaves are generally large, broad, thin with different shapes.

Anatomical adaptations

- Cuticle in aerial parts are moderately developed.
- Epidermis is well developed and stomata are generally present on both the epidermis.
- Mesophyll is well differentiated into palisade and spongy parenchyma.
- Vascular and mechanical tissues are fairly developed and well differentiated.

Physiological adaptations

- All physiological processes are normal.
- Temporary wilting takes place at room temperature when there is water scarcity.

Tropophytes are plants which behave as xerophytes at summer and behave as mesophytes (or) hydrophytes during rainy season.

Epiphytes

Epiphytes are plants which grow perched on other plants (Supporting plants). They use the supporting plants only as shelter and not for water or food supply. These epiphytes

are commonly seen in tropical rain forests. Examples: Orchids, Lianas, Hanging Mosses and Money plant.

Morphological adaptations

- Root system is extensively developed. These roots may be of two types. They are Clinging roots and Aerial roots.

  Clinging roots fix the epiphytes firmly on the surface of the supporting objects.

  Aerial roots are green coloured roots which may hang downwardly and absorb moisture from the atmosphere with the help of a spongy tissue called **velamen**.
- Stem of some epiphytes are succulent and develop pseudo bulb or tuber.
- Generally the leaves are lesser in number and may be fleshy and leathery
- **Myrmecophily** is a common occurrence in the epiphytic vegetation to prevent the predators.
- The fruits and seeds are very small and usually dispersed by wind, insects and birds.

Anatomical adaptations

- Multilayered epidermis is present. Inner to the velamen tissue, the peculiar exodermis layer is present.
- Presence of thick cuticle and sunken stomata greatly reduces transpiration.
- Succulent epiphytes contain well developed parenchymatous cells to store water.

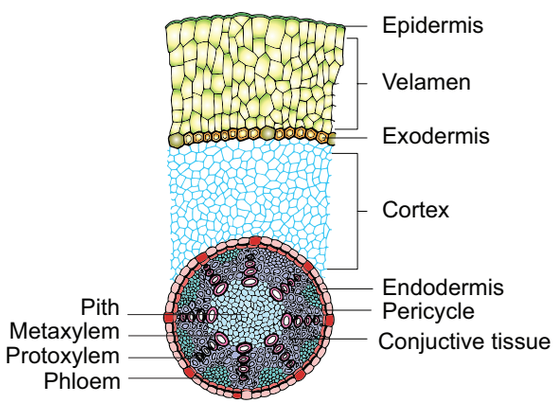


Figure 6.25: T.S. of an aerial root of orchid showing velamen tissue

Physiological adaptations

Special absorption processes of water by velamen tissue .

Halophytes

There are special type of **Halophytic plants** which grow on soils with high concentration of salts. Examples: *Rhizophora, Sonneratia* and *Avicennia*.

Halophytes are usually found near the sea-shores and Estuaries. The soils are physically wet but physiologically dry. As plants cannot use salt water directly they require filtration of salt using physiological processes. This vegetation is also known as **mangrove forest** and the plants are called **mangroves.**

Morphological adaptations

- The temperate halophytes are herbaceous but the tropical halophytes are mostly bushy
- In addition to the normal roots, many stilt roots are developed
- A special type of negatively geotropic roots called **pneumatophores** with **pneumathodes** to get sufficient aeration are also present. They are called breathing roots. Example: *Avicennia*

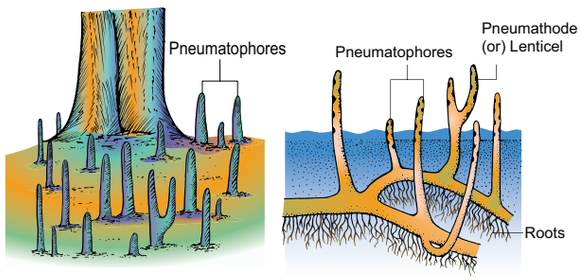


Figure 6.26a: Pneumatophores of mangrove plant

- Presence of thick cuticle on the aerial parts of the plant body
- Leaves are thick, entire, succulent and glossy. Some species are **aphyllous** (without leaves).

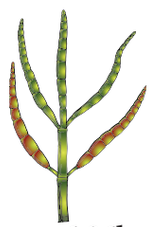
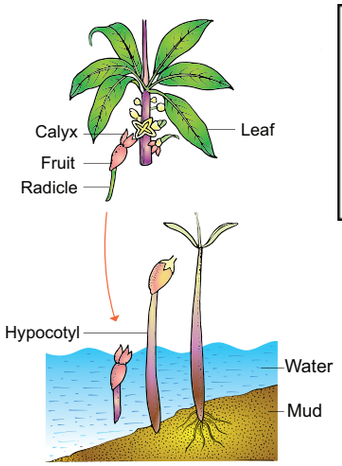


Figure 6.26b: Succulent halophyte - *Salicornia*

• Vivipary mode of seed germination is found in halophytes



J6KJGI

Figure 6.27: Vivipary germination

Anatomical adaptations

- Epidermal cells of stem is heavy cutinized, almost squarish and are filled with oil and tannins.
- **'Star' shaped** sclereids and **'H' shaped** heavy thickened spicules that provide mechanical strength to cortex are present in the stem.
- The leaves may be dorsiventral or isobilateral with **salt secreting glands**.

Physiological adaptations

- High osmotic pressure exists in some plants .
- Seeds germinate in the fruits of mother plant itself (**Vivipary).**

DO YOU KNOW?

Out of three districts of Tamil Nadu (Nagapattinam, Thanjavur and Thiruvarur), Muthupet (Thiruvarur district) was less damaged by Gaja cyclone (November 2018) due to the presence of mangrove forest.

6.4 Dispersal of Fruits and Seeds

Both fruits and seeds possess attractive colour, odour, shape and taste needed for the dispersal by birds, mammals, reptiles, fish, ants and insects even earthworms. The seed consists of an embryo, stored food material and a protective covering called **seed coat**. As seeds contain miniature but dormant future plants, their dispersal is an important criterion for distribution and establishment of plants over a wide geographical area. The dissemination of seeds and fruits to various distances from the parent plant is called seed and fruit dispersal. It takes place with the help of ecological factors such as wind, water and animals.

Seed dispersal is a regeneration process of plant populations and a common means of colonizing new areas to avoid seedling level competition and from natural enemies like herbivores, frugivores and pathogens.

Fruit maturation and seed dispersal is influenced by many ecologically favourable conditions such as Season (Example: Summer), suitable environment, and seasonal availability of dispersal agents like birds, insects etc.

Seeds require agents for dispersal which are crucial in plant community dynamics in many ecosystems around the globe. They offer many benefits to communities such as food and nutrients, migration of seeds across habitats and helps spreading plant genetic diversity.

6.4.1 Dispersal by Wind (Anemochory)

The individual seeds or the whole fruit may be modified to help for the dispersal by wind. Wind dispersal of fruits and seeds is quite common in tall trees. The adaptation of the wind dispersal plants are

- **Minute seeds:** Seeds are minute, very small, light and with inflated covering. Example: Orchids.
- **Wings:** Seeds or whole fruits are flattened to form a wing. Examples: Maple, *Gyrocarpus, Dipterocarpus* and *Terminalia*

Figure 6.28: Asclepias

Figure 6.29: Gyrocarpus

- **Feathery Appendages:** Seeds or fruits may have feathery appendages which greatly increase their buoyancy to disperse to high altitudes. Examples: *Vernonia* and *Asclepias.*
- **Censor mechanisms:** The fruits of many plants open in such a way that the seeds can escape only when the fruit is violently shaken by a strong wind. Examples: *Aristolochia* and Poppy.

Guess!! Who am I…….? I am dispersed by ant and I have caruncle.

6.4.2 Dispersal by Water (Hydrochory)

Dispersal of seeds and fruits by water usually occurs in those plants which grow in or near water bodies . Adaptation of hydrochory are

- Obconical receptacle with prominent air spaces. Example: *Nelumbo*.
- Presence of fibrous mesocarp and light pericarp. Example: Coconut.
- Seeds are light, small, provided with aril which encloses air.Example: *Nymphaea*.
- The fruit may be inflated. Examples: *Heritiera littoralis*.
- Seeds by themselves would not float may be carried by water current. Example: Coconut.

Figure 6.30: Nelumbo

Figure 6.31: Coconut

6.4.3 Dispersal by Animals (Zoochory)

Birds and mammals, including human beings play an efficient and important role in the dispersal of fruit and seeds. They have the following devices.

i. Hooked fruit: The surface of the fruit or seeds have hooks,(*Xanthium*), barbs (*Andropogon*), spines (*Aristida*) by means of which they adhere to the body of animals or clothes of human beings and get dispersed.

ii. Sticky fruits and seeds:

a. Some fruits have sticky glandular hairs by which they adhere to the fur of grazing animals. Example: *Boerhaavi*a and *Cleome*.

b. Some fruits have viscid layer which adhere to the beak of the bird which eat them and when they rub them on to the branch of the tree, they disperse and germinate. Example: *Cordia* and *Alangium*

iii. Fleshy fruits: Some fleshy fruits with conspicuous colours are dispersed by human beings to distant places after consumption. Example: Mango and *Diplocyclos*

Figure 6.32: Sunflower

Figure 6.33: Papaya

6.4.3 Dispersal by Explosive Mechanism (Autochory)

Some fruits burst suddenly with a force enabling to throw seeds to a little distance away from the plant. Autochory shows the following adaptations.

- Mere touch of some plants causes the ripened fruit to explode suddenly and seeds are thrown out with great force. Example: *Impatiens* (Balsam), *Hura*.
- Some fruits when they come in contact with water particularly after a shower of rain, burst suddenly with a noise and scatter the seeds.Examples: *Ruellia* and *Crossandra.*
- Certain long pods explode with a loud noise like cracker, scattering the seeds in all directions. Example: *Bauhinia vahlii* (Camel's foot climber)
- As the fruit matures, tissues around seeds are converted into a mucilaginous fluid, due to which a **high turgor pressure** develops inside the fruit which leads to the dispersal of seeds.

Example: *Ecballium elatrium* (Squirting cucumber) *Gyrocarpus* and *Dipterocarpus.*

Figure 6.34: *Ecballium*

Figure 6.35: *Impatents*

Human aided seed dispersal

Figure 6.36: Seed ball

Seed Ball : Seed ball is an ancient Japanese technique of encasing seeds in a mixture of clay and soil humus (also in cow dung) and scattering them on to suitable ground, not planting of trees manually. This method is suitable for barren and degraded lands for tree regeneration and vegetation before monsoon period where the suitable dispersal agents become rare.

Guess? what is atelochory or Achory?

Ecologically important days
March 21 - World forest day
April 22 - Earth day
May 22 - World bio diversity day
June 05 - World environment day
July 07 - Van Mohostav day
September 16 - International Ozone day

Advantages of seed dispersal:

- Seeds escape from mortality near the parent plants due to predation by animals or getting diseases and also avoiding competition.
- Dispersal also gives a chance to occupy favourable sites for growth.
- It is an important process in the movement of plant genes particularly this is the only method available for self-fertilized flowers and maternally transmitted genes in outcrossing plants.
- Seed dispersal by animals help in conservation of many species even in human altered ecosystems.
- Understanding of fruits and seed dispersal acts as a key for proper functioning and establishment of many ecosystems from deserts to evergreen forests and also for the maintenance of biodiversity conservation and restoration of ecosystems.

Summary

Ecology is a division of biology and deals with the study of environment in relation to organisms. Ecology is mainly divided into two branches Autecology and Synecology. The environment (surrounding) includes physical, chemical and biological components. These factors can be classified into living (biotic) and non-living (abiotic), which make the environment of an organism. The ecological factors are meaningfully grouped into four classes, which are as follows: 1. Climatic factors 2. Edaphic factors 3. Topographic factors 4. Biotic factors.

Climate is one of the important natural factors controlling the plant life. The climatic factors includes light, temperature, water, wind, fire, etc. Edaphic factors, the abiotic factors related to soil, include the physical and chemical composition of the soil formed in a particular area. The surface features of earth are called topography. Topographic influence on the climate of any area is determined by the interaction of solar radiation, temperature, humidity ,rainfall, latitude and altitude. The interactions among living organisms, the plants and animals are called biotic factors, which may cause marked effects upon vegetation.

The modifications in the structure of organisms to survive successfully in an environment are called adaptations of organisms. Based on the habitats and the corresponding adaptations of plants, they are

classified into 1) Hydrophytes 2) Xerophytes 3) Mesophytes 4) Epiphytes and 5) Halophytes. The dissemination of seeds and fruits to various distances from the parent plant is called **seed and fruit dispersa**l. It takes place with the help of ecological factors such as wind, water and animals.

Evaluation

K1DDHI

1. Arrange the correct sequence of ecological hierarchy starting from lower to higher level.
   a) Individual organism → Population Landscape → Ecosystem
   b) Landscape → Ecosystem → Biome → Biosphere
   c) community → Ecosystem → Landscape → Biome
   d) Population → organism → Biome → Landscape

2. Ecology is the study of an individual species is called
   i) Community ecology ii) Autecology
   iii) Species ecology iv) Synecology
   a) i only b) ii only
   c) i and iv only d) ii and iii only

3. A specific place in an ecosystem, where an organism lives and performs its functions is
   a) habitat b) niche
   c) landscape d) biome

4. Read the given statements and select the correct option.
   i) Hydrophytes possess aerenchyma to support themselves in water.
   ii) Seeds of *Viscum* are positively photoblastic as they germinate only in presence of light.
   iii) Hygroscopic water is the only soil water available to roots of plant growing in soil as it is present inside the micropores.
   iv) High temperature reduces use of water and solute absorption by roots.
   a) i, ii, and iii only b) ii, iii and iv
   c) ii and iii only d) i and ii only

5. Which of the given plant produces cardiac glycosides?
   a) *Calotropis* b) *Acacia*
   c) *Nepenthes* d) *Utricularia*

6. Read the given statements and select the correct option.
   i) Loamy soil is best suited for plant growth as it contains a mixture of silt, sand and clay.
   ii) The process of humification is slow in case of organic remains containing a large amount of lignin and cellulose.
   iii) Capillary water is the only water available to plant roots as it is present inside the micropores.
   iv) Leaves of shade plant have more total chlorophyll per reaction centre, low ratio of chl *a* and chl *b* are usually thinner leaves.
   a) i, ii and iii only b) ii, iii and iv only
   c) i, ii and iv only d) ii and iii only

7. Read the given statements and select the correct option.
   Statement A : Cattle do not graze on weeds of *Calotropis*.
   Statement B : *Calotropis* have thorns and spines, as defense against herbivores.
   a) Both statements A and B are incorrect.
   b) Statement A is correct but statement B is incorrect.
   c) Both statements A and B are correct but statement B is not the correct explanation of statement A.
   d) Both statements A and B are correct and statement B is the correct explanation of statement A.

8. In soil water available for plants is
   a) gravitational water
   b) chemically bound water
   c) capillary water
   d) hygroscopic water

9. Read the following statements and fill up the blanks with correct option.
   i) Total soil water content in soil is called _____
   ii) Soil water not available to plants is called _____
   iii) Soil water available to plants is called _____

	(i)	(ii)	(iii)
(a)	Holard	Echard	Chresard
(b)	Echard	Holard	Chresard
(c)	Chresard	Echard	Holard
(d)	Holard	Chresard	Echard

10. Column I represent the size of the soil particles and Column II represents type of soil components. Which of the following is correct match for the Column I and Column IL

Column - I	Column - II
I). 0.2 to 2.00 mm	i) Slit soil
II) Less than 0.002 mm	ii) Clayey soil
III) 0.002 to 0.02 mm	iii) Sandy soil
IV) 0.002 to 0.2 mm	iv) Loamy soil

	I	II	III	IV
a)	ii	iii	iv	i
b)	iv	i	iii	ii
c)	iii	ii	i	iv
d)	None of the above			

11. The plant of this group are adapted to live partly in water and partly above substratum and free from water
   a) Xerophytes b) Mesophytes
   c) Hydrophytes d) Halophytes

12 . Identify the A, B, C and D in the given table

Interaction	Effects on species X	Effects on species Y
Mutualism	A	(+)
B	(+)	(-)
Competition	(-)	C
D	(-)	0

	A	B	C	D
a)	(+)	Parasitism	(-)	Amensalism
b)	(-)	Mutalism	(+)	Competition
c)	(+)	Competition	(0)	Mutalism
d)	(0)	Amensalism	(+)	Parasitism

13. *Ophrys* an orchid resembling the female of an insect so as to able to get pollinated is due to phenomenon of
   a) Myrmecophily b) Ecological equivalents
   c) Mimicry d) None of these

14. A free living nitrogen fixing cyanobacterium which can also form symbiotic association with the water fern *Azolla*
   a) *Nostoc* *b) Anabaena*
   c) *chlorella* d) *Rhizobium*

15. Pedogenesis refers to
   a) Fossils b) Water c) Population d) Soil

16. Mycorrhiza promotes plant growth by
   a) Serving as a plant growth regulators
   b) Absorbing inorganic ions from soil
   c) Helping the plant in utilizing atmospheric nitrogen
   d) Protecting the plant from infection

17. Which of the following plant has a non-succulent xerophytic and thick leathery leaves with waxy coating
   a) *Bryophyllum* b) *Ruscus*
   c) Nerium d) *Calotropis*

18. In a fresh water environment like pond, rooted autotrophs are
   a) Nymphaea and typha
   b) *Ceratophyllum* and *Utricularia*
   c) *Wolffia* and *pistia*
   d) *Azolla* and *lemna*

19. Match the following and choose the correct combination from the options given below:

Column I (Interaction)	**Column II (Examples)**
I. Mutualism	i). *Trichoderma* and *Penicillium*
II. Commensalism	ii). *Balanophora, Orobanche*
III. Parasitism	iii). *Orchids* and *Ferns*
IV. Predation	iv). *Lichen* and *Mycorrhiza*
V. Amensalism	v). *Nepenthes* and *Diaonaea*

	I	II	III	IV	V
a)	i	ii	iii	iv	v
b)	ii	iii	iv	v	i
c)	iii	iv	v	i	ii
d)	iv	iii	ii	v	i

20. Strong, sharp spines that get attached to animal's feet are found in the fruits of
    a) *Argemone* b) Ecballium
    c) *Heritier* d) *Crossandra*

21. Sticky glands of *Boerhaavia* and *Cleome* support
    a) Anemochory b) Zoochory
    c) Autochory d) Hydrochory

22. Define ecology.

23. What is ecological hierarchy? Name the levels of ecological hierarchy.

24. What are ecological equivalents? Give one example .

25. Distinguish habitat and niche

26. Why are some organisms called as eurythermals and some others as stenohaline ?

27. 'Green algae are not likely to be found in the deepest strata of the ocean'. Give at least one reason.

28. What is Phytoremediation ?

29. What is Albedo effect and write their effects?

30. The organic horizon is generally absent from agricultural soils because tilling, e.g., plowing, buries organic matter. Why is an organic horizon generally absent in desert soils ?

31. Soil formation can be initiated by biological organisms. Explain how?

32. Sandy soil is not suitable for cultivation. Explain why?

33. Describe the mutual relationship between the fig and wasp and comment on the phenomenon that operates in this relationship.

34. *Lichen* is considered as a good example of obligate mutualism. Explain.

35. What is mutualism? Mention any two example where the organisms involved are commercially exploited in modern agriculture.

36. List any two adaptive features evolved in parasites enabling them to live successfully on their host?

37. Mention any two significant roles of predation plays in nature.

38. How does an orchid *ophrys* ensures its pollination by bees ?

39. Water is very essential for life. Write any three features for plants which enable them to survive in water scarce environment.

40. Why do submerged plants receive weak illumination than exposed floating plants in a lake?

41. What is vivipary? Name a plant group which exhibits vivipary.

42. What is thermal stratification? Mention their types.

43. How is rhytidome act as the structural defence by plants against fire?

44. What is myrmecophily?

45. What is seed ball?

46. How is anemochory differ from zoochory?

47. What is co evolution?

48. Explain Raunkiaer classification in the world's vegetation based on the temperature.

49. List out the effects of fire to plants.

50. What is soil profile? Explain the characters of different soil horizons.

51. Give an account of various types of parasitism with examples.

52. Explain different types of hydrophytes with examples.

53. Enumerate the anatomical adaptations of xerophytes.

54. List out any five morphological adaptations of halophytes.

55. What are the advantages of seed dispersal?

56. Describe dispersal of fruit and seeds by animals.

Glossary

Antibiosis: An association of two organisms which is harmful to one of them.

Biome: A major regional community of plants and animals with similar life forms and environmental conditions.

Biosphere: The envelope containing all living organisms on earth.

Community: A group of organism living in the same place.

Flora: The kinds of plants in region

Frugivores: Fruit eating organisms

Hekistotherms: (Temperature less than 70°C) Where very low temperature prevails and the dominant vegetation is alpine vegetation.

Landscape: The visible features of an area of land.

Lianes: Twining vines with woody stems, common in forest of warm climate.

Megatherms: (Temperature more than 240°C) Where high temperature prevails throughout the year and the dominant vegetation is tropical rain forest.

Mesotherms: (Temperature ranges between 170°C and 240°C) Where high temperature alternates with low temperature and the dominant vegetation is tropical deciduous forest.

Microtherms: (Temperature ranges between 70°C and 170°C) Where low temperature prevails and the dominant vegetation is mixed coniferous forest.

Population: A group of individuals of a single species.

Scotoactive type of stomata: Stomata opens during night in succulent plants and closes during the day.

Vivipary: When seeds or embryos begin to develop before they detach from the parent.

ICT Corner

Principles of Ecology

Let us know about the Environmental Studies- Complete Reference Guide in detail.

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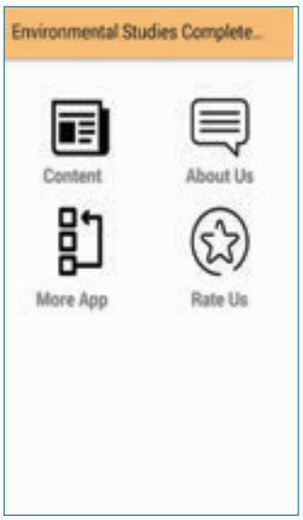
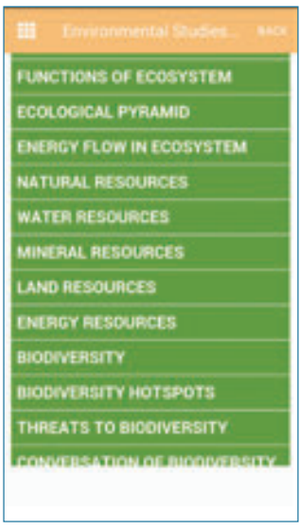


Step 1



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Chapter 7

UNIT IX: Plant Ecology

Ecosystem

Learning Objectives

Learning objectives

The learner will be able to,

- Describe the Structure, functions and types of ecosystems
- Draw ecological pyramids by means of number, biomass and energy
- Interpret carbon and phosphorus cycle
- Recognise pond ecosystem as a self-sufficient and self-regulating system
- Analyse ecosystem services and its management
- Discuss about the importance and conservation of ecosystem
- Explain the types of plant succession

Chapter outline

KFW8IU

Have you seen lakes, ponds and pools in your surroundings? They are all called water bodies with many components in them. Can you list out the things which are found in water bodies? Mud, nutrients, clay, dissolved gases, planktons, microorganisms, plants like algae, *Hydrilla, Nelumbo, Nymphaea* and animals like snake, small fish, large fish, frog, tortoise and crane are the components in the water bodies which are all together form an **ecosystem**. Further, we all know that plants and animals are prominent living components in the environment. They interact with nonliving components such as air, water, soil, sunlight, etc. For example, you have studied in class XI, one of the life processes, photosynthesis which utilize sunlight , water, carbondioxide, nutrients from the soil and release oxygen to the atmosphere. From this, we understand that the exchange of materials takes place between living and nonliving components. Likewise, you can study the structure, function and types of ecosystem in this chapter. The term **'ecosystem'** was proposed by A.G. Tansley (1935), who defined it as '**the system resulting from the integration of all the living and nonliving factors of the environment'**. Whereas, Odum (1962) defined ecosystem **'as the structural and functional unit of ecology'.**

Parallel terms for ecosystem coined by various ecologists

- Biocoenosis – Karl Mobius
- Microcosm – S.A. Forbes
- Geobiocoenosis – V. V. Dokuchaev, G.F. Morozov
- Holocoen - Friederichs
- Biosystem – Thienemann
- Bioenert body – Vernadsky

7.1 Structure of ecosystem

Ecosystem comprises of two major components. They are:

i) **Abiotic (non-living) components**: It includes climatic factors (air, water, sunlight, rainfall, temperature and humidity), edaphic factors (soil air, soil water and pH of soil),topography (latitude, altitude), organic components (carbohydrates, proteins, lipids and humic substances) and inorganic substances (C, H, O, N and P). Abiotic components play vital role in any ecosystem and hence the total inorganic substances present in any ecosystem at a given time is called **standing quality** (or) **standing state**.

ii) **Biotic (living) components**: It **i**ncludes all living organisms like plants, animals, fungi and bacteria. They form the trophic structures of any ecosystem. On the basis of nutritional relationships, trophic levels of an ecosystem has two components. (1) autotrophic components and (2) heterotrophic components.

(1) Autotrophic components: Autotrophs are organisms which can manufacture the organic compounds from simple inorganic components through a process called photosynthesis. In most of the ecosystems, green plants are the autotrophs and are also called **producers**.

(2) Heterotrophic components: Those organisms which consume the producers are called **consumers** and can be recognized into macro and micro consumers. **Macroconsumers** refer to herbivores, carnivores and omnivores (primary, secondary and tertiary consumers). **Microconsumers** are called decomposers. Decomposers are organisms that decompose the dead plants and animals to release organic and inorganic nutrients into the environment which are again reused by plants. Example: Bacteria, Actinomycetes and Fungi.

The amount of living materials present in a population at any given time is known as **standing crop**, which may be expressed in terms of number or biomass per unit area. **Biomass** can be measured as fresh weight or dry weight or carbon weight of organisms. Biotic components are essential to construct the food chain, food web and ecological pyramids.

7.2 Functions of ecosystem

The function of ecosystem include to energy creation, sharing of energy and cycling of materials between the living and nonliving component of an ecosystem.

Before studying the productivity in any ecosystem, We should understand the essential role of sunlight used by producers of the first trophic level. The quantity of sunlight is directly proportional to the production of energy by plants.

7.2.1 Photosynthetically Active Radiation (PAR)

The amount of light available for photosynthesis of plants is called **P**hotosynthetically **A**ctive **R**adiation (PAR) which is between the range of 400-700 nm wave length. It is essential for photosynthesis and plant growth. PAR is not always constant because of clouds, tree shades, air, dust particles, seasons, latitudes and length of the daylight availability. Generally plants absorb more blue and red light for efficient photosynthesis.

Of the total sunlight, 34 percent that reaching the atmosphere is reflected back into the atmosphere, moreover 10% is held by ozone, water vapours and atmospheric gases and the remaining 56% reaches the earth's surface. Out of this 56%, only 2 – 10% of the solar energy is used by green plants for photosynthesis while the remaining portion is dissipated as heat.

PAR is generally reported as millimoles / square meter / second by using silicon photo

voltic detectors which detect only 400 – 700 nm wavelength of light. PAR values range from 0 to 3000 millimoles /square meter / second. At night PAR is zero and during midday in the summer, PAR often reaches 2000 – 3000 millimoles /square meter/second.

Types of Carbon

Green carbon – carbon stored in the biosphere (by the process of photosynthesis).

Grey carbon – carbon stored in fossil fuel (coal, oil and biogas deposits in the lithosphere).

Blue carbon – carbon stored in the atmosphere and oceans.

Brown carbon – carbon stored in industrialized forests (wood used in making commercial articles)

Black carbon – carbon emitted from gas, diesel engine and coal fired power plants.

7.2.2 Productivity of an ecosystem

The rate of biomass production per unit area in a unit time is called productivity. It can be expressed in terms of gm /m^2/year or Kcal/m^2/ year. It is classified as given bellow.

1. Primary productivity
2. Secondary productivity
3. Community productivity

1. Primary productivity:

The chemical energy or organic matter generated by autotrophs during the process of photosynthesis and chemosynthesis is called **primary productivity**. It is the source of energy for all organisms, from bacteria to human.

a. Gross Primary Productivity (GPP)

The total amount of food energy or organic matter or biomass produced in an ecosystem by autotrophs through the process of photosynthesis is called **gross primary productivity**

b. Net Primary Productivity (NPP)

The proportion of energy which remains after respiration loss in the plant is called **net primary productivity**. It is also called as apparent photosynthesis. Thus the difference between GPP and respiration is known as NPP.

$$NPP = GPP - Respiration$$

NPP of whole biosphere is estimated to be about 170 billion tons (dry weight) per year. Out of which NPP of oceanic producers is only 55 billion tons per year in unit time.

2. Secondary productivity

The amount of energy stored in the tissues of heterotrophs or consumers is called **secondary productivity**.

a. Gross secondary productivity

It is equivalent to the total amount of plant material is ingested by the herbivores minus the materials lost as faeces.

b. Net secondary productivity

Storage of energy or biomass by consumers per unit area per unit time, after respiratory loss is called **net secondary productivity**.

3. Community productivity

The rate of net synthesis of organic matter (biomass) by a group of plants per unit area per unit time is known as **community productivity**.

Factors affecting primary productivity

Primary productivity depends upon the plant species of an area, their photosynthetic capacity, availability of nutrients, solar radiation, precipitation, soil type, topographic factors (altitude, latitude, direction), and other environmental factors. It varies in different types of ecosystems.

Productivity of different Ecosystems

The primary productivity of an ecosystem is not determined by size and number of population, but by the rate of total fixation of radiant energy.

Generally, the average world net primary productivities of open ocean and tropical rain forest are the maximum among aquatic and terrestrial ecosystems respectively.

The following graph represents net primary productivity of various ecosystems.

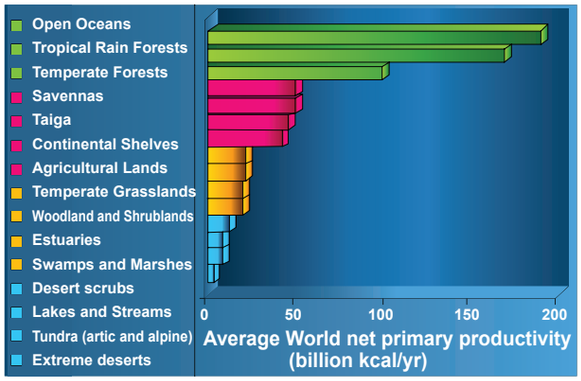


Figure 7.1: Average world net primary production of various ecosystems.

7.2.3 Concept of trophic level in an ecosystem

(Greek word ' trophic' = to food or feeding)

A trophic level refers to the position of an organism in the food chain. The number of trophic levels is equal to the number of steps in the food chain. The green plants (producers) occupying the first trophic level (T_1) are called **producers**. The energy produced by the producers is utilized by the plant eaters (herbivores) they are called **primary consumers** and occupies the second trophic level (T_2).

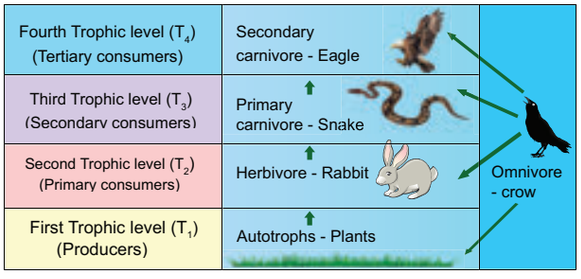


Figure 7.2: Diagrammatic representation of trophic levels

Herbivores are eaten by carnivores, which occupy the third trophic level (T_3). They are also called **secondary consumers** or **primary carnivores**. Carnivores are eaten by the other carnivores, which occupy the fourth trophic level (T_4). They are called the **tertiary consumers or secondary carnivores**. Some organisms which eat both plants and animals are called as **omnivores** (Crow). Such organisms may occupy more than one trophic level in the food chain.

7.2.4 Energy flow

The transfer of energy in an ecosystem between trophic levels can be termed as energy flow. It is the key function in an ecosystem. Part of the energy obtained from the sun by producer is transferred to consumers and decomposers through the each trophic level, while some amount of energy is dissipated in the form of heat. Energy flow is always unidirectional in an ecosystem.

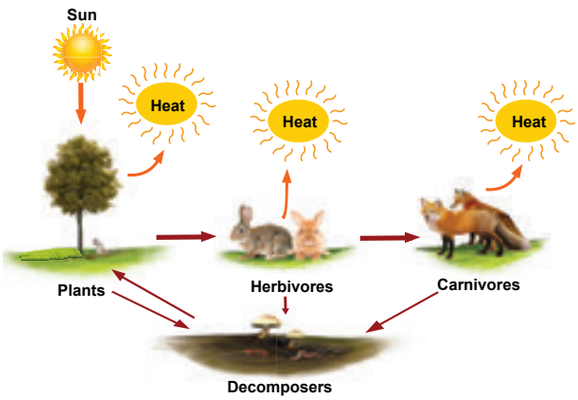


Figure 7.3: Diagrammatic representation of energy flow

Laws of thermodynamics

The storage and loss of energy in an ecosystem is based on two basic laws of thermo-dynamics.

i. First law of thermodynamics

It states that energy can be transmitted from one system to another in various forms. Energy cannot be destroyed or created. But it can be transformed from one form to another. As a result, the quantity of energy present in the universe is constant.

Example:

In photosynthesis, the product of starch (chemical energy) is formed by the combination of reactants (chlorophyll, H_2O, CO_2). The energy stored in starch is acquired from the external sources (light energy) and so there is

no gain or loss in total energy. Here light energy is converted into chemical energy.

$$6\,CO_2 + 6\,H_20 \xrightarrow[\text{Chlorophyll}]{\text{light}} C_6H_{12}0_6 + 6\,O_2$$

Light energy ⟶ chemical energy

ii. Second law of thermodynamics

It states that energy transformation results in the reduction of the free energy of the system. Usually energy transformation cannot be 100% efficient. As energy is transferred from one organism to another in the form of food, a portion of it is stored as energy in living tissue, whereas a large part of energy is dissipated as heat through respiration. The transfer of energy is irreversible natural process. Example: Ten percent law

Ten percent law

This law was proposed by Lindeman (1942). It states that during transfer of food energy from one trophic level to other, only about 10% stored at every level and rest of them (90%) is lost in respiration, decomposition and in the form of heat. Hence, the law is called **ten percent law.**

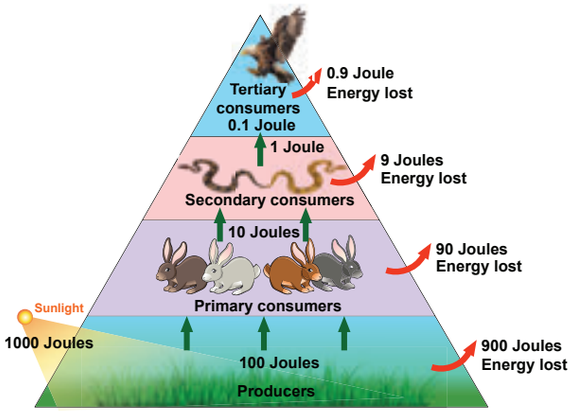


Figure 7.4: Ten percent law

Example: It is shown that of the 1000 Joules of Solar energy trapped by producers. 100 Joules of energy is stored as chemical energy through photosynthesis. The remaining 900 Joules would be lost in the environment. In the next trophic level herbivores, which feed on producers get only 10 Joules of energy and the remaining 90 Joules is lost in the environment. Likewise, in the next trophic level, carnivores, which eat herbivores store only 1 Joule of energy and the remaining 9 Joules is dissipated. Finally, the carnivores are eaten by tertiary consumers which store only 0.1 Joule of energy and the remaining 0.9 Joule is lost in the environment. Thus, at the successive trophic level, only ten percent energy is stored.

7.2.5 Food chain

The movement of energy from producers upto top carnivores is known as **food chain**, i.e., in any food chain, energy flows from producers to primary consumers, then from primary consumers to secondary consumers, and finally secondary consumers to tertiary consumers. Hence, it shows linear network links. Generally, there are two types of food chain, (1) Grazing food chain and (2) Detritus food chain.

1. Grazing food chain

Main source of energy for the grazing food chain is the **Sun**. It begins with the first link, producers (plants). The second link in the food chain is primary consumers (mouse) which get their food from producers. The third link in the food chain is secondary consumers (snake) which get their food from primary consumers. Fourth link in the food chain is tertiary consumers (eagle) which get their food from secondary consumers.

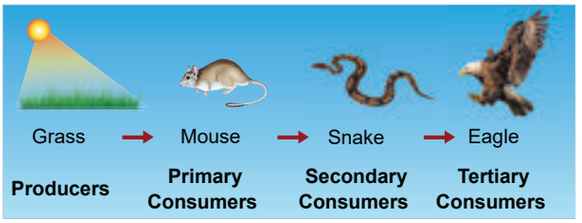


Figure 7.5: Diagrammatic representation of Grazing food chain

2. Detritus food chain:

This type of food chain begins with **dead organic matter** which is an important source of energy. A large amount of organic matter is derived from the dead plants, animals and their excreta. This type of food chain is present in all ecosystems.

The transfer of energy from the dead organic matter, is transferred through a series of organisms called detritus consumers (detritivores)- small carnivores - large (top) carnivores with repeated eating and being eaten respectively. This is called the detritus food chain.

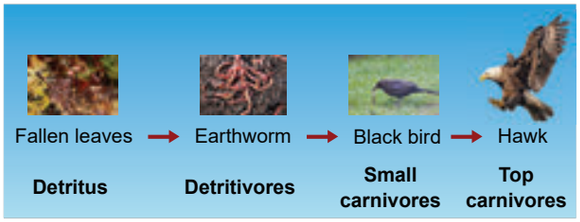


Figure 7.6: Diagrammatic representation of Detritus food chain.

7.2.6 Food Web

The inter-locking pattern of a number of food chain form a web like arrangement called **food web**. It is the basic unit of an ecosystem, to maintain its stability in nature. It is called homeostasis.

Example: In a grazing food chain of a grass land, in the absence of a rabbit, a mouse may also eat food grains. The mouse in turn may be eaten directly by a hawk or by a snake and the snake may be directly eaten by hawks.

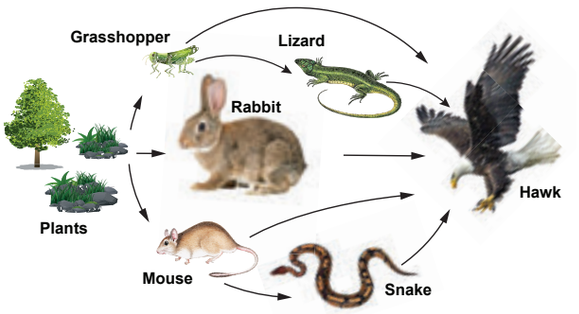


Figure 7.7: Diagrammatic representation of Food web in a grassland ecosystem

Hence, this interlocking pattern of food chains is the food web and the species of an ecosystem may remain balanced to each other by some sort of natural check.

Significance of food web

- Food web is constructed to describe species interaction called direct interaction.
- It can be used to illustrate indirect interactions among different species.
- It can be used to study bottom-up or top-down control of community structure.
- It can be used to reveal different patterns of energy transfer in terrestrial and aquatic ecosystems.

7.2.7 Ecological pyramids

Graphic representation of the trophic structure and function at successive trophic levels of an ecosystem is called **ecological pyramids**. The concept of ecological pyramids was introduced by **Charles Elton (1927)**. Thus they are also called as **Eltonian pyramids**.

There are three types: (1) pyramid of number (2) pyramid of biomass (3) pyramid of energy.

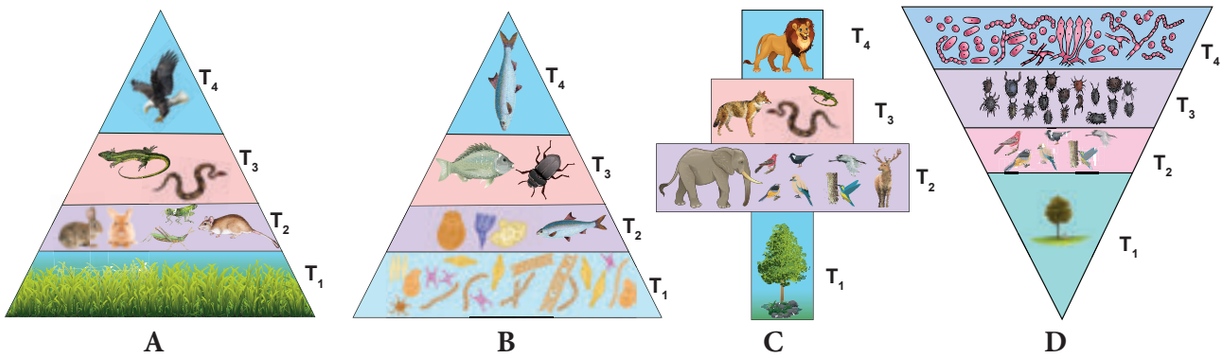
1. Pyramid of number

A graphical representation of the number of organisms present at each successive trophic level in an ecosystem is called **pyramids of number.** There are three different shapes of pyramids upright, spindle and inverted.

There is a gradual decrease in the number of organisms in each trophic level from producers to primary consumers and then to secondary consumers, and finally to tertiary consumers. Therefore, pyramids of number in **grassland** and **pond ecosystem** are always **upright**.

In a **forest ecosystem** the pyramid of number is somewhat different in shape, it is because the base (T_1) of the pyramid occupies large sized trees (Producer) which are lesser in number. Herbivores (T_2) (Fruit eating birds, elephant, deer) occupying second trophic level, are more in number than the producers. In final trophic level (T_4), tertiary consumers (lion) are lesser in number than the secondary consumer (T_3) (fox and snake). Therefore, the pyramid of number in forest ecosystem looks **spindle shaped**.

The pyramid of number in a **parasite ecosystem** is always **inverted**, because it



T_1 - Producers | T_2 - Herbivores | T_3 - Secondary consumers | T_4 - Tertiary consumers

Figure 7.8: Pyramids of numbers (individuals per unit area) in different types of ecosystems. **Upright**-A) Grassland ecosystem B) Pond ecosystem , **Spindle shaped** -C) Forest ecosystem, **Inverted**-D) Parasite ecosystem

starts with a single tree. Therefore there is gradual increase in the number of organisms in successive tropic levels from producer to tertiary consumers.

2 Pyramid of biomass

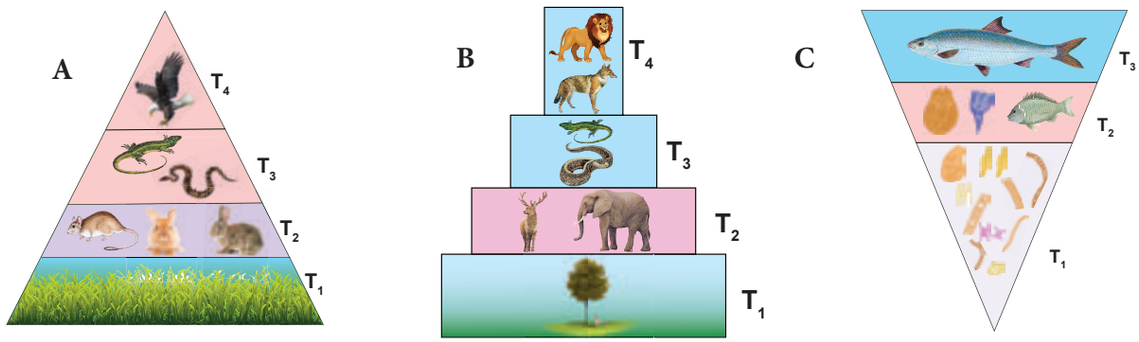
A graphical representation of the amount of organic material (biomass) present at each successive trophic level in an ecosystem is called **pyramid of biomass**.

In **grassland** and **forest ecosystems**, there is a gradual decrease in biomass of organisms at successive trophic levels from producers to top carnivores (Tertiary consumer). Therefore, these two ecosystems show pyramids as **upright** pyramids of biomass.

However, in **pond ecosystem**, the bottom of the pyramid is occupied by the producers, which comprise very small organisms possessing the least biomass and so, the value gradually increases towards the tip of the pyramid. Therefore, the pyramid of biomass is always **inverted** in shape.

3. Pyramid of energy

A graphical representation of energy flow at each successive trophic level in an ecosystem is called **pyramids of energy.** The bottom of the pyramid of energy is occupied by the producers. There is a gradual decrease in energy transfer at successive tropic levels from producers to the upper levels. Therefore, the pyramid of energy is **always upright**.



T_1 - Producers | T_2 - Herbivores | T_3 - Secondary consumers | T_4 - Tertiary consumers

Figure 7.9: Pyramids of biomass (dry weight per unit area)in different types of ecosystems. **Upright**-A) Grassland ecosystem B) Forest ecosystem, **Inverted**- C)Pond ecosystem

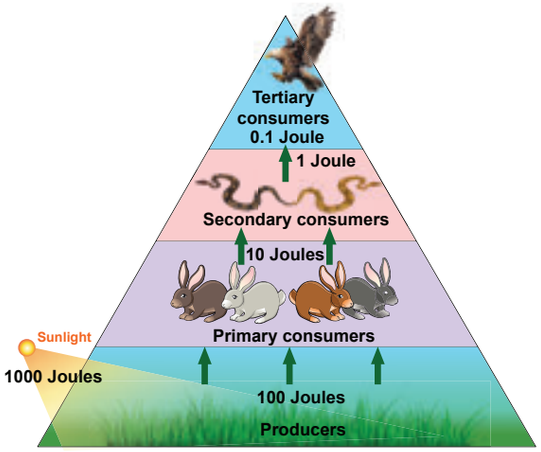


Figure 7.10: Pyramids of energy(Kcal/unit area/unit time) in any ecosystem

7.2.8 Decomposition:

Decomposition is a process in which the detritus (dead plants, animals and their excreta) are breakdown in to simple organic matter by the decomposers. It is an essential process for recycling and balancing the nutrient pool in an ecosystem.

Nature of decomposition

The process of decomposition varies based on the nature of the organic compounds, i.e., some of the compounds like carbohydrate, fat and protein are decomposed rapidly than the cellulose, lignin, chitin, hair and bone.

Mechanism of decomposition

Decomposition is a step wise process of degradation mediated by enzymatic reactions. Detritus acts as a raw material for decomposition. It occurs in the following steps.

a. **Fragmentation** - The breaking down of detritus into smaller particles by detritivores like bacteria, fungi and earth worm is known as **fragmentation**. These detritivores secrete certain substances to enhance the fragmentation process and increase the surface area of detritus particles.

b. **Catabolism** - The decomposers produce some extracellular enzymes in their surroundings to break down complex organic and inorganic compounds in to simpler ones. This is called **catabolism**

c. **Leaching or Eluviation** - The movement of decomposed, water soluble organic and inorganic compounds from the surface to the lower layer of soil or the carrying away

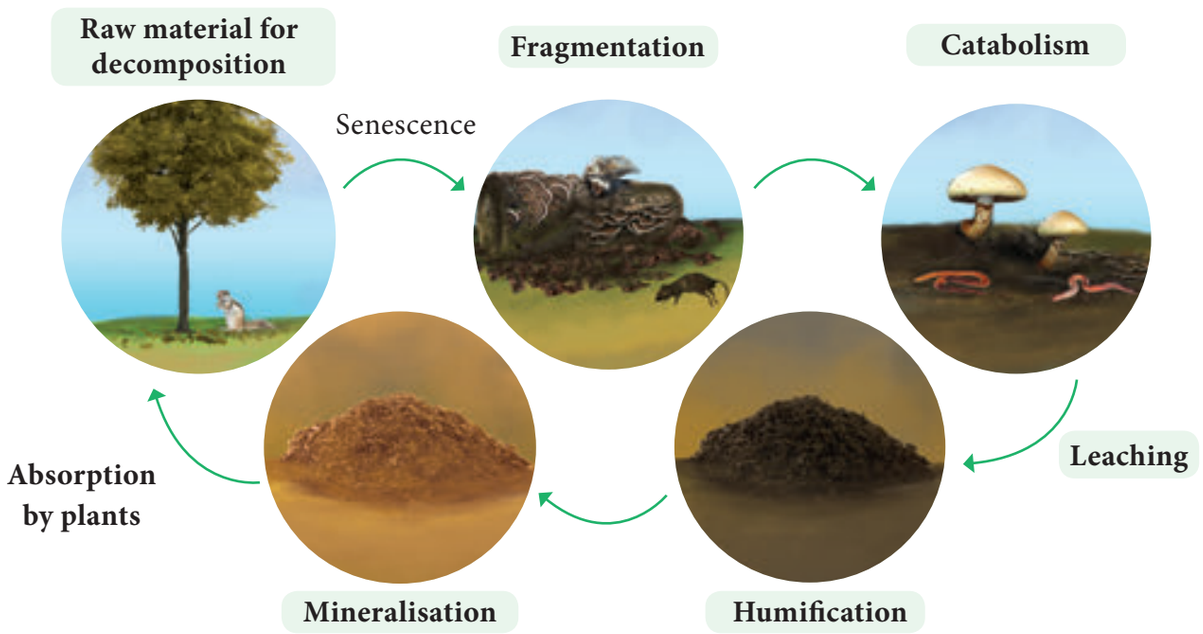


Figure 7.11: Diagrammatic representation – Process of decomposition and cycling of nutrients.

of the same by water is called **leaching** or **eluviation**.

d. **Humification** - It is a process by which simplified detritus is changed into dark coloured amorphous substance called **humus**. It is highly resistant to microbial action, therefore decomposition is very slow. It is the reservoir of nutrients.

e. **Mineralisation** - Some microbes are involved in the release of inorganic nutrients from the humus of the soil, such process is called **mineralisation**.

Factors affecting decomposition

Decomposition is affected by climatic factors like temperature, soil moisture, soil pH ,oxygen and also the chemical quality of detritus.

7.2.9 Biogeochemical cycle (Nutrient cycle)

Exchange of nutrients between organisms and their environment is one of the essential aspects of an ecosystem. All organisms require nutrients for their growth, development, maintenance and reproduction. Circulation of nutrients within the ecosystem or biosphere is known as **biogeochemical cycles** and also called as 'cycling of materials.' There are two basic types,

1. **Gaseous cycle** – It includes atmospheric Oxygen, Carbon and Nitrogen cycles.
2. **Sedimentary cycle** – It includes the cycles of Phosphorus, Sulphur and Calcium - Which are present as sediments of earth.

Many of the cycles mentioned above are studied by you in previous classes. Therefore, in this chapter, only the carbon and phosphorous cycles are explained.

Carbon cycle

The circulation of carbon between organisms and environment is known as the **carbon cycle**. Carbon is an inevitable part of all biomolecules and is substantially impacted by the change in global climate. Cycling of carbon between organisms and atmosphere is a consequence of two reciprocal processes of photosynthesis and respiration. The relesing of carbon in the atmosphere increases due to burning of fossile fules, deforestration, forest fire, volcanic eruption and decomposition of dead organic matters. The details of carbon cycle are given in the figure.

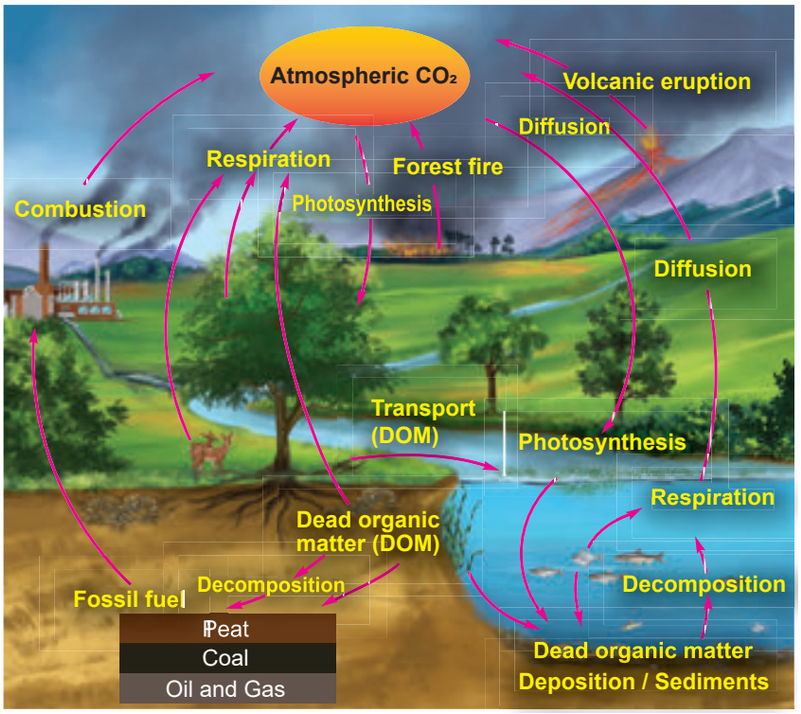


Figure 7.12: Diagrammatic Sketch showing Carbon cycle

Phosphorus cycle

It is a type of sedimentary cycle. Already we know that phosphorus is found in the biomolecules like DNA, RNA, ATP, NADP and phospholipid molecules of living organisms. Phosphorus is not abundant in the biosphere, whereas a bulk quantity of phosphorus is present in rock deposits, marine sediments and guano. It is released from these deposits by weathering

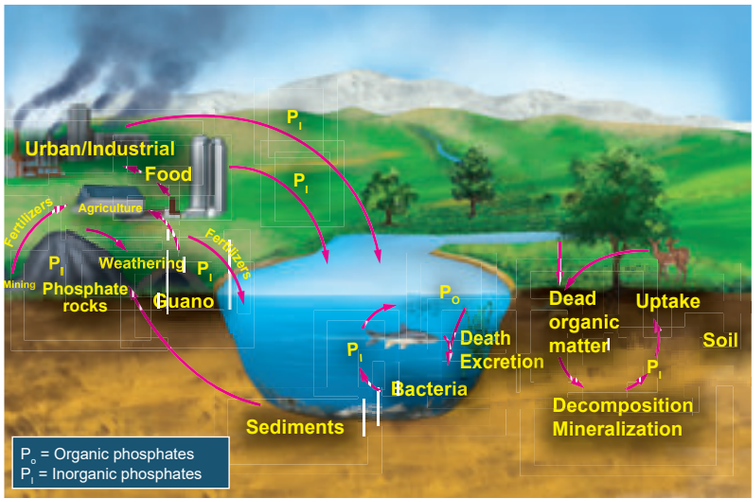


Figure 7.13: Diagrammatic sketch showing Phosphorous cycle

process. After that, it circulates in lithosphere as well as hydrosphere. The producers absorb phosphorus in the form of phosphate ions, and then it is transferred to each trophic level of food chain through food. Again death of the organisms and degradation by the action of decomposers, the phosphorus is released back into the lithosphere and hydrosphere to maintain phosphorus cycle.

7.2.10 Types of ecosystem

Biosphere consists of different types of ecosystems, which are as follows:

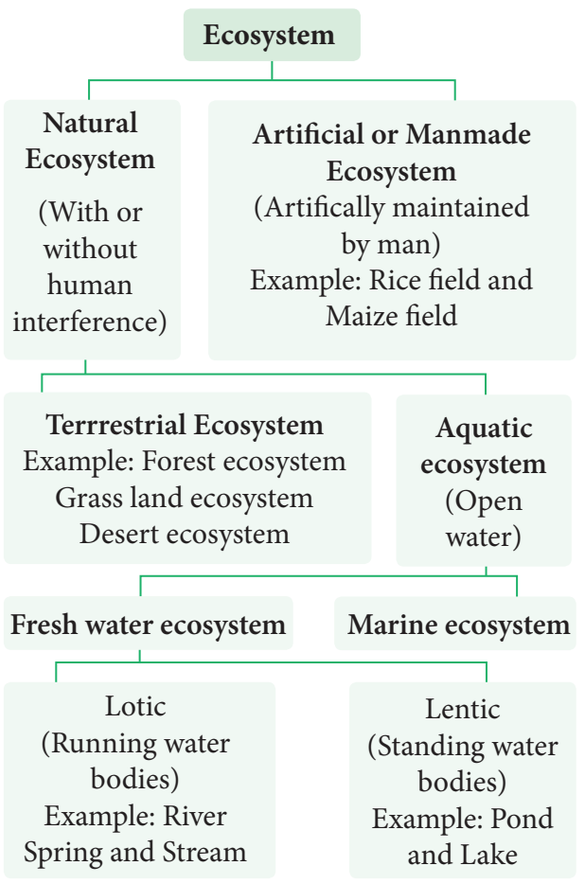


Figure 7.14: Types of Ecosystem

Though there are many types of ecosystems as charted above. Only the pond ecosystem is detailed below.

Structure of Pond ecosystem

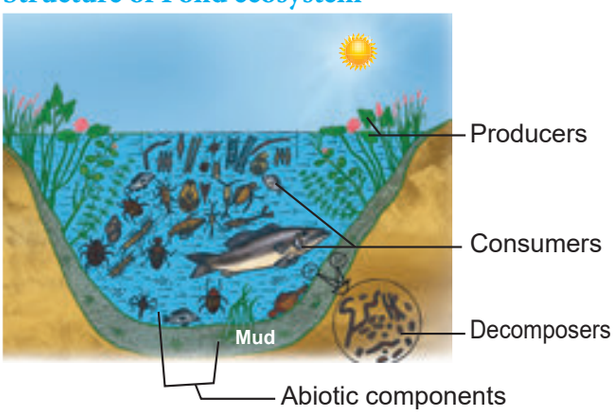


Figure 7.15: Diagram shows structure of pond ecosystem with abiotic and biotic components.

It is a classical example for natural, aquatic, freshwater, lentic type of ecosystem. It helps us to understand the structure and function of an ecosystem. When rain water gathers in a shallow area, gradually over a period of time, different kinds of organisms (microbes, plants, animals) become part of this ecosystem. This pond ecosystem is a self sustaining and self regulatory fresh water ecosystem, which shows a complex interaction between the abiotic and biotic components in it.

Activity

Collect few living and nonliving components from any water body found near by.

Abiotic components

A pond ecosystem consists of dissolved inorganic (CO_2, O_2, Ca, N, Phosphate) and organic substances (amino acids and humic acid) formed from the dead organic matter. The function of pond ecosystem is regulated by few factors like the amount of light, temperature, pH value of water and other climatic conditions.

Biotic components

They constitute the producers, variety of consumers and decomposers (microorganisms).

a. Producers

A variety of phytoplanktons like *Oscillatoria, Anabaena, Eudorina, Volvox* and *Diatoms.* Filamentous algae such as *Ulothrix, Spirogyra, Cladophora* and *Oedogonium;* floating plants *Azolla, Salvia, Pistia, Wolffia* and *Eichhornia*; sub-merged plants *Potamogeton* and *Phragmitis*; rooted floating plants *Nymphaea* and *Nelumbo*; macrophytes like *Typha* and *Ipomoea,* constitute the major producers of a pond ecosystem.

b. Consumers

The animals represent the consumers of a pond ecosystem include zooplanktons like *Paramoecium* and *Daphnia* (primary consumers); benthos (bottom living animals) like mollusces and annelids; secondary consumers like water beetles and frogs; and tertiary consumers (carnivores) like duck , crane and some top carnivores which include large fish, hawk ,man, etc.

Sea grasses and mangroves of Estuarine and coastal ecosystems are the most efficient in carbon sequestration. Hence, these ecosystems are called as " **Blue carbon ecosystems**". They are not properly utilized and maintained all over the world although they have rich bioresources potential.

c. Decomposers

They are also called as microconsumers. They help to recycle the nutrients in the ecosystem. These are present in mud water and bottom of the ponds. Example: Bacteria and Fungi. Decomposers perform the process of decomposition in order to enrich the nutrients in the pond ecosystem.

The cycling of nutrients between abiotic and biotic components is evident in the pond ecosystem, making itself self sufficient and self regulating.

Limnology
It is the study of biological, chemical, physical and geological components of inland fresh water aquatic ecosystems (ponds, lakes, etc.).

Oceanography – It is the study of biological, chemical, physical and geological components of ocean.

Stratification of pond ecosystem

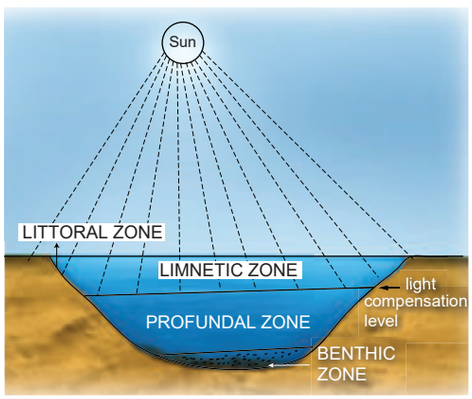


Figure 7.16: Diagrammatic sketch shows stratification of Pond ecosystem

Based on the factors like distance from the shore, penetration of light, depth of water, types of plants and animals, there may be three zones, littoral, limnetic and profundal. The littoral zone, which is closest to the shore with shallow water region, allows easy penetration of light. It is warm and occupied by rooted plant

species. The limnetic zone refers the open water of the pond with an effective penetration of light and domination of planktons. The deeper region of a pond below the limnetic zone is called profundal zone with no effective light penetration and predominance of heterotrophs. The bottom zone of a pond is termed benthic and is occupied by a community of organisms called benthos (usually decomposers).The primary productivity through photosynthesis of littoral and limnetic zone is more due to greater penetration of light than the profundal zone.

7.2.11 Ecosystem services (Benefits)

Ecosystem services are defined as the benefits that people derive from nature. Robert Constanza et al (1927) stated "Ecosystem services are the benefits provided to human, through the transformation of resources (or Environmental assets including land, water, vegetation and atmosphere) into a flow of essential goods and services".

Study on ecosystem services acts as an effective tool for gaining knowledge on ecosystem benefits and their sustained use. Without such knowledge gain, the fate of any ecosystem will be at stake and the benefits they provide to us in future will become bleak.

DO YOU KNOW?

Robert Constanza and his colleagues estimated the value of global ecosystem services based on various parameters. According to them in 1997, the average global value of ecosystems services estimated was US $ 33 trillion a year. The updated estimate for the total global ecosystem services in 2011 is US $ 125 trillion / year, indicating a four-fold increase in ecosystem services from 1997 to 2011.

Mangrove ecosystem services

- Offers habitat and act as nursery for aquatic plants and animals
- Provides medicine, fuel wood and timber.
- Act as bridge between sea and rivers by balancing sedimentation and soil erosion.
- Help to reduce water force during cyclones, tsunamis and high tide periods.
- Help in wind break, O_2 production, carbon sequestration and prevents salt spray from waves.

The varieties of benefits obtained from the ecosystem are generally categorized into the following four types

Ecosystem services

Provisoning services
- Food, fiber and fuel
- Genetic resources
- Bio-chemicals
- Fresh water
- Medicines

Cultural services
- Spiritual and religious values
- Knowledge system
- Education and inspiration
- Recreation and aesthetic values
- Ecotourism

Supporting services
- Primary production
- Provision of habitat
- Nutrient cycling
- Soil formation and retention
- Production of atmospherc oxygen
- Water cycling

Regulating services
- Invasion resistance
- Herbivory pollination
- Seed dispersal
- Climate regulation
- Pest regulation
- Disease regulation
- Erosion regulation
- Water purification
- Natural hazard protection

Figure 7.17: Types of Ecosystem services

How do anthropogenic activities affect ecosystem services?

Now, we all exploit the ecosystem more than that of our needs. The **Millennium Ecosystem Assessment (2005)** found that "over the past 50 years, humans have changed the ecosystem more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, medicine, timber, fiber and fuel."

Generally the following human activities disturb or re-engineer an ecosystem every day.

- Habitat destruction
- Deforestation and over grazing
- Erosion of soils
- Introduction of non-native species
- Over harvesting of plant material
- Pollution of land, water and air
- Run off pesticides, fertilizers and animal wastes

Ecosystem resilience

Ecosystem is damaged by disturbances from fire, flood, predation, infection, drought, etc., removing a great amount of biomasss. However, ecosystem is endowed with the ability to resist the damage and recover quickly. This ability of ecosystem is called ecosystem resilience or ecosystem robustness.

How to protect the ecosystem?

It is a practice of protecting ecosystem at individual, organisational and governmental levels for the benefits of both nature and humans. Threats to ecosystems are many, like adverse human activities, global warming, pollution, etc. Hence, if we change our everyday life style, we can help to protect the planet and its ecosystem.

"If we fail to protect environment, we will fail to save posterity".

Therefore, we have to practice the following in our day today life:

- Buy and use only ecofriendly products and recycle them.
- Grow more trees
- Choose sustained farm products (vegetables, fruits, greens, etc.)
- Reduce the use of natural resources.
- Recycle the waste and reduce the amount of waste you produce.
- Reduce consumption of water and electricity.
- Reduce or eliminate the use of house-hold chemicals and pesticides.
- Maintain your cars and vehicles properly. (In order to reduce carbon emission)
- Create awareness and educate about ecosystem protection among your friends and family members and ask them to find out solution to minimise this problem.

Go green

It refers to the changing of one's lifestyle for the safety and benefits of the environments (Reduce, Reuse, Recycle)

Way to go green and save green

- Close the tap when not in use.
- Switch off the electrical gadgets when not in use.
- Never use plastics and replace them with biodegradable products
- Always use ecofriendly technology and products.

"USE ECOSYSTEM BUT DON'T LOSE ECOSYSTEM; MAKE IT SUSTAINABLE"

7.2.12 Ecosystem Management

It is a process that integrates ecological, socio economic and institutional factors into a comprehensive strategy in order to sustain and enhance the quality of the ecosystem to meet current and future needs.

Ecosystem management emphasis on human role in judicious use of ecosystem and for sustained benefits through minimal human impacts on ecosystems. Environmental degradation and biodiversity loss will result in depletion of natural resources, ultimately affecting the existence of human

"By 2025, at least 3.5 billion people, nearly 50% of the world's population are projected to face water scarcity." – IUCN.

"Forests house approximately 50% of global bio-diversity and at least 300 million people are dependent on forest's goods and services to sustain their livelihood." – IUCN

Strategy of ecosystem management

- It is used to maintain biodiversity of ecosystems.
- It helps in indicating the damaged ecosystem (Some species indicate the health of the ecosystem: such species are called a **flagship species**).
- It is used to recognize the inevitability of ecosystem change and plan accordingly.
- It is one of the tools used for achieving sustainability of ecosystem through sustainable development programme (or projects).
- It is also helpful in identifying ecosystems which are in need of rehabilitation.

LAP2JU

- It involves collaborative management with government agencies, local population, communities and NGO's.
- It is used to build the capacity of local institutions and community groups to assume responsibility for long term implementation of ecosystem management activities even after the completion of the project.

Urban ecosystem restoration model

Adayar Poonga is located in Chennai and covers an area around a total of 358 acres of Adayar creek and estuary, of which 58 acres were taken up for eco restoration under the auspices of Government of Tamil Nadu. It is maintained by Chennai Rivers Restoration Trust (CRRT).This was a dumping site previously.

Presently it has 6 species of mangroves, about 170 species of littoral and tropical dry evergreen forests (TDF) which have successfully established as a sustainable ecosystem. Restoration of plants species has brought other associated fauna such as butterflies, birds, reptiles, amphibians and other mammals of the ecosystem.

Currently Adayar Poonga functions as an environmental education Centre for school and college students and the public. The entire area stands as one of the best examples for urban eco restoration in the state of Tamil Nadu.

Adayar Poonga

7.3 Plant Succession

We very often see that forests and lands in our areas are drastically affected by natural calamities (Flood, earthquake) and anthropogenic activities (Fire, over grazing, cutting of trees). Due to these reasons all plants of an area are destroyed and the areas become nude. When we observe this area, over a period of a time we can see that it will be gradually covered by plant community again and become fertile. Such successive replacement of one type of plant community by the other of the same area/ place is known as plant **succession**. The first invaded plants in a barren area are called **pioneers**. On the other hand, a series of transitional developments of plant communities one after another in a given area are called **seral communities**. At the end a final stage and a final plant community gets established which are called as climax and climax community respectively.

7.3.1 Characteristics of ecological succession

- It is a systematic process which causes changes in specific structure of plant community.
- It is resultant of changes of abiotic and biotic factors.
- It transforms unstable community into a stable community.
- Gradual progression in species diversity, total biomass, niche specialisation, and humus content of soil takes place.
- It progresses from simple food chain to complex food web.
- It modifies the lower and simple life form to the higher life forms.
- It creates inter-dependence of plants and animals.

7.3.2 Types of succession

The various types of succession have been classified in different ways on the basis of different aspects. These are as follows:

1. Primary succession - The development of plant community in a barren area where no community existed before is called primary succession. The plants which colonize first in a barren area is called **pioneer species** or **primary community** or **primary colonies**. Generally, Primary succession takes a very long time for the occurrence in any region.

Example: Microbes, Lichen, Mosses.

2. Secondary succession - The development of a plant community in an area where an already developed community has been destroyed by some natural disturbance (Fire, flood, human activity) is known as **secondary succession**.

	Primary succession	Secondary succession
1	Developing in an barren area	Developing in disturbed area
2	Initiated due to a biological or any other external factors	Starts due to external factors only
3	No soil, while primary succession starts	It starts where soil covers is already present
4	Pioneer species come from outside environment	Pioneer species develop from existing environment
5	It takes more time to complete	It takes comparatively less time to complete

Table 1: Differences between primary and secondary succession

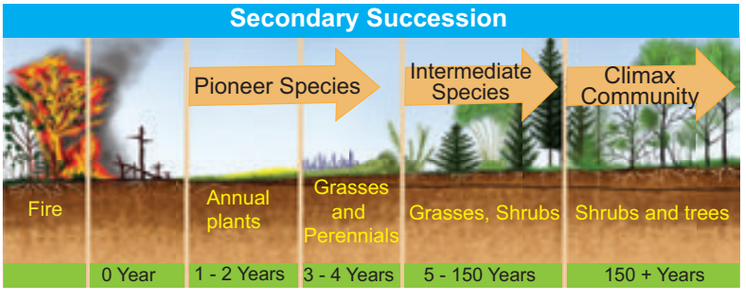


Figure 7.18: Diagrammatic representation of secondary succession

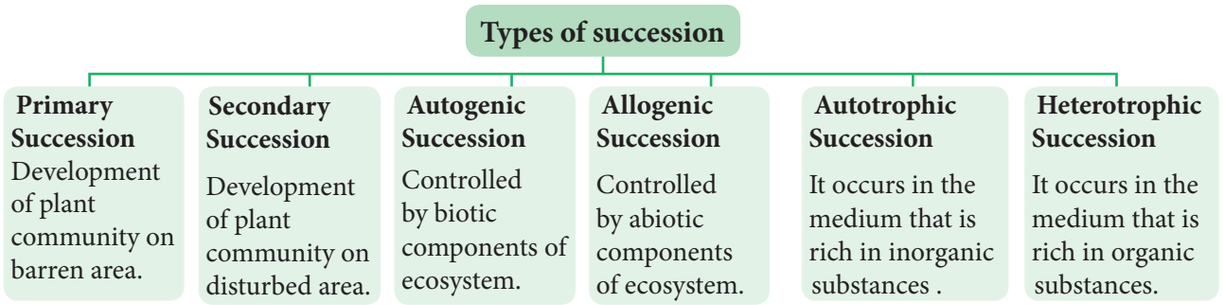


Figure 7.19: Types of succession

Generally, This succession takes less time than the time taken for primary succession.

Example: The forest destroyed by fire and excessive lumbering may be re-occupied by herbs over period of times.

3. Autogenic succession

Autogenic succession occurs as a result of biotic factors. The vegetation reacts with its environment and modifies its own environment causing its own replacement by new communities. This is known as **autogenic succession**.

Example: In forest ecosystem, the larger trees produce broader leaves providing shade to the forest floor area. It affects the shrubs and herbs which require more light (heliophytes) but supports the shade tolerant species (sciophytes) to grow well.

4. Allogenic succession

Allogeneic succession occurs as a result of abiotic factors. The replacement of existing community is caused by other external factors (soil erosion, leaching, etc.,) and not by existing organisms.

Example: In a forest ecosystem soil erosion and leaching alter the nutrient value of the soil leading to the change of vegetation in that area.

5. Autotrophic succession

If the autotrophic organisms like green plants are dominant during the early stages of succession it is called **autotrophic succession**, this occurs in the habitat which is rich in inorganic substances. Since, green plants dominate in the beginning of this succession, there is a gradual increase in organic matter and subsequently the energy flow in the ecosystem.

LQ7WL6

6. Heterotrophic succession

If heterotrophic organisms like bacteria, fungi, actinomycetes, and animals are dominant during the early stages of succession it is called **heterotrophic succession**. Such a succession takes place in organic habitats. Since heterotrophs dominate in the beginning of such succession, there will be a gradual decrease in the energy content.

7.3.3 Classification of plant succession

Detailed study of Hydrosere and Lithosere are discussed below:

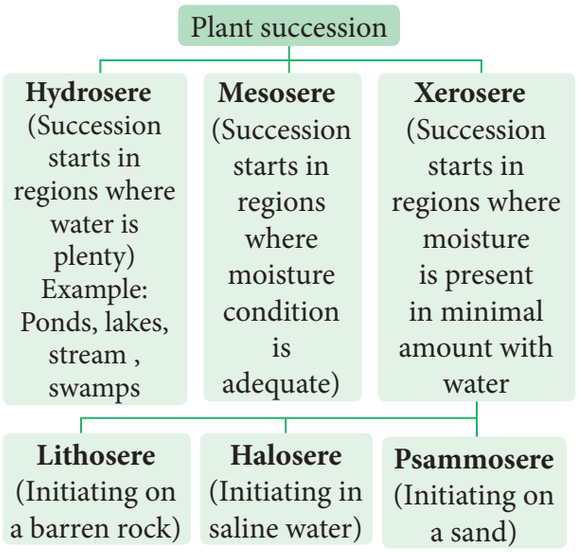


Figure 7.20: Classification of plant succession

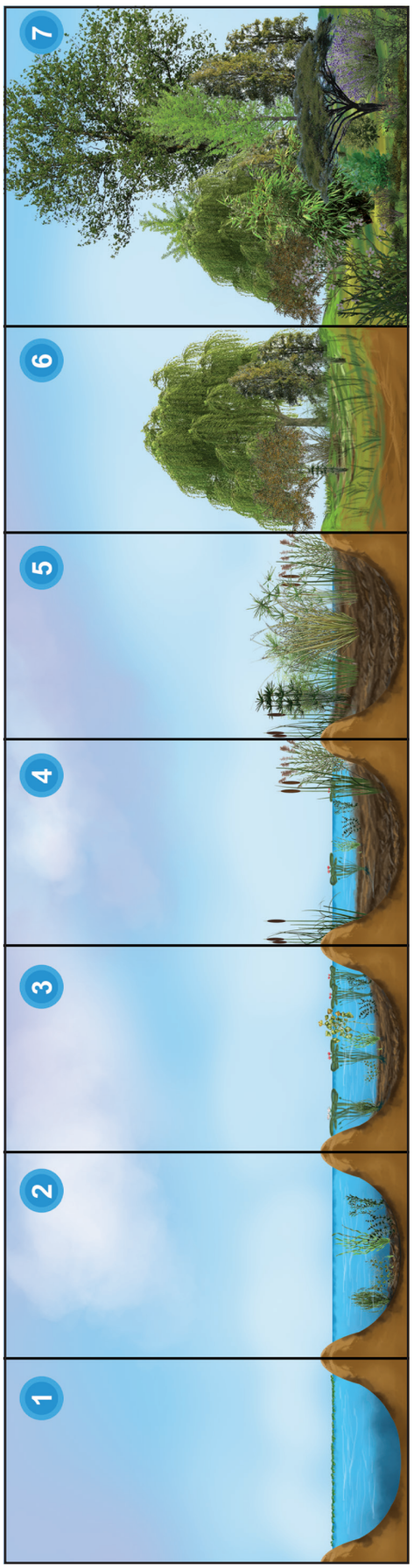


Figure 7.21: Diagrammatic representation shows different stages of hydrosere.

Hydrosere

The succession in a freshwater ecosystem is also referred to as hydrosere. Succession in a pond, begins with colonization of the pioneers like phytoplankton and finally ends with the formation of climax community like forest stage. It includes the following stages Fig 7.21.

1. Phytoplankton stage - It is the first stage of succession consisting of the pioneer community like blue green algae, green algae, diatoms, bacteria, etc., The colonization of these organisms enrich the amount of organic matter and nutrients of pond due to their life activities and death. This favors the development of the next seral stages.

2. Submerged plant stage - As the result of death and decomposition of planktons, silt brought from land by rain water, lead to a loose mud formation at the bottom of the pond. Hence, the rooted submerged hydrophytes begin to appear on the new substratum. Example: *Chara, Utricularia, Vallisneria* and *Hydrilla* etc. The death and decay of these plants will build up the substratum of pond to become shallow. Therefore, this habitat now replaces another group of plants which are of floating type.

3. Submerged free floating stage - During this stage, the depth of the pond will become almost 2-5 feet. Hence, the rooted hydrophytic plants and with floating large leaves start colonising the pond. Example: Rooted floating plants like *Nelumbo, Nymphaea* and *Trapa*. Some free floating species like *Azolla, Lemna, Wolffia* and *Pistia* are also present in this stage. By death and decomposition of these plants, further the pond becomes more shallow. Due to this reason, floating plant species is gradually replaced by another species which makes new seral stage.

4. Reed-swamp stage - It is also called an amphibious stage. During this stage, rooted floating plants are replaced by plants which can live successfully in aquatic as well as aerial

environment. Example: *Typha, Phragmites, Sagittaria* and *Scirpus* etc. At the end of this stage, water level is very much reduced, making it unsuitable for the continuous growth of amphibious plants.

5. Marsh meadow stage - When the pond becomes swallowed due to decreasing water level, species of Cyperaceae and Poaceae such as *Carex, Juncus, Cyperus* and *Eleocharis* colonise the area. They form a mat-like vegetation with the help of their much branched root system. This leads to an absorption and loss of large quantity of water. At the end of this stage, the soil becomes dry and the marshy vegetation disappears gradually and leads to shurb stage.

6. Shrub stage - As the disappearance of marshy vegetation continues, soil becomes dry. Hence, these areas are now invaded by terrestrial plants like shrubs (*Salix* and *Cornus*) and trees (*Populus* and *Alnus*). These plants absorb large quantity of water and make the habitat dry. Further, the accumulation of humus with a rich flora of microorganisms produce minerals in the soil, ultimately favouring the arrival of new tree species in the area.

7. Forest stage - It is the climax community of hydrosere. A variety of trees invade the area and develop any one of the diverse type of vegetation. Example:Temperate mixed forest (*Ulmus,Acer* and *Quercus*), Tropical rain forest (*Artocarpus* and *Cinnamomum*) and Tropical deciduous forest (*Bamboo* and *Tectona*).

In the 7 stages of hydrosere succession, stage1 is occupied by pioneer community, while the stage 7 is occupied by the climax community. The stages 2 to 6 are occupied by seral communities.

7.3.4 Significance of Plant Succession

- Succession is a dynamic process. Hence an ecologist can access and study the seral stages of a plant community found in a particular area.
- The knowledge of ecological succession helps to understand the controlled growth of one or more species in a forest.
- Utilizing the knowledge of succession, even dams can be protected by preventing siltation.
- It gives information about the techniques to be used during reforestation and afforestation.
- It helps in the maintenance of pastures.
- Plant succession helps to maintain species diversity in an ecosystem.
- Patterns of diversity during succession are influenced by resource availability and disturbance by various factors.
- Primary succession involves the colonization of habitat of an area devoid of life.
- Secondary succession involves the reestablishment of a plant community in disturbed area or habitat.
- Forests and vegetation that we come across all over the world are the result of plant succession.

Summary

The interaction between biotic and abiotic components in an environment is called ecosystem. Autotrophs and heterotrophs are the producers and consumers respectively. The function of ecosystem refers to creation of energy, flow of energy and cycling of nutrients. The amount of light available for photosynthesis is called Photo synthetically Active Radiation . It is essential for increase in the productivity of ecosystem. The rate of biomass production per unit area /time is called productivity. It is classified as primary productivity, secondary productivity and community productivity. The transfer of energy in an ecosystem can be termed as energy flow. It is explained through the food chain, food web , ecological pyramids (pyramid of number, biomass and energy) and biogeochemical cycle. Cycling of nutrients between abiotic and biotic components is evident in the pond ecosystem,

making itself self sufficient and self regulating Ecosystem protected for the welfare of posterity is called ecosystem management.

Successive replacement of one type of plant community by the other of the same area/ place is known as plant succession. The first invaded plants in a barren (nude) area are called pioneers (pioneers communities). On the other hand, a series of transitional developments of plant communities one after another in a given area are called seral communities. Succession is classified as primary succession, secondary succession, autogenic succession, allogeneic succession, autotrophic succession and heterotrophic succession. Plant succession is classified in to hydrosere (Initiating on a water bodies) ,Mesosere and xerosere. Further xerosere is subdivided in to Lithosere (Initiating on a barren rock), Halosere and Pasmmosere.

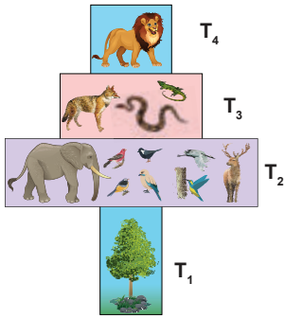
Evaluation

I Choose the most suitable answer from the given four alternatives and write the option code and the corresponding answer.

M5QRMH

1. Which of the following is not a abiotic component of the ecosystem?
   a) Bacteria
   b) Humus
   c) Organic compounds
   d) Inorganic compounds
2. Which of the following is / are not a natural ecosystem?
   a) Forest ecosystem
   b) Rice field
   c) Grassland ecosystem
   d) Desert ecosystem
3. Pond is a type of
   a) forest ecosystem
   b) grassland ecosystem
   c) marine ecosystem
   d) fresh water ecosystem
4. Pond ecosystem is
   a) not self sufficient and self regulating
   b) partially self sufficient and self regulating
   c) self sufficient and not self regulating
   d) self sufficient and self regulating
5. Profundal zone is predominated by heterotrophs in a pond ecosystem, because of
   a) with effective light penetration
   b) no effective light penetration
   c) complete absence of light
   d) a and b
6. Solar energy used by green plants for photosynthesis is only
   a) 2 – 8% b) 2 – 10%
   c) 3 – 10% d) 2 – 9%
7. Which of the following ecosystem has the highest primary productivity?
   a) Pond ecosystem
   b) Lake ecosystem
   c) Grassland ecosystem
   d) Forest ecosystem
8. Ecosystem consists of
   a) decomposers b) producers
   c) consumers d) all of the above
9. Which one is in descending order of a food chain
   a) Producers → Secondary consumers → Primary consumers → Tertiary consumers
   b) Tertiary consumers → Primary consumers → Secondary consumers → Producers
   c) Tertiary consumers → Secondary consumers → Primary consumers → Producers
   d) Tertiary consumers → Producers → Primary consumers → Secondary consumers
10. Significance of food web is / are
    a) it does not maintain stability in nature
    b) it shows patterns of energy transfer
    c) it explains species interaction
    d) b and c

11. The following diagram represents



a) pyramid of number in a grassland ecosystem
b) pyramid of number in a pond ecosystem
c) pyramid of number in a forest ecosystem
d) pyramid of biomass in a pond ecosystem

12. Which of the following is / are not the mechanism of decomposition
a) Eluviation b) Catabolism
c) Anabolism d) Fragmentation

13. Which of the following is not a sedimentary cycle
a) Nitrogen cycle b) Phosphorous cycle
c) Sulphur cycle d) Calcium cycle

14. Which of the following are not regulating services of ecosystem services
i) Genetic resources
ii) Recreation and aesthetic values
iii) Invasion resistance
iv) Climatic regulation
a) i and iii b) ii and iv
c) i and ii d) i and iv

15. Productivity of profundal zone will be low. Why?

16. Discuss the gross primary productivity is more efficient than net primary productivity.

17. Pyramid of energy is always upright. Give reasons

18. What will happen if all producers are removed from ecosystem?

19. Construct the food chain with the following data.
Hawk, plants, frog, snake, grasshopper.

20. Name of the food chain which is generally present in all type of ecosystem. Explain and write their significance.

21. Shape of pyramid in a particular ecosystem is always different in shape. Explain with example.

22. Generally human activities are against to the ecosystem, where as you a student how will you help to protect ecosystem?

23. Generally in summer the forest are affected by natural fire. Over a period of time it recovers itself by the process of successions . Find out the types of succession and explain.

24. Draw a pyramid from following details and explain in brief.
Quantities of organisms are given-Hawks-50, plants-1000.rabbit and mouse-250 +250, pythons and lizard- 100 + 50 respectively.

25. Various stages of succession are given bellow. From that rearrange them accordingly. Find out the type of succession and explain in detail.
Reed-swamp stage, phytoplankton stage, shrub stage, submerged plant stage, forest stage, submerged free floating stage, marsh medow stage.

Glossary

Ecosystem: Study of interaction between living and non-living components

Standing quality: Total inorganic substances presents in any ecosystem at a given time and given area

Standing crops: Amount of living material present in a population at any time.

Biomass: Can be measured as fresh weight or dry weight of organisms

Benthic: Bottom zone of the pond

Trophic: Refers to the position of organisms in food chain

Omnivores: Those eats both plants and animals

Food chain: Refers movement of energy from producers up to top carnivores

Food web: Interlocking pattern of food chain

Pyramid of number: Refers number of organisms in a successive trophic level

Pyramid of biomass: Refers to quantitative relationship of the standing crops

Pyramid of energy: Refers transformation of energy at successive trophic levels

Ten per cent law: refers only 10 per cent of energy is stored in each successive trophic levels

Bio geo chemical cycle: Exchange of nutrients between organisms and environments

Carbon cycle: Circulation of carbon among organisms and environments

Guano: It is a accumulated excrement of sea birds and bats.

Phosphorus cycle: Circulation of Phosphorus among organisms and environments

Succession: Successive replacement of one type of plant communities by other on barren or disturbed area.

Pioneers: Invaded plants on barren area

Primary succession: Plants colonising on barren area

Secondary succession: Plants colonising on disturbed area.

Climax communities: Final establishment of plant communities which are not replaced by others.

ICT Corner

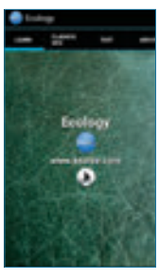
ECO SYSTEM

B266_12_BOT_EM

Let us know about the **Ecosystem** in detail through this activity.

Steps

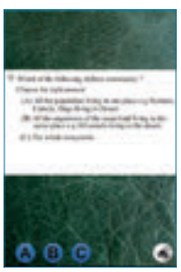
- Type the URL or scan the QR code to open the activity page then Introduction page will open.
- Click on the Learn icon in the introduction page to know in detail.
- Click on the Flashcards icon in the introduction page to know about the topics easily.
- Click on the Test icon to write a quiz test finally it displays the marks we scored.



Step 1

Step 2

Step 3



Step 4

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* Pictures are indicative only

Chapter

8

Unit IX - Plant Ecology

Environmental Issues

Learning Objectives

Learning objectives

The learner will be able to,

- Understand the importance of growing more plants to mitigate the environmental problems.
- Distinguish between the importance and conservation of endemic and endangered species.
- Appreciate the use of technologies for agriculture and forestry.
- Participate in community activities to improve environmental conditions.
- Develop methods in conservation of water and plants for sustainable development.
- Get acquainted with satellite technology and utilising it in our daily life needs

Chapter outline

MZIKNH

After understanding the structure and functions of major ecosystems of the world, now student community should observe and understand environmental problems of their surroundings at local, national and international level.

Now we are going to understand some of the environmental issues such as

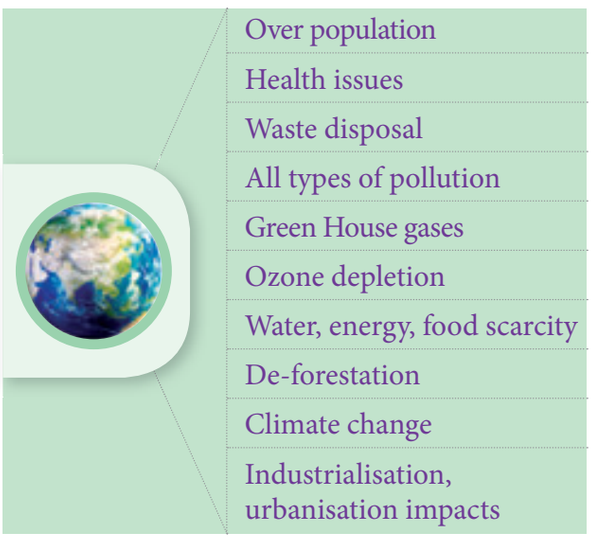

Figure 8.1: Environmental issues

Environmental issues are the problems and harmful effects created by human's unmindful activity and over utilisation of valuable resources obtained from the nature (environment). Student should understand not only the environmental issues we are facing now, but also find solutions to rectify or reduce these problems.

Countries of the whole world agree that something needs to be done about these important environmental issues. Many global summits, conferences and conventions are regularly conducted by the United Nations and many steps are taken to minimise human-induced issues by signing agreements with around 150 countries.

Activity

Students may form 'ECOGROUPS' and discuss eco-issues of their premises and find solutions to the existing problems like, litter disposal, water stagnation, health and hygiene, greening the campus and its maintenance.

Drastic increase in population resulted in demand for more productivity of food materials, fibres, fuels which led to many environmental issues in agriculture, land use modifications resulting in loss of biodiversity, land degradation, reduction in fresh water availability and also resulting in man-made global warming by green house gases even altering climatic conditions.

8.1 Green House effect and Global Warming

Green House Effect is a process by which radiant heat from the sun is captured by gases in the atmosphere that increase the temperature of the earth ultimately. The gases that capture heat are called **Green House Gases** which include carbon dioxide (CO_2), methane (CH_4), Nitrous Oxide (N_2O) and a variety of manufactured chemicals like chlorofluorocarbon (CFC). Increase in greenhouse gases lead to irreversible changes in major ecosystems and climate patterns. For example, coral ecosystem is affected by increase in temperature, especially **coral bleaching** observed in Gulf of Mannar, Tamil Nadu.

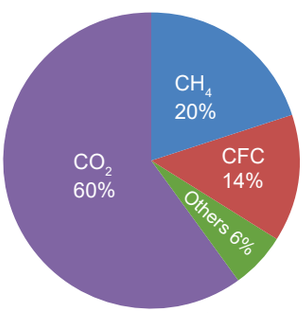

Figure 8.2: Relative contribution of green house gases

Human activities lead to produce the green house effect by

- Burning fossil fuels, which releases CO_2 and CH_4
- Way of Agriculture and animal husbandry practices
- Electrical gadgets like refrigerator and air conditioners release chloro fluoro carbons
- The fertilizers used in Agriculture which release N_2O
- The emissions from automobiles.

The increase in mean global temperature (highest in 4000 years) due to increased concentration of green house gases is called **global warming.**

One of the reasons for this is over population which creates growing need for food, fibre and fuel and considered to be the major cause of global warming.

Clouds and Dust particles can also produce Green House effect. That is why clouds, dusts and humid nights are warmer than clear dust free dry nights.

8.1.1. Effects of Global Warming

- Rise in global temperature which causes sea levels to rise as polar ice caps and glaciers begin to melt causing submergence of many coastal cities in many parts of the world.
- There will be a drastic change in weather patterns bringing more floods or droughts in some areas.
- Biological diversity may get modified, some species ranges get redefined. Tropics and sub-tropics may face the problem of decreased food production.

8.1.2. Sources of Green House Gases Emission (Natural and Anthropogenic)

CO_2 (Carbon dioxide)

- Coal based power plants, by the burning of fossil fuels for electricity generation.
- Combustion of fuels in the engines of automobiles, commercial vehicles and air planes contribute the most of global warming.
- Agricultural practices like stubble burning result in emission of CO_2.
- Natural from organic matter, volcanoes, warm oceans and sediments.

Methane

Methane is 20 times as effective as CO_2 at trapping heat in the atomosphere. Its sources are attributed paddy cultivation, cattle rearing, bacteria in water bodies, fossil fuel production, ocean, non-wetland soils and forest / wild fires.

N_2O (Nitrous oxide)

It is naturally produced in Oceans from biological sources of soil and water due to microbial actions and rainforests. Man-made sources include nylon and nitric acid production, use of fertilizers in agriculture, manures cars with catalytic converter and burning of organic matter.

Global Warming Effects on Plants

- Low agricultural productivity in tropics
- Frequent heat waves (Weeds, pests, fungi need warmer temperature)
- Increase of vectors and epidemics
- Strong storms and intense flood damage
- Water crisis and decreased irrigation
- Change in flowering seasons and pollinators
- Change in Species distributional ranges
- Species extinction

8.1.3 Strategies to deal with Global Warming

- Increasing the vegetation cover, grow more trees
- Reducing the use of fossil fuels and green house gases
- Developing alternate renewable sources of energy
- Minimising uses of nitrogeneous fertilizers, and aerosols.

8.1.4. Ozone depletion

Ozone layer is a region of Earth's stratosphere that absorbs most of the Sun's ultra violet radiation. The ozone layer is also called as the **ozone shield** and it acts as a protective shield, cutting the ultra-violet radiation emitted by the sun.

Just above the atmosphere there are two layers namely troposphere (the lower layer) and stratosphere (the upper layer). The ozone layer of the troposphere is called **bad ozone** and the ozone layer of stratosphere is known as **good ozone** because this layer acts as a shield for absorbing the UV radiations coming from the sun which is harmful for living organisms

Ozone is a colourless gas, reacts readily with air pollutants and cause rubber to crack, hurt plant life, damages lung tissues. But ozone absorbs harmful ultra violet β (uv-β) and UV – α radiation from sunlight.

What is Dobson Unit? DU is the unit of measurement for total ozone. One DU (0.001 atm. cm) is the number of molecules of ozone that would be required to create a layer of pure ozone 0.01 millimetre thick at a temperature of 0° C and a pressure of 1 atmosphere (atm = the air pressure at the surface of earth). Total ozone layer over the earth surface is 0.3 centrimetres (3 mm) thick and is written as 300 DU.

The false colour view of total ozone - The purple and blue colours are where there is the least ozone, and the yellows and reds are where there is more ozone.

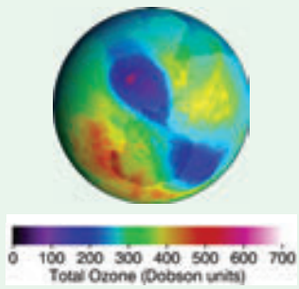

Figure 8.3: The false colour view of total ozone

causing DNA damage. The thickness of the ozone column of air from the ground to the top of the atmosphere is measured in terms of **Dobson Units**.

The ozone shield is being damaged by chemicals released on the Earth's surface notably the chlorofluorocarbons widely used in refrigeration, aerosols, chemicals used as cleaners in many industries. The decline in the thickness of the ozone layer over restricted area is called **Ozone hole.**

September 16 is WORLD OZONE DAY

Ozone depletion in the stratosphere results in more UV radiations especially UV B radiations (shortwaves). UV B radiation destroys biomolecules (skin ageing) and damages living tissues. UV – C is the most damaging type of UV radiation, but it is completely filtered by the atmosphere (ozone layer). UV – a contribute 95% of UV radiation which causes tanning burning of skin and enhancing skin cancer. Hence the uniform ozone layer is critical for the wellbeing of life on earth.

During 1970's research findings indicated that man-made chlorofluorocarbons (CFC) reduce and convert ozone molecules in the atmosphere. The threats associated with reduced ozone pushed the issue to the forefront of global climate issues and gained promotion through organisation such as World Meterological Organisation and the United Nations. The Vienna Convention was agreed upon at the Vienna conference of 1985 but entered into force in 1988 provided the frameworks necessary to create regulative measures in the form of the Montreal protocol. The International treaty called the **Montreal Protocol** (1987) was held in Canada on **substances that deplete ozone layer** and the main goal of it is gradually eliminating the production and consumption of ozone depleting substances and to limit their damage on the Earth's ozone layer.

Clean Development Mechanism (CDM) is defined in the **Kyoto protocol** (2007) which provides project based mechanisms with two objectives to prevent dangerous climate change and to reduce green house gas emissions. CDM projects helps the countries to reduce or limit emission and stimulate sustainable development.

An example for CDM project activity, is replacement of conventional electrification projects with solar panels or other energy efficient boilers. Such projects can earn Certified Emission Reduction (CER) with credits / scores, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets.

Plant indicators

The presence or absence of certain plants indicate the state of environment by their response. The plant species or plant community acts as a measure of environmental conditions, it is referred as biological indicators or phytoindicators or plant indicators.

Examples

	Plants	Indicator for
1	*Lichens, Ficus, Pinus,* Rose	SO_2 pollution
2.	*Petunia, Chrysanthemum*	Nitrate
3.	*Gladiolus*	Flouride pollution
4.	*Robinia pseudoacacia (Black locust tree)*	Indicator of heavy metal contamination

8.1.5 Effects of Ozone depletion

The main ozone depletion effects are:

- Increases the incidence of cataract, throat and lung irritation and aggravation of asthma or emphysema, skin cancer and diminishing the functioning of immune system in human beings.
- Juvenile mortality of animals.
- Increased incidence of mutations.

- In plants, photosynthetic chemicals will be affected and therefore photosynthesis will be inhibited. Decreased photosynthesis will result in increased atmospheric CO_2 resulting in global warming and also shortage of food leading to food crisis.
- Increase in temperature changes the climate and rainfall pattern which may result in flood / drought, sea water rise, imbalance in ecosystems affecting flora and fauna.

8.2 Forestry

8.2.1 Agro forestry

Agroforestry is an integration of trees, crops and livestock on the same plot of land. The main objective is on the interaction among them . Example: intercropping of two or more crops between different species of trees and shrubs, which results in higher yielding and reducing the operation costs. This intentional combination of agriculture and forestry has varied benefits including increased bio-diversity and reduced erosion.

Some of the major species cultivated in commercial Agroforestry include *Casuarina, Eucalyptus*, Malai Vembu, Teak and Kadambu trees which were among the 20 species identified as commercial timber. They are of great importance to wood-based industries.

Benefits of agroforestry

- It is an answer to the problem of soil and water conservation and also to stabilise the soil (salinity and water table) reduce landslide and water run-off problem.
- Nutrient cycling between species improves and organic matter is maintained.
- Trees provide micro climate for crops and maintain O_2 – CO_2 balanced, atmospheric temperature and relative humidity.
- Suitable for dry land where rainfall is minimum and hence it is a good system for alternate land use pattern.
- Multipurpose tree varieties like *Acacia* are used for wood pulp, tanning, paper and firewood industries.
- Agro-forestry is recommended for the following purposes. It can be used as Farm Forestry for the extension of forests, mixed forestry, shelter belts and linear strip plantation.

Rehabilitation of degraded forests and recreation forestry

The production of woody plants combined with pasture is referred to **silvopasture** system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuel wood and fruit or to improve the soil.

This system is classified into following categories.

i. **Protein Bank:** In this various multipurpose trees are planted in and around farm lands and range lands mainly for fodder production.

   Example: *Acacia nilotica, Albizzia lebbek, Azadirachta indica, Gliricidia sepium, Sesbania grandiflora.*

ii. **Livefence of fodder trees and hedges:** Various fodder trees and hedges are planted as live fence to protect the property from stray animals or other biotic influences.

   Example: *Gliricidia sepium, Sesbania grandiflora, Erythrina* spp., *Acacia* spp..

8.2.2 Social forestry

It refers to the sustainable management of forests by local communities with a goal of climate carbon sequestration, change mitigation, depollution, deforestation, forest restoration and providing indirect employment opportunity for the youth. Social forestry refers to the **management of forests and afforestation on barren lands** with the purpose of helping the environmental, social and rural development and benefits. Forestry programme is done for the benefit of people and participation of

the people. Trees grown outside forests by government and public organisation reduce the pressure on forests.

In order to encourage tree cultivation outside forests, **Tree cultivation in Private Lands** was implemented in the state from 2007-08 to 2011-12. It was implemented by carrying out block planting and inter-crop planting with profitable tree species like Teak, *Casuarina, Ailanthus*, Silver Oak, etc. in the farming lands and by a free supply of profitable tree species for planting in the bunds. The **Tank foreshore plantations** have been a major source of firewood in Tamil Nadu. The 32 **Forestry extension centres** provide technical support for tree growing in rural areas in Tamil Nadu. These centres provide quality tree seedlings like thorn / thornless bamboo, *casuarinas*, teak, neem, *Melia dubia*, grafted tamarind and nelli, etc. in private lands and creating awareness among students by training / camps.

8.2.3. Major activities of forestry extension centres

- Training on tree growing methods
- Publicity and propaganda regarding tree growing
- Formation of demonstration plots
- Raising and supply of seedlings on subsidy
- Awareness creation among school children and youth about the importance of forests through training and camps.

8.3 Deforestation

Deforestation is one of the major contributors to enhance green house effect and global warming. The conversion of forested area into a non-forested area is known as deforestation. Forests provide us many benefits including goods such as timber, paper, medicine and industrial products. The causes are

- The conversion of forests into agricultural plantation and livestock ranching is a major cause of deforestation.
- Logging for timber
- Developmental activities like road construction, electric tower lines and dams.
- Over population, Industrialisation, urbanisation and increased global needs.

Effects of deforestation

- Burning of forest wood release stored carbon, a negative impact just opposite of carbon sequestration.
- Trees and plants bind the soil particles. The removal of forest cover increases soil erosion and decreases soil fertility. Deforestation in dry areas leads to the formation of deserts.
- The amount of runoff water increases soil erosion and also creates flash flooding, thus reducing moisture and humidity.
- The alteration of local precipitation patterns leading to drought conditions in many regions. It triggers adverse climatic conditions and alters water cycle in ecosystem.
- It decreases the bio-diversity significantly as their habitats are disturbed and disruption of natural cycles.
- Loss of livelihood for forest dwellers and rural people.
- Increased global warming and account for one-third of total CO_2 emission.
- Loss of life support resources, fuel, medicinal herbs and wild edible fruits.

8.4 Afforestation

Afforestation is planting of trees where there was no previous tree coverage and the conversion of non-forested lands into forests by planting suitable trees to retrieve the vegetation. Example: Slopes of dams afforested to reduce water run-off, erosion and siltation. It can also provide a range of environmental services including carbon sequestration, water retention.

The Man who Single Handedly Created a Dense Forest

Jadav "Molai" Payeng (born 1963) is an environmental activist has single-handedly planted a forest in the middle of a barren wasteland. This Forest Man of India has transformed the world's largest river island, Majuli, located on one of India's major rivers, the Brahmaputra, into a dense forest, home to rhinos, deers, elephants, tigers and birds. And today his forest is larger than Central Park.

Former vice-chancellor of Jawahar Lal Nehru University, Sudhir Kumar Sopory named Jadav Payeng as **Forest Man of India**, in the month of October 2013. He was honoured at the Indian Institute of Forest Management during their annual event 'Coalescence'. In 2015, he was honoured with Padma Shri, the fourth highest civilian award in India. He received honorary doctorate degree from Assam Agricultural University and Kaziranga University for his contributions.

Afforestation Objectives

- To increase forest cover, planting more trees, increases O_2 production and air quality.
- Rehabilitation of degraded forests to increase carbon fixation and reducing CO_2 from atmosphere.
- Raising bamboo plantations.
- Mixed plantations of minor forest produce and medicinal plants.
- Regeneration of indigenous herbs / shrubs.
- Awareness creation, monitoring and evaluation.
- To increase the level and availability of water table or ground water and also to reduce nitrogen leaching in soil and nitrogen contamination of drinking water, thus making it pure not polluted with nitrogen.
- Nature aided artificial regeneration.

Achievements

- Degraded forests were restored
- Community assets like overhead tanks bore-wells, hand pumps, community halls, libraries, etc were established
- Environmental and ecological stability was maintained.
- Conserved bio-diversity, wildlife and genetic resources.
- Involvement of community especially women in forest management.

8.5 Alien invasive species

Invasion of alien or introduced species disrupts ecosystem processes, threaten biodiversity, reduce native herbs, thus reducing the ecosystem services (benefits). During eradication of these species, the chemicals used increases greenhouse gases. Slowly they alter ecosystem, micro climate and nature of soil and make it unsuitable for native species and create human health problems like allergy, thus resulting in local environmental degradation and loss of important local species.

According to World Conservation Union invasive alien species are the second most significant threat to bio-diversity after habitat loss.

What is invasive species?

A non-native species to the ecosystem or country under consideration that spreads naturally, interferes with the biology and existence of native species, poses a serious threat to the ecosystem and causes economic loss.

It is established that a number of invasive species are accidental introduction through ports via air or sea. Some research organisations import germplasm of wild varieties through which also it gets introduced. Alien species with edible fruits are usually spread by birds.

Invasive species are fast growing and are more adapted. They alter the soil system by changing litter quality thereby affecting the

soil community, soil fauna and the ecosystem processes.

It has a negative impact on decomposition in the soils by causing stress to the neighbouring native species. Some of the alien species which cause environmental issues are discussed below

Eichhornia crassipes

Figure 8.4:
Eichhornia crassipes

It is an invasive weed native to South America. It was introduced as aquatic ornamental plant, which grows faster throughout the year. Its widespread growth is a major cause of biodiversity loss worldwide. It affects the growth of phytoplanktons and finally changing the aquatic ecosystem.

It also decreases the oxygen content of the waterbodies which leads to eutrophication. It poses a threat to human health because it creates a breeding habitat for disease causing mosquitoes (particularly *Anopheles*) and snails with its free floating dense roots and semi submerged leaves. It also blocks sunlight entering deep and the waterways hampering agriculture, fisheries, recreation and hydropower.

Prosopis juliflora

Prosopis juliflora is an invasive species native to Mexico and South America. It was first introduced in Gujarat to counter desertification and later on in Andhra Pradesh, Tamil Nadu as a source of firewood. It is an aggressive coloniser and as a consequence the habitats are rapidly covered by this species. Its invasion reduced the cover of native medicinal herbaceous species. It is used to arrest wind erosion and stabilize sand dunes on coastal and desert areas. It can absorb hazardous chemicals from soil and it is the main source of charcoal.

Figure 8.5:
Prosopis juliflora

8.6 Conservation

India due to its topography, geology and climate patterns has diverse life forms. Now this huge diversity is under threat due to many environmental issues for this conservation becomes an important tool by which we can

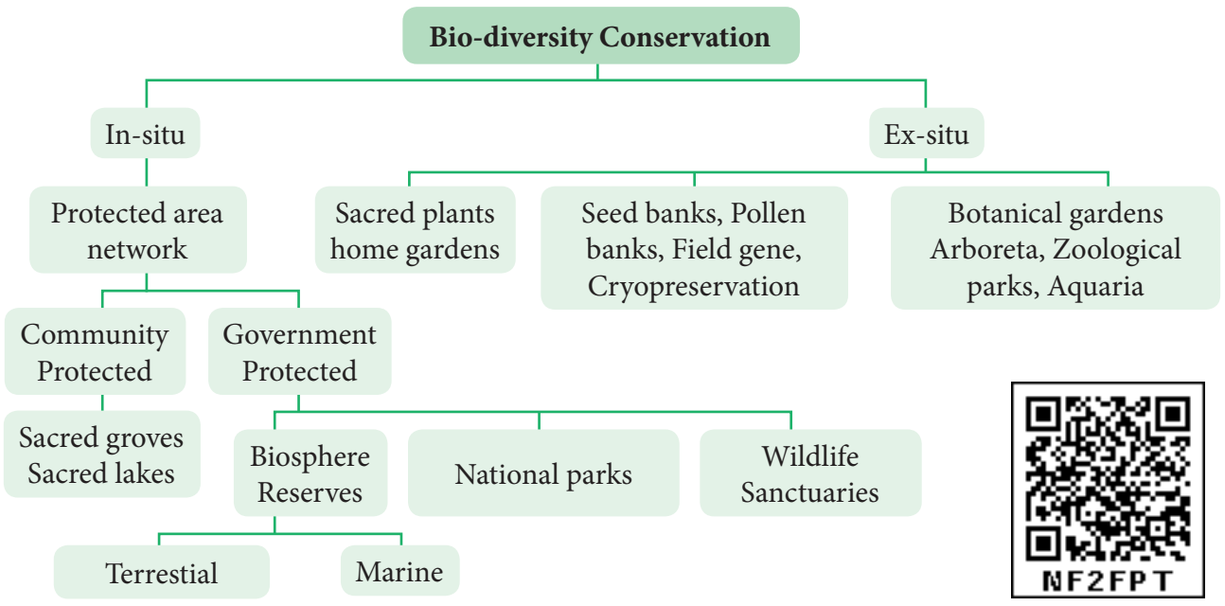

Figure 8.6: Flow chart on biodiversity conservation

Conservation movement

A community level participation can help in preservation and conservation of our environment. Our environment is a common treasure for all the living organisms on earth. Every individual should be aware of this and participate actively in the programs meant for the conservation of the local environment. Indian history has witnessed many people movements for the protection of environment.

Chipko Movement

The tribal women of Himalayas protested against the exploitation of forests in 1972. Later on it transformed into **Chipko Movement** by **Sundarlal Bahuguna** in Mandal village of Chamoli district in 1974. People protested by hugging trees together which were felled by a sports goods company. Main features of Chipko movement were,

- This movement remained non political
- It was a voluntary movement based on Gandhian thought.
- It was concerned with the ecological balance of nature
- Main aim of Chipko movement was to give a slogan of five F's – Food, Fodder, Fuel, Fibre and Fertilizer, to make the communities self sufficient in all their basic needs.

Appiko Movement

The famous Chipko Andolen of Uttarakhand in the Himalayas inspired the villagers of Uttar Karnataka to launch a similar movement to save their forests. This movement started in Gubbi Gadde a small village near Sirsi in Karnataka by Panduranga Hegde. This movement started to protest against felling of trees, monoculture, forest policy and deforestation.

reduce many species getting lost from our native land. By employing conservation management strategies like germplasm conservation, in situ, ex-situ, in-vitro methods, the endemic as well as threatened species can be protected

In-situ conservation

It means conservation and management of genetic resources in their natural habitats. Here the plant or animal species are protected within the existing habitat. Forest trees, medicinal and aromatic plants under threat are conserved by this method. This is carried out by the community or by the State conservation which include wildlife, National park and Biosphere reserve. The ecologically unique and biodiversity rich regions are legally protected as wildlife sanctuaries, National parks and Biosphere reserves. Megamalai, Sathyamangalam wildlife, Guindy and Periyar National park, and Western ghats, Nilgiris, Agasthyamalai and Gulf of Mannar are the biosphere reserves of Tamil Nadu.

Sacred groves

These are the patches or grove of cultivated trees which are community protected and are based on strong religious belief systems which usually have a significant religious connotation for protecting community. Each grove is an abode of a deity mostly village God Or Goddesses like Aiyanar or Amman. 448 grooves were documented throughout Tamil Nadu, of which 6 groves (Banagudi shola, Thirukurungudi and Udaiyankudikadu, Sittannnavasal, Puthupet and Devadanam) were taken up for detailed floristic and faunistic studies. These groves provide a number of ecosystem services to the neighbourhood like protecting watershed, fodder, medicinal plants and micro climate control.

Ex-situ conservation

It is a method of conservation where species are protected outside their natural environment. This includes establishment of botanical gardens, zoological parks, conservation strategies such as gene, pollen, seed, in-vitro conservation, cryo preservation, seedling, tissue culture and DNA banks. These facilities not only provide housing and care for endangered species, but

also have educational and recreational values for the society

8.6.1 Endemic Centres and Endemic Plants

Endemic species are plants and animals that exist only in one geographic region. Species can be endemic to large or small areas of the earth. Some are endemic to a particular continent, some to a part of a continent and others to a single island.

Any species found restricted to a specified geographical area is referred to as ENDEMIC.. It may be due to various reasons such as isolation, interspecific interactions, seeds dispersal problems, site specificity and many other environmental and ecological problems. There are 3 Megacentres of endemism and 27 microendemic centres in India. Approximately one third of Indian flora have been identified as endemic and found restricted and distributed in three major phytogeographical regions of india, that is Indian Himalayas, Peninsular India and Andaman nicobar islands. Peninsular India, especially Western Ghats has high concentration of endemic plants. *Hardwickia binata* and *Bentinckia condapanna* are good examples for endemic plants. A large percentage of Endemic species are herbs and belong to families such as Poaceae. Apiaceae, Asteraceae and Orchidaceae.

Endemic plants	Habit	Name of endemic centre
Baccaurea courtallensis	Tree	Southern Western Ghats
Agasthiyamalaia pauciflora	Tree	Peninsular india
Hardwickia binata	Tree	Peninsular and northern India
Bentinckia condappana	Tree	Western ghats of Tamil Nadu and kerala
Nepenthes khasiyana	Liana	Khasi hills, Meghalaya

Table 1: Endemic plants

Majority of endemic species are threatened due to their narrow specific habitat, reduced seed production, low dispersal rate, less viable nature and human intereferences.. Serious efforts need to be undertaken for their conservation, otherwise these species may become globally extinct.

Figure 8.7: Endemic Plants
a. *Bentinckia condapanna* **b.** *Baccaurea courtallensis*

8.7 Carbon Capture and Storage (CCS)

Carbon capture and storage is a technology of capturing carbondioxide and injects it deep into the underground rocks into a depth of 1 km or more and it is an approach to mitigate global warming by capturing CO_2 from large point sources such as industries and power plants and subsequently storing it instead of releasing it into the atmosphere. Various safe sites have been selected for permanent storage in various deep geological formations, liquid storage in the Ocean and solid storage by reduction of CO_2 with metal oxide to produce stable carbonates. It is also known as Geological sequestration which involves injecting CO_2 directly into the underground geological formations (such as declining oil fields, gas fields saline aquifers and unmineable coal have been suggested as storage sites).

Carbon Sequestration

Carbon sequestration is the process of capturing and storing CO2 which reduces the amount of CO2 in the atmosphere with a goal of reducing global climate change.

Carbon sequestration occurs naturally by plants and in ocean. Terrestrial sequestration is typically accomplished through forest and soil conservation practices that enhance the storage carbon.

As an example microalgae such as species of *Chlorella*, *Scenedesmus*, *Chroococcus* and *Chlamydomonas* are used globally for CO_2 sequestration. Trees like *Eugenia caryophyllata*,

Tecomastans, *Cinnamomum verum* have high capacity and noted to sequester carbon macroalgae and marine grasses and mangroves are also have ability to mitigate carbon-di-oxide.

Carbon Foot Print (CFP)

Every human activity leaves a mark just like our footprint. This **Carbon foot print** is the total amount of green house gases produced by human activities such as agriculture, industries, deforestation, waste disposal, buring fossil fuels directly or indirectly. It can be measured for an individual, family, organisation like industries, state level or national level. It is usually estimated and expressed in equivalent tons of CO_2 per year. The burning of fossil fuels releases $CO_2$and other green house gases. In turn these emissions trap solar energy and thus increase the global temperature resulting in ice melting, submerging of low lying areas and inbalance in nature like cyclones, tsunamis and extreme weather conditions. To reduce the carbon foot print we can follow some practices like (i) Eating indigenous fruits and products (ii) Reduce use of your electronic devices (iii) Reduce travelling (iv) Do not buy fast and preserved, processed, packed foods. (v) Plant a garden (vi) Less consumption of meat and sea food. Poultry requires little space, nutrients and less pollution comparing cattle farming. (vii) reduce use of Laptops (when used for 8 hours, it releases nearly 2 kg. of CO_2 annually) (viii) Line dry your clothes. (Example: If you buy imported fruit like kiwi, indirectly it increases CFP. How? The fruit has travelled a long distance in shipping or airliner thus emitting tons of CO_2)

Carbon Sink

Any system having the capacity to accumulate more atmospheric carbon during a given time interval than releasing CO_2. Example: forest, soil, ocean are natural sinks. Landfills are artificial sinks.

Biochar

Biochar is another long term method to store carbon. To increase plants ability to store more carbon, plants are partly burnt such as crop waste, waste woods to become carbon rich slow decomposing substances of material called Biochar. It is a kind of charcoal used as a soil amendment. Biochar is a stable solid, rich in carbon and can endure in soil for thousands of years. Like most charcoal, biochar is made from biomass via pyrolysis. (Heating biomas in low oxygen environment) which arrests wood from complete burning. Biochar thus has the potential to help mitigate climate change via carbon

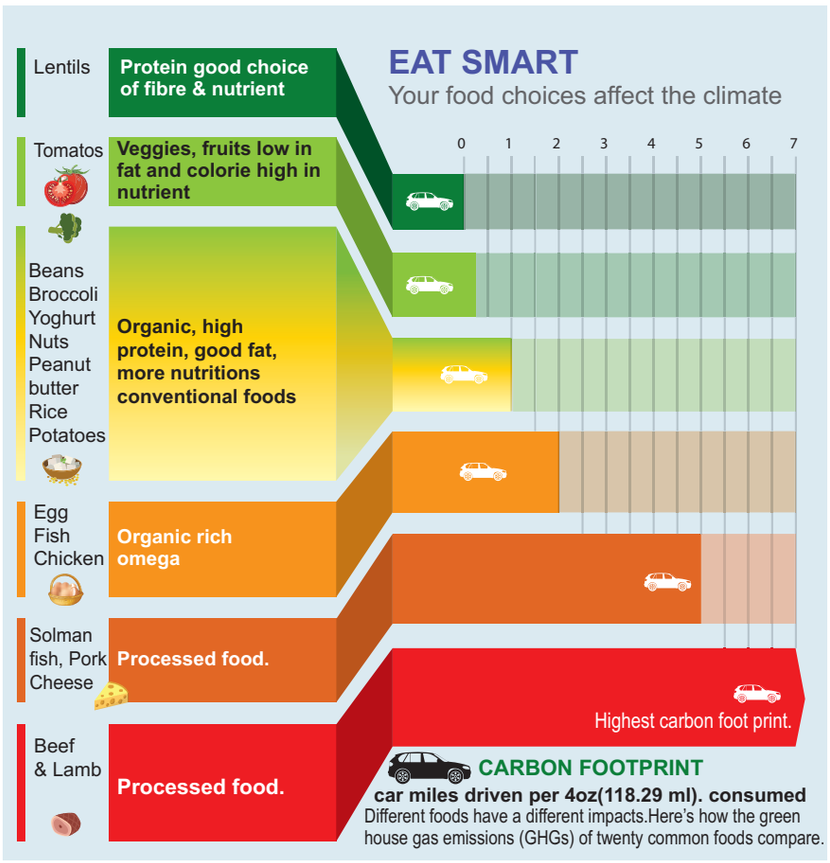

Figure 8.8: Carbon foot print

sequestration. Independently, biochar when added to soil can increase soil fertility of acidic soils, increase agricultural productivity, and provide protection against some foliar and soil borne diseases. It is a good method of preventing waste woods and logs getting decayed instead we can convert them into biochar thus converting them to carbon storage material.

8.8 Rain water harvesting – RWH (Solution to water crisis – A ecological problem)

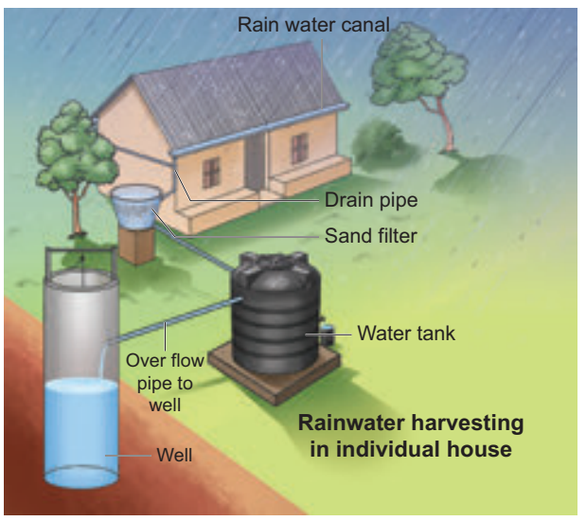

Figure 8.9: Pictures of Rain Water Harvesting Structures in Ooraniers

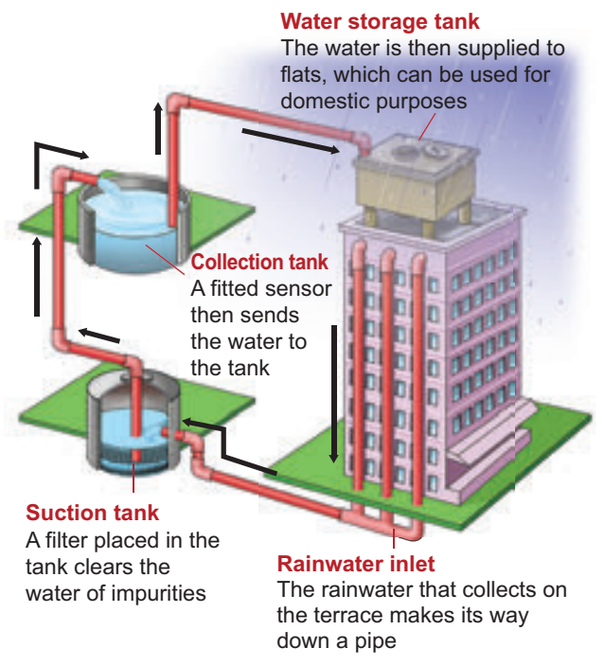

Figure 8.10: Rain Water Harvesting Structures in Water Supply sources

Rainwater harvesting is the accumulation and storage of rain water for reuse in-site rather than allowing it to run off. Rainwater can be collected from rivers, roof tops and the water collected is directed to a deep pit. The water percolates and gets stored in the pit. RWH is a sustainable water management practice implemented not only in urban area but also in agricultural fields, which is an important economical cost effective method for the future.

8.8.1 Environmental benefits of Rain Water Harvesting:

- Promotes adequacy of underground water and water conservation.
- Mitigates the effect of drought.
- Reduces soil erosion as surface run-off is reduced.
- Reduces flood hazards.
- Improves groundwater quality and water table / decreases salinity.
- No land is wasted for storage purpose and no population displacement is involved.
- Storing water underground is an eco-friendly measure and a part of sustainable water storage strategy for local communities.

8.8.2 Importance of Lakes

Water bodies like lakes, ponds not only provide us a number of environmental benefits but they strengthen our economy as well as our quality of life like health. Lakes as a storage of rain water provides drinking water, improves ground water level and preserve the fresh water bio-diversity and habitat of the area where in occurs.

In terms of services lakes offer sustainable solutions to key issues of water management and climatic influences and benefits like nutrient retention, influencing local rainfall, removal of pollutants, phosphorous and nitrogen and carbon sequestration.

8.9 Environmental Impact Assessment (EIA)

Environmental Impact Assessment is an environmental management tool. It helps to regulate and recommend optimal use of natural resources with minimum impact on ecosystem and biotic communities. It is used to predict the environmental consequences of future proposed developmental projects (example: river projects, dams, highway projects) taking into account inter-related socio-economic, cultural and human-health impacts. It reduces environmental stress thus helping to shape the projects that may suit local environment by ensuring optimal utilization of natural resources and disposal of wastes to avoid environmental degradation.

The benefits of EIA to society

- A healthier environment
- Maintenance of biodiversity
- Decreased resource usage
- Reduction in gas emission and environment damage

Biomonitoring

The act of observing and assessing the current state and ongoing changes in ecosystem, biodiversity components, landscape including natural habitats, populations and species.

An agricultural drone is an unmanned aerial vehicle applied to farming in order to help increased crop production and monitor crop growth. Agricultural drones let farmers see their fields from the sky. This bird's eye-view can reveal many issues such as irrigation problems, soil variation and pest and fungal infestations. It is also used for cost effective safe method of spraying pesticides and fertilizers, which proves very easy and non-harmful.

Figure 8.11: Agricultural drone

8.9.1 Biodiversity Impact Assessment (BIA)

Biodiversity Impact Assessment can be defined as a decision supporting tool to help biodiversity inclusive of development, planning and implementation. It aims at ensuring development proposals which integrate bio-diversity considerations. They are legally compliant and include mechanisms for the conservation of bio-diversity resources and provide fair and equitable sharing of the benefits arising from the use of bio-diversity.

Bio-diversity impacts can be assessed by

- Change in land use and cover
- Fragmentation and isolation
- Extraction
- External inputs such as emissions, effluents and chemicals
- Introduction of invasive, alien or genetically modified species
- Impact on endemic and threatened flora and fauna.

8.10 Geographic Information System

GIS is a computer system for capturing, storing, checking and displaying data related to positions on Earth's surface. Also to manipulate, analyse, manage and present spacial or geographic data.

GPS is a satellite navigation system used to determine the ground position of an object. It is a **constellation** of approximately 30 well spaced satellites that orbit the earth and make it possible for the people with ground receivers to pinpoint their geographic location. Some applications in which GPS is currently being used for around the world include Mining, Aviation, Surveying Agricultural and Marine ecosystem.

Importance of GIS

- Environmental impact assessment
- Disaster management
- Zoning of landslide hazard

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- Determination of land cover and land use
- Estimation of flood damage
- Management of natural resources
- Soil mapping
- Wetland mapping
- Irrigation management and identification of volcanic hazard
- Vegetation studies and mapping of threatened and endemic species.

Remote Sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance from the targeted area. It is an tool used in conservation practices by giving exact picture and data on identification of even a single tree to large area of vegetation and wild life for classification of land use patterns and studies, identification of biodiversity rich or less areas for futuristic works on conservation and maintenance of various species including commercial crop, medicinal plants and threatened plants.

Specific uses

- Helps predicting favourable climate, for the study of spreading of disease and controlling it.
- Mapping of forest fire and species distribution.
- Tracking the patterns of urban area development and the changes in Farmland or forests over several years
- Mapping ocean bottom and its resources

Applications of Satellites

Name of the Satellites	Year of Launch	Application
SCATSAT – I	Sep. 2016	Weather forecasting, cyclone prediction and tracking services in India
INSAT 3DR	Sep. 2016	Disaster management
CARTOSAT – 2	Jan. 2018	Earth observation
GSAT – 6A	March 2018	Communication
CARTOSAT – 2 (100^{th} Satellite)	Jan. 2018	To watch border surveillance

Summary

Green house effect leads to climate change which results in global warming. Deforestation causes soil erosion, whereas Afforestation helps to restore vegetation and increases ground water table. Regeneration of trees by Agroforestry is possible with the involvement of community and government. Help to conserve the flora and fauna in their natural habitat and man-made environments like zoological parks and national parks. Mitigation of carbon in the atmosphere done in the form of sequestration. Rain water harvesting is done for improving the ground water table. Importance and location of lakes in Tamil Nadu which aids water supply to the city is a measure of conservation of drinking water. Assessment of Environment and Biodiversity helps to study risk analysis and disaster management. Forest cover is monitored through Remote sensing and GIS.

Evaluation

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1. Which of the following would most likely help to slow down the greenhouse effect.
   a) Converting tropical forests into grazing land for cattle.
   b) Ensuring that all excess paper packaging is buried to ashes.
   c) Redesigning landfill dumps to allow methane to be collected.
   d) Promoting the use of private rather than public transport.

2. With respect to *Eichhornia*
   Statement A: It drains off oxygen from water and is seen growing in standing water.
   Statement B: It is an indigenous species of our country.
   a) Statement A is correct and Statement B is wrong.
   b) Both Statements A and B are correct.
   c) Statement A is correct and Statement B is wrong.
   d) Both statements A and B are wrong.

3. Find the wrongly matched pair.
   a) Endemism - Species confined to a region and not found anywhere else.
   b) Hotspots - Western ghats
   c) Ex-situ Conservation - Zoological parks
   d) Sacred groves - Saintri hills of Rajasthan
   e) Alien sp. Of India - Water hyacinth

4. Depletion of which gas in the atmosphere can lead to an increased incidence of skin cancer?
   a) Ammonia b) Methane
   c) Nitrous oxide d) Ozone

5. One green house gas contributes 14% of total global warming and another contributes 6%. These are respectively identified as
   a) N_20 and CO_2 b) CFCs and N_20
   c) CH_4 and CO_2 d) CH_4 and CFCS

6. One of the chief reasons among the following for the depletion in the number of species making endangered is
   a) over hunting and poaching
   b) green house effect
   c) competition and predation
   d) habitat destruction

7. Deforestation means
   a) growing plants and trees in an area where there is no forest
   b) growing plants and trees in an area where the forest is removed
   c) growing plants and trees in a pond
   d) removal of plants and trees

8. Deforestation does not lead to
   a) Quick nutrient cycling
   b) soil erosion
   c) alternation of local weather conditions
   d) Destruction of natural habitat weather conditions

9. The unit for measuring ozone thickness
   a) Joule b) Kilos
   c) Dobson d) Watt

10. People's movement for the protection of environment in Sirsi of Karnataka is
    a) Chipko movement
    b) Amirtha Devi Bishwas movement
    c) Appiko movement
    d) None of the above

11. The plants which are grown in silivpasture system are
    a) Sesbania and Acacia
    b) Solenum and Crotalaria
    c) Clitoria and Begonia
    d) Teak and sandal

12. What is ozone hole?

13. Give four examples of plants cultivated in commercial agroforestry.

14. Expand CCS.

15. How do forests help in maintaining the climate?

16. How do sacred groves help in the conservation of biodiversity?

17. Which one gas is most abundant out of the four commonest greenhouse gases? Discuss the effect of this gas on the growth of plants?

18. Suggest a solution to water crisis and explain its advantages.

19. Explain afforestation with case studies.

20. What are the effects of deforestation and benefits of agroforesty?

Glossary

Algae Blooms: Sudden sprout of algae growth, which can affect the water quality adversely and indicate potentially hazardous changes in local water chemistry.

Atmosphere: A major regional community of plants and animals with similar life forms and environmental conditions.

Biodegradable waste: Organic waste, typically coming from a plant or animal sources, which other living organisms can break done.

Biosphere: The portion of earth and its atmosphere that can support life.

Oil spill: The harmful release of oil into the environment, usually through water, which is very difficult to clean up and often kills, birds, fish and other wildlife.

Radiation: A form of energy that is transmitted in waves, rays or particles from a natural source such as the sun and the ground or an artificial source such as an X-ray machine.

Radioactive: A materials is said to be radioactive if it emits radiation.

Recycle:To break waste items done into their raw materials, which are then used to remake the original item or to make new items.

Sustainable development: Development using hand of energy sources in a way that meets the needs of people today without reducing the ability in future generation to meet their own needs.

ICT Corner

Environmental Issues

Let us know about the Environmental issues using the **EARTH NOW** app through this activity.

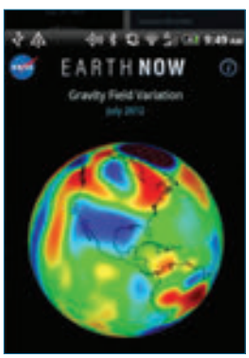
Steps

- Type the URL or scan the QR code to open the activity page.
- Click on the satellite it displays the shape and activities of the satellite.
- Click on the Vital Signs to see the global Climate data including surface air temperature, Carbondioxide, Ozone, etc.,

Step 1

Step 2

Step 3



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https://play.google.com/store/apps/details?id=gov.nasa.jpl.earthnow.activity

* Pictures are indicative only

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Chapter

9

Unit X: Economic Botany

Plant Breeding

Learning Objectives

The learner will be able to

- Appreciate the relationship between humans and plants.
- Recognise the origin of agriculture.
- Perceive the importance of organic agriculture.
- Understand the different conventional methods of plant breeding.

Chapter outline

Q4VYTG

Economic botany is the study of the relationship between people and economically important plants. It explores the ways by which humans use plants for food, medicines and other uses. Economic botany intersects many fields including established disciplines such as agronomy, anthropology, archaeology, chemistry, trade and commerce.

9.1 Relationship between humans and plants

From the very early times, human beings have co-existed with plants which played a vital role in their survival. Through a long process of trial and error, our ancestors have selected hundreds of wild plants from the various parts of the world for their specific use. The knowledge of the plants and its applications have led to the development of the humans and their civilization in many ways.

9.2 Domestication of plants

Domestication is the process of bringing a plant species under the control of humans and gradually changing it through careful selection, genetic alteration and handling so that it is more useful to people. The domesticated species are renewable sources that have provided food and other benefits to human.

The possible changes in the plant species due to domestication are listed below;

- Adaptation to a greater diversity of environments and a wider geographical range.
- Simultaneous /uniform flowering and fruiting.

- Lack of shattering or scattering of seeds.
- Increased size of fruits and seeds.
- Change from a perennial to annual habit.
- Change in breeding system.
- Increased yield.
- Increased resistance for disease and pest.
- Developing seedless parthenocarpic fruit.
- Enhancing colour, appearance, palatability and nutritional composition.

9.3 Origin of Agriculture

Archeological evidence for earliest record of agriculture is found in the fertile crescent region in and around Tigris and Euphrates river valleys, approximately about 12,000 years ago.

The earlier Greek and Roman naturalists like Theophrastus, Dioscorides, Pliny the elder and Galen laid down the scientific foundation in understanding origin and domestication of cultivated plants.

9.4 History of Agriculture

1807 Alexander Von Humboldt considered the original sources of most useful plants and their origin is an impenetrable secret.

1868 Darwin's evolutionary theory proposed that origin of useful cultivated plants have existed through natural selection and hybridisation.

1883 De Candolle in his "Origin of cultivated plants" studied 247 cultivated plant species and attempted to solve the mystery about the ancestral form, region of domestication and history.

1887- 1943 Nikolai Ivanovich Vavilov made an inventory of the diverse forms of our most important cultivated plants and their distribution based on variety of facts obtained from morphology, anatomy, cytology, genetics and plant geography. Vavilov has given the centre of diversity of a crop species which may be the centre of origin for that species.

Vavilov initially proposed eight main geographic centres of origin originally in 1926. Later (1935) he named 11 centres of origin by dividing few centres into two and three centres and added a new centre USA thus making the 8 centres of origin into 12.

1968 Zhukovsky put forward the concept of mega gene centre for the origin of cultivated plants. He divided the whole world into 12 mega gene centres.

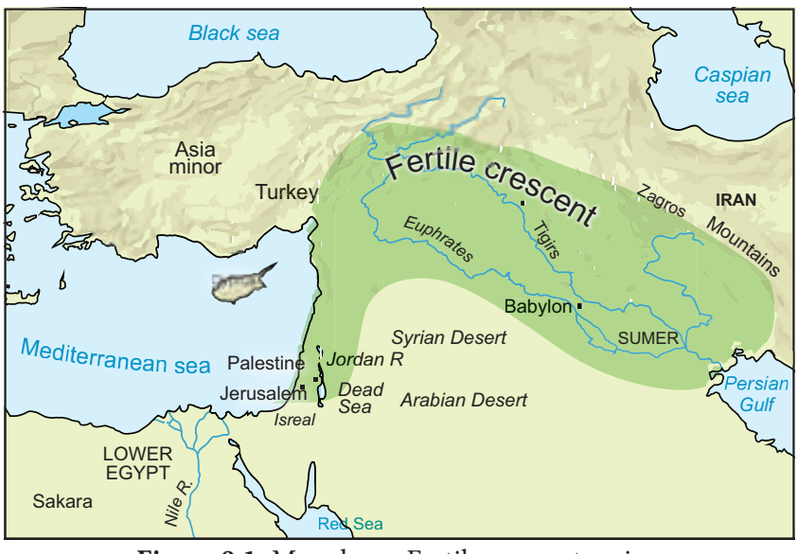

Figure 9.1: Map shows Fertile crescent region

1971 According to Harlan, agriculture originated independently in three different areas in different times or simultaneously. Hence a crop may not have a single centre of origin. Harlan says that the centre of crop plant means the places of agricultural origin of the crop plants. The non-centre denotes the place where agriculture of the crop was introduced and spread. Thus centre and non-centre interact with each other.

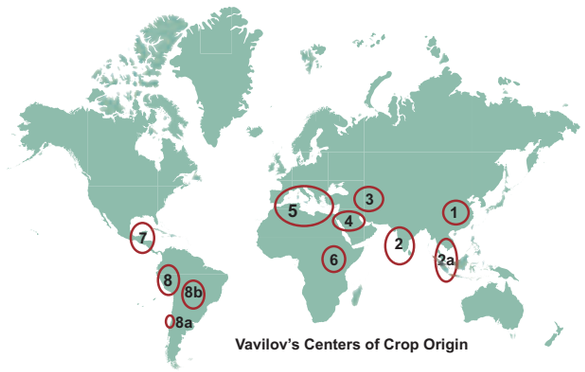

Figure 9.2: Vavilov's centres of crop origin and crops domesticated

Vavilov's Centre of Crop Origin		Crops domesticated
1	China	Foxtail millet, soybean, bamboo, onion, crucifers.
2	India	Rice, sugarcane, mango, orange, eggplant, sesame.
2 a	South East Asia	Rice, banana, coconut, clove , hemp.
3	Central East	Wheat, pea, hemp, cotton etc.
4	The Near East	Wheat, rye, many subtropical and tropical fruits.
5	Mediterranean	Olive, vegetables, oil yielding plants, wheats
6	Ethiopia (Abyssinian)	Wheat, barley, sesame, castor, coffee.
7	Mesoamerica (South Mexican & Central American Centre)	Maize, bean, sweet potato, papaya, guava, tobacco.
8	South America	Tomato, pine-apple
8 a	The Chiloe Centre	Potato
8 b	The Brazilian –Paraguayan Centre	Groundnut, cashew nut, pine apple, peppers, rubber.

9.5 Organic Agriculture

Organic farming is an alternative agricultural system which originated early in the twentieth century in reaction to rapidly changing farming practices. It is a production system that sustains the health of the soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects.

Indian Plant Breeders

a. **Dr. M. S. Swaminathan** – He is pioneer mutation breeder.

b. **Sir. T.S. Venkataraman** – An eminent sugarcane breeder.

c. **Dr. B.P. Pal** – Famous wheat breeder, developed superior disease resistant varieties of wheat.

d. **Dr. K. Ramiah** – Eminent rice breeder, developed several high yielding varieties of rice.

e. **N.G.P. Rao** – An eminent sorghum breeder, developed world's first hybrid of Sorghum (CSH-1).

f. **C.T. Patel** – Who developed world's first cotton hybrid.

g. **Choudhary Ram Dhan** – Wheat breeder, who is famous for C-591 variety of wheat, which is made Punjab as wheat granary of India.

9.5.1. Biofertilizers

Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. Biofertilizers could be also called as microbial cultures, bioinoculants, bacterial inoculants or bacterial fertilizers.

They are efficient in fixing nitrogen, solubilising phosphate and decomposing cellulose. They are designed to improve the soil fertility, plant growth, and also the number and biological activity of beneficial microorganisms in the soil. They are eco-friendly organic agro inputs and are more efficient and cost effective than chemical fertilizers.

S.N	Groups		Examples
A	**N_2 fixing Biofertilize**		
	1.	Free-living	*Azotobacter, Clostridium, Anabaena, Nostoc,*
		Symbiotic	*Rhizobium, Anabaena azollae*
	3.	Associative Symbiotic	*Azospirillum*
B	**P Solubilizing Biofertilizer**		
	1.	Bacteria	*Bacillus subtilis, Pseudomonas striata*
	2.	Fungi	*Penicillium, Aspergillus.*
C	**P Mobilizing Biofertilizers**		
	1.	Arbuscular Mycorrhiza	*Glomus, Scutellospora.*
	2.	Ectomycorrhiza	*Amanita.*
D	**Biofertilizer for Micro nutrients**		
	1.	Silicate and Zinc solubilizers	*Bacillus.*
E	**Plant Growth Promoting Rhizobacteria**		
	2.	Pseudomonas	*Pseudomonas fluorescence*

Figure 9.3: Classification of Biofertilizers

Rhizobium

Bio-fertilisers containing rhizobium bacteria are called rhizobium bio-fertilizer culture. Symbiotic bacteria that reside inside the root nodules convert the atmospheric nitrogen into a bio available form to the plants. This nitrogen fixing bacterium when applied to the soil undergoes multiplication in billions and fixes the atmospheric nitrogen in the soil. Rhizobium is best suited for the paddy fields which increase the yield by 15 – 40%.

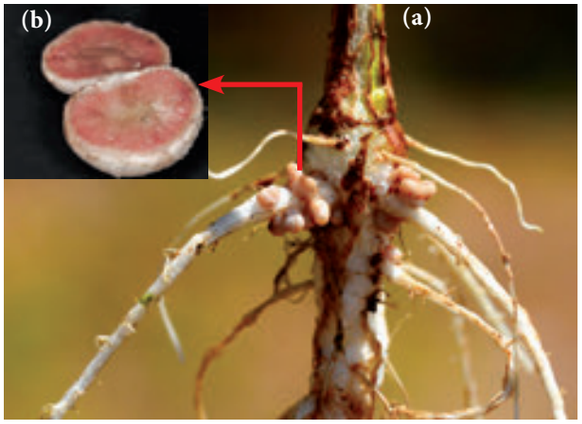

Figure 9.4 (a) : Root nodules occur on root
(b) C.S. of Root nodule

Azolla

Azolla is a free-floating water fern that fixes the atmospheric nitrogen in association with nitrogen fixing blue green alga *Anabaena azolla*. It is used as a bio-fertilizer for wetland rice cultivation and is known to contribute 40 – 60 kg/ha/crop. The agronomic potential of Azolla is quite significant particularly for increasing the yield of rice crop, as it quickly decompose in soil.

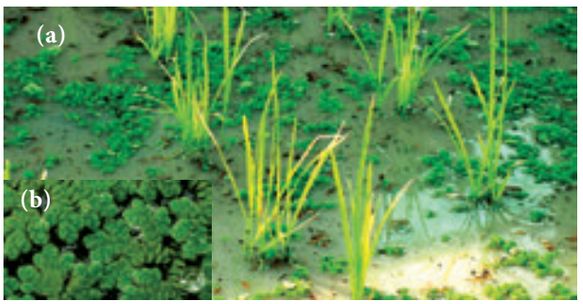

Figure 9.5: (a) *Azolla* in paddy field
(b) *Azolla*

Arbuscular mycorrhizae

Arbuscular mycorrhizae (AM) is formed by the symbiotic association between certain phycomycetous fungi and angiosperm roots. They have the ability to dissolve the phosphates found in abundance in the soil.

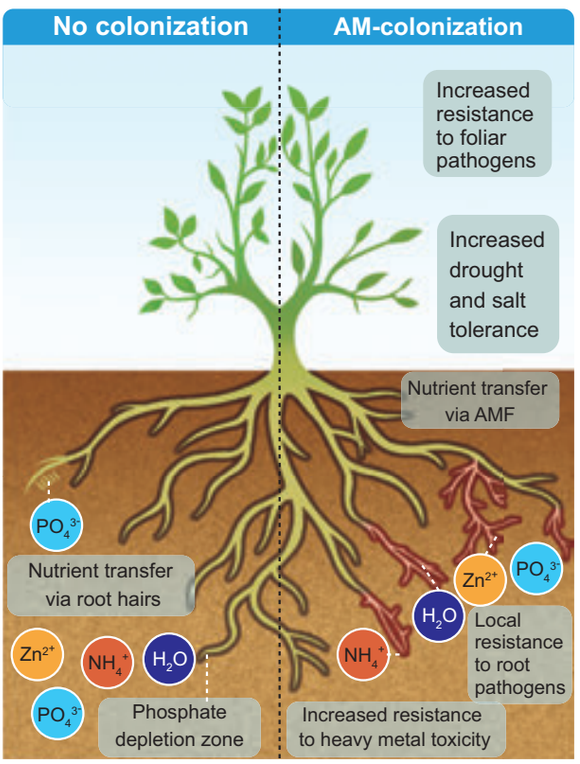

Figure 9.6 Benefits of AM colonisation

Apart from increasing the availability of phosphorus, AM provides necessary strength to resist disease, germs and unfavourable weather conditions. It also assures water availability.

Seaweed Liquid Fertilizer

Seaweed liquid fertilizer (SLF) contains cytokinin, gibberellins and auxin apart from macro and micro nutrients. Most seaweed based fertilizers are made from kelp (brown algae) which grows to length of 150 metres. Liquid seaweed fertilizer is not only organic but also eco-friendly. The alginates in the seaweed that reacts with metals in the soil and form long, cross-linked polymers in the soil. These polymers improve the crumbing in the soil, swell up when they get wet and retain moisture for a long time. They are especially useful in organic gardening which provides carbohydrates for plants. Seaweed has more than 70 minerals, vitamins and enzymes. It promotes vigorous growth. Improves resistance of plants to frost and disease. Seeds soaked in seaweed extract germinate much rapidly and develop a better root system.

Figure 9.7 : Seaweed – Kelp

Bio-Pesticides

Bio-pesticides are biologically based agents used for the control of plant pests. They are in high use due to their non-toxic, cheaper and eco-friendly characteristics as compared to chemical or synthetic pesticides. Bio-pesticides have become an integral component of pest management in terms of the environmental and health issues attributed to the use of chemicals in agriculture.

Trichoderma species are free-living fungi that are common in soil and root ecosystem. They have been recognized as bio-control agent for (1) the control of plant disease (2) ability to enhance root growth development (3) crop productivity (4) resistance to abiotic stress and (5) uptake and use of nutrients.

Figure 9.8:
(a) *Trichoderma* fungi

Figure 9.8:
(b) Biopesticide

Beauveria species is an entomo-pathogenic fungus that grows naturally in soils throughout the world. It acts as a parasite on various arthropod species causing white muscardine disease without affecting the plant health and growth. It also controls damping off of tomato caused by *Rhizoctonia solani*.

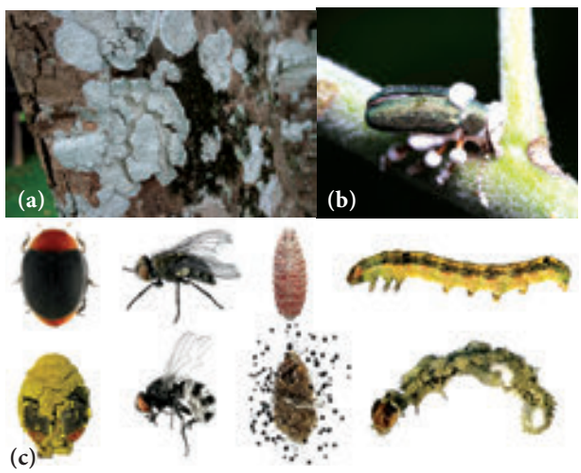

Figure 9.9 : (a) *Beauveria* Fungi
(b) *Beauveria* sps infected insect on green plant
(c)Entomopathogenic fungi on insets

Green Manuring

Green manuring is defined as the growing of green manure crops and use of these crops directly in the field by ploughing. One of the main objectives of the green manuring is to increase the content of nitrogen in the soil. Also it helps in improving the structure and physical properties of the soil. The most important green manure crops are *Crotalaria juncea, Tephrosia purpurea, Indigofera tinctoria*

The green manuring can be practised as Green in-situ manuring or Green leaf manuring. Green in-situ manuring refers to the growing of green manuring crops in the border rows or as intercrops along with the main crops. Example: Sun hemp, Cowpea, Green gram etc. whereas green leaf manuring is the application of green leaves and twigs of trees, shrubs, plants growing in wastelands and field bunds. The important plant species useful for green leaf manure are *Cassia fistula*, *Sesbania grandiflora, Azadirachta indica, Delonix regia, Pongamia pinnata* etc.,

9.6 Plant Breeding

Plant breeding is the science of improvement of crop varieties with higher yield, better quality, resistance to diseases and shorter durations which are suitable to particular environment. In other words, it is a purposeful manipulation of plant species in order to create desired genotype and phenotype for the benefit of humans. In early days, plant breeding activities were based mainly on skills and ability of person involved. But as the principles of genetics and cytogenetics have elucidated breeding methods such as selection, introduction, hybridization, ploidy, mutation, tissue culture and biotechnology techniques were designed to develop improved crop varieties.

9.6.1. Objectives of Plant Breeding

- To increase yield, vigour and fertility of the crop
- To increase tolerance to environmental condition, salinity, temperature and drought.
- To prevent the premature falling of buds, fruits etc.
- To improve synchronous maturity.
- To develop resistance to pathogens and pests.
- To develop photosensitive and thermos-sensitive varieties.

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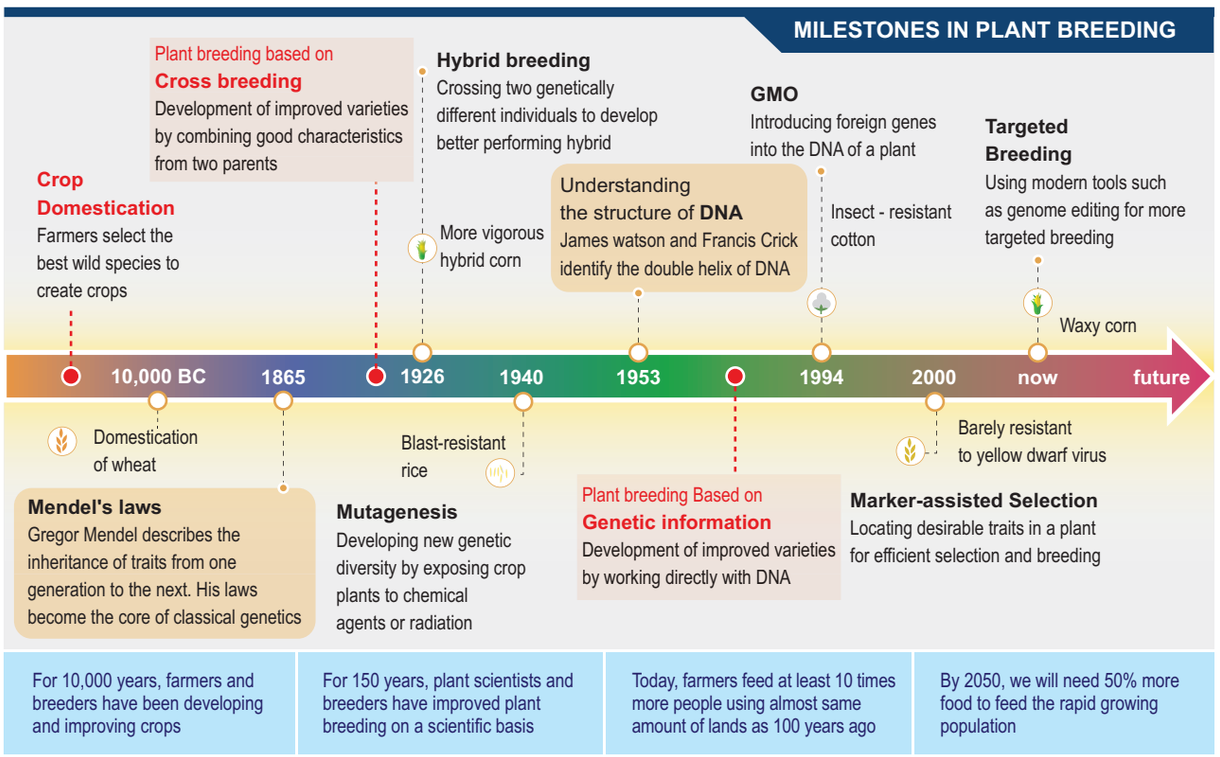


Figure 9.10 : Milestones in Plant Breeding

9.6.2. Steps in Plant Breeding

The main steps in plant breeding are given below

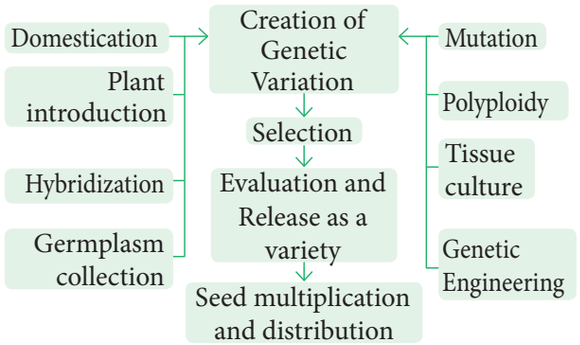


Figure 9.11 : Steps in Plant Breeding

9.7 Conventional Plant Breeding Methods

Conventional plant breeding methods resulting in hybrid varieties had a tremendous impact on agricultural productivity over the last decades. It develops new plant varieties by the process of selection and seeks to achieve expression of genetic material which is already present within the species. In this chapter we will discuss about some of the conventional methods of plant breeding.

9.7.1. Plant Introduction

Plant introduction may be defined as the introduction of genotypes from a place where it is normally grown to a new place or environment. Rice variety of IR8 introduced from Philippines and Wheat varieties of Sonora 63, Sonora 64 from Mexico.

The newly introduced plant has to adapt itself to the new environment. This adjustment or adaptation of the introduced plant in the changed environment is called **acclimatization.** All the introductions must be free from presence of weeds, insects and disease causing organisms. This has to be carefully examined by the process called **quarantine**, a strict isolation imposed to prevent the spread of disease.

Introduction may be classified as Primary introduction and Secondary introduction

(1) **Primary introduction** - When the introduced variety is well adapted to the new environment without any alternation to the original genotype.

(2) **Secondary introduction** - When the introduced variety is subjected to selection to isolate a superior variety and hybridized with a local variety to transfer one or a few characters to them. The botanical garden in different parts of the world also played a significant role in plant introduction. Example : Tea varieties collected from China and North East India initially grown in Botanical Garden of Kolkata from which appropriate clones have selected and introduced to different parts of India.

National Bureau of plant Genetic Resources (NBPGR) The Bureau is responsible for introduction and maintenance of germ plasm of various agricultural and horticultural station in our country. It is also responsible for maintenance of plant materials of botanical and medicinal interest. It is located at Rangpuri, New Delhi and has four regional plant quarantine stations at Amristsar, Kolkata, Mumbai and Chennai at Meenambakkam

9.7.2. Selection

Selection is the choice of certain individuals from a mixed population for a one or more desirable traits. Selection is the oldest and basic method of plant breeding. There are two main types of Selection.

i. **Natural Selection:** This is a rule in the nature and results in evolution reflected in the Darwinian principle "survival of the fittest". It takes longer time in bringing about desired variation.

ii. **Artificial Selection:** It is a human involved process in having better crop from a mixed population where the individuals differ in character. The following are the three main types of artificial selection.

a. **Mass Selection:** In mass selection a large number of plants of similar phenotype or morphological characters are selected and their seeds are mixed together to constitute a new variety. The population obtained

from the selected plants would be more uniform than the original population and are not individually tested. After repeated selection for about five to six years, selected seeds are multiplied and distributed to the farmers. The only disadvantage of mass selection is that it is difficult to distinguish the hereditary variation from environmental variation.

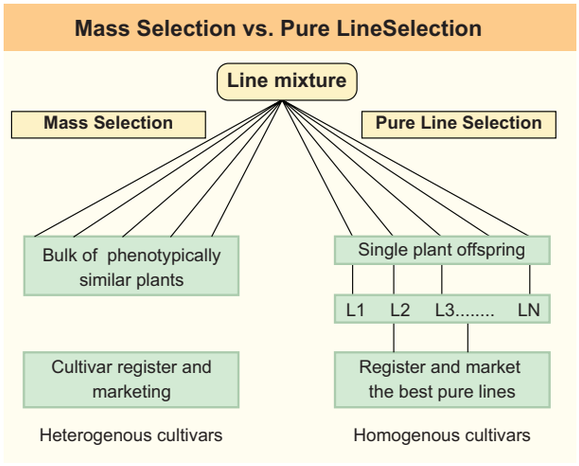


Figure 9.12 : Mass selection vs Pureline selection

b. Pureline selection: Johannsen in 1903 coined the word pureline. It is a collection of plants obtained as a result of repeated self-pollination from a single homozygous individual. Hence, a variety formed by this method shows more homozygosity with respect to all genes. The disadvantage of this type is that the new genotypes are never created and they are less adaptable and less stable to the environmental fluctuations.

c. Clonal Selection: In asexually propagated crop, progenies derived from a plant resemble in genetic constitution with the parent plant as they are mitotically divided. Based on their phenotypic appearance, clonal selection is employed to select improved variety from a mixed population (clones). The selected plants are multiplied through vegetative propagation to give rise to a clone. The genotype of a clone remains unchanged for a long period of time.

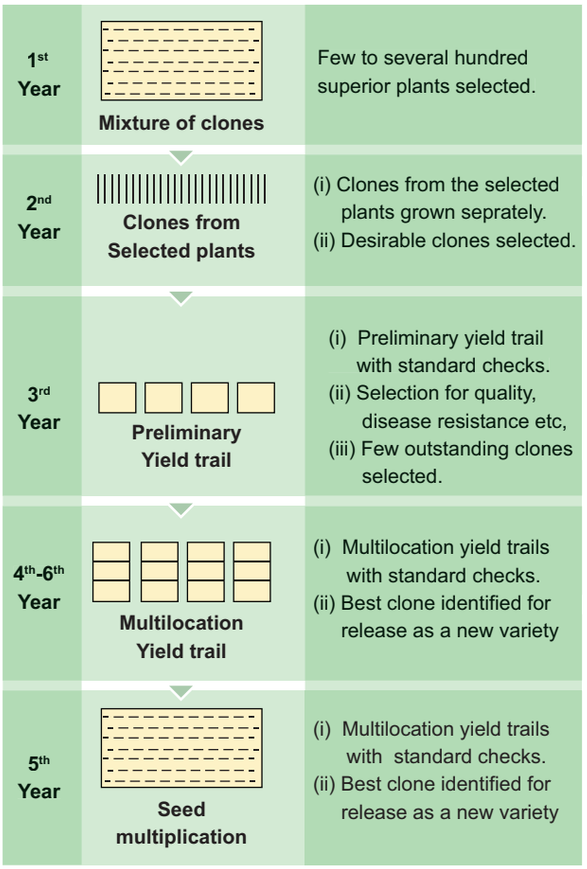


Figure 9.13 Clonal Selection

9.7.3. Hybridization

Hybridization is the method of producing new crop varieties in which two or more plants of unlike genetically constitution is crossed together that result in a progeny called hybrid. Hybridization offers improvement in crop and is the only effective means of combining together the desirable characters of two or more varieties or species. The first natural hybridization was observed by Cotton Mather in maize.

Steps in Hybridization

Steps involved in hybridization are as follows.

1. **Selection of Parents:** Male and female plants of the desired characters are selected. It should be tested for their homozygosity.
2. **Emasculation:** It is a process of removal of anthers to prevent self pollination before anthesis (period of opening of a flower)
3. **Bagging:** The stigma of the flower is protected against any undesirable pollen grains, by covering it with a bag .

Figure 9.14 a & b: Emasculation and Bagging (Wheat)

4. **Crossing:** Transfer of pollen grains from selected male flower to the stigma of the female emasculated flower.
5. **Harvesting seeds and raising plants**: The pollination leads to fertilization and finally seed formation takes place. The seeds are grown into new generation which are called hybrid.

Types of Hybridization

According to the relationship between plants, the hybridization is divided into.

i. **Intravarietal hybridization** - The cross between the plants of same variety. Such crosses are useful only in the self-pollinated crops.

ii. **Intervarietal hybridization** - The cross between the plants belonging to two different varieties of the same species and is also known as intraspecific hybridization. This technique has been the basis of improving self-pollinated as well as cross pollinated crops

iii. **Interspecific hybridization** - The cross between the plants belonging to different species belonging to the same genus is also called intragenic hybridization. It is commonly used for transferring the genes of disease, insect, pest and drought resistance from one species to another. **Example:** *Gossypium hirsutum* x *Gossypium arboreum* – Deviraj.

Figure 9.15 Flower -
(a) *G. hirsutum* (b) *G. arboreum*

iv. **Intergeneric hybridization** – The crosses are made between the plants belonging to two different genera. The disadvantages are hybrid sterility, time consuming and expensive procedure. **Example:** Raphanobrassica, Triticale. (Refer chapter 4 for detail illustration)

9.7.4. Heterosis

Heterosis (hetero- different; sis - condition) G.H. Shull was the first scientist to use the term heterosis in 1912. The superiority of the F1 hybrid in performance over its parents is called heterosis or hybrid vigour. Vigour refers to increase in growth, yield, greater adaptability of resistance to diseases, pest and drought. Vegetative propagation is the best suited measure for maintaining hybrid vigour, since the desired characters are not lost and can persist over a period of time. Many breeders believe that its magnitude of heterosis is directly related to the degree of genetic diversity between the two parents. Depending on the nature, origin, adaptability and reproducing ability heterosis can be classified as:

i. Euheterosis- This is the true heterosis which is inherited and is further classified as:

a. Mutational Euheterosis - Simplest type of euheterosis and results from the sheltering or eliminating of the deleterious, unfavourable often lethal, recessive, mutant genes by their adaptively superior dominant alleles in cross pollinated crops.

b. Balanced Euheterosis – Well balanced gene combinations which is more adaptive to environmental conditions and agricultural usefulness.

ii. Psuedoheterosis – Also termed as luxuriance. Progeny possess superiority over parents in vegetative growth but not in yield and adaptation, usually sterile or poorly fertile.

9.7.5. Mutation Breeding

Muller and Stadler (1927- 1928) coined the term mutation breeding. It represents a new method of conventional breeding procedures as they have the advantage of improving the defect without losing agronomic and quality character in agriculture and crop improvement. Mutation means the sudden heritable changes in the genotype or phenotype of an organism. Gene mutations are of considerable importance in plant breeding as they provide essential inputs for evolution as well as for re-combination and selection. It is the only method for improving seedless crops.

Radiation such as UV short wave, X-ray, Alpha (α), Beta (β), Gamma waves and many chemicals such as cesium, EMS (ethyl methane sulfonate), nitromethyl, urea induces mutation to develop new variety of crops. **Example:** Triple gene dwarf wheat with increase in yield and height. Atomita 2 - rice with saline tolerance and pest resistance.

Gamma Garden or Atomic Garden: Is a form of mutation breeding where plants are exposed to radioactive sources typically cobalt-60 or caesium-137 in order to generate desirable mutation in crop plants. The first Gamma garden in India is Bose Research Institute at Calcutta in 1959 and the second is IARI in 1960 which produced large variation in short type.

9.7.6. Polyploid Breeding

Majority of flowering plants are diploid (2n). The plants which possess more than two sets of chromosome are called polyploids. Polyploidy is a major force in the evolution of both wild and cultivated plants. Polyploidy often exhibit increased hybrid vigour increased heterozygosity, increase the tolerance to both biotic and abiotic stresses, buffering of deleterious mutations. In addition, polyploidy often results in reduced fertility due to meiotic error allowing the production of seedless varieties.

When chromosome number is doubled by itself in the same plant, is called autopolyploidy. Example: A triploid condition in sugarbeets, apples and pear has resulted in the increase in vigour and fruit size, large root size, large leaves, flower, more seeds and sugar content in them. It also resulted in seedless tomato, apple, watermelon and orange. Polyploidy can be induced by the use of colchicine to double the chromosome number. Allopolyploids are produced by multiplication of chromosome sets that are initially derived from two different species. Example: Triticale (Triticum durum x secale cereale) Raphanobrassica (Brassica oleraceae x Raphanus sativus).

9.7.7. Green Revolution

Green revolution the term was coined by William S.Gaud in (1968). It is defined as the cumulative result of a series of research, development, innovation and technology transfer initiatives. Agricultural production (especially wheat and rice) manifolds worldwide particularly in the developing countries between the 1940's and the late 1960's.

The Green revolution or third Agricultural Revolution is the intensive plan of 1960's to increase crop yield in developing countries by introducing the high yielding, resistant varieties, increased irrigation facilities, fertilizer application and better agricultural management. The scheme began in Mexico in 1940's and was successfully introduced in parts of India, Asia, Middle East and Latin America. Dr.B.P Pal the Director of IARI, requested M.S.Swaminathan to arrange for Dr.NE Borlaug visit to India and for obtaining a wide range of dwarf wheat possessing the Norin 10 dwarfing genes from Mexico.

In 1963 semi-dwarf wheat of Mexico was introduced from which India got five prolonged strategies for breeding a wide range of high varieties like Sonora 64, Sonalika and Kalyansona possessing a broad spectrum of resistance to major biotic and abiotic condition. Same as wheat M.S.Swaminathan produced the first semi-dwarf fertiliser responsive hybrid variety of rice_TNI (Taichung Native-1) in 1956 from Taiwan. The derivatives were introduced in 1966. Later better yielding semi dwarf varieties of rice Jaya and Ratna developed in India.

NORIN 10 – The cultivars found that Norin 10 dwarfing genes have high photosynthetic rate per unit leaf area and increase respiratory activity. Gonjiro Inazuka selected the semi-dwarf wheat variety that became Norin 10. He would have never thought that the semi dwarf genes would not only revolutionize the world of wheat but also helped to save more than one billion lives from hunger and starvation.

Plant Breeding for Developing Resistance to diseases

Some crop varieties bred by hybridization and selection, for disease resistance to fungi, bacteria and viral diseases are released (Table 9.1).

Crop	Variety	Resistance to diseases
Wheat	Himgiri	Leaf and Stripe rust, hill bunt
Brassica	Pusa swarnim (Kara rai)	White rust
Cauliflower	Pusa Shubhra, Pusa snowball K-1	Black rot and curl blight black rot
Cowpea	Pusa Komal	Bacterial blight
Chilli	Pusa Sadabahar	Chilly mosaic virus, Tobacco mosaic virus and Leaf curl.

Table 9.1: Disease resistance varieties

Norman E. Borlaug: The plant pathologist plant breeder devoted his life at the International Maize and Wheat improvement centre at Sonord in Mexico. He developed a new high yielding, rust resistant, non-lodging dwarf wheat varieties like Norin-10, Sonora-64, Lerma rojo-64, etc. which are now being cultivated in many countries. This formed the base for 'green revolution'. He was awarded a Nobel prize for Peace in 1970.

Dr. M. S. Swaminathan: He is pioneer mutation breeder. He has produced Sharbati Sonora, is the amber grain coloured variety of wheat by mutation, which is responsible for green revolution in India. Dr. Swaminathan is called "Father of green revolution in India".

Nel Jayaraman: Mr. Jayaraman, hails from Adirangam village in Tiruvarur district. He was a disciple of Dr.Nammalvar and state co-ordinator of 'Save our rice campaign, Tamil Nadu. He strived hard for conservation of traditional rice varieties. He had trained a team of farmers and regularly update them on the current issues that affect them.

In 2005, he organized a first ever traditional paddy seed festival in his farm as an individual. The seed festival in May 2016 at Adhirangam was 10th in a row and in which 156 different traditional varieties were distributed to more than 7000 farmers across Tamil Nadu. He was invited by the Philippines Government to give a talk at the International Rice Research Institute (IRRI) on his work and mission. In 2011, he received the State Award for best organic farmer for his contribution to organic farming, and in the year 2015, he received the National Award for best Genome Savior.

Biofortification – breeding crops with higher levels of vitamins and minerals or higher protein and healthier fats – is the most practical means to improve public health.

Breeding for improved nutritional quality is undertaken with the objectives of improving

- Protein content and quality
- Oil content and quality
- Vitamin content and
- Micronutrient and mineral content

In 2000, maize hybrids that had twice the amount of amino acids, lysine and tryptophan, compared to existing maize hybrids were developed. Wheat variety, Atlas 66 having a high protein content, has been used a donor for improving cultivated wheat. It has been possible to develop an iron fortified rice variety containing over five times as much iron as in commonly consumed varieties.

The Indian Agricultural Research Institute, New Delhi has also released several vegetable crops that are rich in vitamins and minerals, example: vitamin A enriched carrots, spinach, pumpkin; vitamin C enriched bitter gourd, bathua, mustard, tomato; iron and calcium enriched spinach and bathura; and protein enriched beans – broad, lablab, French and garden peas.

Sugar cane: *Saccharum bareri* was originally grown in North India, but had poor sugar content and yield. Tropical canes grown in South India *Saccharum officinarum* had thicker stems and higher sugar content but did not grow well in North India. These two species were successfully crossed to get sugar cane varieties combining the desirable qualities of high yield, thick stems, high sugar and ability to grow in the sugarcane areas of North India.

Resistance to yellow mosaic virus in bhindi (Abelmoschus escullentus) was transferred from a wild species and resulted in a new variety of A. Escullentus called Parbharni kranti.

Plant Breeding for Developing Resistance to Insect Pests

Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics. Hairy leaves in several plants are associated with resistance to insect pests. Example: resistance to jassids in cotton and cereal leaf beetle in wheat. In wheat, solid stems lead to non-preference by the stem sawfly and smooth leaves and nectar-less cotton varieties do not attract bollworms. High aspartic acid, low nitrogen and sugar content in maize leads to resistance to maize stem borers.

Crop	Variety	Insect pests
Brassica (rapeseed mustard)	Pusa Gaurav	Aphids
Flat been	Pusa Sem 2 Pusa Sem 3	Jassids, aphids and fruit borer
Okra (Bhindi)	Pusa Sawani Pusa A-4	Shoot and Fruit borer

Table 9.2 Pest resistance varieties

9.8 Modern Plant Breeding

In the milestones of plant breeding methods Genetic Engineering, Plant tissue culture, Protoplasmic fusion or somatic hybridisation, Molecular marking and DNA finger printing are some of the modern plant breeding tools used to improve the crop varieties. We have already discussed about the various techniques and application of the above mentioned concepts in Unit VIII.

New Plant Engineering Techniques / New Breeding Techniques (NBT)

NBT are a collection of methods that could increase and accelerate the development of new traits in plant breeding. These techniques

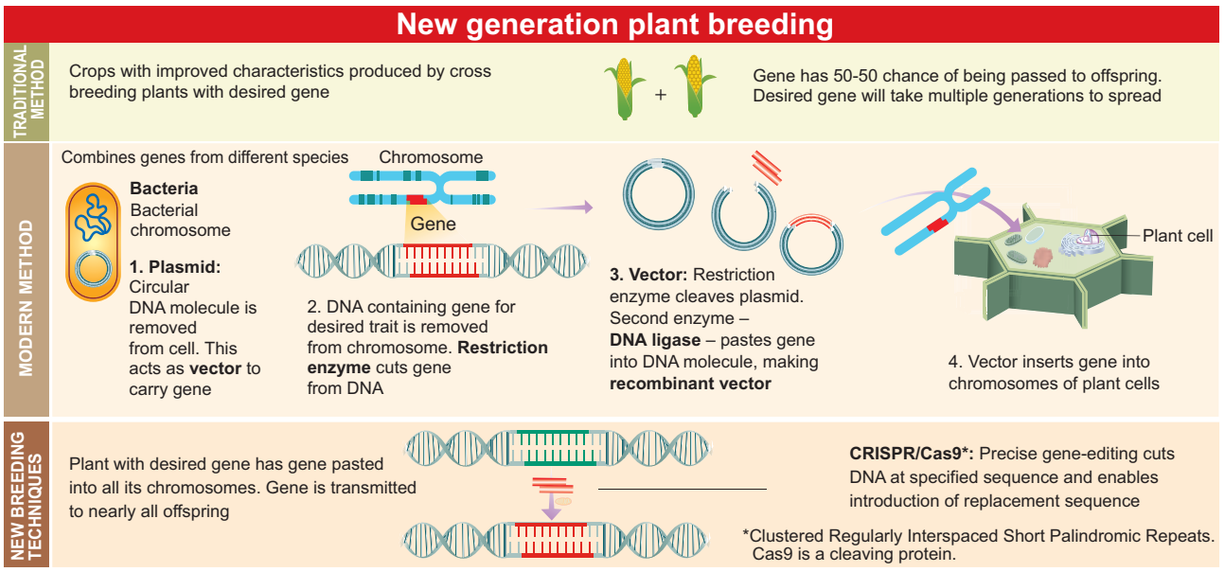


Figure 9.16 Sequential development of plant breeding techniques

often involve genome editing, to modify DNA at specific locations **within the plants** to produce new traits in crop plants. The various methods of achieving these changes in traits include the following.

- Cutting and modifying the genome during the repair process by tools like CRISPR /Cas.
- Genome editing to introduce changes in few base pairs using a technique called Oligonucleotide-directed mutagenesis (ODM).
- Transferring a gene from an identical or closely related species (cisgenesis)
- Organising processes that alter gene activity without altering the DNA itself (epigenetic methods).

Summary

Economic Botany deals with the relationship between people and economically important plants to fulfill the three basic needs of life such as food, clothing and shelter. Domestication, a term often used for a more intricate process, involves the genetic alteration of plants which did not appear at once, but rather over a substantial period of time, perhaps hundreds of years for some species. In the history of agriculture Vavilov has given the eight main centres of origin of plants were now divided into 12 centres of origin. In Organic agriculture biofertilizers are microbial inoculants which is ecofriendly, more effective even though cost effective than chemical fertilizers. Rhizobium, Azolla, VAM and sea weeds are used as fertilizers which increase the crop yield many fold.

Plant breeding is a purposeful manipulation of plant species in order to create desirable genotype and phenotype for the benefit of mankind. Plant introduction, selection, hybridization, heterosis, mutation breeding, polyploidy breeding and green revolution are the different methods of conventional breeding.

Evaluation

1. **Assertion:** Genetic variation provides the raw material for selection

   Reason: Genetic variations are differences in genotypes of the individuals.

   a) Assertion is right and reason is wrong.
   b) Assertion is wrong and reason is right.
   c) Both reason and assertion is right.
   d) Both reason and assertion is wrong.

2. While studying the history of domestication of various cultivated plants _____ were recognized earlier
   a) Centres of origin
   b) Centres of domestication
   c) Centres of hybrid
   d) Centres of variation

3. Pick out the odd pair.
   a) Mass selection - Morphological characters
   b) Purline selection - Repeated self pollination
   c) Clonal selection - Sexually propagated
   d) Natural selection - Involves nature

4. Match Column I with Column II

Column I	Column II
i) William S. Gaud	I) Heterosis
ii) Shull	II) Mutation breeding
iii) Cotton Mather	III) Green revolution
iv) Muller and Stadler	IV) Natural hybridization

   a) i – I, ii – II, iii – III, iv – IV
   b) i – III, ii – I, iii – IV, iv – II
   c) i – IV, ii – II, iii – I, iv – IV
   d) i – II, ii – IV, iii – III, iv – I

5. The quickest method of plant breeding is
   a) Introduction b) Selection
   c) Hybridization d) Mutation breeding

6. Desired improved variety of economically useful crops are raised by
   a) Natural Selection b) hybridization
   c) mutation d) biofertilisers

7. Plants having similar genotypes produced by plant breeding are called
   a) clone b) haploid
   c) autopolyploid d) genome

8. Importing better varieties and plants from outside and acclimatising them to local environment is called
   a) cloning b) heterosis
   c) selection d) introduction

9. Dwarfing gene of wheat is
   a) pal 1 b) Atomita 1
   c) Norin 10 d) pelita 2

10. Crosses between the plants of the same variety are called
    a) interspecific b) inter varietal
    c) intra varietal d) inter generic

11. Progeny obtained as a result of repeat self pollination a cross pollinated crop to called
    a) pure line b) pedigree line
    c) inbreed line d) heterosis

12. Jaya and Ratna are the semi dwarf varieties of
    a) wheat b) rice
    c) cowpea d) mustard

13. Which one of the following are the species that are crossed to give sugarcane varieties with high sugar, high yield, thick stems and ability to grow in the sugarcane belt of North India?
    a) *Saccharum robustum* and *Saccharum officinarum*
    b) *Saccharum barberi* and *Saccharum officinarum*
    c) *Saccharum sinense* and *Saccharum officinarum*
    d) *Saccharum barberi* and *Saccharum robustum*

14. Match column I (crop) with column II (Corresponding disease resistant variety) and select the correct option from the given codes.

Column I	Column II
I) Cowpea	i) Himgiri
II) Wheat	ii) Pusa komal
III) Chilli	iii) Pusa Sadabahar
IV) Brassica	iv) Pusa Swarnim

	I	II	III	IV
a)	iv	iii	ii	i
b)	ii	i	iii	iv
c)	ii	iv	i	iii
d)	i	iii	iv	ii

15. A wheat variety, Atlas 66 which has been used as a donor for improving cultivated wheat, which is rich in
    a) iron b) carbohydrates
    c) proteins d) vitamins

16. Which one of the following crop varieties correct matches with its resistance to a disease?

Variety	Resistance to disease
a) Pusa Komal	Bacterial blight
b) Pusa Sadabahar	White rust
c) Pusa Shubhra	Chilli mosaic virus
d) Brassica	Pusa swarnim

17. Which of the following is incorrectly paired?
    a) Wheat - Himgiri
    b) Milch breed - Sahiwal
    c) Rice - Ratna
    d) Pusa Komal - Brassica

18. Match list I with list II

List I	List II
Biofertilizer	**Organisms**
i) Free living N2	a) *Aspergillus*
ii) Symbiotic N2	b) *Amanita*
iii) P Solubilizing	c) *Anabaena azollae*
iv) P Mobilizing	d) *Azotobactor*

    a. ic, iia, iiib, ivd b. id, iic, iiia, ivb.
    c. ia, iic, iiib, ivd c. ib, iia, iiid, ivc.

19. Differentiate primary introduction from secondary introduction.
20. How are microbial innoculants used to increase the soil fertility?
21. What are the different types of hybridization?
22. Explain the best suited type followed by plant breeders at present?
23. Write a note on heterosis.
24. List out the new breeding techniques involved in developing new traits in plant breeding.

Glossary

Acclimatization : The adaptation of an individual to a changed climate or the adjustment of a species or a population to a changed environment over a number of generations.

Agronomy : Science of farming

Anthesis : Period of opening of flower.

Germplasm Collection : The entire collection (of plants / seeds) having all the diverse alleles for all genes in a given crop is called **germplasm collection.**

Non recurrent parent : The parent of a hybrid that is not again used as a parent in backcrossing

Quarantine : Strict isolation imposed to prevent the spread of disease

Strain : A group of similar individuals from a common origin.

ICT Corner

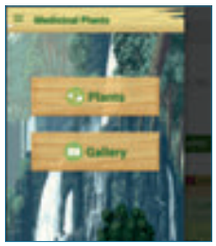
Plant Breeding

Let us know about the details of Medicinal Plants in detail.

B266_12_BOT_EM

Steps

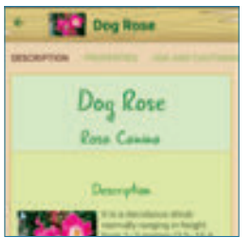
- Type the URL or scan the QR code to open the activity page then Introduction page will open.
- Click on 'Plants' it will display list of Medicinal Plants.
- Click on each plants individually on the next screen it displays the description, harvesting and properties of the plants.
- Click the option on the top left side of the front page to see the preparation of oils, Powder etc.,



Step 1

Step 2

Step 3



Step 4

* Pictures are indicative only

URL:
https://play.google.com/store/apps/details?id=com.dssoft.plantasmedicinales

Chapter

10

Unit X: Economic Botany

Economically Useful Plants and Entrepreneurial Botany

Learning Objectives

The learner will be able to

- Acquire knowledge about origin, area of cultivation and uses of various food yielding plants.
- Describe the different spices and condiments and their uses.
- Elicit the uses of fibre, timbers, paper and dye yielding plants.
- Acquire knowledge about the active principles, chemical composition and medicinal uses of plants.
- Gains knowledge of organic farming- bio fertilisers and bio pest repellants.

Chapter outline

SNIBY4

The land and water of the earth sustain a vast assemblage of plants upon which all other living forms are directly or indirectly dependent. Pre-historic humans lived on berries, tubers, herbage, and the wild game which they collected and hunted that occupied whole of their time. Domestication of plants and animals has led to the production of surplus food which formed the basis for civilizations. Early civilization in different parts of the world has domesticated different species of plants for various purposes. Based on their utility, the economically useful plants are classified into food plants, fodder plants, fibre plants, timber plants, medicinal plants, and plants used in paper industries, dyes and cosmetics. Selected examples of economically important plants for each category are discussed in this chapter.

10.1 Food plants

Currently about 10,000 food plants are being used of which only around 1,500 species were brought under cultivation. However, food base of majority of the population depends only on three grass species namely rice, wheat and maize.

10.1.1 Cereals

The word cereal is derived from Ceres, which according to the Roman mythology denotes "Goddess of agriculture". All cereals are members of grass family (Poaceae) that are grown for their edible starchy seeds. The prominence of cereals as food plants is due to the following attributes:

i. Greater adaptability and successful colonisation on every type of habitat.
ii. The relative ease of cultivation
iii. Tillering property that produce more branches which results in higher yield per unit area.
iv. Compact and dry grains that they can be easily handled, transported and stored without undergoing spoilage.
v. High caloric value that provides energy.

The nutrients provided by cereals include carbohydrates, proteins, fibres and a wide range of vitamins and minerals. Cereals can be classified into two different types based on their size namely Major Cereals and Minor Cereals.

Major Cereals

Rice / Paddy

Botanical name : *Oryza sativa*

Paddy is a semi-aquatic crop and is grown in standing water. It is an important food crop of the world, occupying the second position in terms of area under cultivation and production, next to wheat. Rice is the chief source of carbohydrate.

Origin and Area of cultivation

South East Asia is considered as the center of origin of rice. Earliest evidences of rice cultivation have been found in China, India and Thailand. It is mainly cultivated in Delta and irrigated regions of Tamil Nadu.

Uses

Rice is the easily digestible calorie rich cereal food which is used as a staple food in Southern and North East India. Various rice products such as **Flaked rice** (Aval), **Puffed rice / parched rice** (Pori) are used as breakfast cereal or as snack food in different parts of India.

Rice bran oil obtained from the rice bran is used in culinary and industrial purposes.

Husks are used as fuel, and in the manufacture of packing material and fertilizer.

Figure 10.1: Major Cereals

Wheat

Botanical name : *Triticum aestivum*

Origin and Area of cultivation

Earliest evidence for wheat cultivation comes from Fertile Crescent region. The common cultivated wheat, *Triticum aestivum* is cultivated for about 7,500 years. Wheat is mostly cultivated in the North Indian states such as Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh and Bihar.

Uses

Wheat is the staple food in Northern India. Wheat flour is suitable to make bread and other bakery products. Processed wheat flour, that has little fibre, is called Maida which is used extensively in making parota, naan and bakery products. Malted wheat is a major raw material for producing alcoholic beverages and nutritive drinks.

PSEUDO-CEREAL

The term pseudo-cereal is used to describe foods that are prepared and eaten as a whole grain, but are botanical outliers from grasses. Example: **quinoa**. It is actually a seed from the *Chenopodium quinoa* plant belongs to the family Amaranthaceae. It is a gluten-free, whole-grain carbohydrate, as well as a whole protein (meaning it contains all nine essential amino acids) and have been eaten for 6,000 years in Andes hill region.

Pseudo cereal - Chenopodium quinoa

Uses

Most of the corn produced is used as fodder than food. Corn syrup is used in the manufacture of infant foods. Corn is a raw material in the industrial production of alcohol and alcoholic beverages.

10.1.2 Millets (Siru Thaniyangal)

The term millet is applied to a variety of very small seeds originally cultivated by ancient people in Africa and Asia. They are gluten free and have less glycemic index.

Figure 10.2: Millets

Finger Millet – Ragi

Botanical name : *Eleusine coracana*

Finger millet is the crop of early introduction from East Africa into India. Ragi is rich in calcium.

Uses

It is used as a staple food in many southern hilly regions of India. Ragi grains are made into porridge and gruel. Ragi malt is the popular nutrient drink. It is used as a source of fermented beverages.

Sorghum

Botanical name : *Sorghum vulgare*

Sorghum is native to Africa. It is one of the major millets in the world and is rich in calcium and iron.

Uses

It is fed to poultry, birds, pigs and cattle and a source of fermented alcoholic beverage.

10.1.3 Minor Millets

Foxtail Millet

Botanical name : *Setaria italica*

This is one of the oldest millet used traditionally in India. Which is domesticated first in China about 6000 years. Rich in protein, carbohydrate, vitamin B and C, Potassium and Calcium.

Uses

It supports in strengthening of heart and improves eye sight. Thinai porridge is given to lactating mother.

Kodo Millet

Botanical name : *Paspalum scrobiculatum*

Kodo millet is originated from West Africa, which is rich in fibre, protein and minerals.

Uses

Kodo millet is ground into flour and used to make pudding. Good diuretic and cures constipation. Helps to reduce obesity, blood sugar and blood pressure.

10.1.4 Pulses

The word Pulse is derived from the Latin words 'puls' or 'pultis' meaning "thick soup". Pulses are the edible seeds that are harvested from the fruits of Fabaceae. They provide vital source of plant-based protein, vitamins and minerals for people around the globe.

Black gram

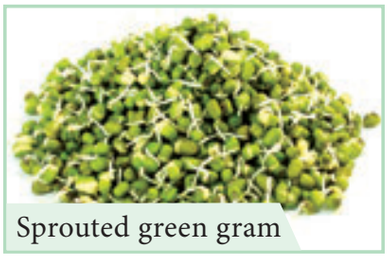
Botanical name : *Vigna mungo*

Origin and Area of cultivation

Black gram is native to India. Earliest archeobotanical evidences record the presence of black gram about 3,500 years ago. It is cultivated as a rain fed crop in drier parts of India. India contributes to 80% of the global production of black gram. Important states growing black gram in India are Uttar Pradesh, Chattisgarh and Karnataka.

Figure 10.3: Minor Millets


Black gram


Sprouted green gram


Red gram

Figure 10.4: Pulses

Uses

Black gram is eaten whole or split, boiled or roasted or ground into flour. Black gram batter is a major ingredients for the preparation of popular Southern Indian breakfast dishes. Split pulse is used in seasoning Indian curries.

Red gram / Pigeon pea

Botanical name : *Cajanus cajan*

Origin and Area of cultivation: It is the only pulse native to Southern India. It is mainly grown in the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujarat.

Uses

Red gram is a major ingredient of sambar, a characteristic dish of Southern India. Roasted seeds are consumed either salted or unsalted as a popular snack. Young pods are cooked and consumed.

Green gram

Botanical name : *Vigna radiata*

Origin and Area of cultivation

Green gram is a native of India and the earliest archaeological evidences are found in the state of Maharashtra. It is cultivated in the states of Madhya Pradesh, Karnataka and Tamil Nadu.

Uses

It can be used as roasted cooked and sprouted pulse. Green gram is one of the ingredients of pongal, a popular breakfast dish in Tamil Nadu. Fried dehulled and broken or whole green gram is used as popular snack. The flour is traditionally used as a cosmetic, especially for the skin.

10.1.5 Vegetables

While walking through a market filled with fresh vegetables like stacks of lady's finger, mountains of potatoes, pyramids of brinjal, tomatoes, cucurbits, we learn to choose the vegetables that is fresh, tender, ripe and those suit the family taste through experience and cultural practices. Why do we need to eat vegetables and what do they provide us?

Vegetables are the important part of healthy eating and provide many nutrients, including potassium, fiber, folic acid and vitamins A, E and C. The nutrients in vegetables are vital for maintenance of our health.

Lady's finger / Okra

Botanical name : *Abelmoschus esculentus*

Family: Malvaceae

Origin and Area of cultivation

Lady's finger is a native of the Tropical Africa. Assam, Maharashtra and Gujarat are the important states where Lady's finger is grown in abundance. Coimbatore, Dharmapuri and Vellore are the major cultivating regions of Tamil Nadu.

Uses

The fresh and green tender fruits are used as a vegetable. Often they are sliced and dehydrated to conserve them for later use. It has most important nutrients.

10.1.6 Fruits

Edible fruits are fleshy structures with a pleasant aroma and flavours. Fruits are sources of many nutrients including potassium, dietary fiber, folic acid and vitamins.Depending on the climatic region in which fruit crops grow, they

can be classified into temperate(apple, pear, plum) and tropical fruits (mango, jack, banana). In this chapter we will study an example of tropical fruit.

Mango (National fruit of India)

Botanical name : *Mangifera indica*
Family: Anacardiaceae

Figure 10.5: Mango

Origin and Area of cultivation

The mango is the native to Southern Asia, especially Burma and Eastern India. It is the National fruit of India. Major mango producing States are Andhra Pradesh, Bihar, Gujarat and Karnataka. Salem, Krishnagiri, Dharmapuri are the major mango producing districts of Tamil Nadu. Some of the major cultivars of mango in India are Alphonsa, Banganapalli, neelam and malgova.

Uses

Mango is the major table fruit of India, which is rich in beta carotenes. It is utilized in many ways, as dessert, canned, dried and preserves in Indian cuisine. Sour, unripe mangoes are used in chutneys, pickles, side dishes, or may be eaten raw with salt and chili. Mango pulp is made into jelly. Aerated and non-aerated fruit juice is a popular soft drink.

10.1.7 Nuts

Nuts are simple dry fruits composed of a hard shell and an edible kernel. They are packed with a good source of healthy fats, fibre, protein, vitamins, minerals and antioxidants.

Cashew nut

Botanical name : *Anacardium occidentale*
Family: Anacardiaceae

Origin and Area of cultivation

Cashew has originated in Brazil and made its way to India in the 16th century through Portuguese sailors. Cashew is grown in Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, and Orissa.

Uses

Figure 10.6: Nuts

Cashews are commonly used for garnishing sweets or curries, or ground into a paste that forms a base of sauces for curries or some sweets. Roasted and raw kernels are used as snacks.

10.1.8 Sugars

We experienced sweetness while eating the stems of sugarcane, roots of sugar beet, fruits of apple and while drinking palmyra sap. This is due to the different proportions of sugars found in it. Sugar is the generic name for sweet tasting soluble carbohydrate, which are used in foods and beverages. Sugars found in sugarcane and palmyra make them ideal for efficient extraction to make commercial sugar.

Sugarcane

Botanical name : *Saccharum officinarum*
Family : Poaceae

Origin and Area of cultivation

The cultivated *Saccharum officinarum* has evolved by repeated back crossing of *S.officinarum* of New Guinea with wild *S.spontaneum* of India to improve the quality. All districts except Kanyakumari and Nilgiris of Tamil Nadu cultivate Sugarcane.

Uses

Sugar cane is the raw material for extracting white sugar. Sugarcane supports large number of industries like sugar mills producing refined sugars, distilleries producing liquor grade

Figure 10.7: Sugars

ethanol and millions of jaggery manufacturing units. Fresh sugarcane juice is a refreshing drink. Molasses is the raw material for the production of ethyl alcohol.

Palmyra (State tree of Tamil Nadu)

Botanical name : *Borassus flabellifer*

Family: Arecaceae

Origin and Area of cultivation

Palmyra is native to tropical regions of Africa, Asia and New Guinea. Palmyra grows all over Tamil Nadu, especially in coastal districts.

Uses

Exudate from inflorescence axis is collected for preparing palm sugar. Inflorescence is tapped for its sap which is used as health drink. Sap is processed to get palm jaggery or fermented to give **toddy**.

Endosperm is used as a refreshing summer food. Germinated seeds have an elongated embryo surrounded by fleshy scale leaf which is edible.

10.1.9 Oil Seeds

Why fried foods are tastier than boiled foods?

There are two kinds of oils namely, essential oils and vegetable oils or fatty oils. The essential oils or volatile oils which possess aroma evaporate or volatilize in contact with air. Any organ of a plant may be the source of essential oil. For example, flowers of Jasmine, fruits of orange and roots of ginger. The vegetable oils or non-volatile oils or fixed oils that do not evaporate. Whole seeds or endosperm form the sources of vegetable oils.

Let us know about few oil seeds

Groundnut / Peanut

Botanical name : *Arachis hypogaea*

Family : Fabaceae

Origin and Area of Cultivation: Groundnut is native of Brazil. Portuguese introduced groundnut into Africa. The Spanish took it to the South East Asia and India via Philippines. In India Gujarat, Andhra Pradesh and Rajasthan are top producers.

T426ZF

Uses

Nuts contain about 45% oil. The kernels are also rich sources of phosphorous and vitamins, particularly thiamine, riboflavin and niacin. It is premium cooking oil because it does not smoke. Lower grade oil is used in manufacture of soaps and lubricants.

Sesame / Gingelly

Botanical name : *Sesamum indicum*

Family : Pedaliaceae

Origin and Area of cultivation: *Sesamum indicum* has originated from Africa.. Sesame is cultivated as a dry land crop. West Bengal and Madhya Pradesh are the top producers in India during 2017-18. It is considered as a healthy oil in Southern Indian culture.

Uses

Sesame oil is used for mostly culinary purposes in India. Lower grades are used in manufacture of soaps, in paint industries, as a lubricant and as an illuminant. In India, the oil is the basis of most of the scented oils used in perfumes. Sesame seed snacks are popular throughout India.


Groundnut


Sesame

Figure 10.8: Oil Seeds

10.1.10 Beverages

How about a cup of coffee or tea? We always entertain our guests with this offer.

All non-alcoholic beverages contain alkaloids that stimulate central nervous system and also possess mild diuretic properties.

Coffee

Botanical name : *Coffea arabica*

Family : Rubiaceae

Why does a student or a driver prefer tea or coffee during night work?

Figure 10.9: Beverages

Origin and Area of cultivation: *Coffea arabica* is the prime source of commercial coffee which is native to the tropical Ethiopia An Indian Muslim saint, Baba Budan introduced coffee from Yemen to Mysore.Karnataka is the largest coffee producing state in India followed by Tamil Nadu and Kerala. Tamil Nadu is the largest consumer of coffee in India.

Uses

Drinking coffee in moderation provides the following health benefits:

Caffeine enhances release of acetylcholine in brain, which in turn enhances efficiency. It can lower the incidence of fatty liver diseases, cirrhosis and cancer. It may reduce the risk of type 2 diabetes.

10.2 Spices and Condiments

"Aroma attracts everyone"

History:

Spices were used extensively throughout the world for several thousands of years. Records of use of garlic and onion dates back 2500 years.

Majority of the spices are native to Mediterranean region, India and South East Asian countries. Spices, especially pepper triggered the search for sea route to India and paved way for the exploratory voyages by Spanish and Portuguese.

Spices are accessory foods mainly used for flavouring during food preparation to improve their palatability. Spices are aromatic plant products and are characterized by sweet or bitter taste. Spices are added in minimal quantities during the cooking process. For example black pepper.

Condiments, on the other hand, are flavouring substances having a sharp taste and are usually added to food after cooking. For example, curry leaves.

The following spices and condiment are discussed in detail.

Spices

Cardamom

Botanical name : *Elettaria cardamomum*

Family : Zingiberaceae

Origin and Area of cultivation: It is indigenous to Southern India and Sri Lanka. Cardamom is called as "Queen of Spices". In India it is one of the main cash crops cultivated in the Western Ghats, and North Eastern India

Uses

The seeds have a pleasing aroma and a characteristic warm, slightly pungent taste. It is used for flavouring confectionaries, bakery products and beverages. The seeds are used in the preparation of curry powder, pickles and cakes. Medicinally, it is employed as a stimulant and carminative. It is also chewed as a mouth freshener.

Black Pepper

Botanical name : *Piper nigrum*

Family : Piperaceae

Figure 10.10: Spices

Origin and Area of cultivation: It is indigenous to Western Ghats of India. Pepper is one of the most important Indian spices referred to as the "King of Spices" and also termed as "Black Gold of India". Kerala, Karnataka and Tamil Nadu are the top producers in India.

The characteristic pungency of the pepper is due to the presence of alkaloid Piperine. There are two types of pepper available in the market namely black and white pepper.

Uses

It is used for flavouring in the preparation of sauces, soups, curry powder and pickles. It is used in medicine as an aromatic stimulant for enhancing salivary and gastric secretions and also as a stomachic. Pepper also enhances the bio-absorption of medicines.

Turmeric

Botanical name : *Curcuma longa*

Family : Zingiberaceae

Origin and Area of cultivation: It is indigenous to Southern Asia India is the largest producer, consumer and exporter of turmeric. Erode in Tamil Nadu is the World's largest wholesale turmeric market.

Uses

Turmeric is one of the most important and ancient Indian spices and used traditionally over thousands of years for culinary, cosmetic, dyeing and for medicinal purposes. It is an important constituent of curry powders. Turmeric is used as a colouring agent in pharmacy, confectionery and food industry. Rice coloured with turmeric (yellow) is considered sacred and auspicious which is used in ceremonies. It is also used for dyeing leather, fibre, paper and toys.

Curcumin extracted from turmeric is responsible for the yellow colour. Curcumin is a very good anti-oxidant which may help fight various kinds of cancer. It has anti-inflammatory, anti-diabetic, anti-bacterial, anti-fungal and anti-viral activities. It stops platelets from clotting in arteries, which leads to heart attack.

Chillies / Red Pepper

Botanical name : *Capsicum annuum, C. frutescens*.

Family : Solanaceae

Origin and Area of cultivation: Capsicum is native to South America and is popularly known as chillies or red pepper in English. India is leading producer and exporter. *C. annuum* and *C. frutescens* are important cultivated species of chillies.

Uses

The fruits of *C.annuum* are less pungent than the fruits of *C.frutescens*. *C.annum* includes large, sweet bell peppers. Long fruit cultivars of this species are commercially known as 'Cayenne pepper' which are crushed, powdered and used as condiment. Chillies are used in manufacture of sauces, curry powders and preparation of pickles. Capsaicin is an active component of chillies. It has pain relieving properties and used in pain relieving balms. Chillies are a good source of Vitamin C, A and E.

Capsaicin is responsible for the pungency or spicy taste of chillies. Pungency of Chillies is measured in Scoville Heat Units (SHU). World's hottest chilli, Carolina reaper pepper measures 2,200,000 SHU. Naga viper chilli is the hottest in India that measures 1,349,000 SHU. Commonly used cayenne pepper measures 30,000 to 50,000 SHU.

Condiment

Tamarind

Botanical name: *Tamarindus indica*

Family : Fabaceae-Caesalpinioideae

Figure 10.11 : Tamarind

Origin and Area of cultivation: Tamarind is native of tropical African region and was

introduced into India several thousand years before. It is cultivated in India, Myanmar, south asian countries and several African and Central American countries. Tamarind has long been used in Africa and in Southern Asia. The name tamarindus is of Arabian origin, which means "dates of India". (tamar – dates; Indus – India).

Uses

It is used in flavouring sauces in the United States and Mexico. In India, the fruit pulp is major ingredients for many culinary preparations. Sweet tamarinds are sold as table fruits in India imported from Thailand and Malaysia.

10.3 Fibres

Botanically a fiber is a long narrow and thick-walled cell.

Cotton

Botanical name : *Gossypium* spp.

Family : Malvaceae

Cotton is the world's most important non-food commercial crop.

Origin and Area of cultivation: It is one of the oldest cultivated crops of the world. It has been cultivated for about 8000 years both in new world and in old world. Commercial cotton comes from four cotton species: two from the new world and two from the old world. (1) *G. hirsutum* (2) *G.barbadense* are the New world species and (3) *G. arboretum* (4) *G. herbaceum* are the old world species. In India cotton is cultivated in Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu.

Uses

It is mainly used in the manufacturing of various textile, hosiery products, toys and is also used in hospitals.

Jute

Botanical name : *Corchorus* spp.

Family : Malvaceae

Origin and Area of cultivation: Jute is derived from the two cultivated species (1) *Corchorus capsularis* and (2) *C.olitorius* is of African origin whereas *C. capsularis,* is believed to be Indo-Burmese origin. It is an important cultivated commercial crop in Gangetic plains of India and Bangladesh.

Uses

It is one of the largest exported fibre material of India. The jute industry occupies an important place in the national economy of India. Jute is used for 'safe' packaging in view of being natural, renewable, bio-degradable and eco-friendly product. It is used in bagging and wrapping textile. About 75% of the jute produced is used for manufacturing sacks and bags. It is also used in manufacture of blankets, rags, curtains etc. It is also being used as a textile fibre in recent years.


Cotton plant


Jute products

Figure 10.12: Fibres

10.4 Timber

The basic need of shelter is obtained from the timber trees.

Teak

Botanical name : *Tectona grandis*

Family: Lamiaceae

Origin and Area of cultivation: This is native to South east Asia. It is observed wild in Assam. But cultivated in Bengal, Assam, Kerala, Tamil Nadu and North-West India.


Teak wood carving

Figure 10.13: Timber

Uses

It is one of best timbers of the world.

The heartwood is golden yellow to golden brown when freshly sawn, turning darker when exposed to light. Known for its durability as it is immune to the attack of termites and fungi.

The wood does not split or crack and is a carpenter friendly wood. It was the chief railway carriage and wagon wood in India. Ship building and bridge-building depends on teakwood. It is also used in making boats, toys, plywood, door frames and doors.

10.5 Latex

Rubber

Botanical name : *Hevea brasiliensis*

Family : Euphorbiaceae

Figure 10.14: Rubber Tree

Origin and Area of cultivation: It is a native of Brazil and was introduced outside its native range during the colonial period and has become an important cash crop. Asia contributed 90% of the world production. Kerala is the largest producer in India followed by Tamil Nadu.

Uses

Tyre and other automobile parts manufacturing industries consume 70% of the rubber production. Rubber is used in manufacturing footwear, wire and cable insulations, rain-coats, household and hospital goods, shock absorbers, belts, sports goods, erasers, adhesives, and rubber-bands Hard rubber is used in the electrical and radio engineering industries Concentrated latex is used for making gloves, balloons and condoms. Foamed latex is used in the manufacture of cushions, pillows and life-belts.

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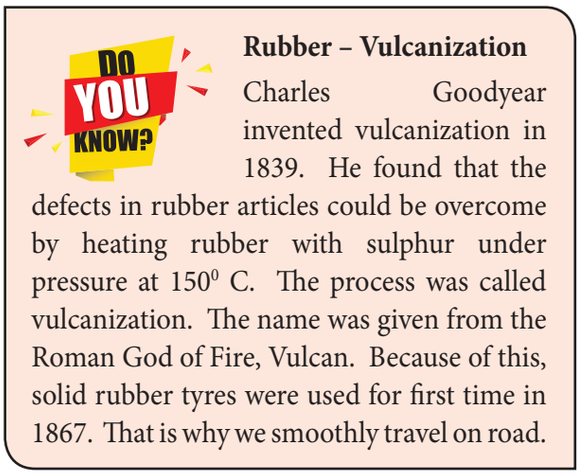


Rubber – Vulcanization

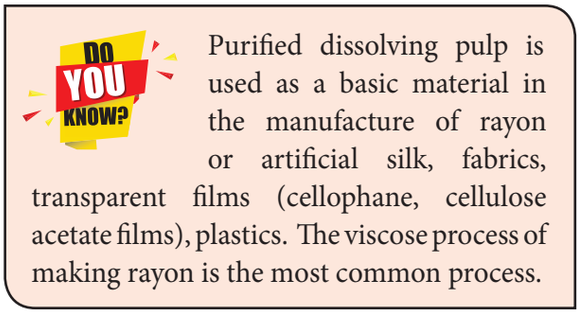
Charles Goodyear invented vulcanization in 1839. He found that the defects in rubber articles could be overcome by heating rubber with sulphur under pressure at 150^0 C. The process was called vulcanization. The name was given from the Roman God of Fire, Vulcan. Because of this, solid rubber tyres were used for first time in 1867. That is why we smoothly travel on road.

10.6 Pulp Wood

Figure 10.15 : Wood pulp

The term paper is derived from the word 'papyrus' a plant (*Cyperus papyrus*) that was used by Egyptians to make paper-like materials. Paper production is a Chinese invention. The Chinese discovered the paper that was prepared from the inner bark of paper mulberry in 105 A.D. For a long time, the art of paper making remained a monopoly of the Chinese until Arabs learned the technique and improved it around 750 A.D. Invention of printing increased the demand for paper.

Manufacture of Wood pulp: Wood is converted into pulp by mechanical, and chemical processes. Wood of Melia azadirachta, *Neolamarkia chinensis*, *Casuarina* spp, *Eucalyptus* spp are used for making paper pulp.



Purified dissolving pulp is used as a basic material in the manufacture of rayon or artificial silk, fabrics, transparent films (cellophane, cellulose acetate films), plastics. The viscose process of making rayon is the most common process.

10.7 Dyes

The ability to perceive colour is a wonderful aspect of human eyes and dyes add colour to the goods we use. They have been in use since the ancient times.

The earliest authentic records of dyeing were found in the tomb painting of ancient Egypt. Colourings on mummy cements (wrapping) included saffron and indigo. They can also be seen in rock paintings in India.

Henna

Botanical name : *Lawsonia inermis*

Family : Lythraceae

Origin and Area of cultivation: It is indigenous to North Africa and South-west Asia. It is grown mostly throughout India, especially in Gujarat, Madya Pradesh and Rajasthan.

Uses

An orange dye 'Henna' is obtained from the leaves and young shoots of *Lawsonia inermis.* The principal colouring matter of leaves 'lacosone" is harmless and causes no irritation to the skin. This dye has long been used to dye skin, hair and finger nails. It is used for colouring leather, for the tails of horses and in hair-dyes.

Figure 10.16: Naturals Dyes

10.8 Cosmetics

Traditionally in Southern India, people have been using turmeric, green gram powder, henna, sigaikai and usilai for their skin and hair care. These were mostly home prepared products that are used for grooming. Today, cosmetics have a high commercial value and have become chemical based industrial products. Providing personal care services has become a major industry. In recent years, people have realized the hazards of chemical-based cosmetics and are turning back to natural products. In this chapter one of the major plants namely Aloe which is used in the cosmetic industries is discussed.

Aloe

Botanical name : *Aloe vera*

Family: Asphodelaceae (formerly Liliaceae)

Origin and Area of cultivation: It is a native of Sudan. It is cultivated on a large scale in Rajasthan, Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu.

Figure 10.17: *Aloe vera*

Uses

'Aloin' (a mixture of glucosides) and its gel are used as skin tonic. It has a cooling effect and moisturizing characteristics and hence used in preparation of creams, lotions, shampoos, shaving creams, after shave lotions and allied products. It is used in gerontological applications for rejuvenation of aging skin. Products prepared from aloe leaves have multiple properties such as emollient, antibacterial, antioxidant, antifungal and antiseptic. Aloe vera gel is used in skin care cosmetics.

10.8.1 Perfumes

The word **perfume** is derived from the Latin word **Per** (through) and **fumus** (to smoke), meaning **through smoke**. It refers to the age-old tradition of burning scented woods at religious ceremonies.In early days, when people were less conscious of personal hygiene, essential oils not only masked offensive odours, but also may have acted as antiseptics. Perfumes are added to baths and used for anointing the body.

Perfumes are manufactured from essential oil which are **volatile** and **aromatic**. Essential oils are found at different parts of the plant such as leaves, (curry leaf, mint), flowers (rose, jasmine), fruits (citrus, straw berry) and wood (sandal, eucalyptus).

Madurai Malli

'Madurai Malli' is the pride of Madurai has a distinct reputation universally because of its uniqueness and has been given the Geographical Indications (GI) mark by the Geographical indication Registry of India. Madurai malli has thick petals with long stalk equal to that of petals and the distinct fragrance is due to the presence of chemicals such as jasmine and alpha terpineol. This makes it easy to distinguish Madurai Malli from other places. This is the second GI tag for Jasmine after 'Mysore Malli'.

Jasmine

Botanical name : *Jasminum grandiflorum*

Family: Oleaceae

Figure 10.18: Jasmine

Jasmine, as a floral perfume, ranks next to the rose oil. Major species cultivated on the commercial scale is Jasminum grandiflorum, a native of the north-western Himalayas. In Tamil Nadu, the major jasmine cultivation centres are Madurai and Thovalai of Kanyakumari District. The essential oil is present in the epidermal cells of the inner and outer surfaces of both the sepals and petals. One ton of Jasmine blossom yields about 2.5 to 3 kg of essential oil, comprising 0.25 to 3% of the weight of the fresh flower.

Uses

Jasmine flowers have been used since ancient times in India for worship, ceremonial purposes, incense and fumigants, as well as for making perfumed hair oils, cosmetics and soaps. Jasmine oil is an essential oil that is valued for its soothing, relaxing, antidepressant qualities.

Jasmine blends well with other perfumes. It is much used in modern perfumery and cosmetics and has become popular in air freshners, anti-perspirants, talcum powders, shampoos and deodorants.

10.9 Traditional Systems of Medicines

India has a rich medicinal heritage. A number of Traditional Systems of Medicine (TSM) are practiced in India some of which come from outside India. TSM in India can be broadly classified into **institutionalized** or documented and **non-institutionalized** or oral traditions. Institutionalized Indian systems include Siddha and Ayurveda which are practiced for about two thousand years. These systems have prescribed texts in which the symptoms, disease diagnosis, drugs to cure, preparation of drugs, dosage and diet regimes, daily and seasonal regimens. Non- institutional systems, whereas, do not have such records and or practiced by rural and tribal peoples across India. The knowledge is mostly held in oral form. The TSM focus on healthy lifestyle and healthy diet for maintaining good health and disease reversal.

Siddha system of medicine

Siddha is the most popular, widely practiced and culturally accepted system in Tamil Nadu. It is based on the texts written by 18 Siddhars. There are different opinions on the constitution of 18 Siddhars. The Siddhars are not only from Tamil Nadu, but have also come from other countries. The entire knowledge is documented in the form of poems in Tamil. Siddha is principally based on the **Pancabūta** philosophy. According to this system three humors namely **Vātam, Pittam** and **Kapam** that are responsible for the health of human beings and any disturbance in the equilibrium of these humors result in ill health. The drug sources of Siddha include plants, animal parts, marine products and minerals. This system

specializes in using minerals for preparing drugs with the long shelf-life. This system uses about 800 herbs as source of drugs. Great stress is laid on disease prevention, health promotion, rejuvenation and cure.

Ayurveda system of medicine

Ayurveda supposed to have originated from Brahma. The core knowledge is documented by **Charaka, Sushruta** and **Vagbhata** in compendiums written by them. This system is also based on three humor principles namely, Vatha, Pitha and Kapha which would exist in equilibrium for a healthy living. This system Uses more of herbs and few animal parts as drug sources. Plant sources include a good proportion of Himalayan plants. The **Ayurvedic Pharmacopoeia** of India lists about 500 plants used as source of drugs.

Folk system of medicine

Folk systems survive as an oral tradition among innumerable rural and tribal communities of India. A consolidated study to document the plants used by ethnic communities was launched by the Ministry of Environment and Forests, Government of India in the form of All India Coordinated Research Project on Ethnobiology. As a result about 8000 plant species have been documented which are used for medicinal purposes. The efforts to document in several under-explored and unexplored pockets of India still continue. Major tribal communities in Tamil Nadu who are known for their medicinal knowledge include **Irulas, Malayalis, Kurumbas, Paliyans** and **Kaanis**. Some of the important medicinal plants are discussed below.

10.10 Medicinal Plants

India is a treasure house of medicinal plants. They are linked to local heritage as well as to global-trade. All institutional systems in India primarily use medicinal plants as drug sources. At present, 90% collection of medicinal plants is from the non-cultivated sources. Growing demand for herbal products has led to quantum jump in volume of plant materials traded within and across the countries. Increasing demand exerts a heavy strain on the existing resources. Now efforts are being made to introduce cultivation techniques of medicinal plants to the farmers.

Medicinal plants play a significant role in providing primary health care services to rural and tribal people. They serve as therapeutic agents as well as important raw materials for the manufacture of traditional and modern medicines. Medicinally useful molecules obtained from plants that are marketed as drugs are called Biomedicines. Medicinal plants which are marketed as powders or in other modified forms are known as Botanical medicines.

Keezhanelli

Botanical name : *Phyllanthus amarus*

Family : Euphorbiaceae (Now in Phyllanthaceae)

Origin and Area of cultivation: The plant is a native of Tropical American region and is naturalised in India and other tropical countries. It is not cultivated and is collected from moist places in plains. *Phyllanthus maderspatensis* is also commonly sold in the medicinal plant markets collected from non-forest are as keezhanelli.

Active principle: Phyllanthin is the major chemical component.

Medicinal importance

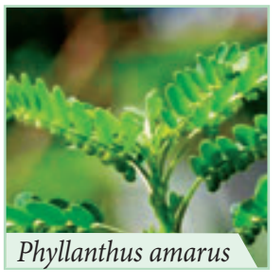
Phyllanthus is a well-known hepato-protective plant generally used in Tamil Nadu for the treatment of Jaundice. Research carried out by Dr. S P Thyagarajan and his team from University of Madras has scientifically proved that the extract of *P. amarus* is effective against hepatitis B virus.

Nilavembu

Botanical name : *Andrographis paniculata*

Family : Acanthaceae

Andrographis paniculata, known as the


Phyllanthus amarus

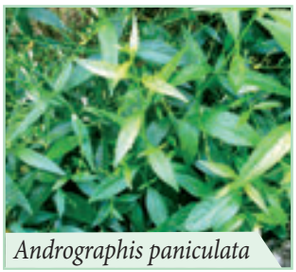

Andrographis paniculata

Figure 10.19: Medicinal Plants

King of Bitters is traditionally used in Indian systems of medicines.

Active principle: Andrographolides.

Medicinal importance:

Andrographis is a **potent hepatoprotective** and is widely used to treat liver disorders. Concoction of *Andrographis paniculata* and eight other herbs (Nilavembu Kudineer) is effectively used to treat malaria and dengue.

Psychoactive Drugs

In the above chapter you have learnt about plants that are used medicinally to treat various diseases. Phytochemicals / drugs from some of the plants alter an individual's perceptions of mind by producing hallucination are known as psychoactive drugs. These drugs are used in all ancient culture especially by Shamans and by traditional healers. Here we focus on two such plants namely Poppy and Marijuana.

Opium poppy

Botanical name : *Papaver somniferum*

Family: Papaveraceae

Origin and Area of cultivation: *Opium poppy* is native to South Eastern Europe and Western Asia. Madhya Pradesh, Rajasthan and Uttar Pradesh are the licenced states to cultivate opium poppy.

Opium is derived from the exudates of fruits of poppy plants. It was traditionally used to induce sleep and for relieving pain. Opium yields **Morphine**, a strong analgesic which is used in surgery. However, opium is an addiction forming drug.

Cannabis / Marijuana

Botanical name : *Cannabis sativa*

Family: Cannabiaceae

Origin and Area of Cultivation: Marijuana is native to China. States such as Gujarat, Himachal Pradesh, Uttarkand, Uttarpradesh and Madhaya Pradesh have legally permitted to cultivate industrial hemp/Marijuana

The active principle in Marijuana is **trans-tetrahydrocanabinal** (THC). It possess a number of medicinal properties.

Table 1: Other commo Medicinal plants

S. No	Common Name	Tamil Name	Botanical Name	Family	Plant part used	Medicinal Uses
1	Holy basil	துளசி	*Ocimum sanctum*	Lamiaceae	Leaves and Roots	The leaves are stimulant, antiseptic, anti-hypertensive and anti-bacterial and expectorant used in bronchitis. Decoction of roots is given as a diaphoretic in malarial fevel.
2	Indian gooseberry	நெல்லி	*Phyllanthus emblica*	Phyllanthaceae	Fruit	It is a potent rejuvenator and immune modulator. It has a anti-ageing properties. It helps to promote longevity, enhance digestion, treat constipation and reduce fever and cough.
3	Indian Acalypha	குப்பைமேனி	*Acalypha indica*	Euphorbiaceae	Leaves	Used to cure skin diseases caused by ringworms. Powdered leaves are used to cure bedsores and infected wounds.
4	Vilvam	வில்வம்	*Aegle marmelos*	Rutaceae	Fruit	The unripe fruit is used to treat problems of stomach indigestion. It kills intestinal parasites.
5	Veldt grape	பிரண்டை	*Cissus quadrangularis*	Vitaceae	Stem and root	Paste obtained from the powdered stem and root of this plant is used in bone fractures. Whole plant is useful to treat asthma and stomach troubles.

It is an effective pain reliever and reduces hypertension. THC is used in treating **Glaucoma** a condition in which pressure develops in the eyes. THC is also used in reducing nausea of cancer patients undergoing radiation and chemotherapy. THC provides relief to bronchial disorders, especially asthma as it dilates bronchial vessels. Because of these medicinal properties, cultivation of cannabis is legalized in some countries. However, prolonged use causes addiction and has an effect on individual's health and society. Hence most of the countries have banned its cultivation and use.

Narcotics Control Bureau (NCB)

Drugs come in various forms and can be taken in numerous ways. Some are legal and others are not. Drug abuse and misuse can cause numerous health problems and in serious cases death can occur.

The Narcotics Control Bureau (NCB) is the nodal drug law enforcement and intelligence agency of India and is responsible for fighting drug trafficking and the abuse of illegal substances.

10.11 Entrepreneurial Botany

Entrepreneurial Botany is the study of how new businesses are created using plant resources as well as the actual process of starting a new business. An **entrepreneur** is someone who has an idea and who works to create a product or service that people will buy, by building an organization to support the sales. **Entrepreneurship** is now a popular topic for higher secondary students, with a focus on developing ideas to create new ventures among the young people.

Vast opportunities are there for the students of Botany. In the present scenario students should acquire ability to merge skills and knowledge in a meaningful way. Converting botanical knowledge into a business idea that can be put into practice for earning a livelihood is the much-needed training for the students.

Few examples for activities of entrepreneurship are Mushroom cultivation, Single cell protein (SCP) production, Seaweed liquid fertilizer, Organic farming, Terrarium, Bonsai and Cultivation of medicinal and aromatic plants

This part of the chapter is dealt about organic farming in brief.

10.11.1 Organic farming

Organic farming is an alternative agricultural system in which plants/crops are cultivated in natural ways by using biological inputs to maintain soil fertility and ecological balance thereby minimizing pollution and wastage. Indians were organic farmers by default until the green revolution came into practice.

Use of biofertilizers is one of the important components of integrated organic farm management, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. Organic farming is thus considered as the movement directed towards the philosophy of **Back to Nature.**

I. Organic Pesticide

Pest like aphids, spider and mites can cause serious damage to flowers, fruits, and vegetables. These creatures attack the garden in swarms, and drain the life of the crop and often invite disease in the process. Many chemical pesticides prove unsafe for human and the environment. It turns fruits and vegetables unsafe for consumption. Thankfully, there are many homemade, organic options to turn to war against pests.

Preparation of Organic Pesticide

Mix 120g of hot chillies with 110 g of garlic or onion. Chop them thoroughly. 1

Blend the vegetables together manually or using an electric grinder until it forms a thick paste. 2

Add the vegetable paste to 500 ml of warm water. Give the ingredients a stir to thoroughly mix them together. 3

Pour the solution into a glass container and leave it undisturbed for 24 hours. If possible, keep the container in a sunny location. If not, at least keep the mixture in a warm place. 4

Strain the mixture. Pour the solution through a strainer, remove the vegetables and collect the vegetable-infused water and pour into another container. This filtrate is the pesticide. Either discard the vegetables or use it as a compost. 5

Pour the pesticide into a squirt bottle. Make sure that the spray bottle has first been cleaned with warm water and soap to get rid it of any potential contaminants. Use a funnel to transfer the liquid into the squirt bottle and replace the nozzle. 6

Spray your plants with the pesticide. Treat the infected plants every 4 to 5 days with the solution. After 3 or 4 treatments, the pest will be eliminated. If the area is thoroughly covered with the solution, this pesticide should keep bugs away for the rest of the season. 7

Avoid spraying the plants during the sunny times of the day since it could burn plants. Many other plants possess insect repellent or insecticidal properties. Combinations of these plants can be fermented and used as biopesticide.

Figure 10.20: Preparation of organic pesticide

II. Bio-pest repellent

Botanical pest repellent and insecticide made with the dried leaves of *Azadirachta indica*

Preparation of Bio-pest repellent

- Pluck leaves from the neem tree and chop the leaves finely.
- The chopped up leaves were put in a 50-liter container and fill to half with water; put the lid on and leave it for 3 days to brew.
- Using another container, strain the mixture which has brewed for 3 days to remove the leaves, through fine mesh sieve. The filtrate can be sprayed on the plants to repel pests.
- To make sure that the pest repellent sticks to the plants, add 100 ml of cooking oil and the same amount of soap water. (The role of the soap water is to break down the oil, and the role of the oil is to make it stick to the leaves).

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- The stewed leaves from the mixture can be used in the compost heap or around the base of the plants.

Summary

Early civilization in different parts of the world has domesticated different species of plants for various purposes. Based on their utility, the economically useful plants are classified into food plants, fibre plants, timber plants, medicinal plants, and plants used in paper industries, dyes and cosmetics.

However, food base of majority of the population depends on very few Cereals, Millets, Pulses, Vegetables, Fruits, Nuts, Sugars, Oil seeds, Beverages, Spices and Condiments.

Oils can be classified into two types namely, essential oils and vegetable oils. Fatty acids in oil may be saturated or unsaturated. The oil yielding plants are groundnut and sesame. The oils are used in cooking, making soaps and other purposes. Beverages contain alkaloids that stimulate central nervous system. Spices were used throughout the world for several years. Cardamom is 'Queen of Spices' used for flavouring confectionaries and beverages. Black pepper is King of Spices.

Botanically a fibre is a long, narrow, thick walled cell. Cotton and Jute are fibre yielding plants. Teak is wood used for making furniture. Rubber is produced from the latex of Hevea brasiliensis. Paper production is a Chinese invention. Dyes have been used since ancient times. The orange dye henna is from the leaves of Lawsonia. Perfumes are volatile and aromatic in nature, manufactured from essential oils which are found at different parts of the plant. Medicinal plants serve as therapeutic agents. Medicinally useful molecules obtained from these plants are marketed as drugs are called Biomedicines. Whereas phytochemicals from some of the plants which alter an individual's perceptions of mind by producing hallucination are known as psychoactive drugs.

Entrepreneurial Botany is the study of how new businesses are created using plant resources as well as the actual process of starting a new business.

Evaluation

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1. Consider the following statements and choose the right option.
   i) Cereals are members of grass family.
   ii) Most of the food grains come from monocotyledon.
   a) (i) is correct and (ii) is wrong
   b) Both (i) and (ii) are correct
   c) (i) is wrong and (ii) is correct
   d) Both (i) and (ii) are wrong

2. Assertion: Vegetables are important part of healthy eating.
   Reason: Vegetables are succulent structures of plants with pleasant aroma and flavours.
   a) Assertion is correct, Reason is wrong
   b) Assertion is wrong, Reason is correct
   c) Both are correct and reason is the correct explanation for assertion.
   d) Both are correct and reason is not the correct explanation for assertion.

3. Groundnut is native of _____
   a) Philippines b) India
   c) North America d) Brazil

4. Statement A: Coffee contains caffeine
   Statement B: Drinking coffee enhances cancer
   a) A is correct, B is wrong
   b) A and B – Both are correct
   c) A is wrong, B is correct
   d) A and B – Both are wrong

5. *Tectona grandis* is coming under family
   a) Lamiaceae b) Fabaceae
   c) Dipterocaipaceae e) Ebenaceae

6. *Tamarindus indica* is indigenous to
   a) Tropical African region
   b) South India, Sri Lanka

c) South America, Greece
d) India alone

7. New world species of cotton
a) Gossipium arboretum
b) G.herbaceum
c) Both a and b
d) G.barbadense

8. Assertion: Turmeric fights various kinds of cancer
Reason: Curcumin is an anti-oxidant present in turmeric
a) Assertion is correct, Reason is wrong
b) Assertion is wrong, Reason is correct
c) Both are correct
d) Both are wrong

9. Find out the correctly matched pair.
a) Rubber — *Shorea robusta*
b) Dye — *Lawsonia inermis*
c) Timber — *Cyperus papyrus*
d) Pulp — *Hevea brasiliensis*

10. Observe the following statements and pick out the right option from the following:
Statement I – Perfumes are manufactured from essential oils.
Statement II – Essential oils are formed at different parts of the plants.
a) Statement I is correct
b) Statement II is correct
c) Both statements are correct
d) Both statements are wrong

11. Observe the following statements and pick out the right option from the following:
Statement I: The drug sources of Siddha include plants, animal parts, ores and minerals.
Statement II: Minerals are used for preparing drugs with long shelf-life.
a) Statement I is correct
b) Statement II is correct
c) Both statements are correct
d) Both statements are wrong

12. The active principle trans-tetra hydro canabial is present in
a) Opium b) Curcuma
c) Marijuana d) Andrographis

13. Which one of the following matches is correct?
a) Palmyra - Native of Brazil
b) Saccharun - Abundant in Kanyakumari
c) Steveocide - Natural sweetener
d) Palmyra sap - Fermented to give ethanol

14. The only cereal that has originated and domesticated from the New world.
a) *Oryza sativa* b) *Triticum asetumn*
c) *Triticum duram* d) *Zea mays*

15. Write the cosmetic uses of *Aloe*.

16. What is pseudo cereal? Give an example.

17. Discuss which wood is better for making furniture.

18. A person got irritation while applying chemical dye. What would be your suggestion for alternative?

19. Name the humors that are responsible for the health of human beings.

20. Give definitions for organic farming?

21. Which is called as the "King of Bitters"? Mention their medicinal importance.

22. Differentiate bio-medicines and botanical medicines.

23. Write the origin and area of cultivation of green gram and red gram.

24. What are millets? What are its types? Give example for each type.

25. If a person drinks a cup of coffee daily it will help him for his health. Is this correct? If it is correct, list out the benefits.

26. Enumerate the uses of turmeric.

27. What is TSM? How does it classified and what does it focuses on?

28. Write the uses of nuts you have studied.

29. Give an account on the role of *Jasminum* in perfuming.

30. Give an account of active principle and medicinal values of any two plants you have studied.
31. Write the economic importance of rice.
32. Which TSM is widely practiced and culturally accepted in Tamil Nadu? - explain.
33. What are psychoactive drugs? Add a note *Marijuana* and *Opium*
34. What are the King and Queen of spices? Explain about them and their uses.
35. How will you prepare an organic pesticide for your home garden with the vegetables available from your kitchen?

Glossary

Alzheimer's disease: A type of dementia that causes problems with memory, thinking and behavior

Antiperspirant: Products whose primary function is to inhibit perspiration / sweat

Anti-inflammatory: the property of a substance or treatment that reduces swelling.

Antioxidant: A substance that scavenges free radicals.

Carminative: A drug causing expulsion of gas from the stomach or bowel.

Cirrhosis: A chronic liver disease typically caused by alcoholism or hepatitis.

Confectionary: a place where confections/ sweets are kept or made

Cosmetics: substances or products used foe personal grooming.

Diuretic: Substance that promote urine production

Ethnobiology: Ethnobiology is the study of relationships between peoples and plants.

Fixative: A substance used to reduce the evaporation rate and improve stability when added to more volatile components.

Lubricant: Oily substance reduces friction.

Malnutrition: Deficiencies, excesses or imbalances in a person's intake of energy and / or nutrients

Odour: Smell (pleasant or unpleasant).

Perfumery: The art or process of making perfume

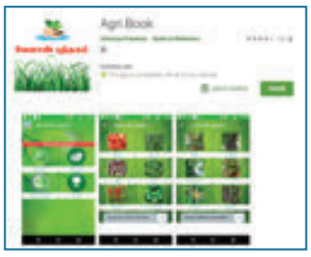
Pharmacopoeia: Is a book containing directions for the identification of compound medicines, and published by the authority of a government or a medical or pharmaceutical society.

Seasoning: The processing of food with spices and condiments to enhance the flavour.

ICT Corner

Economically Useful Plants

Let us know about the agriculture in detail through this activity



B266_12_BOT_EM

Steps

- Type the URL or scan the QR code to open the activity page then Introduction page will open.
- Select Package of Practices to know the various methods of agricultural crops breeding system.
- Click on Chat with expert helps the farmers to clarify their doubts.
- Click on Videos to know about the agricultural methods visually through videos.

Step 1

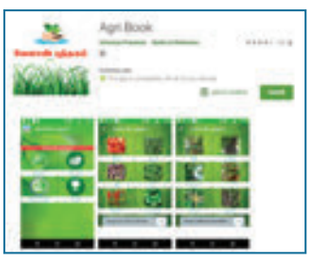
Step 2

Step 3

Step 4

URL: **https://play.google.com/store/apps/details?id=com.criyagen**

Let us know about the Agri book in detail through this activity.



B266_12_BOT_EM

Steps

- Type the URL or scan the QR code to open the activity page then Introduction page will open.
- Click on Agriculture it will display the approaches to cultivate the planted paddy, cotton and sugarcane.
- Click on Horticulture it will display the approaches to cultivate the agricultural crops like tea, coffee.
- Click on Organic Farming it will explain the Traditional method of farming and Traditional Fertilizers.
- Click on Forestry it will explain the gardening methods about plants.

Step 1

Step 2

Step 3

Step 4

URL: * Pictures are indicative only

https://play.google.com/store/apps/details?id=com.agribook.venkatmc.agri

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English – Tamil Terminology

Unit VI – Reproduction in plants

Apomixis	கருவுறா இனப்பெருக்கம்
Apospory	கருவுறா வித்து
Archesporium	முன்வித்து திசு
Cleistogamous flower	மூடிய பூ
Cryopreservation	குளிர்பாதுகாப்பு
Embryo sac	கருப்பை
Floral primordium	மலர் தோற்றுவி
Funiculus	சூல் காம்பு
Microsporogenesis	நுண் வித்துருவாக்கம்
Polyembryony	பல்கருநிலை
Scion	ஒட்டுத் தண்டு
Stock	வேர்கட்டை

Unit VII - Genetics

Allele	அல்லீல்
Allopolyploidy	அயல்பன்மடியம்
Alternative splicing	மாற்று இயைத்தல்
Autopolyploidy	தன்பன்மடியம்
Backcross	பிற்கலப்பு
Blending inheritance	கலப்பு பாரம்பரியம்
Branch migration	கிளைவழி இடம்பெயர்தல்
Codominance	இணைஓங்குத்தன்மை
Complete linkage	முழுமையான பிணைப்பு
Complementation test	நிரப்பு சோதனை
Coupling	இணைப்பு
Crossing over	குறுக்கேற்றம்
DNA metabolism	DNA வளர்சிதை மாற்றம்
Dominance	ஓங்குத்தன்மை
Duplication	இரட்டிப்பாதல்
F_1 generation (first filial generation)	முதல் மகவுச்சந்ததி
Frame shift mutation	கட்ட நகர்வு சடுதி மாற்றம்
Gene interaction	மரபணு இடைச்செயல்
Gene mapping	மரபணு வரைபடம்
Genome	மரபணுத்தொகையம்
Genotype	மரபணுவகையம்
Haploidy	ஒருமடியம் (பன்மம்)
Heredity	பாரம்பரியம்
Heterozygous	மாறுபட்டபண்பிணைவு
Homologous chromosome	ஒத்த அமைவிட குரோமோசோம்
Incomplete dominance	முழுமைபெறா ஓங்குத்தன்மை
Incomplete linkage	முழுமையற்ற பிணைப்பு
Independent assortment	சாராஒதுங்கு விதி
Internal methylation	அக மெத்திலாக்கம்
Inversion	தலைகீழ் திருப்பம்
Jumping genes	தாவும் மரபணுக்கள்
Linkage group	பிணைப்புத் தொகுதி
Locus	நிலையிடம்
Map unit	வரைபட அலகு
Mis-sense mutation	தவறாக வெளிப்பாட்டடையும் சடுதிமாற்றம்
Monohybrid	ஒரு பண்புக்கலப்புயிரி
Multiple alleles	பல்கூட்டு அல்லீல்கள்
Mutagen	சடுதிமாற்றக் காரணி
Mutation	சடுதிமாற்றம்
Non-sense mutation	வெளிப்பாடடையாத சடுதி மாற்றம்
Palindrome	முன்பின்ஒத்தவரிசை
Phenotype	புறத்தோற்றவகையம்
Purity of gametes	இனச்செல்கலப்பற்றது
Recessive	ஒடுங்குத்தன்மை
Repulsion	விலகல்

Restriction enzymes	தடைக்கட்டு நொதிகள்
Saltation	திடீர் மாற்றம்
Segregation	தனித்தொதுங்குதல்
Sequence	தொடர்வரிசை
Sex linkage	பால் பிணைப்பு
Silent mutation	அமைதி சடுதிமாற்றம்
Split genes	பிளவுறு மரபணு
Synaptonemal complex	இணைப்பிணைப்புக் கூட்டமைப்பு
Synopsis	இணைச் சேர்தல்
Tassel seed	கதிர் குஞ்சவிதை
Test cross	சோதனைக்கலப்பு
Tetrad stage	நான்மய நிலை
Three point test cross	முப்புள்ளி சோதனைக் கலப்பு
Translocation	இடம்பெயர்தல்

UNIT VIII - Biotechnology

Artificial seeds	செயற்கை விதைகள்
Aseptic condition	நுண்ணுயிர் அற்ற நிலை
Autoradiography	கதிரியக்க படமெடுப்பு
Biochip	உயிரி சில்லு
Biomass	உயிரி கூளம்
Biopharming	உயிரி மருந்தாக்கம்
Biopiracy	உயிரிபொருள் கொள்ளை
Bioreactor / Fermentor	உயிரி வினைகலன் / நொதிகலன்
Biosynthesis	உயிரி உற்பத்தி
Buffer	தாங்கல் கரைசல்
Carriers	கடத்தி
Cloned Plants	நகலொத்த தாவரங்கள்
Cloning	நகல்பெருக்கம்
Cloning Site	நகலாக்க களம்
Cryoconservation	உறைகுளிர் வெப்பநிலை பேணல்
Cybrids	கலப்பின பிளாஸ்மிட்கள்

Dedifferentiation	வேறுபாடு இழத்தல்
Differentiation	வேறபாடுறுதல்
DNA Bank	DNA வங்கி
Downstream Process	கீழ்காற் பதப்படுத்தம்
Embryogenesis	கரு உருவாக்கம்
Embryoids	சிறுகருக்கள்
Explant	பிரிகூறு
Fermentation	நொதித்தல்
Gel Electrophoresis	இழும மின்னாற் பிரித்தல்
Gene	மரபணு
Gene Bank	மரபணு வங்கி
Gene Gun	மரபணு துப்பாக்கி
Gene Manipulation Technique	மரபணு கையாளும் தொழில்நுட்பம்
Genetically modified plants	மரபணு மாற்றப்பட்ட தாவரங்கள்
Genome	மரபணு தொகையம்
Green Fluorescence Protein	பசுமை ஒளிர் புரதம்
Hardening	வன்மையாக்குதல்
Human Genome Sequence	மனித மரபணு தொகைய தொடர் வரிசை
Inoculation	உள்நுழைத்தல்
Insert	செருகி
invitro culture	ஆய்வுகூட சோதனை வளர்ப்பு
Isolation	தனிமைபடுத்துதல்
Laminar air flow chamber	சீரடுக்கு காற்று பாய்வு அறை
Liquid medium/ liquid culture	திரவ ஊடகம் / திரவ வளர்ப்பு
Marker	அடையாளக்குறி
Microinjection	நுண்செலுத்துதல்
Micropropagation	நுண்பெருக்கம்
Mycoremediation	பூஞ்சை சீரமைப்பாக்கம்
Nutritional medium	ஊட்ட ஊடகம்
Organogenesis	உறுப்புகளாக்கம்
Palindrome Sequence	முன்பின் ஒத்த வரிசை
Phytoremediation	தாவர சீரமைப்பாக்கம்

Pollen Bank	மகரந்த வங்கி
Probe	துருவி
Recombinant DNA	மறுகூட்டிணைவு DNA
Recombinant	மறுகூட்டிணைவு
Redifferentiation	மறுவேறுபாடுறுதல்
Regeneration	மீள் உருவாக்கம்
Replica Blotting Technique	நகல் முலாம் தொழில்நுட்பம்
Restriction Enzyme	தடை கட்டு நொதி
Somatic Embryoids	உடல் கருவுருக்கள்
Sterile condition	நுண்ணுயிர் நீக்கிய நிலை
Sterilization	நுண்ணுயிர் நீக்கம்
Tissue culture	திசு வளர்ப்பு
Totipotency	முழு ஆக்குத்திறன் பெற்றவை
Transfection	தொற்றுதல்
Transposon	இடமாற்றிக் கூறுகள்
Upstream Process	மேல்காற் பதப்படுத்தம்
Vector	தாங்கி கடத்தி
Virus free plants	வைரஸ் அற்றத் தாவரங்கள்
Walking Genes	நடக்கும் மரபணுக்கள்

UNIT IX – Plant Ecology

Agroforestry	வேளாண்காடுகள்
Alien Invasive species	அயல் ஊடுருவும் சிற்றினங்கள்
Allelopathic chemicals	வேதியத்தடைப் பொருட்கள்
Altitude	குத்துயரம்
Autecology	சுய சூழ்நிலையில்
Benthic	ஆழ்மிகு மண்டலம்
Benthos	ஆழ் உயிரிகள்
Biochar	உயிரித்தொகுப்பு
Biome	உயிர்மம்
Biotope	உயிரி நில அமைவு

Carbon foot print	கார்பன் தடம்
Carbon sequestration	கார்பன் ஒதுக்கமடைதல்
Carbon sink	கார்பன் தேக்கி
Co-evolution	கூட்டுப் பரிணாமம்
Decomposers	சிதைப்பவைகள்
Ecological hierarchy	சூழ்நிலைப்படிகள்
Ecotone	இடைச்சூழலமைப்பு
Ecotope	சூழல் நில அமைவு
Frugivores	பழ உண்ணிகள்
Gnano	கடல் அருகு வாழ் பறவைகளின் எச்சம்
Habitat	புவி வாழிடம்
Humus	மட்கு
Latitude	விரிவகலம்
Mimicry	பாவனை செயல்கள்
Niche	செயல் வாழிடம்
Ozone depletion	ஓசோன் குறைதல்
Photosyntheicaly active radioactive	ஒளிச்சேர்க்கை சார் செயலூக்கக் கதிர்வீச்சு
Plant Ecology	தாவர சூழ்நிலையியல்
Predation	கொன்றுண்ணும் வாழ்க்கை முறை
Sacred groves	கோயில் காடுகள்
Seedball	விதைப்பந்து
Social forestry	சமூகக்காடுகள்
Soil profile	மண்ணின் நெடுக்குவெட்டு விவரம்
Standing crops	நிலைப்பயிர்
Standing quality	நிலைத்தரம்
Succession	வழிமுறை வளர்ச்சி
Synecology	கூட்டுச் சூழ்நிலையில்
Topographic factors	நிலப்பரப்பு வடிவமைப்பு காரணிகள்
Trophic level	ஊட்டஞ்சார் மட்டம்

UNIT X - Economic Botany

Acclimatization	புதிய தட்பவெப்ப நிலைக்கு பழகுதல்
Archeological records	தொல்லியல் பதிவுகள்
Bio medicine	உயிரிமூலக்கூறு மருந்து
Biofertilizers	உயிரி உரம்
Culinary	சமையல்
Decoction	வடிநீர்
Domestification	வளர்ப்புச் சூழலுக்கு உட்படுத்துதல்
Emasculation	மகரந்தத்தாள் நீக்கம்
Entrepreneur	தொழில் முனைவோர்
Essential oil	நறுமண எண்ணெய்
Gluten	பசையம்
Green manuring	தழை உரம்
Kelp	பழுப்பு பாசி
Organic agriculture	இயற்கை வேளாண்மை
Plant pathology	தாவர நோயியல்
Pseudo cereal	பொய் தானியம்
Pungent	நெடி (அல்லது) காரம்
Resin	பிசின்
Sapwood	மென்கட்டை
Saturated fatty acids	நிறைவுற்ற கொழுப்பு அமிலம்
Stimulant	தூண்டி
Tillering	புல் கிளைத்தல்
Unsaturated fatty acids	நிறைவுறா கொழுப்பு அமிலம்
Vigour	வீரியம்
Volatile oil	எளிதில் ஆவியாகும் எண்ணெய்

Competitive Examination Questions

UNIT VI – Reproduction in plants

1. Which of the following plant reproduces by leaf (DPMT 2003)
   a) *Agave* b) ***Bryophyllum***
   c) *Gladiolus* d) Potato

2. Advantage of cleistogamy (NEET 2013)
   a) Higher genetic variability
   b) More vigorous offspring
   c) **No dependence on pollinators**
   d) Vivipary

3. An example for edible underground stem is (NEET 2014)
   a) Carrot b) Groundnut
   c) Sweet potato d) **Potato**

4. Pollen tablets are available in the market for (NEET 2014)
   a) *invitro* fertilization
   b) Breeding programmes
   c) **supplementing food**
   d) *ex situ* conservation

5. Geitonogamy involves (NEET 2014)
   a) **Fertilization of a flower by pollen from another flower of a same plant**
   b) Fertilization of a flower by pollen of the same flower
   c) Fertilization of a flower by pollen from a flower of another plant in a same population
   d) Fertilization of a flower by the pollen from a flower of another plant belongs to distant population.

6. Which one of the following generates new genetic combinations leading to variations? (NEET 2016)
   a) vegetative reproduction
   b) parthenogenesis
   c) **Sexual reproduction**
   d) Nucellar polyembryony

7. Functional megaspore in angiosperm develops into an (NEET 2017)
a) endosperm b) **Embryo sac**
c) embryo d) ovule

8. Which of the statement is not true. (NEET 2016)
a) Pollen grain of many species cause severe allergies
b) Stored pollen in liquid nitrogen can be used in crop breeding programmes
c) **Tapetum helps in the dehiscence of anther**
d) Exine of pollen grains is made up of sporopollenin

9) When a diploid female plant is crossed with a tetraploid male, the ploidy of endosperm cells in the resulting seed is (AIPMT 2004)
a) pentaploidy b) diploidy
c) triploidy d) **tetraploidy**

10) Which one of the following pairs of plant structures has haploid number of chromosomes? (AIPMT 2008)
a) Egg nucleus and secondary nucleus
b) Megaspore mother cell and antipodal cells
c) **Egg cell and and antipodal cells**
d) Nucellus and antipodal cells

11) The arrangement of nuclei in a normal embryo sac in the dicot plant is (AIPMT 2006)
a) 2 + 4 + 2 b) **3 + 2 + 3**
c) 2 + 3 + 3 d) 3 + 3 + 2

12) Wind pollinated flowers are (AIPMT PRE 2010)
a) Small, producing nectar and dry pollen
b) small, brightly colored, producing large number of pollen grains
c) **small, producing large number of pollen grains**
d) large, producing abundant nectar and pollen

13) Function of filiform apparatus is to (AIPMT 2014)
a) recognize the suitable pollen at stigma
b) stimulate division of generative cell
c) produce nectar
d) **guide the entry of pollen tube**

14) The coconut water from tender coconut represents (NEET 2016)
a) endocarp
b) fleshy mesocarp
c) free nuclear proembryo
d) **free nuclear endosperm**

15) Pollination in water hyacinth and water lily is brought about by the agency of (NEET 2016)
a) **insects or wind** b) birds
c) bats d) water

16) Perisperm differs from endosperm in (NEET 2013)
a) being haploid tissue
b) having no reserve food
c) **being a diploid tissue**
d) its formation by fusion of secondary nucleus with several sperms

17) Male gametes in angiosperms are formed by the division of (AIPMT 2007)
a) microspore mother cell b) microspore
c) **generative cell** d) vegetative cell

18) In a type of apomixes known as adventive polyembryony,embryo develop directly from the (AIPMT 2005)
a) synergids or antipodals in an embryo sac
b) **nucellus or integuments**
c) zygote
d) accessory embryo sac in the ovule

19) In a cereal grain the single cotyledon of the embryo is represented by (AIPMT 2006)
a) coleorhizae b) **scutellum**
c) prophyll d) coleoptiles

20) An ovule which becomes curved so that the nucellus and embryo sac lie at right angles to the funicle is (AIPMT 2004)
a) camylotropous b) anatropous
c) orthotropous d) **hemianatropous**

21) Endosperm is formed during the double fertilization by (AIPMT 2000)
a) **two polar nuclei and one male gamete**
b) one polar nuclei and one male gamete
c) ovum and male gametes
d) two polar nuclei and two male gametes

UNIT VII – Genetics

1. Genes for cytoplasmic male sterility in plants are generally located in (AIPMT 2005)
a) **Mitrochondrial genome** b) Cytosol
c) Chloroplast genome d) Nuclear genome

2. In which mode of inheritance do you expect more maternal influence among the off spring (AIPMT 2006)
a) Autosomal b) **Cytoplasmic**
c) Y-linked d) X-linked

3. Which one of the following cannot be explained on the basis of Mendel's Law of Dominance? (AIPMT 2010)
a) Factors occur in pairs
b) The discrete unit controlling a particular character is called a factor
c) Out of one pair of factors one is dominant and the other is recessive
d) Alleles does not show any blending and both the characters recover as such in F_2 generation

4. F_2 generation in a Mendelian cross shows that both genotypic and phenotypic ratios are same as 1:2:1. It represents a case of (AIPMT 2012)
a) Monohybrid crosses with incomplete dominance
b) Co-dominance c) Dihybrid cross
d) Monohybrid cross with complete dominance

5. A Pleiotropic gene (AIPMT 2015 – Re-exam)
a) Controls multiple traits in an individual
b) Is expressed only in primitive plants
c) Is a gene evolved during Pliocene
d) Controls a trait only in combination with another L gene

6. A true breeding plant is (NEET Phase II 2016)
a) Near homozygous and produces offspring of its own kind
b) Always homozygous recessive in its genetic construction
c) One that is able to breed on its own
d) Produced due to cross pollination among unrelated plants

7. Mendel obtained wrinkled seeds in pea due to the deposition of sugars instead of starch. It was due to which enzyme? (AIPMT 2001)
a) Amylase b) Invertase c) Diastase
d) **Absence of starch branching enzyme**

8. Ratio of complementary gene is (AIPMT 2001)
a) 9:3:4 b) 12:3:1 c) 9:3:3:4 d) **9:7**

9. If there are 999 bases in an RNA that codes for a protein with 333 amino acid and the base at position 901 is deleted such that the length of the RNA becomes 998 bases, how many codons will be altered? (NEET 2017)
a) 1 b) 11 c) 33 d) **333**

10. If a homozygous red flowered plant is crossed with a homozygous white flowered plant, then the off-springs will be (AIIMS 1999, 2002, 2007)
a) Half-white flowered b) Half-red flowered
c) All white flowered d) **All red flowered**

11. The ratio in a dihyrbid test cross between two individuals is given by (AIIMS 2001)

a) 2:1 b) 1:2:1 c) 3:1 d) **1:1:1:1**

12. Pure line breed refers to (AIIMS 2002, AIIMS 2007)
a) Heterozygosity only
b) Heterozygosity and linkage
c) **Homozygosity only**
d) Homozygosity and self assortment

13. How many different types of gametes can be formed by F_1 progeny, resulting from the following cross AABBCC x aabbcc (AIIMS 2004)
a) 3 b) **8** c) 27 d) 64

14. Which of the following conditions represents a case of co-dominant genes? (AIIMS 2009)
a) A gene expresses itself, suppressing the phenotypic effect of its alleles
b) Genes that are similar in phenotypic effect when present separately, but when together interact to produce a different trait
c) Alleles both of which interact to produce a trait which may or may not resemble either of the parental type
d) Alleles, each of which produces an independent effect in a heterozygous condition.

15. If 'A' represents the dominant gene and 'a' represents its recessive allele, which of the following would be most likely result in the first generation off spring when Aa is crossed with aa? (AIIMS 2016)
a) All will exhibit dominant phenotype
b) All will exhibit recessive phenotype
c) **Dominant and recessive phenotypes will be 50% each**
d) Dominant phenotype will be 75%

16. In *Pisum Sativum*, there are 14 chromosomes. How many types of homologous pairs can be prepared? (JIPMER 2010)
a) 14 **b) 7** c) 2^{14} d) 2^{10}

17. The year 1900 AD is highly significant for geneticists due to (JIPMER 2013)
a) Discovery of genes
b) Principle of linkage
c) Chromosomal theory of heredity
d) **Rediscovery of Mendelism**

18. The phenotypic ratio of trihybrid cross in F_2 generation is (JIPMER 2016)
a) **27:9:9:9:3:3:3:1** b) 9:3:3:1
c) 1:4:6:4:1 d) 27:9:3:3:9:1:2:1

19. In a mutational event when adenine is replaced by guanine, it is the case of (AIPMT 2004)
a) Frameshift mutatin b) Transcription
c) **Transition** d) Transversion

20. Mutations can be induced with (AIPMT 2011)
a) **Gamma radiations** b) Infrared radiations
c) IAA d) Ethylene

21. The mechanism that causes a gene to move from one linkage group to another is called (AIPMT 2015, NEET (Phase – II) 2016)
a) **Translocation** b) Crossing over
c) Inversion d) Duplication

22. A point mutation comprising the substitution of a purine by pyrimidine is called (AIIMS 2002)
a) Transition b) Translocation
c) Deletion d) **Transversion**

23. Frameshift mutation occurs when (AIPMT 2008)
a) Base is substituted
b) **base is deleted or added**
c) Anticodons are absent
d) None of these

24. The distance between two genes in a chromosome is measured in cross-over units which represent (AIIMS 2008)
a) Ratio of crossing over between them
b) **Percentage of crossing over between them**
c) Number of crossing over between them
d) None of these

25. When a cluster of genes show linkage behaviour they (AIPMT 2003)
a) do not show a chromosome map
b) show recombination during meiosis
c) **do not show independent assortment**
d) induce cell division

26. Genetic map is one that (AIPMT 2003)
a) **Establish sites of the genes on a chromosome**
b) Establishes the various stages in gene evolution
c) Shows the stages during the cell division
d) Shows the distribution of various species in a region

27. After a mutation at a genetic locus of the character of an organism changes due to the change in (AIPMT 2004)
a) DNA replication
b) Protein synthesis pattern
c) RNA transcription pattern
d) **Protein structure**

28. In a hexaploidy wheat, the haploid (n) and basic (x) numbers of chromosomes are (AIPMT 2007)
a) **n =21 and x =7** b) n =7 and x =21
c) n =21 and x =21 d) n =21 and x =14

29. Point mutation involves (AIPMT 2009)
a) Deletion b) Insertion
c) **Change in single base pair**
d) duplication

30. Which one of the following is a wrong statement regarding mutations**?** (AIPMT 2012)
a) UV and Gamma rays are mutagens
b) **Change in a single base pair of DNA does not cause mutation**
c) Deletion and insertion of base pairs cause frame shift mutations.
d) Cancer cells commonly show chromosomal aberrations.

31. Which of the following statement is not true of two genes that show 50% recombination frequency? (NEET 2013)
a) The genes may be on different chromosomes
b) **The genes are tightly linked**
c) The genes show independent assortment
d) If the genes are present on the same chromosome, they undergo more than one crossover in every meiosis.

32. Haploids are more suitable for mutation studies than the diploids. This is because (AIPMT 2008)
a) **All mutations, whether dominant or recessive are expressed in haploids**
b) Haploids are reproductively more stable than diploids
c) Mutagens penetrate in haploids more effectively than diploids
d) Haploids are more abundant in nature than diploids

33. Crossing over that results in genetic recombination in higher organisms occurs between (AIPMT 2004)
a) **Non-sister chromatids of a bivalent**
b) Two daughter nuclei
c) Two different bivalents
d) Sister chromatids of bivalents

UNIT VIII – Biotechnology

1. What is the criterion for DNA fragments movement on agarose gel during gel electrophoresis? (NEET 2017)
a) **The smaller the fragment size, the farther it moves.**
b) Positively charged fragments move to farther end.
c) Negatively charged fragments do not move.
d) The larger the fragment size, the farther it moves.

2. Stirred-tank bioreactors have been designed for (NEET – II 2016)
   a) Purification of product.
   b) Addition of preservatives to the product
   c) **Availability of oxygen throughout the process**
   d) Ensuring anaerobic conditions in the culture vessel.

3. Which of the following is not a component of downstream processing? (NEET-II 2016)
   a) Separation b) Purification
   c) Preservation d) **Expression**

4. Which of the following is not a feature of the plasmids? (NEET-I 2016)
   a) Transferable **b) Single-stranded**
   c) Independent replication
   d) Circular structure

5. Which of the following is not required for nay of the techniques of DNA fingerprinting available at present? (NEET-I 2016)
   a) Restriction enzymes
   b) DNA-DNA hybridization
   c) Polymerase chain reaction
   d) Zinc finger analysis

6. Which vector can clone only a small fragment of DNA? (AIPMT 2014)
   a) Bacterial artificial chromosome
   b) Yeast artificial chromosome
   c) Plasmid d) Cosmid

7. The colonies of recombinant bacteria appear white in contrast to blue colonies of non-recombinant bacteria because of (NEET 2013)
   a) Insertional inactivation of alpha galactosidase in recombinant bacteria.
   b) Inactivation of glycosidase enzyme in recombinant bacteria.
   c) N**on-recombinant bacteria containing beta galactosidase.**
   d) Insertional inactivation of alpha galactosidase in non-recombinant bacteria.

8. During the process of isolation of DNA, chilled ethanol is added to (Karnataka NEET 2013)
   a) **Precipitate DNA**
   b) Break open the cell to release DNA
   c) Facilitate action of restriction enzymes
   d) Remove proteins such as histones.

9. For transformation, micro-particles coated with DNA to be bombarded with gene gun are made up of (AIPMT 2012)
   a) Silver or platinum b) Platinum or zinc
   c) Silicon or platinum **d) Gold or tungsten.**

10. Biolistics (gene-gun) is suitable for (AIPMT Mains 2012)
    a) disarming pathogen vectors
    b) transformation of plant cells
    c) constructing recombinant DNA by joining with vectors
    d) DNA fingerprinting.

11. Genetic engineering is possible because (CBSE 1998)
    a) phenomenon of transduction in bacteria understood
    b) we can see DNA by electron microscope
    c) we can cut DNA at specific sites by endonuclease like DNAase I
    d) restriction endonuclease purified from bacteria can be used invitro

12. Genetic Engineering is (BHU 2003)
    a) Making artificial genes
    b) **Hybridisation of DNA of one organism to that of the others**
    c) Production of alcohol by using microorganisms
    d) Making artificial limbs, diagnostic instruments such as ECG, EFG, etc.

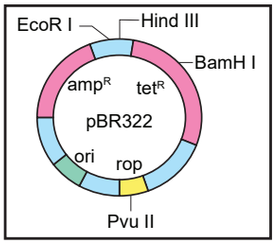
13. Ligase is used for (AMU 2006)
    a) **Joining of two DNA fragments**
    b) Separating DNA
    c) DNA polymerase reaction
    d) All of these

14. In genetic engineering, gene of interest is transferred to the host cell through a vector. Consider the following four agents (1-4) in this regard and select the correct option about which one or more of these can be used as vectors
1. A bacterium 2. Plasmid
3. Plasmodium 4. Bacteriophage
(AIPMT Main 2010)
a) 1 and 4 only b) **2 and 4 only**
c) 1 only d) 1 and 3 only

15. Given below is a sample of a portion of DNA strand giving the base sequence on the opposite strands. What is so special shown in it? (AIPMT 2014)
5'---GAATTC---3' 3'---CTTAAG---5'
a) **Palindromic sequence of base pairs**
b) Replication completed
c) Deletion mutation
d) Start codon at the 5'end

16. There is a restriction endonuclease called EcoRI. What does "co" part in it stand for ? (AIPMT 2011)
a) Coelom b) Colon
c) **Coli** d) Coenzyme

17. The figure below is the diagrammatic representation of the vector pBR322. Which one of the given options correctly identifies its certain components? (AIPMT 2012)



a) Ori-original restriction enzyme
b) rop-reduced osmotic pressure
c) Hind III, EcoRI – selectable markers
d) **ampR, tetR – antibiotic resistance genes**

18. A mixture containing DNA fragments a,b,c,d with molecular weights of a+b=c, a>b and d>c, was subjected to agarose gel electrophoresis. The position of these fragmets from cathode to anode sides of the gel would be (DPMT 2010)
a) **b,a,c,d** b) a,b,c,d
c) c,b,a,d d) b,a,d,c

19. An analysis of chromosomal DNA using the southern hybridisation technique does not use (AIPMT 2014)
a) Electrophoresis
b) Blotting
c) Autoradiography
d) **PCR**

20. The colonies of recombinant bacteria appear white in contrast to blue colonies of non- recombinant bacteria because of (NEET 2013)
a) Non-recombinant bacteria containing beta galactosidase
b) Insertional inactivation of a-galactosidase in non-recombinant bacteria
c) **Insertional inactivation of b-galactosidase in recombinant bacteria**
d) Inactivation of glycosidase enzyme in recombinant bacteria

21. Which one of the following palindromic base sequence in DNA can be easily cut at about the middle by some particular restriction enzyme? (AIPMT 2010)
a) 5'CGTTCG3' 3'ATCGTA 5'
b) 5' GATATG 3' 3' CTACTA 5'
c) **5' GAATTC 3' 3' CTTAAG 5'**
d) 5' CACGTA 3' 3' CTCAGT 5'

22. Silencing of mRNA has been used in producing transgenic plants resistant to (AIPMT, 2011)
a) Boll worms b) **Nematodes**
c) White rusts d) Bacterial blights

23. Some of the characteristics of Bt cotton are (AIPMT,2010)
a) Long fibre and resistant to aphids

b) Medium yield, long fibre and resistant to beetle pests

c) High yield and production of toxic protein crystals which kill dipteran pests

d) **High yield and resistant to boll worms**

24. An improved variety of transgenic basmati rice (AIPMT,2010)

a) Does not require chemical fertilisers and growth hormones

b) **Gives high yield and is rich in vitamin A**

c) Is completely resistant to all insect pests and diseases of paddy

d) Gives high yield but no characteristic aroma

25) Consumption of which one of the following foods prevent the kind of blindness associated with vitamin A deficiency? (AIPMT 2012)

a) Flavr Savr b) Canola

c) **Golden rice** d) Bt brinjal

26. A protoplast is a cell (NEET 2016)

a) undergoing division

b)without cell wall

c) without plasma membrane

d) without nucleus.

27. A technique of micropropagation is (NEET 2015)

a) Protoplast fusion

b) embryo rescue

c) somatic hybridization

d) somatic embryogenesis

28. To obtain virus-free healthy plants from a diseased one by tissue culture technique, which part/parts of the diseased plant will be taken? (AIPMT 2014)

a) Apical meristem only

b) Palisade parenchyma

c) **Both apical and axillary meristems**

d) Epidermis only.

29. Cellular totipotency was demonstrated by (AIPMT 1991)

a) Theodore Schwann

b) A.V. Leeuwenhoek

c) F.C. Steward

d) Robert Hooke

30. Tissue culture technique can produce infinite number of new plants from a small parental tissue. The economic importance of the technique is raising. (Karnataka NEET 2013)

a) **genetically uniform population identical to the original parent.**

b) homozygous diploid plants

c) new species

d) variants through picking up somaclonal variations

31. Which of the following statements is not true about somatic embryogenesis? (Karnataka NEET 2013).

a. The pattern of development of a somatic embryo is comparable to that of a zygotic embryo.

b) **Somatic embryos can develop from microspores.**

c) Somatic embryo is induced usually by an auxin such as 2, 4-D.

d) A somatic embryo develops from a somatic cell.

32. Which one of the following is a case of wrong matching? (AIPMT 2012)

a) Somatic - Fusion of two diverse hybridization cells

b) Vector DNA - Site for tRNA synthesis

c) Micropropagation - *in vitro* production of plants in large numbers

d) Callus - Unorganised mass of cells produced in tissue culture.

33. Polyethylene glycol method is used for (AIPMT 2010)

a) biodiesel production

b) seedless fruit production

c) energy production from sewage

d) gene transfer without a vector.

34. Somaclones are obtained by (AIPMT 2009)
a) Plant breeding
b) Irradiation
c) genetic engineering
d) tissue culture.

35. The technique of obtaining large number of plantlets by tissue culture method is called
a) Plantlet culture (AIPMT 2005)
b) Organ culture
c) Micropropagation
d) Macropropagation

36. Coconut milk is used in tissue culture in which present (AIPMT 2000)
a) cytokinin b) auxin
c) gibberellins d) ethylene.

37. Haploid plants can be obtained by culturing. (AIPMT 1994)
a) pollen grains b) root tips
c) young leaves d) endosperm.

UNIT IX - Plant Ecology

1. Plants which produce characteristic pneumatophores and show vivipary belong to (NEET 2017)
a) **Halophytes** b) psammophytes
c) hydrophytes d) mesophytes

2. Mycorrhizae are the example of (NEET I 2017)
a) amensalism b) antibiosis
c) **mutualism** d) fungistatis

3. If '+' sign is assigned to beneficial interaction, '-' sign to detrimental and '0' sign to neutral interaction, then the population interaction represented by '+' '-' refers to (NEET 2016)
a) mutualism b) amensalism
c) commensalism d) **parasitism**

4. Which of the following is correctly matched? (NEET Phase 2 – 2016)
a) Aerenchyma - *Opuntia*
b) Age pyramid - Biome
c) ***Parthenium hysterophorus*** - **Threat to biodiversity**
d) Stratification - Population

5. An association of individuals of different species living in the same habitat and having functional interactions is (Re-AIPMT 2015)
a) Population b) Ecological niche
c) **Biotic community** d) Ecosystem

6. Roots play in significant role in absorption of water in (Re-AIPMT 2015)
a) Wheat b) Sunflower
c) ***Pistia*** d) Pea

7. If we uncover half of the forest covering the earth, what crisis will be produced at most and the first? (AIPMT 1996)
a. Some species will be extinct
b. Population and ecological imbalance will rise up
c. Energy crisis will occur
d. Rest half forests will maintain this imbalance.

8. Most animals are tree dwellers in a (AIPMT 2015)
a) **Tropical rain forest**
b)Coniferous forest
c) Thorn woodland
d) Temperate deciduous fo

9. *Cuscuta* is an example of (AIPMT Mains 2012)
a) **Ectoparasitism** b) Brood parasitism
c) Predation d) Endoparasitism

10. Large woody vines are more commonly found in (AIPMT Prelims 2011)
a) Alphine forests b) Temperate forests
c) Mangroves d) **Tropical rain forests**

11. Niche overlap indicates (AIPMT Prelims 2006)

a) Active co-operation between two species
b) Two different parasites on the same host
c) **Sharing of one or more resources between the two species**
d) Mutualism between two species

12. Which one of the following pairs is **mismatched?** (AIPMT Prelims 2005)

a) Savanna – Acacia trees
b) **Prairie – Epiphytes**
c) Tundra – Permafrost
d) Coniferous forest – Evergreen trees

13. Which ecosystem has the maximum biomass? (NEET 2017)

a) Grassland ecosystem
b) Pond ecosystem
c) Lake ecosystem
d) **Forest ecosystem**

14. Which of the following would appear as the pioneer organisms on bare rocks? (NEET 2016)

a) Mosses b) Green algae
c) **Lichens** d) Liverworts

15. In which of the following both pairs have correct combination? (NEET 2015)

a)	Gaseous nutrient cycle Sedimentary nutrient cycle	Nitrogen and Sulphur Carbon and Phosphorous
b)	Gaseous nutrient cycle Sedimentary nutrient cycle	Sulphur and Phosphorous Carbon and Nitrogen
c)	**Gaseous nutrient cycle** **Sedimentary nutrient cycle**	**Carbon and Nitrogen** **Sulphur and Phosphorous**
d)	Gaseous nutrient cycle Sedimentary nutrient cycle	Carbon and Sulphur Nitrogen and Phosphorous

16. Secondary succession takes place on / in (NEET 2015 cancelled)

a) newly created pond b) newly cooled lava
c) bare rock d) **degraded forest**

17. In an ecosystem the rate of production of organic matter during photosynthesis is termed as (NEET 2015 cancelled)

a) Secondary productivity
b) net productivity
c) Net primary productivity
d) **gross primary productivity**

18. Natural reservoir of phosphorous is (NEET 2013)

a) **rock** b) fossils
c) sea water d) animal bones

19. Secondary productivity is rate of formation of new organic matter by (NEET 2013)

a) **consumers** b) decomposers
c) producers d) parasites

20. Which one of the following processes during decomposition is correctly described? (NEET 2013)

a) Catabolism – Last step in the decomposition under fully anaerobic condition
b) Leaching – Water soluble inorganic nutrient rise to the top layers of soil
c) **Fragmentation – Carried out by organisms such as earthworms.**
d) Humification – Leads to the accumulative of a dark coloured substance humus which undergoes microbial action in a very fast rate.

21. Which one of the following is not a functional unit of an ecosystem? (AIPMT 2012)

a) Energy flow b) decomposition
c) Productivity d) **stratification**

22. The upright pyramid of number is absent in (AIPMT 2012)

a) Pond b) **forest**
c) lake d) grassland

23. The rate of formation of new organic matter by rabbit in a grassland is called (Mains 2012)
a) net productivity
b) **secondary productivity**
c) net primary productivity
d) gross primary productivity

24. The second stage of hydrosere is occupied by plants like (Mains 2012)
a) *Azolla* b) *Typha*
c) *Salix* d) ***Vallisneria***

25. Which one of the following is a characteristic feature of cropland ecosystem? (NEET 2016)
a) Ecological succession
b) Absence of soil organisms
c) **Least genetic diversity**
d) Absence of weeds

26. Most animals that live in deep oceanic waters are (Re-AIPMT 2015)
a) **Detritivores**
b) Primary consumers
c) Secondary consumers
d) Tertiary consumers

27. During ecological succession (Re-AIPMT 2015)
a) The changes lead to a community that is in near equilibrium with the environment and is called pioneer community.
b) **The gradual and predictable change in species composition occurs in a given area**.
c) The establishment of a new biotic community is very fast in its primary phase.
d) The number and types of animals remain constant.

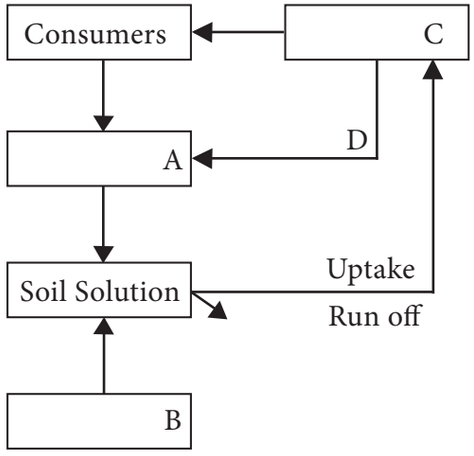
28. The mass of living material at a trophic level at a particular time is called (AIPMT 2015)
a) **Standing crop**
b) Gross primary productivity
c) Standing state
d) Net primary productivity

29. Match the following and select the **correct** option (AIPMT 2014)

Column I	**Column II**
(I) Earthworm	(i) pioneer species
(II) Succession	(ii) Detritivore
(III) Ecosystem service	(iii) Natality
(IV) Population growth	(iv) Pollination

	I	II	III	IV
a)	i	ii	iii	iv
b)	iv	i	iii	ii
c)	iii	ii	iv	i
d)	**ii**	**i**	**iv**	**iii**

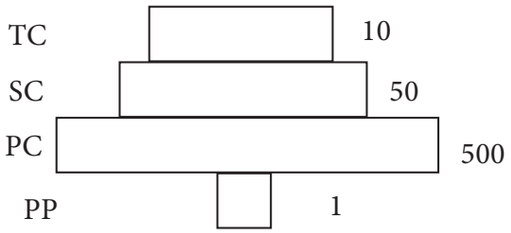
30. Given below is a simplified model of phosphorous cycling in a terrestrial ecosystem with four blanks (A – D. Identify the blanks. (AIPMT 2014)



	A	B	C	D
a)	Rock minerals	Detritus	Litter fall	Producers
b)	Litter fall	Producers	Rock minerals	Detritus
c)	**Detritus**	**Rock minerals**	**Producers**	**Litter fall**
d)	Producers	Litter fall	Rock minerals	Detritus

31. If 20 J of energy is trapped at producer level, then how much energy will be available to peacock as food in the following chain? (AIPMT 2014)
Plant → Mice → Snake → Peacock
a) **0.02 J** b) 0.002 J
c) 0.2 J d) 0.0002 J

32. Given below is an imaginary pyramid of numbers. What could be one of the possibilities about certain organisms at some of the different levels ? (AIPMT Prelims 2012)



a) Level one PP is 'pipal trees' and the level SC is 'sheep'.
b) Level PC is 'rats' and level SC is 'cats'
c) **Level PC is 'insects' and level SC is 'small insectivorous birds'**
d) Level PP is 'phytoplanktons' in sea and 'whale' on top level TC

33. Which one of the following statements for pyramid of energy is incorrect, whereas the remaining three are correct? (AIPMT Prelims 2011)
a) It is upright in shape
b) Its base is broad
c) It shows energy content of different trophic level organisms
d) **It is inverted in shape**

34. Which one of the following animals may occupy more than one trophic levels in the same ecosystem at the same time? (AIPMT Mains 2011)
a) Goat b) Frog
c) **Sparrow** d) Lion

35. Both hydrarch and xerarch successions lead to (AIPMT Mains 2011)
a) Highly dry conditions
b) Excessive wet conditions
c) **Medium water conditions**
d) Xeric conditions

36. Of the total incident solar radiation the proportion of PAR is (AIPMT Prelims 2011)
a) More than 80% b) About 70%
c) About 60% d) **Less than 50%**

37. The breakdown of detritus into smaller particles by earthworm is a process called (AIPMT Mains 2011)
a) Mineralisation b) Catabolism
c) Humification d) **Fragmentation**

38. The biomass available for consumption by the herbivores and the decomposers is called (AIPMT Prelims 2010)
a) Gross primary productivity
b) **Net primary productivity**
c) Secondary productivity
d) Standing crop

39. The correct sequence of plants in a hydrosere is (AIPMT Prelims 2009)
a) ***Volvox*** → ***Hydrilla*** → ***Pistia*** → ***Scirpus*** → ***Lantana*** → **Oak**
b) *Pistia*→*Volvox*→*Scirpus*→*Hydrilla*→Oak → *Lantana*
c) Oak→*Lantana*→*Volvox*→*Hydrilla*→*Pistia* →*Scirpus*
d) Oak→*Lantana*→*Scirpus*→*Pistia*→*Hydrilla* →*Volvox*

40. About 70% of the total global carbon is found in (AIPMT Prelims 2008)
a) Forests b) Grasslands
c) Agro ecosystems d) **Oceans**

41. Consider the following statements concerning food chains
i) Removal of 80% tigers from an area resulted in greatly increased growth of vegetation.
ii) Removal of most of the carnivores resulted in an increased population of deers.
iii) The length of food chains is generally limited to 3 – 4 trophic levels due to

energy loss.

iv) The length of food chains may vary from 2 to 8 trophic levels.

Which two of the above statements are correct? (AIPMT Prelims 2008)

a) i and ii b) **ii and iii**

c) iii and iv d) i and iv

42. Which one of the following is not used for construction of ecological pyramids? (AIPMT Prelims 2006)

a) Dry weight

2) Number of individuals

c) Rate of energy flow

4) **Fresh weight**

43. The UN Conference of Parties on climate change in the year 2012 was held at (NEET 2015)

a. Lima b. Warsaw

c. Durban **d. Doha.**

44. Which of the following are most suitable indicators of SO_2 pollution in the environment? (NEET 2015)

a. Algae b. Fungi

c. Lichens d. Conifers

45. Which of the following is not one of the prime health risks associated with greater UV radiations through the atmosphere due to depletion of stratospheric ozone? (NEET 2015)

a. Damage to eyes

b. Increased liver cancer

c. Increased skin cancerd.

d. Reduced Immune system

46. A location with luxuriant growth of lichens on the trees indicates that the (AIPMT 2014)

a. trees are very healthy

b. trees are heavily infested

c. location is highly polluted

d. location is not polluted.

47. The ozone of atmosphere in which the ozone layer is present is called (AIPMT 2014)

a. ionosphere b. mesosphere

c. stratosphere d. troposphere

48. Which one of the following is a wrong statement? (AIPMT 2012)

a. Most of the forests have been lost in tropical areas.

b**. Ozone in upper part of atmosphere is harmful to animals.**

c.Greenhouse effect is a natural phenomenon.

d. Eutrophication is a natural phenomenon in freshwater bodies.

49. Good ozone is found in the (Mains 2011)

a. mesosphere b.troposphere

c. stratosphere d. ionosphere

50. Chipko movement was launched for the protection of (AIPMT 2009)

a. **forests** b. livestock

c.wetlands d.grasslands

51. Identify the correctly matched pair. (AIPMT 2005)

a. Basal convention conservation - Biodiversity

b.Kyoto protocol -Climatic change

c. Montreal protocol -Global warming

d. Ramsar convention -Ground water pollution

52. Common indicator organism of water pollution is (AIPMT 2004)

a. *Lemna pancicostata*

b. *Eichhornia crassipes*

c. *Escherichia coli*

d. *Entamoeba histolytica*

53. Which country has the greatest contribution for the hole formation in ozone layer? (AIPMT 1996)

a. Russia b. Japan

c. USA d Germany

UNIT X - Economic Botany

1. The name of Dr. Norman Borlaug is associated with (JIPMER 2007)

   a) **Green revolution**
   b) Yellow revolution
   c) White revolution
   d) Blue revolution

2. Which of the following is generally used for induced mutageneis in crop plants (JIPMER 2007)

   a) Alpha b) X-ray
   c) UV ray d) **Gamma ray**

3. A man-made allopolyploid cereal crop is (OJEE 2010)

   a) *Hordeum vulgare* **b) *Triticale***
   c) *Raphanus brassica* d) *Zee mays*

4. Objective of plant breeding is (MP PMT 2001)

   a) better yield
   b) better quality
   c) disease / stress resistance
   d) All of the above

5. Selection is a method of (MP Pmet 2001)

   a) cytology b) plant phycology
   c) plant breeding d) genetics

6. Green revolution in India occurred during (AIPMT 2012)

   a) 1960's b) 1970's
   c) 1980's d) 1950's

7. Jaya and ratna developed for green revolution in India are the varieties of (AIPMT 2011)

   a) maize **b) rice**
   c) sugarcane d) wheat.

9. First man-made cereal triticale is (HPMT 2008)

   a) Octaploid **b) hexaploid**
   c) Both a & b d) diploid

11. In plant breeding programmes, the entire collection (of plants / seeds) having all the diverse alleles for all genes in a given crop is called (NEET 2013)

    a) cross hybridization among the selected parents
    b) evaluation is selection of parents
    c) **germplasm collection**
    d) selection of superior recombinants

16. An example for semi dwarf variety of wheat is (HPPMT 2012)

    a) IR 8 b) **Sonalika**
    c) *Triticum* d) *Saccharum*

17. Himgiri developed by hybridization is selection for disease resistance against rust pathogen is a variety of (AIPMT 2011)

    a) Chilli b) Maize
    c) Sugarcane d) **Wheat**

18. Breeding of crops with high levels of minerals, vitamins and proteins is called (CBSE AIPMT 2010)

    a) somatic hybridization
    b) **biofortification**
    c) bio magnification
    d) micro propagation

19. The reason for vegetatively reproducing crop plants to suit for maintaining hybrid vigour is that (AIPMT 1998)

    a) they are more resistant to disease
    b) **once a desired hybrid produced, no chances of losing it**
    c) they can be easily propagated
    d) they have a longer life span.

20. Wonder wheat is a new wheat variety developed by (AIIMS 2009)

    a) **Mexico's International Wheat and Maize improvement centre**
    b) Indian National Botanical Research Institute
    c) Australian crop Improvement centre
    d) African Crop Improvement centre

HIGHER SECONDARY - SECOND YEAR
BIOLOGY: BOTANY PRACTICALS

INTRODUCTION

Laboratory is a place where ideas and concepts can be tested through experiments. Laboratory investigations in biology increase the reasoning abilities, brings scientific attitude in a learner and also helps in acquisition of skills of scientific processes. Hence, a biology student too, is obliged to attend practical in laboratory with utmost sincerity, honesty and inquisitiveness. The practical work includes

- Study of permanent slides
- Microscopic preparation of slides
- Study of preserved and fresh specimens
- Section, cutting and mounting
- Analysing the problem and solving it
- Physiological experiments, etc.

GENERAL INSTRUCTIONS

In order to perform experiments successfully, a learner needs to go to the Biology Laboratory well prepared. This includes the following.

VMNJ53

1. Laboratory record book
2. Dissection box
3. Laboratory manual
4. A laboratory coat or apron
5. A hand towel
6. Drawing pencil (HB) and pencil eraser to record various experiments and to draw diagrams
7. Any item more as per the instructions of the teacher

While in the laboratory, a student should be very careful and methodical. One should listen carefully to the instructions given by the teacher / instructor before performing an experiment. Maintain a complete silence and working atmosphere in the laboratory. Record keeping is most important in practical. Diagrams should be correctly drawn and well labelled. Always get the signature of the teacher in the practical note book on each day after the practical class.

However, it is important that every student of Botany / Biology may pay proper attention to the practical work and should try to acquire basic laboratory skills and develop a keen sense of observation and acquire a sound training in the reporting of the work done.

If the material suggested for a particular experiment is not available, a suitable alternate material may be used.

BIOLOGY BOTANY PRACTICALS

MODEL QUESTION

I.	Identify the given slide 'A' and give any two reasons. Draw a neat labelled diagram.
II.	Identify the given specimen / model / photograph 'B" and give any two reasons.
III.	Analyse the given ecological / genetic problem 'C'. Solve it by giving appropriate reasons.
IV.	Write the aim, procedure, observation and inference of the given experiment 'D'.
V.	Identify the economically important plant product 'E'. Mention its Botanical name, useful part and their uses.

MARKS ALLOTMENT-PRACTICAL EXAMINATION

I.	A	Identification – ½ , Reason (any two) – ½ , Diagram – ½ , Labelling – ½	2
II.	B	Identification – ½ , Reason (any two) – ½	1
III.	C	Identification – ½ , Solve/ Construct– ½, Reason/ Observation and Inference/ Answer – ½	1 ½
IV.	D	Aim – ½ , Procedure – ½ , Table (Observation and Inference) – ½	1 ½
V.	E	Identification and Botanical name – ½ , Useful part – ½, use – ½.	1 ½
		Total 7 ½ marks	
		Record 1 ½ marks	
		Skill 1 marks	
		Maximum marks 10 marks	

QUESTION No- I (A) - Preparation and Demonstration of Slides	
Note: Teacher has to prepare a temporary slide using fresh specimen for demonstration. (During examination permanent slides can be used if temporary slide preparation is not possible).	
Exercise 1	T.S. of Mature anther
Exercise 2	L.S. of an Angiospermic ovule
Exercise 3	T.S. of *Nerium* leaf
QUESTION No- II (B) - Fresh or preserved specimens and Models / Photographs / Charts	
Exercise 4	Adaptations of flowers for pollination by different agents – Wind, Insects.
Exercise 5	Structure of Dicotyledonous seed – Gram (*Cicer*).
Exercise 6	Picture of a vector (pBR 322)
Exercise 7	Plant tissue culture – Callus with plantlets
Exercise 8	Types of ecological pyramids – Number, Biomass, Energy
QUESTION No- III (C) - Problems – Genetics and Ecology	
Exercise 9	To verify Mendel's Monohybrid cross
Exercise 10	Analysis of seed sample to study Mendelian Dihybrid Ratio
Exercise 11	Flow of energy and Ten percent law
Exercise 12	Determination of population density and percentage frequency of different plant species of given area by Quadrat method
Exercise 13	Chromosomal aberration – Deletion, Duplication, Inversion
Exercise 14	Genetic / Linkage maps
QUESTION No- IV (D) - Experiments	
Exercise 15	Study of pollen germination on a slide
Exercise 16	Study of pH of different types of soils
Exercise 17	Isolation of DNA from plant material
QUESTION No- V (E) -Economic importance of plants	
Exercise 18	Economically important plant products and their uses:Sesame / Gingelly oil, Rubber, Aval (Flaked rice), Rose water, Henna powder,Aloe gel

BIOLOGY BOTANY PRACTICALS

I - Preparation and Demonstration of Slides

Note: Teacher has to prepare a temporary slide using fresh specimen for demonstration. (During examination permanent slides can be used if temporary slide preparation is not possible)

Exercise 1: T.S of Anther

Aim: To study and identify the given slide – T.S of Anther

Principle: Androecium is made up of stamens. Each stamen possesses an anther and a filament. Anther bears pollen grains which represent the male gametophyte.

Requirements: Anther of *Datura metel*, glycerine, safranin, slide, cover slip, blade, brush, needle to prepare temporary slides, permanent slide of T.S. of mature anther and compound microscope.

Collect buds and opened flowers of *Datura metel*. Dissect the stamens, separate the anthers and take thin sections and observe the structure under the microscope. Record the various stages of anther from your observation.

Diagnostic Features

- A mature anther is bilobed (dithecous) and the two lobes are joined by a connective.
- Each anther lobe has two pollen chambers in which pollen grains are produced.
- A microsporangium or pollen sac is surrounded by four wall layers. They are epidermis , endothecium, middle layers and tapetum.
- Centre of the microsporangium (pollen sac) is filled with haploid pollen grains.

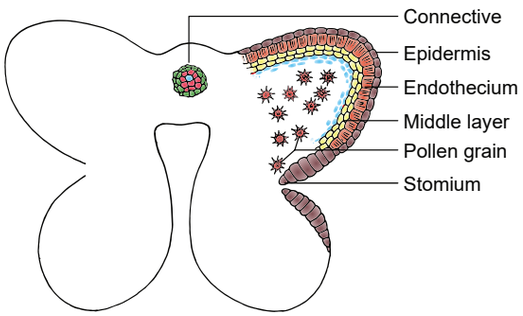


Figure 1: Pollen grain stage of anther

Exercise 2: L.S of an Angiospermic ovule.

Aim: To study and identify the L.S. of an Angiospermic Ovule.

Principle: In female reproductive part of a flower, the basal swollen part is ovary. The ovules are present inside the ovary, later they develops to seed.

Requirement: Permanent slide of L.S. of Ovule, microscope

Diagnostic Features

- Ovule or megasporangium is protected by one / two coverings called integuments.
- The stalk of the ovule is called funicle.
- The point of attachment of funicle to the body of the ovule is known as hilum.
- The body of the ovule is made up of a central mass of parenchymatous tissue called nucellus.
- The integuments form a pore called micropyle and the region opposite to the micropyle is called as chalaza.
- The nucellus has a large, oval, sac like structure towards the micropylar end called embryo sac.
- A mature ovule, has 8 nuclei in its embryo sac.

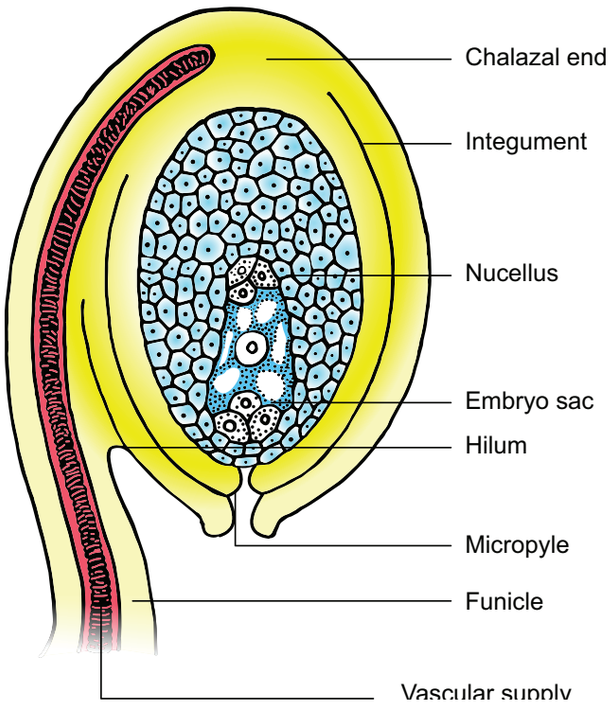


Figure 2: L.S of ovule

Exercise 3: T.S. of *Nerium* Leaf

Aim: To observe and understand the xerophytic adaptations found in *Nerium* leaves for living in dry or xeric habitat.

Principle: The plants which are living in dry or xeric condition are known as Xerophytes.

Requirements: *Nerium* leaf, few pieces of carrot / pith / styrofoam, blade, brush, needle, compound microscope, glycerine, coverslip, wash glass, microslide, saffranin solution, petri dish, etc.

Start cutting transverse sections of *Nerium* leaf placing it in between a piece of carrot. Select the thinnest section of the material with the help of a delicate brush. Take a clean watch glass with water, transfer thin sections of the material. Put a few drops of safranin stain in the watch glass with water. Leave it for 3-5 minutes. Drain off stain and wash with water if necessary. Put the thinnest section in the centre of the slide. Put a drop of glycerine over the material. Cover it with a coverslip with the help of needle. Observe it under a compound microscope.

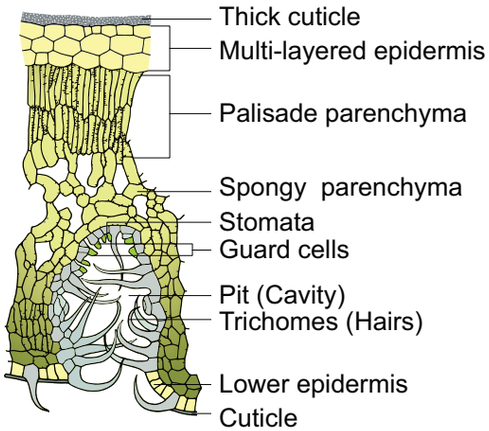


Figure 3: T.S. of Nerium leaf

Diagnostic Features

- Presence of multilayered epidermis with thick cuticle.
- Sunken stomata are present only in the lower epidermis.
- Mesophyll is well differentiated into palisade and spongy parenchyma.
- Mechanical tissues are well developed.

II - Fresh or preserved specimens and Models / Photographs / Charts

Exercise 4: Adaptations of flowers for pollination by different agents.

Aim: To study the adaptations in flowers for pollination by different agents (wind and insects)

Principle: The process of transfer of pollen grains from the anther to stigma of a flower is called **pollination**.

Requirements: Fresh flowers of maize or any other cereal / gram, any insect pollination flowers like *Salvia*, *Calotropis, Ocimum* and Asteraceae flowers.

Place the given flower on a slide and observe it with the help of hand lens. Note down the adaptations of the flowers meant for pollination by the external agents.

5 A. Wind Pollinated Flowers - Anemophily

Diagnostic Features

- The flowers are small, inconspicuous, colourless, odourless and nectarless.
- Anthers and stigmas are commonly exerted.
- Pollen grains are light, small, powdery and produced in large numbers.
- The stigmas are large, sometimes feathery and branched adapted to catch the pollens.

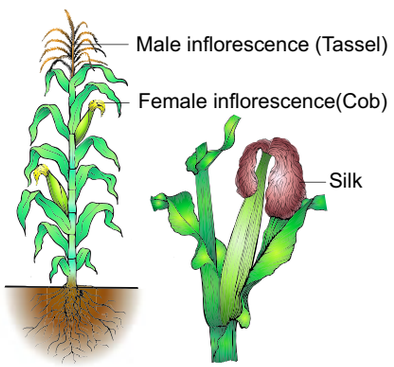


Figure 4a: Maize

5 B. Insect Pollinated Flowers - Entemophily

Diagnostic Features

- The flowers are showy, brightly coloured and scented.
- The flowers produce nectar or edible pollen.
- Anthers and stigmas are commonly inserted.
- Stigmas are usually unbranched and flat or lobed.

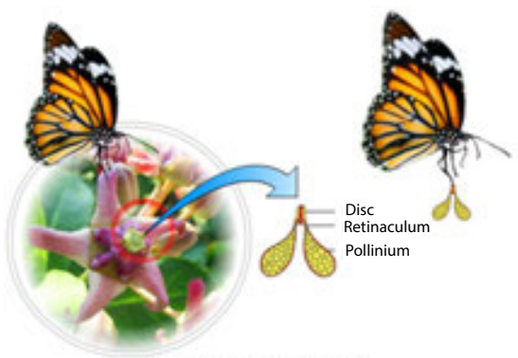


Figure 4b: *Calotropis*

Exercise 5: Dicot seed

Aim: To study and identify the Dicot seed

Principle: The fertilized ovule is called seed and possesses an embryo, endosperm and a protective coat. Seeds may be endospermous or non endospermous.

Requirements: Chick pea, bowl, water

Soak the seeds of chick pea or gram in water for 2 – 3 hours. Drain the water and place the seeds in a moist cotton cloth for 2 – 3 days. Observe for germination. Select some sprouted seeds, observe under a dissection microscope and record the parts.

Diagnostic Features

- Seeds of gram have two cotyledons and an embryonal axis.
- Each seed is covered by two seed coats (a) Testa – outer coat and (b) Tegmen – inner coat.
- The embryonal axis consists of radicle and plumule.
- The portion of the embryonal axis above the level of cotyledons is called epicotyl. It terminates into the plumule.
- The portion of the embryonal axis below the level of cotyledons is called hypocotyl. It terminates into the radicle or root tip.

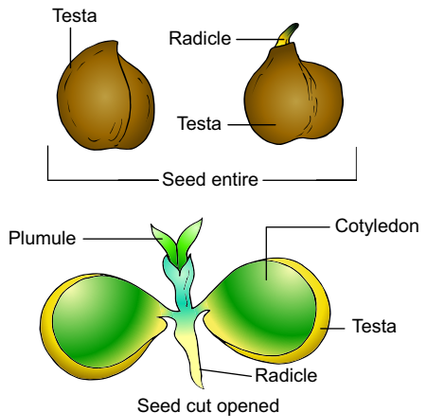


Figure 5: Dicot seed – Gram (*Cicer*)

Exercise 6: E.coli cloning vector (pBR 322)

Aim: To study and identify the features of cloning vector – pBR 322

Principle: Vectors are used as carriers to deliver the desired foreign DNA into a host cell.

Requirements: Models/ Photographs / Pictures of E.coli Cloning vector pBR 322.

Diagnostic Features

- pBR 322 plasmid is a reconstructed plasmid containing 4361 base pairs and most widely used as cloning vector.
- In pBR, p denotes plasmid and B and R respectively the notes of scientists Boliver and Rodriguez who developed the plasmid. The number 322 is the number of plasmids developed from their laboratory.
- It contains two different antibiotic resistance genes and recognition site for several restriction enzymes (Hind III, Eco R I, Bam H I, Sal I, Pvu II, Pst I, Cla I), Ori and antibiotic resistance genes (amp^R and tet^R). Rop codes for the proteins involved in the replication of the plasmid.

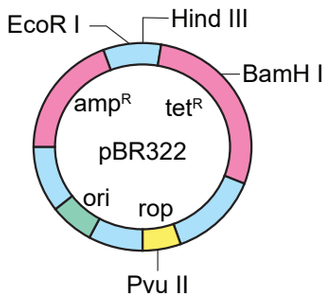


Figure 6: E-coli cloning vector (pBR 322)

Exercise 7: Plant tissue culture – Callus with plantlets

Aim: To study and identify the Callus with plantlets.

Principle: Growing the plant cells, tissues and organs in an artificial, synthetic medium under controlled conditions is called plant tissue culture. The technique of cloning plant is easier than animals because plant cells are simple in structure and most plant cells shows totipotency (i.e) ability to regenerate from cells.

Requirements: Model / Photograph / Picture of callus with plantlets.

Diagnostic Features

- The callus is an unorganized mass of undifferentiated tissue.
- The mechanism of callus formation is that auxin induce cell elongation and cytokinin induces cell division as a result of which masses of cells are formed.
- Roots and shoots are differentiated from the callus.

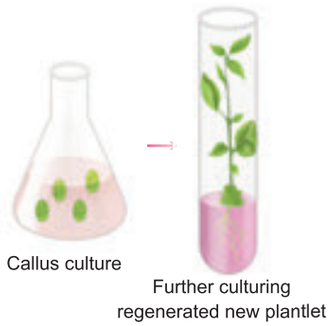


Figure 7: Callus with plantlets

Exercise 8: Types of ecological pyramid

Aim: To study and identify the different types of ecological pyramids

Principle: The relationship between different trophic levels in an ecosystem when shown diagrammatically appear as 'ecological pyramids'. In these ecological pyramids, the successive tiers represent successive trophic levels towards the apex. The base of the pyramid is of producers, the next one above it is of herbivores and the top tiers are of carnivores. The top most or apex represents the tertiary or top level consumers.

Requirements: Models / Photographs / Pictures of different types of ecological pyramid.

8 A. Pyramid of numbers

Diagnostic Features

- The number of organism that are present in successive trophic levels of an ecosystem is shown in the pyramid of numbers of a grassland ecosystem.
- There is a gradual decrease in the number of organisms in each trophic level from producers to primary consumers, then to secondary consumer, and finally to tertiary consumers.
- Therefore, pyramid of number in grassland ecosystem is always upright.

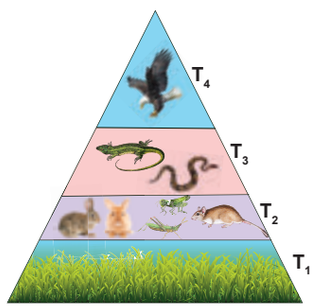


Figure 8 a: Pyramid of numbers in grassland ecosystem

T_1 - Producers | T_2 - Herbivores | T_3 - Secondary consumers | T_4 - Tertiary consumers

8 B. Pyramid of biomass

Diagnostic Features

- Pyramid of biomass represents the total biomass or standing crop (dry weight) of organisms in each trophic level at a particular time.
- In aquatic ecosystem, the bottom of the pyramid is occupied by the producers, which comprises very small organisms (algae and phytoplanktons) possessing the least biomass and so the value gradually increases towards the tip of the pyramid.
- Therefore, here the pyramid of biomass is always inverted in shape.

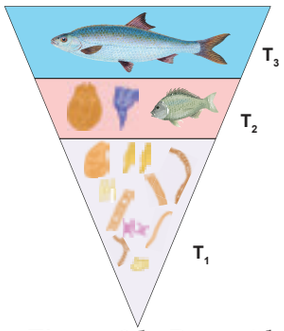


Figure 8 b: Pyramid of biomass in aquatic ecosystem

T_1 - Producers | T_2 - Herbivores | T_3 - Secondary consumers |

8 C. Pyramid of energy

Diagnostic Features

- Pyramid of energy represents the number of joules transferred from one trophic level to next.
- The bottom of the pyramid of energy is occupied by the producers. There is a gradual decrease in energy transfer at successive trophic levels from producers to the upper levels.
- Therefore pyramid of energy is always upright.

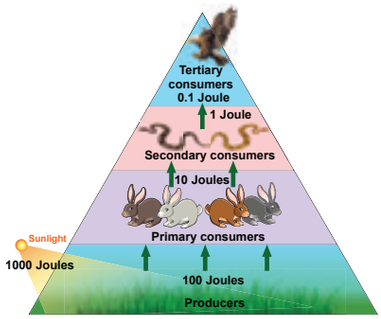


Figure 8 c: Pyramid of Energy

III - Solving the Problems

Exercise 9: To verify Mendel's Monohybrid cross

NOTE: Student have to work in pairs to perform this experiment and record the data in the observation and record note book with the help of the teacher.

Need not consider this Monohybrid cross experiment for Board Practical Examination.

Aim:

To verify Mendel's Monohybrid cross.

Principle:

When two purelines with contrasting traits of a particular character (phenotype) are crossed to produce the next generation (F_1 generation), all the members of the progeny are of only one phenotype, i.e. of one of the two parents. The phenotype that appears is called dominant and the one that does not appear is called recessive. When the F_1 plants are selfed, the progeny i.e. the F_2 generation, is in the ratio of 3 dominant : 1 recessive (¾ : ¼ of 75% : 25%). This reappearance of the recessive phenotype in F_2 generation, verifies Mendel's Monohybrid cross.

Requirements:

64 yellow and 64 green plastic beads, all of exactly same shape and size (when beads are not available, pea seeds may be painted and used). Plastic beakers, petri dish and a napkin / hand towel.

Procedure

Make the student to work in pairs to perform the experiment. Follow the steps in given sequence.

1. Put 64 yellow beads in one beaker and 64 green beads in the other to represent male and female gametes respectively. Let the yellow bead be indicated by 'Y' and the green bead by 'y'
2. Take a bead from each container and place them together (it represents fertilization) on the hand towel spread before you on the table.
3. Just like the previous step, continue to pick beads and arrange them in pairs. Thus 64 pairs of beads are obtained representing the 64 heterozygous F_1 progeny.

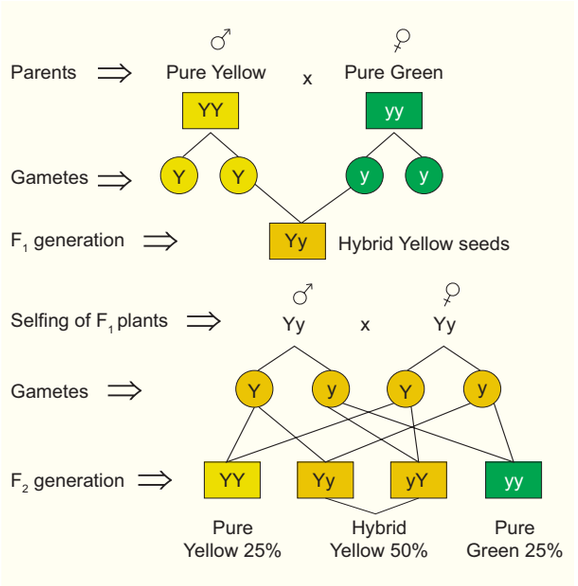


Figure 9 : Monohybrid cross

4. Put 32 F_1 progeny in one petridish and the remaining 32 in another petridish (representing the F_1 males and females).
5. To obtain the F_2 generation, the student should withdraw one bead from one beaker labelled male and one from the other beaker labelled female keeping his / her eyes closed (to ensure randomness) and put them together on the hand towel spread over the table. Continue this process till all the beads are paired. Thus 64 offsprings of F_2 progeny are obtained.
6. Note the genotype (YY or Yy or yy) of each pair and their possible phenotype.
7. Pool all the data and calculate the genotypic and phenotypic ratios.

Observation:

Record the result in the following table:

Generation	Total Number of individuals	Genotypes			Phenotype(s)
		YY	Yy	yy	
F_1					
	Total				
F_2					
	Total				

Phenotypic ratio : in F_1 _____

in F_2 _____

Genotypic ratio : in F_1 _____

in F_2 _____

Inference:

The results are so because when the F_1 individuals are crossed together to raise the F_2 generation, each F_1 individual produces two types of gametes: 50% having dominant allele and the remaining 50% having recessive allele. These gametes undergo random fusion during fertilization to produce the F_2 generation. According to simple probability of mixing of opposite sex gametes, offsprings of three genotypes are likely to appear as follows:

Among these, proportion of dominant phenotype would be YY + Yy = yellow and recessive phenotype yy = green, which occur in 3 : 1 or 75% : 25% ratio.

This ratio of 3 :1 in the F_2 suggests that the hybrids or heterozygotes of F_1 generation have two contrasting factors or alleles of dominant and recessive type. These factors, though remain together for a long time, do not contaminate or mix with each other. They separate or segregate at the time of gamete formation so that a gamete carries only one factor, either dominat or recessive.

Precautions:

1. Take a sufficiently large number of seeds for analysis to minimise the error.
2. Observe the contrasting form of trait carefully.

Exercise 10: Analysis of seed sample to study Mendelian dihybrid ratio

Aim:

To analyse seed sample of pea for Mendelian dihybrid ratio of 9 : 3 : 3 : 1.

Principle:

In a dihyrbid cross, the segregation of one gene pair is independent of the segregation of the other pair. It means that when the factors (genes) for different characters inherited from parents do not remain linked in the offsprings, but their distribution in the gametes and in the progeny of subsequent generations is independent of each other.

Requirement:

Plastic beakers, Pea seed samples or plastic beads, tray, petri dishes, notebook, pencil / pen.

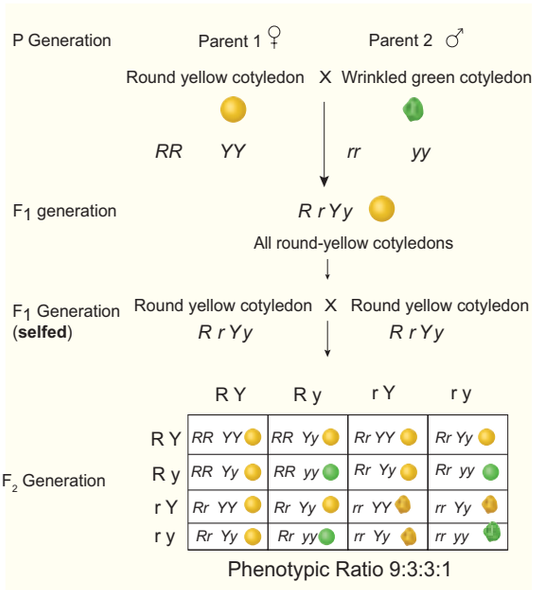


Figure 10 : Dihybrid cross

Teachers should select the Pea seed or plastic beads which represents the four types of traits such as yellow round, yellow wrinkled, green round and green wrinkled in the ratio of 9:3:3:1

Procedure:

1. Take a lot of about 160 Pea seeds or plastic beads in a tray.
2. Separate out yellow round, yellow wrinkled, green round and green wrinkled and put them in separate petridishes.
3. Note down the number of seeds in each plate and find out their approximate ratio.

Observation:

Present your finding in the form of a table.

Total Number of seeds observed	No. of yellow round seeds	No. of yellow wrinkled seeds	No. of green round seeds	No. of green wrinkled seeds	Approximate ratio
160	90	30	30	10	9 : 3:3:1

Inference:

The ratio of yellow round : yellow wrinkled : Green round : green wrinkled is approximately 9 : 3 : 3 : 1 which is exactly the same as obtained by Mendel for a dihybrid cross. This indicates that the contrasting genes for seed colour and seed shape show an independent assortment in the population of pea seeds.

Exercise 11: Flow of energy and Ten percent law

Aim:

To understand the unidirectional flow of energy in an ecosystem and transfer of energy follows the 10% law.

Principle:

The student studies about flow of energy and that only about 10% of energy is made available to the next trophic level. Large amount of energy about 90% is lost at each trophic level in a food chain.

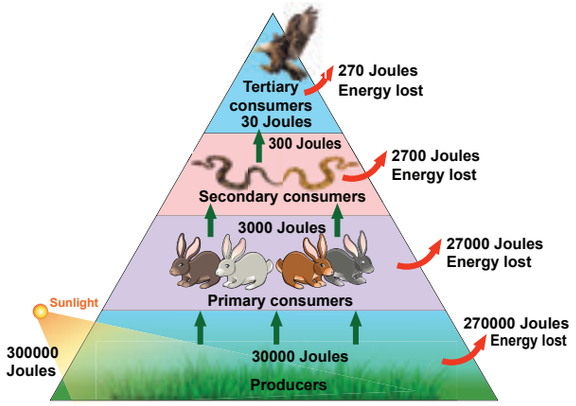


Figure 11: Ten percent law

Requirements:

Problems to be given to students based on different examples with alternating food chain and amount of energy.

The teacher must train the student by giving them various kinds of food chain with different values.

Problem

Analyse the food chain given below and find out the amount of energy received by the organism in third trophic level.

Sun

↓ Grass receives 30,000. J of energy from sun

Grass ⟶ Rabbit ⟶ Snake ⟶ Eagle

Given: The amount of energy in the producers, i.e. grass = 30,000 J.

Solution:

Grass	⟶	Rabbit	⟶	Snake	⟶	Eagle
T_1		T_2		T_3		T_4
Producer		Primary Consumer		Secondary Consumer		Tertiary Consumer

T_1 – Grass (Producer) = 30,000 J of energy

T_2 – Rabbit (Primary Consumer) = ?

T_3 – Snake (Secondary Consumer) = ?

According to the ten percent law, during the transfer of energy, only about 10% of the energy flows from each trophic level to the next lower trophic level. So 10% of energy from T_1 gets transferred to T_2

So T_2 - Rabbit (primary consumer) receives $30000 \times \frac{10}{100} = 3000$ J

Similarly, 10% of energy from T_2 gets transferred to T_3

So T_3 – Snake (Secondary consumer) receives $3000 \times \frac{10}{100} = 300$ J

Answer:

1. The third tropic level T_3 – (Snake) receives 300 J of energy.

Exercise 12: Determination of Population density and Percentage frequency by Quadrat method.

NOTE: Teachers can take the students to open space and teach them how to construct plot/ quadrats and to record the number of individuals of each plant species occurring in the quadrat. The percentage frequency should be calculated and entered in the practical observation and record note book. Examiner need not consider this experiment for Board Practical Examinations.

Aim:

To study population density and percentage frequency of different plant species of a given area by quadrat method.

Principle:

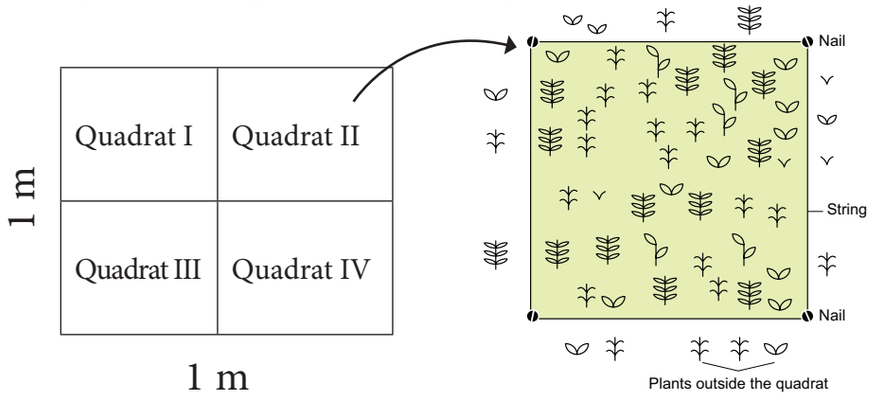
The number of individuals in a population never remains constant. It may increase or decrease due to many factors like birth rate, death rate, migration, etc. The number of individuals of a species presents per unit area or space of a given time is called population density. The population density and percentage frequency of different plant species can be determined by laying quadrats / segments of suitable size and recording of the number of individuals of each species occurring in the quadrat.

Requirements:

Metre scale, string or cord, hammer, nails, paper, pencil, etc.

Procedure:

1. In the selected site of study, hammer the nails firmly in the soil without damaging the vegetation.
2. Fix four nails to make a square plot.
3. Tie each end of the nails using a thread, to make 1 m X 1 m plot.
4. If the number of plants in the plot is large, the plot can be divided into quadrats.
5. Count the number of individuals of a species "A" present in the first quadrat and record the data in the table.
6. Similarly count the individuals of the species "A" in other quadrats respectively and record the data in the table.
7. Count the number of individuals of a species "B" present in the all quadrats and record the data in the table.
8. Repeat the same procedure for other species and record the data in the table.



A plot

Figure 12: Occurrance of plant species in a quadrat

$$\text{Population Density} = \frac{\text{Total number of individuals in all the quadrats studied}}{\text{Total number of quadrats studied}}$$

$$\text{Percentage frequency} = \frac{\text{Total number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \text{ X } 100$$

Observation and Inference:

Different plant species, their population density and percentage frequency occurring in a given area.

S. No.	Plant species	No. of individuals per quadrat				Total number of individuals in all the quadrats studied (N)	Total number of quadrats in which each species occurred (A)	Total Number of quadrats studied (B)	Population Density (N/B)	Frequency percentage (A/B) x 100
		I	II	III	IV					
1										
2										
3										
4										
5										

Precautions:

1. The measurement of quadrat should be accurate.
2. The string or cord used should not be very thick.

Exercise 13: Chromosomal aberrations – Deletion, Duplication and Inversion

Problem:

Given below is the representation of a kind of chromosomal aberration such as deletion, duplication and inversion. Identify and give reasons for identification. Also mentions its significance.

Aim:

To understand the abnormality in the chromosomal structure in an organism.

Principle:

To study about the chromosomal aberration which can occur due to ionizing radiations or chemicals. On the basis of breaks and reunions in the chromosomal segment different types of aberrations can be recognized.

Requirements:

Copper wire, Alphabets marked (A to H) yellow colour beads denotes gene, and red colour bead without alphabet denote centromere. Using this materials make different kinds of chromosomal segments with specific gene sequence, that can be given to the students and asked to analyse the aberration involved in it.

Procedure:

1. Make a normal chromosome model using copper wire and yellow beads and place it on the table. In the model chromosome with gene sequence A to H, along with centromere (red bead).
2. For Deletion - Give yellow colour beads without one or more marked alphabets A to H (The lack

of any one or more beads denotes deletion type of chromosomal aberration).

3. For Duplication – Give yellow colour beads with addition of one or more marked alphabets A to H (The repetition of one or more beads denotes duplication type of chromosomal aberration).
4. For Inversion – Give yellow colour beads which marked alphabets from A to H as in normal chromosome. (There is no addition or deletion of beads (A to H) given, so the students can construct the inverted segment of the chromosome using the given beads).

Based on the type of beads given the student has to identify and construct the relevant chromosomal aberration.

13 A. Chromosomal Aberration – Deletion

Reasons:

1. The deletion of the chromosomal segement A and D. (Refer figure 13a)
2. When there is a loss of a segment of the genetic material in a chromosome it is called deletion.

Significance:

Most of the deletions lead to death of an organism.

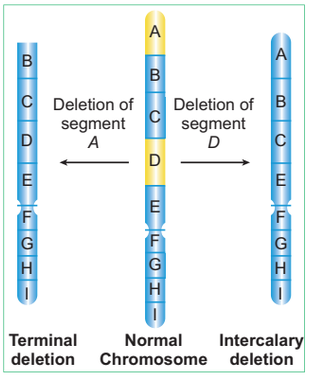


Figure: 13 a: Deletion

13 B. Chromosomal Aberration - Duplication

Reasons:

1. When a segment of a chromosome is present more than once in a chromosome, then it is called duplication (Tandem duplication)
2. The order of the genes in a chromosome is A, B, C, D, E, F, G, H and I. Due to aberration, the genes B and C are duplicated and the sequence of genes becomes A, B, C, B, C, D, E, F, G, H and I. (Refer figure 13b)

Significance:

Some duplications are useful in the evolution of the organism.

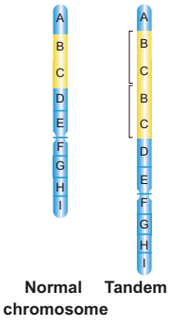


Figure 13 b: Duplication

13 C. Chromosomal Aberration - Inversion

Problem:

Given below is the representation of a kind of chromosomal aberration. Identify it giving reasons for your identification. Also mentions its significance.

Identification:

The given genetic problem is identified as inversion type of chromosomal aberration.

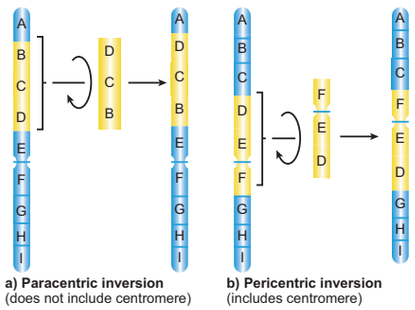


Figure: 13 c: Inversion

Reasons:

1. When the order of genes in a chromosomal segment is reversed due to rotation by an angle of 180°, it is called inversion.
2. The order of genes in a chromosome is A, B, C, D, E, F, G, H and I. Due to aberration, the sequence of genes become A, D, C, B, E, F, G, H and I (Refer figure 13c)

Significance:

Sometimes inversion is responsible for evolution of the organism.

NOTE: Likewise the teacher can give different types of chromosomal aberrations with various gene sequence to students for practise. The external examiner can also use the same technique by giving different gene sequence.

Exercise 14: Genetic / linkage maps

Aim:

To understand the frequency of recombination between the gene pairs on the same chromosome.

Principle:

To analyse the relative distance between the various genes and map their position in the chromosome, which is called genetic or linkage maps.

Requirements:

Different kinds of linkage / genetic maps can be constructed by giving the students the relative distance between the linked genes of a chromosome. A diagrammatic representation can be drawn showing the location and arrangement of genes and their relative distance between them.

Solve the Problem

Problem: There are three linked genes A, B and C in a chromosome. Percentage of crossing over (recombination frequency) between A and B is 20, B and C is 28 and A and C is 8. What is the sequence of genes on the linkage map?

Given: Percentage of crossing over between the 3 linked genes A – B = 20%, B – C = 28% and A – C = 8%.

Solution

Figure 14: Linkage Map

Reasons:

1. The frequency of crossing over is directly proportional to the relative distance of the genes on the chromosomes.
2. More crossing over = More distance between two genes and
   Less crossing over = Less distance between the two genes.

In the above problem, the sequence of the genes on the linkage map is B, A, C

NOTE: Teachers can give different crossing over percentage between its linked genes in a chromosome and make the students construct the linkage maps. The external examiner can also do the same for the Board Practical Examinations.

IV - Experiments

Exercise 15: Study of Pollen germination on a slide

NOTE: Pollen germination can be studied by dusting some pollens from common flowers like *Crotalaria*, *Hibiscus*, *Pisum*, etc. on a glass slide containing a drop of 10% sugar solution or tender coconut water or any nutrient medium.

Observe the slide after about 10 – 15 minutes under the low power of compound microscope. You will be able to observe the pollen tubes coming out of the pollen grains.

Aim: To study the pollen germination on a slide.

Requirements: Fresh seasonal flowers, cavity slide, cover slip, compound microscope, sucrose, boric acid, distilled water, beakers, etc.

Procedure:

1. Prepare a nutrient solution by dissolving 1 gm. of sucrose / 1 gm. of boric acid in 100 ml. of distilled water.
2. Take a clean cavity slide and put a few drops of nutrient solution in the cavity of the slide.
3. Dust a few pollen grains from the stamen of a mature flower on it.
4. View the slide in the microscope after 5 minutes and then observe it regularly for about half an hour.

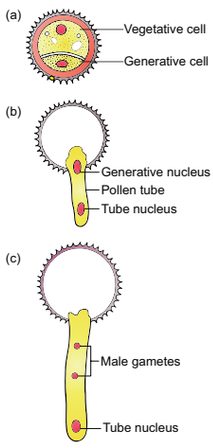


Figure 15: Pollen germination

Observation: In nutrient medium, the pollen grains germinate. The tube cell enlarges and comes out of the pollen grain through one of the germ pores to form a pollen tube. The tube nucleus descends to the tip of the pollen tube. The generative cell also passes into it. It soon divides into two male gametes.

Inference: Different stages of germinating pollens are observed. Some pollens are in their initial stage of germination while others have quite long pollen tube containing tube nucleus and two male gametes.

Precautions: 1. Flowers should be freshly plucked. 2. Use clean cavity slide to observe the pollen grains. 3. The slides should not be disturbed, otherwise position of pollen grains will get changed.

Exercise 16: Study of pH of different types of soil

Some nutrients become toxic in higher concentration. Therefore pH of the soil is an important chemical property of the soil. Plants thrive well in neutral or slightly acidic soils. The pH of the soil determines the types of soil organisms and also controls the solubility of different nutrients. The pH of soil ranges from 0 - 14.

a. pH level 7 - Neutral soil

b. pH level below 7 - Acidic soil

c. pH level above 7 -Alkaline soil

d. Optimum pH for plant growth ranges from 5.5 to 7.

Most plants thrive best in neutral pH. Slight acidity favours tree growth and forms forests. Slight alkalinity is favourable for grasses and legume crops.

Aim:

To study pH of different types of soil.

Requirements:

Soil samples (from two different sites such as crop soil, garden soil, roadside soil, pond soil, river bank soil), test tubes, funnel, filter papers, pH papers of different range, distilled water, beaker.

Figure 16: Study of pH of different types of soil

Procedure:

Dissolve one tablespoon or 1 gram of soil from each soil sample in 100 ml of distilled water in separate beakers. Stir the solutions well and keep aside for half an hour to settle down the suspended particles. Filter off each solution separately in different test tubes. Dip a small piece of broad range pH paper on each of the solution. Match the colour of the pH paper with the colour scale given on the pH paper booklet. This gives an approximate pH.

Observation:

Record the pH of different soil samples in the observation table.

S. No.	Soil sample	pH Value
1		
2		
3		

Inference:

Thus the pH value of different soil samples required for plant growth can be determined.

Precautions:

1. Wash the glassware thoroughly and get it dried before the experiment.
2. Dry the pH papers before comparing the colour with the colour scale.
3. Match the colour carefully and determine pH accurately.

Exercise 17: Isolation of DNA from plant materials

DNA is one of the nucleic acids found in living systems. DNA acts as the genetic material in most of the organisms.

Principle: Recombinant DNA technology has allowed breeders to introduce foreign DNA in other organisms including bacteria, yeast, plants and animals. Such organisms are called Genetically Modified Organisms (GMOs). Thus rDNA technology involves isolation of DNA from a variety of sources and formation of new combination of DNA.

Aim: To isolate DNA from available plant materials such as spinach leaves, fresh green pea seeds, green papaya, etc.

Requirements: Plant materials, mortar and pestle, beakers, test tubes, ethanol, etc.

Procedure: Take a small amount of plant material and grind it in a mortar with a little amount of water and sodium chloride. Make it into a solution and filter it. To this filterate, add liquid soap solution or any detergent solution and mix it with a glass rod. Then tilt the test tube and add

chilled ethanol and leave it aside in the stand. After half-an-hour we can observe the precipitated DNA as fine threads. DNA that separates can be removed by spooling

Observation: DNA appears as white precipitate of very fine threads on the spool.

Inference: Thus DNA can be isolated from the plant cell nucleus by this technique.

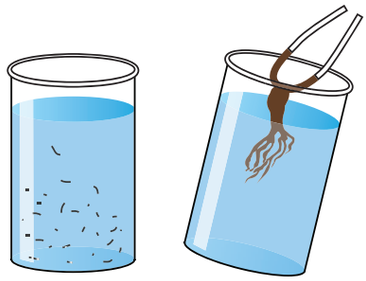


Figure 22: Isolation of DNA

Precautions:

1. All the glasswares must be thoroughly cleaned and dried.
2. The chemicals used for the experiments must be of standard quality.
3. If ordinary ethanol is used, the time duration for obtaining precipitated DNA may extend further.

V - Economic Importance of Plants

Exercise 18: Economically important plant products

S. no	Identification (Product name)	Botanical Name	Useful parts	Uses
1.	Sesame/ Gingelly oil	*Sesamum indicum*	Seeds	1. Sesame oil is mostly used for culinary purposes. 2. Lower grades are used in manufacture of soaps, in paint industries, as a lubricant and as an illuminant.
2.	Rubber	*Hevea brasiliensis*	Latex	1. Rubber is used in the manufacture of footwear, wire and cable insulations, rain coat, sports goods, erasers, adhesives, rubber bands, household and hospital goods and shock absorbers. 2. Concentrated latex is used for making gloves and balloons. 3. Foamed latex is used in the manufacture of cushions, pillows and life-belts.
3.	Flaked Rice (Aval)	*Oryza sativa*	Seeds	1. Flaked rice (aval) is used as breakfast cereal or as snacks.
4.	Henna Powder	*Lawsonia inermis*	Leaves	1. An orange dye "henna" obtained from leaves and young shoots is used to dye skin, hair and fingernails. 2. It is also used for colouring leather, tails of horses and hair.
5.	Aloe Gel	*Aloe vera*	Leaves	1. Aloe gel is used as skin tonic. 2. Because of its cooling effect and moisturizing characteristics, it is used in the preparation of creams, lotions, shampoos, shaving creams and allied products. 3. It is used in gerontological applications for rejuvenation of ageing skin.

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