UNIT – I: REPRODUCTION

CHAPTER-1
REPRODUCTION IN ORGANISMS

Topic-1 Asexual Reproduction

Concepts Covered • *Definition of life span; life span of a few organisms,* • *Asexual reproduction – definition, types,* • *Definition of clone, vegetative propagation.*

Revision Notes

Life span:

- Life span is the period from birth to the natural death of an organism.
- It is not necessarily correlated with the size of the organisms.
- No individual is immortal, except single-celled organisms.
- **Life spans of some organisms are tabulated below:**

S. No.	Organisms	Life Span
1.	Banana tree	25 years
2.	Cow	20 – 25 years
3.	Parrot	140 years
4.	Crocodile	60 years
5.	Horse	60 years
6.	Fruit fly	30 days
7.	Rice plant	3 – 4 months
8.	Tortoise	100 – 150 years
9.	Banyan tree	200 – 250 years
10.	Elephant	20 – 90 years
11.	Rose	5 – 7 years
12.	Dog	10 – 13 years
13.	Crow	15 years
14.	Butterfly	1 – 2 weeks

Reproduction

- Reproduction is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself.
- The offspring grow, mature and in turn produce new offspring.

Advantages of Reproduction

(a) Reproduction enables the continuity of the species, generation after generation.
(b) Reproduction maintains life on the earth.
(c) Reproduction creates genetic variation among populations.

Factors Responsible for the Reproduction

(a) The habitat of organisms.
(b) The internal physiology of organisms.
(c) The environmental conditions of organisms.

Types of Reproduction

- Based on the participation of one or two in the process of reproduction, it is classified into two types namely:
  (a) Asexual reproduction.
  (b) Sexual reproduction.

Asexual Reproduction

- When the offspring are produced by single parent with or without the gamete formation, the reproduction is called **asexual reproduction**.
- In this method, a single individual (parent) is capable of producing offspring that are not only identical to one another but are also exact copies of their parent.
- The morphologically and genetically identical individuals of same parents are called **clone**.
- Asexual reproduction is common among single-celled organisms.
- Asexual reproduction is the common method of reproduction in organisms having simple organisation like algae and fungi, as they shift to sexual method of reproduction just before the onset of adverse conditions.
- Since there is no variation, asexual reproduction does not contribute to evolution of the species.
- In some species, the organism or the parent cell divides into two to give rise to new individuals. Thus, in such organisms cell division is itself a mode of reproduction. Example; Protists, Monerans.

Binary Fission

- In *Amoeba* and *Paramecium*, a cell divides into two halves and each rapidly grows into an adult by the process of binary fission.

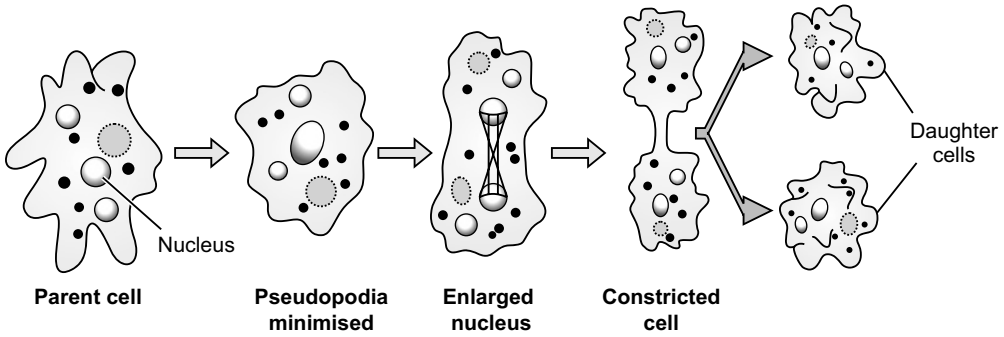


Fig. 1.1. Binary fission in *Amoeba*

Budding

- In yeast and *Hydra*, the division is unequal and small buds are produced that remain attached initially to the parent cell which, eventually get separated and mature into new yeast organisms. The complex budded condition with multiple buds attached to a single cell is known as Torula stage.

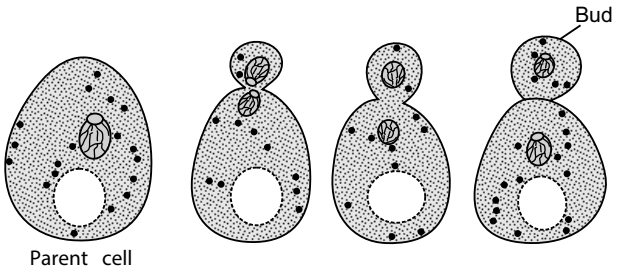


Fig 1.2. Budding in Yeast

Sporulation

- **Sporulation** "means formation of" tiny, single-celled, thick walled spores which are resistant to environmental extremes, which forms new individuals. It is commonly seen in organisms that belong to Kingdom Monera, Protista, Fungi and Algae.
- Under unfavourable condition, the *Amoeba* withdraws its pseudopodia and secretes a three-layered hard covering or cyst around itself. This phenomenon is known as encystation.
- During favourable conditions, the encysted *Amoeba* divides by multiple fission and produces many minute pseudopodiospores.
- Later, the wall of the cyst bursts and liberates these spores in the surrounding medium to grow up into individual Amoebae. This phenomenon is known as sporulation.

Fragmentation

- In some organisms, the body breaks into fragments and each fragment grows into an adult that has the ability to produce offspring. This mode of asexual reproduction is known as fragmentation.
- It is observed in *spirogyra*.

Other Reproductive Structures

- Members of the Kingdom Fungi and simple plants such as algae reproduce through special asexual reproductive structures as follows:

Asexual Reproductive Structures	Examples
Zoospores	*Chlamydomonas*
Conidia	*Penicillium*
Budding	*Hydra*
Gemmules	Sponge

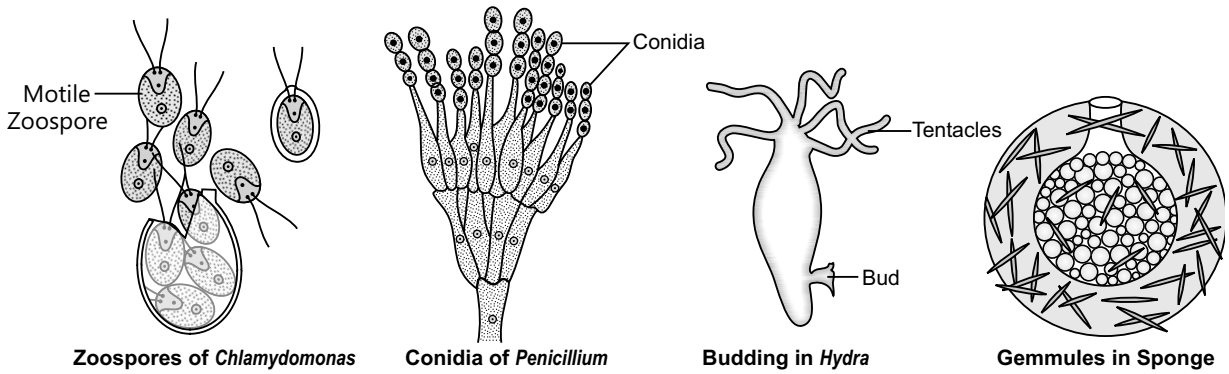


Fig 1.3. Asexual Reproductive Structures in various organisms.

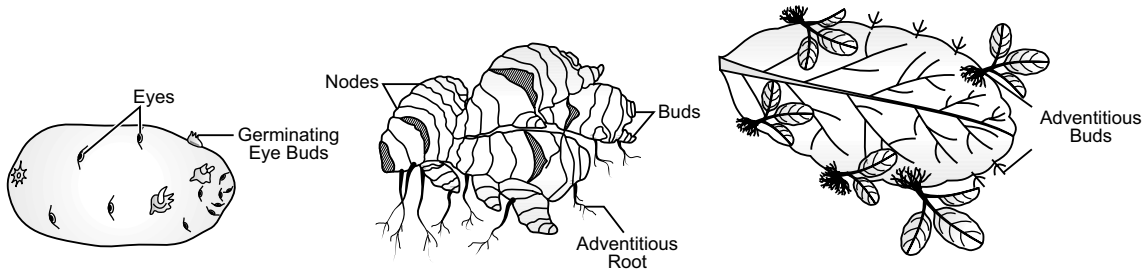
Characteristics of Asexual Reproduction

(a) A single parent is involved.
(b) Gametes are not formed.
(c) No fertilisation.
(d) There is only mitotic cell division takes place.
(e) Daughter organisms are genetically identical to parent.
(f) Multiplication occurs rapidly.

Vegetative Propagation

- The process of multiplication in which fragments of the plant body function as propagule and develop into new individual is called vegetative propagation.
- In plants, the term 'asexual' is replaced by the term 'vegetative reproduction or vegetative propagation'.
- In plants, the units of vegetative propagation such as runner, rhizome, sucker, tuber, offset and bulb are all capable of giving rise to new offspring. These structures are called **vegetative propagules**.
- Since the formation of these structures does not involve two parents, the process involved is asexual.
- **The vegetative propagules and the species involved are given as follows:**

Vegetative Propagules	Parts Involved	Plants
Bulb	Stem	Onion and Garlic
Bulbil	Stem	*Agave*, Lily and *Dioscorea*
Rhizome	Stem	Ginger, Banana and Turmeric
Runner	Stem	*Oxalis*, *Centella*
Tuber or eyes	Stem	Potato
Offset	Stem	Water hyacinth, *Pistia*
Leaf buds	Leaves	*Bryophyllum*
Suckers	Stem	Mint and *Chrysanthemum*
Corms	Stem	*Colocasia, Crocus*
Stolon	Stem	Jasmine
Tuber	Root	Sweet potato, Dahlia



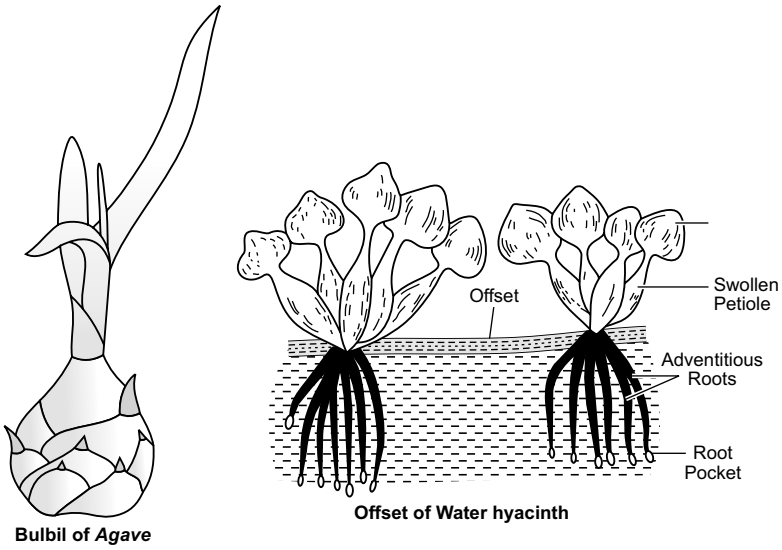


Fig 1.4: Vegetative propagules in various plants.

- The site of origin of the new plantlets in stem propagating plants is the **nodes**.
- When the nodes come in contact with damp soil or water, they produce roots and new plants.
- Similarly, adventitious buds arise from the **notches** present at margins of leaves of *Bryophyllum*.
- This ability is fully exploited by gardeners and farmers for commercial propagation.

Terror of Bengal

- The most invasive aquatic weed plant *Eichhornia crassipes* 'water hyacinth' is found growing wherever there is standing water.
- It drains dissolved oxygen from the water, which leads to death of fishes.
- This plant was introduced in India because of its beautiful flowers and shape of leaves.
- Since it can propagate vegetatively at a phenomenal rate and spread all over the water body in a short period of time, it is very difficult to get rid off them.

Key Terms

- **Reproduction:** Reproduction is the process of formation of new individuals of a species from the pre-existing ones.
- **Clone:** The term clone is used to describe a group of organisms derived from a single individual by various types of asexual reproduction which are genetically and morphologically similar.
- **Regeneration:** A type of asexual reproduction in which the lost part of the organism is restored by the proliferation of cells.
- **Vegetative propagules:** Units of vegetative propagation like runner, rhizome, sucker, tuber which are capable of producing new offsprings.
- **Cell division:** The process in which the parent cell divides into two, forming new individuals.

Mnemonics

Concept: Types of asexual reproduction

Mnemonics: Barking **B**Unny slowly **F**ollowed **R**ed **V**iper.

Barking - Binary **D**ivision

Interpretation: BUnny - B Udding, **Slowly - S**porulation, **Followed - F**ragmentation, **Red** - Regeneration

Viper - Vegetative **P**ropagation

Topic-2 Sexual Reproduction

Concepts Covered • *Sexual reproduction: Plants – definition, phases of life cycle, unusual flowering phenomenon • Animals – continuous and seasonal breeders • Events in sexual reproduction – pre-fertilisation; fertilisation), post-fertilisation, parthenogenesis, differences between asexual and sexual reproduction.*

Revision Notes

Sexual Reproduction

- It is an elaborate, complex and slow process.
- Sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex.
- These gametes fuse to form the zygote which develops to form the new organism.
- Due to the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.
- The various organisms (like fungi, plants, animals) extremely differ in internal structure, external morphology and physiology but they have similar mode of reproduction pattern.

Phases of Life cycle:

(a) Juvenile phase/vegetative phase: Phase in which an individual prepares itself to undergo reproduction (pre-reproductive period). It is known as **vegetative phase** in plants.

(b) Reproductive phase: Phase in which an individual shows active reproductive behaviour.

(c) Senescence phase (end of reproductive phase and ageing): Phase in which hormonal cycle beings to cease and individual loses its ability to reproduce. The organism grows old and ultimately dies.

- In both plants and animals, hormones are responsible for the transitions between the three phases.
- Interaction between hormones and certain environmental factors regulate the reproductive processes and the associated behavioural expressions of organisms.

Sexual Reproduction in Plants

- Both the annual and biennial plant types show clear cut vegetative, reproductive and senescent phases whereas in the perennial species: it is very difficult to clearly define these phases.
- The bamboo species flowers only once in their life time, generally after 50–100 years, produce large number of fruits and die.
- *Strobilanthes kunthiana* (Neelakurinji), flowers once in 12 years during September–October. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamil Nadu into blue stretches and attracted a large number of tourists.

Sexual Reproduction in Animals

- Many animals, especially those living in natural, wild conditions exhibit cyclic changes in reproduction only during favourable seasons in their reproductive phase and are therefore called **seasonal breeders**.
- Many other animals are reproductively active throughout their reproductive phase and hence are called **continuous breeders**.
- Birds living in nature lay eggs only seasonally but poultry birds (birds in captivity) are commercially exploited by making them lay eggs throughout the year.
- The females of placental mammals exhibit cyclical changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase.
- In non-primate mammals like cows, sheep, rats, deers, dogs, tiger, etc., such cyclical changes during reproduction are called **oestrus cycle** whereas in primates (monkeys, apes and humans) it is called **menstrual cycle**.

Sexuality in Organisms

(a) Sexuality in plants

- Plants may have both male and female reproductive structures in the same plant (bisexual) or on different plants (unisexual).
- In several fungi and plants, homothallic and monoecious are used to denote the bisexual condition while heterothallic and dioecious are the terms used to describe unisexual condition.
- In flowering plants, the unisexual male flower is staminate,, i.e., bearing stamens, while the female is pistillate or bearing pistils.
- In some flowering plants, both male and female flowers may be present on the same individual (monoecious) or on separate individuals (dioecious).

- Examples of monoecious plants include cucurbits and coconuts and of dioecious plants include papaya and Date palm.

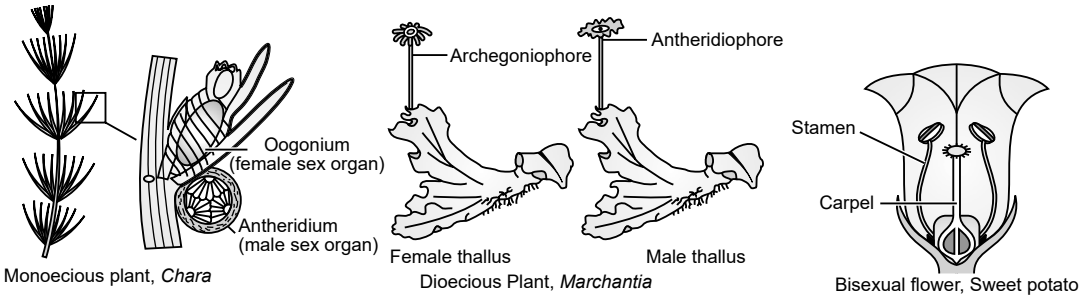


Fig 1.5. Sexuality in various plants

(b) Sexuality in Animals

- Based on the sexuality, animals are classified into two categories namely, unisexual and bisexual.
- When an animal possesses both sexes with clear distinct male and female individuals, they are called unisexual animal, e.g., cockroach, dog, etc.
- When an animal possesses both male and female reproductive organs in the same individual, they are called bisexual animal, e.g., earthworms, tapeworms, leech, sponge, etc. These are also called as **hermaphrodites**.

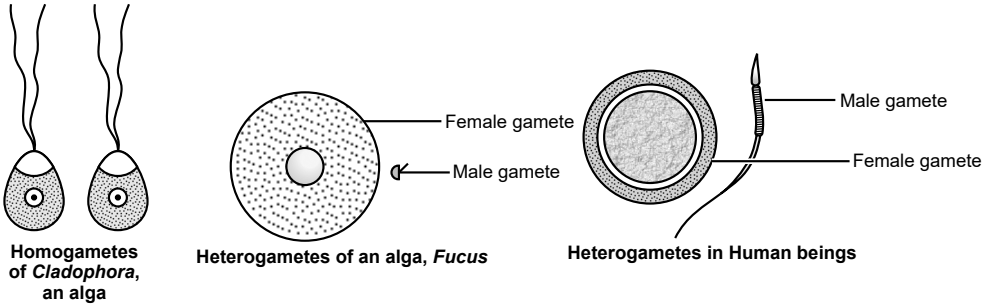


Fig 1.6. Types of gametes

(A) Pre fertilisation events

Cell Division During Gamete Formation

- Gametes are haploid, though the parent plant body from which they arise may be either haploid or diploid.
- A haploid parent produces gametes by mitotic division. Organisms of monera, fungi, algae and bryophytes have haploid plant body.
- In organisms belonging to pteridophytes, gymnosperms, angiosperms and most of the animals including human beings, the parental body is diploid**.**
- The reduction division, meiosis, has to occur if a diploid body has to produce haploid gametes.
- In diploid organisms, specialised cells called meiocytes (gamete mother cell) undergo meiosis**.** At the end of meiosis, only one set of chromosomes gets incorporated into each gamete.
- **Chromosome numbers in meiocytes (diploid, 2*n*) and gametes (haploid, *n*) of some of the organisms are tabulated as follows:**

Name of organism	Chromosome number in meiocyte (2*n*)	Chromosome number in gamete (*n*)
Human beings	46	23
House fly	12	6
Rat	42	21
Dog	78	39
Cat	38	19
Fruit fly	8	4
Ophioglossum (a fern)	1260	630
Apple	34	17
Rice	24	12
Maize	20	10

Potato	48	24
Butterfly	380	190
Onion	32	16

Based on their structure, gametes can be of three types:

- Isogametes or homogametes where both the gametes have same structure and motility.
- Heterogametes where both the gametes differ. They can differ in both appearance and physiology (oogamy) nor can differ in physiology only (anisogamy).

(B) The Fertilisation Events

- The most vital event of sexual reproduction is the fusion of gametes. The process of fusion of gametes is known as **syngamy**.
- It results in the formation of a diploid zygote.
- In some organisms like rotifers, honeybees and some lizards and birds (turkey), the female gamete undergoes development to form new organisms without fertilisation.This phenomenon is called **parthenogenesis.**
- **Parthenocarpy** is the process by which a fruit develops without fertilisation, as a result the fruit is seedless.
- Based on the occurrence of syngamy, fertilisation can be classified into two types namely: external fertilisation and internal fertilisation.

(a) External Fertilisation

- In some aquatic organisms, such as algae and fishes as well as amphibians, syngamy occurs in the external medium (water), i.e., outside the body of the organism. This type of gametic fusion is called **external fertilisation**.
- These organisms show great synchrony between the sexes and release a large number of gametes into the surrounding medium (water) in order to enhance the chances of syngamy.
- A major disadvantage is that the offspring are extremely vulnerable to predators threatening their survival up to adulthood.

(b) Internal Fertilisation

- In many terrestrial organisms such as fungi, higher animals such as reptiles, birds, mammals and in a majority of plants such as bryophytes, pteridophytes, gymnosperms and angiosperms, syngamy occurs inside the body of the organism, i.e., egg is formed inside the female body where they fuse with the male gamete. This type of gametic fusion is called **internal fertilisation**.
- In these organisms, the male gamete is motile and has to reach the egg in order to fuse with it.
- Though the number of sperms produced is very large, there is a significant reduction in the number of eggs produced.
- In seed plants, the non-motile male gametes are carried to female gamete by pollen tubes.

(C) Post-Fertilisation Events

- All events in sexual reproduction which occur after the formation of zygote are called post-fertilisation events.
- Fertilisation results in the formation of diploid zygote.
- **Zygote** is the vital link that ensures continuity of species between organisms of one generation and the next.
- Every sexually reproducing organism begins life as a single cell – the zygote.
- Further development of the zygote depends on the type of life cycle and the environment.
- In fungi and algae, zygote develops a thick wall that is resistant to desiccation and damage to undergo a period of rest before germination.
- In haplontic life cycle, zygote divides by meiosis to form haploid spores that grow into haploid individuals.
- The process of development of embryo from the zygote is known as **embryogenesis**.
- During this process,
  (a) zygote undergoes cell division (mitosis)
  (b) cell differentiation.
- The cell divisions increase the number of cells in the developing embryo while cell differentiation helps groups of cells to undergo certain modifications to form specialised tissues and organs to form an organism.
- Based on the development of zygote, the animals are classified into two types namely, viviparous and oviparous.

(a) Viviparous

- In viviparous animals (majority of mammals including human beings), the zygote develops into a young one inside the body of the female organism.
- After attaining a certain stage of growth, the young ones are delivered out of the body of the female organism.
- Because of proper embryonic care and protection, the chance of survival of young ones is greater in viviparous organisms.

(b) Oviparous

- In oviparous animals (like reptiles, birds), the fertilised eggs covered by hard calcareous shell are laid in a safe place in the environment.
- After a period of incubation, young ones hatch out.

Development of Zygote in Plants

- In flowering plants, the zygote is formed inside the ovule.
- After fertilisation, the sepals, petals and stamens of the flower wither and fall off.
- The pistil remains attached to the plant.
- The zygote develops into the embryo and the ovules develop into the seed.
- The ovary develops into the fruit which develops a thick wall called pericarp that is protective in function. After dispersal, seeds germinate to produce new plants under favourable conditions.

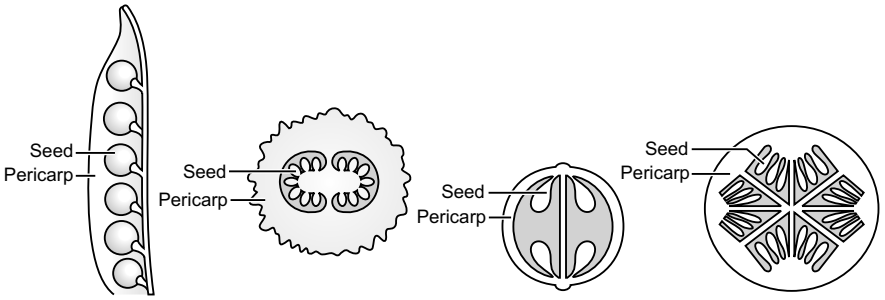


Fig 1.7. Fruits showing seeds and pericarp.

- **Difference between asexual and sexual reproduction.**

	Characters	Asexual reproduction	Sexual reproduction
1.	Number of parents involved	Always uniparental reproduction	Usually biparental type except *Taenia, Fasciola*.
2.	Gametes	Not involved	Involved
3.	Types of divisions involved	Only mitotic divisions	Meiosis occurs during gametogenesis. Mitosis occurs after fertilisation.
4.	Nature of cells involved	Somatic cells of the parent	Germ cells of the parent.
5.	Nature of daughters produced	Genetically similar to the parent	Genetically different from the parent
6.	Rate of reproduction	Faster	Slower
7.	Units of reproduction	Whole parent body or bud or body fragment	Gametes
8.	Occurrence	Found in only lower invertebrates and lower chordates.	Found in higher plants and animals

Key Terms

- **Gametogenesis:** Process of formation of the male and female gametes.
- **Hermaphrodite:** When animals possess both male and female reproductive organs, it is known as hermaphrodite.
- **Meiocyte:** In diploid organisms, specialised cells that undergo meiosis are called as meiocytes or gamete mother cells.
- **Chordate:** An animal of phylum chordata comprising the vertebrates together with the sea squirts and lancelets.

Mnemonics

1. **Concept:** Examples of isogamy
   Mnemonic: Irritated chef marinated chicken
   Interpretation: Isogamy: *Chlamydomonas, **M**icrocystis, **C**ladophora***
2. **Concept:** Examples of anisogamy
   Mnemonic: Air cooler broke
   Interpretation: Anisogamy: *Chlamydomonas braunii***
3. **Concept:** Examples of oogamy
   Mnemonic: Organic food and vegetables
   Interpretation: Oogamy: *Fucus, **V**olvox***

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CHAPTER-2
SEXUAL REPRODUCTION IN FLOWERING PLANTS

Topic-1 Male and Female Reproductive Structures in Flowering Plants

Concepts Covered • *Pre-fertilisation Structure and Events*

Revision Notes

Sexual Reproduction in Plants

- Sexual reproduction is the process of fusion of haploid gametes forming a diploid zygote, finally developing into a new organism.
- All flowering plants (angiosperms) show sexual reproduction.
- The sexual reproduction includes
  - **(a)** Pre-fertilisation structures and events
  - **(b)** Pollination and fertilisation
  - **(c)** Post-fertilisation structures and events

Structure of Microsporangium

- It is circular and is generally surrounded by four wall layers namely,
  - **(a)** Epidermis
  - **(b)** Endothecium
  - **(c)** Middle layers
  - **(d)** Tapetum
- The first two layers perform the function of protection and help in dehiscence of anther to release the pollen.
- The innermost layer **(tapetum)** nourishes the developing pollen grains.
- The cells of the tapetum possess dense cytoplasm and more than one nucleus.
- When the anther is young, a group of compactly arranged homogeneous cells called sporogenous tissues occupies the centre of each microsporangium.

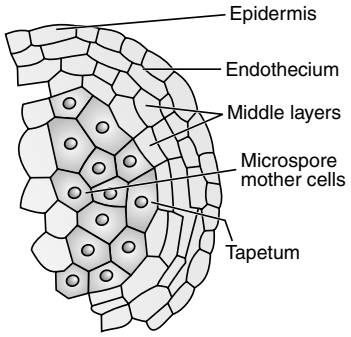


Fig. 2.1: Enlarged view of one microsporangium

Microsporogenesis

- When the anther develops, each cell of sporogenous tissue undergoes meiotic division to form microspore tetrads.
- Each cell of sporogenous tissue is a microspore mother cell (MMC) or pollen mother cell (PMC).
- The process of formation of microspores from a pollen mother cell (PMC) through meiosis is called **microsporogenesis**.
- The microspores get arranged in a cluster of four cells and hence are called **microspore tetrad**.
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains.
- In each microsporangium, thousands of pollen grains are formed and released with the dehiscence of anther.

Pollen Grain (Male Gametophyte)

- The pollen grains represent the male gametophytes.
- These are spherical, measuring about 25-50 micrometres in diameter.
- Pollen grains are well preserved as fossils due to the presence of sporopollenin, a tough, resistant and stable material.

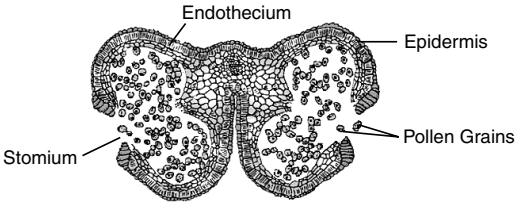


Fig. 2.2: T.S. anther at the time of dehiscence

- A pollen grain has a two-layered wall namely, exine and intine.

(a) Exine:

- It is the hard outer layer which is made up of sporopollenin.
- The sporopollenin is one of the most resistant organic materials.
- It can withstand high temperatures and strong acids and alkali.
- It cannot be degraded by enzymes.
- Pollen grain exine has prominent apertures called **germ pores** where sporopollenin is absent.

(b) Intine:

- It is the inner, thin and continuous layer which is made up of cellulose and pectin.
- A mature pollen grain contains two cells namely, vegetative cell and generative cell.

(i) Vegetative cell

- It is the bigger cell having abundant food reserve and a large irregularly shaped nucleus.

(ii) Generative cell

- It is the smaller cell that floats in the cytoplasm of the vegetative cell.
- It is spindle-shaped with dense cytoplasm and a nucleus.
- The pollen grains are generally shed at the 2-celled stage in flowering plants.
- In other plants, the generative cell divides mitotically which give rise to two male gametes before pollen grains are shed in 3-celled stage.
- Once they are shed, pollen grains have to land on the stigma before they lose viability.
- The period of pollen grains remaining viable varies and depends on the prevailing temperature and humidity.
- The viability of pollen grains of some cereals such as rice, wheat, etc, is 30 minutes while some members of the family *Leguminosae, Rosaceae* and *Solanaceae* have viability of months.
- Pollen grains of some plants like *Parthenium* (carrot grass) are allergic for some people leading to chronic respiratory disorders such as asthma, bronchitis, etc.
- Pollen grains are rich in nutrients.
- Pollen tablets are used as food supplements.
- Pollen consumption in the form of tablets and syrups increases performance of athletes and race horses.
- It is possible to store pollen grains for years in liquid nitrogen (–196°C). The stored pollen can be used in pollen banks for crop breeding programmes.

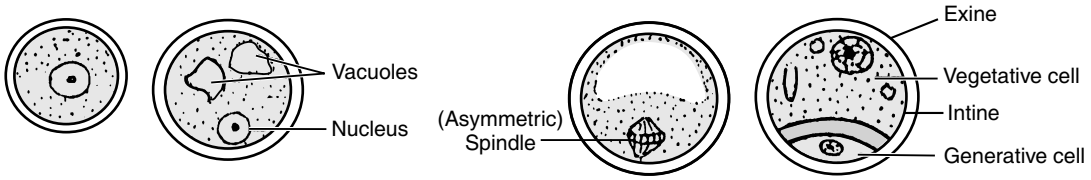


Fig. 2.3: Stages of Microscope maturing into a pollen grain

Megasporangium (Ovule)

- Ovule is a small structure attached to the placenta by a stalk called **funicle**.
- The junction where the body of ovule and funicle fuse is called **hilum**.
- Each ovule has one or two and sometimes three protective coverings called **integuments**.
- Integuments encircle the ovule except at the tip where a small opening called **micropyle** is organised.
- Opposite to the micropylar end is the chalaza which is the basal part of the ovule.
- Within the integuments, there is a mass of cells called **nucellus**, the body of ovule. Cells of nucellus are rich in reserve food.
- Inside the nucellus is the embryo sac, which is also called the **female gametophyte**.
- An ovule has a single embryo sac formed usually from a single haploid megaspore.

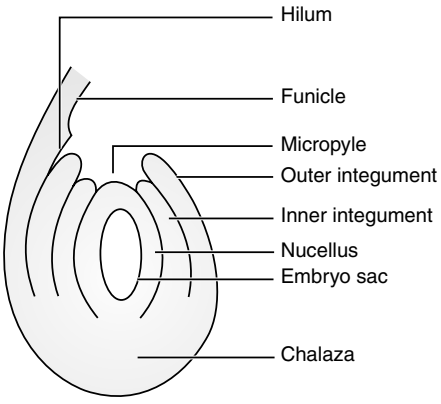


Fig. 2.4 : A diagrammatic view of typical anatropous ovule

Megasporogenesis

- The formation of haploid megaspores from the diploid megaspore mother cell (MMC) as a result of meiosis is called **megasporogenesis**.
- A single megaspore mother cell is differentiated in the micropylar region of the nucellus.

- The megaspore mother cell is a large cell containing dense cytoplasm and a prominent nucleus.
- The megaspore mother cell undergoes meiotic division resulting in the production of four haploid megaspores.

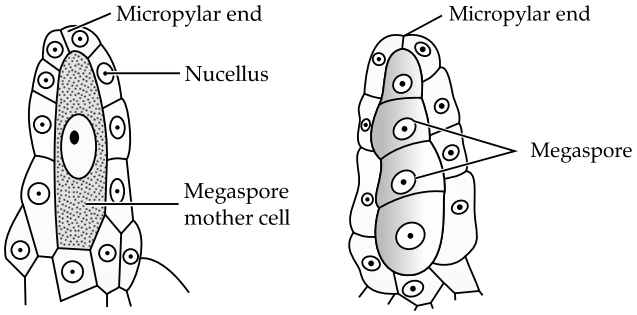


Fig. 2.5: (a) Megaspore mother cell (b) Megaspore tetrad

Female Gametophyte (Embryo Sac)

- In most of the flowering plants, only one of the four megaspores formed as a result of megasporogenesis that is functional while the other three degenerate.
- The functional megaspore develops into the female gametophyte or embryo sac.
- This method of embryo sac formation from a single megaspore is termed **monosporic development**.

Formation of the Embryo Sac

- The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles forming 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
- These divisions are strictly free nuclear, i.e. nuclear divisions are not followed immediately by cell wall formation.
- After the 8-nucleate stage, the organisation of the typical female gametophyte or embryo sac takes place.
- Generally six of the eight nuclei are surrounded by cell walls and organised into cells.
- The remaining two nuclei called the **polar nuclei** are found below the egg apparatus in the large central cell.

Distribution of the Cells within the Embryo Sac

- The three cells consisting of two synergids and one egg cell which are grouped together at the micropylar end constitute the egg apparatus.
- The synergids have special cellular thickenings at the micropylar tip called **filiform apparatus**.
- The filiform apparatus helps to guide the pollen tube into the synergid.
- Three cells at the chalazal end organise as the antipodals.
- Thus, a typical mature angiosperm embryo sac at maturity is 8-nucleate but 7-celled.

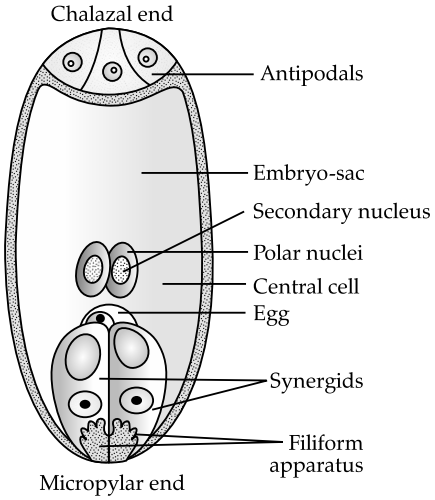


Fig: 2.6: A mature embryo sac

Key Terms

- **Bisexual flower:** Flower which contains both male (stamens) and female (carpels or pistils) reproductive parts in it.
- **Unisexual flower:** Flower which contains only one i.e., either male or female reproductive parts in it.
- **Dithecous:** The anthers that contain two lobes and four pollen sacs are called dithecous.
- **Monothecous:** The anthers that contain one lobe and two pollen sacs are called monothecous.
- **Tapetum:** The innermost layer in the anther is called the **tapetum** and it nourishes the developing pollen grains. The cells of the tapetum possess dense cytoplasm and more than one nucleus.

Key Terms

- **Microsporogenesis:** The process of formation of haploid microspores from diploid pollen mother cell (PMC) through meiosis is called microsporogenesis.
- **Sporogenous tissues:** It is compactly arranged homogenous cells which are present at the centre of each microsporangium when the anther is young.
- **Megasporogenesis:** The process of formation of haploid megaspores from the diploid megaspore mother cell (MMC) as a result of meiosis is called megasporogenesis.
- **Chalaza:** Basal part of an ovule.
- **Micropyle:** Small opening at the tip of ovule where pollen tube enters.
- **Tapetum:** Innermost layer of cells in pollen sac which provide nutrition to developing pollen grains.
- **Synergid cells:** Synergid cells are two small, specialised cells found in the embryo sac adjacent to the egg cells in the female gametophyte of a flowering plant. It nourishes the ovum and plays an important role in guiding the pollen tube. These structures are key for the cessation of pollen tube growth and in the release of the sperm cells.

Mnemonics

1. Concept Name: Examples of Syncarpous
Mnemonics: Synaa **H**as **M**ashed **T**he **P**otato
Interpretation: Syncarpous: **H**ibiscus, **M**ustard, **T**omato, **P**otato
2. Concept Name: Examples of Apocarpous
Mnemonics: All Land **R**esource **M**anagement
Interpretation: Apocarpous: **L**otus, **R**ose, **M**ichelia

Topic-2 Fertilisation

Concept Covered • *Pollination - types, agencies and examples, outbreeding Devices, and Pollen–pistil Interaction*

Revision Notes

- Transfer of pollen grains shed from the anther to the stigma of a pistil is termed pollination.
- Depending upon the source of pollen, pollination can be divided into three types:
- **Autogamy:** transfer of pollen grains from the anther to the stigma of the same flower. Some plants like Viola, Oxalis and Commelina produce two types of flowers Chasmogamous (normal flowers with exposed anther and stigma) and Cleistogamous (flowers which do not open at all).
- **Geitonogamy:** transfer of pollen grains from the anther to the stigma of another flower of the same plant. It is genetically self -pollination but functionally cross -pollination as requires a pollinating agent.
- **Xenogamy:** Transfer of pollen grains from the anther to the stigma of a different plant.
- **Pollination agencies:** Plants use abiotic (air and water) and biotic (animals) agents for pollination.
- Wind pollination requires pollen grains to be light and non-sticky so that they can be transported in wind currents. Wind -pollinated plants often possess well exposed stamens and large often feathery stigmas; single ovule in each ovary and numerous flowers packed into an inflorescence. Examples are grasses.
- Water pollination is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons. Some examples include fresh water ones like Vallisneria and Hydrilla or marine grasses like Zostera.
- In most of the water pollinated species, pollen grains are protected from wetting by a mucilaginous covering.
- Majority of aquatic plants like water lily or lotus have flowers above water and are either insect or wind pollinated.
- Both wind and water -pollinated flowers are not very colourful and do not produce nectar.
- Majority of flowering plants use a range of animals such as bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and hummingbirds) and bats as pollinating agents.

- Even larger animals like some primates (lemurs), arboreal rodents, and some reptiles like gecko and garden lizard have also been reported as pollinator for some plants.
- Majority of insect-pollinated flowers are large, colourful, fragrant and rich in nectar (as a reward for pollinators to sustain visits).
- In some species floral rewards are in providing safe places to lay eggs. Example, *Amorphophallus*. *Yucca* and a moth species cannot complete their life cycles in absence of other.
- Advantage of cross -pollination over self-pollination is that it prevents inbreeding depression.
- Continued self-pollination (inbreeding) causes inbreeding depression. Cross-pollination increases recombinations of genes causing better characters to appear and reducing the chances of expression of unfavourable mostly recessive traits.
- **Outbreeding Devices**

  Hermaphrodite flowers can undergo self-pollination. Continued self-pollination results in inbreeding depression.

  To discourage self-pollination and to encourage cross-pollination, there are some devices in plants:

  - **Pollen release and stigma receptivity – not synchronised**, i.e., the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen. This is known as dichogamy. Dichogamy refers to the different maturation time of stamen and pistil. This helps to avoid self-fertilisation. This prevents autogamy. Dichogamy is of two types protandry and protogyny.

    (a) Protoandry: Anthers mature earlier than gynoecium, e.g., China rose, Cotton, Sunflower, etc.

    (b) Protogyny: Gynoecium matures earlier than anthers, e.g., *Brassica*, *Ficus, Mirabilis*, etc.

    Stigma and anther – placed at different positions so that the pollen cannot come in contact with the stigma of the same flower. This prevents autogamy.

    (i) Long-styled flowers

    (ii) Short-styled flowers

    Based on the difference in length, the phenomenon is called heterostyly, e.g., *Primula vulgaris.*
  - **Self-incompatibility:** It is a genetic mechanism to prevent self-pollen (from the same flower or other flowers of the same plant) from fertilisation by inhibiting pollen germination or pollen tube growth in the soil. The pollen of a flower has no fertilising effect on the stigma of the same flower, e.g., Tea (*Thea sinensis*).
  - **Monoecious plants:** Male and female flowers are present in the same plant, e.g., Maize.
  - **Dioecious plants:** Male and female flowers are present in different plants, e.g., Mulberry. It prevents both autogamy and geitonogamy, e.g., castor, maize (prevents autogamy); papaya (prevents autogamy and geitonogamy).

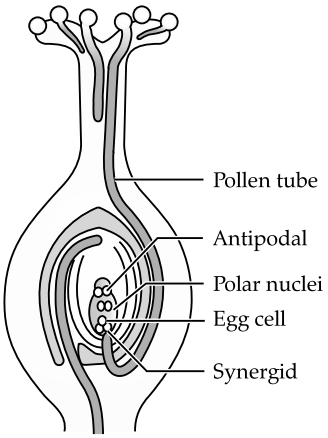


Fig. 2.7: Longitudinal section of a flower showing growth of pollen tube

- **Pollen–pistil interaction**
  - The pollen–pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
  - Pollination does not guarantee the transfer of the right type of pollen.
  - The pistil has the ability to recognise the pollen, whether it is of the right type (compatible) or of the wrong type (incompatible).
  - If it is of right type, the pistil accepts the pollen and promotes post-pollination events leading to fertilisation.
  - If the pollen is of the wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
  - The ability of the pistil to recognise the pollen is the result of a continuous dialogue between the pollen grain and the pistil mediated by chemical components.
  - After the right type of pollination, the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
  - The contents of the pollen grain move into the pollen tube.
  - Pollen tube grows through the tissues of the stigma and style and reaches the ovary.
  - After entering the ovary through the micropyle, it enters one of the synergids through the filiform apparatus. All these events – from pollen deposition on the stigma until pollen tubes enter the ovule – are together referred to as pollen–pistil interaction.

➢ **Double Fertilisation**

- After entering one of the synergids, the pollen tube releases the two male gametes into the cytoplasm of the synergid.
- One of the male gametes moves towards the egg cell and fuses with its nucleus for syngamy which results in the formation of a diploid cell, the zygote.
- The other male gamete moves towards the two polar nuclei in the central cell and fuses with them to produce a triploid primary endosperm nucleus (PEN). As this involves the fusion of three haploid nuclei, the process is termed as triple fusion.
- Since two types of fusions, i.e., syngamy and triple fusion take place in an embryo sac, the phenomenon is termed double fertilisation.
- The process of double fertilisation is an event unique to flowering plant.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo.

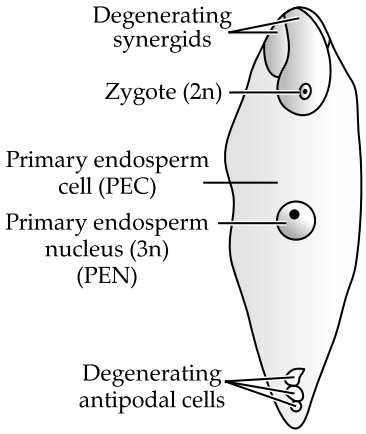


Fig. 2.8: Fertilised embryo Sac

Key Terms

➢ **Outbreeding devices:** Devices that have been developed by the flowering plants to avoid self-pollination and to encourage cross-pollination.

➢ **Pollen–pistil interaction:** All the events – from pollen deposition on the stigma until pollen tubes enter the ovule – are together referred as pollen–pistil interaction.

Topic-3 Post-fertilisation Events

Concepts Covered • *Types of Endosperm and Embryo Formation*

Revision Notes

Post-fertilisation events:

(1) Endosperm and embryo development
(2) Maturation of ovule(s) into seed(s)
(3) Maturation of ovary into fruit

Post-fertilisation structures:

(a) Endosperm

- The endosperm, a tissue, present in the seed during the fertilisation, precedes the development of an embryo. This is because the primary endosperm cell divides repeatedly to form a triploid endosperm tissue filled with reserve food materials which provide the nutrition for the developing embryo.
- The development of endosperm can be categorised into three types:

(i) Nuclear Endosperm: The first few cell divisions are not accompanied by cell wall formation. The PEN (primary endosperm nucleus) undergoes successive nuclear divisions to give rise to nuclei which remain free in the cytoplasm of the embryo sac. This stage of endosperm development is called free-nuclear endosperm, For example, in *Cocos nucifera* (Coconut), the watery liquid endosperm which fills the large embryo sac contains numerous free nuclei.

(ii) Cellular Formation: Later, the cell wall formation occurs with the first division of the primary endosperm nucleus and the endosperm becomes cellular.

- The number of free nuclei formed before cellularisation varies greatly, For example, in *Cocos nucifera* (Coconut), the watery liquid endosperm is free-nuclear endosperm and the surrounding white kernel is the cellular endosperm.
- After the first transverse division, the subsequent divisions are irregular.
- Endosperm tissue cells do not show regular arrangement.

(iii) Helobial endosperm:

- In between nuclear and cellular formation, another intermediate endosperm formation happens and this is known as Helobial endosperm.
- First division of primary endosperm nucleus accompanied by the formation of a transverse wall.
- This divides the embryo sac unequally into a small chalazal chamber and a large micropylar chamber.
- This is followed by free nuclear division in each chamber and then cell wall formation makes the endosperm cellular.

(b) Embryo

- Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- The zygote starts to divide only after a certain amount of endosperm is formed in order to provide assured nutrition to the developing embryo.
- The early stages of embryo development, known as embryogeny are similar in both monocotyledons and dicotyledons.
- The zygote gives rise to the pro-embryo and then to the globular, heart-shaped and mature embryo

Zygote → Pro-embryo → Globular → Heart-shaped → Mature embryo.

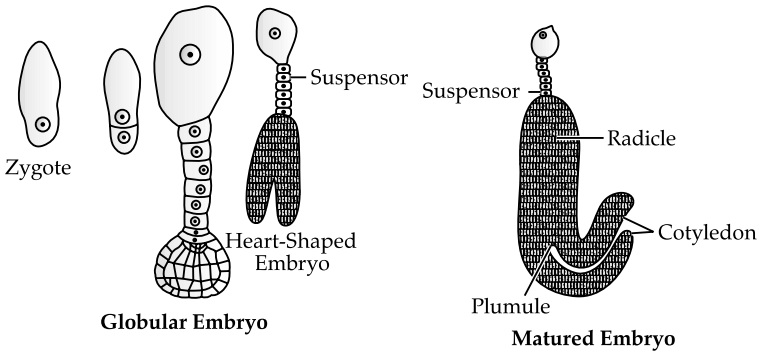


Fig. 2.9: Stages in embryo development in a dicot

(i) Dicotyledonous Embryo

- It has an embryonal axis and two cotyledons.
- The portion of the embryonal axis above the level of cotyledons is the epicotyl, which terminates with the plumule (stem tip).
- The cylindrical portion below the level of cotyledon is hypocotyl that terminates with the radicle (root tip).
- The root tip is covered with a root cap.

(ii) Monocotyledonous Embryo

- It has only one cotyledon.
- In grass, the cotyledon is called scutellum which is situated towards one side of the embryonal axis.
- At the lower end of the scutellum, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorhiza.
- The portion of the embryonal axis above the level of attachment of the scutellum is the epicotyl.

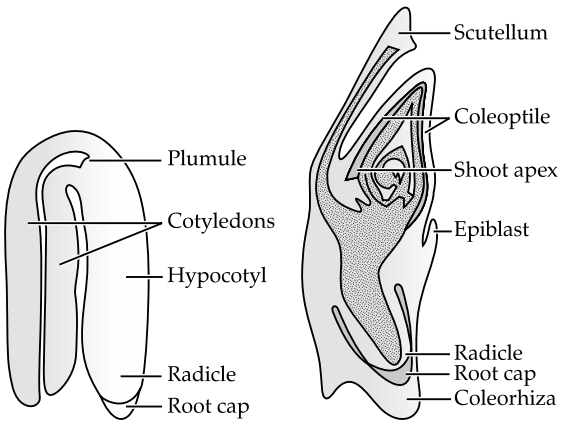


Fig. 2.10

- Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.

Seed

- Seed is the fertilised ovule formed inside fruits. It is the final product of sexual reproduction.
- It consists of **seed coat(s), cotyledon(s) and an embryo axis**.
- The cotyledons are simple, generally thick and swollen due to the storage food (as in legumes).
- Mature seeds are classified according to the presence of endosperms:

- **Non-albuminous (Ex-albuminous) seeds or non-endospermic:** Seeds have no residual endosperm as it is completely consumed during embryo development, e.g., pea, groundnut, beans.
- **Albuminous seeds or endospermic seeds:** Retain a part of the endosperm. These seeds have thin and membranous endosperm, e.g., wheat, maize, barley, castor, coconut.
- Occasionally, in some seeds (black pepper, beet, etc.) remnants of nucellus are also persistent. This residual, persistent nucellus is called **perisperm**.
- Integuments of ovules harden as tough protective seed coats. It has a small pore (micropyle) through which O_2 and water enter into the seed during germination.
- As the seed matures, it becomes dry by reducing water content (10–15% moisture by mass). The metabolic activity of the embryo slows down. It may enter a state of inactivity **(dormancy)**. Under favourable conditions (moisture, oxygen and suitable temperature), they germinate.

Fruit

- The ovary develops into a fruit. Transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
- The wall of ovary develops into **pericarp** (wall of fruit).
- The fruits may be **fleshy** (e.g., guava, orange, mango, etc.) or **dry** (e.g., groundnut, mustard, etc.).
- **Fruits are of two types:**
  - **True fruits:** In this, the fruit develops **only from the ovary**. Other floral parts degenerate and fall off, e.g., mango, orange, papaya.
  - **False fruits:** In this, the **thalamus** also contributes to fruit formation, e.g., apple, strawberry, cashew, etc.
- In some species, fruits develop without fertilisation. Such fruits are called **parthenocarpic fruits**, e.g., banana.
- **Parthenocarpy** can be induced through the application of growth hormones. Such fruits are seedless.

Dispersal of seeds

- Transport of seeds away from their parents to reduce competition and improve chances of germination is called seed dispersal.
- Seed dispersal is done with the help of wind, water, or animals.

Apomixis and Polyembryony

- Apomixis is the production of seeds without fertilisation. For example, some species of *Asteraceae* and grasses.
- It is a form of asexual reproduction that mimics sexual reproduction.
- In some species, diploid egg cell is formed without reduction division and develops into an embryo without fertilisation.
- In many species (e.g., many *citrus* and *mango* varieties) some **nucellar cells** surrounding the embryo sac divide, protrude into the embryo sac to form embryos. Thus, each ovule contains many embryos. The occurrence of more than one embryo in a seed is called **polyembryony**.

Importance of Apomixis in Hybrid Seed Industry

- Production of hybrid seeds is costly. So, hybrid seeds are also expensive. If the hybrids are made into apomicts, there is no segregation in the hybrid progeny. So, farmers can keep on using hybrid seeds to raise new crop.

Key Terms

- **Polyembryony:** The process of formation of two or more embryos from a single fertilised egg is known as polyembryony, e.g., citrus varieties like lemon, oranges.
- **Pericarp:** The pericarp is the wall of the ovary that develops as the wall of the fruits. The pericarp of the fruits might be fleshy as in guava, mango, etc. or might be dry as in mustard, walnut, etc.
- **Viability:** Ability of seeds to retain the power of germination.
- **Apomixis:** The term apomixis (apo = without; mixis = mingling) is the production of seeds without fertilisation. It is a kind of asexual reproduction that mimics sexual reproduction, e.g., asteraceae – asters, daisy, sunflower family and grasses.
- **Endosperm:** Endosperm is the nutritive tissue for the developing embryo and also the seedling. In angiosperms, the endosperm develops from triploid (3n) primary endosperm nucleus which is formed as a result of vegetative fertilisation, triple fusion or fusion of a male gamete with secondary nucleus of the central cell.
- **Coleoptile:** It is the protective sheath which encloses the plumule in a monocot seed.
- **Coleorhiza:** It is an undifferentiated sheath which encloses the radicle and the root cap in a monocot seed.
- **Scutellum:** The single cotyledon is called the scutellum which is situated towards one side of the embryonal axis.
- **Dormancy:** State of inactivity.

Mnemonics

1. **Concept Name:** Albuminous and Non-albuminous seeds
   (a) **Mnemonics: A**ll **E**uropeans **BMW C**ar **s**howroom
   Interpretation: Albuminous or **E**ndospermic seeds: **B**arley, **M**aize, rice, **C**astor
   (b) **Mnemonics: N**o **A**lternative **N**ever **E**nd **G**rowing **G**ram **B**efore **P**loughing
   Interpretation: Non-**A**lbuminous or **N**on-**E**ndospermic seeds: **G**roundnut, **G**ram, **B**ean, **P**ea.
2. **Concept Name: P**olyembryony
   Mnemonics: PELO—Please Erase **L**eaders **O**rders
   Interpretation: Poly**E**mbryony**:** e.g., **L**emon, **O**ranges
3. **Concept Name:** Nuclear and Cellular Endosperm
   (a) **Mnemonics: C**an **S**unil **M**arry **W**innie
   Interpretation: Nuclear Endosperm—Cotton, **S**unflower, **M**aize, **W**heat
   (b) **Mnemonics: B**irth **D**ay **P**arty
   Interpretation: Cellular Endosperm—Balsum, **D**atura, **P**etunia
4. **Concept Name:** False fruit
   Mnemonics: Can Arvind **S**ing?
   Interpretation: Cashewnut**, A**pple, **S**trawberry

❑❑

CHAPTER-3
HUMAN REPRODUCTION

Topic-1 Male and Female Reproductive System and Gametogenesis

Concepts Covered • *Male and Female Reproductive System and Its Parts,* • *Spermatogenesis,* • *Oogenesis*

Revision Notes

Reproduction in Humans

- Human beings reproduce sexually and are viviparous. In humans, the reproductive phase starts after puberty. It involves:
  • Gametogenesis • Insemination • Fertilisation • Implantation • Gestation • Parturition

Male Reproductive System

- It consists of:
  (a) A pair of testes (primary sex organ) **(b)** Accessory ducts **(c)** Accessory glands **(d)** External genitalia

Testes

- Testes are the primary sex organs that produces sperms and testosterone male sex hormone.
- Testes are contained situated outside the abdominal cavity in a sac of skin called scrotum located between the upper thighs.
- The low temperature (2–2.5°C less than the normal internal body temperature) of scrotum helps for proper functioning of testes and for spermatogenesis.
- Each testis is oval in shape.
- Each testis has about 250 (200–300) compartments called **testicular lobules**.
- Each lobule is filled with connective tissue and contains 1–3 coiled yellow seminiferous tubules in which sperms are produced.
- Seminiferous tubule is lined internally with spermatogenic cells ($2n$) called **spermatogonia** or primary male germ cells and Sertoli cells or nurse cells.

- Spermatogonia undergo meiotic divisions and lead to sperm (n) formation.
- Sertoli cells give shape and nourishment to developing spermatogenic cells; therefore they are also called **nurse cells**.
- The regions outside the seminiferous tubules are the interstitial spaces which contain small blood vessels and interstitial cells or Leydig cells.
- The Leydig cells are endocrine in nature and secrete testicular hormones called androgens.
- Immunologically competent cells are also present.

Accessory Ducts

- The duct system includes rete testis, vasa efferentia, epididymis and vas deferens.
- The seminiferous tubules open into the vasa efferentia through rete testis.
- The vasa efferentia opens into epididymis.
- The epididymis leads to vas deferens that ascends into the abdomen and loops over the urinary bladder.
- It receives a duct from the seminal vesicle and opens into urethra as the ejaculatory duct.
- These ducts store and transport the sperms from the testis to the outside through urethra.
- The urethra originates from the urinary bladder and extends through the penis to its external opening called **urethral meatus**.

Accessory Male Genital Glands

- It includes paired seminal vesicles, a single prostate gland and paired bulbourethral glands (Cowper's glands).
- The secretions of these glands constitute the seminal plasma, which is rich in fructose, calcium and certain enzymes.
- Seminal vesicles produce seminal fluid and form 60–70% of semen.
- The secretion of bulbourethral glands is alkaline and rich in mucus. It helps in the lubrication of the penis, supplies nutrients to sperms and provides an alkaline medium to counteract the acidity of the female reproductive canal.

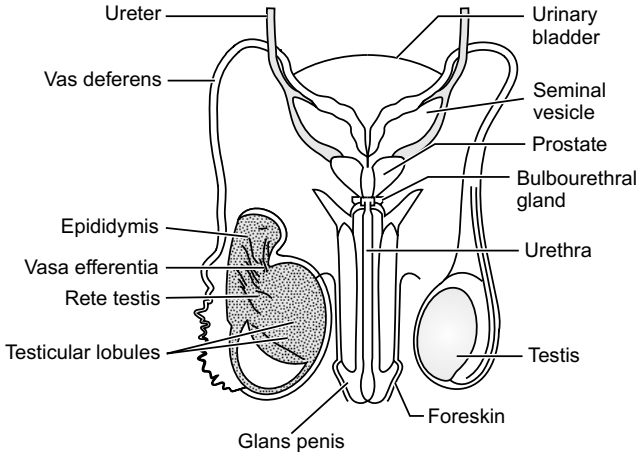


Fig. 3.1: Male Reproductive System

External Genitalia

- The penis is the male external genitalia.
- It is made up of special tissue that helps in the erection of the penis to facilitate insemination.
- The enlarged end of the penis is called the glans penis which is covered by a loose fold of skin called **foreskin.**

Female Reproductive System

- It includes a pair of ovaries, accessory ducts and external genitalia.
- **Ovaries** Are the primary female sex organs which produce ova or the female gametes. It secretes a number of steroid ovarian hormones such as estrogen and progesterone.
- Ovaries are located on both sides in the lower abdominal cavity.
- Each ovary is about 2–4 cm in length.
- The ovaries are connected to the pelvic wall and uterus by ligaments.
- Each ovary is covered by a thin epithelium which encloses the ovarian stroma.
- The stroma has an outer cortex and inner medulla.
- Ovary contains groups of cells known as **ovarian or Graafian follicles**.
- Each follicle carries a centrally placed ovum.

Accessory Ducts

- It includes two oviducts or Fallopian tubes, a uterus and vagina.
- Each oviduct is 10–12 cm long and has four parts namely, infundibulum, ampulla, isthmus and uterine part.

(a) Infundibulum

- It is the funnel-shaped opening provided with many finger-like projections called fimbriae to collect released ovum.
- It helps to collect the ovum after its release from the ovary.

(b) Ampulla

- The infundibulum leads to the curved and dilated part called **ampulla**.

(c) Isthmus
- It is the last straight part of the oviduct.
- It has a narrow lumen and joins the uterus.

(d) Uterine Part
- It is about 1 cm long part of the oviduct which passes into the uterus.

Uterus (Womb)

- The shape of the uterus is like an inverted pear.
- It is supported by ligaments attached to the pelvic wall.
- The uterus opens into the vagina through a narrow cervix.
- The cavity of the cervix is called **cervical canal** which along with the vagina forms the birth canal.
- The wall of the uterus is thick and muscular and is differentiated into three layers of tissue namely,
  (a) The external thin membranous **perimetrium**.
  (b) The middle thick layer of smooth muscle, **myometrium**.
  (c) The inner glandular layer called **endometrium**.
- The endometrium undergoes cyclic changes during the menstrual cycle while the myometrium exhibits strong contraction during the delivery of a baby.
- Vagina opens to the exterior between urethra and anus.
- The lumen of vagina is lined by a glycogen-rich mucous membrane consisting of sensitive papillae and Bartholin's glands.
- The secretions of Bartholin's glands lubricate the vagina during sexual act.

External Genitalia

- It includes mons pubis, labia majora, labia minora, hymen and clitoris. The external genitalia are collectively called **vulva**.
- **Mons pubis** is a cushion of fatty tissue covered by skin and pubic hair.
- The **labia majora** are a pair of large thicker fleshy folds of tissue which surround the vaginal opening.
- The **labia minora** are a pair of narrow fleshy folds of tissue found below labia majora.
- The opening of the vagina is often covered either partly or entirely by a membrane called **hymen**.
- The hymen is often torn during the first coitus (intercourse) or accidentally, during sports, cycling.
- The clitoris is a tiny finger-like structure which lies at the upper junction of the two labia minora above the urethral opening.

Mammary Glands

- A pair of mammary glands containing glandular and fatty tissue present in the chest region.
- Glandular tissue of each breast has 15–20 mammary lobes containing clusters of cells called **alveoli**.
- The cells of alveoli secrete milk which is stored in the cavities or lumen of alveoli.
- The alveoli open into mammary tubules.
- The tubules of each lobe join to form a mammary duct.
- Several mammary ducts join to form a wider mammary ampulla which is connected to lactiferous duct through which milk is released.

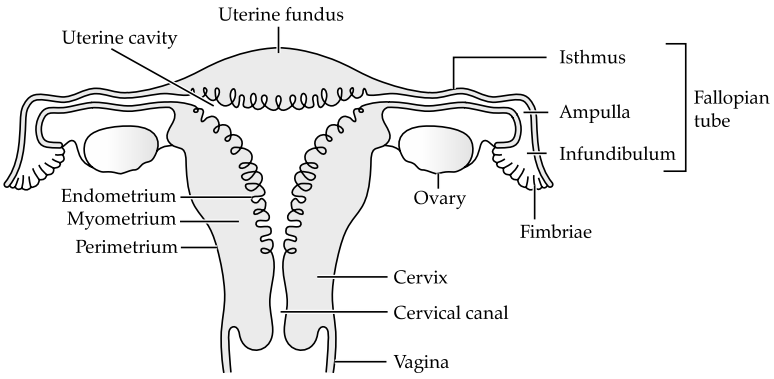


Fig. 3.2: Female Reproductive System

Gametogenesis

- The process by which the primary sex organs, i.e., the testis in the males and the ovaries in the females produce gametes, i.e., sperms and ovum, respectively.
- Gametogenesis is classified into two types,
  (a) Spermatogenesis
  (b) Oogenesis

Spermatogenesis

- It is the process of formation of spermatids in seminiferous tubules of testes.

- The spermatids are non-motile structures that are transformed into spermatozoa (mature sperms) by the process called spermiogenesis.
- In testis the spermatogonia, i.e., sperm mother cells or immature male germ cells produce spermatids.
- The spermatogonia multiply mitotically and increase in numbers. Each spermatogonium is diploid containing 46 number of chromosomes.
- Some of the spermatogonia called **primary spermatocytes** periodically undergo meiosis.
- A primary spermatocyte completes the first meiotic division or reduction division resulting in the formation of two equal, haploid cells called **secondary spermatocytes**.
- The secondary spermatocytes have only 23 chromosomes each.
- The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid spermatids.
- The spermatids are transformed into spermatozoa or sperms by the process called **spermiogenesis**.
- After spermiogenesis, sperm heads become embedded in the Sertoli cells and are released from the seminiferous tubules by the process called **spermiation**.
- In the diagram spermatid and spermatozoa are both marked as the same structure.

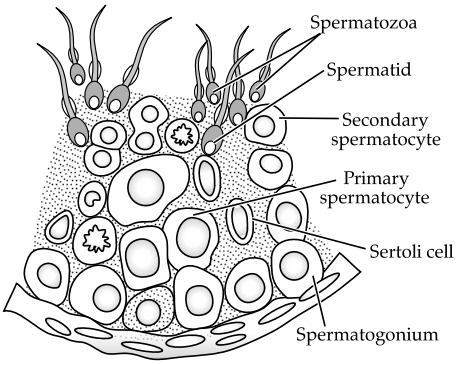


Fig. (a) Diagrammatic view of a seminiferous tubule

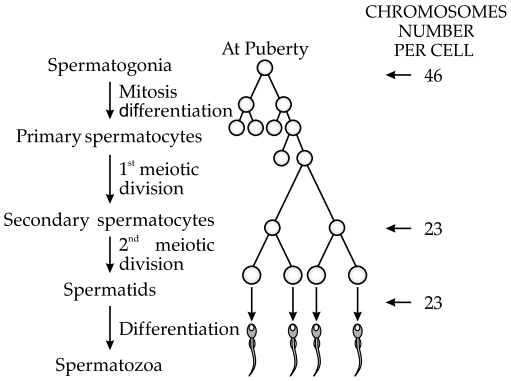


Fig. (b) Spermatogenesis

Fig. 3.3

Role of Hormones in Spermatogenesis

- Spermatogenesis starts at the age of puberty due to a significant increase in the secretion of gonadotropin releasing hormone (GnRH), a hypothalamic hormone.
- The increased levels of GnRH act at the anterior pituitary gland and stimulate the secretion of two hormones namely,
  - **(a)** Luteinising hormone (LH)
  - **(b)** Follicle stimulating hormone (FSH)
- LH acts at the Leydig cells and stimulates the synthesis and secretion of androgens.
- Androgens stimulate the process of spermatogenesis.
- FSH acts on the Sertoli cells and stimulates the secretion of some factors which help in the process of spermiogenesis.

Structure of a Sperm

- It is a microscopic structure composed of a head, neck, a middle piece and a tail.
- A plasma membrane envelops the whole body of sperm.
- The sperm head contains a large elongated haploid nucleus.
- The anterior portion is covered by a cap-like structure called acrosome.
- The acrosome contains hydrolytic enzymes that help in dissolving membranes of an ovum for fertilisation.

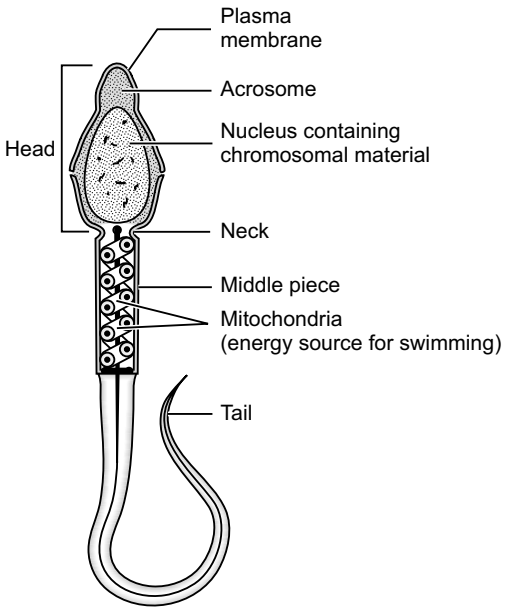


Fig. 3.4: Structure of a sperm

- The middle piece possesses numerous mitochondria, which produce energy for the movement of a tail that facilitate sperm motility essential for fertilisation.
- The human male ejaculates about 200 to 300 million sperms during coitus.
- Sperms released from the seminiferous tubules are transported by the accessory ducts.
- The secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for the maturation and motility of sperms.
- The seminal plasma along with the sperms constitutes the semen.
- The functions of male sex accessory ducts and glands are maintained by the testicular hormones or androgens.

Oogenesis

- The process of formation of a mature female gamete is called oogenesis.
- It takes place in Graafian follicles.
- Oogenesis is initiated during the embryonic development stage when gamete mother cells (oogonia) are formed within each fetal ovary.
- No more oogonia are formed and added after birth.
- These cells start meiotic division and get temporarily arrested at the prophase-I stage, called **primary oocytes**.
- Each primary oocyte then gets surrounded by a layer of granulosa cells called **primary follicle**.
- A large number of these follicles degenerate during the phase from birth to puberty.
- Therefore, at puberty, only 60,000–80,000 primary follicles are left in each ovary.
- The primary follicles get surrounded by more layers of granulosa cells and a new theca are called secondary follicles.
- The secondary follicle transforms into a tertiary follicle, which is characterised by a fluid filled cavity, called **antrum.**
- The theca layer is organised into two layers namely,
  - **(a)** An inner theca interna
  - **(b)** An outer theca externa.
- The primary oocyte within the tertiary follicle grows in size and completes its first meiotic division (unequal division) resulting in the formation of a large haploid secondary oocyte and a tiny first polar body.
- The secondary oocyte retains the bulk of the nutrient rich cytoplasm of the primary oocyte.
- The tertiary follicle further changes into the mature follicle or **Graafian follicle**.
- The secondary oocyte forms a new membrane called **zona pellucida** surrounding it.
- The Graafian follicle now ruptures to release the secondary oocyte (ovum) from the ovary by the process called **ovulation**.

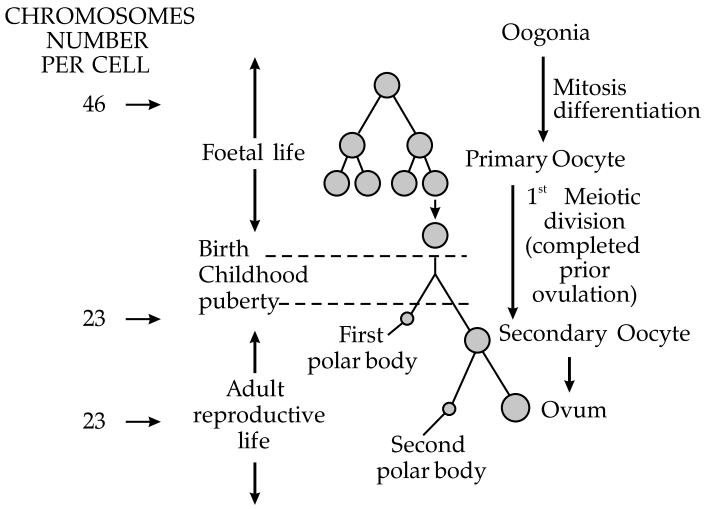


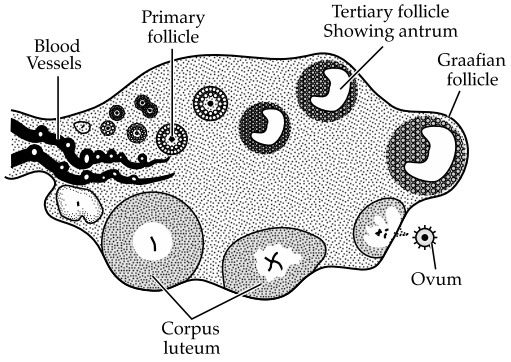
Fig. 3.5: Oogenesis in human female

Comparison between Spermatogenesis and Oogenesis:

S. No.	Spermatogenesis	Oogenesis
1.	Produces male gametes (sperms).	Produces female gametes (oocytes).
2.	Occurs in testis.	Occurs in ovary.
3.	Limited growth phase.	Elaborated growth phase.
4.	Each primary spermatocyte gives four sperms.	Each primary oocyte gives only one ovum. Polar bodies are formed.
5.	It begins at puberty.	It begins at embryonic stage and suspended at the time of birth. The remaining part takes place only after puberty.
6.	It occurs in seminiferous tubules of testes.	It occurs in the follicles of ovary.

Structure of Ovum or Egg

- It is spherical and non-motile.
- It is about 0.2 mm in diameter.
- Ovum has four membranes namely,
  - **(a) Plasma membrane (Oolemma):** Innermost layer.
  - **(b) Vitelline membrane:** Attached to plasma membrane.
  - **(c) Zona pellucida:** Transparent non-cellular layer found outer to the vitelline membrane.
  - **(d) Corona radiata:** Outer layer formed of follicular cells. These cells are bound together by hyaluronic acid.



Section of an Ovary

Fig. 3.6: Section of an ovary

Key Terms

- **Acrosome:** A small, cap-like structure at the end of a sperm's head which contains hydrolytic enzymes.
- **Endometrium:** Innermost glandular layer lining the uterine cavity.
- **Hymen:** A thin membrane partially covering the vaginal apertures.
- **Ovulation:** The rupturing of Graafian follicle to release the secondary oocyte (ovum) from the ovary is called ovulation.
- **Puberty:** A stage at which immature reproductive system of boy or girl becomes mature.
- **Primary sex organs:** They are the reproductive organs which produce gametes and sex hormones.
- **Secondary sex organs:** They are the reproductive organs which perform functions of reproduction, but do not form gametes or secrete sex hormones.
- **Spermatogenesis:** It is the process of the formation of sperms (spermatozoa) from the immature germ cells in males.
- **Spermiogenesis:** It is the process of transformation of non-motile, rounded haploid spermatid into a functional and motile spermatozoan.
- **Spermiation:** It is the process when mature spermatozoa are released from the Sertoli cells into the lumen of seminiferous tubules.
- **Oogenesis:** It is the process of formation of a mature ovum from the oogonia in a female.

Mnemonics

1. Concept: Parts of male reproductive system
Mnemonics: SEVEn UP
Interpretation: Seminiferous tubule, **E**pididymis, **V**as deferens, **E**jaculatory duct, **U**rethra , **P**enis

2. Concept: Male accessory gland
Mnemonics: BSP (Bahujan Samaj Party)
Interpretation: Bulbourethral glands, **S**eminal vesicle, **P**rostrate gland

3. Concept: Accessory ducts in females
Mnemonics: Our **U**nited **V**illage
Interpretation: Oviduct, **U**terus, **V**agina

4. Concept: Accessory ducts in females
Mnemonics: Infection **A**nd **I**mmunity
Interpretation: Infundibulum, **A**mpulla, **I**sthmus

5. Concept: External Genitalia (Female)
Mnemonics: Mobile's **L**ight **L**et **H**im **C**razy
Interpretation: Mons **p**ubis, **l**abia **m**ajora, **l**abia **m**inora, **h**ymen and **c**litoris.

6. Concept: Steps involved in Spermatogenesis
Mnemonics: Government **E**mphasise on **S**overeignty, **S**ecularism, **S**ocialism and **S**ecurity
Interpretation: Germinal Epithelium, **S**permatogonia, **S**permatocytes, **S**permatids, **S**perm

7. Concept: Steps involved in Oogenesis
Mnemonics: German **E**mpire **O**rganised **O**rphan **O**riented **O**peration
Interpretation: Germinal Epithelium, **O**ogonia, **O**ocyte, **O**otid, **O**vum

Topic-2 Menstrual Cycle, Fertilisation and Pregnancy

Concepts Covered • *Menstruation, Fertilisation, Stages of Embryonic Development*

Revision Notes

Menstrual Cycle

- The reproductive cycle or rythemic changes in the reproductive organs of female primates (e.g., monkeys, apes and human beings) is called menstrual cycle.
- The first menstruation begins at puberty and is called menarche.
- In human females, menstruation is repeated at an average interval of about 28/29 days, and the cycle of events starting from one menstruation till the next one is called the menstrual cycle.
- One ovum is released (ovulation) during the middle of each menstrual cycle.
- The cycle starts with the menstrual phase, when menstrual flow occurs and it lasts for 3-5 days.
- During menstrual flow, liquid comes out through the vagina due to breakdown of endometrial lining of the uterus.
- Menstruation occurs if the released ovum is not fertilized.
- Lack of menstruation may be indicative of pregnancy.
- No menstruation can also be caused due to some other underlying causes like stress, poor health, etc.
- The menstrual phase is followed by the follicular phase. During this phase, the primary follicles in the ovary grow to become a fully mature Graafian follicle and simultaneously the endometrium of uterus regenerates through proliferation.
- These changes in the ovary and the uterus are induced by changes in the levels of pituitary and ovarian hormones.
- The secretion of gonadotropins (LH and FSH) increases and stimulates follicular development as well as secretion of estrogens by the growing follicles.

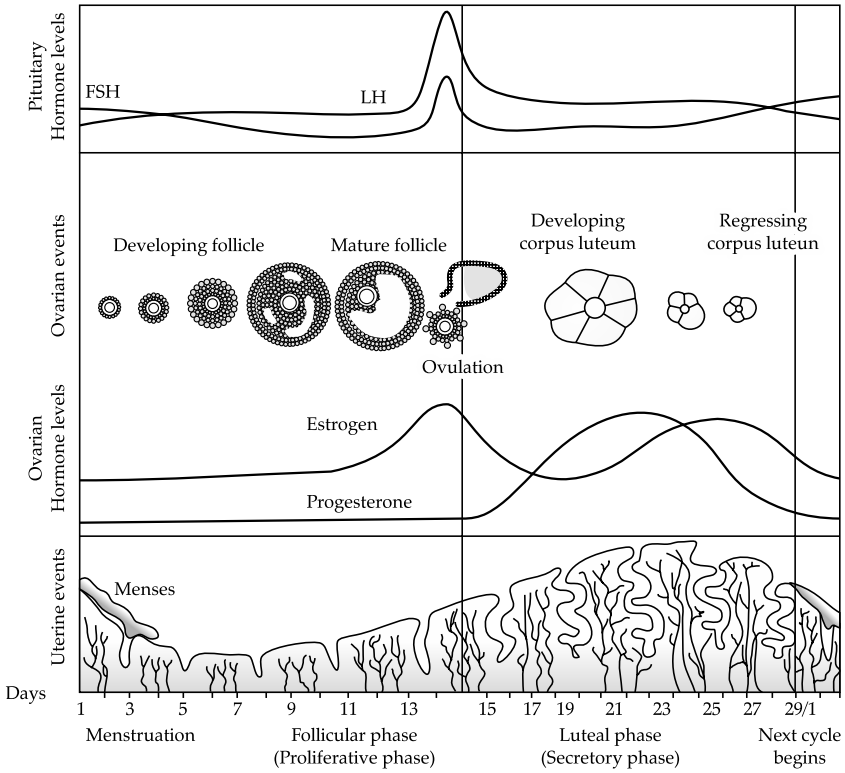


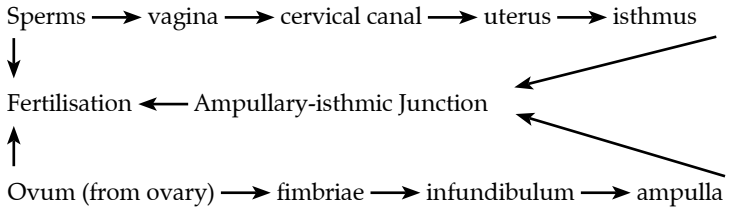
Fig. 3.7: Events menstrual cycle

- Both LH and FSH attain a peak level in the middle of cycle (about 14th day).
- Rapid secretion of LH leading to its maximum level during the mid-cycle called LH surge induces rupture of Graafian follicle and thereby the release of ovum (ovulation).
- The ovulation phase is followed by luteal phase, during which the remaining parts of the Graafian follicle transform into corpus luteum.
- The corpus luteum secretes large amounts of progesterone, which is essential for the maintenance of the endometrium. Endometrium is necessary for implantation of the fertilized ovum and pregnancy.
- During pregnancy, there is no menstruation.
- In the absence of fertilisation, the corpus luteum degenerates.
- This causes the disintegration of endometrium leading to menstruation.
- In human beings, menstrual cycles cease around 50 years of age termed as menopause.
- Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.
- In non-primate female mammals cyclic changes that occur during the reproductive phase is called oestrous cycle.

Oestrus cycle	Menstrual cycle
• The cyclic changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase of non-primate mammals is called oestrus cycle. • Females show strong irresistible sexual urge. • There is estrous/heat production at the time of ovulation and copulation occurs only at that period. • The shedding of endometrium and bleeding do not occur, e.g., cows, sheep, rats, deers, dogs and tigers, etc.	• The cyclic changes in the activities of ovaries and accessory ducts as well as hormones during the reproductive phase of primate mammals is called menstrual cycle. • Females do not show irresistible sexual urge. • There is no heat period and copulation occurs during any time of the cycle. • The shedding of endometrium and bleeding occurs, e.g., monkeys, apes and humans.

Fertilisation

- During copulation (coitus), semen is released by the penis into the vagina (insemination).
- The motile sperms swim rapidly, pass through the cervix, enter into the uterus and finally reach the junction of the isthmus and ampulla (ampullary-isthmic junction) of the fallopian tube.
- The process of fertilisation takes place as follows:



- The ovum released by the ovary is also transported to the ampullary-isthmic junction where fertilisation takes place.
- Fertilisation can only occur if the ovum and sperms are transported simultaneously to the ampullary-isthmic junction. Hence, not all copulations lead to fertilisation and pregnancy.
- The process of fusion of a sperm with an ovum is called **fertilisation**.
- During fertilisation, a sperm comes in contact with the zona pellucida layer of the ovum and induces changes in the membrane that block the entry of additional sperms to ensure that only one sperm can fertilise an ovum.
- The secretions of the acrosome help the sperm enter into the cytoplasm of the ovum through the zona pellucida and the plasma membrane.
- This includes the completion of the meiotic division of the secondary oocyte.
- The second meiotic division is also unequal and results in the formation of a second polar body and a haploid ovum (ootid).
- Soon, the haploid nucleus of the sperm and that of the ovum fuse together to form a diploid zygote.

Sex Determination in Human

- The chromosome pattern in the human female is XX and that in the male is XY.
- Therefore, all the haploid gametes produced by the female (ova) have the sex chromosome X whereas in the male gametes (sperms) the sex chromosome could be either X or Y, hence, 50% of sperms carry the X chromosome while the other 50% carry the Y chromosome.
- After fusion of the male and female gametes, the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum.
- The zygote carrying XX would develop into a female baby and XY would form a male baby.

Implantation

- The mitotic division starts as the zygote moves through the isthmus of the oviduct towards the uterus called cleavage and forms 2, 4, 8, 16 daughter cells are called **blastomeres**.

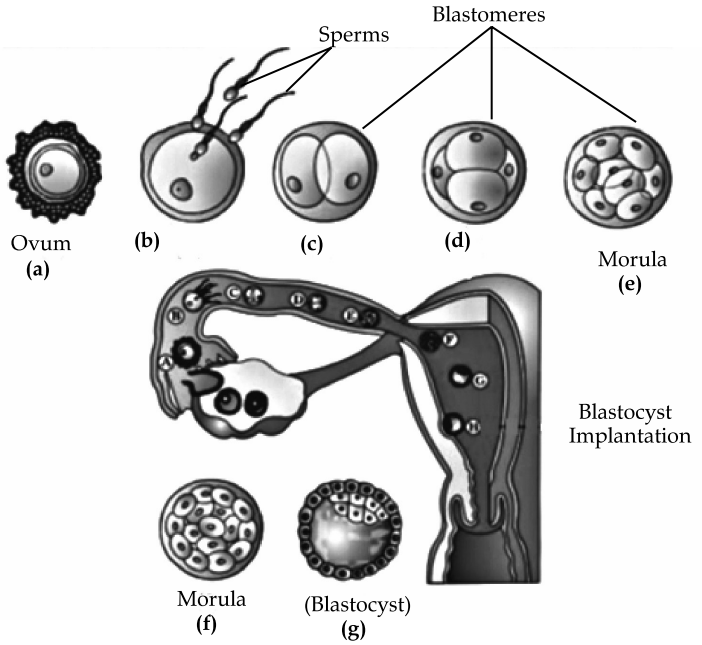


Fig. 3.8: Various events after fertilisation (transport of ovum, fertilisation and stages of embryonic development)

- The embryo with 8 to 16 blastomeres is called a **morula**.
- The morula continues to divide and transforms into blastocyst as it moves further into the uterus.
- The blastomeres in the blastocyst are arranged into an outer layer called trophoblast and an inner group of cells attached to trophoblast called the inner cell mass.
- The trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the embryo.
- After attachment, the uterine cells divide rapidly and cover the blastocyst.
- As a result, the blastocyst becomes embedded in the endometrium of the uterus. This is called implantation and it leads to pregnancy.

Pregnancy and Embryonic Development

- After implantation, finger-like projections appear on the trophoblast called **chorionic villi** which are surrounded by the uterine tissue and maternal blood.
- The chorionic villi and uterine tissue become interdigitated with each other and jointly form a structural and functional unit between developing embryo (foetus) and maternal body called **placenta.**
- The placenta facilitates the supply of oxygen and nutrients to the embryo and also removal of carbon dioxide and excretory/ waste materials produced by the embryo.
- The placenta is connected to the embryo through an umbilical cord which helps in the transport of substances to and from the embryo.

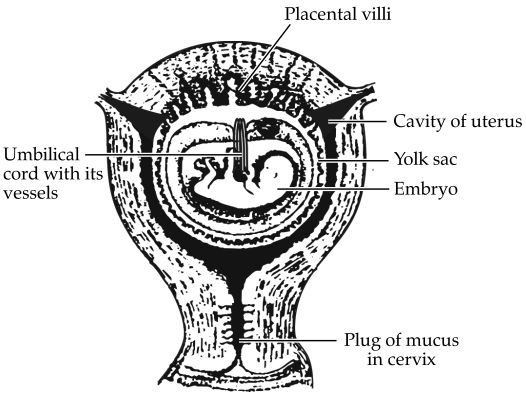


Fig. 3.9: Human foetus within uterus

- Placenta villi should be changed to placental villi.
- Uterine cavity is marked as amniotic cavity here, Amniotic cavity is the sac where foetus is present. Correct these labellings.

Functions of Placenta

- It acts as barrier between the foetus and mother.
- Soluble inorganic and organic materials, nutrients, hormones, antibodies, etc., can pass through the placenta from the mother to foetus.
- It helps in gaseous exchange between mother and foetus.
- It helps to eliminate nitrogenous wastes of foetus.
- It acts as an endocrine gland by secreting several hormones like human chorionic gonadotropin (hCG), human placental lactogen (hPL), oestrogens, progesterone and relaxin.

Pregnancy

- In the later phase of pregnancy, a hormone called relaxin is also secreted by the ovary.
- hCG, hPL and relaxin are produced in women only during pregnancy.
- Levels of hormones like estrogens, Progesterone, cortisol, prolactin, thyroxine, etc., are increased several folds in the maternal blood.
- Increased production of these hormones is essential for supporting the foetal growth, metabolic changes in the mother and maintenance of pregnancy.
- After implantation, embryo differentiates into an outer layer called ectoderm and an inner layer called endoderm.
- A mesoderm soon appears between the ectoderm and the endoderm.
- These three layers give rise to all tissues (organs) in adults.
- The inner cell mass contains certain cells called stem cells which have the potency to give rise to all the tissues and organs.
- The human pregnancy lasts for 9 months.

Changes in Embryo during Pregnancy

- After one month of pregnancy, the embryo's heart is formed.
- By the end of the second month of pregnancy, the foetus develops limbs and digits.
- By the end of 12 weeks (first trimester), most of the major organ systems are formed, for example, the limbs and external genital organs are well-developed.
- The first movements of the foetus and the appearance of hair on the head are observed during the fifth month.
- By the end of 24 weeks (second trimester), the body is covered with fine hair, eye-lids separate, and eyelashes are formed.
- By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

Parturition

- The average duration of human pregnancy is about 9 months (around 280 days) which is called the **gestation period**.
- Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus. This process of delivery of the foetus (child birth) is called parturition.
- The parturition is induced by a complex neuroendocrine mechanism.
- The signals for parturition originate from the fully developed foetus and the placenta which induces mild uterine contractions called foetal ejection reflex.
- The release of oxytocin from the maternal pituitary takes place. Oxytocin acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin.
- This results into stronger and stronger contractions.
- This leads to the expulsion of the baby out of the uterus through the birth canal.
- Soon after the infant is delivered, the placenta is also expelled out of the uterus.

Lactation

- The mammary glands of the female undergo differentiation during pregnancy and start producing milk towards the end of pregnancy by the process called lactation. This helps the mother in feeding the newborn.
- The milk produced during the initial few days of lactation is called colostrum. It contains several antibodies absolutely essential to develop resistance for the new-born babies.
- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

Key Terms

- **Blastula:** A stage of embryogenesis which comes after morula and has a hollow fluid filled space called blastocoel.
- **Cleavage:** It is the first phase of embryonic development where the zygote undergoes mitotic division to become a multicellular structure.
- **Colostrum:** The milk produced by mother during the initial few days of lactation is called colostrum. It contains several antibodies (IgA) and nutrients (like lactose, calcium, fats) absolutely essential to develop resistance for the new-born babies.
- **Foetal Ejection Reflex:** It is the initial and mild contractions of the uterus initiated by the fully developed foetus and the placental hormones.
- **Foetus:** An advanced stage of embryo within the uterus.
- **Gestation Period:** A period between fertilisation of ovum and the birth of a baby.
- **Insemination:** It refers to the deposition of sperms into the female genital tract.
- **Implantation:** It is the process in which the embryo becomes embedded into the wall of the uterus.
- **Lactation:** It refers to the feeding of the new born baby with mother's milk.
- **Menarche:** It is the beginning of menstruation at puberty in primate females.
- **Menopause:** It refers to the stoppage of menstruation at around the age of 45–50.

Mnemonics

1. Concept: Parts of mammary gland:
Mnemonics: MAMMAL
Interpretation: Mammary gland, **A**lveoli lumen, **M**ammary tubules, **M**ammary duct, **A**mpula, **L**actiferous duct, **L**actiferous **S**inus

2. Concept: Phases of Menstrual cycle
Mnemonics: FOLM-First **O**ption is **L**anguage and **M**aths; (or) **F**aculty **O**f **L**ight **M**usic
Interpretation: Follicular **phase-O**vulation**-L**uteal **phase-M**enstruation

3. Concept: Hormones acting on mammary gland
Mnemonics: Hari **O**pted for **P**hysical **E**ducation **P**rogram (or) **H**otel of **P**aris **E**vacuated **P**eople
Interpretation: Human Placental lactogen, **O**xytocin, **P**rolactin, **E**strogen, **P**rogesteron

4. Concept: Phases of embryonic development:
Mnemonics: Give **F**ree **C**hocolate **I**cing **G**anache as **O**rdered
Interpretation: Gametogenesis, **F**ertilization, **C**leavage, **I**mplantation, **G**astrulation, **O**rganogenesis

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CHAPTER-4
REPRODUCTIVE HEALTH

Topic-1 Reproductive Health, Problems and Strategies

Concepts Covered • *Strategies and factors of reproductive health and methods of birth control*

Revision Notes

Reproductive Health

- Reproductive health refers to healthy reproductive organs with normal functions.
- It also includes the emotional and social aspects of reproduction.

- According to the World Health Organisation (WHO), reproductive health means a total well-being in all aspects of reproduction, i.e., physical, emotional, behavioural and social.
- Thus, people having physically and functionally normal reproductive organs, emotional and behavioural interactions in all sex-related aspects are called reproductively healthy.

Problems Associated with Reproductive Health

- Rapid increase in human population leads to population explosion.
- Lack of awareness and sex education in people.
- A number of myths and misconceptions about sex related aspects.
- Common occurrence of sexually transmitted diseases.
- Illegal abortions and female foeticides.
- Sex abuse and sex related crime.

Strategies of Reproductive Health Programmes

- To achieve total reproductive health, programmes called 'family planning' were started in 1951.
- Improved programmes covering wider reproduction-related areas are currently in operation under the name Reproductive and Child Health Care Programmes.
- **The Aim of Reproductive and Child Care Programme was to:**
  - **(a)** **Create awareness** in both males and females about various reproductive aspects with the help of audio–visual and print media by both Government and Non-Government agencies.
  - **(b)** **Provide sex education** in schools to save the young generation from myths and misconceptions about sex related issues.
  - **(c)** **Prevention and control of sexually transmitted diseases** by providing the correct information about reproductive organs, adolescence and safe and hygienic sexual practices.
  - **(d)** **Educate the fertile couples** and those in marriageable age about birth control devices, pre-natal and post-natal care of mother and child, importance of breast feeding etc.
  - **(e)** Provide awareness about **ill-effects of population explosion, sexual abuses, sex discrimination and sex related crimes**.
  - **(f)** **Provide medical facilities and support** like infrastructural facilities, professional expertise and material support to decrease maternal and infant mortality rates.
  - **(g)** Lessen the **problem of infertility** by promoting the **Assisted Reproductive Techniques (ARTs)**.

Factors Responsible for Improved Reproductive Health of Society

- **(a)** Better awareness about sex related matters and sex-related problems etc.
- **(b)** Increased number of medically assisted deliveries and better post-natal care leading to decreased maternal and infant mortality rates.
- **(c)** Increased number of couples with small families.
- **(d)** Early detection and cure of Sexually Transmitted Diseases (STDs).
- **(e)** Overall increased medical facilities for all sex-related problems.
- **(f)** Statutory ban on **amniocentesis** for sex-determination to legally check increasing female foeticides, massive child immunisation, etc. Amniocentesis is a foetal sex determination test based on the chromosomal pattern in the amniotic fluid surrounding the developing embryo.
- **(g)** 'Saheli'–a new oral contraceptive for the females–was developed by scientists at Central Drug Research Institute (CDRI) in Lucknow, India.
- **(h)** Rigorous implementation of immunization programs.

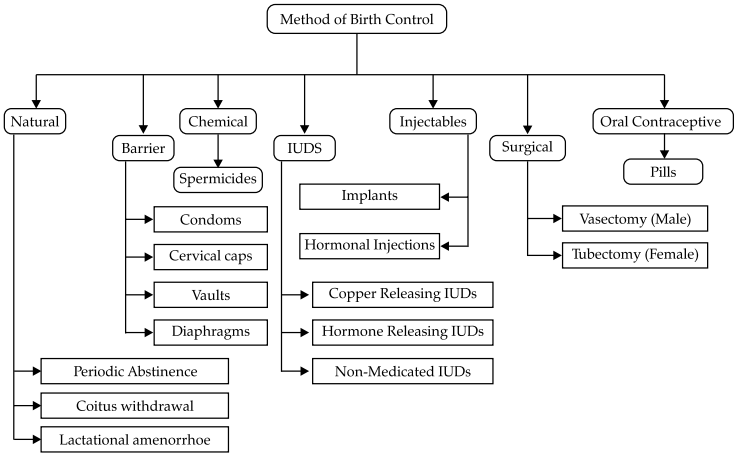
How to Control Over Population

- People should be given education regarding advantages of small family and family planning methods.
- Increasing the age of marriage.
- Incentives to those families, which adopting family planning methods.
- Birth control through **vasectomy** and **tubectomy**.
- Awareness about the Family planning programmes with the slogan 'Hum Do Hamare Do'.

Birth Control

- The contraceptive methods are used to prevent the unwanted pregnancy and modify the menstrual cycle. The contraceptive methods are the best way to birth control.

- An ideal contraceptive should be:
  - **(a)** User-friendly
  - **(b)** Easily available
  - **(c)** Effective
  - **(d)** Reversible with no or least side effects.
  - **(e)** In no way interfere with the sexual drive, desire and/or the sexual act of the user.
- **Different methods of birth control are:**
- Change coitus withdrawal under natural methods to coitus interruptus or withdrawal method



Contraceptive Method

I. Natural Methods: They works on the principle of avoiding chances of ovum and sperms meeting. It includes,

(a) Periodic abstinence: It is a method in which the couples avoid or abstain from coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected, a chances of fertilisation are very high during this period. It is called the **fertile period**. Therefore, by abstaining from coitus during this period, conception could be prevented.

(b) Withdrawal or coitus interrupts: It is another method in which the male partner withdraws his penis from the vagina just before ejaculation so as to avoid insemination. It is the oldest method of voluntary fertility control.

(c) Lactational amenorrhea: It is a method which is based on the fact that ovulation and therefore the cycle does not occur during the period of intense lactation following parturition. Therefore, as long as the mother breast-feeds, the chances of conception are almost nil. It also has no side effects but is effective only up to a maximum period of six months after parturition.

II. Artificial Methods: This involves mechanical or barrier methods. In barrier methods, ovum and sperms are prevented from physically meeting with the help of barriers. These methods are available for both males and females. It includes-

(a) Condoms

- These are barriers made of thin rubber or latex sheath that are used to cover the penis in the male or vagina and cervix in the female, just before coitus, so that the ejaculated semen would not enter or deposits into the female reproductive tract, thereby preventing conception.

Fig. 4.1: Condom for male

- Using condoms also protects the user from contracting STDs.
- Both the male and the female condoms are disposable, can be self-inserted.
- One of the common condoms is 'Nirodh'.

(b) Diaphragms, Cervical caps and Vaults

- These are also barriers made of rubber that are inserted into the female reproductive tract to cover the cervix during coitus. They prevent conception by blocking the entry of sperms through the cervix. They are reusable.
- Spermicidal creams, jellies and foams are usually used along with these barriers to increase their contraceptive efficiency.

III. Intra Uterine Devices (IUDs)

- Another effective and popular method is the use of Intra Uterine Devices (IUDs).
- These devices are inserted by doctors or expert nurses in the uterus through the vagina.
- These are available as the non-medicated IUDs such as Lippes loop, copper-releasing IUDs such as CuT, Cu7, Multiload 375 and the hormone-releasing IUDs like Progestasert, LNG-20.
- IUDs increase phagocytosis of sperms within the uterus and the Cu ions released suppress sperm motility and the fertilising capacity of sperms.
- The hormone-releasing IUDs make the uterus unsuitable for implantation and the cervix hostile to the sperms. IUDs are ideal contraceptives for the females to delay pregnancy.
- It is one of the most widely accepted methods of contraception in India.

IV. Oral Contraceptives

- Oral administration of small doses of either progestogens or progestogen–estrogen combinations is another contraceptive method used by females.
- They are used in the form of tablets and hence are popularly called the pills.
- Pills have to be taken daily for a period of 21 days preferably within the first five days of the menstrual cycle.
- After a gap of 7 days, (during which menstruation occurs) it has to be repeated in the same pattern till the female desires to prevent conception.
- The oral contraceptives inhibit ovulation and implantation as well as alter the quality of cervical mucus to prevent or retard entry of sperms.
- Pills are very effective with lesser side effects.
- **Saheli**, the new oral contraceptive for females contains a non-steroidal preparation.
- It is a 'once a week' pill with very few side effects and high contraceptive value.
- **Drawbacks of Oral Contraceptives:** Nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding, breast cancer, etc.

V. Injections and Implants

- Progestogens alone or in combination with estrogen can be used by females as injections or implants under the skin.
- Their mode of action is similar to that of pills and their effective periods are much longer.
- Administration of progestogens or progestogen–estrogen combinations or IUDs within 72 hours of coitus is very effective as emergency contraceptives as they could be used to avoid possible pregnancy due to rape or casual unprotected intercourse.

VI. Surgical Methods: Surgical methods are also called **sterilisation**.

- This is a terminal method advised for the male/female partner to prevent any more pregnancies.
- Surgical intervention blocks gamete transport thereby preventing conception.
- Sterilisation procedure in the male is called **'vasectomy'** while that in the female is called **'tubectomy'**.
- In vasectomy, a small part of the vas deferens is removed or tied up through a small incision on the scrotum whereas in tubectomy, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through the vagina.
- These techniques are highly effective but their reversibility is very poor.

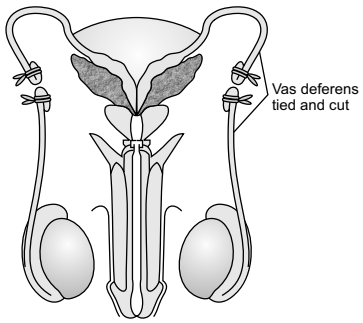


Fig. 4.2: Vasectomy in male

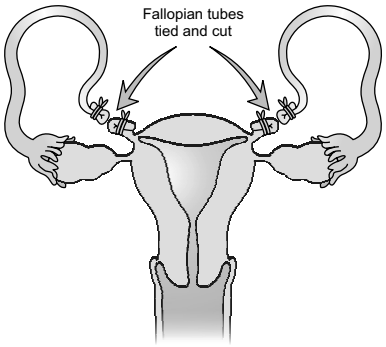


Fig. 4.3: Tubectomy in female

Disadvantages of Contraceptive Methods

- The selection of a suitable contraceptive method should always be undertaken in consultation with qualified medical professionals.

- The contraceptives are not regular requirements for the maintenance of reproductive health.
- They are practised against a natural reproductive event.
- They may cause ill-effects like nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding or even breast cancer.

Medical Termination of Pregnancy (MTP)

- Intentional or voluntary termination of pregnancy before full term is called (MTP) or induced abortion.
- MTP has a significant role in decreasing the population.
- Accepting or legalizing MTP is in debate due to emotional, ethical, religious and social issues.
- Government of India legalised MTP in 1971 with some strict conditions to avoid its misuse such as to check indiscriminate and illegal female foeticides.

Disadvantages of MTP

- MTPs are safe during the first trimester, up to 12 weeks of pregnancy. Second trimester abortions are very risky.
- Majority of the MTPs are performed illegally by unqualified quacks which are not only unsafe but could be fatal too.
- It is being misused to determine the sex of the unborn child.

Importance/Advantages of MTP

- To avoid unwanted pregnancies due to casual intercourse or failure of the contraceptive used during coitus or rapes.
- Essential in cases where the continuation of the pregnancy could be harmful to the mother or to the foetus or both.

Major Misuses Related with MTPs

- Majority of the MTPs are performed illegally.
- **Misuse of amniocentesis:** Amniocentesis is a foetal sex determination test based on the chromosomal pattern in the amniotic fluid. If the foetus is female, MTP is followed. Such practices are dangerous for the young mother and foetus.

Amniocentesis

- It is a pre-natal diagnostic method to determine the sex of the developing baby. This method has both positive and negative application.
  - **(a) Positive application:** It helps to detect any genetically controlled congenital disease or any metabolic disorders in foetus.
  - **(b) Negative application:** People use this method for sex determination leading to female foeticide.

Key Terms

- **IUDs:** Intra Uterine Devices. These are the devices inserted in the uterus to achieve contraception.
- **Population Explosion:** It refers to an enormous increase in the population in a short span of time.
- **Periodic Abstinence:** It is a natural method of contraception in which the couples avoid coitus from day 10 to 17 of the menstrual cycle.
- **Lactational Amenorrhea:** It refers to the absence of menstruation during the period of intense lactation following parturition.
- **MTP:** Medical Termination of Pregnancy. It is the intentional or voluntary termination of pregnancy or induced abortion.
- **RCH:** Reproductive and Child Health care.
- **WHO:** World Health Organisation.
- **STDs:** Sexually Transmitted Diseases.
- **MMR:** Maternal Mortality Rate.
- **IMR:** Infant Mortality Rate.
- **ZPG:** Zero Population Growth

Mnemonics

1. Concept: Intra Uterine Devices
Mnemonics: **C**at **C**an **N**ever **M**arch
Interpretation: Copper releasing IUds- **C**uT, **C**u7, **N**ova T, **M**ultiload 375

2. Concept: Hormone releasing IUD-LNG 20, Progestasert
Mnemonics: **H**arsh **R**aj **L**oves **P**izza
Interpretation: **H**ormone **R**eleasing-LNG 20, **P**rogestasert

3. Concept: Non-medicated IUD
Mnemonics: **N**ever **M**ind **L**over's **L**anguage (or) **N**ever **M**i**x** **L**anguage and **l**iterature
Interpretation: **N**on-**m**edicated IUD-Lippes loop

4. Concept: Barrier Methods
Mnemonics: CDC **V**olunteered **S**tudent's **J**unior **F**ellowship
Interpretation: **C**ondoms, **D**iaphragm, **C**ervical caps, **V**aults, **S**permicidal creams, **j**ellies, **f**oams.

Topic-2 Sexually Transmitted Diseases (STDs), Assisted Reproductive Technologies (ART) and Infertility

Concepts Covered • *Examples of STDs and Techniques of ART*

Revision Notes

Sexually Transmitted Diseases (STDs)

- Diseases or infections which are transmitted through sexual intercourse are called sexually transmitted diseases (STDs) or venereal diseases (VDs) or reproductive tract infections (RTIs).
- It includes gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B and HIV-AIDS.
- HIV infection is most dangerous.
- Hepatitis–B and HIV infections are transmitted by sharing of injection needles, surgical instruments, etc., with infected persons, transfusion of blood, or from an infected mother to the foetus too.
- Except for hepatitis-B, genital herpes and HIV infections, other diseases are completely curable if detected early and treated properly.
- **Symptoms of Sexually Transmitted Diseases**
  - **(a)** Early symptoms are – itching, fluid discharge, slight pain, swellings, etc., in the genital region.
  - **(b)** Infected females may often be asymptomatic and hence, may remain undetected for long.
  - **(c)** No Absence or less significant symptoms in the early stages of infection and the social stigma attached to the STDs deter the infected persons from going for timely detection and proper treatment leading to pelvic inflammatory diseases (PID), abortions, still births, ectopic pregnancies, infertility or even cancer of the reproductive tract. ?

Prevention of STDs

- STDs are a major threat to a healthy society and therefore one could prevent them by following the simple principles:
  - **(i)** Avoid sex with unknown partners/multiple partners.
  - **(ii)** Always use condoms during coitus.
  - **(iii)** Go to a qualified doctor for early detection and get complete treatment if diagnosed with disease.
  - **(iv)** Awareness about STDs.
  - **(v)** Using sterilised needles and syringes.

Infertility

- A large number of couples are unable to produce children in spite of unprotected sexual co-habitation.
- The reasons could be many–physical, congenital, diseases, drugs, immunological or even psychological.

- Often the female is blamed for the couple being childless, but more often the problem lies in the male partner.
- Specialised health care units such as infertility clinics enable these couples to have children.

Causes of Infertility in Males and Females

- **In males,**
  - **(a)** Low semen quality.
  - **(b)** Low sperm count is called **oligospermia**.
  - **(c)** Absence of sperms is called **azoospermia**.
  - **(d)** Sexual dysfunction.
- **In females,**
  - **(a)** Polycystic ovarian syndrome.
  - **(b)** Age-related factors.
  - **(c)** Uterine problem.
  - **(d)** Blockage or damage in fallopian tube.
  - **(e)** Previous tubal ligation.

Assisted Reproductive Technologies [ART]

- The couples could be assisted to have children through certain special techniques commonly known as **assisted reproductive technologies (ART)**.
- This technology includes IVF, IUT, ICSI, ZIFT, GIFT, AI, etc.
  - **(a) IVF [*In vitro* Fertilisation] and *In vivo* Fertilisation**
    - Here, the fertilisation takes place outside the body followed by embryo transfer (ET).
    - This method is popularly known as test tube baby programme in which ova from the wife/donor (female) and sperms from the husband/donor (male) are collected and induced to form zygote under simulated conditions in the laboratory.
  - **(b) ZIFT [Zygote Intra Fallopian Transfer] and IUT [Intra Uterine Transfer]**
    - When the zygotes or early embryos have developed up to 8 blastomeres, and then they are transferred into the fallopian tube. This method is called ZIFT.
    - When the zygotes or embryos are more than 8 blastomeres, then they are directly placed into the uterus for its further complete development. This method is called IUT.
  - **(c) GIFT [Gamete Intra Fallopian Transfer]**
    - In this method, the ovum collected from a donor is transferred into the fallopian tube of another female who cannot produce one, but can provide a suitable environment for fertilisation and for its further development.
  - **(d) ICSI [Intra Cytoplasmic Sperm Injection]**
    - In this method, a single sperm collected is directly injected into the ovum using micro needle.
    - This method is used in case of male infertility where the sperm count is low.
  - **(e) AI [Artificial Insemination]**
    - In this technique, the semen collected either from the husband or a healthy donor is artificially introduced either into the vagina or into the uterus (IUI – intra-uterine insemination) of the female.
    - This method is used in infertility cases either due to inability of the male partner to inseminate the female or due to very low sperm counts.

Disadvantages in ART

- **(a)** It requires extremely high precision handling by specialised professionals and expensive instrumentation.
- **(b)** It is affordable to only a limited number of people.

Child Adoption

- Legal adoption is one of the best methods for couples looking for parenthood.
- If the orphaned and destitute children are taken care of they could survive till maturity if adopted childless couples.
- Emotional, religious and social factors are deterrents in the adoption of these methods.

Key Terms

- **STD:** Sexually Transmitted Diseases
- **VD:** Venereal Diseases
- **RIT:** Reproductive Tract Infections
- **AIDS:** Acquired Immunodeficiency Syndrome

Key Terms

- **PID:** Pelvic Inflammatory Diseases (PID)
- **ARTs:** Assisted Reproductive Technologies
- **IVF:** *In vitro* Fertilisation
- **ZIFT:** Zygote Intra Fallopian Transfer
- **IUT:** Intra Uterine Transfer
- **GIFT:** Gamete Intra Fallopian Transfer
- **ICSI:** Intra Cytoplasmic Sperm Injection
- **AI:** Artificial Insemination
- **GIFT:** It is the method of transfer of an ovum from donor to another female who cannot produce it, but can provide suitable environment for fertilisation and its further development.
- **Infertility:** It is the inability of a couple to produce children in spite of unprotected sexual co-habitation.
- **IVF:** It refers to fusion of gametes outside the body in the laboratory in petri-dish.
- **ZIFT:** It is the method in which the zygote or early embryo up to 8-blastomeres is transferred into the fallopian tube.

❑❑

UNIT – 2: GENETICS AND EVOLUTION

CHAPTER-5
PRINCIPLES OF INHERITANCE AND VARIATION

Topic-1 Mendel's Principles of Inheritance and Chromosomal Theory of Inheritance

Concepts Covered • *Concept of Genetics and Mendel's Experiments on pea-plant* • *Chromosomal Theory*

Revision Notes

- **Genetics** (Greek word: *Genesis* meaning decent) is a branch of biology that deals with the study of inheritance, heredity and variation of characters from parents to offspring.
- **Inheritance** is the process of transmission of characters from parents to progeny.
- **Heredity**: (Latin word – *Hereditas* meaning heirship or inheritance) means resemblance between parents and offspring.
- **Father of Genetics**: Gregor Johann Mendel was the first to conduct experiments to understand the pattern of inheritance of variation in living beings.
- **Mendel's Experiments**:
  - Mendel conducted hybridisation experiments on garden peas (*Pisum sativum*) for seven years (1856–1863).
  - He selected 14 true – breeding pea varieties, as pairs which were similar except for character with contrasting traits.
  - Mendel was the first one to apply statistical analysis and mathematical logic to problems in biology.
  - **Reason for selecting garden pea plant**:
    - **(a)** Easy availability on a large scale.
    - **(b)** Pea plants have bisexual flowers.
    - **(c)** Many varieties are available with distinct characteristics.

(d) Garden pea plants are self-pollinated and can be cross-pollinated also.

(e) Pea flowers are self-pollinating flowers, thus are mostly pure line as they bear the same character generation after generation.

(f) Life span is short.

- **Mendel selected seven pairs of true breeding pea varieties:**

S. No.	Characters	Dominant	Recessive
1.	Height of the stem	Tall	Dwarf
2.	Colour of the flower	Violet	White
3.	Position of the flower	Axial	Terminal
4.	Shape of the pod	Inflated	Constricted
5.	Colour of the pod	Green	Yellow
6.	Shape of seed	Round	Wrinkled
7.	Colour of seed	yellow	green

- He observed one trait at a time.

➢ **Inheritance of one Gene**

Steps in Making a Cross in Pea Plants

- Selection of two pea plants with contrasting characters.
- Removal of anthers (emasculation) of one plant to avoid self-pollination. This is a female parent.
- Collection of pollen grains from the other plant (male parent) and its transference to the female parent (pollination).
- Collection of seeds and production of offspring.
- These hybrid offspring including the seeds constitute the next generation termed Filial$_1$ progeny or the F_1 generation.
- The plants of F_1 generation were allowed to perform self-pollination. The seeds and plants raised from them constitute the filial$_2$ or F_2 generation.

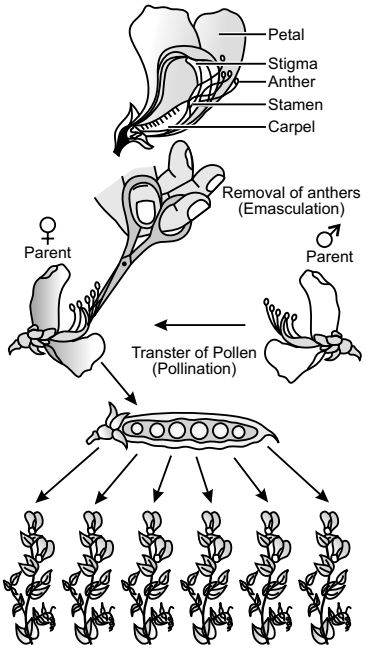


Fig. 5.1: Steps of making a cross in Pea

Back Cross and Test Cross

➢ **Back cross**: When crossing takes place between F_1 hybrids with its any of the parent, it is known as back cross.

➢ **Test cross**: When crossing takes place between F_1 hybrids with its recessive parent, it is known as test cross.

➢ The ratio of test cross =1: 1.

➢ It is used to find out the unknown genotype.

➢ Mendel conducted a test cross to determine the F_2 genotype.

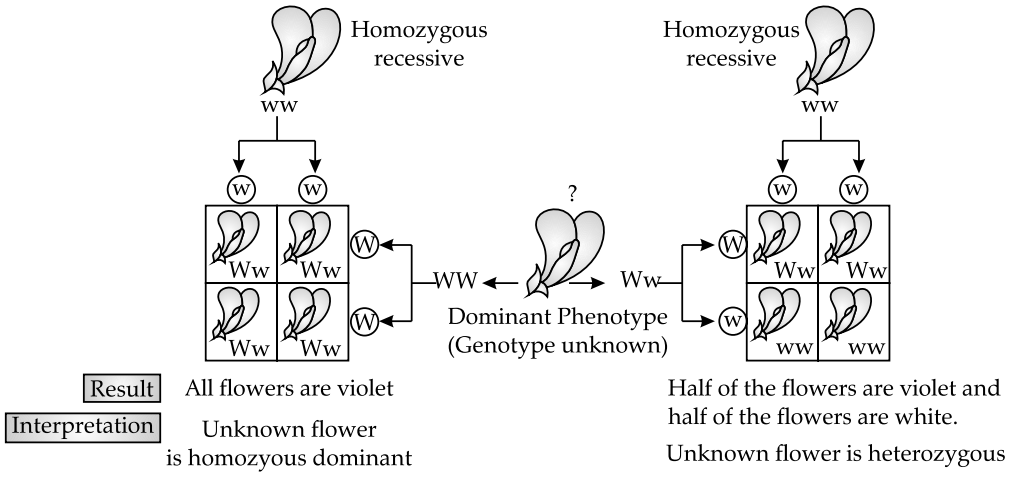


Fig. 5.2: Diagrammatic representation of a test cross

Mendel's Principles or Laws of Inheritance

(a) First Law or Law of dominance:

- Characters are controlled by discrete units called factors.
- Factors occur in pairs.
- **First Law or Law of dominance** states that characters are controlled by genes occurring in pair. In a dissimilar pair of factors or contrasting alleles, i.e., if heterozygous condition present in an organism, only one factor (dominant) expresses itself in F_1 generation whereas the other factor (recessive) remains hidden. 3:1 ratio is obtained in F_2 generation.

(b) Second Law or Law of segregation states that during gamete formation, the factor (alleles) of a character pair present in parents segregate or separate during gamete formation and randomly unite at fertilisation, such that a gamete receives only one of the two factors. Homozygous parent produces similar gametes, e.g., TT or tt. Heterozygous parent produces two kinds of gametes each having one allele with equal proportion, e.g., Tt, they are not pure and are called hybrid for that character.

(c) Third Law or Law of independent assortment states that (in dihybrid cross) the alleles of two (or more) different genes get sorted into gametes independently of one another.

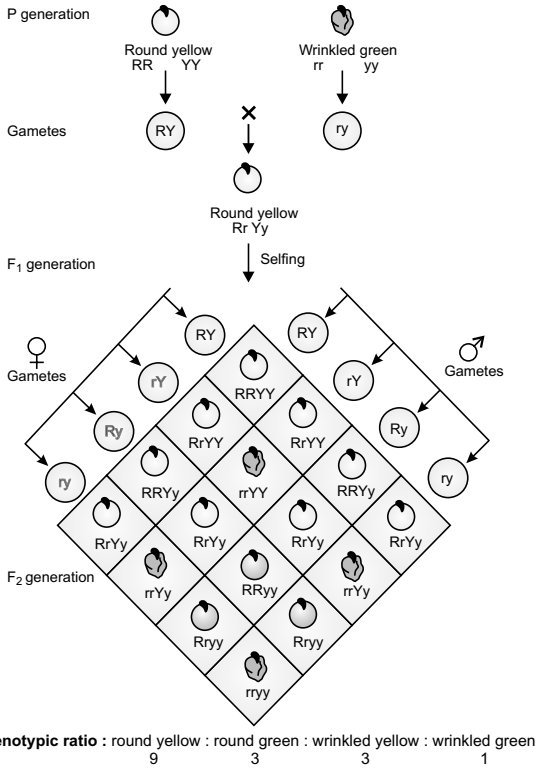


Fig. 5.3: Results of dihybrid cross

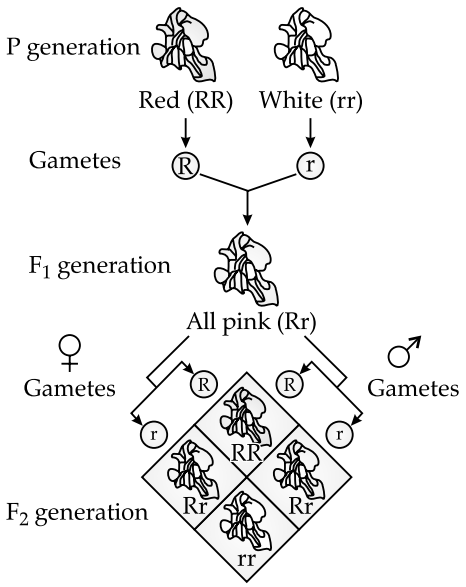
➢ **The Concept of Dominance**

- In heterozygotes, there are dominant and recessive alleles.
- The normal (unmodified or functioning) allele of a gene for example, produces a normal enzyme that is needed for the transformation of a substrate.
- The modified allele could be responsible for production of:
  - (i) The normal/less efficient enzyme: The modified allele will produce the same phenotype like unmodified allele, i.e., it will result in the transformation of substrate.
  - (ii) A non-functional enzyme.
  - (iii) No enzyme at all.
- **In the first case:** The modified allele will produce the same phenotype like unmodified allele. It becomes dominant.
- **In (ii) and (iii) case**, the phenotype will only be dependent on the functioning of the unmodified allele. Here, the modified allele becomes recessive. The recessive trait is seen due to non-functional enzyme or no enzyme is produced.

Non-mendelian Inheritance

(a) Incomplete Dominance

- It is an inheritance in which heterozygous offspring shows intermediate character between two parental characteristics.
- Example: Flower colour in snapdragon (dog flower or *Antirrhinum sp.*) and *Mirabilis jalapa* (4'o clock plant).
- In a cross between true-breeding red flowered (RR) and true-breeding white-flowered plants (rr), as a result the F_1 generation (Rr) was pink.
- When the F_1 was self-pollinated the F_2 resulted in the following ratio 1(RR) Red: 2(Rr) Pink: 1(rr) white.
- Here, phenotypic and genotypic ratios are same.
- **Phenotypic Ratio**: 1 Red: 2 Pink: 1 White
- **Genotypic Ratio**: 1 (RR): 2 (Rr): 1 (rr)
- This means that R was not completely dominant over r.
- Pea plants also show incomplete dominance in other traits.



Phenotypic ratio : red : pink : white
1 : 2 : 1
Genotypic ratio : RR : Rr : rr
1 : 2 : 1

Fig. 5.4: Incomplete dominance in the plant Snapdragon

(b) Co-dominance

- It is the inheritance in which both alleles of a gene are expressed in a hybrid, e.g., ABO blood grouping in human.
- ABO blood groups are controlled by the gene I.
- The plasma membrane of the RBC has sugar polymers that protrude from its surface and are controlled by the gene I.
- The gene (I) has three alleles I^A, I^B and i.
- The alleles I^A and I^B produce a slightly different form of sugar while allele i does not produce any sugar.
- When I^A and I^B are present together, they both express their own types of sugars. This is due to co-dominance.

Allele from parent 1	Allele from parent 2	Genotype of offspring	Blood type of offspring	Antigen type	Antibodies type
I^A	I^A	$I^A I^A$	A	A	B
I^A	I^B	$I^A I^B$	A, B	A, B	O
I^A	i	I^A i	A	A	B
I^B	I^A	$I^A I^B$	A, B	A, B	O
I^B	I^B	$I^B I^B$	B	B	A
I^B	i	I^B i	B	B	A
i	i	ii	O	O	A, B

(c) Multiple Allelism

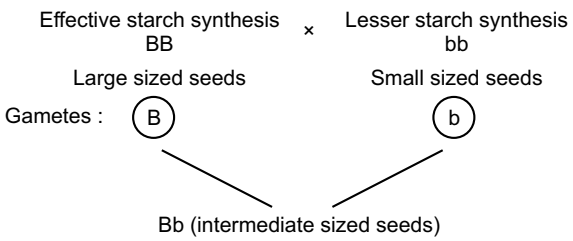
- Here more than two alleles govern the same character.
- Since in an individual, only two alleles can be present, multiple alleles can be found only when population studies are made.
- Example: Multiple Allelism can also be explained by ABO blood grouping. ABO blood grouping has three alleles: I^A, I^B and i.

(d) Pleiotropy

- A single gene which shows multiple phenotypic expressions is called pleiotropic gene and the phenomenon is called pleiotropy.
- The mechanism of pleiotropy is the effect of a gene on metabolic pathways which contribute to different phenotypes.
- Example: Starch synthesis in pea seeds, sickle cell anaemia, Phenylketonuria (PKU), etc.

(i) Starch synthesis in pea plant

- Starch synthesis in pea seeds is controlled by one gene.
- It has two alleles (B and b).
- Starch is synthesised effectively by BB homozygotes and therefore, large starch grains are produced while bb homozygotes have lesser efficiency in starch synthesis and produce smaller starch grains.
- After maturation of the seeds, BB seeds are round and the bb seeds are wrinkled.
- Heterozygotes produce round seeds and so B seems to be the dominant allele.
- But, the starch grains produced are of intermediate size in Bb seeds.



- So, if starch grain size is considered as the phenotype, then the alleles show incomplete dominance.
- Therefore, dominance is not an autonomous feature of a gene or the product that it has information for.
- It depends on the gene product and the production of a particular phenotype when more than one phenotype is influenced by the same gene.

(ii) Phenylketonuria: It is a disorder caused due to a recessive mutant allele on chromosome 12 (autosome). The affected individual lacks an enzyme phenylalanine hydroxylase that converts the amino acid phenylalanine into tyrosine. As a result, phenylalanine and its derivatives accumulate in the blood and cerebrospinal fluid leading to mental retardation. Excess phenylalanine is secreted in the urine.

(e) Epistasis

- It is a phenomenon which takes place when the presence of one gene suppresses the expression of another gene at a different locus.
- It is an example of a single trait or characteristic being controlled by two or more pairs of genes.
- The gene that suppresses the effect is called inhibiting gene or epistasis gene. The gene whose effect gets suppressed is called hypostatic gene.

(f) Polygenic inheritance

- In **1833, Galton** discovered polygenic inheritance. Polygenic traits are the traits controlled by three or more genes (multiple genes). Phenotype shows involvement of each allele which is influenced by the environment and is known as quantitative inheritance. For example, human skin colour is caused by the pigment **melanin**. The amount of melanin is due to three pairs of polygenes (A, B and C). If black or very dark (AA BB CC) and white or very light (aa bb cc) individuals marry each other, the offspring shows intermediate colour called mulatto (Aa Bb Cc).

  Importance of polygenic inheritance:

  1. One particular trait is determined by more than one gene.
  2. Individually each gene has little effect on the phenotype but their combined effect is very significant.
  3. Continuous variations are produced by the combined effect of many genes and the environmental factors.
  4. Each gene has a certain amount of effect and more the number of dominant genes, the more pronounced is the characteristic.

(g) Complementary genes: The complementary gene is an interaction of two dominant non-inter-allelic gene in which each gene has its own effect but when comes together to interact a new trait is developed and the Mendelian ratio 9:3:3:1 is changed into 9 : 7 due to complementation of both genes.

- In 1900, de Vries, Correns and von Tschermak independently rediscovered Mendel's results.
- **Mendel's work remained unrecognised till 1900 because**,
  - **(a)** Communication was not easy.
  - **(b)** His mathematical approach was new and unacceptable.
  - **(c)** The concept of genes (factors) as stable and discrete units was not accepted. (Mendel could not explain the continuous variation seen in nature.)
  - **(d)** Mendel could not provide any physical proof for the existence of factors.
- **Chromosomal Theory (1902): Walter Sutton and Theodor Boveri**
  - According to them, the pairing and separation of a pair of chromosomes lead to the segregation of a pair of factors they carried.
  - Sutton united the knowledge of chromosomal segregation with Mendelian principles and called it the **chromosomal theory of inheritance**.
  - It states that,
    - **(a)** Chromosomes are the vehicles of heredity that are transmitted from parents to offspring, i.e., they are immortal.
    - **(b)** Two identical chromosomes form a homologous pair.
    - **(c)** They segregate at the time of gamete formation.
    - **(d)** Independent pairs segregate independently of each other.
    - **(e)** Chromosomes are mutable.
  - Genes are present on chromosomes. Hence they show similar behaviour.

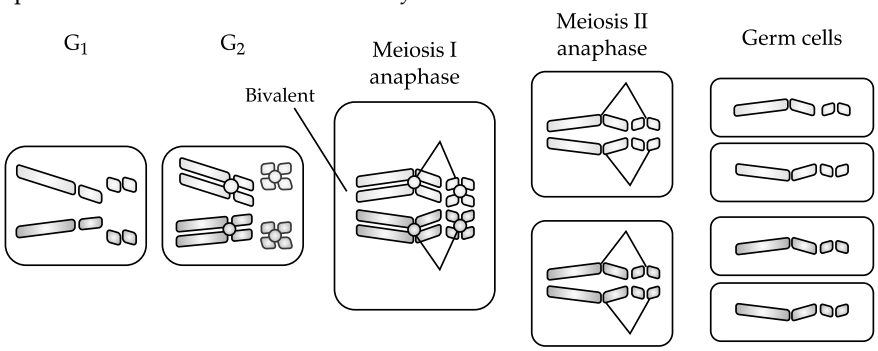


Fig. 5.5: Meiosis and Germ cell formation in a cell with four chromosomes

- **Chromosomal Theory of Inheritance in Fruit Flies**
  - Thomas Hunt Morgan proved the chromosomal theory of inheritance using fruit flies (*Drosophila melanogaster*).
  - **Fruitfly is a suitable material for these studies because**
    - **(a)** It breeds very quickly.
    - **(b)** It has shorter generation time (life cycle: 12–14 days).
    - **(c)** Breeding can be done throughout the year.
    - **(d)** Hundreds of progenies can be produced per mating.
    - **(e)** They can grow on simple synthetic medium.
    - **(f)** Male and female flies are easily distinguishable.
    - **(g)** It has many types of hereditary variations that can be seen with low power microscopes.
- **Recombination:** It is the generation of non-parental gene combinations.
- **Linkage:** The physical association of two or more genes on a chromosome is known as linkage. They do not show independent assortment.
- **Sex-Linked Genes**
  - Morgan carried out several dihybrid crosses in *Drosophila* to study sex-linked genes.
  - **Cross A:** Yellow-bodied, white-eyed females X Brown-bodied, red-eyed males (wild type).
  - **Cross B**: White-eyed, miniature winged X Red eyed, large winged (wild type).
  - **Morgan intercrossed their F_1 progeny and found that:**
    - **(a)** The two genes did not segregate independently of each other.
    - **(b)** The F_2 ratio deviated from the 9: 3: 3: 1 ratio (when the two genes are independent).

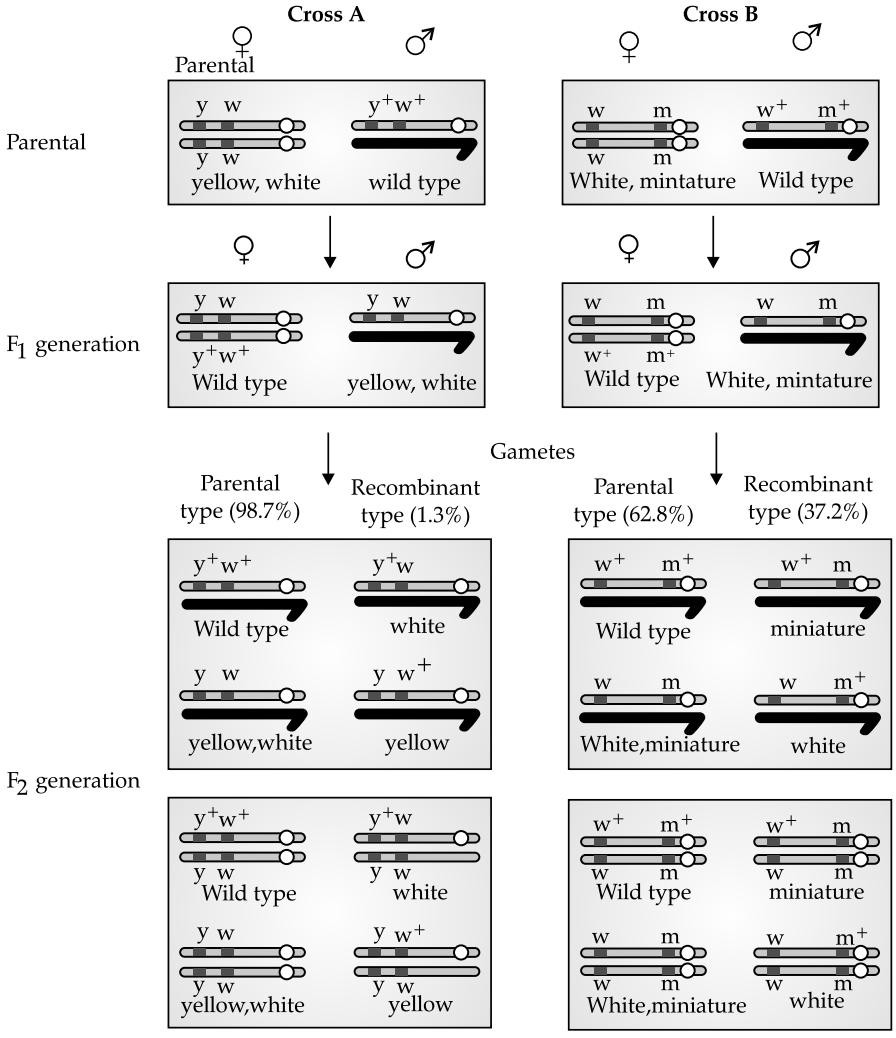


Fig. 5.6: Linkage: Results of two dihybrid crosses conducted by Morgan

(c) Genes were located on the X chromosome.
(d) When two genes were situated on the same chromosome, the proportion of parental gene combinations was much higher than the non-parental type. This is due to linkage.
(e) Genes of white eyed and yellow-bodied were very tightly linked and showed only 1.3% recombination while white and miniature wing showed 37.2% recombination (loosely linked).

- Thus, the tightly linked genes show low recombination while loosely linked genes show high recombination.

- In Fig. 5.6. Cross A shows a crossing between gene y and w; Cross B shows a crossing between gene w and m. Here dominant wild type alleles are represented with (+) sign. The strength of linkage between y and w is higher than w and m.
- **Mapping**
  - **Alfred Sturtevant** used the recombination frequency between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome.
  - Genetic maps are used as a starting point in the sequencing of genomes as was done in Human Genome Sequencing Project.
- **Pedigree analysis:** It is a system of analysis by following the movement and distribution of certain genetic traits in a family for generations.
- **Usefulness of pedigree analysis:**
  - It helps to predict the possible genotypes by knowing the phenotypes only.
  - It helps to study the pattern of inheritance of a specific trait, abnormality or diseases.
  - The possible genetic make-up of a person for a trait can be known.
  - It helps genetic counsellors to advice about the possibility of having genetically defective children.
  - It helps to identify the possible origin of the defective gene in the family or in a population.

Key Terms

- **Diploid:** An individual or cell containing two complete haploid set of chromosomes.
- **Punnett square or checker board:** A grid that enables to calculate the results of simple genetic crosses.
- **Trait**: A phenotypic characteristic of an inherited character.
- **Clone:** The group of organisms produced by asexual reproduction. They are morphologically and genetically similar to one another as well as their parents (The independent individuals of a clone are called **ramet**).
- **Offspring:** The organism derived by sexual reproduction.
- **Alleles (Allelomorphs):** The alternative forms of a gene located at the same locus of homologous chromosomes, e.g., T (tall) and t (dwarf) are two alleles of a gene responsible for the character height.
- **Hybrid:** An individual produced by the mating of genetically unlike parents.
- **Haploid (Monoploid):** An individual or cell containing a single complete set of chromosomes.
- **Reciprocal cross:** Cross which involves two types of individuals where the male of one type is crossed with the female of the second type and vice versa.
- **Back cross:** Cross between hybrid and one of its parents.
- **Test cross:** Cross to know whether an individual is homozygous or heterozygous for dominant characters. The F_1 individual is crossed with one of its recessive parent.
- **Dominant factor or allele:** It is one of a pair of alleles which can express itself whether present in homozygous or heterozygous state, e.g., T (tallness in pea), R (round seed in pea), A (axial flower in pea).
- **Recessive factors or allele:** The factor of an allelic or allelomorphic pair which is unable to express its effect in the presence of its contrasting factor in a heterozygote is called recessive factor or allele. The effect of recessive factor becomes known only when it is present in the pure or homozygous state, e.g., tt in dwarf pea plant.
- **Wild and mutant alleles (wild and mutant phenotype)**: Wild allele is one which was originally present in the population, is dominant and usually widespread. Recessive allele is less common and is believed to be formed through mutation of wild allele.
- **F_1 generation:** F_1 or first filial (filus – son/daughter) generation is the generation of hybrids produced from a cross between the genetically different individuals called parents, e.g., Tt individuals are produced in F_1 generation from a cross between TT and tt parents.
- **Phenotype**: The external/observable characteristics of an organism constitute its phenotype.
- **Genotype:** The genetic constitution of an organism is its genotype.
- **F_2 generation**: It is the generation of individuals which arises as a result of interbreeding or selfing amongst individuals of F_1 generation.
- **Monohybrid cross**: It is a cross between individuals of the same species, in which the inheritance of contrasting pairs of a single trait is considered.
- **Dihybrid cross:** It is a cross between two individuals of the same species, in which the inheritance of contrasting pairs of two traits is considered.

Mnemonics

1. Non-Mendelian Inheritance:
Mnemonics- I Can **M**anage **P**hysics
Interpretation: Incomplete dominance, **C**o-dominance, **M**ultiple alleles, **P**leiotropy

2. Law of Incomplete Dominance-
Mnemonics- Mira the **Dragon is Incomplete**
Interpretation: *M**irabilis jalapa***, **S**napdragon are examples of Incomplete Dominance

3. Concept: Co-Dominance
Mnemonics: Amar **B**enny and **O**mar play CoD
Interpretation: ABO (ABO blood group) example of Co-dominance

Topic-2 Sex Determination and Chromosomal Disorders

Concepts Covered • *Mechanism of Sex Determination* • *Pedigree Analysis* • *Genetic Disorder*

Revision Notes

Sex Determination

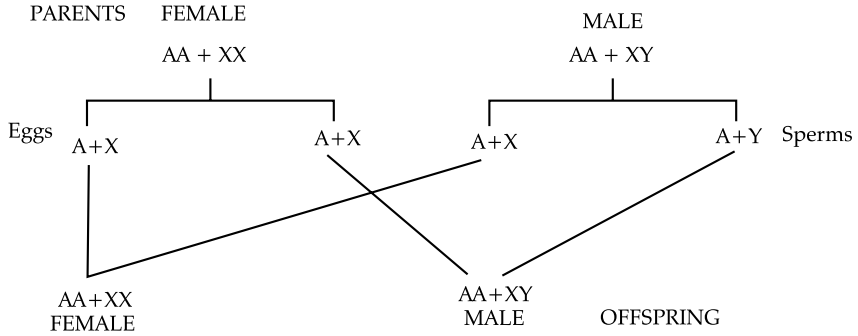
- Henking (1891) studied spermatogenesis in some insects and observed that 50% of sperm received a nuclear structure after spermatogenesis, whereas other 50% sperm did not receive it.
- Henking called this structure as the X body (later it is called as X-chromosome).
- Later it was observed that the ovum receives the sperms with X body becomes female and those which do not receive become male. Hence, this X body was called as **sex chromosome** due to its involvement in the determination of sex and other chromosomes were called **autosomes**.
- Autosomes are chromosomes other than sex chromosomes.
- Number of autosomes is same in males and females.
- Sex chromosomes, i.e., allosomes (X & Y) are the chromosomes which are involved in sex determination.

Mechanism of Sex Determination

(i) The Male Heterogamety: In this mechanism, the male produces two different types of gametes. It includes,

(a) ***XX – XY* Mechanism:**

- Here, male is heterogametic (X & Y) and female is homogametic (X only).
- For example: Human & *Drosophila* and most of the insects.

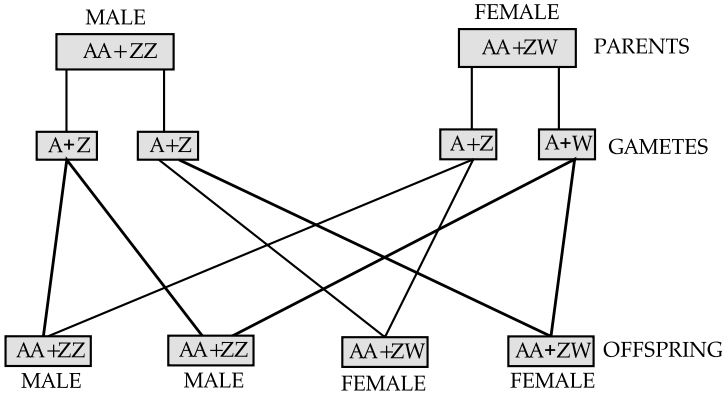


(ii) **The Female Heterogamety:** In this mechanism, the total number of chromosomes is same in both males and females. Here, the female produces two different types of gametes.

(a) ***ZZ–ZW* Mechanism:**

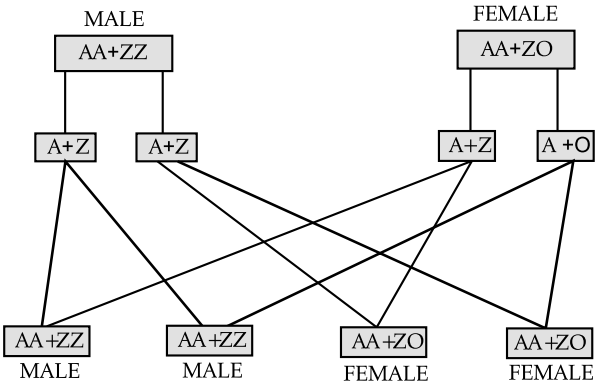
- Here, the male is homogametic (ZZ) and the female is heterogametic (Z & W).

- For example: Birds.



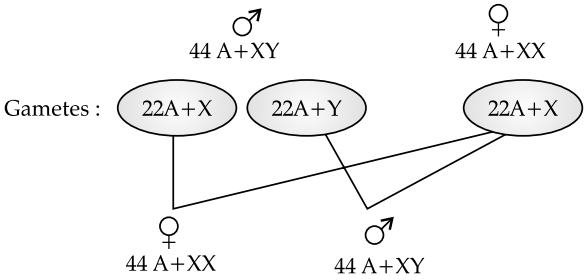
(b) ***ZZ – ZO* Mechanism:**

- In this mechanism, the female is heterogametic (ZO) and male is homogametic (ZZ).
- For example: some butterflies and moths.



Sex Determination in Humans (XX-XY type)

- Human has 23 pairs of chromosomes in which 22 pairs are autosomes and 1 pair is sex chromosomes.
- A pair of X-chromosomes (XX) is present in the female whereas X and Y chromosomes are present in male.
- During spermatogenesis, the males produce two types of gametes, 50% with X-chromosome and 50% with Y-chromosome, i.e., (22 + Y) or (22 + X).



- Females produce only ovum with an X-chromosome.
- There is an equal probability of fertilisation of the ovum with the sperm carrying either X or Y chromosome.
- The sperm determines whether the offspring is male or female.

Haplodiploid Sex Determination in Honey Bee

- The sex determination in honey bee is based on the number of chromosomes an individual receives.
- An offspring formed from the fusion of a sperm and an egg develops as a female queen or worker and an unfertilised egg develops as a male drone by parthenogenesis.
- This shows that males have half the number of chromosomes than that of female.
- The females are diploid having 32 chromosomes and males are haploid having 16 chromosomes.
- This is called the **haplodiploid sex determination system**.

Mutation

- It is a sudden heritable change in DNA sequences resulting in changes in the genotype and the phenotype of an organism.
- It leads to variation in DNA.
- The loss (deletions) or gain (insertion/duplication) of a segment of DNA, resulting in alteration in chromosomes. Since genes are known to be located on chromosomes, alteration in chromosomes results in abnormalities or aberrations.
- Chromosomal aberrations are seen in cancer cells.
- **Causes of Mutation**
  - **(a) Frame-shift mutation:** Loss (deletions) or gain (insertion/duplication) of a DNA segment.
  - **(b) Point mutation:** Mutation due to a change in a single base pair of DNA, e.g., sickle cell anaemia.
- The physical and chemical factors that induce mutations are referred to as **mutagens.**
- Mutagens (agents which induce mutation) include,
  - **(a) Physical mutagens:** UV radiation, α, β, γ rays, X-ray, etc.
  - **(b) Chemical mutagens:** Mustard gas, phenol, formalin, etc.

Pedigree Analysis

- The practice of analysing inheritance pattern of traits in several generations of a family is called the pedigree analysis.
- The representation or chart showing family history is called **family tree (pedigree**).
- In human genetics, pedigree study provides a strong tool, which is utilised to trace the inheritance of a specific trait, abnormality or disease.
- **Some of the important standard symbols used in the pedigree analysis are as follows:**

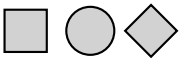
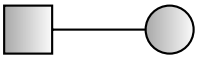
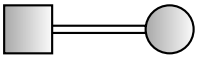
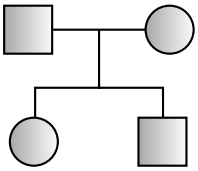
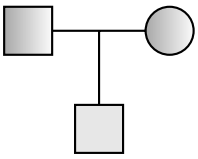
Symbols	Pedigree Analysis
	Male
	Female
	Sex unspecified
	Affected individuals
	Mating
	Mating between relatives (consanguinous mating)
	Parents above and children below in order of birth from left to right
	Parents with a male child affected with disease
	Five unaffected offspring

Fig. 5.7: Symbols used in the human pedigree analysis

Genetic Disorders

(A) Mendelian Disorders

- It is caused by alteration or mutation in the single gene.
- The pattern of inheritance of Mendelian disorders can be traced in a family by the pedigree analysis.
- For example: Haemophilia, Cystic fibrosis, Sickle-cell anaemia, Colour blindness, Phenylketonuria, Thalassemia, etc.
- Mendelian disorders may be dominant or recessive.
- By pedigree analysis one can easily understand whether the trait is dominant or recessive.
- A pedigree representation for dominant and recessive traits or characters linked to both autosomes and sex chromosomes are:

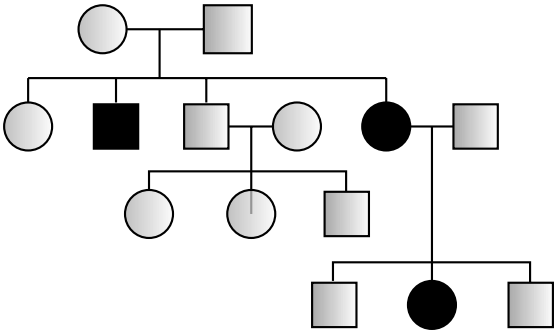


Fig. 5.8: Autosomal Dominant Trait, Myotonic dystrophy

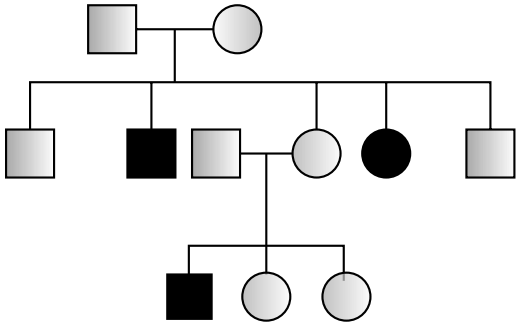


Fig. 5.9: Autosomal Recessive Trait, Sickle cell anaemia

(i) **Thalassemia**

- It is an autosome-linked recessive blood disease transmitted from parents to offspring when both partners are unaffected carrier for the gene.
- This is due to either mutation or deletion which results in the reduction of synthesis of one of the globin chains that make up haemoglobin.
- Thus, an abnormal haemoglobin molecule resulting in anaemia is formed.

Thalassemia is classified into three types as follows:

(a) α-Thalassemia

- It is controlled by two closely linked genes HBA1 and HBA2 on chromosome 16 of each parent.
- The production of α-globin chain is affected due to the mutation or deletion of one or more of the four genes.

(b) β-Thalassemia

- It is controlled by a single gene HBB on chromosome 11.
- The production of β-globin chain is reduced due to mutation of one or both the alleles of the gene.

(ii) Sickle-cell Anaemia

- This is an autosome linked recessive trait.
- It can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous).
- The disease is controlled by a pair of allele, Hb^A and Hb^S .
  - **(a) Homozygous dominant (Hb^AHb^A):** Normal.
  - **(b) Heterozygous (Hb^AHb^S):** Sickle cell trait.
  - **(c) Homozygous recessive ($Hb^S Hb^S$):** Affected.
- The defect is caused by the substitution of Glutamic acid (Glu) by Valine (Val) at the sixth position of the β-globin chain of the haemoglobin (Hb).
- The substitution of amino acid in the globin protein results due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG.
- The mutant haemoglobin molecule undergoes polymerisation under low oxygen tension causing the change in the shape of the RBC from biconcave disc to elongated sickle like structure.
- Thalassemia differs from sickle-cell anaemia in that the former is a quantitative problem of synthesising too few globin molecules while the latter is a qualitative problem of synthesising an incorrectly functioning globin.

(iii) Phenylketonuria

- It is an inborn error of metabolism.
- It is an autosomal recessive trait.
- The affected individual lacks an enzyme (phenylalanine hydroxylase) that converts the amino acid phenylalanine into tyrosine.

- As a result, phenylalanine accumulates and converts into phenyl pyruvic acid and other derivatives.
- They accumulate in brain resulting in mental retardation.
- These are also excreted through urine because of poor absorption by kidney.

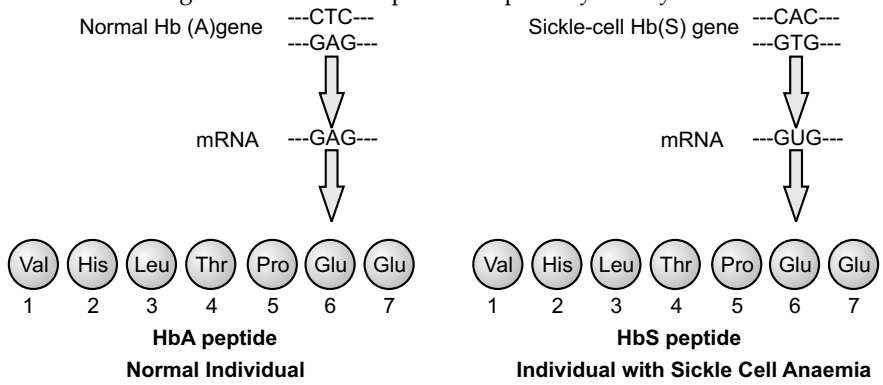


Fig. 5.10: Amino acid composition of the relevant portion of Beta-chain of haemoglobin

(B) Chromosomal Disorders

- They are caused due to absence or excess or abnormal arrangement of one or more chromosomes.
- These are of two types namely, Aneuploidy and polyploidy.

(I) Aneuploidy

- The gain or loss of chromosomes due to failure of segregation of chromatids during cell division is known as aneuploidy.

  For example: Down's syndrome results in the gain of extra copy of chromosome 21. Similarly, Turner's syndrome results due to loss of an X chromosome in human females.
- It includes,
  - **(a) Nullisomy ($2n - 2$):** A chromosome pair is lost from diploid set.
  - **(b) Monosomy ($2n - 1$):** One chromosome is lost from diploid set.
  - **(c) Trisomy ($2n + 1$):** One chromosome is added to diploid set.
  - **(d) Tetrasomy ($2n + 2$):** 2 chromosomes are added to diploid set.

(i) Down's Syndrome

- It is a genetic disorder caused due to the presence of an additional copy of the chromosome number 21 (trisomy of 21).
- This disorder was first described by Langdon Down (1866).
- **Genetic Constitution**: 45 + XX or 45 + XY (i.e., 47 chromosomes).
- **Characteristics**:
  - **(a)** The affected individual is short statured with small round head, furrowed tongue and partially open mouth.
  - **(b)** Palm is broad with characteristic palm crease.
  - **(c)** Physical, psychomotor and mental development is retarded.

(ii) Klinefelter's Syndrome

- It is the genetic disorder caused due to the presence of an additional copy of X-chromosome.
- **Genetic Constitution**: 44 + XXY (i.e. 47 chromosomes).
- **Characteristics:**
  - **(a)** Overall masculine development, however, the feminine development such as development of breast, i.e., Gynaecomastia is also expressed.
  - **(b)** Sterile.
  - **(c)** Mentally retarded.

(iii) Turner's Syndrome

- It is a genetic disorder caused due to the absence of one of the X chromosomes.
- **Genetic Constitution:** 44 + XO (i.e. 45 chromosomes).

  Females are sterile as ovaries are rudimentary.
- Lack of secondary sexual characters.

(II) Polyploidy (Euploidy)

- It is an increase in a whole set of chromosomes due to failure of cytokinesis after telophase stage of cell division. This is often seen in plants.
- Aneuploidy differs from polyploidy in the addition of one or more complete sets of chromosome in the genome.

Key Terms

- **Genome:** It is a complete set of chromosomes where every gene/chromosome is represented singly as in a gamete.
- **Gene pool:** Aggregation of all the genes and their alleles present in an interbreeding population is known as gene pool.
- **Dysgenics**: Study of undesirable traits of human race and the genes that cause them.
- **Ishihara cards**: Cards used for checking colour blindness.
- **Aneuploidy**: The gain or loss of chromosomes due to failure of segregation of chromatids during cell division
- **Polyploidy**: It is an increase in a whole set of chromosomes due to failure of cytokinesis after telophase stage of cell division.
- **Mutation:** It is a sudden heritable change in DNA sequence, which results in changes in the genotype and the phenotype of an organism.
- **Frame-shift mutation**: Mutation which results due to loss (deletions) or gain (insertion/duplication) of a DNA segment.
- **Point mutation**: Mutation that arise due to change in a single base pair of DNA, by substitution, deletion or insertion of a single nitrogenous base.
- **Mutagens:** These are agents that lead to mutations.
- **Pedigree analysis**: It is a record of occurrence of a trait in several generations of a family.
- **Mendelian Disorders:** Disorders caused by alteration or mutation in the single gene.
- **Chromosomal disorders:** Disorders caused due to absence or excess or abnormal arrangement of one or more chromosomes.

Mnemonics

Concept: Mendelian disorders: Few examples of the Mendelian disorder in humans are
Mnemonic: PMT Competition **S**abse **C**omplicated **H**ai
Interpretation:
Phenylketonuria
Muscular dystrophy
Thalassemia
Cystic fibrosis
Sickle cell anaemia
Colour blindness
Haemophilia

❑❑

CHAPTER-6
MOLECULAR BASIS OF INHERITANCE

Topic-1 Nucleic Acid–DNA and RNA Transcription

Concepts Covered • *Concept of DNA & RNA • Double Helix Model, Properties of Genetic Material • Experimental Proof to Show that DNA is Genetic Material • Transcription*

Revision Notes

Nucleic Acid

- Nucleic acids are the building blocks of genetic material.
- Nucleic acids are polymers of nucleotides.

- Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) are the two types of nucleic acids found in living systems.
- DNA acts as a genetic material in most of the organisms.
- RNA acts as a genetic material in some viruses, mostly functions as a messenger.
- RNA also functions as an adapter, structural and in some cases as a catalytic molecule of DNA.
- DNA is a long polymer of deoxy ribonucleotides.
- The **length of DNA** is defined as number of nucleotides (or a pair of nucleotide referred to as base pairs) present in it.
- It is the characteristic of an organism. For example, a bacteriophage ($\phi \times 174$) has 5375 nucleotides, Bacteriophage lambda has 48,502 base pairs (bp), *Escherichia coli* has 4.6×10^6 bp, and haploid content of human DNA is 3.3×10^9 bp.

Structure of Polynucleotide Chain

- DNA and RNA are referred to as Polynucleotide chain.
- **Nucleotide**: Nucleoside + Phosphate moiety (linked via **Phosphodiester** bond)
- **Nucleoside**: Pentose Sugar + Nitrogenous base (linked via the **N-Glycosidic** Bond)
- **A nucleotide has three components namely**:
  (a) A nitrogenous base,
  (b) A pentose sugar (ribose in case of RNA, and deoxyribose for DNA),
  (c) A phosphate group.
- There are two types of nitrogenous bases namely:
  (a) **Purines** (Adenine and Guanine)
  (b) **Pyrimidines** (Cytosine, Uracil and Thymine).
- Cytosine, adenine and guanine is common for both DNA and RNA whereas thymine is present in DNA and uracil is present in RNA at the place of thymine.
- A nitrogenous base is linked to the pentose sugar through an **N-glycosidic** linkage to form a nucleoside, such as adenosine or deoxyadenosine, guanosine or deoxyguanosine, cytidine or deoxycytidine and uridine or deoxythymidine.
- When a phosphate group is linked to 5′-OH of a nucleoside through **phosphodiester** linkage, a nucleotide or deoxynucleotide is formed.
- Two nucleotides are linked through 3′-5′ phosphodiester linkage to form a dinucleotide.
- Number of nucleotides joins together through 3′ – 5′ **phosphodiester** bond to form the polynucleotide chain.
- A polymer formed has at one end a free phosphate moiety at 5′-end of ribose sugar, which is referred to as 5′-end of polynucleotide chain.
- At the other end of the polymer, the ribose has a free 3′-OH group which is referred to as 3′-end of the polynucleotide chain.
- **Sugar and phosphate** form the **backbone** of polynucleotide chain.
- In RNA, every nucleotide residue has an additional –OH group present at 2′-position in the ribose.

Discovery of DNA and Determination of its Structure

- DNA as an acidic substance present in nucleus was first identified by **Friedrich Meischer** in 1869. He named it as '**Nuclein**'.
- **Wilkins & Franklin:** Produced the X-ray diffraction data for DNA structure.
- In 1953, the double helix structure of DNA was given by **James Watson** and **Francis Crick**, based on X-ray diffraction data produced by **Maurice Wilkins** and **Rosalind Franklin**.

Erwin Chargaff's Rule

- For a double stranded DNA (dsDNA), the ratio between adenine and thymine, and guanine and cytosine are constant and are equal to one.
- In DNA, the proportion of A is equal to T and the proportion of G is equal to C.
  [A] + [G] = [T] + [C] or [A] + [G] / [T] + [C] = 1
- A unique property of base pairing is that they are said to be complementary to each other and therefore if the sequence of bases on one strand is known, then the sequence on the other strand can be predicted.
- If each strand from a DNA acts as a template for synthesis of a new strand, the two double stranded DNA produced would be identical to the parental DNA molecule.
- **Length of DNA** = Number of base pairs X Distance between two adjacent base pairs. Example: Haploid content of human DNA is 3.3×10^9 bp.
  $\therefore$ Number of base pairs in human = 6.6×10^9

Hence, the length of DNA = $6.6 \times 10^9 \times 0.34 \times 10^{-9} = 2.2$ m
or In *E. coli*, length of DNA =1.36 mm (1.36×10^{-3} m)
$\therefore$ The number of base pairs = $1.36 \times 10^{-3}/0.34 \times 10^{-9} = 4 \times 10^6$ bp

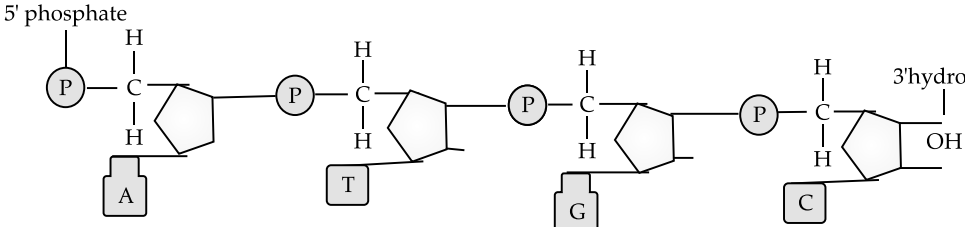


Fig. 6.1: A Polynucleotide chain

Salient Features of Double Helix Model for the Structure of DNA

1. It is made of two polynucleotide chains, where the backbone is constituted by sugar-phosphate, and the bases project towards inside.
2. The two chains have anti-parallel polarity. It means, if one chain has the polarity 5′ → 3′, the other has 3′ → 5′.
3. The bases on two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). Adenine forms two hydrogen bonds with thymine from opposite strand. Guanine is bonded with cytosine with three H-bonds, i.e., the nitrogen bases of the two strands are paired by hydrogen bonding. A purine always pairs with a pyrimidine. A = T and C ≡ G. As a result, uniform distance between the two strands of the helix is formed.
4. The helix is right handed.
   - Pitch (distance parallel to helix that corresponds to one turn of 360^0): 3.4 nm or 34Å.
   - Number of bases per turn: 10
   - Distance between two adjacent base pair: 0.34 nm.
5. The plane of one base pair stacks over the other. This provides stability to the helix along with hydrogen bonding.

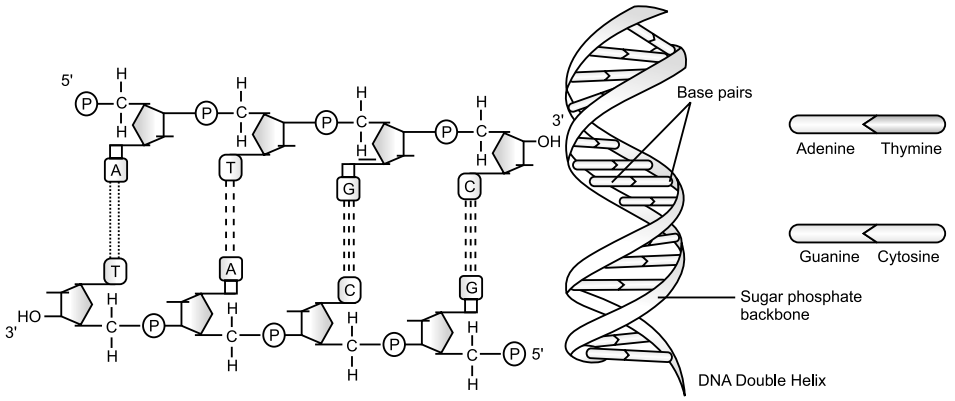


Fig. 6.2: Double stranded polynucleotide chain

➢ **Central Dogma of Molecular Biology**
- Proposed by **Francis Crick**.
- Talks about the direction of flow of genetic information.
- DNA → RNA → Protein
- In some viruses, the flow of information is in reverse direction, i.e., from RNA to DNA.

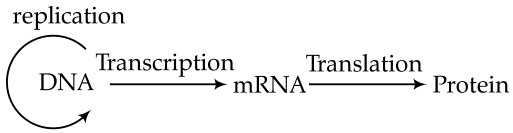


Fig. 6.3: Central dogma

➢ **Packaging of DNA Helix**
- The length of DNA if uncoiled is too long to be accommodated in a single cell. For example, there is 6.6×10^9 bp per cell in humans. Taking 0.34 nm as the distance between consecutive bp, the total length of DNA happens to be 2.2 m. (6.6×10^9 bp $\times 0.34 \times 10^{-9}$m = 2.2 m).
- 2.2 m of DNA is too large to be accommodated in the nucleus with a dimension of 10^{-6} m.
- That is why the DNA needs to be packaged in a way that takes up a lot less space?

- **Packaging of DNA in Prokaryotes (e.g., *E. coli*)**
  - Prokaryotes lack a well-defined nucleus.
  - Genetic material is scattered in the cytoplasm.
  - **Nucleoid**: The region where DNA being negatively charged (due to phosphate moiety) is associated with non-histone protein that is positively charged.
- **Packaging of DNA in Eukaryotes**
  - In eukaryotes, DNA is packaged with the help of **Histones** that are positively charged, basic protein.
  - Histones are rich in basic amino acids like lysine and arginine that gives positive charge. Both of these amino acid residues carry positive charges in their side chains.
  - **Histone octamer** is a unit of eight molecules of histone.
  - The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called **nucleosome**.
  - One nucleosome has approximately 200 bp of DNA.
  - Nucleosomes in a chromatin resemble beads present on strings.
  - Beads on string structure in chromatin are further packaged to form chromatin fibres, which further coil and condense to form chromosomes during metaphase.
  - **Non-histone chromosomal (NHC) proteins** – Additional set of proteins required for packaging of chromatin at a higher level.
  - A protein acquires charge depending upon the abundance of amino acids residues with charged side chains.
- **Type of Chromatin:**

(i) Euchromatin:
- Lightly stained.
- Loosely coiled region of chromatin.
- Transcriptionally active.

(ii) Heterochromatin:
- Darkly stained.
- Tightly coiled region of chromatin.
- Transcriptionally inactive.

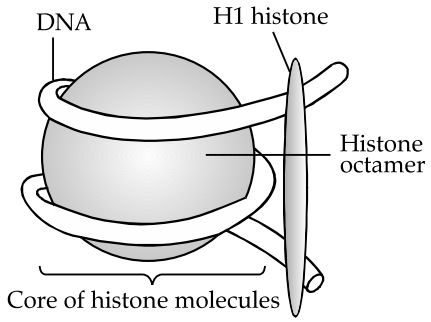


Fig. 6.4: Nucleosome

Transforming Principle

- In 1928, Frederick Griffith, in a series of experiments with *Streptococcus pneumoniae* (bacterium responsible for pneumonia), found a transformation in the bacteria in physical form.
- When *Streptococcus pneumoniae* (pneumococcus) bacteria are grown on a culture plate, some produce smooth shiny colonies (S) while others produce rough colonies (R).
- This is because the S strain bacteria have a mucous (polysaccharide) coat, while the R strain does not.
- Mice infected with the S strain (virulent) die from pneumonia infection but mice infected with the R strain do not develop pneumonia.

  S strain → Inject into mice → Mice die

  R strain → Inject into mice → Mice live
- Griffith was able to kill bacteria by heating them.
- He observed that heat-killed S strain bacteria injected into mice did not kill them.
- When he injected a mixture of heat-killed S and live R bacteria, the mice died.
- He recovered living S bacteria from the dead mice.
- Thus, he concluded that the R strain bacteria had been transformed by the heat-killed S strain bacteria. This must be due to the transfer of the genetic material (transforming principle).
- However, the biochemical nature of genetic material was not defined from his experiments.

Biochemical Characterisation of Transforming Principle

- Before the work of **Oswald Avery, Colin Macleod and Maclyn McCarty (1933-44)**, the genetic material was thought to be a protein.
- They worked to determine the biochemical nature of 'transforming principle' in Griffith's experiment.
- They purified biochemicals such as proteins, DNA, RNA, etc., from the heat-killed S cells to see what could transform live R cells into S cells and found that DNA from S bacteria caused R bacteria to become transformed.
- They also discovered that protein-digesting enzymes (proteases) and RNA-digesting enzymes (RNases) did not affect transformation.
- DNase did inhibit transformation suggesting that the DNA caused the transformation. Hence, they concluded that DNA is a hereditary material.

The Genetic Material is DNA

- The unequivocal proof that DNA is the genetic material came from the experiments of **Alfred Hershey and Martha Chase** (1952).
- They worked with viruses that infect bacteria called **bacteriophages**.
- The bacteriophage attaches to the bacteria and its genetic material enters the bacterial cell.
- The bacterial cell manufactures more viral genetic particles.
- Hershey and Chase worked to discover whether it was protein or DNA from the viruses that entered the bacteria.
- They grew some viruses on a medium that contained radioactive phosphorus **(^{32}P)** and some others on medium that contained radioactive sulphur **(^{35}S)**.
- Viruses grown in the presence of radioactive phosphorus contained radioactive DNA but not radioactive protein because DNA contains phosphorus but protein does not.
- On the other hand, viruses grown on radioactive sulphur contained radioactive protein but not radioactive DNA because DNA does not contain sulphur.
- Radioactive phages were allowed to attach to *E. coli* bacteria.
- As the infection proceeded, the viral coats were removed from the bacteria by agitating them in a blender.
- The virus particles were separated from the bacteria by spinning them in a centrifuge.

Observation

- In bacteria infected with phage with radioactive protein (^{35}S), no radioactivity was detected in cell, but radioactivity was detected in the supernatant.
- In bacteria infected with phage with radioactive DNA (^{32}P), radioactivity was detected in cell, but not in the supernatant.

Conclusion

- Virus infected bacteria had radioactive DNA, indicating that DNA was the material that passed from the virus to the bacteria.
- Virus infected bacteria had proteins that were not radioactive.
- This indicated that proteins did not enter the bacteria from the viruses.
- DNA is therefore the genetic material that is passed from virus to bacteria.

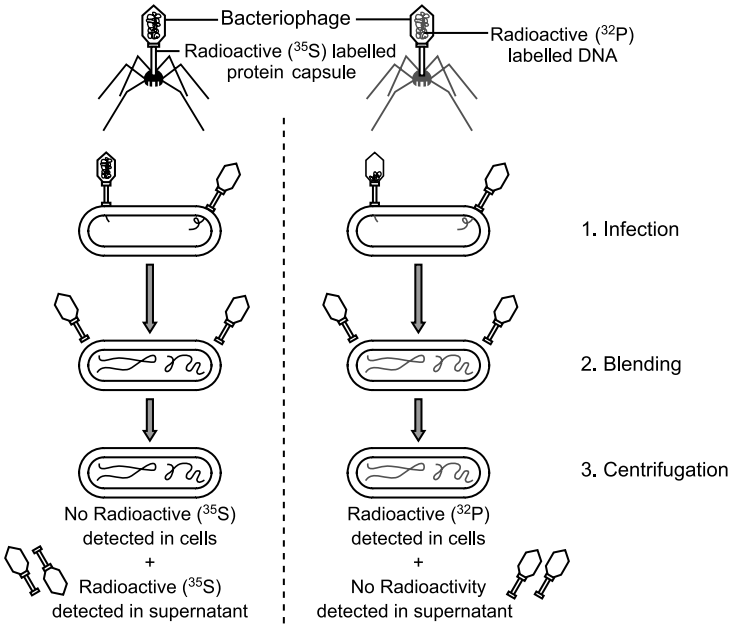


Fig. 6.5: The Hershey – Chase Experiment

Properties of Genetic Material (DNA versus RNA)

- DNA is the predominant genetic material whereas RNA performs dynamic functions of messenger and adapter.
- **Criteria for a biomolecule to be genetic material:**

1. **It should be able to generate its replica (Replication).**
   - Due to the rule of base pairing and complementarity, both the nucleic acids (DNA and RNA) have the ability to direct their duplications.
   - However, proteins fail to fulfil first criteria itself.
2. **It should be chemically and structurally stable**.
   - The genetic material should not change with different stages of life cycle, age or with change in physiology of the organism.
   - Stability as one of the properties of genetic material was evident in Griffith's 'transforming principle' which showed that the two strands of DNA being complementary if separated by heating come together under appropriate conditions.

- Further, 2'-OH group present at every nucleotide in RNA is a reactive group and makes RNA labile and easily degradable.
- RNA is also now known to be catalytic, hence reactive.
- Therefore, DNA chemically is less reactive and structurally more stable when compared to RNA. DNA is a better genetic material.
- The presence of thymine at the place of uracil provides additional stability to DNA.

3. **It should provide the scope for slow changes (mutation) that are required for evolution.**
   - Both DNA and RNA are able to mutate.
   - RNA being unstable, mutates at a faster rate.
   - Thus, viruses having RNA genome and having shorter life span will mutate and evolve faster.
4. **It should be able to express itself in the form of 'Mendelian Characters'.**
   - RNA can directly code for the synthesis of proteins and hence can easily express the characters.
   - DNA is dependent on RNA for the synthesis of proteins.
   - Both RNA and DNA can function as genetic material.
   - However, DNA being more stable is preferred for storage of genetic information while RNA is preferred for the transmission of genetic information.

RNA World

- RNA was the first genetic material.
- RNA can act as a genetic material as well as a catalyst.
- RNA being a catalyst was reactive and hence unstable.
- Therefore, DNA has evolved from RNA with chemical modifications that make it more stable.
- Further, DNA being double and complementary stranded resists changes by repair.

Types of RNA

- **mRNA (messenger RNA):** Provides template for translation (protein synthesis).
- **rRNA (ribosomal RNA):** Structural and catalytic role during translation. e.g., 23S rRNA in bacteria acts as ribozyme.
- **tRNA (transfer RNA or sRNA or soluble RNA):** Brings amino acids for protein synthesis and reads the genetic code.

Replication of DNA

- After proposing the double helical structure for DNA, Watson and Crick proposed a scheme for replication of DNA.
- The scheme suggested that the two strands would separate and act as a template for the synthesis of new complementary strands.
- After the completion of replication, each DNA molecule would have one parental and one newly synthesized strand. This scheme was termed as semi-conservative DNA replication.

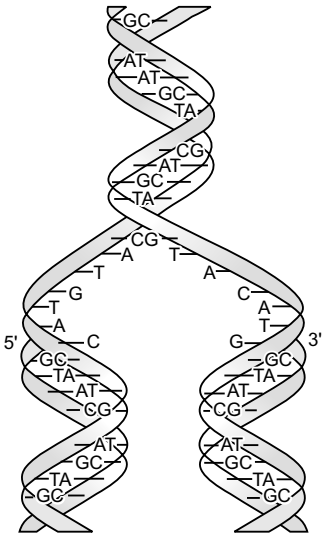


Fig. 6.6: Watson Crick model for semi-conservative DNA replication

The Experimental Proof (Meselson and Stahl's Experiment)

- The DNA replicates semi-conservatively was shown first in *E. coli.*
- Mathew Meselson and Franklin Stahl performed the following experiment in 1958:
  - **(a)** They grew *E. coli* in a medium containing $^{15}NH_4$ Cl in which ^{15}N is the heavy isotope of nitrogen. This led to the incorporation of ^{15}N into newly synthesized DNA. This heavy DNA molecule could be distinguished from the normal DNA by centrifugation in a **Cesium Chloride (CsCl) density gradient.**
  - **(b)** Then they transferred the cells into a medium with normal $^{14}NH_4Cl$ and took samples at various definite time intervals as the cells multiplied, and extracted the DNA that remained as double-stranded helices. The various samples were separated independently on CsCl gradients to measure the densities of DNA.

(c) The DNA extracted from the culture one generation after the transfer from ^{15}N to ^{14}N medium had a hybrid or intermediate density. DNA extracted from the culture after another generation was composed of equal amounts of the hybrid DNA and of 'light' DNA.

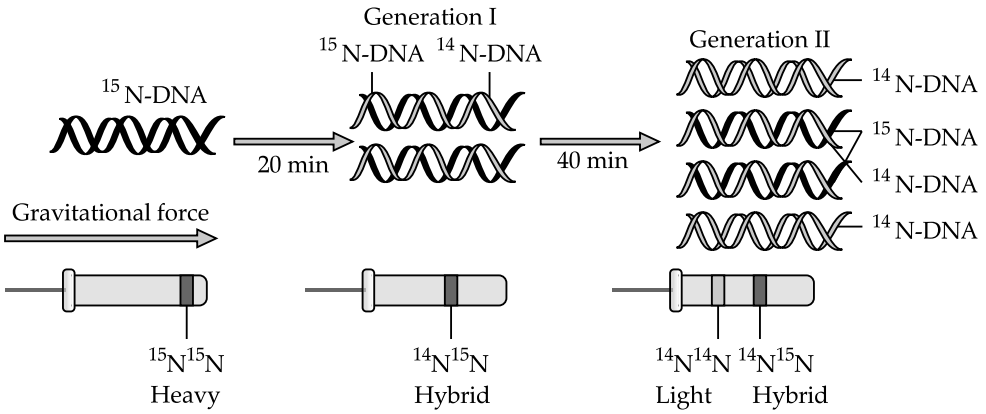


Fig. 6.7: Meselson and Stahl Experiment (Separation of DNA by Centrifugation)

- Similar experiments involving the use of radioactive thymidine to detect distribution of newly 117polymerisat DNA in the chromosomes was performed on *Vicia faba* (faba beans) by Taylor and colleagues in 1958.

The Machinery and the Enzymes

- In *E. coli*, the process of replication requires a set of catalysts (enzymes).
- The main enzyme involved is the **DNA dependent DNA polymerase**.
- The main enzyme is referred to as **DNA-dependent DNA polymerase,** since it uses a DNA template to catalyse the 117 polymerisation of deoxynucleotides.
- These enzymes are highly efficient as they have to catalyse 117 polymerisation in a very short time. *E. coli* that has only 4.6 $\times 10^6$ bp completes the process of replication within 38 minutes, i.e., the average rate of polymerisation is approximately 2000 bp per second.
- These polymerases have to be fast and catalyse the reaction with a high degree of accuracy.
- Any mistake during replication would result into mutations.
- Energetically, replication is a very expensive process.
- **Deoxyribonucleoside triphosphates (dNTPs) serve dual purpose as follows**:
  (a) Act as substrates
  (b) They provide energy for polymerisation reaction.
- There are many additional enzymes required to complete the process of replication with a high degree of accuracy.
- **Replication fork**: In long DNA molecules, the two strands of DNA cannot be separated in their entire length as it requires high energy. Thus, the replication occurs within a small opening of the DNA helix, referred to as replication fork.
- **Continuous/ leading strand**: One of the DNA strands with polarity 3′ → 5′ that acts as a template for the new strand synthesis, synthesises the strand continuously.
- The DNA-dependent DNA polymerases catalyse polymerisation only in one direction (5′ → 3′).
- **Discontinuous/lagging strand:** The other strand with polarity 5′ → 3′, acting as the template synthesizes the new strand in fragments **(Okazaki fragments)** that are later joined together by the enzyme DNA ligase.
- The DNA polymerases cannot initiate the process of replication and do not initiate randomly at any place in DNA on their own.
- Therefore, there is a definite region called **origin of replication** in *E. coli* DNA where the replication originates.
- If a piece of DNA is needed to be propagated during recombinant DNA procedures, it requires a vector which provides the origin of replication.
- In eukaryotes, the replication of DNA takes place at S-phase of the cell-cycle.
- The replication of DNA and cell division cycle should be highly coordinated.
- A failure in cell division after DNA replication results into polyploidy.

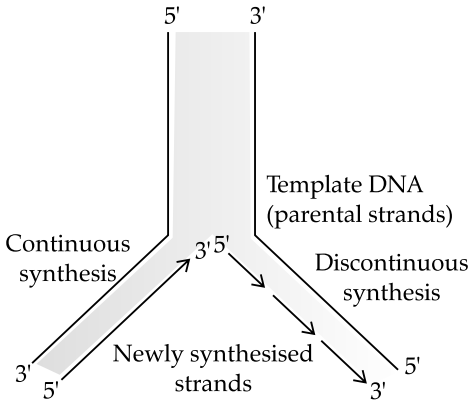


Fig. 6.8: Replicating fork

Transcription

- The process of copying genetic information from one strand of the DNA into RNA is termed as **transcription**.
- The principle of complementarity governs the process of transcription, except the adenosine which forms base pair with uracil.
- In transcription, only a segment of DNA and only one of the strands is copied into RNA.
- This necessitates defining the boundaries that would demarcate the region and the strand of DNA that would be transcribed.
- Both the strands are not copied during transcription. This is because:
  - **(a)** The code for proteins is different in both strands. This complicates the translation.
  - **(b)** The two RNA molecules if produced simultaneously would be complementary to each other and hence will form a double stranded RNA. This would prevent RNA from being translated into protein.

Transcription Unit

- A transcription unit in DNA is differentiated into three regions namely,
  - **(a)** A promoter.
  - **(b)** The structural gene.
  - **(c)** A terminator.
- Since the two strands of DNA have opposite polarity and the DNA-dependent RNA polymerase catalyse the polymerisation in only one direction (5′ → 3′), the strand that has the polarity 3′ → 5′ acts as a template, and is referred to as **template strand**.
- The other strand which has the polarity (5′ → 3′) is referred to as **coding strand**.
- For example – a hypothetical sequence from a transcription unit is represented below:
  3′-ATGCATGCATGCATGCATGCATGC-5′ **Template Strand**
  5′-TACGTACGTACGTACGTACGTACG-3′ **Coding Strand**
- The promoter and terminator play an important role in transcription unit.
- The promoter is located towards 5′-end in the upstream of the structural gene.
- It is a DNA sequence that provides binding site for RNA polymerase.
- The promoter defines the template and coding strands.
- By switching its position with terminator, the coding and template strands could be reversed.
- The terminator is located towards 3′-end in the downstream of the coding strand and defines the end of the process of transcription.

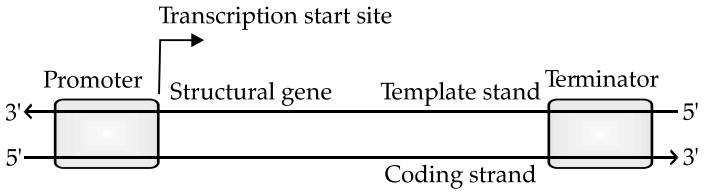


Fig. 6.9: A transcription unit

- Inheritance of a character is also affected by promoter and regulatory sequences of a structural gene.
- Hence, regulatory sequences are loosely defined as regulatory genes, though these do not code for any RNA or protein

Transcription Unit and the Gene

- A gene is defined as the functional unit of inheritance.
- It is the DNA sequence coding for tRNA or rRNA molecule.
- **Cistron**: A segment of DNA coding for a polypeptide.
- **Structural gene in a transcription unit is of two types:**
  - **(a) Monocistronic structural genes (split genes)**: It is seen in eukaryotes. Here, the coding sequences (expressed sequences or exons) are interrupted by introns (intervening sequences).
  - **(b) Polycistronic structural genes**: It is seen in prokaryotes. Here, there are no split genes.
- **Transcription in Prokaryotes**
  - In prokaryote such as bacteria, there are three major types of RNAs – mRNA, tRNA and rRNA. All three RNAs are needed to synthesise a protein in a cell.
  - The mRNA provides the template.

- tRNA brings amino acids and reads the genetic code.
- rRNA play structural and catalytic role during translation.
- A single DNA dependent RNA polymerase catalyses transcription of all types of RNA.

(a) Initiation

- Here, the enzyme RNA polymerase binds at the promoter site of DNA. This causes the local unwinding of the DNA double helix.
- An **initiation factor** *(σ factor)* present in RNA polymerase initiates the RNA synthesis.

(b) Elongation

- The RNA chain is synthesized in the 5′–3′ direction.
- In this process, activated ribonucleoside triphosphates (ATP, GTP, UTP & CTP) are added. This is complementary to the base sequence in the DNA template.

(c) Termination

- A **termination factor** *(ρ factor)* binds to the RNA polymerase and terminates the transcription.
- In bacteria, translation can begin much before the mRNA is fully transcribed since the mRNA does not require any processing to become active, and transcription and translation take place in the same compartment.

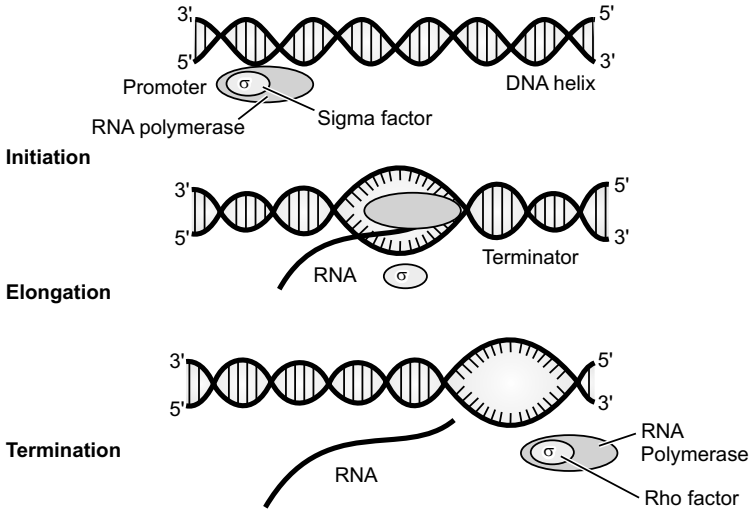


Fig. 6.10: Process of Transcription in Bacteria

Steps of Transcription in Eukaryotes

- In eukaryotes, the monocistronic structural genes have interrupted coding sequences, i.e., the genes in eukaryotes are split.
- The coding sequences or expressed sequences are defined as **exons**.
- Exons are said to be those sequence that appear in mature or processed RNA.
- The exons are interrupted by **introns** (non-coding sequence).
- Introns or intervening sequences do not appear in mature or processed RNA.
- **In eukaryotes, there are two additional complexities**:

(a) There are three RNA polymerases in the nucleus in addition to the RNA polymerase found in the organelles.

(i) The RNA polymerase I: It transcribes rRNAs (28S, 18S, and 5.8S).

(ii) The RNA polymerase II: It transcribes the precursor of mRNA, heterogeneous nuclear RNA (hnRNA).

(iii) The RNA polymerase III: It is responsible for transcription of tRNA, 5srRNA, and snRNAs (small nuclear RNAs).

(b) The primary transcripts (hnRNA) contain both the exons and the introns and are non-functional. In order to remove the introns, it undergoes the following processes:

(i) Splicing: The introns are removed from hnRNA and exons are joined together.

(ii) Capping: Here, a nucleotide methyl guanosine triphosphate is added to the 5′ end of hnRNA.

(iii) Tailing (Polyadenylation): Here, adenylate residues (200-300) are added at 3′-end.

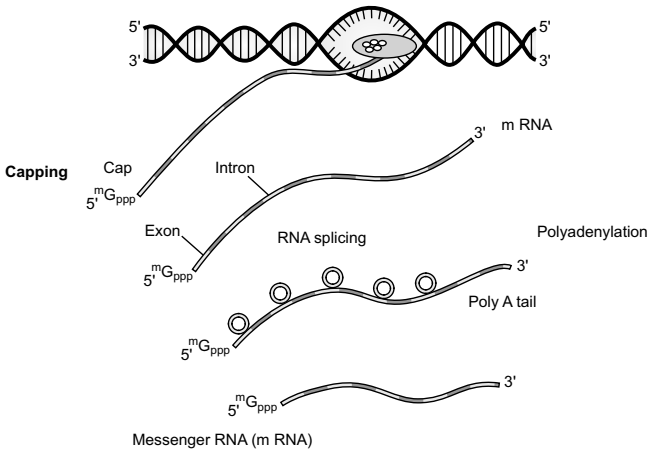


Fig. 6.11: Process of transcription in Eukaryotes

- The fully processed hnRNA is now called mRNA that is transported for translation.
- **Significance of the Split-gene Arrangements in Eukaryotes**
  (a) It represents an ancient feature of the genome.
  (b) The presence of introns is reminiscent of antiquity, and the process of splicing represents the dominance of RNA-world.

Key Terms

- **DNA:** Deoxyribonucleic acid
- **RNA:** Ribonucleic acid
- **hnRNA:** Heterogeneous nuclear RNA. It is the precursor of mRNA.
- **Exons:** These are the coding sequences of DNA, hnRNA which become part of mRNA and code for the different regions of proteins.
- **Introns:** These are the non-coding sequences of DNA, which do not form part of mRNA and are removed during the processing of hnRNA.
- **Histones:** A set of positively charged basic protein.
- **Gene:** It is a segment of DNA that codes for a polypeptide.
- **Cistron:** The structural unit of gene which contains the genetic information of a character.
- **Muton**: The smallest unit of DNA which can mutate.
- **Recon:** The smallest unit of DNA capable of undergoing crossing over and recombination.
- **Central Dogma:** The flow of genetic information from DNA to RNA to Protein.
- **Origin of Replication:** It is the definite region of DNA where the replication originates.
- **Replication Fork:** It is Y-shaped structure formed when the double stranded DNA is unwound up to a point during its replication.
- **Splicing:** It is a process where the introns are removed and exons are joined together to form mRNA.
- **Transcription:** It is the process of formation of RNA from DNA.
- **Translation:** It is the process of polymerisation of amino acids to form a polypeptide by mRNA

Mnemonics

Concept: Central Dogma

Mnemonics: Roast **T**urkey **L**ater

Interpretation: **R** = Replication
T = Transcription
L = Translation

Topic-2 Genetic Code, Translation, Gene Expression, Human Genome Project and DNA Fingerprinting

Concepts Covered • *Codons of Amino Acids* • *Features of Genetic Code* • *Types of RNA* • *Operon Concept, Human Genome Project, DNA Fingerprinting*

Revision Notes

- Genetic code is the sequence of nucleotides (nitrogen bases) in mRNA that contains information for protein synthesis (translation).
- There are 22 amino acids involved in translation as follows:

Alanine (Ala)	Leucine (Leu)
Arginine (Arg)	Lysine (Lys)
Asparagine (Asn)	Methionine (Met)
Aspartic acid (Asp)	Phenylalanine (Phe)
Cysteine (Cys)	Proline (Pro)
Glutamine (Gln)	Serine (Ser)
Glutamic acid (Glu)	Threonine (Thr)
Glycine (Gly)	Tryptophan (Trp)
Histidine (His)	Tyrosine (Tyr)
Isoleucine (Ile)	Valine (Val)

- **George Gamow:** Suggested that for coding 20 amino acids, the code should be made up of three consecutive nucleotides.
- **Har Gobind Khorana**: Developed the chemical method in synthesizing RNA molecules with defined combinations of bases (homopolymers and copolymers).
- **Marshall Nirenberg:** Developed cell-free system for protein synthesis.
- **Severo Ochoa:** Discovered an enzyme polynucleotide phosphorylase also called *Severo Ochoa enzyme*, is used to polymerise RNA with defined sequences in a template independent manner.

Codons for Amino Acids

- The checker board below shows the codons for the various amino acids.

	U		C		A		G		
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC	Phe	UCC	Ser	UAC	Tyr	UGC	Cys	C
	UUA	Leu	UCA	Ser	UAA	Stop	UGA	Stop	A
	UUG	Leu	UCG	Ser	UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC	Leu	CCC	Pro	CAC	His	CGC	Arg	C
	CUA	Leu	CCA	Pro	CAA	Gin	CGA	Arg	A
	CUG	Leu	CCG	Pro	CAG	Gin	CGG	Arg	G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC	Ile	ACC	Thr	AAC	Asn	AGC	Ser	C
	AUA	Ile	ACA	Thr	AAA	Lys	AGA	Arg	A
	AUG	Met	ACG	Thr	AAG	Lys	AGG	Arg	G
G	GUU	Val	GCU	Ala	GAU	Asn	GGU	Gly	U
	GUC	Val	GCC	Ala	GAC	Asp	GGC	Gly	C
	GUA	Val	GCA	Ala	GAA	Glu	GGA	Gly	A
	GUG	Val	GCG	Ala	GAG	Glu	GGG	Gly	G

Salient Features of Genetic Code

- The codon is triplet.
- 61 codons code for amino acids while three codons, i.e., UAA, UAG & UGA do not code for any amino acids, hence they function as stop codons or called as non-sense codons.
- Genetic code is unambiguous and specific, i.e., one codon specifies only one amino acid.
- A single amino acid is represented by many codons; such codons are called **degenerate codons** (except AUG which codes for methionine and UGG for tryptophan).

- No punctuations between adjacent codons (commaless codon). The codon is read in mRNA in a contiguous fashion.
- Genetic code is universal, e.g., from bacteria to human, UUU codes for Phenylalanine. Some exceptions are found in mitochondrial codons, and in some protozoans.
- AUG has dual functions. It codes for Methionine (met), and also acts as initiator codon. In eukaryotes, methionine code for first amino acid and *formyl methionine* in prokaryotes.

Mutation and Genetic Code

- The effect of large deletions, addition and rearrangements in a segment of DNA results in loss or gain of a gene that can be easily comprehended.
- For example – A point mutation is a change of single base pair in the gene for beta globin chain that changes amino acid residue glutamate to valine resulting in a diseased condition called as **sickle cell anemia**.
- Insertion or deletion of one or two bases changes the reading frame from the point of insertion or deletion.
- Insertion or deletion of three or its multiple bases insert or delete one or more multiple codon hence one or more amino acids, and reading frame remains unaltered from that point onwards. Such mutations are known as **Frame-shift insertion or deletion mutations**.

Types of RNA

- In prokaryotes such as bacteria, there are three major types of RNAs namely,
  (a) mRNA (messenger RNA).
  (b) tRNA (transfer RNA).
  (c) rRNA (ribosomal RNA).
- All three RNAs are needed to synthesise a protein in a cell.
- The mRNA provides the template, tRNA brings amino acids and reads the genetic code, and rRNAs play structural and catalytic role during translation.
- There is single DNA-dependent RNA polymerase that catalyses transcription of all types of RNA.

The tRNA, the Adapter Molecule

- Francis Crick postulated the presence of an adapter molecule that would on one hand read the code and on other hand, would bind to specific amino acids.
- The tRNA, called **sRNA** (soluble RNA) plays the role as an adapter molecule.
- The tRNAs are specific for each amino acid.
- There is an initiator tRNA for initiation and no tRNAs for stop codons.
- Secondary (2D) structure of tRNA looks like a clover leaf while 3D structure looks like inverted 'L'.
- **The tRNA is a compact molecule having the following:**
  (a) An anticodon loop that has bases complementary to the code.
  (b) An amino acid acceptor end to which amino acid binds.

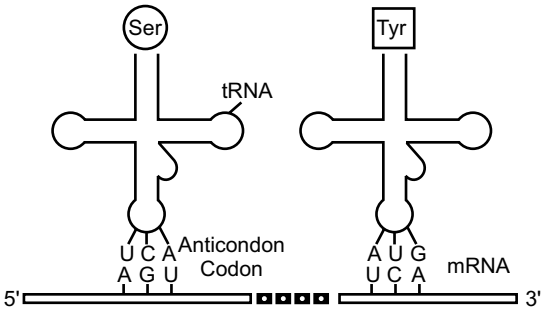


Fig. 6.12: tRNA – the adapter molecule

Translation

- The ribosome is the cellular factory for synthesising proteins. The ribosome in its inactive state exists as two subunits; a large subunit and a small subunit. When the small subunit encounters an mRNA, the process of the mRNA to protein begins.
- There are two sites in the large subunit A-site and P-site, for subsequent amino acids to bind to and thus close enough to each other.
- The ribosome also acts as a catalyst (23 S rRNA in bacteria is the enzyme-ribozyme) for the formation of peptide bond.
- A translational unit in mRNA is the sequence of RNA that is flanked by the start codon (AUG) and the stop codon and codes for a polypeptide.
- An mRNA also has some additional sequences that are not translated and are known as untranslated regions (UTR).
- The UTRs are present at both 5′ end (before start codon) and at 3′ end (after stop codon). They are required for efficient translation process.

- Translation refers to the process of polymerization of amino acids to form a polypeptide. The order and sequence of amino acids are defined by the sequence of bases in the mRNA. The amino acids are joined by a peptide bond.
- **It involves four steps**:
  - **Activation** of amino acids (charging of tRNA/aminoacylation of tRNA).
  - **Initiation** of polypeptide synthesis.
  - **Elongation** of polypeptide synthesis.
  - **Termination** of polypeptide synthesis.

Activation of Amino Acids

(a) Charging of tRNA or aminoacylation of tRNA: In this step, amino acids are activated in the presence of ATP and linked to their cognate tRNA.

(b) Initiation of polypeptide chain: The initiator methionyl-tRNA charged with amino acid methionine and anticodon UAC interacts with the initiation codon by codon-anticodon recognition. With the initiator methionyl-tRNA at P site, the larger subunit binds to the smaller subunit, thus forming an initiation complex.

(c) Elongation of polypeptide chain: A second tRNA charged with an appropriate amino acid enters the ribosome at the A-site, close to the P-site.

- A peptide bond is formed between the first amino acid and the second amino acid.
- Then the first tRNA is removed from the P-site and the second tRNA at the A site, now carrying a dipeptide, is pulled along with mRNA to the P-site (translocation).
- Now the A-site is occupied by a third codon and an appropriate aminoacyl tRNA will bind to it.
- This process of peptide bond formation and translocation will be repeated and the polypeptide chain grows in length.

(d) Termination of polypeptide chain: When the untranslated regions/termination codon come at the A-site, no amino acid would be added, as it is not recognized by any t-RNA.

- The protein synthesis will stop.
- At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome.

Regulation of Gene Expression

- The expression of gene resulting in the formation of a polypeptide can be regulated at several levels.
- In eukaryotes, the regulation could be exerted at:
  1. Transcriptional level (formation of primary transcript),
  2. Processing level (regulation of splicing),
  3. Transport of mRNA from nucleus to the cytoplasm,
  4. Translational level.
- The genes are expressed to perform a particular function or a set of functions, e.g., in bacteria like *E. coli*, the enzyme β-*galactosidase* hydrolyses lactose into galactose and glucose.
- The metabolic, physiological and environmental conditions regulate expression of genes.
- In prokaryotes, the expression of gene is done at transcriptional level.
- Here, the activity of RNA polymerase at a given promoter is regulated by interaction with accessory proteins, which affect its ability to recognize start sites.
- These regulatory proteins can act both positively (activators) and negatively (repressors).
- The accessibility of promoter regions of prokaryotic DNA is regulated by the interaction of proteins with sequences termed operators.
- The operator region is adjacent to the promoter elements in most operons and in most cases, the sequences of the operator bind a repressor protein.
- Each operon has its specific operator and specific repressor.
- For example, *lac* operator is present only in the *lac* operon and it interacts only with *lac* repressor.

Operon Concept

- Francis Jacob and Monod were the first to explain a transcriptionally regulated system, *lac* operon.
- "Each metabolic reaction is controlled by a set of genes".

- All the genes regulating a metabolic reaction constitute an Operon, e.g., *lac* operon, *trp* operon, *ara* operon, *his* operon, *val* operon, etc.
- When a substrate is added to growth medium of bacteria, a set of genes is switched on to metabolize it. This is called **induction**.
- When a metabolite (product) is added, the genes to produce it are turned off. This is called **repression**.

Lac Operon in *E. coli*

- The operon controls lactose metabolism. It consists of two genes namely,
  - **(a)** A regulatory or inhibitory gene
  - **(b)** Three structural genes: 'z' gene, 'y' gene and 'a' gene.
- The inhibitory gene *i* codes for the repressor.
- The 'z' gene codes for β *galactosidase* and helps in hydrolyzing lactose to galactose and glucose.
- The 'y' gene codes for *permease* and helps to increase the permeability of the cell to lactose.
- The 'a' gene codes for a *transacetylase*.
- The genes present in the operon function together in the same or related metabolic pathway.
- There is an operator region for each operon.
- Lactose is the substrate for the enzyme beta-galactosidase and it regulates switching ON and OFF the operon. Hence it is termed as inducer.
- If there is no lactose (inducer), *lac* operon remains switched off.
- The regulator gene synthesizes mRNA to produce the repressor protein.
- This protein binds to the operator genes and blocks RNA polymerase movement. So, the structural genes are not expressed.
- If lactose is provided in the growth medium, the lactose is transported into the *E. coli* cells by the action of permease.
- Lactose (inducer) binds with repressor protein and so, the repressor protein cannot bind to operator gene.
- Thus, the operator gene becomes free and induces the RNA polymerase to bind with promoter gene to start transcription.
- Regulation of *lac* operon by repressor is called **negative regulation**.

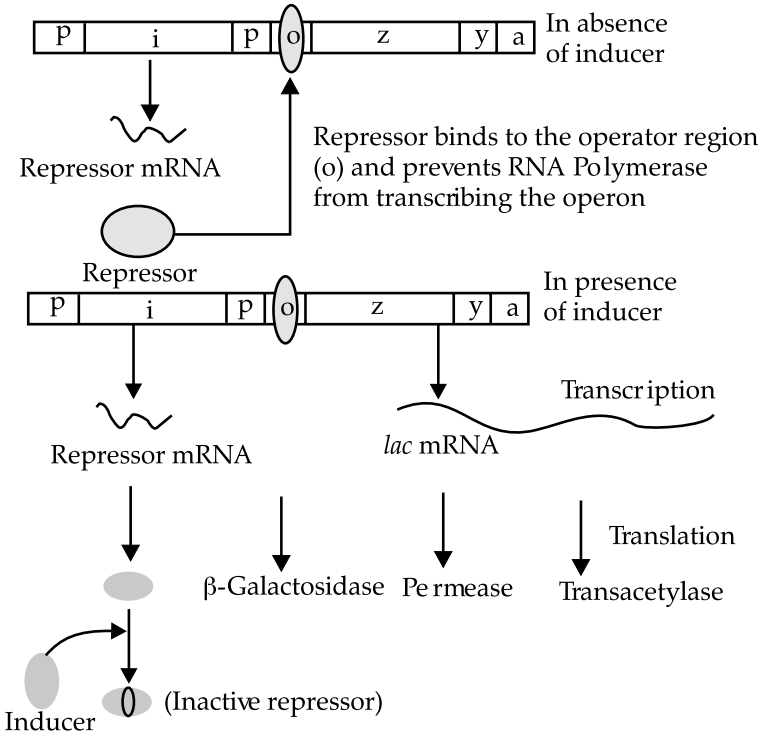


Fig. 6.13: The *lac* operon

Human Genome Project (HCG)

- The entire DNA in the haploid set of chromosome of an organism is called a **genome**.
- In human genome, DNA is packed in 23 chromosomes.
- Human Genome Project was the 13-year project (1990–2003) is the first effort in identifying the sequence of nucleotides and mapping of all the genes in human genome.
- Human genome contains about 3×10^9 bp.
- HGP was closely associated with bioinformatics.

Bioinformatics

- It is the application of computer science and information technology to the field of biology & medicine.
- It helps to analyse DNA sequence data.

Goals of HGP

(a) Identify all the estimated genes (20,000–25,000) in human DNA.
(b) Determine the sequences of the 3 billion chemical base pairs that make up human DNA.
(c) Store this information in databases.
(d) Improve tools for data analysis.
(e) Transfer related technologies to other sectors.
(f) Address the ethical, legal and social issues (ELSI) that may arise from the project.

Methodologies of HGP

- The methods of HGP involve two major approaches:
  (a) Expressed Sequence Tags: It focusses on identifying all the genes that express as RNA [referred to as Expressed Sequence Tags (ESTs)].
  (b) Sequence Annotation: It involves sequencing the whole set of genome containing all the coding and non-coding sequence, and assigning different regions in the sequence with functions (a term referred to as Sequence Annotation).

Procedure

- For sequencing, the total DNA from a cell is isolated and converted into random fragments.
- These fragments are then cloned in suitable host using specialised vectors.
- This results in the amplification of each piece of DNA fragment so that it could be sequenced with ease.
- The fragments were sequenced using automated DNA sequencers using Frederick Sanger method.
- These sequences were then arranged based on some overlapping regions present in them.
- Alignment of these sequences was done using specialised computer based programs.
- Genetic and physical maps on the genome were generated using information on polymorphism of restriction endonuclease recognition sites and some repetitive DNA sequences (microsatellites).

Salient Features of Human Genome

(a) The human genome contains 3164.7 million nucleotide bases.
(b) The average gene consists of 3000 bases, but sizes vary greatly, with the largest known human gene being dystrophin at 2.4 million bases.
(c) The total number of genes is estimated at 30,000.
(d) Almost all (99.9%) nucleotide bases are exactly the same in all people.
(e) The functions of 50% of discovered genes are unknown.
(f) Less than 2% of the genome codes for proteins.
(g) Repeated sequences make up very large portion of the human genome.
(h) Repetitive sequences are stretches of DNA sequences that are repeated many times, sometimes hundred to thousand times. They have no direct coding functions, but help in understanding chromosome structure, dynamics and evolution.
(i) Chromosome 1 has most genes (2968), and the Y has the fewest (231).
(j) About 1.4 million locations where single-base DNA differences (SNPs- Single nucleotide polymorphism or 'snips') occur in humans.

Rice Genome Project

- Rice was the first sequenced crop genome, paving the way for the sequencing of additional and more complicated crop genomes.
- The impact that the genome sequence made on rice genetics and breeding research was immediate, as evidenced by citations and DNA marker use.
- Rice has a genome size of 389 megabytes. A total of 37,544 protein-coding sequences associated with non-transposable elements were discovered.
- The compact nature of rice genome provides distinct advantage in gene isolation and genome sequencing as against other cereal crops.

DNA Fingerprinting or DNA Profiling

- It is the technique to identify the similarities of the DNA fragments of two individuals.
- It is developed by Alec Jeffreys (1985).
- DNA carries some non-coding sequences called repetitive sequence [variable number tandem repeats (VNTR)].
- Number of repeats is specific from person to person.
- The size of VNTR varies from 0.1 to 20 kb.
- Repetitive DNA is separated from bulk genomic DNA as different peaks during density gradient centrifugation.
- The bulk DNA forms a major peak and the other small peaks are called as satellite DNA.
- Satellite DNA is classified into many categories, (micro-satellites, mini-satellites, etc.) based on base composition (A:T rich or G:C rich), length of segment and number of repetitive units.
- An inheritable mutation observed in a population at high frequency is called DNA polymorphism (variation at genetic level).
- Polymorphism is higher in non-coding DNA sequence. This is because the mutations in these sequences may not have any immediate effect in an individual's reproductive ability.
- These mutations accumulate generation after generation and cause polymorphism.
- Polymorphism plays an important role in evolution and speciation.

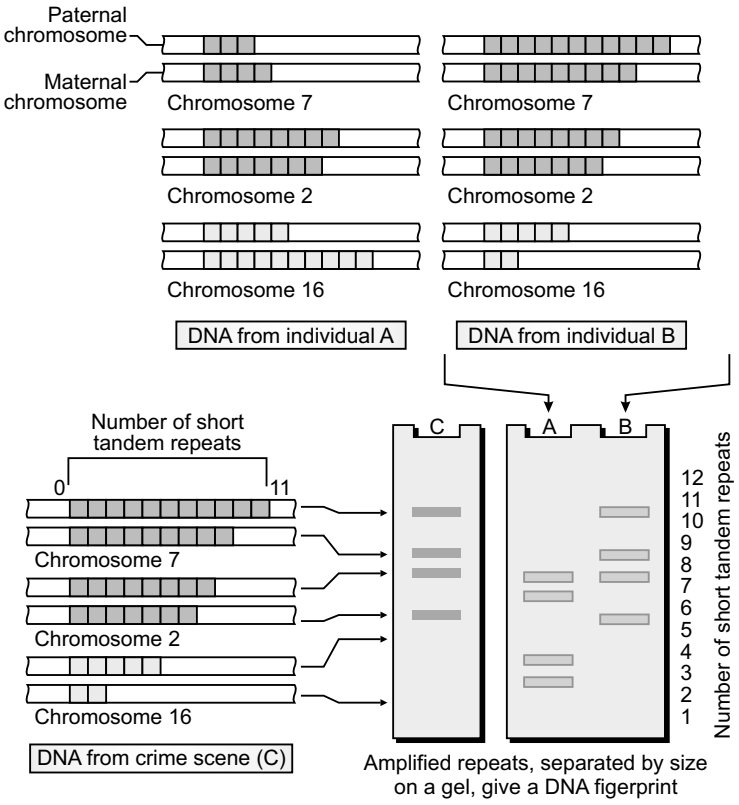


Fig. 6.14 : Schematic representation of DNA fingerprinting

Southern Blot Hybridisation

- It is the technique used earlier which involves radiolabeled VNTR as a probe.
- **The steps included in southern blot hybridisation are as follows:**
  - **(a)** Isolate DNA (from any cells like blood stains, semen stains or hair roots).
  - **(b)** Digestion of DNA by restriction endonucleases
  - **(c)** Separation of DNA fragments by electrophoresis.
  - **(d)** Transferring (blotting) of separated DNA fragments to synthetic membranes, such as nitrocellulose or nylon.
  - **(e)** Hybridisation using labelled VNTR probe.

(f) Detection of hybridised DNA fragments by autoradiography.

(g) The image obtained in the form of dark and light bands is called DNA fingerprint.

- These bands give a characteristic pattern for an individual DNA. It differs from individual to individual in a population except in case of monozygotic twins.

Applications of DNA Fingerprinting

(a) Forensic tool to solve paternity, rape, murder, etc.

(b) Used to diagnose genetic diseases.

(c) To determine phylogenetic status of animals.

Key Terms

- **Anticodon:** It is a sequence of three nucleotides on tRNA that is complementary to the codon for the particular amino acid.
- **Codon:** It is a sequence of three nucleotides on mRNA that codes for a particular amino acid.
- **Translation:** It is the process of polymerisation of amino acids to form a polypeptide by mRNA.
- **Satellite DNA:** It refers to the repetitive DNA sequences which do not code for any proteins, but form a large part of human genome.
- **Operon:** A group of genes which control a metabolic pathway.
- **DNA polymorphism:** An inheritable mutation observed in a population at high frequency.
- ***Lac* operon:** The prototype operon in bacteria, which codes for genes responsible for metabolism of lactose.
- **Fingerprinting:** A technique to find out variation in individuals of a population at DNA level.
- **Satellite DNA:** It refers to the repetitive DNA sequences which do not code for any proteins, but form a large part of human genome.
- **VNTRS:** Variable Number of Tandem Repeats
- **SNPs:** Single Nucleotide polymorphism
- **ESTs:** Expressed Sequence Tags
- **HGP:** Human Genome Project
- **YAC:** Yeast Artificial Chromosome
- **BAC:** Bacterial Artificial Chromosome
- **Polymorphism:** Variation at genetic level

Mnemonics

1. **Concept:** Purines
   Mnemonics- – PURe As Gold. (or)
   Interpretation
   PURe (purines) As (adenine) **G**old (guanine)
   PURines (A, G)
   A- Adenine
   G- Guanine

2. **Concept:**
   Mnemonics for Pyrimidines- CUT the **PY (pie)**
   Interpretation:
   C- Cytosine
   U- Uracil
   T- Thymine PYrimidines

❑❑

CHAPTER-7
EVOLUTION

Topic-1 Origin of Life on the Earth and Related Evidence

Concepts Covered • *Theories of Origin of Life* • *Experimental Evidence for Abiogenic Molecular Evolution of Life* • *Evidence of Evolution*

Revision Notes

- Evolution is an orderly change from one form to another.
- Evolutionary Biology is the study of the history of life forms on the Earth.
- **Origin of Life**
  - Big Bang theory states that universe originated about 20 billion years ago, by a thermonuclear explosion (big bang) of a dense entity.
  - The Earth was formed about 4.5 billion years ago.
  - There was no atmosphere on early Earth.
  - Water vapour, CH_4, CO_2 and NH_3 released from molten mass covered the surface.
  - The UV rays from the Sun broke up water to hydrogen and oxygen and the lighter H_2 escaped. Oxygen combined with ammonia and methane to form water, CO_2 and others.

    $H_2O \rightarrow H_2 + O_2$
    $NH_3 + O_2 \rightarrow$ water + NO
    $CH_4 + O_2 \rightarrow CO_2 + H_2O$
  - Then the ozone layer was formed.
  - As it cooled, the water vapour led to to rain which filled the depression on Earth's surface, forming water bodies like oceans.
- **Theories of Origin of Life**

1. Theory of Spontaneous Generation (Abiogenesis)

- The spontaneous genesis of life from non-living substances (i.e., the theory of abiogenesis, *Gr., a = not + bios= life + genesis=origin)* was the most convincing concept regarding the origin of life till 17th century.
- It states that life came out of decaying and rotting matter like straw, mud, etc.
- It was believed that the frogs, toads, snakes and field mice arose from the mud; parasites, beetles and flies arose from the sweat and manure, aphids and other insects arose under the influence of heat and moisture from plant juices and microorganisms arose spontaneously from air or water.
- Experiments performed by **Francesco Redi**, **Spallanzani** and the French Microbiologist **Louis Pasteur** went well against the theory of spontaneous generation of life and thus this theory became obsolete.

2. Biogenesis

- Biogenesis (*Gr., bios= life + genesis=origin*) is based on the theory that life can only come from life, and it refers to any process by which a life form can give rise to other life forms. For instance, a chicken laying eggs, which hatch and become a baby chicken.
- It was proposed by Francesco Redi, Spallanzani and Louis Pasteur.
- It states that life originates from pre-existing life only.
- Louis Pasteur demonstrated that nothing developed in meat broth in sterilised and sealed flasks. Microorganisms did grow on open, sterilised flasks. He also used swan-neck flasks with fermentable broth. The structure of the flask allowed the air to enter while the dust particles were made to stick to the long curving tube and therefore were prevented from reaching the broth. Despite the air entering the flask, nothing grew on the broth. Conversely, microorganisms grew on the broth when the flask was tilted sideways. This caused the broth to touch the tube wall contaminated with dust. This disproved the notion that microorganisms could spontaneously form from the air. Instead, the microorganisms on the dust caused the spoilage of the broth.

3. Cosmic theory (Theory of Panspermia)

- This theory was proposed by Richter and supported by Arrhenius.
- It states that the units of life (called spores) were transferred to different planets including Earth. Panspermia is a hypothesis which says that life came from outside the Earth, i.e., from another celestial body.
- Units of life in the form of so-called spores were transferred to Earth from outer space as believed by some scientists.

4. Theory of special creation

- It states that living and non-living things were created by some supernatural power (God).
- These forms were designed according to their surroundings and have existed unchanged from the time they were formed.
- The greatest supporter of this theory was Father Suarez.

5. Theory of chemical evolution

- It was proposed by Oparin and Haldane.
- It states that the first form of life originated from non-living inorganic and organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, RNA, nucleic acids, etc.
- It states "**Abiogenesis** first, but biogenesis ever since".

Experimental Evidence for Abiogenic Molecular Evolution of Life

➢ **Urey–Miller Experiment**

- Harold C. Urey and Stanley L. Miller conducted an experiment to prove theory of chemical evolution.
- They created a condition similar to that of primitive Earth (i.e., high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, H_2O, and H_2, etc.)
- They operated electric discharge in a closed flask containing CH_4, NH_3, H_2 and water vapour at 800°C.
- As a result, some amino acids were formed.
- In similar experiments, others observed the formation of sugars, nitrogen bases, pigment and fats.
- First non-cellular form of life originated 3 billion years ago.
- They were RNA, proteins, polysaccharides, etc.
- Many scientists believe chemical evolution, i.e., formation of biomolecules preceded the appearance of the first cellular forms of life. All early single celled life forms originated in water environment only.

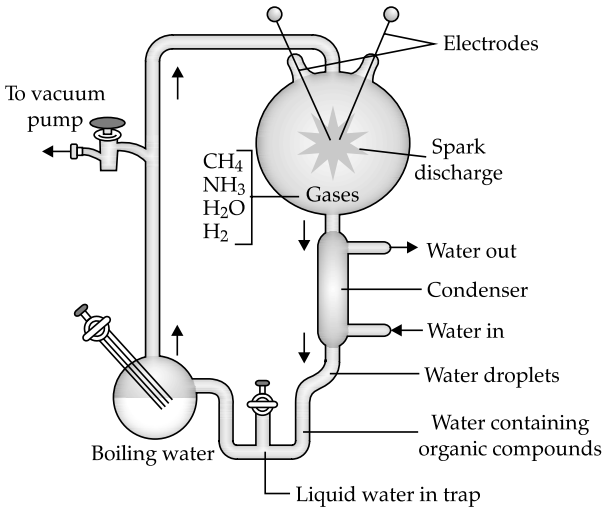


Fig. 7.1: Showing Urey–Miller Experiment

➢ **Evolution of Life Forms—A Theory**

- Based on observations made during a sea voyage in a sail ship called H.M.S. Beagle round the world, Charles Darwin concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago.
- There had been extinctions of different life forms in the years gone by just as new forms of life arose at different periods of the history of the Earth.
- There has been a gradual evolution of life forms due to variation in characteristics.
- Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors etc.) would outbreed others that are less-endowed to survive under such natural conditions.
- The fitness, according to Darwin, refers ultimately and only to reproductive fitness. Hence, those who are better fit in an environment, leave more progeny than others.
- These, therefore, will survive more and hence are selected by nature.
- He called it natural selection and implied it as a mechanism of evolution.
- Alfred Wallace, a naturalist who worked in Malay Archipelago also came to similar conclusions around the same time.
- All the existing life forms share similarities and share common ancestors.
- However, these ancestors were present at different periods in the history of the Earth.
- The geological history of the Earth closely correlates with the biological history of the Earth.

Evidence for Evolution

➢ **Evidence of evolution come from:**

(i) Palaeontology
(ii) Comparative anatomy and morphology
(iii) Biochemical/Physiology
(iv) Biogeographical evidence
(v) Embryology

1. **Palaeontological Evidence**
   - The study of fossils is known as **palaeontology**.
   - Fossils are the remains or traces of animal and plant life of the past, found embedded in rock either as petrified hard parts or as moulds, casts or tracks.
   - Rocks form sediments and a cross-section of the Earth's crust indicates the arrangement of sediments one over the other during the long history of the Earth.
   - Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment.
   - **Significance of Fossils**
   - To study phylogeny (evolutionary history or race history), e.g., Horse evolution.
   - To study the connecting link between two groups of organisms, e.g., *Archaeopteryx*.
   - To study about extinct animals, e.g., Dinosaurs
   - To study about geological period by analysing fossils in different sedimentary rock layers. The study showed that life forms varied over time and certain life forms are restricted to certain geological time spans.

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

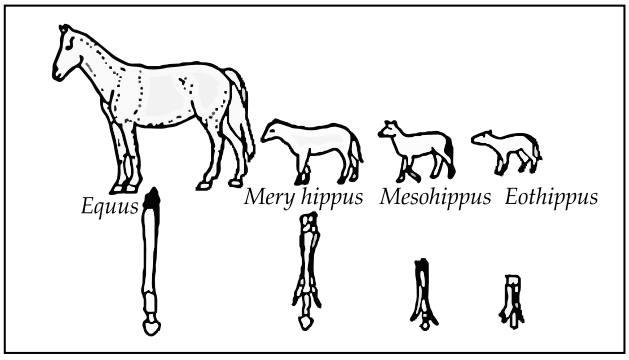


Fig. 7.2: Fossil record of bone of hind legs of horses from *Eohippus* to *Equus* showing a decrease in the number of toes

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

   (i) Homologous and analogous organs
   (ii) Vestigial organs
   (iii) Connecting links

   - The comparative study of various organs in different groups of vertebrates exhibits common features which show that they evolved from a common ancestor.
   - This can be explained as follows:

   (a) Homologous Organs and Homology: Homologous organs are the organs having fundamental similarities in structure and origin but different in functions. This phenomenon is called **homology**, e.g., Human hand, Whale's flippers, Bat's wing and Cheetah's foot.

   - Forelimbs of vertebrates are a good example of homologous organs. They are built on the same fundamental plan yet they appear different and perform different functions.
   - In each case, the forelimb consists of humerus, radius and ulna, carpals, metacarpals and phalanges. This basic similarity in the structure of the apparently different forelimbs of different kinds of vertebrates is due to the fact that all these limbs have evolved from a common type called the pentadactyl (five-fingered) limb.

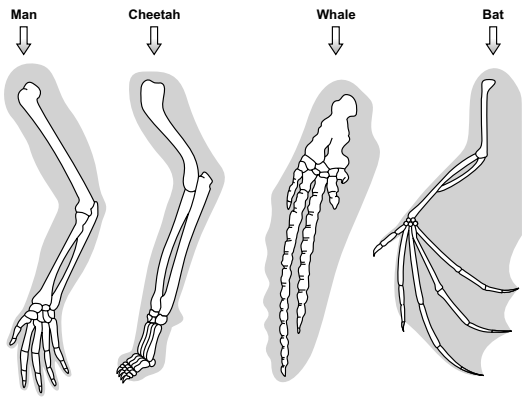


Fig. 7.3: Example of homologous organs in animals

- Homology can also be seen in heart, blood vessels, excretory system, brain, etc.
- Homology found in different animals indicates their evolution from common ancestors. The process in which species diverged after origin from common ancestor giving rise to new species adapted to new habitats and ways of life is called **adaptive radiation**. Such species, exhibit a large number of homologous organs.
- Homology shows divergent evolution, e.g., Adaptive radiation gave rise to a variety of marsupials in Australia.
- Divergent evolution is the development of different functional structures from a common ancestral form is called divergent evolution, e.g., Development of Homologous organs.
- Examples of homology in Plants: The thorns of *Bougainvillea* and tendrils of *Cucurbita.*

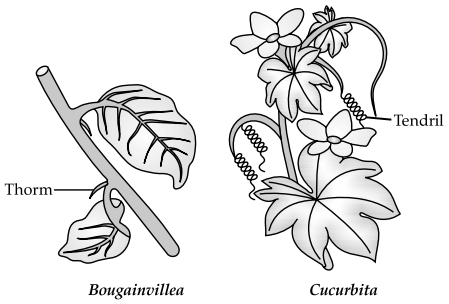


Fig. 7.4: Example of homologous organs in plants

- The divergent evolution is the process by which related species become less similar in order to survive and adapt to different environmental condition.
- **Biochemical Homology:** Similarities in proteins and genes performing similar functions among diverse organisms give hints to common ancestry. These biochemical similarities point to the same ancestry as structural similarities among diverse organisms.

(b) Analogous Organs and Analogy: Analogous organs are the organs having similar functions but different structures and origins. This phenomenon is called analogy.

- Examples:
  - **(i)** Wings of insects (formed of a thin flap of chitin) and wings of birds (modified forelimbs) and bats.

Fig. 7.5: Wings of insects and wings of birds

  - **(ii)** Eyes of Octopus (retina from skin) and eyes of mammals (retina from embryonic brain).
  - **(iii)** Flipper of Penguins and Dolphins.
  - **(iv)** Sweet potato (modified root) and Potato (modified stem).
  - **(v)** Trachea of insects (from ectoderm) and lungs of vertebrates (from endoderm).
- The origin of analogous organs is due to convergent evolution.
- The convergent evolution is the process by which unrelated species become more similar in order to survive and adapt in similar environmental condition.
- Development of similar adaptive functional structures in unrelated groups of organisms is called **convergent evolution**. For example, some of the marsupials of Australia resemble equivalent placental mammals that live in similar habitats of other continents. When adaptive convergence is found in closely related species, it is called **parallel evolution**.
- Analogous organs do not show common ancestry but they show evolution.

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

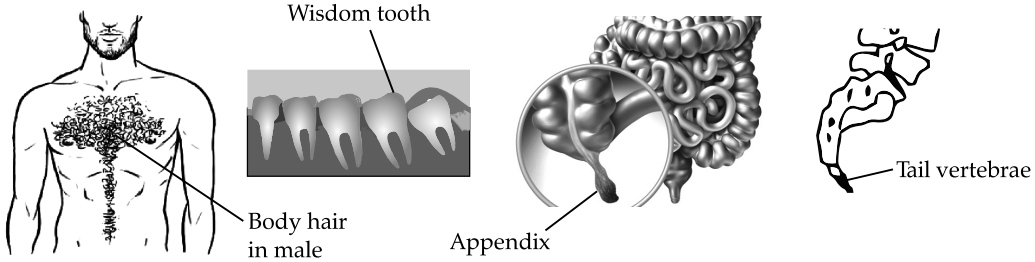


Fig. 7.6: Some vestigial organs in human body

- The only rational explanation for the presence of these non-functional organs is that they have been inherited from ancestors in which they were functional.

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

Evidence from Embryology

- An embryology is the study of the development of an organism.
- The aspects of embryology which support the doctrine of organic evolution are:
  - Similar stages of early development (morula, blastula or gastrula) in all animals.
  - The embryos of all vertebrates are similar in shape and structure in their early stages.
  - All vertebrates start their life from a single cell, the zygote.
  - All of them during their life history, pass through two-layered blastula and three-layered gastrula stage and then through fish like stage with gill-slits.

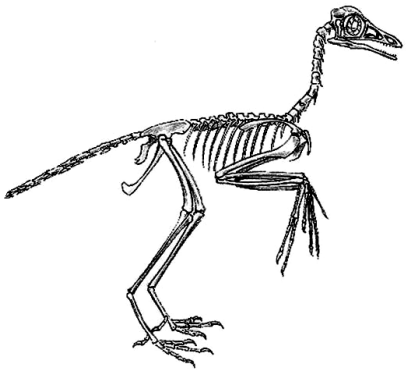


Fig. 6.7: An extinct bird - *Archaeopteryx*

- All the different aspects of embryology strongly support the fact that the different classes of vertebrates had common ancestors.
- **Ernst Haeckel's biogenetic law:** This law states that "*ontogeny* [development of the embryo] *recapitulates phylogeny* [development of race]. Example: Vertebrate head at embryonic stage has vestigial gill slits like fishes.

Adaptive Radiation (Biogeographical Evidences)

- Adaptive radiation (evolution by adaptation) is the evolution of closely related species in a given geographical area starting from a point and radiating to other areas of geographic geographical areas habitations.
- Example:
  (a) Darwin's Finches (birds seen in Galapagos Islands); varieties of small black birds with altered beaks evolved on same island.
  (b) Australian marsupials; a number of different marsupials evolved from an ancestral stock within the Australian island continent.
  (c) Placental mammals in Australia; varieties of placental mammals, each appearing to be similar to a corresponding marsupial.

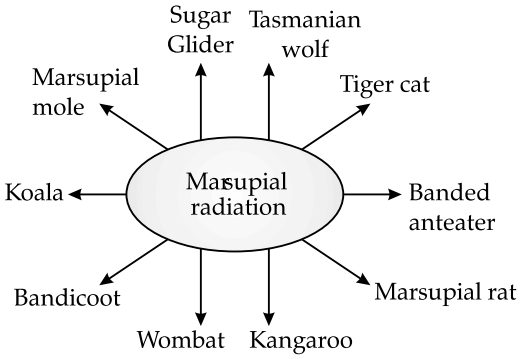


Fig. 7.8: Adaptive radiation of marsupials of Australia

- When more than one adaptive radiation appears in an isolated geographical area, this may be called as convergent evolution.

  For example, Australian Marsupials and Placental mammals show convergent evolution.
- **Parallel evolution:** When more than one adaptive radiation appeared to have occurred in an isolated geographical area then it is called parallel evolution, e.g., Australian marsupials and placental mammals (corresponding).

Placental mammals	Australian Marsupials
Mole	Marsupial mole
Ant eater	Numbat (Ant eater)
Mouse	Marsupial mouse
Lemur	Spotted cuscus
Flying squirrel	Flying phalanger
Bobcat	Tasmanian tiger cat
Wolf	Tasmanian Wolf

- **Evidence for Evolution by Natural Selection**
  - Natural selection is the process by which the organisms that are best suited for their environment, survive and reproduce.
  - Many examples of natural selection in action are available now. Given below are three such examples.

- **Example 1: DDT resistant mosquitoes:** About 50 years back, the mosquito population had been kept in control with the help of DDT. Thereafter, it was found that mosquitoes could not be killed with DDT any longer. They are DDT-resistant mosquitoes. What had happened was that a gene mutation (variation) had conferred on the mosquitoes, the ability to resist the effect of DDT. While DDT killed other mosquitoes, those with the gene mutation survived and slowly within a few generations DDT-resistant mosquitoes replaced the DDT-sensitive ones. In other words, the DDT resistant mosquitoes 'reproduced differentially' by the action of natural selection.
- **Example 2: Metal tolerance in grasses:** Certain metal residues sometimes collect in the soil near some industries using heavy metals. Being poisonous, they kill the grasses. However, resistant grasses are found to evolve a metal tolerance.
- **Example 3: Industrial melanism**

Industrial Melanism (In England): Before industrialisation (1850s):

- There were more white winged moths *(Biston betularia)* on trees than dark winged or melanised moths *(Biston carbonaria).*
- **Reason:** Thick growth of almost while coloured lichen covered the trees. In that background the white winged moths survived but the dark coloured moths were picked out by predators.

After industrialisation (1920):

- There were more dark winged moths and less white winged moths.
- **Reason:** The tree trunks became dark due to industrial smoke and soot. The growth of lichens was hampered due to pollution. Under this condition, the white winged moth did not survive because the predators identified them easily. Dark winged moth survived as they were able to camouflage themselves because of suitable dark background.

- **Example 4: Natural selection by anthropogenic action:** Excess use of herbicides, pesticides, antibiotics or drugs, etc., resulted in selection of resistant varieties.
  - **Molecular evidence of evolution:** These pieces of evidence show common ancestry based on parallel nucleic acid and amino acid sequences as well as universal genetic codes, e.g., Human and Chimpanzee DNA is 98.2% same and protein cytochrome c is similar.

A Brief Account of Evolution

- **2000 mya:** First cellular forms of life appeared on Earth.
- **500 mya:** Invertebrates formed
- **350 mya:** Jawless fish evolved probably, fish with stout and strong fins evolved which can move on lands as well as go back to water.
- **320 mya:** Sea weeds and few plants existed probably.
- **In 1938:** Fish caught in south Africa happened to be a coelacanth which was thought to be extinct. These animals are called lobefins (evolved into first amphibians).
- **200 mya:** Some land reptiles went back into water to evolve into fish like reptiles, e.g. *Ichthyosaurus*. Land reptiles were Dinosaurs. Biggest Dinosaur: *Tyrannosaurus rex* (20 feet in height, had huge dagger like teeth.)
- First mammals were like shrews-They were small sized, viviparous intelligent.

Evolution of Man

- About 15 mya, primates called *Dryopithecus* and *Ramapitheus* were existing.
- ***Dryopithecus:*** Were more ape-like, lived in Asia, Africa and Europe. Walked semierect, Hand and Skull were monkey like.
- ***Ramapithecus:*** First man-like, walked straight on legs, not taller than 4 feet.
- ***Australopithecus:*** 2 mya, lived in east African grassland, hunted with stones, ate fruits, Teeth larger.
- ***Homo habilis:*** 2 mya, brain capacity 650–800cc, did not eat meat, dentition like humans.
- ***Homo erectus:*** 1.5 mya, brain capacity 900cc, ate meat, walked erect.
- **Cro-Magnon Man:** Discovered in 1868, Cro-Magnon was among the first fossils to be recognized as belonging to our own species—*Homo sapiens*. First ones to have prominent chins, made tools and cave paintings.
- ***Homo sapiens:*** 5 lakhs years ago, in Africa, and spread to all parts of world. Neanderthal man: 40,000–1,00,000 years ago, brain capacity 1400cc, broad forehead, lived in caves, used hides to protect their bodies.

Key Terms

- **Analogous Organs:** Those organs which perform the same function but are dissimilar in their basic structural plan and developmental origin.
- **Fossils:** These are the remains or impressions of organisms that lived in the remote past.
- **Homologous Organs:** Those organs which have similar basic structural plan and developmental origin, but look different and perform different functions.
- **Convergent Evolution:** It is the evolutionary process where anatomically different structures in different group of organisms evolve towards the same function
- **Adaptive Radiation:** It is the process of evolution of different species starting from a point in a geographical area and finally radiating to other areas of geography.
- **Evolutionary biology:** The study of history of life forms on earth.
- **Abiogenesis:** Origin of life from non-living materials.
- **Biogeny:** Origin of first life.
- **Biopoiesis:** Origin of life.
- **Protobiogenesis:** Biochemical origin of life.
- **Chemogeny:** Origin and development of different types of organic molecules.
- **Cognogeny:** Development of different forms of life.
- **Eobiont:** Cell like structure capable of self-duplication.
- **Nebula:** Condensed mass of dust and gas.
- **Artificial Selection:** It is the process carried out by man to select better plants and animals.
- **Biogeography:** The study of patterns of distribution of plants and animals in different parts of earth.
- **Panspermia:** Units of life in the forms of so called spores, which were transferred to earth from outer space (as believed by some scientists).
- **Organic (Biological) Evolution:** Changes in the characteristics/features of organisms or groups of such populations over a number of generations.

Mnemonics

1. **Concept: Homologous Organs**
   Mnemonic: Vijay's **H**overing **B**all and **B**at for **T**est **C**ricket **T**oday **L**et us **W**in the match **B**y **C**atch
   Interpretation: Vertebrate **H**earts or **B**rains. (In plants also, the) ***B****ougainvillea's* **T**horn ***C****ucurbita's* **T**endrils, **L**imbs of **W**hale, **B**ats and **C**heetah

2. **Concept: Analogous Organs**
   Mnemonic: All **P**eople **o**f **D**ehradun **a**nd **F**rance **a**re **S**weet **a**nd **P**eaceful **W**ho give **B**est **B**reads **a**nd **M**any **O**ptions **o**f **E**gg dishes
   Interpretation: Penguins and **D**olphins **F**lippers, **S**weet **P**otato and **P**atato, Wings of **B**irds and **B**utterflies, Mammals and **O**ctopus **E**yes

3. **(a) Concept: To memorise** the **Eras:**
   Mnemonics: Please Pay **M**y **C**ash!
   Interpretation: Precambrian, **P**aleozoic, **M**esozoic, **C**enozoic
   (b) Concept: To **memorise the Periods:**
   Mnemonics: Come Over **S**ome **D**ay, **M**aybe **P**lay **P**oker **T**hree **J**acks **C**an **T**ake **Q**ueen
   Interpretation: Cambrian, **O**rdovician, **S**ilurian, **D**evonian, **M**ississippian, **P**ennsylvanian, **P**ermian, **T**riassic, **J**urassic, **C**retaceous, **T**ertiary, **Q**uaternary:
   (c) Concept: To **memorise the Epochs of Cenozoic Era:**
   Mnemonics: Place Eggs **O**n **M**ira's **P**late **P**lease **H**arish.
   Interpretation: Paleocene, **E**ocene, **O**ligocene, **M**iocene, **P**liocene, **P**leistocene, **H**olocene (or Recent):

Topic-2 Evolutionary Theories and Mechanism

Concepts Covered • *Theories of Biological Evolution* • *Mechanism of Evolution*

Revision Notes

Theories of Biological Evolution

- Based on the evidence of evolution, various theories have been put forth regarding evolution of life. The most important are the theory postulated by Lamarck and Darwin

1. Lamarckism (Theory of Inheritance of Acquired Characters)

- According to Lamarck's postulation of evolution, the acquired characters achieved by an organism during their life time can be transferred or transmitted to offspring. Even in the offspring, these modifications become pronounced depending upon continuous use or disuse of the organs. After certain generations, the offspring produced become totally different from their original parents giving new species.
- The environment factors force the living organisms to change and adopt themselves accordingly.
- On the basis of transmission of acquired characters, whole postulation is known as "theory of inheritance of acquired characters".
- The theory of inheritance of acquired character is simply known as Lamarckism. This theory consists of following postulates:

(i) The environment changes regularly due to different geological or bio-physical processes. The change in environment greatly affects the habit, habitat and composition of living organisms. This change in environment increases the possibility of new organisms with respect to various habitats.

(ii) Use and disuse of organs:

- The use and disuse of any organ affects the development of organ and body too.
- According to change in environment, body tends to increase the size of the organ which are used most frequently and continuously. It means the frequently used organs become more developed and become more strong and large.
- When the organ is not in continuous use, it gradually reduces in size and disappears or remains as less developed form (Vestigial form).

(iii) Inheritance of acquired characters:

- All the changes occurred in an organism are preserved within the body. These acquired characters are then transmitted to their offspring through the gametes.
- This inheritance of acquired characters is due to use and disuse of organs. Therefore, after many generations, new species are formed which are distinctly different from their ancestors.

- **Evidence to prove or support Lamarckism:**
  - There are some examples by which theory of evolution can be best explained in favour of Lamarck.

(i) Long necked giraffe:

- **Long necked giraffe:** The evolution of long necked giraffe took place from short-necked giraffe due to continuous stretching of the neck muscles in order to find food from tall trees. In the beginning, the short-necked giraffe used to eat the grasses.
- Later on, sources of grass on land reduced and it forced to eat the leaves of tall trees stretching of neck is continuous and is gradually transmitted to offspring.

(ii) Loss of limb of snake:

- The continuous creeping through holes and crevices made snakes body elongated and due to continuous disuse of limbs because they hinder while creeping in burrows results in loss of their limbs.
- In the same way, vestigial organs in human and other animals show disuse of those organs.

(iii) Web of hind limbs of frog:

- Development of webs on hind limbs of frog and ducks for swimming in water because they used more continuously in search of food.

2. Darwinism (Theory of Natural Selection)

- It was proposed by Charles Darwin.
- It is based on two key concepts namely,

(a) Branching Descent

- It explains that all organisms are modified descendants of previous life forms.

(b) Natural Selection

- Consider a bacterial colony (say A) growing on a given medium.
- If the medium composition is changed, only a part of the population (say B) can survive under new condition. This variant population outgrows the others and appears as new species, i.e., B is better than A under new condition.
- Nature selects for fitness.
- The work of Thomas Malthus on populations influenced Darwin.
- **Natural selection is based on the following facts:**
  - **(i)** Heritable minor variations.
  - **(ii)** Over production by organisms.
  - **(iii)** Limited natural resources.
  - **(iv)** Struggle for existence.
  - **(v)** Survival of the fittest.

- Population size grows exponentially if everybody reproduces maximally (e.g., Bacterial population).
- In fact, population size is limited due to competition for resources (Struggle for existence).
- Only some survive (Survival of the fittest).
- Darwin said that the organisms with heritable variation and which make resource utilisation better will enable only those to reproduce and leave more progeny.
- It leads to a change in population characteristics and new forms appear.

Mechanism of Evolution

- Darwin ignored about origin of variation and mechanism of speciation.
- **Mutation Theory:** Hugo de Vries proposed Mutation Theory of evolution.
- He conducted some experiments on *Oenothera lamarckiana* (evening primrose) and believed that evolution takes place through mutation and not by minor variation.
- Evolution for Darwin was gradual while Hugo de Vries believed mutation caused speciation and hence called it saltation (single step large mutation)
- **Differences between Darwinian Variation and Mutation are**

S.No.	Darwinian Variation	Mutation
1.	It shows minor variation.	It shows large variation.
2.	It is slow and directional.	It is random, sudden and directionless.
3.	It showed gradual evolution.	It showed speciation by saltation.

- **Hardy–Weinberg Principle**
  - It says that allele frequencies in a population are stable and constant from generation to generation.
  - The gene pool (total genes and their alleles in a population) remains constant. This is called genetic equilibrium (Hardy–Weinberg equilibrium).
  - Sum total of all the allelic frequencies = 1
  - Example, In a diploid, p and q are the frequencies of alleles A & a respectively.
  - The frequency of AA = p^2 (i.e. the probability of an allele A with frequency p is the product of the probabilities, i.e., p^2)
  - The frequency of $aa = q^2$
  - The frequency of A$a = 2pq$
  - Hence $p^2 + 2pq + q^2 = 1$ [binomial expansion of $(p+q)^2$]
  - Change of frequency of alleles in a population causes disturbance in genetic equilibrium, due to evolution.
- **Factors affecting Hardy–Weinberg Equilibrium**

(a) Gene Migration

- Gene flow from one population to another.
- Here, gene frequencies change in both populations.
- There would be a gene flow if migration happens multiple times.

(b) Genetic Drift: It occurs in small populations when a part breaks off from a large population. Only representative genes of the large population are present which undergo change at a right time and the small population may evolve into a new sub-species or species.

- The accidental gene flow causing change in frequency.
- Sometimes, the change in allele frequency is so different in the new sample of population that they become a different species.
- The original drifted population becomes founders and the effect is called founder effect.

(c) Mutation, which is a sudden genetic change.

- It may be a change in a single gene (genic mutation or point mutation) or may affect many genes (chromosomal mutation)

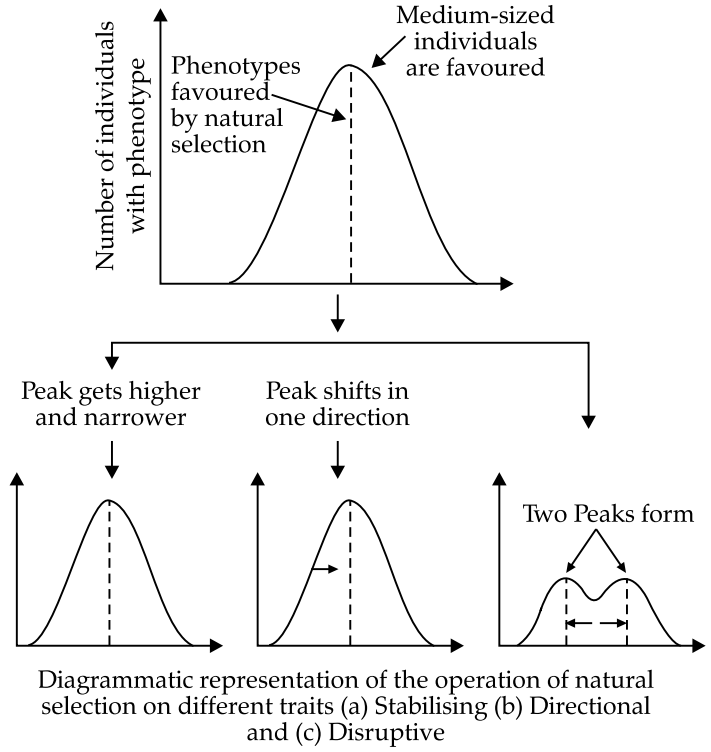
- Mutations result in formation of new phenotypes.
- Over few generations, this leads to speciation.

➢ **Genetic Recombination**

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

➢ **Natural Selection**

- Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave greater number of progeny.
- These are of three types namely, stabilising selection, directional selection and disruptive selection.
  - **(i) Stabilising selection:** Here, more individuals acquire mean character value and variation is reduced.
  - **(ii) Directional selection:** Here, individuals of one extreme are more favoured.
  - **(iii) Disruptive selection:** It eliminates most of the individuals acquire peripheral character value at both ends of the distribution curve.



Diagrammatic representation of the operation of natural selection on different traits (a) Stabilising (b) Directional and (c) Disruptive

Fig. 7.9

Key Terms

- **Genetic Recombination:** It is the exchange of genetic material between different organisms which leads to production of offspring with combinations of traits that differ from those found in either parent.
- **Mutation:** It is the sudden appearance of variations.
- **Natural Selection:** It is the process of occurring in nature that acts over a number of generations and slowly increases the proportion of those individuals which are adapted to the environment due to their heritable characters.
- **Speciation:** It is the process of formation of new species from the pre-existing species.
- **Hardy–Weinberg Principle:** It states that the allele frequencies in a population are stable and remain constant from generation to generation.
- **Gene pool:** Sum total of all the genes in a population.
- **Atavism:** It is a modification of a biological structure whereby an ancestral trait reappears after having been lost through evolutionary change in previous generations.

Mnemonics

1. **Concept:** Factors affecting Hardy-Weinberg Equilibrium
   Mnemonic: Grand **M**other, **G**rand Daughter **M**eet Great **R**oyals **N**ear **S**ociety
   Interpretation: Gene **M**igration, **G**enetic drift, **M**utation, **G**enetic **R**ecombination, **N**atural **S**election.

2. **Concept:** Hardy-Weinberg **equilibrium:** Causes for deviations from it.
   Mnemonic: Mudra **M**ichael **D**oes Not **S**moke"
   Interpretation: Mutations, **D**rift, **N**on-random mating, **S**election

3. **Concept:** Human evolution
   Mnemonics: Doctor **R**am in **A**ustralia **H**ave researched **E**volution on **N**ew **H**umans.
   Interpretation:

D*ryopithecus*	—	Doctor
R*amapithecus*	—	Ram in
A*ustralopithecus*	—	Australia
Homo ***h****abilis*	—	Have researched
Homo ***e****rectus*	—	Evolution on
Homo ***n****eanderthalensis*	—	New
H*omo* ***s****apiens*	—	Humans

❑❑

UNIT – 3: BIOLOGY AND HUMAN WELFARE

CHAPTER-8
HUMAN HEALTH AND DISEASES

Topic-1 Health, Common Diseases in Human and Immunity

Concepts Covered • *Disease and Its Types* • *Prevention and Control of Diseases* • *Immunity and Its Types* • *Vaccination* • *AIDS & CANCER: Causes and Treatment*

Revision Notes

- Health is a state of complete physical, mental and social well-being.
- Health simply does not mean disease free condition or physical fitness
- Health is affected by:
  - **(a)** Genetic disorders – the defect which child inherits from its parents.
  - **(b)** Infections from microbes or other organisms.
  - **(c)** Life style – includes food and water we take, exercise and rest.
- When people are healthy, they are more efficient at work. This increases productivity and brings prosperity. It also increases longevity of life and reduces infant and maternal mortality.
- **Good health can be maintained by:**
  - **(a)** Balanced diet.
  - **(b)** Personal hygiene.
  - **(c)** Regular exercise.
  - **(d)** Awareness about the disease and their effect.
  - **(e)** Immunisation against the infectious disease.
  - **(f)** Proper disposal of wastes.
  - **(g)** Control of vectors.
  - **(h)** Maintenance of hygienic food and water.

Diseases

Types of Diseases

- Diseases can be of two types namely, communicable and non-communicable.
- The diseases which are easily transmitted from infected person to healthy persons are called **communicable** (infectious) diseases and those diseases which cannot be transmitted from one person to another are called **non-communicable** (non-infectious) diseases.

Common Communicable Diseases in Man

- The disease causing micro-organisms like bacteria, virus, fungus, protozoa, helminths are called pathogen.
- The pathogen can enter the body by various means and multiply and interfere with normal vital activities resulting in morphological and functional damages.

Bacterial Diseases

Pneumonia:

Pathogen: *Streptococcus pneumoniae* and *Haemophilus influenzae.*

Mode of Transmission: Inhaling the droplets/aerosols released by an infected person, sharing glasses and utensils with an infected person.

Symptoms:

(a) Infects alveoli of the lungs where the alveoli get filled with fluid leading to respiratory problems.

(b) Fever, chills, cough, headache.

(c) Severe cases: Lips and finger nails turn grey to bluish colour.

Other Bacterial Diseases

Disease	Pathogen	Transmission
Dysentery	*Shigella dysenteriae*	Contact, Contaminated food and water
Plague	*Pasteurella pestis*	Rat fleas
Diphtheria	*Corynebacterium diphtheriae*	Contaminated food, Direct contact
cholerae	*Vibrio cholerae*	Food and water contaminated with faeces
Tuberculosis	*Mycobacterium tuberculosis*	Droplets from patient/carrier
Tetanus	*Clostridium tetani*	Contamination of wound by bacteria
Whooping cough	*Bordetella pertussis*	Contact, Droplets
Leprosy	*Mycobacterium leprae*	Direct contact
Anthrax	*Bacillus anthracis*	Contact with cattle
Weil's disease	*Leptospira*	Contact with rodents, dogs, etc.

Viral Diseases

Common cold:

Pathogen: *Rhino viruses*

Mode of Transmission: Inhaling droplets resulting from cough or sneezes, through contaminated objects.

Symptoms:

(a) Infected nose and respiratory passage.

(b) Nasal congestion and discharge, sore throat, hoarseness, cough, headache, tiredness, etc.

(c) Last for 3–7 days.

Other Viral Diseases

Disease	Pathogen	Transmission
Rabies	*Rabies virus*	Rabid dogs
Dengue	*Dengue virus*	*Aedes* mosquito
Influenza	*Influenza virus*	Coughing and sneezing

Disease	Pathogen	Transmission
Measles (Rubeola disease)	*Rubeola virus*	Droplets
German measles (Rubella disease)	*Rubella virus*	Close contact
Mumps	*Mumps virus*	Air borne droplets
Chicken pox	*Varicella zoster*	Air borne droplets
Small pox	*Variola virus*	Direct contact
Polio	*Polio virus*	Faeces and air
Chikungunya	*Chikungunya virus (CHIKV)*	*Aedes* mosquito
Avian flu	*H5N1 virus*	Contact with infected poultry, air borne spread
Swine flu	*H1N1 virus*	Contact with pigs, cough and sneeze of infected person

Protozoan Diseases

Malaria:

Pathogen: *Plasmodium* sp. *(P. vivax, P. malariae, and P. falciparum).*

Mode of Transmission: Bite of infected female *Anopheles* mosquito.

Symptoms: Haemozoin causes chill and high fever recurring every 3–4 days.

Life Cycle of *Plasmodium:*

- *Plasmodium* enters the human body as sporozoites (infectious form) through the bite of infected female *Anopheles* mosquito.

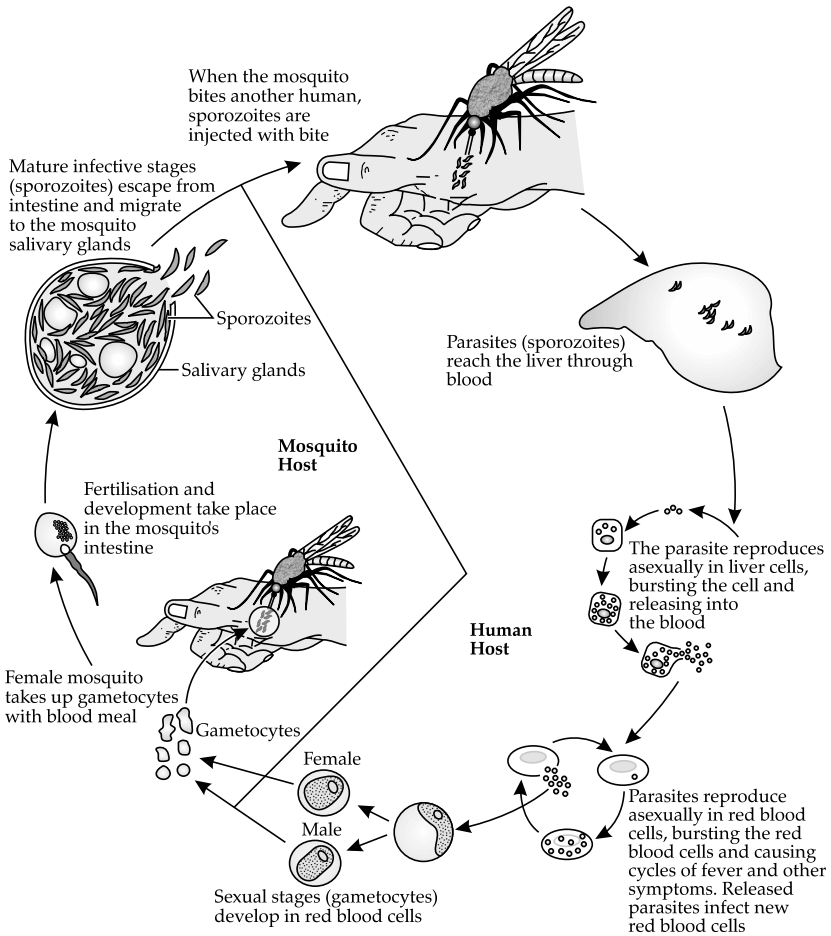


Fig. 8.1: Stages in the life cycle of *Plasmodium*

- The parasites initially multiply within the liver cells and then attack the red blood cells (RBCs) resulting in their rupture.
- The rupture of RBCs is associated with the release of a toxic substance, haemozoin, which is responsible for the chill and high fever recurring every three to four days.

- When a female *Anopheles* mosquito bites an infected person, these parasites enter the mosquito's body and undergo further development.
- The parasites multiply within them to form **sporozoites** that are stored in their salivary glands.
- When these mosquitoes bite a human, the sporozoites are introduced into his/her body.
- The malarial parasite requires two hosts to complete its life cycle namely, human and mosquito.
- The **female Anopheles** mosquito is the vector (transmitting agent).

Fungal Diseases

Ring worms

Pathogens: *Microsporum*, *Trichophyton* and *Epidermophyton*.

Mode of Transmission:

(a) From soil or by using towels, clothes, etc., comb of infected individuals.

(b) Heat and moisture help fungi to grow.

Symptoms:

(a) Appearance of dry, scaly lesions on various body parts such as skin, nails and scalp.

(b) Intense itching.

(c) They are seen growing in between toes, in the groin, etc.

Prevention and Control of Diseases

1. **Personal hygiene**
   - **(a)** Keep the body clean.
   - **(b)** Use clean drinking water, food, etc.
2. **Public hygiene**
   - **(a)** Proper disposal of wastes and excreta.
   - **(b)** Periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks.
   - **(c)** Avoid contact with infected persons or their belongings (to control air-borne diseases).
   - **(d)** Observing standard practices of hygiene in public catering.
   - **(e)** Control and eliminate the vectors (e.g., mosquitoes) and their breeding places.
3. **Methods to Control Breeding Places**
   - **(a)** Avoid stagnation of water.
   - **(b)** Regular cleaning of household coolers.
   - **(c)** Use of mosquito nets.
   - **(d)** Introduce larvivorous fishes like *Gambusia* in ponds.
   - **(e)** Spraying insecticides in ditches, drainage and swamps.
   - **(f)** Doors and windows should be provided with wire mesh to prevent entry of mosquitoes.
   - **(g)** These precautions can avoid vector borne diseases like Malaria, Filariasis, Dengue and Chikungunya.

Immunity

- It is the ability of the immune system to fight the disease-causing organisms. It is of two types namely:

Innate Immunity and Acquired Immunity

(i) Innate immunity

- It is the non-specific defence present at the time of birth.
- It provides different types of barriers to the entry of foreign agents into our body.
- It consists of four types of barriers.

(a) Physical barriers: It includes:

- Skin (Prevent entry of foreign bodies).
- Mucous coating of epithelium lining the respiratory, gastro-intestinal and urinogenital tracts to trap microbes entering our body.

(b) Physiological barriers: It includes acid in the stomach, saliva in the mouth, tears from eyes – all prevent microbial growth.

(c) Cellular barriers: It includes leucocytes (WBC) such as neutrophils or Polymorpho-nuclear leucocytes (PMNL-neutrophils), monocytes and natural killer lymphocytes, macrophages, etc.

(d) Cytokine barriers: It includes virus-infected cells, which secrete proteins called interferons that protect non-infected cells from further viral infection.

(ii) Acquired immunity

- It is pathogen specific immunity.
- It is characterized by memory, i.e., during first encounter of a pathogen, our body produces primary response in low intensity. Second encounter with the same pathogen produces a secondary (anamnestic) response in high intensity.
- The primary and secondary immune responses are carried out with two special types of lymphocytes namely, B-lymphocytes and T-lymphocytes.

(a) B-lymphocytes (B-cells)

- It produces proteins in response to pathogens into our blood to fight with them.
- These proteins are called antibodies.

(b) T-lymphocytes (T-cells)

- It helps B-cells to produce antibodies.
- Each antibody has four peptide chains namely,
  - **(a)** Two small chains called light chains
  - **(b)** Two longer chains called heavy chains
- Hence, an antibody is represented as $H_2 L_2$
- Types of antibodies produced in our body: IgG, IgA, IgM, IgE and IgD.

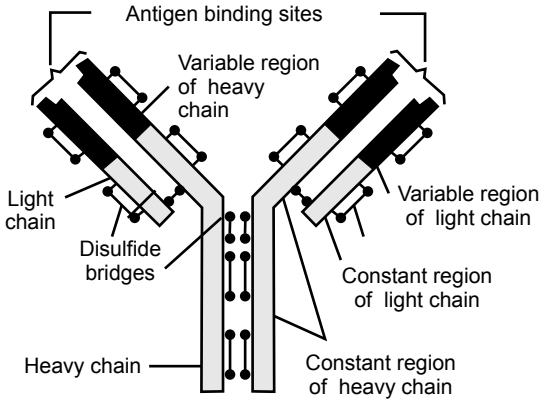


Fig. 8.2: Structure of an antibody molecule

Acquired Immune Response

- These are of two types namely: Antibody mediated response and cell mediated response.
  - **(a) Humoral or antibody mediated response/antibody mediated immunity (AMI):** Because these antibodies are found in the blood, the response is also called as humoral immune response.
  - **(b) Cell-mediated response/cell-mediated immunity (CMI):**
    - T-lymphocytes (T-cells) mediate CMI.
    - CMI is responsible for graft rejection.
    - The body is able to differentiate between 'self' and 'non-self'.
    - Tissue matching and blood group matching are essential before undertaking any graft/transplant. After this, the patient has to take immune-suppressants all his life.

Types of Immunity

There are two types of immunity namely: **Active immunity and passive immunity**.

(a) Active Immunity

- When a host is exposed to antigens, which may be in the form of living or dead microbes or other proteins, antibodies are produced in the host body. This type of immunity is called active immunity.
- Active immunity is slow and takes time to give its full effective response.
- Injecting the microbes deliberately during immunisation or infectious organisms gaining access into body during natural infection induce active immunity.

(b) Passive Immunity

- When ready-made antibodies are directly given to protect the body against foreign agents, it is called passive immunity.
- The yellowish fluid colostrum secreted by the mother during the initial days of lactation has abundant antibodies (IgA) to protect the infant.
- The foetus also receives some antibodies from their mother, through the placenta during pregnancy.

Vaccination and Immunisation

- Immunisation is based on the memory of the immune system.
- There are two types namely: active immunisation and passive immunisation.

(a) Active Immunisation

- A preparation of vaccine (antigenic proteins of pathogen or inactivated pathogen) is introduced into body.
- The antibodies produced in the body against the antigens neutralise the pathogenic agents during actual infection.

- The vaccines also generate memory B and T-cells that recognise the pathogen quickly, e.g., Polio vaccine, Hepatitis B vaccine, DPT vaccine, etc.
- Vaccines are produced using DNA recombinant technology (e.g., Hepatitis-B vaccine produced from Yeast).

(b) Passive Immunisation

- It is the direct injection of pre-formed antibodies or antitoxin. It is required for quick immune response, e.g., Immunisation against Tetanus, snake venom, etc.

Allergies

- It is the exaggerated response of the immune system to certain antigens present in the environment.
- The substances causing allergy are called allergens, e.g., mites in dust, pollens, animal dander, fur, etc.
- Antibodies produced against the allergens are IgE type.
- Allergy is due to the release of chemicals like histamine and serotonin from the mast cells.
- Modern-day life style results in lowering of immunity and more sensitivity to allergens.
- More children in India suffer from allergies and asthma due to sensitivity to the environment. This could be because of the protected environment provided early in life.
- **Symptoms of Allergy**
  - **(a)** Sneezing.
  - **(b)** Watery eyes.
  - **(c)** Running nose.
  - **(d)** Difficulty in breathing.
- **Treatment for Allergy:** Drugs like anti-histamine, adrenaline and steroids quickly reduce the symptoms of allergy.

Auto Immunity

- Sometimes, due to the genetic and other unknown reasons, body attacks self-cell resulting into auto-immune disease, e.g., Rheumatoid arthritis.

Immune System in the Body

- It is the system that gives immunity to the body by recognising, responding and remembering foreign antigens.
- It plays a role in allergic reaction, auto-immune disease and organ transplantation.
- It includes lymphoid organs, tissues, cells and soluble molecules like antibodies.

Lymphoid Organs

- These are the organs where origin, maturation and proliferation of lymphocytes occur.
- It is of two types namely: primary lymphoid organs and secondary lymphoid organs.

(a) Primary Lymphoid Organs

- The primary lymphoid organs are bone marrow and thymus where immature lymphocytes differentiate into antigen-sensitive lymphocytes.

Bone Marrow and Thymus

- The bone marrow is the main lymphoid organ where all blood cells including lymphocytes are produced.
- The thymus is a lobed organ located near the heart and beneath the breastbone.
- The thymus is large at the time of birth but keeps reducing in size with age and by the time puberty is attained it reduces to a very small size.
- Both bone marrow and thymus provide micro environments for the development and maturation of T-lymphocytes.

(b) Secondary Lymphoid Organs

- After maturation, the lymphocytes migrate to secondary lymphoid organs like spleen, lymph nodes, tonsils, Peyer's patches of small intestine and appendix.
- The secondary lymphoid organs provide the sites for interaction of lymphocytes with the antigen, which then proliferate to become effector cells.

Spleen

- The spleen is a large bean shaped organ.
- It mainly contains lymphocytes and phagocytes.
- It acts as a filter of the blood by trapping blood-borne microorganisms.
- Spleen also has a large reservoir of erythrocytes.

Lymph Nodes

- The lymph nodes are small solid structures located at different points along the lymphatic system.
- Lymph nodes serve to trap the microorganisms or other antigens, which happen to get into the lymph and tissue fluid.
- Antigens trapped in the lymph nodes are responsible for the activation of lymphocytes present there and cause the immune response.

MALT [Mucosa Associated Lymphoid Tissue]

- There is lymphoid tissue located within the lining of the major tracts (respiratory, digestive and urogenital tracts) called mucosal associated lymphoid tissue (MALT).
- It constitutes about 50% of the lymphoid tissue in human body.

AIDS

- AIDS stands for **Acquired Immuno Deficiency Syndrome**. It means deficiency of immune system, acquired during the lifetime of an individual indicating that it is not a congenital disease.
- The word 'syndrome' refers to a group of symptoms.
- It was first reported in 1981.
- It has spread all over the world killing more than 25 million people.
- There is a time-lag between the infection and appearance of AIDS symptoms.
- It varies from months to years (5–10yrs).

Causes of AIDS

- It is caused by the Human Immuno deficiency Virus (HIV), a member of a group of viruses called retrovirus which have a protein envelope enclosing the RNA genome.
- It is transferred:
  - **(a)** By sexual contact with infected person.
  - **(b)** By transfusion of contaminated blood and blood products.
  - **(c)** By sharing infected needles.
  - **(d)** From infected mother to her child through placenta.
  - **(e)** Through body fluids.
- So, people having multiple sexual partners, drug addicts, individuals who require repeated blood transfusion and children born to an infected mother have high risk of getting this disease.
- It does not spread by touching, physical contact and hence it is imperative for the physical and psychological well-being, that the infected persons are not isolated from family and society.

Symptoms of AIDS

- The person suffers from bouts of fever, diarrhoea and weight loss.
- Due to decrease in the number of helper T-lymphocytes, a person starts suffering from infections which are caused due to pathogens like bacteria especially *Mycobacterium*, viruses, fungi and parasites like *Toxoplasma*. The patient becomes unable to protect himself against these infections.

Test or Identification for AIDS

- It can be identified by ELISA (Enzyme Linked Immuno Sorbent Assay) test.

Treatment of AIDS

- The anti-retroviral drugs give partial effect and can prolong the life of the patient but cannot prevent death, which is inevitable.

Replication of AIDS Virus

- After getting into the body of the person, the virus enters into macrophages where RNA genome of the virus replicates to form viral DNA with the help of enzyme reverse transcriptase.
- The viral DNA enters host cell's DNA and directs the infected cells to produce virus particles.
- The macrophages produce more and more virus and act as a HIV factory.
- Simultaneously, HIV enters into helper T-lymphocytes (TH), replicates and produces progeny viruses.

- The progeny viruses released in the blood attack other helper T-lymphocytes resulting in the decrease in number of helper T-lymphocytes in the body and the person starts suffering from infections that could have been otherwise overcome.

Prevention of AIDS

- AIDS has no cure but can be prevented.
- The only excuse may be ignorance and it has been rightly said "don't die of ignorance".
- NACO (National AIDS Control Organisation) and NGOs (Non-Governmental Organisation) are educating people about AIDS.
- WHO (World Health Organisation) has started a number of programmes to prevent the spreading of HIV infection.

Steps to Prevent AIDS

(a) Using disposable syringes and needles in private and public hospitals.
(b) Using condoms.
(c) Controlling drug abuse.
(d) Advocating safe sex.
(e) Promoting regular check-up

- **HIV/AIDS:** infected people need help and sympathy instead of being shunned by society. Unless society recognises it as a problem, the chances of spreading of disease increase manifold. It is difficult to be tackled, unless the society and medical fraternity act together, to prevent the spread of the disease.

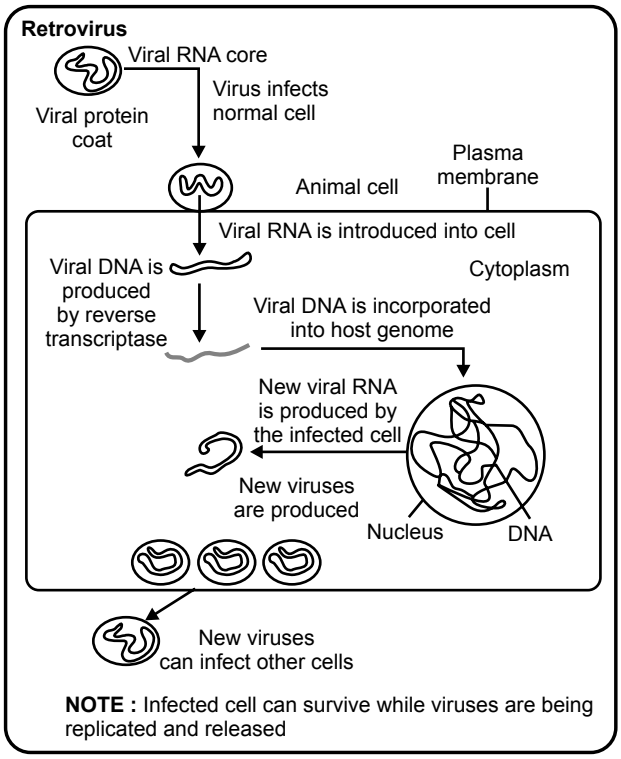


Fig. 8.3: Replication of retrovirus

Cancer

- It is one of the most dreadful diseases of human beings.
- It is a major cause of death all over the world.
- In cancer cells, the cell growth and differentiation are not controlled. Normal cells show a property called contact inhibition by virtue of which contact with other cells inhibits their uncontrolled growth.
- Cancer cells lose their property and continue to divide giving rise to mass of cells called tumours.
- Tumours are of two types namely, Benign and Malignant.
- **Benign tumours** remain in their original position and do not spread to other parts of the body causing little damage.
- **Malignant tumours** are a mass of proliferating cells called neoplastic or tumor cells which grow rapidly, invading and damaging the surrounding normal tissues.
- These cells starve the normal cells by competing for vital nutrients.
- Cells sloughed from such tumours reach distant sites through blood and whenever get lodged in the body, they start a new tumour. This property is called **metastasis.**

Causes of Cancer

- Normal cells can be transformed into cancerous cells by physical, chemical or biological agents which are called carcinogens.
- Ionising radiations such as X-rays and gamma rays and non-ionising radiations such as UV cause DNA damage.
- The chemical carcinogens in tobacco smoke are the major cause of lung cancer.
- The virus causing cancer is called oncogenic viruses which have genes called viral oncogenes.
- Several genes called **cellular oncogenes** (c-onc) or proto oncogenes in normal cells under certain conditions leads to oncogenic transformation of the cells.

Detection and Diagnosis of Cancer

- Cancer detection is based on biopsy and histopathological studies of the tissue, blood and bone marrow tests for increased cell counts as in case of leukemia.

- In biopsy, a piece of the suspected tissue cut into thin sections is stained and examined under microscope by a pathologist.
- Techniques such as CT (Computed Tomography), radiography and MRI (Magnetic Resonance Imaging) are useful in detecting cancer in internal organs.
- CT uses X-rays to produce 3D image of the internal organs, MRI uses strong magnetic fields and non-ionising radiations to detect the changes in tissues.
- Antibodies against cancer-specific antigens are also used for detecting cancers.
- Molecular biology helps to detect genes in individuals with certain cancers. Such individuals are advised to avoid exposure to particular carcinogens to which they are susceptible., e.g., Tobacco smoke in case of lung cancer.

Treatment of Cancer

- The common approaches are surgery, radiation therapy and immunotherapy.
- In radiation therapy, the tumour cells are irradiated lethally, taking care of the normal tissues.
- Chemotherapeutic drugs are used to kill cancerous cells.
- Majority of the drugs have side effects like hair loss, anaemia, etc.
- Some cancers are treated by a combination of surgery, radiotherapy and chemotherapy.
- Tumour cells avoid detection and destruction by immune system. Therefore, the patients are given substances called biological response modifiers such as α-interferon which activate their immune system and help in destroying the tumour.

Key Terms

- **Health:** A state of complete physical, mental and social well-being.
- **NACO:** National AIDS Control Organisation.
- **PMNC:** Polymorphonuclear cells.
- **WHO:** World Health Organisation.
- **CMI:** Cell Mediated Immunity.
- **AIDS:** Acquired Immuno Deficiency Syndrome.
- **HIV:** Human Immuno Deficiency Virus.
- **MALT:** Mucosal Associated Lymphoid Tissue.
- **HLA:** Human Leukocyte Antigen.
- **MHC:** Major histocompatibility complex.
- **SCID:** Severe combined immune deficiency.
- **Antigens:** These are large and complex foreign molecules that activate the specific immune system to generate antibodies.
- **Antibodies:** These are the protein molecules produced in response to the antigens.
- **Cancer:** It is the state characterised by uncontrolled divisions of cells that results due to the breakdown of regulatory mechanisms which govern the normal cell behaviour.
- **Disease:** It is the condition when the functioning of one or more organs of the body are is adversely affected and characterised by various symptoms.
- **Immunity:** It refers to the overall ability of a living body to fight against diseases.
- **Interferons:** These are the glycoproteins produced by our body cells in response to a viral infection.
- **Metastasis:** It is the phenomenon in which cancer cells spread to different sites through the body fluids and develop secondary tumours.
- **Pathogens:** These are the organisms which cause diseases.
- **Retroviruses:** These are viruses which have RNA as genetic material, but can produce DNA by reverse transcription.
- **Syndrome:** It refers to a group of symptoms.
- **Tumours:** These are the masses of cells produced by the uncontrolled proliferation of cancerous cells.
- **Vaccination:** It is the process of introducing a preparation of antigenic proteins of pathogens or killed or inactivated pathogens into the body to generate the immune response.
- **Vectors:** These are the organisms which spread the pathogens.

Mnemonics

1. **Concept:** Viral Diseases
   Mnemonics: Influence the **C**ool **M**anager **S**o You **C**ould **H**elp **M**e **P**acify **R**ich **S**eller **H**ero **A**li to **G**et Diamonds
   Interpretation:

S.No.	Diseases	S.No.	Diseases	S.No.	Diseases
1.	Influenza	6.	Herpes	11.	Hepatitis
2.	Common **cold**	7.	Measles	12.	AIDS
3.	Mumps	8.	Polio	13.	Gastroentritis
4.	Small pox	9.	Rabies	14.	Dengue
5.	Chicken **pox**	10.	SARS	15.	Yellow **fever**

2. **Concept:** Bacterial Diseases
   Mnemonics: Tell **P**eter **T**o **C**ome **P**lay and **D**ance **T**ill **L**ate
   Interpretation:

S.No.	Diseases	S.No.	Diseases	S.No.	Diseases
1.	Typhoid	4.	Cholera	7.	Tetanus
2.	Pneumonia	5.	Plague	8.	Lep**rosy**
3.	Tuberculosis	6.	Diphtheria		

3. **Concept:** Detection and Diagnosis
   Mnemonics: Book **R**eader **C**um **M**anager
   Interpretation: Biopsy, **R**adiography, **C**T, **M**RI
4. **Concept:** Primary Lymphoid Organs
   Mnemonics: Profit **B**efore **T**ax (or) **P**lease **B**ook **T**ickets
   Interpretation: Primary Lymphoid organs: **B**one marrow, **T**hymus
5. **Concept:** Secondary Lymphoid Organs
   Mnemonics: See Sakshi Lifting **T**ongs (or) **S**amosa **S**eems **L**ight and **T**asty
   Interpretation: Secondary Lymphoid organs: **S**pleen, **L**ymph node, **T**onsils

Topic-2 Adolescence and Drug/Abuse

Concepts Covered • *Drugs, Alcohol and Tobacco Addiction/ Reasons for addiction*
• *Effects and Prevention of Drugs/Abuse withdrawal syndrome.*

Revision Notes

Introduction

- Adolescence means both 'a period' and 'a process' during which a child becomes mature in terms of his/her attitudes and beliefs for effective participation in society.
- The period between 12 and 18 years of age is said to be adolescence period.
- The term adolescence is a bridge linking childhood and adulthood.
- It is accompanied by biological and behavioural changes.
- Thus adolescence is a vulnerable phase of mental and psychological development of an individual.
- Curiosity, excitement, experimentation and the adventure motivate youngsters towards drug and alcohol.
- Later the youngster starts using these to escape facing problems, stress, pressure to excel in academics, etc.
- There is a perception among youth that it is 'cool' to smoke or use drugs.
- Television, movies, newspapers and internet helps to promote this perception.
- Other factors includes unsupportive family structures and peer pressure.

Drug Abuse

- The surveys and statistics show that the use of drugs and alcohol has been increased among youths.
- Proper education and guidance would enable youth to safeguard themselves against the drug abuse by following healthy life styles.
- The drugs commonly abused are opioids, cannabinoids and coca alkaloids.

- These drugs are obtained from flowering plants and fungi.

Opioids

- These drugs bind specific opioid receptors in the central nervous system and gastrointestinal tract., e.g., – morphine and heroin.

(a) Morphine

- It is obtained from the latex of poppy plant (*Papaver somniferum*).
- It is sedative and pain killer.
- It is used to reduce pain after surgery.

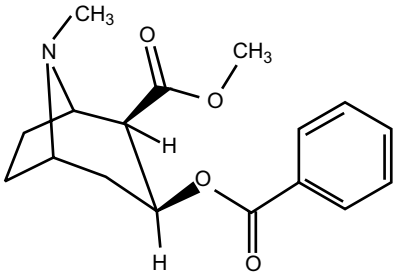


Fig. 8.4: Chemical structure of morphine

(b) Heroin

- It is commonly called smack and chemically called diacetylmorphine.
- It is bitter, white, odourless and crystalline compound obtained by acetylation of morphine.
- It is generally taken by snorting and injection.
- It is a depressant and slows down the body functions.

(c) Cannabinoids

- These are a group of chemicals which interact with cannabinoid receptors present mainly in the brain.
- Natural cannabinoids are obtained from the inflorescence of *Cannabis sativa*.
- Marijuana, hashish, ganja and charas are produced by the tops, leaves and resins of *Cannabis* plant.
- These are taken by inhalation and oral ingestion.
- These affect cardiovascular system of the body.

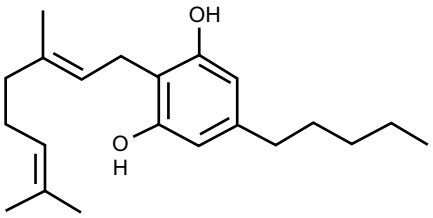


Fig. 8.5: Skeletal structure of cannabinoid molecule

Coca Alkaloid or Cocaine

- It is obtained from *Erythroxylum coca,* native to South America.
- It interferes with the transport of the neurotransmitter dopamine.
- It is commonly called coke or crack.
- It is generally taken by snorting.
- It has a potential stimulating action on central nervous system producing a sense of euphoria and increased energy.
- Excessive dosage of cocaine causes hallucinations.
- These are abused by sports persons.
- Other plants having hallucinogenic properties are *Atropabelladonna* and *Datura*.
- Drugs like barbiturates, amphetamines, benzodiazepines, lysergic acid diethyl amides [LSD] are abused.
- When these are taken for a purpose other than medicinal use or in high amounts, it impairs one's physical, physiological or psychological functions and constitutes drug abuse.

Tobacco

- Tobacco for more than 400 years is smoked, chewed or used as a snuff.
- It contains a large number of chemical substances including nicotine, an alkaloid.
- Nicotine stimulates the adrenal gland to release adrenaline and nor-adrenaline into blood circulation, both of which raise blood pressure and increase heart rate.
- Smoking increases cancer in lungs, urinary bladder and throat, bronchitis, emphysema, coronary heart diseases, gastric ulcer, etc.
- Tobacco chewing increases the risk of cancer of the oral cavity.
- Smoking increases CO content in blood and reduces the concentration of haem-bound oxygen thereby causing oxygen deficiency in the body.
- Smoking is prevalent in society, both among young and old. Knowing the dangers of smoking and chewing tobacco and its addictive nature, the youth and old need to avoid these habits.
- Addicted individuals require counseling and medical help to get rid of this habit.

Addiction

- Addiction is a psychological attachment to certain effects such as euphoria and a temporary feeling of well-being associated with drugs and alcohol.
- It makes people to use it even when not required.
- With repeated use of drugs, the tolerance level of the receptors increases and the receptors respond to higher doses of drugs or alcohol leading to greater intake.
- Thus, the addictive potential of drugs and alcohol pull the user leading to regular use from which the person may be unable to get out.
- In absence of guidance and counselling, the person gets addicted and becomes dependent on them.

Hallucinogens

- Also known as psychedelic or mind expanding drugs.
- Hallucinogens heighten a person's thoughts, feelings and perceptions.
- The person claims to hear sounds, see things that do not exist.
- The person loses the sense of space and time and gets visions.
- LSD, Mescaline and Psilocybin are the examples.

Sedatives

- They are the substances that reduces irritability or excitement.
- Tranquilizers are the drugs that reduce tension and anxiety, bring calmness without inducing sleep.
- They depress the activity of CNS and produce a feeling of calmness and relaxation.
- They bring drowsiness and in higher doses induces deep sleep.

Dependence

- It is the tendency of the body to manifest a characteristic and unpleasant withdrawal syndrome if regular dose of drugs or alcohol is abruptly discontinued.
- It is characterised by anxiety, shakiness, nausea and sweating which may be relieved when its use is resumed again.
- Sometimes withdrawal symptoms become severe and even life threatening and the person may need medical supervision.
- Dependence leads the patient to ignore all social norms in order to get sufficient funds to satisfy his or her needs.
- It results in many social adjustment problems.

Effects of Drug/Abuse

- The immediate adverse effects of drug and alcohol abuse leads to reckless behaviour, vandalism and violence.
- Excessive doses of drug lead to coma and death due to respiratory failure, heart failure or cerebral haemorrhage.
- A combination of drugs may result in overdosing and even death.
- The most common warning signs of drugs and alcohol abuse among youth are drop in academic performance, not going to school/college, lack of interest in personal hygiene, withdrawal, isolation, depression, fatigue, aggressiveness, rebellious behaviour, deteriorating relationships with family and friends, loss of interest in hobbies, change in sleeping and eating habits, fluctuations in weight, appetite, etc.
- Sometimes, a drug/alcohol addict becomes the cause of mental and financial distress to his/her entire family and friends.
- Those who take drugs intravenously, i.e., by directly injecting into the vein using a needle or syringe acquire serious infections like AIDS and Hepatitis B.
- Both AIDS and Hepatitis B are chronic infections and leads to death.
- AIDS can be transmitted to one's life partner through sexual contact while Hepatitis B is transmitted through infected blood.
- The chronic use of drugs and alcohol damages nervous system and liver (cirrhosis).
- The use of drugs during pregnancy affects the foetus.
- The narcotic analgesic drugs and steroids are misused by sports person to improve the performance, increase muscle strength, to promote aggressiveness and increase athletic performance.
- The side-effects of the use of anabolic steroids in females include masculinisation, increased aggressiveness, mood swings, depression, abnormal menstrual cycle, excessive hair growth on the face and body, enlargement of clitoris and deepening of voice.
- In males it includes acne, increased aggressiveness, mood swings, depression, reduction of size of testicles, decreased sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of prostate gland.

- In adolescent males and females, severe facial and body acne and premature closure of growth centres of the long bones may result in stunted growth.

Prevention and Control of Drug/Abuse

- The habits such as smoking, taking drug taken up at a young age is more during adolescence.
- So, parents and the teachers have a special responsibility.
- Parenting with high levels of nurturance and consistent discipline reduces the risk of drug/abuse.
- Some of the measures useful for prevention and control of alcohol and drug abuse are as follows:-
  - **(i) Avoid undue peer pressure:** Every child should be respected for her/his personality and choice. He/she should not be pushed to perform beyond his/her threshold limits in studies, sports and other activities.
  - **(ii) Education and counselling:** Education and counselling helps him/her to face problems and stress and to accept disappointments and failures as a part of their life. Make them involve in other extra-curricular activities.
  - **(iii) Seeking help from parents and peers:** Parents and peers should help them immediately to give proper guidance and solution to sort out the problems to escape from anxiety and guilty.
  - **(iv) Looking for danger signs:** Teachers and friends should not hesitate to bring the habit to the notice of parents and the parents should take appropriate measures to diagnose the underlying cause to initiate proper remedial steps or treatment.
  - **(v) Seeking professional and medical help:** Highly qualified psychiatrist, psychologists conduct de-addiction and rehabilitation programmes to help individuals to overcome from drug/alcohol abuse and lead a normal and healthy life.

Key Terms

- **NACO:** National AIDS Control Organisation.
- **Adolescence:** It refers to the period and process of rapid growth and physical and mental development from childhood to adulthood.
- **Addiction:** It is a psychological attachment to certain effects such as euphoria and a temporary felling of well being associated with drugs and alcohol.
- **Dependence:** It is the tendency of the body to manifest a characteristic and unpleasant withdrawal syndrome if regular dose of drugs or alcohol is abruptly discontinued.
- **Cirrhosis:** A chronic disease of the liver leading to degeneration of cells, inflammation, and fibrous thickening of tissue.
- **LSD:** Lysergic acid diethyl amides.

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CHAPTER-9
STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

Topic-1 Animal Husbandry and Apiculture

Concepts Covered • *Measures for proper maintenance of dairy farms and poultry farms; apiculture and pisciculture – definition, brief idea and advantages of each.* • *Animal breeding - brief idea of inbreeding, out-breeding, cross-breeding and artificial insemination, Multiple Ovulation Embryo Transfer Technology (MOET). Advantages of artificial insemination.*

Revision Notes

Animal Husbandry

- It is the process of agricultural practice of breeding and raising livestock.
- It deals with the care and breeding of livestock such as buffaloes, cows, pigs, horses, cattle, sheep, camels, goats, bees, silkworms, etc., and also poultry farming and fisheries.

- Fisheries include rearing, catching, selling, etc., of fish, molluscs like shell-fish and crustaceans like prawns, crabs, etc.
- Since time immemorial animals like bees, silk-worm, prawns, crabs, fishes, birds, pigs, cattle, sheep and camels have been used by humans for products like milk, eggs, meat, wool, silk, honey, etc.
- More than 70% of the world livestock population is in India and China.
- The contribution of farm produce to the world is only 25%, i.e., the productivity per unit is very low.
- Hence, new technologies have to be applied to achieve improvement in quality and productivity.

Management of Farms and Farm Animals

- A professional management procedure/approach to the traditional practices of farm management will enhance the food production in the country.

1. Dairy Farm Management (Dairying)

- Dairying is the management of animals for milk and its products for human consumption.
- It deals with the processes and systems that increase yield and improve quality of milk.
- The yield of milk depends on the quality of breeds in the farm.
- Good breeds having high yielding potential and resistance to diseases are selected.
- **For the yield potential to be realised:**
  - **(a)** The cattle have to be looked after well.
  - **(b)** They have to be housed well.
  - **(c)** They should have adequate water.
  - **(d)** They should be maintained in disease free condition.
  - **(e)** The feeding of cattle should be carried out in a scientific manner and with special emphasis on the quality and quantity of fodder.
  - **(f)** Stringent cleanliness and hygiene (of cattle and handlers) while milking, storage and transport of the milk should be maintained.
- However, these processes have been mechanised and so it has reduced the chance of direct contact of the produce with the handler.
- **To ensure these stringent measures there should be:**
  - **(a)** Regular inspections, with proper record keeping. It also helps to identify and rectify the problems.
  - **(b)** Regular visits by a veterinary doctor.

Animal Breeding

- A breed is a group of animals related by descent and similar in most characters like general appearance, features, size, etc.
- Breeding is the modification of genotype of an organism to make that organism more useful to humans.
- Animal breeding aims at increasing the yield of animals and improving the desirable qualities of the produce.
- There are two types of breeding namely, inbreeding and outbreeding.

(a) Inbreeding

- It is the process of mating more closely related individuals within the same breed for 4–6 generations.
- Superior males and superior females of the same breed are identified and mated in pairs.
- The progeny obtained are evaluated and superior males and females among them are identified for further mating.
- In cattle, a superior female is the one that produces more milk per lactation whereas a superior male (bull) is the one which gives rise to superior progeny.
- **Advantages of Inbreeding:**
  - **(a)** It increases homozygosity to evolve a pureline animal.
  - **(b)** It exposes harmful recessive genes that are eliminated by selection.
  - **(c)** It helps in accumulation of superior genes and elimination of less desirable genes. This approach increases the productivity of inbred population.
- **Disadvantage of Inbreeding:**
  - **(i)** Continued inbreeding, especially close inbreeding, may reduce fertility and productivity. This is called inbreeding depression.
  - **(ii)** To solve this problem, selected animals of the breeding population should be mated with unrelated superior animals of the same breed which helps to restore fertility and yield.

(b) Out-breeding

- It is the breeding of the unrelated animals which may be between individuals of the same breed (but having no common ancestors), or between different breeds (cross-breeding) or different species (inter-specific hybridisation).
- It includes outcrossing, cross-breeding and inter-specific hybridisation.

(i) Out-crossing

- It is the practice of mating of animals within the same breed having no common ancestors on either side of their pedigree up to 4–6 generations.
- The offspring formed is known as out-cross.
- It is the best breeding method for animals having low productivity in milk production, growth rate in beef cattle, etc.
- It helps to overcome inbreeding depression.

(ii) Cross-breeding

- In this method, superior males of one breed are mated with superior females of another breed.
- It allows the desirable qualities of two different breeds to combine to form the progeny hybrid animals that may be used for commercial production or may be subjected to inbreeding and selection to develop new stable superior breeds.
- For example, *Hisardale* (sheep) developed in Punjab by crossing *Bikaneri ewes* and *Marino rams*.

(iii) Interspecific hybridisation

- It is the mating of male and female animals of two different species.
- The progeny formed may combine desirable features of both the parents, and may be of considerable economic value.
- For example, Mule (Male ass × Female horse).

Controlled Breeding Experiments

(a) Artificial Insemination [AI]

- The controlled breeding experiments are carried out using artificial insemination.
- In this process, the semen collected from male parent is injected into the reproductive tract of selected female by the breeder.
- The semen may be used immediately or can be frozen and used later.
- It can also be transported in a frozen form to where the female is housed to obtain desirable hybrid.
- Success rate of crossing mature male and female animals is low even though artificial insemination is carried out.
- **Advantages of artificial insemination:**
  - **(i)** Semen can be transported in frozen form to a distant place.
  - **(ii)** Semen from selected male animal can be used on a number of female animals.

(b) Multiple Ovulation Embryo Transfer Technology (MOET)

- It is a programme for herd improvement, i.e., to improve the chances of successful production of hybrids.
- In this process, a cow is administered with hormones like FSH to induce follicular maturation and super ovulation to produce 6–8 eggs per cycle instead of one egg.
- The animal is either mated with an elite bull or artificially inseminated.
- Then the fertilised eggs at 8–32 celled stages are recovered and transferred to surrogate mothers.
- This technology has been demonstrated for cattle, sheep, rabbits, buffaloes, mares, etc.
- High milk yielding breeds of females and high quality (lean meat with less lipid) meat-yielding bulls have been bred successfully to increase herd size in a short time.

Bee-keeping (Apiculture)

- It is the process of maintenance of hives of honeybees for the production of honey and beeswax.
- Honey is a food of high nutritive and medicinal value.
- Honeybee produces beeswax which is used in the preparation of cosmetics, polishes, etc.
- The increased demand of honey has led to large-scale beekeeping practices as income generating industry.

- Bee-keeping can be practiced in area where there are sufficient bee pastures of some wild shrubs, fruit orchards and cultivated crops.
- Most common species that can be reared is *Apis indica*.

Important Features for Successful Bee-keeping

- **Bee-keeping though relatively easy does require some specialized knowledge as follows:**
  - **(i)** Knowledge of the nature and habits of bees.
  - **(ii)** Selection of suitable location for keeping beehives.
  - **(iii)** Catching and hiving of swarms (group of bees).
  - **(iv)** Management of beehives during different seasons
  - **(v)** Handling and collection of honey and of beeswax.
- Bees are the pollinators of many of our crop species such as sunflower, Brassica, apple and pear.
- Keeping beehives in crop fields during flowering period increases pollination which thereby improves crop and honey yield.

Fisheries

- It deals with catching, processing or selling of fish, shellfish or other aquatic animals (prawn, crab, lobster, edible oyster, etc).
- It includes,
  - **(a) Freshwater fishes:** *Catla*, *Rohu*, common carp, etc.
  - **(b) Marine fishes:** *Hilsa*, Sardines, Mackerel, Pomfrets, etc.
- Fisheries provide income and employment to fishermen and farmers.
- There are two main techniques namely, aquaculture and pisciculture which help to increase the production of aquatic plants and animals.
- The culturing of all aquatic organisms in fresh water, brackish and marine environment is called aquaculture.
- Pisciculture is breeding and rearing of only fishes in water bodies for commercial purposes.
- The development and flourishing of the fishery industry is known as blue revolution.

Key Terms

- **Animal husbandry:** It is the agricultural practice of breeding and raising livestock useful to humans.
- **Apiculture:** It is the maintenance of hives of honeybees for the production of honey.
- **Breed:** It is a group of animals of same species that are similar in most of their characters.
- **Cross breeding:** It is a method of outbreeding in which superior males of one breed are mated with the superior females of another breed of the same species.
- **Dairying:** It is the management of animals for milk and milk products for human consumption.
- **Fishery:** It is an industry dealing with catching, rearing, processing and selling of fishes, molluscs, crustaceans, etc., and their products.
- **Germplasm:** It is the sum total of all the alleles of the genes present in an individual organism and its related species.
- **Inbreeding:** It refers to the mating of more closely related individuals within the same breed.
- **Interspecific hybridisation:** It is the method of outbreeding in which the male and the female animals of two different species are crossed.
- **Inbreeding depression:** It is the loss in vigour and fertility associated with inbreeding.
- **Outbreeding:** It is the breeding of unrelated animals either of same or of different breeds or even different species.
- **Outcrossing:** It is the practice of mating of animals within the same breed having no common ancestors on either side upto 4–6 generations.
- **Poultry:** It is the class of domesticated fowl used for food or for their eggs.
- **MOET:** Multiple Ovulation Embryo Transfer Technology
- **Aquaculture:** The culturing of all aquatic organisms in fresh water, brackish and marine environment .
- **Pisciculture:** The breeding and rearing of only fishes in water bodies for commercial purposes.

Mnemonics

Concept: Animal breeding

Animesh, **A**pratim, **P**iya and **A**ku **B**ought **C**ap, **B**elt, **F**rock and **W**ater **B**ottle.

Animal husbandry: Cattle and poultry

Apiculture: Bee keeping

Pisciculture: Fish rearing

Aquaculture: Water organisms rearing

Topic-2

Plant Breeding, Single Cell Protein and Tissue Culture

Concepts Covered • *Green revolution.* • *Steps in plant breeding (germplasm collection, evaluation, selection, cross hybridisation or artificial hybridisation (concept of emasculation and bagging), selection and testing of superior recombinants, testing, release and commercialisation of new cultivars), advantages of mutation breeding, examples of some Indian hybrid crops Definition of heterosis and inbreeding depression.* • *Application of plant breeding, Tissue culture (technique and application - micropropagation, somaclones, disease free plants and somatic hybridisation), single cell protein - source and significance.*

Revision Notes

- Green revolution. Steps in plant breeding (germplasm collection, evaluation, selection, cross hybridisation or artificial hybridisation (concept of emasculation and bagging), selection and testing of superior recombinants, testing, release and commercialisation of new cultivars), advantages of mutation breeding, examples of some Indian hybrid crops Definition of heterosis and inbreeding depression.
- Application of plant breeding, Tissue culture (technique and application – micropropagation, somaclones, disease free plants and somatic hybridisation), single cell protein – source and significance.

Plant Breeding

- It is the method where manipulation of plant species helps to create desired plant types that are better suited for cultivation, give better yields and are disease resistant.
- Plant breeding as a technology has helped us to increase yield in food production resulting in green revolution.
- 33% of India's Gross Domestic Product (GDP) comes from agriculture and it also employs about 62% of the population.

Green Revolution

- The development and flourishing of the agriculture is known as green revolution.
- Green revolution was dependent to a large extent on plant breeding techniques for development of high-yielding and disease resistant varieties in wheat, rice, maize, etc.
- The mid- 1960s, is often referred to as Green Revolution because in India various plant breeding techniques led to development of several high yielding varieties of wheat and rice. This led to dramatic increase in food production.
- Indian scientist M.S. Swaminathan played an important role in it, and is called "**Father of Green Revolution in India**"

Types of Plant Breeding

- There are two main methods of plant breeding namely, conventional plant breeding and classical plant breeding.
- Conventional plant breeding has been practiced for thousands of years, since the beginning of human civilisation.
- Classical plant breeding involves hybridisation of pure lines and artificial selection to produce desirable traits of higher yield, nutrition and resistance to diseases.
- Nowadays, plant breeding is carried out by using molecular genetic tools.

Desirable Traits

- The following are the traits or characters that the breeders have tried to incorporate into crop plants:
  (a) Increased crop yield.
  (b) Improved quality.

(c) Increased tolerance to environmental stresses (salinity, extreme temperatures and drought), resistance to pathogens.
(d) Increased tolerance to insect pests.

Steps in Breeding

(i) Collection of Variability

- Genetic variability is the root of any breeding programme.
- The pre-existing genetic variability is available from wild relatives of many crops.
- The collection and preservation of all different wild varieties, species and relatives of the cultivated species is a pre-requisite for effective exploitation of natural genes.
- The entire collection of plants or seeds having all the diverse alleles for all genes in a given crop is called germplasm collection.

(ii) Evaluation and selection of parents

- The germplasm is evaluated to identify plants with desirable combination of characters.
- Selected plants are multiplied and used for hybridisation.
- Pure lines are created wherever it is desirable and possible.

(iii) Cross hybridisation among the selected parents

- The desired characters are combined from two different plants (parents) to produce hybrids having the combined desired characters in a single plant.
- For example, High protein quality of one parent is combined with disease resistance from another parent. On cross hybridisation produces hybrids that genetically combine the desired characters in one plant.
- **Limitations of Cross Hybridisation**
  (a) This is a very time-consuming process. Since the pollen grains from the desirable male plant have to be collected and placed on the stigma of the flowers selected as female parent.
  (b) The hybrids may not combine the desirable characters. Usually only one in few hundred to a thousand crosses shows the desirable combination.

(iv) Selection and Testing of Superior Recombinants

- It includes the process of selecting among the progeny of the hybrids of those plants that have the desired character combination.
- It is crucial to the success of the breeding objective and requires careful scientific evaluation of the progeny.
- It yields plants that are superior to both of the parents. (Hybrid vigour)
- These are self-pollinated for several generations till they reach a state of uniformity (homozygosity), so that the characters will not segregate in the progeny.

(v) Testing, Release and Commercialisation of New Cultivars

- The newly selected lines are evaluated for their yield and agronomic traits of quality, disease resistance, etc., by growing them in the research fields and recording their performance under ideal fertiliser application, irrigation and other crop management practices.
- Then the materials are tested in farmers' fields for at least three growing seasons at several locations in the country, representing all the agro climatic zones.
- The material is then evaluated in comparison to the best available local crop cultivar – a reference cultivar.

Indian Hybrid Crops

(a) Wheat and Rice

- During the period 1960–2000, wheat and rice production was increased due to the development of semi-dwarf varieties of wheat and rice.
- Nobel laureate Norman E. Borlaug, at International Centre for Wheat and Maize Improvement in Mexico, developed semi-dwarf wheat.
- Later, high yielding and disease resistant varieties such as Sonalika and Kalyan Sona were introduced all over the wheat-growing belt of India.
- Semi-dwarf rice varieties were derived from IR-8, (developed at International Rice Research Institute (IRRI), Philippines) and Taichung Native-1 (from Taiwan).
- Better-yielding semi dwarf varieties Jaya and Ratna were also developed in India.

(b) Sugar cane

- *Saccharum barberi*, grown in North India having poor sugar content and yield was crossed with *Saccharum officinarum*, grown in South India having thicker stems and higher sugar content. On crossing these two, a hybrid sugar cane having desirable qualities like high yield, thick stems, high sugar and ability to grow in north India was obtained.

(c) Millets

- Hybrid maize, jowar and bajra were also developed in India.
- It includes high yielding varieties resistant to water stress.

Plant Breeding for Disease Resistance

- A wide range of fungal, bacterial and viral pathogens, affect the yield of cultivated crop species.
- Hence, breeding and development of cultivars resistant to disease helps to:
  (a) Enhance the food production
  (b) Reduce the use of fungicides and bactericides
- Resistance of the host plant is the genetic ability to prevent the pathogens from causing disease and is determined by the genetic constitution of the host plant.
- For this, before breeding it is important to know the causative organism and the mode of transmission.

Plant Diseases

- **Some plant diseases are as follows:**
  (a) Fungi: Rusts (e.g., brown rust of wheat, red rot of sugarcane and late blight of potato).
  (b) Bacteria: Black rust of crucifers.
  (c) Virus: Tobacco mosaic, turnip mosaic, etc.

Methods of Breeding for Disease Resistance

- It includes two types namely, conventional breeding and mutation breeding.

(a) Conventional Method:

- The steps are:
  (a) Screening germplasm for resistance sources.
  (b) Hybridisation of selected parents.
  (c) Artificial hybridisation is done between desired parents. To ensure that no chance pollination occurs, hermaphrodite flowers are emasculated, i.e., stamens are removed in bud stage before anthesis. After this both emasculated bisexual flowers as well as female unisexual flowers (depending upon the concerned plant species) are bagged so that no undesired pollen reaches the gynoecium.
  (d) Selection and evaluation of the hybrids.
  (e) Testing and release of new varieties.

The following tabular column shows the crop varieties bred by conventional method:

Crop	Variety	Resistance to
Wheat	*Himgiri*	Leaf and stripe rust, hill bunt
Brassica	*Pusa swarnim (Karan 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.

- Conventional breeding is constrained by the availability of limited number of disease resistance genes in the crop varieties.

Mutation Breeding

- Mutation is the process by which genetic variations are created through changes in the base sequence within genes resulting in the creation of a new character or trait not found in the parental type.
- Mutation is induced by using chemicals or radiations (like gamma radiations) and selecting the plants that have desirable character as source in breeding.
- Inducing mutations in plants and then screening the plant materials for resistance help to identify the desirable genes.
  - Plants having these desirable characters can then be either multiplied directly or can be used in breeding.
- For example, In mung bean, the resistance to yellow mosaic virus and powdery mildew were induced by mutations.
- Since different cultivated species show certain resistant characters with low yield, resistant genes from wild species are introduced into the high-yielding cultivated varieties.
- For example, Resistance to yellow mosaic virus in bhindi (*Abelmoschus esculentus*) was transferred from a wild species and resulted in a new variety called *Parbhani kranti*.
- Transfer of resistance genes is achieved by sexual hybridisation between the target and the source plant followed by selection.

Heterosis and inbreeding depression

- Hybrid vigour or heterosis refers to the phenomenon that progeny of genetically diverse parents exhibit superior traits and variations than both parents.
- Continued mating for generations between the relatives in a small population may lower the population's ability to persist and reproduce which is referred to as inbreeding depression.

Plant Breeding for Developing Resistance to Insect Pests

- Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics.
  (a) Hairy leaves: resistance to jassids in cotton and cereal leaf beetle in wheat.
  (b) Solid stems in wheat: non-preference by the stem sawfly.
  (c) Smooth leaved and nectar-less cotton varieties do not attract bollworms.
  (d) High aspartic acid, low nitrogen and sugar content in maize leads to resistance to maize stem borers.

The tabular column below shows some crop varieties breed for insect pest resistance:

Crop	Variety	Resistance to
Brassica (rapeseed mustard)	*Pusa Gaurav*	Aphids
Flat bean	*Pusa Sem 2*, *Pusa Sem 3*	Jassids, aphids and fruit borer.
Okra (Bhindi)	*Pusa Sawani*, *Pusa A-4*	Shoot and fruit borer

Plant Breeding for Improved Food Quality

- A majority of people in our country suffer from micronutrient, protein and vitamin deficiencies or 'hidden hunger' because they cannot afford to buy enough fruits, vegetables, legumes, fish and meat.
- **Biofortification:** It refers to breeding crops with higher levels of nutrients that help to improve public health.
- **Objectives of breeding for improved nutritional quality:**
  (a) To improve protein content and quality.
  (b) To improve oil content and quality.
  (c) To improve vitamin content.
  (d) To improve micronutrient and mineral content.
- **Examples of hybrids with improved nutritional quality:**
  (a) Maize hybrids having twice the amount of amino acids, lysine and tryptophan compared to existing maize hybrids.
  (b) Wheat variety, Atlas 66, having high protein content.
  (c) Iron-fortified rice variety containing over five times as much iron as in common varieties.
  (d) Vegetable crops rich in vitamins and minerals are also released by Indian Agricultural Research Institute, New Delhi.
  (e) Examples – vitamin A enriched carrots, spinach, pumpkin; vitamin C enriched bitter gourd, bathua, mustard, tomato; iron and calcium enriched spinach and bathua; and protein enriched beans (broad, lablab, French and garden peas).
- **Single Cell Protein (SCP):** It is an alternate source of proteins for animal and human nutrition, e.g., microbes like *Spirulina*.
- *Spirulina* is rich in protein, minerals, fats, carbohydrate and vitamins.
- It is grown on materials like waste water from potato processing plants, straw, molasses, animal manure and sewage. This also reduces environmental pollution.
- A 250 kg cow produces 200 g of protein/day. In the same period, 250 g of a micro-organism like *Methylophilus methylotrophus* produce 25 tonnes of protein.

Tissue Culture

- It is a technique of growing plant cells/tissues/organs in sterile culture medium under controlled aseptic conditions.
- The ability to generate a whole plant from any cell/explant is called totipotency.
- An explant is any part of a plant that is grown in a test tube under sterile nutrient media.
- The nutrient medium must provide a carbon source (such as sucrose), inorganic salts, vitamins, amino acids and growth regulators like auxins, cytokinins, etc.
- The method of producing thousands of plants in very short time through tissue culture is called micropropagation.
- These plants will be genetically identical to original plant, from which they were grown, i.e., they are somaclones.

- Tomato, banana, apple, etc., are produced using this method.
- Tissue culture is also used for recovering healthy plants from diseased plants.
- The meristem apical and axillary is free of virus in a virus-infected plant. It is removed and grown in vitro to obtain virus-free plants.
- Scientists have cultured meristems of banana, sugarcane, potato, etc.

Somatic Hybridisation

- Protoplasts from two different varieties of plants (with desirable characters) are fused to get hybrid protoplasts.
- It can be grown to form a new plant called somatic hybrids. This process is called somatic hybridisation.
- Protoplasts can be isolated after digesting the cell walls of single cells of plants. Enzymes used for isolation of protoplasts are cellulase, hemicellulase and pectinase.
- A protoplast of tomato has been fused with that of potato to form new hybrid plants with the characteristics of tomato and potato called **pomato**.
- However, this plant did not have all the desired combination of characteristics for its commercial utilisation.

Key Terms

- **Biofortification:** It refers to the breeding of crops to produce varieties with higher levels of nutrients.
- **Explant:** It is the part of plant excised from a specific location in a plant to be used for initiating a culture.
- **Micropropagation:** It is the method of producing plants through tissue culture.
- **Plant Breeding:** It is the manipulation of plant species to obtain desired plant types better suited for cultivation, give better yields and disease resistant.
- **Plant Tissue Culture:** It refers to the regeneration of whole plant from any cell or tissue or organ of a plant on a suitable synthetic medium in vitro.
- **Somaclones:** These are the genetically identical plants developed from any part of the plant by tissue culture or micropropagation.
- **Somatic Hybridisation:** It is the process of fusion of protoplasts of somatic cells derived from two different varieties or species of plants on a suitable nutrient culture medium.
- **Heterosis:** Heterosis or hybrid vigour is the exhibition of superiority of the hybrid offspring over both of its parents in one or more traits such as the ability to give higher yield or disease or pest resistance.
- **Green Revolution:** The development and flourishing of the agriculture .
- **Mutation:** The genetic variations are created through changes in the base sequence within genes.
- **SCP:** Single Cell Protein.
- **Totipotency:** The ability of a living cell to express all of its genes to regenerate a whole new individual.
- **IRRI:** International Rice Research Institute.

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CHAPTER-10

MICROBES IN HUMAN WELFARE

Topic-1 Microbes in Industrial Products and in Sewage Treatment

Concepts Covered • *Role of Microbes in: (a) Fermented Beverages. (b) Chemical Enzymes and Other Bioactive Molecules, (c) Sewage Treatment, BOD, Biogas*

Revision Notes

Microbes

- Microbes are the major components of biological systems on this Earth.
- Microbes are present everywhere such as in soil, water, air, inside our bodies and that of other animals and plants.

- They are also found at sites such as deep inside the geysers (thermal vents) where the temperature may be as high as 100°C, deep in the soil, under the several metres of thick layers of snow, and in highly acidic environments.
- Microbes are diverse–protozoa, bacteria, fungi and microscopic plants viruses, viroid and prions that are proteinaceous infectious agents.
- Microbes like bacteria and many fungi can be grown on nutritive media to form colonies that can be seen with the naked eyes.
- Microbes cause a large number of diseases in human beings, plants and animals.
- **Other Uses of Microbes**
  - **'Toddy'** a traditional drink of southern India is made by fermenting sap from palms.
  - Microbes are used to ferment fish, soya bean and bamboo-shoots to make foods.

Microbes in Industrial Products

- Microbes are used to synthesise a number of products such as beverages, antibiotics, etc., valuable to human beings.
- Production of beverages, antibiotics, etc., on an industrial scale require growing microbes in very large vessels called fermenters.

(a) Fermented Beverages

- Wine and Beer are produced without distillation.
- Whisky, Brandy and Rum are produced by distillation of fermented broth.

(b) Chemicals, Enzymes and Other Bioactive molecules

1. **Production of organic acids:**
   (i) *Aspergillus niger* (a fungus): Citric acid
   (ii) *Acetobacter aceti* (a bacterium): Acetic acid
   (iii) *Clostridium butylicum* (a bacterium): Butyric acid
   (iv) *Lactobacillus* or LAB (a bacterium): Lactic acid
2. **Alcohol**
   (i) *Saccharomyces cerevisiae* (yeast): Used to produce ethanol.
3. **Enzymes**
   (a) Lipases:
   (i) Used in detergent formulations.
   (ii) Help to remove oily stains from the laundry.
   (b) Pectinases and Proteases: To clarify bottled juices.
   (c) Streptokinase: As a `clot buster' to remove clots from the blood vessels of patients who have myocardial infarction. It is produced by the bacterium *Streptococcus* and modified by genetic engineering.
4. **Cyclosporin A:** Produced by *Trichoderma polysporum* (fungus). It is used as an immunosuppressive agent in organ transplant patients.
5. **Statins:** Are produced by *Monascus purpureus* (yeast).
   (a) Used as blood-cholesterol lowering agents.
   (b) It inhibits the enzymes responsible for the synthesis of cholesterol.

Microbes in Sewage Treatment

- Sewage (municipal waste-water) contains large amount of human excreta, organic matter and microbes.
- Sewage is treated in Sewage Treatment Plants to make it less polluting. It includes two different stages namely primary and secondary treatment.

(a) Primary Treatment

- It is a physical treatment.
- It is the physical removal of large and small particles from sewage. It includes:
  - Removal of floating debris by sequential filtration.
  - Removal of the grit (soil and pebbles) by sedimentation.
  - All solids that settle down form the primary sludge and the supernatant forms the primary effluent.
  - The effluent is taken for secondary treatment.

(b) Secondary treatment (Biological treatment)

- Primary effluent is passed into large aeration tanks and constantly agitated.

- This allows vigorous growth of useful aerobic microbes into **flocs** (masses of bacteria associated with fungal filaments to form mesh-like structures).
- These microbes consume the major part of the organic matter in the effluent.
- This reduces the BOD (Biochemical Oxygen Demand) of the effluent.
- The effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment.
- This sediment is called **'activated sludge'**.
- A small part of the activated sludge is pumped back into the aeration tank to serve as the **inoculum**.
- The remaining major part of the sludge is pumped into large tanks called anaerobic sludge digesters.
- Here, some anaerobic bacteria digest the bacteria and fungi in the sludge by producing gases like CH_4, H_2S and CO_2. These gases form the biogas.
- The effluent from the secondary treatment plant is released into natural water bodies like rivers and streams.
- The Ministry of Environment and Forests has initiated Ganga Action Plan and Yamuna Action Plan to save rivers from water pollution.

Biological Oxygen Demand (BOD)

- BOD represents the amount of dissolved oxygen required for the complete oxidation of all the organic matter present in one litre of water by bacteria at 20°C.
- BOD measures the amount of organic matter present in water by measuring the rate of O_2 taken up by microbes.
- Higher BOD indicates that the water is highly polluted by organic matter. Lower value of BOD means the water is less polluted or normal.

Microbes in the Production of Biogas

- Biogas is a mixture of gases (containing predominantly methane) produced by microbial activity.
- Biogas is used as fuel.
- Microbes produce different types of gaseous end products during growth and metabolism.
- The type of gas produced depends upon the microbes and the organic substrates they use.
- In fermentation of dough, cheese making and production of beverages, the main gas produced is carbon dioxide.
- Certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with carbon dioxide and hydrogen. These bacteria are collectively called methanogens., e.g., *Methanobacterium*.
- *Methanobacterium* is found in the anaerobic sludge and in the rumen of cattle (for cellulose digestion).
- The cattle dung called *gobar* is rich in these bacteria.
- Dung can be used for the generation of biogas commonly called **gobar gas**.
- **The biogas plant consists of four parts namely**,
  - **(a)** A concrete tank (digester)
  - **(b)** A floating cover
  - **(c)** Two outlets
  - **(d)** Gas holder
- A concrete tank (10–15 feet deep) is used to collect bio-wastes and slurry of dung.
- A floating cover is placed over the slurry, which keeps on rising as the biogas is produced.
- An outlet is connected to a pipe to supply biogas.
- There is another outlet to remove the spent slurry that can be used as fertiliser.
- The technology of biogas production in India was developed by Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC).

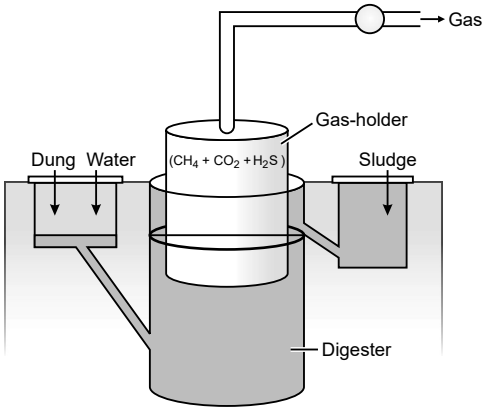

Fig. 10.1: A Biogas Plant

Key Terms

- **GAP:** Ganga Action Plan.
- **KVIC:** Khadi and Village Industries Commission.
- **YAP:** Yamuna Action Plan.
- **BOD:** Biochemical Oxygen Demand. It is a measure of the oxygen needed by aerobic decomposers in the sewage water.
- **Fermenters:** These are large vessels used for growing microbes on an industrial scale.
- **Flocs:** These are the masses of bacteria associated with fungal hyphae that form mesh-like structures.
- **Methanogens:** These are bacteria which produce large quantities of methane during decomposition of organic matter.

Mnemonics

1. Concept: Alcoholic beverages produced by distillation.

Mnemonics: White **BiRD**

Interpretation:

W - Whisky
B - Brandy
R - Rum
D - Distillation

2. Concept: Microbes in human welfare

(a) Mnemonics: Ye Sach **C**er **B**read.

Interpretation: Yeast/*Saccharomyces cerevisiae*/ Bread.

(b) Mnemonics: BB Strep Clot.

Interpretation: Bacteria/Bacterium *Streptococcus*/ Clot Buster Enzyme.

(c) Mnemonics: Fun **Tri C**yclo Immune.

Interpretation: Fungus/*Trichoderma polysporum*/ Cyclosporin-A/Immunosuppressive.

(d) Mnemonics: Ye Mona Pur Stat Cholesterol.

Interpretation: Yeast/*Monascus purpureus*/Statin/ Lower Blood Cholesterol.

Topic-2 Microbes as Biocontrol Agents and Biofertilisers

Concepts Covered • *Role of microbes as Biocontrol Agents: (a) Bt, (b) Trichoderma, (c) Baculoviruses; Biofertilisers: (a) Rhizobium, (b) Mycorrhiza, (c) Cyanobacteria*

Revision Notes

Microbes as biocontrol agents

- Biocontrol refers to the use of biological methods for controlling plant diseases and pests.
- Chemical pesticides and insecticides are harmful to all organisms and cause pollution.
- Chemical pesticide kills both useful and harmful life forms.
- The use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.
- An important part of the biological farming is to become familiar with the various life forms that inhabit the field, predators as well as pests, and also their life cycles, patterns of feeding and the habitats that they prefer.
- These help to develop appropriate biocontrol, e.g., Ladybird and Dragonflies are useful to get rid of aphids and mosquitoes respectively.

Microbial Biocontrol Agents

(a) *Bacillus thuringiensis (Bt):*

- *Bacillus thuringiensis* (Bt) is a bio-control agent in controlling butterfly caterpillars.
- These are available in sachets as dried spores which are mixed with water and sprayed onto vulnerable plants such as brassica and fruit trees, where these are eaten by the insects larvae.
- In the gut of the larvae, the toxin is released and the larvae get killed.
- The bacterial disease will kill the caterpillars, but leave other insects unharmed.
- By the development of genetic engineering, scientists have introduced *B. thuringiensis* toxin genes into plants, e.g., Bt cotton.

(b) *Trichoderma* species as biocontrol agents:

- The microbial agent is the fungus *Trichoderma* sp. acts as bio-control agent in the treatment of plant diseases.
- These are free living species seen in the root ecosystems.

- They are effective biocontrol agents of several plant pathogens.

(c) Baculoviruses as biocontrol agent:

- Baculoviruses belonging to genus *Nucleopolyhedrovirus* attack insects and other arthropods.
- These viruses are suitable for species-specific, narrow spectrum insecticidal applications.
- This is desirable in IPM (Integrated Pest Management) program to conserve beneficial insects.

Microbes as biofertilisers

- To meet the ever-increasing demand of agricultural products, there has been a tremendous increase in usage of chemical fertilisers. This in turn has contributed significantly to environmental pollution.
- Since several problems are associated with the overuse of chemical fertilizers, there is large pressure to switch to organic farming, the use of biofertilisers.
- Biofertilisers are organisms that enrich nutrient quality of the soil.
- The main sources of biofertilisers are bacteria, fungi, cyanobacteria, etc.,
- **The example includes:**
  - **(a)** ***Rhizobium***
    - It is a symbiotic bacteria in root nodules of leguminous plants that fix atmospheric N_2.
  - **(b) Mycorrhiza**
    - It is a symbiotic association of fungi (e.g., the genus of *Glomus*) with plants.
    - The fungus gets food from the plant.
    - The fungal symbiont helps to absorb phosphorus from soil and passes it to the plant, gives resistance to root-borne pathogens and tolerance to salinity and drought and also gives an overall increase in plant growth and development.
  - **(c) Cyanobacteria (Blue green algae)**
    - It is an autotrophic microbe that fixes atmospheric nitrogen, e.g., *Anabaena, Nostoc, Oscillatoria*, etc.,
    - In paddy fields, cyanobacteria serve as important biofertilisers.
    - It also adds organic matter to the soil and increases its fertility.

Key Terms

- **Biofertilisers:** These are the organisms that enrich the nutrient content of the soil.
- **Biocontrol:** Use of biological methods for controlling the plant diseases and pests.
- **Symbiosis:** The relationship involving mutually beneficial interaction between two different organisms living in close physical association.

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UNIT – 4: BIOTECHNOLOGY AND ITS APPLICATIONS

CHAPTER-11

BIOTECHNOLOGY – PRINCIPLES AND PROCESSES

Topic-1 Principles of Biotechnology and Tools of Recombinant DNA Technology

Concept Covered • *Concept of genetic engineering*

Revision Notes

Biotechnology

- Biotechnology deals with techniques of using live organisms or their enzymes or products and processes that are useful to humans.

- **Biotechnology deals with:**
  - **(a)** Microbe-mediated processes (making curd, bread, wine, etc.).
  - **(b)** *In vitro* fertilisation ('test-tube' baby programme).
  - **(c)** Synthesis and using of a gene.
  - **(d)** Preparation of a DNA vaccine.
  - **(e)** Correcting a defective gene.
- The European Federation of Biotechnology (EFB) defines biotechnology as 'the integration of natural science and organisms, cells, parts thereof and molecular analogues for products and services'.
- **Modern biotechnology is based on the two core techniques:**
  - **(a) Genetic Engineering:** It is the technique in which the genetic material, i.e., DNA and RNA is chemically altered and introduced into host organisms to change the phenotype.
  - **(b) Maintenance of Sterile Ambience:** It is necessary in chemical engineering processes for growing only the desired microbe/eukaryotic cell in large quantities for the manufacture of antibiotics, vaccines, enzymes, etc.

Conceptual Development of the Principles of Genetic Engineering

- Traditional hybridisation techniques lead to inclusion and multiplication of undesirable genes along with desired genes.
- The techniques of genetic engineering which include creation of recombinant DNA, use of gene cloning and gene transfer, overcome the limitation of traditional hybridisation techniques and allows us to isolate and introduce only the desirable genes into the target organism.
- A piece of DNA is not able to multiply itself in the progeny cells of the organism. But, when it gets integrated into the recipient genome, it multiplies and gets inherited along with the host DNA.
- This is because the alien piece of DNA has become part of a chromosome, which has the ability to replicate.
- In chromosome, there is a specific DNA sequence called the origin of replication, which is responsible for initiating replication. In genetic engineering, the foreign DNA is linked with the origin of replication, so that the foreign DNA can replicate and multiply itself in the host organism, which is also known as cloning or making multiple identical copies of any template DNA.

Formation of First Recombinant DNA

- First recombinant DNA was emerged from the possibility of linking a gene of antibiotic resistance with a natural plasmid of *Salmonella typhimurium*.
- Stanley Cohen and Herbert Boyer (1972) isolated the antibiotic resistance gene by cutting out a piece of DNA from a plasmid which was responsible for conferring antibiotic resistance.
- The cutting of DNA at specific locations became possible with the discovery of 'molecular scissors' called the restriction enzymes.
- The cut piece of DNA was then linked with the plasmid DNA, which acts as vectors to transfer the piece of DNA attached to it.
- The linking of antibiotic gene with the plasmid vector became possible with the enzyme ligase, which acts on cut DNA molecules and joins their ends. This makes a new combination of autonomously replicating DNA created in vitro and is known as recombinant DNA.
- When this DNA is transferred into *Escherichia coli*, a bacterium closely related to *Salmonella*, it could replicate using the new host's DNA polymerase enzyme and make multiple copies.
- The ability to multiply copies of antibiotic resistance gene was called cloning of antibiotic resistance gene in *E. coli*.

Steps Involved in Genetically Modifying an Organism

- **(a)** Identification of DNA with desirable genes.
- **(b)** Introduction of the identified DNA into the host.
- **(c)** Maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

Tools of Recombinant DNA Technology

- **(a)** Restriction enzymes.
- **(b)** Polymerase enzymes.
- **(c)** Ligases.
- **(d)** Vector
- **(e)** Host organism.

Restriction Enzymes (Molecular Scissors)

- In 1963, two enzymes responsible for restricting the growth of bacteriophage in *E. coli* were isolated.
- One of these added methyl groups to DNA while the other (restriction endonuclease) cut DNA.
- **Naming of the restriction enzymes:** First letter indicates genus and the second two letters indicate species of the prokaryotic cell from which they were isolated.
- Restriction enzymes belong to a class of enzymes called nucleases.
- **Nucleases can be classified into two types:**
  - **(a) Exonucleases:** They remove nucleotides from the ends of the DNA.
  - **(b) Endonucleases:** They cut at specific positions within the DNA.
- Each restriction endonuclease can bind to a specific palindromic nucleotide sequence in the DNA and cut each of the two strands at specific points in their sugar-phosphate backbones.
- Each restriction endonuclease recognises a specific palindromic nucleotide sequences in the DNA.

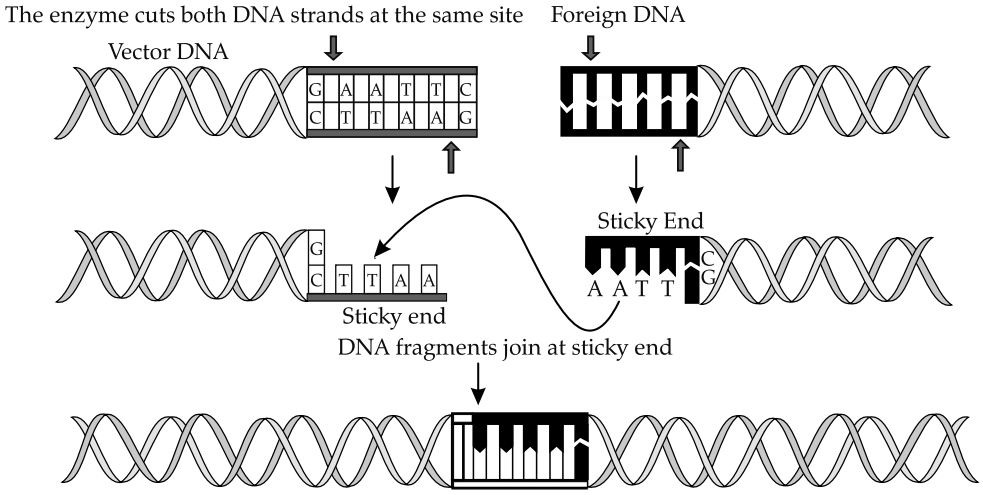

Fig. 11.1: Action of restriction endonuclease enzyme to form recombinant DNA

- The palindrome in DNA is a sequence of base pairs that reads the same on the two strands in 5′ → 3′ direction and in 3′ → 5′ direction.
  Example:
  5′ —— GAATTC —— 3′
  3′ —— CTTAAG —— 5′
- Restriction enzymes cut the strand a little away from the centre of the palindrome sites but between the same two bases on the opposite strands.
- This leaves single stranded over hanging stretches called sticky ends on each strand.
- They form H-bonds with their complementary cut counterparts with the help of the enzyme **DNA ligase**.
- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of sticky-ends and these are joined together by DNA ligases.
- It is important to note that unless one cuts the vector and the source DNA with the same restriction enzyme, the recombinant vector molecule cannot be created.

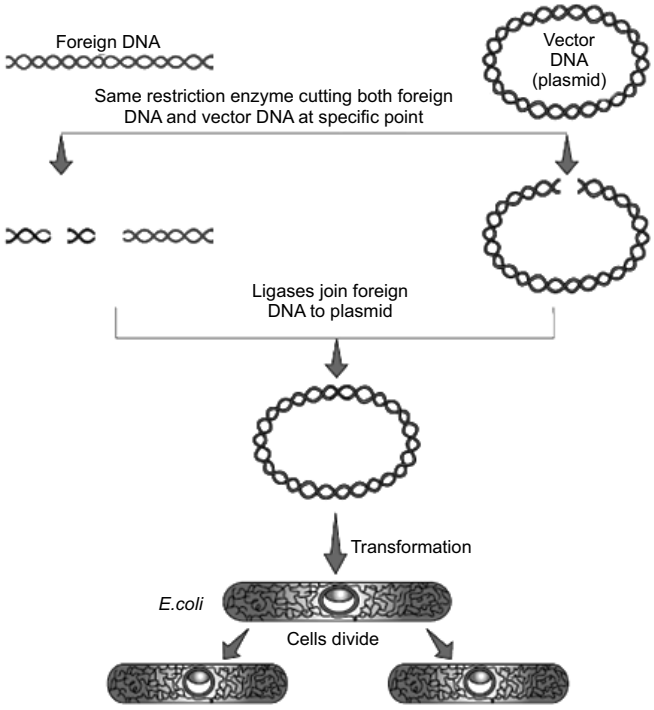

Fig. 11.2: Diagrammatic representation of recombinant DNA technology

Separation and Isolation of DNA Fragments

- DNA fragments formed by restriction endonucleases can be separated by a technique called gel electrophoresis.
- DNA fragments are negatively charged and hence can be separated by moving them towards the anode under an electric field through a medium/matrix such as agarose, a natural polymer extracted from sea weeds.
- The DNA fragments separate (resolve) according to their size through the sieving effect provided by the agarose gel.
- The smaller sized fragment moves farther.
- The separated DNA fragments can be visualised after staining the DNA with ethidium bromide followed by exposure to UV radiation. Bright orange coloured DNA bands can be seen.
- The separated DNA bands are cut out from agarose gel and extracted from gel piece. This step is called **elution**.
- These purified DNA fragments are used in constructing recombinant DNA by joining them with cloning vectors.

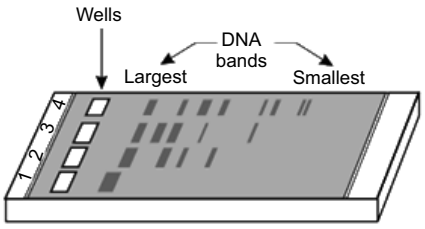

Fig. 11.3 : Agarose Gel Electrophoresis

Cloning Vectors

- These are the DNA molecules that can carry a foreign DNA segment and replicate inside the host cells,

  e.g., Plasmids (circular extra-chromosomal DNA of bacteria)and bacteriophages.
- Bacteriophages have very high copy numbers of their genome within the bacterial cells.
- Some plasmids have only 1–2 copies per cell. Others may have 15–100 copies per cell.
- When the cloning vectors are multiplied in the host, the linked piece of DNA also gets multiplied to the number equal to the copy number of the vectors.
- **Features of Cloning Vector**

  (a) Origin of Replication (ori)
  - This is a sequence from where replication starts.
  - A piece of DNA linked to *ori* can replicate within the host cells and also controls the copy number of the linked DNA.
  - In order to get many copies of the target DNA, it should be cloned in a vector whose origin site supports a high copy number.

  (b) Selectable Marker (Marker Gene)
  - It helps to select the transformants and eliminate the non-transformants.
  - Transformation is a procedure in which a piece of DNA is introduced in a host bacterium.
  - Selectable markers of *E. coli* include the genes encoding resistance to antibiotics like ampicillin, chloramphenicol, tetracycline or kanamycin, etc.
  - The normal *E. coli* cells do not carry resistance against any of these antibiotics.

  (c) Cloning Sites
  - To link the alien DNA, the vector needs very few recognition sites for restriction enzymes.
  - Presence of more than one recognition sites generates several fragments, which complicates the gene cloning.

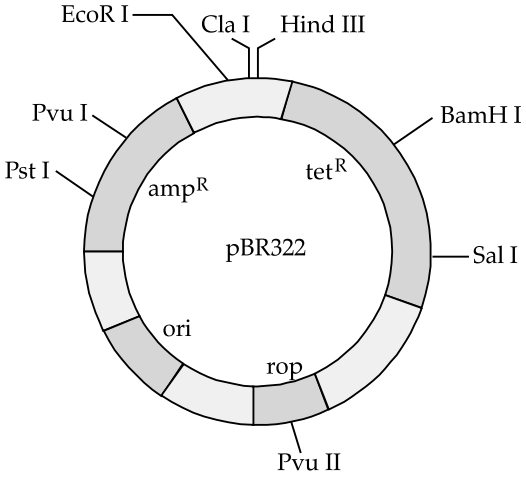

Fig. 9.4 : *E. coli* cloning vector pBR322 showing restriction sites

- The ligation of alien DNA is carried out at a restriction site present in one of the two antibiotic resistance genes, e.g., Ligation of a foreign DNA at the BamH I site of tetracycline resistance gene in the vector pBR322.

- The recombinant plasmids lose tetracycline resistance due to the insertion of foreign DNA.
- But they can be selected out from non-recombinant ones by plating the transformants on ampicillin containing medium.
- Then, these transformants are transferred in a tetracycline medium.
- The recombinants grow in an ampicillin medium but not on tetracycline medium.
- But, non-recombinants will grow on the medium containing both the antibiotics.
- In this case, one antibiotic resistance gene helps to select the transformants whereas the other antibiotic resistance gene gets inactivated due to the insertion of alien DNA and helps in the selection of recombinants.
- Selection of recombinants due to the inactivation of antibiotic requires simultaneous plating on two plates having different antibiotics. This is a cumbersome procedure.
- Therefore, alternative selectable markers have been developed to differentiate recombinants from non-recombinants on the basis of their ability to produce colour in the presence of a chromogenic substrate.
- A recombinant DNA is inserted within the coding sequence of an enzyme, β-galactosidase and so the enzyme becomes inactivated which is called insertional inactivation.
- If the plasmid in the bacteria has an insert, it results in insertional inactivation of the β-galactosidase and hence the colonies do not produce any colour and are identified as recombinant colonies.
- If the plasmid in bacteria has no insert, it gives blue coloured colonies in presence of chromogenic substrate.

Vectors for Cloning Genes in Plants and Animals

- Genetic materials of some pathogens can be transformed into useful vectors for delivering genes to plants and animals.

Example 1

- *Agrobacterium tumefaciens*, a pathogen of many dicot plants can deliver a piece of DNA (t-DNA) to transform normal plant cells into a tumour.
- These tumour cells produce the chemicals required by the pathogen.
- The tumour inducing (Ti) plasmid of *A. tumefaciens* is modified into a cloning vector which is not pathogenic to the plants but is able to use the mechanisms to deliver genes of our interest into plants.

Example 2

- Retroviruses are used to deliver desirable genes into animal cells.
- So, once a gene or a DNA fragment has been ligated into a suitable vector, it is transferred into a bacterial, plant or animal host (where it multiplies).

Competent Host (For Transformation with Recombinant DNA)

- DNA is a hydrophilic molecule and hence it cannot pass through cell membranes.
- Due to this, the bacterial cells are treated with a specific concentration of a divalent cation such as calcium to allow DNA to pass through pores in thew cell wall of bacterium.
- Such cells are incubated with recombinant DNA on ice.
- Then they are placed at 42°C (heat shock) and put back on ice to enable the bacteria to take up the recombinant DNA.
- **Different Methods to Introduce Alien/Foreign DNA into Host Cells are:**

  A. Natural genetic engineering

  Agrobacterium is called natural genetic engineering as it may transfer a gene, naturally without human interference.

  B. Vector less genetic engineering

  (a) Micro-injection
  - In this method, the recombinant DNA is directly injected into the nucleus of an animal cell.

  (b) Biolistics (Gene Gun)
  - In this method, the cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA. This method is suitable for plants.

  (c) 'Disarmed Pathogen' Vectors
  - When these vectors infect the cell, it transfers the recombinant DNA into the host.

Key Terms

- **Biolistics or Gene Gun:** Cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA.
- **Exonucleases:** They remove nucleotides from the ends of the DNA molecule.
- **Endonucleases:** They cut at specific positions within the DNA molecule.
- **Genetic Engineering:** Techniques to alter the chemistry of genetic material (DNA and RNA), to introduce these into host organisms and thus change the phenotype of the host organism.
- **Gene Cloning:** It refers to the method of obtaining identical copies of a particular DNA segment or a gene.
- **Origin of Replication (*ori*):** A specific DNA sequence which is responsible for initiating replication.
- **Plasmid:** Autonomously replicating circular extra-chromosomal DNA of any bacteria.

Key Terms

- **Palindromic Nucleotide Sequences:** The palindrome in DNA is a sequence of base pairs that reads same on the two strands when orientation of reading is kept the same.
- **Recombinant Protein:** It is the protein produced by the expression of rDNA in the transgenic organism.
- **Restriction Enzymes:** Enzymes that are used to cut DNA segment at a specific site are called restriction enzymes.
- **Recombinant Site or Sequence:** It is the specific base sequence of DNA where the restriction enzyme cuts the DNA.
- **Recombinant DNA:** It is the DNA formed by combining DNA from two different organisms.
- **Gene Transfer:** The insertion of unrelated genetic information in the form of DNA into cells.
- **Gel electrophoresis:** The technique used to separate the fragments of DNA.
- **Transformation:** The procedure through which a piece of DNA is introduced in a host bacterium.
- **Selectable marker:** It is a gene introduced into a cell, mainly a bacterium or to cells in culture, that confers a trait suitable for artificial selection of the recombinant cells.
- **Competent host:** It is a cell which is capable of taking up an alien DNA.

Topic-2 Process of Recombinant DNA Technology

Concepts Covered • *Steps involved in Recombinant DNA technology* • *Downstream processing.*

Revision Notes

- **Recombinant DNA technology involves several steps in specific sequence as follows:**
  - **(a)** Isolation of DNA.
  - **(b)** Fragmentation of DNA by restriction endonucleases.
  - **(c)** Isolation of a desired DNA fragment.
  - **(d)** Ligation of the DNA fragment into a vector.
  - **(e)** Transferring the recombinant DNA into the host.
  - **(f)** Culturing the host cells in a medium at large scale and extraction of the desired product.

A. Isolation of the Genetic Material (DNA)

- In order to obtain DNA free from other macro-molecules such as RNA, proteins, polysaccharides and lipids, the bacterial cells/plant or animal tissue are treated with enzymes such as lysozyme (bacteria), cellulase (plant cells), chitinase (fungus), etc.
- The cell is broken to release DNA along with other macromolecules.
- Genes on the DNA are intertwined with proteins such as histones.
- RNA is removed by treating with ribonuclease.
- Proteins are removed by treatment with protease.
- Other molecules are removed by appropriate treatments.

- The purified DNA precipitates out as a collection of fine threads in the suspension when chilled ethanol is added.

B. Cutting of DNA at Specific Locations

- Restriction enzyme digestions are performed by incubating purified DNA with the restriction enzyme, at optimal conditions for the specific enzyme.
- Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion.
- Since DNA is negatively charged, it moves towards the anode.
- The process is repeated with the vector DNA also.
- After cutting the source DNA and the vector DNA, the cut out gene (DNA segment) of interest from the source DNA and the cut vector are mixed and ligase is added.
- This creates recombinant DNA.

C. Amplification of Gene of Interest using PCR

- Polymerase Chain Reaction (PCR) is the synthesis of multiple copies of the gene of interest *in vitro* using two sets of primers and the enzyme DNA polymerase.
- Primers are small chemically synthesised oligonucleotides that are complementary to the regions of DNA.
- The enzyme extends the primers using the nucleotides and the genomic DNA (template).
- By continuous DNA replication, the DNA segment is amplified upto 1 billion copies.
- For repeated amplification, a thermostable DNA polymerase is isolated from a thermophilic bacterium, *Thermus aquaticus*, which remains active during high temperature and induces denaturation of double stranded DNA.
- The amplified fragment can be used to ligate with a vector for further cloning.
- **Steps in PCR technique:**
  - **(a) Denaturation:** Here, the double stranded DNA is denatured using high temperature to form single strand which act as a template for DNA synthesis.
  - **(b) Annealing of Primers:** Two sets of primers are annealed or hybridised at low temperature using suitable enzymes based on the length and the sequence of the primers.
  - **(c) Extension of Primers:** The primers are extended by adding nucleotides complementary to the template by Taq DNA polymerase.

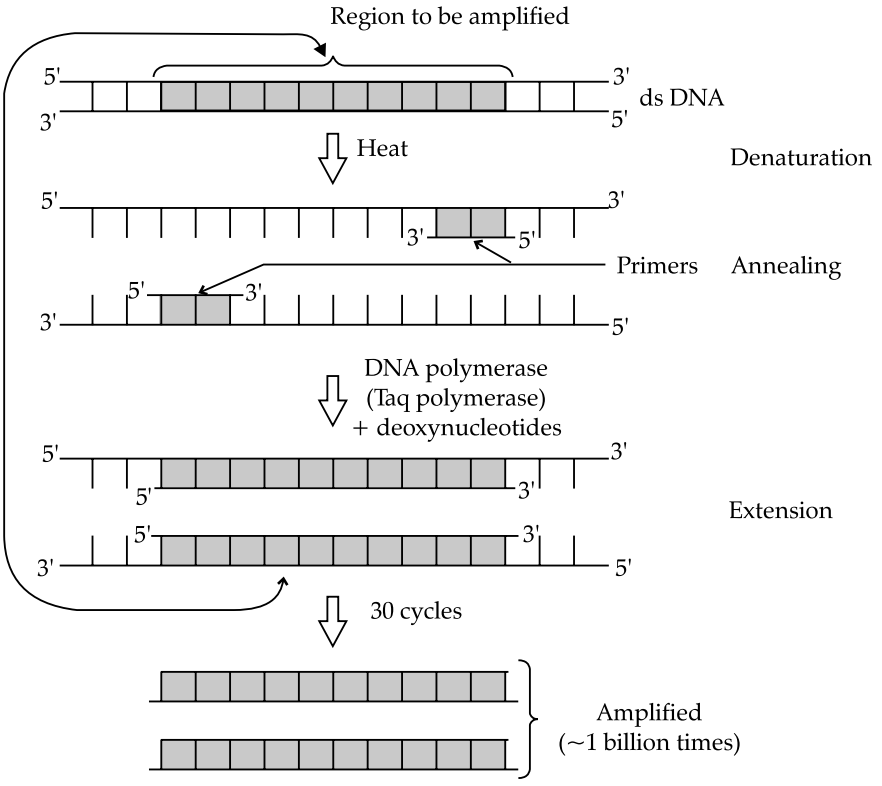

Fig. 11.5: Steps in PCR technique

D. Insertion of Recombinant DNA into the Host Cell/Organism

- There are several methods of introducing the ligated DNA into recipient cells.
- Recipient cells after making them competent, take up DNA present in its surrounding.
- If a recombinant DNA bearing ampicillin resistant gene, a selectable marker gene is transferred into *E. coli* cells, then the host cells become ampicillin resistant cells.
- If the transformed cells are spread on agar plates containing ampicillin, only transformants will grow while the untransformed recipient cells will die.

E. Obtaining the Foreign Gene Product

- The ultimate aim of recombinant DNA technology is to produce a desirable protein.
- For this, there is a need for the recombinant DNA to be expressed.
- The foreign gene gets suppressed under appropriate conditions.
- If a protein encoding gene is expressed in a heterologous host, it is called a recombinant protein.
- The cells with foreign genes may be grown on a small scale in the laboratory.
- The cultures may be used to extract the desired protein and purify it by using different separation techniques.
- The cells can also be multiplied in a continuous culture system.
- In continuous culture system, the used medium is drained out from one side while fresh medium is added from the other.
- It maintains the cells more physiologically active and so produces a larger biomass leading to higher yields of desired protein.
- To produce large quantities of desired products, the bioreactors are used.
- Bioreactors are the vessels in which raw materials are biologically converted into specific products, enzymes etc., using microbial plant, animal or human cells.
- A bioreactor provides the optimal growth conditions such as temperature, pH, substrate, salts, vitamins, oxygen to obtain the desired product.
- The most commonly used bioreactors are of stirring type.

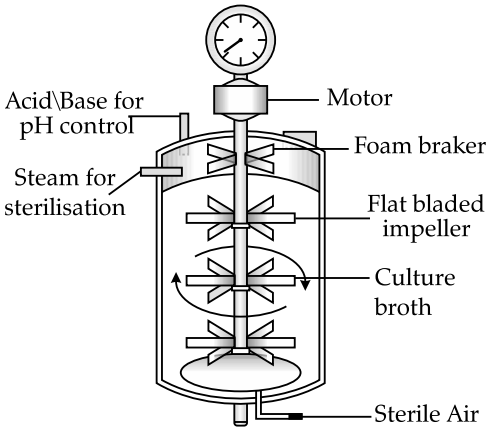

Fig. 11.6: Simple stirred-tank bioreactor

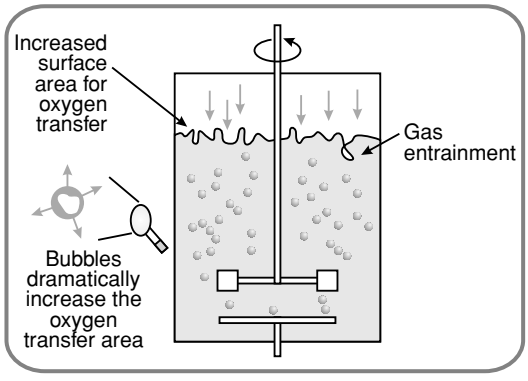

Fig. 11.7: Sparged stirred-tank bioreactor

- **Stirred-Tank Reactor:** A stirred-tank reactor is cylindrical or with a curved base to facilitate the mixing of the reactor contents with available oxygen.
- Alternatively, air can be bubbled through the reactor.
- The bioreactor has:
  - **(a)** An agitator system
  - **(b)** An oxygen delivery system
  - **(c)** A foam control system
  - **(d)** A temperature control system
  - **(e)** pH control system
  - **(f)** Sampling ports, for periodic withdrawal of the culture.

F. Downstream Processing

- It is a series of processes such as separation and purification of products after the biosynthetic stage.
- The product is formulated with suitable preservatives.
- Such formulation undergoes thorough clinical trials as in case of drugs.
- Strict quality control testing for each product is also required.
- The downstream processing and quality control testing vary from product to product.

Key Terms

- **PCR:** Polymerase Chain Reaction.
- **Bioreactors:** Bioreactors are vessels in which raw materials are biologically converted into specific products, enzymes, etc., using microbial plants, animal or human cells.
- **Plasmid DNA:** It is a piece of extra chromosomal DNA present in bacteria and yeast.
- **Chromosomal DNA:** Genetic constitution of cell.
- **Selectable Marker:** The gene encoding desirable information useful in identifying and eliminating non-transformants and selectively permitting the growth of the transformants is called selectable marker.

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CHAPTER-12

BIOTECHNOLOGY AND ITS APPLICATIONS

Topic-1 Applications of Biotechnology in the Field of Agriculture and Medicine

Concepts Covered • *GMO* • *Pest-resistant plants*, • *Genetically engineered insulin*, • *Gene Therapy* • *Molecular Diagnosis*

Revision Notes

- Biotechnology deals with industrial scale production of bio-pharmaceuticals and other useful biological products using genetically modified microbes, fungi, plants and animals.
- Biotechnology has a wide range of application in medicine such as biopharmaceuticals, therapeutics and diagnostics and in agriculture such as genetically modified crops for agriculture, processed food, bioremediation, waste water treatment and energy production.
- **Biotechnology has three critical research areas:**
  - **(a)** Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme.
  - **(b)** Creating optimal conditions through engineering for a catalyst to act.
  - **(c)** Downstream processing technologies to purify the protein/organic compound.

APPLICATIONS OF BIOTECHNOLOGY IN AGRICULTURE

- **There are three options for increasing food production, namely,**
  - **(a)** Agro-chemical based agriculture.
  - **(b)** Organic agriculture.
  - **(c)** Genetically engineered crop-based agriculture.
- **The Green Revolution has increased the yield of crops due to:**
  - **(a)** Use of improved crop varieties.
  - **(b)** Use of agrochemicals such as fertilisers and pesticides.
  - **(c)** Use of better management practices.
- However, further increase in the yield with existing varieties of crops is not possible using conventional methods of breeding.

- Also, the agrochemicals cause soil and water pollution and are expensive for the farmers.
- In order to overcome these problems, genetically modified organisms provide the solution.

Genetically Modified Organisms (GMO) or Transgenic Organisms

- These are the plants, bacteria, fungi and animals whose genes are altered by manipulation.
- **Advantages of Genetic Modification in Plants**
  - **(a)** It makes crops more tolerant to abiotic stresses (cold, drought, salt, heat,, etc.).
  - **(b)** Pest-resistant crops reduce the use of chemical pesticides.
  - **(c)** It helps to reduce post-harvest losses.
  - **(d)** It increases efficiency of mineral usage by plants, thereby preventing early exhaustion of fertility of soil.
  - **(e)** It enhances nutritional value of food, e.g., Vitamin 'A' enriched rice.
  - **(f)** GM (genetic modification) is used to create plants to supply alternative resources to industries, in the form of starch, fuels and pharmaceuticals.

Production of Pest-Resistant Plants

- Pest resistant plants decrease the amount of pesticides used.
- Bt toxin is produced by a bacterium called *Bacillus thuringiensis*.
- Bt toxin gene has been cloned from bacteria and expressed in plants to provide resistance to insects, thus its effects produce a bio-pesticide without the need for insecticides.
- Examples – Bt cotton, Bt corn, rice, tomato, potato and soyabean, etc.

(a) Bt Cotton

- Some strains of *Bacillus thuringiensis* have proteins that kill insects like coleopterans (beetles), lepidopterans (tobacco budworm, armyworm) and dipterans (flies, mosquitoes).
- *B. thuringiensis* forms a toxic insecticidal protein (Bt toxin) crystals during a particular phase of their growth.
- It does not kill the *Bacillus* as it exists as inactive protoxins.
- When an insect ingests the inactive toxin, it is converted into active toxin due to the alkaline pH of the gut which solubilises the crystals.
- The activated toxin binds to the surface of midgut epithelial cells and creates pores that cause cell swelling, lysis and ultimately the death of the insect.
- Bt toxin genes were isolated from *B. thuringiensis* and incorporated into crop plants such as cotton.
- Most Bt toxins are insect-group specific.
- The toxin is coded by a gene named cry, e.g., The proteins encoded by the genes (cryIAc) and (cryIIAb) control the cotton bollworms, that of (cryIAb) controls corn borer.

(b) Nematode Resistance in Tobacco Plants

- A nematode *Meloidegyne incognita* infects the roots of tobacco plants and causes a great reduction in yield.
- RNA interference (RNAi) strategy is used to prevent this infestation.
- RNAi is a method of cellular defence in all eukaryotic organisms.
- It prevents the translation of a specific mRNA (i.e., RNA silencing) due to a complementary dsRNA molecule that binds to the mRNA.
- The source of this complementary RNA is from an infection caused by RNA virus or mobile genetic elements (transposons) that replicate *via* an RNA intermediate.
- Using *Agrobacterium* vectors, nematode-specific genes (DNA) are introduced into the host plant.
- It produces both sense and anti-sense RNA in the host cells.
- These two RNAs being complementary to each other form a double stranded RNA (dsRNA) that initiates RNAi, thereby silencing the specific mRNA of nematode.
- The parasite cannot survive in a transgenic host expressing specific interfering RNA.
- The transgenic plant therefore gets itself protected from the parasite.

(c) Genetically modified crop-producing Hirudin

- Hirudin gene is a chemically synthesised gene that prevents blood clotting.
- Hirudin gene is introduced into the crop *Brassica napus*.
- We get the transgenic crop *Brassica napus* which has the gene hirudin.
- Gene hirudin produces the protein hirudin that gets accumulated in the seeds of the transgenic crop.

(d) Genetically modified tomato plants called "Flavr Savr"

- It's a genetically modified tomato that contains a transgene where the expression of a native tomato gene that allows tomatoes to ripen and rot faster is blocked.
- They have a much longer and more flavourful shelf life due to delayed ripening.

Application in Medicine

- The recombinant DNA technology helps for the mass production of safe and more effective therapeutic drugs.
- The recombinant therapeutics do not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
- At present, there are about 30 recombinant therapeutics that have been approved for human-use the world over.

Genetically Engineered Insulin

- Management of adult-onset diabetes is possible by taking insulin at regular time intervals.
- Now, it is possible to produce human insulin using bacteria.
- Insulin extracted from the pancreas of animals such as cattle and pigs causes allergy or other types of reactions to the foreign protein.
- Insulin consists of two short polypeptide chains namely, chain A and chain B that are linked together by disulphide bridges.
- In mammals, insulin is synthesised as a pro-hormone.
- The pro-hormone needs processing before it becomes a fully matured and functional hormone.
- The pro-hormone contains an extra stretch called the C-peptide, which is removed during maturation into insulin.
- In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains.
- These chains were produced separately, extracted and combined by creating disulphide bonds to form human insulin.

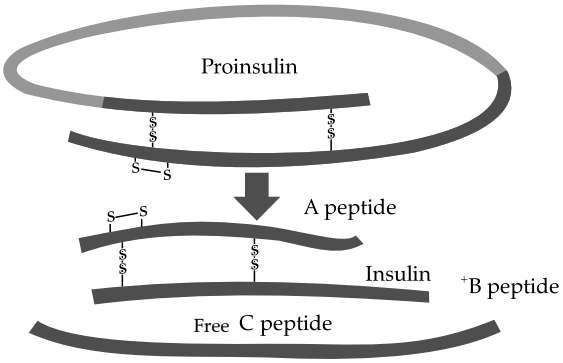

Fig. 10.1: Maturation of pro-insulin into insulin

Gene Therapy

- Gene therapy is a collection of methods that allows the correction of a gene defect that has been diagnosed in a child/embryo.
- Here, genes are inserted into a person's cells and tissues to treat a hereditary disease.
- Correction of a genetic defect involves delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.
- First clinical gene therapy was given in 1990 to a 4-year-old girl with adenosine deaminase (ADA) deficiency.
- The disorder is caused due to the deletion of the gene for adenosine deaminase, the enzyme crucial for the immune system to function.
- This can be cured by bone marrow transplantation or by enzyme replacement therapy where injection of functional ADA is done.
- However, these approaches are not completely curative.
- In gene therapy, lymphocytes from the patient's blood are grown in a culture.
- A functional ADA cDNA, using a retroviral vector is introduced into these lymphocytes.
- Then, they are returned to the patient.
- This should be periodically repeated as these cells are not immortal.
- However, if the ADA gene from marrow cells is introduced into cells at early embryonic stages, it could be a permanent cure.

Molecular Diagnosis

- Recombinant DNA technology, PCR and Enzyme Linked Immuno-Sorbent Assay (ELISA) are some of the techniques for early diagnosis.
- The presence of a pathogen is suspected only when the pathogen produces a disease symptom.

- By this time, the concentration of pathogen becomes very high in the body.
- However, very low concentration of a bacteria or virus can be detected by amplification of their nucleic acid by PCR.
- PCR is used to detect HIV in suspected AIDS patients.
- It is also used to detect mutations in genes in suspected cancer patients.
- It is a powerful technique to identify many genetic disorders.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridise with its complementary DNA in a clone of cells followed by detection using autoradiography.
- The clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene.
- ELISA is based on the principle of antigen-antibody interaction.
- Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins,, etc.) or by detecting the antibodies synthesised against the pathogen.
- **Stem cells:** Stem cells provide new cells for the body as it grows, and replace specialised cells that are damaged or lost. Example includes embryonic cells.
- **They have two unique properties:**
  (a) They can divide over and over again to produce new cells.
  (b) As they divide, they can change into the other types of cells that make up the body.
- They are capable of self-renewal.
- They are capable of dividing many times and for long periods.

Uses of stem cells

- **Research:** To help us understand the basic biology of how living things work and what happens in different types of cells during disease.
- **Therapy:** To replace lost or damaged cells that our bodies cannot replace naturally.
- **Types of stem cells:** According to the sources they are derived from they can be: Embryonic stem cells, Tissue-specific stem cells, Induced pluripotent stem cells and mesenchymal stem cells.
- **According to their potency:** Totipotent, Pluripotent, Multipotent and Unipotent stem cells.
- Stem cell technology is a rapidly developing field that combines the efforts of cell biologists, geneticists and clinicians, and offers hope of effective treatment for a variety of malignant and non-malignant diseases.

Key Terms

- **ADA:** Adenosine Deaminase. This enzyme is crucial for the function of the immune system.
- **GMO:** Genetically Modified Organisms. These are organisms whose genes have been altered.
- **Gene Therapy:** It is a method that allows the correction of a gene defect.
- **Probe:** Hybridisation probe is a fragment of DNA or RNA of variable length (usually 100–1000 bases long) which is radioactively labelled and can be used in DNA or RNA samples to detect the presence of nucleotide sequences (the DNA target) that are complementary to sequence in the probe.
- **PCR:** Polymerase Chain Reaction.
- **ELISA:** Enzyme Linked Immuno-Sorbent Assay.
- **Vaccines:** It is a liquid containing dead or attenuated pathogen or it is an antigen that provides temporary or permanent immunity to a disease.
- **DNA vaccines:** DNA vaccines use one or more isolated genes of a pathogen, incorporate these genes into 'plasmids' and inject them into the muscle or deliver them into human body.
- **SCID:** Severe Combined Immuno Deficiency. It is caused by a defect in the gene for the enzyme adenosine deaminase.
- **Pluripotent cells:** Pluripotent stem cells have the ability to undergo self-renewal and to give rise to all cells of the tissues of the body.
- **Unipotent Cells:** These stem cells can produce only one cell type but have the property ofself-renewall that distinguishes them from non-stem cells.
- **Multipotent cells:** Multipotent stem cells have the ability to differentiate into all cell types within one particular lineage.

- **Totipotent cells:** Totipotent stem cells are the most versatile stem cell type, which are formed shortly after fertilisation. They can become all of the cells of the human body, as well as the cells of the embryo and developing fetus. At about four days into development, these totipotent cells specialize slightly, becoming pluripotent stem cells.

Topic-2 Transgenic Animals and Ethical Issues

Concepts Covered • *Advantages of Transgenic animals and Ethical Issues.*

Revision Notes

Transgenic Animals

- These are the animals whose genome has been altered by introduction of an extra (foreign) gene by manipulation.
- **Examples:** Transgenic rats, rabbits, pigs, sheep, cows and fish.
- Over 95% of all existing transgenic animals are mice.

Transgenic Cow

- In 1997, **Rosie** (first transgenic cow) produced human protein-enriched milk (2.4 g per litre).
- It contains the human **α-lactalbumin**, which is nutritionally more balanced product for human babies than natural cow-milk.

Advantages of Transgenic Animals

(a) To Study Normal Physiology and Development:

- Transgenic animals are used to study the regulation of genes and their effect in normal body functions and its development, e.g., study of complex factors such as insulin-like growth factor.
- Genes from other species that alter the formation of this factor are introduced and the biological effects are studied.
- This gives information about the biological role of the factor in the body.

(b) To Study Various Diseases:

- Transgenic models help investigate new treatments for human diseases.
- **Examples:** Transgenic models for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

(c) To Produce useful Biological Products:

- Some medicines contain biological products, but they are often expensive.
- Transgenic animals are used to produce useful biological products by introducing genes which code for a particular product.
- **Examples:** Human protein (α-1-antitrypsin) is used to treat emphysema, phenylketonuria (PKU) and cystic fibrosis,, etc.

(d) Vaccine Safety:

- Transgenic mice are used in testing the safety of the polio vaccine used on humans.
- If it is found to be reliable, they can replace the use of monkeys to test the safety of batches of the vaccine.

(e) Chemical Safety Testing (Toxicity Testing)

- Transgenic animals are made to carry genes which make them more sensitive to toxic substances than non-transgenic animals.
- Then, they are exposed to the toxic substances and the effects studied.
- It gives immediate results.

Ethical Issues

- Genetic modification may cause unpredictable results when such organisms are introduced into the ecosystem.
- Therefore, Indian Government has set up organisations like GEAC (Genetic Engineering Approval Committee), which make decisions about the validity of GM research and the safety of GM-organisms for public services.
- Certain companies have got patents for products and technologies that make use of the genetic materials, plants, etc., that have been identified, developed and used by farmers and indigenous people of a specific region/country.
- For example: Basmati rice, herbal medicines like turmeric, neem, etc.

Basmati Rice

- It has a unique aroma and flavour.
- India has 27 documented varieties of Basmati.
- In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a 'new' variety of Basmati.
- This had actually been derived from Indian farmer's varieties.
- Indian Basmati was crossed with semi-dwarf varieties and claimed as a novelty.
- Other people selling Basmati rice could be restricted by the patent.

Biopiracy

- It refers to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.
- Most of the industrialised nations are poor in biodiversity and traditional knowledge.
- The developing and the underdeveloped world have rich biodiversity and traditional knowledge related to bio-resources.
- It has to develop laws to prevent the unauthorised exploitation of bio-resources and traditional knowledge.
- Indian Parliament has cleared the second amendment of the Indian Patents Bill that takes such issues into consideration, including patent terms, emergency provisions and research and development initiative.

Key Terms

- **Biopatent:** A patent is the right granted by a government to an inventor to prevent others from commercially using his invention. When patents are granted for biological entities and for products derived from them, these patents are called biopatents.
- **Biopiracy:** Some organisations and multinational companies exploit and patent biological resources or bioresources of other nations, without proper authorisation from the countries concerned without any payment. This is called biopiracy.
- **Biowar:** Biowar refers to the use of biological weapons against humans and/or crops and animals
- **GEAC:** Genetic Engineering Approval Committee. It makes decisions regarding the validity of GM research and safety of introducing GM-organisms for public services.
- **Transgenic animals:** Animals that have their DNA manipulated to possess and express an extra or a foreign gene are known as transgenic animals.

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UNIT – 5: ECOLOGY AND ENVIRONMENT

CHAPTER-13

ORGANISMS AND POPULATIONS

Revision Notes

Ecology

- Ecology refers to the interactions among organism and its physical or abiotic environment.
- Ecology is basically concerned with four levels of biological organisation **organisms, populations, communities and biomes**.
- Each higher level has fewer units than the previous one and higher levels are referred to as ecological levels of the organisation.
- Levels of biological organisation are: Macromolecules – cells – tissues – organs – organisms – population – communities – ecosystem – biomes.

Population

- A population is a group of individuals of same species that live in a given geographical area, share or compete for similar resources and potentially reproduce.

  Example: All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond, etc.
- Population ecology is an important area of ecology as it links ecology to population genetics and evolution.

Population attributes

(a) Birth Rate and Death Rate

- An individual may have deaths and births, but a population has birth and death rates.
- In a population, these rates refer to per capita births and deaths, respectively.
  - **Calculation of Birth Rate**
    - Consider in a pond, there are 20 lotus plants last year and through reproduction 8 new plants are added.
    - Hence, the current population = 28
    - The birth rate = 8/20 = 0.4 offspring per lotus per year.
  - **Calculation of Death Rate**
    - Consider 4 individuals in a laboratory population of 40 fruit flies died during a week.
    - Hence, the death rate = 4/40 = 0.1 individuals per fruit fly per week.

(b) Sex Ratio

- Another characteristic of a population is sex ratio. An individual is either a male or female but a population has a sex ratio, i.e., number of female individuals in relation to male individuals.

(c) Age Pyramid

- When a population at any given time is plotted against the age distribution, the resulting structure is called an age pyramid.
- For human population, the age pyramids show the age distribution of males and females in a combined diagram.
- The shape of the pyramid shows the growth of the population whether it is **growing, stable or declining**.

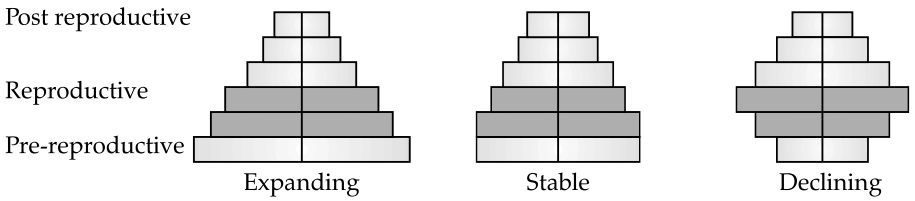


Fig. 11.1: Representation of age pyramids for human population

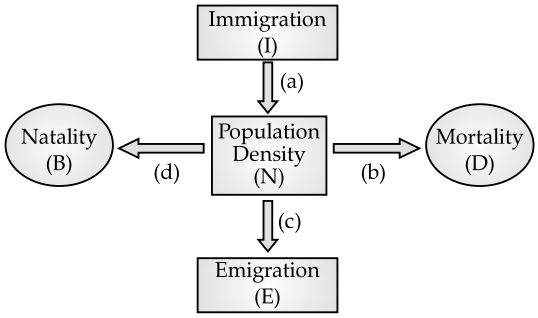
(d) Population Size or Population Density (N)

- It is the number of individuals of a species per unit area or volume.
- The size of the population informs us about its status in the habitat, ecological processes in a population, outcome of competition with another species, the impact of predator or the effect of a pesticide.
- The size could be as low as <10 (Siberian cranes at Bharatpur wetlands) or into millions (*Chlamydomonas* in a pond).
- Population size is technically called population density (N).
- In some cases, population size is measured in percentage cover or biomass.

  Example: Consider in an area, 200 *Parthenium* plants and a single huge banyan tree are seen. Here, the per cent cover or biomass is a measure of the population size to show the importance of banyan tree.
- Total number is a difficult measure for a huge population.
- For ecological investigations, relative density is taken more than the absolute population density.

  Example: The number of fish caught per trap indicates the total population density in the lake.
- Population size can be estimated indirectly, for example, the tiger census in our national parks and tiger reserves is based on pug marks and faecal pellets.
- The population size changes in time, depending on various factors like food availability, predation, pressure and weather.
- Changes in population density give some idea about the population whether it is flourishing or declining.

- **Factors Affecting Population Density**
  - **(a) Natality (B):** It is the number of births in a population during a given period.
  - **(b) Mortality (D):** It is the number of deaths in a population during a given period.
  - **(c) Immigration (I):** It is the number of individuals of the same species that have come into the habitat from elsewhere during a given time period.
  - **(d) Emigration (E):** It is the number of individuals of the population who left their habitat and went elsewhere during a given time period.



- **Differences between Natality Rate and Mortality Rate:**

S.No.	Natality Rate	Mortality Rate
1.	Addition of new individuals due to birth, hatching or germination or division.	It is the number of deaths per unit population per unit time, e.g., per one thousand individuals per year in humans.
2.	It adds new members to the population. As a result, it increases the size of population.	It decreases the size of the population.

- If N is the population density at time t, B is number of births, D is number of deaths, E is emigrants and I is immigrants then its density at time t +1 will be:
- $N_{t+1} = N_t + [(B + I) - (D + E)]$
- This equation indicates that population density increases if $B + I$ is more than $D + E$ otherwise it will decrease.
- Under normal conditions, births and deaths are important factors influencing population density.
- The other two factors have importance only under special conditions.
- For example, if a new habitat is just being colonised, immigration may be more significant to population growth than birth rates.

Growth Model

- There are two growth models namely, exponential growth model and logistic growth model.

(a) Exponential Growth

- Resource availability (food and space) is essential for the unimpeded population growth.
- If resources are unlimited, each species shows its full innate potential to grow in number.
- Then, the population grows in an exponential or geometric fashion.
- If in a population of size N, the birth rates (per capita births) are represented as b and death rates (per capita deaths) as d, then the increase or decrease in N during a unit time period (t), (dN/dt) will be:

  $dN/dt = (b - d) \times N$

  Let $(b - d) = r$, then

  $dN/dt = rN$

  The r ('intrinsic rate of natural increase') is an important parameter for assessing the impacts of any biotic or abiotic factor on population growth.

  The r value for the Norway rat = 0.015

  The r value for the flour beetle = 0.12

  The r value for human population in India (1981) = 0.0205

- The integral form of the exponential growth equation is: $N_t = N_o e^{rt}$

  Where,

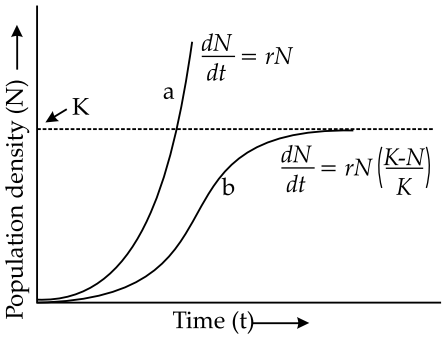
N_t = Population density after time t, N_0 = Population density at time zero, r = Intrinsic rate of natural increase, e = the base of natural logarithms (2.71828)

(b) Logistic Growth

- There is no population in nature having unlimited resources for exponential growth.
- This leads to competition between individuals for limited resources.
- Eventually, the 'fittest' individuals survive and reproduce.
- In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible. It is called **carrying capacity (*K*)**.
- A population with limited resources show initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote when the population density reaches the carrying capacity. This type of population growth is called **Verhulst-Pearl Logistic Growth.**
- **Verhulst-Pearl Logistic Growth**

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

- Where, N is the population density at time t, r is the intrinsic rate of natural increase, K is the carrying capacity.
- Since resources for growth for most animal populations are finite, the logistic growth model is more realistic one.
- **Population Growth Curves:**



- The curve 'a' indicates exponential growth (J-shaped curve) while the curve 'b' indicates logistic growth (Sigmoid curve).

Life History Variation

- Populations evolve to maximise their reproductive fitness or Darwinian fitness (high r value). Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy.
- Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times (most birds and mammals).
- Some produce a large number of small-sized offspring (oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals).
- The above facts indicate that life history traits of organisms have evolved due to limited abiotic and biotic components of the habitat.

Population Interactions

- In nature, animals, plants and microbes interact in various ways to form a biological community.
- Interspecific interactions arise from the interaction of populations of two different species.
- **The interspecific interactions include,**
  - **(a) Mutualism:** Both species are benefitted (+).
  - **(b) Competition:** Both species are harmed (-)
  - **(c) Parasitism:** One species (parasite) is benefitted and other species (host) is harmed, but the host is not killed at once.
  - **(d) Predation:** One species (predator) is benefitted and other species (prey) is harmed (killed and eaten).
  - **(e) Commensalism:** One species is benefitted and the other is neither benefitted nor harmed.
  - **(f) Amensalism:** One species is harmed and the other is unaffected.

Species A	Species B	Name of interaction
+	+	Mutualism
–	–	Competition
+	–	Predation
+	–	Parasitism
+	0	Commensalism
–	0	Amensalism

- In predation, parasitism and commensalism, the interacting species live closely together.

A. Predation

- In a broad ecological context, all carnivores, herbivores, etc., are predators.
- About 25% of all insects are phytophagous.
- If a predator overexploits its prey, then the prey might become extinct.
- It results in the extinction of predator and so, predators in nature are 'prudent'.

Importance of Predators

(a) Predators keep prey populations under control. When certain exotic species are introduced into a geographical area, they spread fast due to the absence of its natural predators in the invaded land. **Example:** The prickly pear cactus introduced into Australia in the early 1920s caused havoc by spreading. Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) was introduced into the country. Biological control methods are based on the ability of the predator to regulate prey population.

(b) Predators maintain species diversity in a community, by reducing the intensity of competition among competing prey species. **Example**: The starfish *Pisaster* is a predator in the rocky intertidal communities of the American Pacific Coast. In an experiment, when all the starfishes were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, due to interspecific competition.

Defences of prey species to lessen the impact of predation:

- Some insects and frogs are camouflaged (cryptically coloured) to avoid being detected by the predator.
- Some are poisonous and so avoided by predators.
- The Monarch butterfly is highly distasteful to its predator (Bird) due to a special chemical in its body.
- This chemical is acquired during its caterpillar stage by feeding on a poisonous weed.
- Thorns (*Acacia*, *Cactus,* etc.) are the most common morphological means of defence of plants.
- Many plants produce chemicals that make the herbivore sick, inhibit feeding or digestion, disrupt its reproduction or kill it.

  Example: *Calotropis* (a weed growing in abandoned fields) produce highly poisonous cardiac glycosides.
- Therefore, cattle or goats do not eat it. Nicotine, caffeine, quinine, strychnine, opium, etc., are defences against grazers and browsers.

B. Competition

- Interspecific competition is a potent force in organic evolution.
- Competition is a process in which fitness of one species (measured as '*r*' value) is significantly lower in presence of another species.
- Competition occurs when closely related species compete for the same limited resources.
- Unrelated species can also compete for the resource.

  Example: Flamingoes and fishes in some shallow South American lakes compete for zooplanktons.
- Competition occurs in abundant resources also.

  Example: In interference competition, the feeding efficiency of one species is reduced due to the interfering and inhibitory presence of other species, even if resources are abundant.

Evidence for Competition

- The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, due to greater browsing efficiency of the goats.

- **'Competitive release':**A species, restricted to a small geographical area (due to the presence of competitively superior species), expands its distributional range when the competing species is experimentally removed.
- Connell's field experiments showed that on the rocky sea coasts of Scotland, the larger & competitively superior barnacle *Balanus* dominates intertidal area, and excludes the smaller barnacle *Chthamalus* from that zone.

Gause's 'Competitive Exclusion Principle'

- It states that "two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually".
- This may be true in limited resources, but not otherwise.
- Species facing competition may evolve mechanisms that promote co-existence rather than exclusion.

  Example: (a) 'Resource partitioning'. If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different foraging patterns.

  (b) Mac Arthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

C. Parasitism

- Many parasites have evolved to be host-specific, i.e., they can parasitize only a single species of a host in such a way that both the host and the parasite tend to co-evolve.
- If the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to counteract and neutralise them, in order to be successful with the same host species.
- **Adaptations of parasites:**
  - **(a)** Loss of sense organs.
  - **(b)** Presence of adhesive organs or suckers to cling on to the host.
  - **(c)** Loss of digestive system, high reproductive capacity, etc.
- Majority of the parasites harm the host.
- They may reduce the survival, population density, growth and reproduction of the host.
- They might render the host more vulnerable to predation by making it physically weak.
- Life cycles of parasites are often complex.

  Examples:

  (a) Human liver fluke depends on two intermediate hosts (i.e., a snail and a fish) to complete its life cycle.

  (b) Malarial parasite needs mosquito to spread to other hosts.
- The parasites are classified into two types namely, ectoparasites and endoparasites.

  (a) Ectoparasites
  - Parasites that feed on the external surface of the host organism are known as ectoparasites.

    Example: Lice on humans and ticks on dogs. Many marine fish are infested with ectoparasitic copepods. *Cuscuta*, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution.
  - It derives its nutrition from the host plant which it parasitises.
  - The female mosquito is not considered a parasite, as it needs our blood for reproduction not for survival. It acts as a vector for a parasite.

  (b) Endoparasites
  - Parasites that live inside the host body at different sites (liver, kidney, lungs, RBC, etc.) are known as endoparasites.
  - The life cycles of endoparasites are more complex.
  - Their morphological and anatomical features are simplified while emphasising their reproductive potential.

Brood Parasitism in Birds

- Here, the parasitic bird lays eggs in the nest of its host and lets the host incubate them.
- During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and removing them from the nest.

  Example: Brood parasitism between cuckoo and crow.

D. Commensalism

Examples:

(a) Orchid (+) growing as epiphyte on a mango branch (0).

(b) Barnacles (+) growing on the back of a whale (0).

(c) Cattle egret (+) and grazing cattle (0). The egrets forage close to where the cattle are grazing. As the cattle move,the vegetation insects come out. Otherwise, it is difficult for the egrets to find and catch the insects.

(d) Sea anemone (0) & clown fish (+). The fish gets protection from predators with the help of stinging tentacles of sea anemone. The anemone has no benefit.

E. Mutualism

- **Examples:**
  - **(a) Lichen:** It is an intimate mutualistic relationship between a fungus and photosynthesising algae or cyanobacteria.
  - **(b) Mycorrhizae:** These are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant provides the fungi with carbohydrates.
- **Example of mutualism between plant and animal through pollination and seed dispersion:**
  1. Many fig trees and wasps. The fig species is pollinated only by its 'partner' wasp species and no other species. The female wasp pollinates the fig inflorescence while searching for suitable egg-laying sites in fruits. The fig offers the wasp some developing seeds, as food for the wasp larvae.
  2. Orchids show a diversity of floral patterns. They can attract the right pollinator insect (Bees & bumble bees) to ensure pollination. Not all orchids offer rewards.
  3. 'Sexual deceit' of *Ophrys* (The Mediterranean orchid). One petal of its flower resembles female bee in size, colour & markings. So, the male bee 'pseudocopulates' with the flower. The bee is dusted with pollen from the flower. When the same bee 'pseudocopulates' with another flower, it transfers the pollen. If the female bee's colour patterns change slightly during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

Key Terms

- **Carrying Capacity:** It is the maximum number of individuals of a population that can be sustained by a given habitat.
- **Emigration:** It refers to the number of individuals of the same species that have left the habitat during the time period under consideration.
- **Immigration:** It refers to the number of individuals of the same species that come into a habitat from elsewhere during the period under consideration.
- **Mortality:** It refers to the number of deaths in a population at a given period.
- **Natality:** It refers to the number of birth added to the initial density in a population during a given period.
- **Population:** It refers to a group of individuals of the same species, occupying the same area at a given time.
- **Population Density:** It refers to the total number of individuals of a species present per unit area or volume at given time.
- **Population Growth Forms/Models:** It is the characteristic patterns of growth of a population with time.
- **Age pyramid:** It is a plot of the age distribution (percent individuals of a given age or age group) for a population.
- **Parasitism:** It is the mode of interaction between two species in which one species (parasite) depends on the other species (host) for food and shelter, in the process harming the host.
- **Mutualism:** It is an interaction that confers benefits to both interacting species.
- **Commensalism:** It is an interaction between two species in which one species is benefitted and the other is neither harmed nor benefitted.
- **Amensalism:** It is an interaction between two species in which one species is harmed and the other is neither benefitted nor harmed.

Mnemonics

1. **Concept:** Ecological Hierarchy
   Mnemonics: **I**ndu! **P**lease **C**arry **E**veryone's **B**iology **B**ooks
   Interpretation:
   I - Individual **P -** Population **C** - Community
   E - Ecosystem **B -** Biome **B** - Biosphere
2. **Concept:** Age Pyramids
   Mnemonic: **T**hree **B**ooks **U**sed: **E**ric **S**top **D**aydreaming
   Interpretation:
   Triangular shaped: **E**xpanding or **G**rowing **B**ell shaped: **S**table **U**rn shaped: **D**eclining
3. **Concept:** Type of interaction: Relationship
   Mnemonic: **C**ompetition **A**lways **M**uffle **P**olitics: **R**ivalry **H**as **F**abulous **B**enefits
   Interpretation:
   Type of interaction: Relationship
   Competition: **R**ivalry **A**ntagonism: **H**armful
   Mutualism: **F**avourable but not Obligatory **P**roto-cooperation: **B**eneficial to both

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CHAPTER-14

ECOSYSTEM

Topic-1

Ecosystem–Structure and Function, Productivity and Decomposition

Concepts Covered • *Concept of Ecosystem and Its Types* • *Structure and Function of Ecosystem* • *Productivity and Decomposition*

Revision Notes

Ecosystem

- An ecosystem is a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
- Ecosystem varies greatly in size from a small pond to a large forest or a sea.
- Many ecologists regard the entire biosphere as a global ecosystem, as a composite of all local ecosystems on Earth.
- The term ecosystem was given by Sir Arthur Tansley in 1935.

Ecosystem: Types, Structure and Function

- The ecosystem includes **biotic** and **abiotic** components.
- In an ecosystem, interaction of biotic and abiotic components takes place in a more integrated manner resulting in a physical structure that is characteristic for each type of ecosystem.
- Major abiotic factors that affect an organism are temperature, water, light and soil.
- Temperature ranges from sub zero levels at poles to > 50 degree centigrade in tropical deserts in summer. Temperature affects the enzyme kinetics and through it basal metabolism and other physiological functions of the organism.
- Some organisms can tolerate a wide range of temperature and are called **eurythermal**, while most organisms are restricted to a narrow range of temperature and are called **stenothermals**.
- Allen's rule (Joel Asaph Allen ,1877) states that animals adapted to cold climates have shorter and thicker limbs and bodily appendages than animals adapted to warm climates.

- Life on earth originated in water and is unsustainable without water. The quantity as well as quality (chemical composition, salinity, pH) of water is important. The animals which can tolerate a wide range of salinities are called **euryhaline** while those which can tolerate a narrow range of salinity are called **stenohaline**.
- Light from Sun is the source of all energy in the ecosystem. Photoperiod affects flowering in plants. Circadian rhythms are affected by light period. It affects the distribution of plant and animal species.
- Soil pH, composition, grain size, water holding capacity also play an important role in an ecosystem.
- Animals respond differently to abiotic factors. Some conform (90% of animals change their physiological state according to environment), some regulate (maintain homeostasis up to a limit), some migrate and some suspend (hibernation or aestivation).
- Animals show morphological, behavioural, physiological adaptations to survive better in their environment. They are called ecological adapatations.For example, CAM cycle of photosynthesis in desert plants.
- Identification and enumeration of plant and animal species of an ecosystem gives its species composition.
- Vertical distribution of different species occupying different levels is called **stratification**.

  Example - Trees occupy top vertical strata (layer) of a forest, shrubs the second and herbs and grasses occupy the bottom layers.

Components of Ecosystem

- There are four basic components that function as a unit. These include,
  - **(a)** Productivity
  - **(b)** Decomposition
  - **(c)** Energy flow
  - **(d)** Nutrient cycling

Types of Ecosystem

(a) Terrestrial ecosystem: Forest, grassland, desert etc.

(b) Aquatic ecosystem: Pond, lake, wetland, river and estuary.

(c) Man-made ecosystem: Crop fields and aquarium.

Aquatic Ecosystem: Pond

- A pond is a shallow, simple, self-sustainable water body that exhibits all basic components of an ecosystem.
- **Abiotic components in pond:** Water with dissolved inorganic and organic substances. The solar input, the cycle of temperature, day length and other climatic conditions regulate the rate of function of the entire pond.
- **Autotrophic components:** Phytoplanktons, some algae and the floating, submerged and marginal plants.
- **Consumers (heterotrophs):** Zooplanktons, free swimming and bottom dwelling forms.
- **Decomposers:** Fungi, bacteria and flagellates.
- **Pond performs all the functions of an ecosystem such as:**
  - **(a)** Conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs.
  - **(b)** Consumption of the autotrophs by heterotrophs.
  - **(c)** Decomposition and Mineralisation of the dead matter to release them back for reuse by the autotrophs.
- There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment.

Productivity

- The rate of biomass production is called productivity. It is expressed in terms of ($g\ m^{-2}yr^{-1)}$ or (kcal m^{-2}) yr^{-1}.
- It includes primary productivity and secondary productivity.
- **(a) Primary Productivity:** It can be divided into gross primary productivity (GPP) and net primary productivity (NPP).
- GPP is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants in respiration.
- NPP is the available biomass for the consumption of heterotrophs (herbivores and decomposers).
- Gross primary productivity minus respiration losses (R) is the net primary productivity (NPP), i.e., NPP = GPP – R
- Primary productivity depends on the plant species inhabiting a particular area and on various environmental factors.
- The primary productivity varies with different types of ecosystems.
- The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter

- Despite occupying about 70% of the surface, the productivity of the oceans is only 55 billion tons.
- **Primary productivity depends on the following:**
  - **(a)** The plant species inhabiting a particular area.
  - **(b)** Environmental factors.
  - **(c)** Availability of nutrients.
  - **(d)** Photosynthetic capacity of plants.
- **Secondary Productivity:** It is the rate of formation of new organic matter by consumers.
- The secondary productivity reflects only the utilization of this food for the production of consumer biomass.

Decomposition

- It is the breakdown of complex organic matter by decomposers into inorganic substances like carbon dioxide, water and nutrients.
- The detritus is the raw material for decomposition. Detritus are dead plant remains such as leaves, bark, flowers and dead remains of animals, including faecal matter.
- The earthworm is referred to as the 'farmer's friend'. . This is so because they help in the breakdown of complex organic matter as well as in loosening of the soil.
- **The steps involved in the decomposition process are:**
  - **(a) Fragmentation:** It is the breakdown of detritus into smaller particles by **detritivores** like earthworm.
  - **(b) Leaching:** Here, the water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
  - **(c) Catabolism:** It is the degradation of detritus into simpler inorganic substances by bacterial and fungal enzymes.
  - **(d) Humification:** The degradation of detritus leads to the accumulation of humus, a dark amorphous substance in soil. Humus is resistant to microbial action and so decomposes very slowly. Being colloidal in nature, it serves as a reservoir of nutrients.
  - **(e) Mineralisation:** The humus gets degraded by some microbes and releases inorganic nutrients. This process is called mineralisation.
  - **(f) Nutrient immobilisation:** At times, the soil nutrients instead of getting mineralised, get bound with biomass of microbes, and so become temporarily unavailable to other organisms. This incorporation of nutrients in living microbes is called nutrient immobilisation.
- **Factors influencing decomposition:**
  - **(a)** It is largely an oxygen-requiring process.
  - **(b)** It is controlled by the chemical composition of detritus. Decomposition rate is slower if detritus is rich in lignin and chitin and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.
  - **(c)** Climatic factors like temperature and soil moisture: Warm and moist environment favours decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build up of organic materials.

Key Terms

- **Biomass:** It refers to the amount of living or organic matter present in an organism.
- **Consumers:** All organisms which depend directly or indirectly on plants for their food are called consumers.
- **Decomposition:** It refers to the process in which the complex organic matter is broken down into simpler organic substances and ultimately into inorganic compounds.
- **Detritus:** It refers to the dead remains of plants and animals and also their faecal matter.
- **Detritivores:** It refers to those organisms which feed on the detritus and break it down into smaller particles.
- **Ecosystem:** An ecosystem is a functional unit of nature consisting of biotic and abiotic factors where the living organisms interact among themselves and also with their physical environment.
- **GPP:** Gross primary productivity is the rate of production of organic matter during photosynthesis.
- **NPP:** Net primary productivity is the available biomass for the consumption to heterotrophs.
- **Standing crop:** It is the living biomass present at a trophic level at a particular given time.
- **Productivity:** It is the rate of production of biomass.
- **Primary Productivity:** It refers to the amount of biomass or organic matter produced per unit area over a time period by the plants during photosynthesis.
- **Stratification:** It refers to the vertical distribution of different species occupying different levels.

- **Secondary Productivity:** It refers to the rate of assimilation and formation of new organic matter by consumers.
- **Ecotone:** The transitional zone between two vegetation regions is called ecotone.
- **Canopy:** Part of a woodland or forest community that is formed by trees is called canopy.

Topic-2 Energy Flow, Ecological Pyramids

Concepts Covered • *Ten Percent Law of Energy Flow, Trophic Levels, Ecological Pyramid and Its Types*

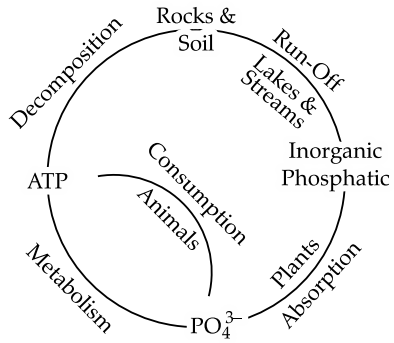
Revision Notes

Energy Flow

- Sun is the only source of energy for all ecosystems except deep sea hydro-thermal ecosystem.
- Out of total incident solar radiation, less than 50% of it is photosynthetically active radiation (PAR).
- Plants, photosynthetic and chemosynthetic bacteria (autotrophs), fix solar radiant energy to prepare food.
- Plants capture only 2-10% of the PAR to sustain the entire living world.

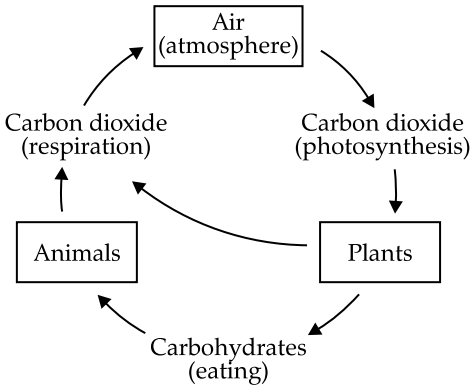
Nutrient Cycling

- Nutrients are never lost from an ecosystem, they are recycled time and again efficiently utilised. These cycles are called nutrient cycles or **biogeochemical cycles**.



Phosphorus Cycle

- **They can be of two types:**
  - **(i)** Gaseous cycles- where the atmosphere is the reservoir for the gaseous nutrient, e.g., oxygen cycle, carbon cycle, etc.
  - **(ii)** Sedimentary cycle- where the reservoir is located in the earth's crust. For example, Sulphur and phosphorus cycle.
- Hence, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem.
- Ecosystems obey second law of thermodynamics.
- They need a constant supply of energy to synthesize the molecules they require, to counteract the universal tendency toward increasing disorderliness.
- The energy flow begins with producers and ends with tertiary consumers.



Basic Carbon Cycle Licing Systems

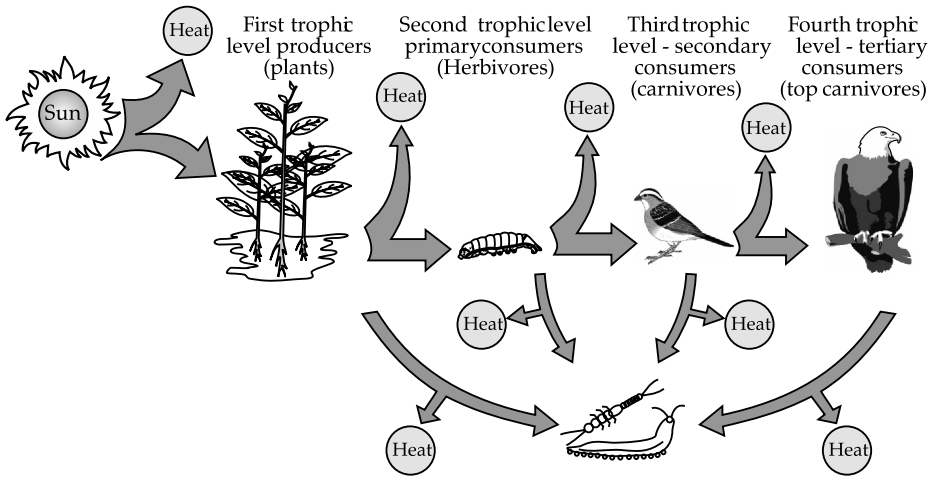


Fig. 15.1: Energy Flow Through Different Trophic Level

Producers (Autotrophs)

- All organisms are dependent for their food on producers (green plants), either directly or indirectly. In a terrestrial ecosystem, major producers are herbaceous and woody plants.
- Primary producers in an aquatic ecosystem are phytoplankton, algae and higher plants.
- The energy trapped by the producer is either passed on to a consumer or the organism dies.
- Death of an organism is the beginning of the detritus food chain/web.

Consumers (Heterotrophs)

These are all animals that depend on plants (directly or indirectly) for their food. They include:

(a) Primary consumers: They are herbivores which feeds on plants. It includes insects, birds and mammals in terrestrial ecosystem and molluscs in aquatic ecosystem.

(b) Secondary consumers: They are primary carnivores which feeds on herbivores. It includes frog, fox, man, etc.

(c) Tertiary consumers: They are secondary carnivores which feeds on primary carnivores.

- **A simple grazing food chain (GFC) is depicted below:**

Grass ----------> Goat ----------> Man
(Producer) (Primary Consumer) (Secondary Consumer)

- **Detritus Food Chain (DFC):** It begins with dead organic matter.
- It is made up of decomposers, i.e., saprotrophs which are heterotrophic organisms.
- It includes fungi and bacteria.
- They meet their energy and nutrient requirements by degrading dead organic matter or detritus.
- Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.
- In an aquatic ecosystem, GFC is the major conduit for energy flow.
- In a terrestrial ecosystem, a much larger fraction of energy flows through the DFC than through the GFC.
- DFC may be connected with GFC at some levels. Some of the organisms of DFC are prey to the GFC animals.
- Some omnivorous animals like cockroaches, crows etc., are also involved in the food chain.
- These interconnections of food chains make a **food web**.

Trophic Levels

- Based on their feeding relationship, organisms occupy a place in the natural surroundings or in a community.
- A specific place of organisms in the food chain is known as their trophic level.
- Producers belong to the first trophic level, herbivores to the second and carnivores to the third.
- The amount of energy decreases at successive trophic levels.
- When an organism dies, it becomes dead biomass (detritus) that serves as an energy source for decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy demands.

- Each trophic level has a certain mass of living material at a particular time called as the standing crop. It is measured as the mass of living organisms (biomass) or the number in a unit area.
- Biomass of a species is expressed in terms of fresh or dry weight. Measurement of biomass in terms of dry weight is more accurate.
- The number of trophic levels in the grazing food chain is restricted as the transfer of energy follows 10% law, i.e., only 10% of the energy is transferred to each trophic level from the lower trophic level.
- It is possible to have so many levels such as producer, herbivore, primary carnivore, secondary carnivore in the grazing food chain.

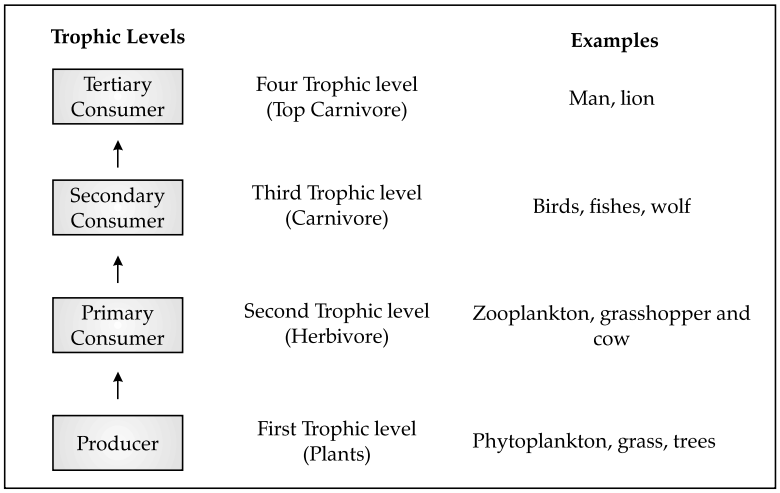


Fig. 15.2: Different Trophic Levels in an Ecosystem

Ecological Pyramids

- The representation of a food chain in the form of a pyramid is called an ecological pyramid.
- The base of a pyramid is broad and it narrows down at the apex.
- The base of each pyramid represents the producers (first trophic level) while the apex represents tertiary or top level consumer.
- **There are three ecological pyramids, namely**
  - **(a)** Pyramid of number
  - **(b)** Pyramid of biomass
  - **(c)** Pyramid of energy
- In most ecosystems, all the pyramids are upright, i.e., producers are more in number than the carnivores.
- Also, energy at a lower trophic level is always more than at a higher level.

Pyramid of Number

Example: Grassland ecosystem

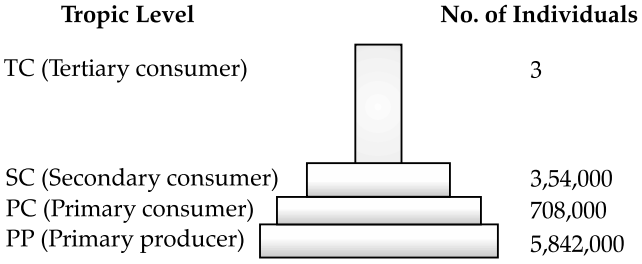


Fig. 15.3: Pyramid of Numbers in a Grassland Ecosystem

Pyramid of Biomass

It shows a sharp decrease in biomass at higher trophic levels.

Pyramid of Energy

Primary producers convert only 1% of the energy of sunlight available to them into NPP.

- Pyramid of energy is always upright, because when energy flows from a trophic level to the next trophic level, some energy is always lost as heat at each step.

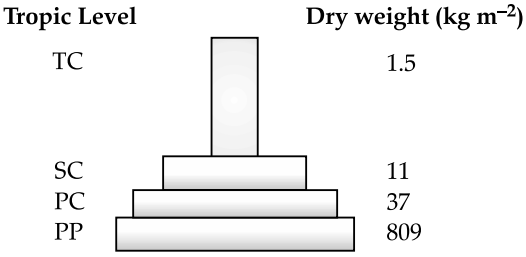


Fig. 15.4: Pyramid of Biomass

- The trophic level represents a functional level.
- A given species may occupy more than one trophic level in the same ecosystem at the same time.

  Example: A sparrow is a primary consumer when it eats seeds, fruits, peas and it becomes a secondary consumer when it eats insects and worms.

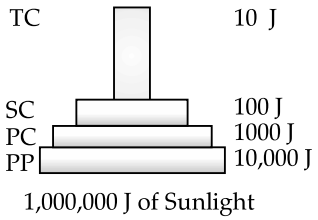


Fig. 15.5: An Ideal Pyramid of Energy

Inverted Pyramid of Biomass

(a) In aquatic habitats, the small standing crop of phytoplankton supports large standing crop of zooplankton. In this case, the pyramid of biomass is inverted.

(b) Pyramid of biomass in the sea is generally inverted because the biomass of fishes far exceeds than that of phytoplankton.

In a parasitic food chain, the pyramid of numbers is inverted. In this food chain, a single tree (producer) provides food to several fruit eating birds, which in turn support several insects.

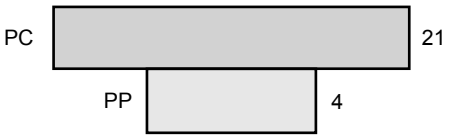


Fig. 15.6: Inverted Pyramid of Biomass

- **Limitations of Ecological Pyramids:**

  (a) It does not take into account the same species belonging to two or more trophic levels.

  (b) It assumes a simple food chain that almost never exists in nature; it does not accommodate a food web.

  (c) Saprophytes are not included in ecological pyramids even though they play a vital role in the ecosystem.

Ecological Efficiencies

- Ecological efficiency describes the efficiency with which energy is transferred from one trophic level to the next.
- Four types of efficiencies are calculated in ecosystem:
  (1) Photosynthetic efficiency: It is the ratio of gross primary productivity to incident solar radiation.
  (2) Net production efficiency: It is the ratio of net primary productivity and gross primary productivity.
  (3) Assimilation efficiency: It is the ratio of food energy assimilated to food energy ingested.
  (4) Ecological efficiency: It is the ratio of energy in biomass production at a specific trophic level to the energy in biomass production at the previous trophic level.

Ecological Succession

- An important characteristic of all the communities is that their composition and structure continuously change in response to the changing environmental conditions.
- This orderly, sequential change parallel to the changes in the environment is called ecological succession.
- The first community in a series is called the **pioneer community** while the final community that is in near equilibrium with the environment is called **climax community**.
- The entire sequence of communities that successively change in a given area are called **sere(s).**
- Succession that starts at a place where no organisms ever existed, such as bare rocks, newly cooled lava etc., is called **primary succession**.
- Succession that starts at a place where all the organisms that existed are somehow lost, such as a burnt forest etc., is called s**econdary succession.**
- Based on the nature of the habitat, whether it is water, desert or a terrestrial plain, succession can be called **hydrosere (hydrarch)**, **xerosere (xerarch)** or **mesosere (mesarch)** respectively.
- The species that invade a bare area are called **pioneer species**.

Ecological Services

- The products of ecosystem processes are named as ecosystem services. For example, forests purify air, reduce droughts and floods; animals help in pollination and seed dispersal etc.
- Researchers have put an average price tag of US $ 33 trillion a year on these fundamental ecosystem services.

Key Terms

- **Food Chain:** It refers to the transfer of energy from the producer through a series of organism.
- **Food Web:** It refers to an interconnected matrix of food chains.
- **Herbivores:** Herbivores are the primary consumers which depend only on plants for their food needs.
- **Producers:** The green plants of an ecosystem are called producers.
- **Primary Carnivores:** These are the secondary consumers which depend on the herbivores for their food needs.
- **Secondary Carnivores:** These are the tertiary consumers which depend on the primary carnivores for their food needs.
- **Standing Crop:** It refers to the amount of biomass present at each trophic level.
- **Ecological Succession:** The orderly, sequential change in a community existing at a place that is in accordance to the change in environment is called ecological succession.
- **Sere:** The entire sequence of communities that successively change in a given area.

❑❑

CHAPTER-15

BIODIVERSITY AND ITS CONSERVATION

Topic-1 Biodiversity and Its Patterns

Concepts Covered • *Concept of Biodiversity and Its Levels* • *Species Diversity in India* • *Patterns of Biodiversity* • *Loss of Biodiversity and Its Impact*

Revision Notes

Biodiversity

- In our biosphere immense diversity (or heterogeneity) exists not only at the species level but at all levels of biological organisation.
- The term 'biodiversity' refers to the diversity of biological organisations ranging from cellular macromolecules to biomes.
- The term 'biodiversity' was popularized by Edward Wilson.

Levels of Biodiversity

(a) Genetic Diversity

- It is the diversity shown by a single species at genetic level.

  For example, Rauwolfia vomitoria grown in Himalayan ranges shows genetic variation in the potency and concentration of the chemical called reserpine.
- India has more than 50,000 different strains of rice and 1000 varieties of mango.

(b) Species Diversity

- It is the diversity at the species level.

  For example, Western Ghats have greater amphibian species than the Eastern Ghats.

(c) Ecological Diversity

- It is the diversity at ecosystem level.

  For example, In India, deserts, rain forests, mangroves, coral reefs, wetlands, estuaries and alpine meadows are seen whereas the Scandinavian countries (like, Norway, Sweden) have less ecological diversity.
- Ecological diversity is subdivided as **(a)** Alpha diversity **(b)** Beta diversity and **(c)** Gamma diversity

Number of Species on Earth and in India (Global Species Diversity)

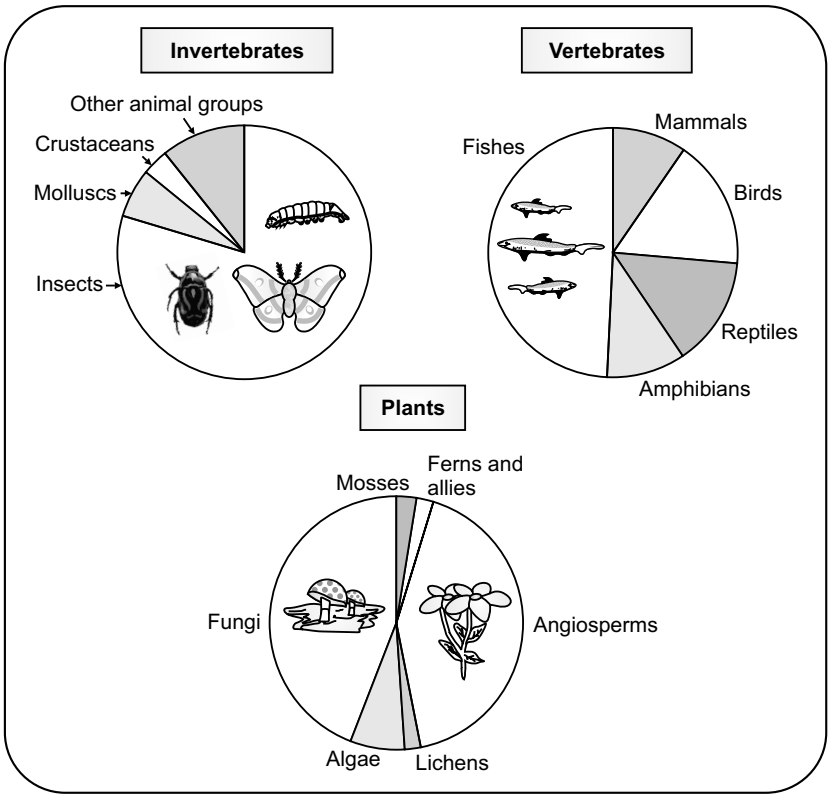
Species on Earth

- According to IUCN (2004): More than 1.5 million species are described so far.

- According to **Robert May's** global estimate, there are about 7 million species. As per May's global estimate only 22 per cent of the total species have been discovered.
- Animals are more diverse (above 70%) than plants including Plantae and Fungi (22%).
- Most species rich taxonomic group among animals are insects. They make up 70% i.e., out of every 10 animals, 7 are insects.
- Number of fungi species is more than the combined total of the species of fishes, amphibians, reptiles & mammals.
- **Biologists are not sure about total number of prokaryotic species because:**
  - **(a)** Conventional taxonomic methods are not suitable for identifying microbial species.
  - **(b)** Many species can not cultured under laboratory conditions.

Species in India

- India has only 2.4% of world's land area, but has 8.1% of the species diversity.
- India is one of the 12 mega diversity countries of the world.
- Nearly 45,000 species of plants and twice as many of animals have been recorded from India.
- India would have more than 1 lakh plant species and 3 lakh animal species.



Patterns of Biodiversity

(a) Latitudinal Gradients

- Species diversity decreases from the equator to the poles.
- Tropics (latitudinal range of 23.5° N to 23.5° S) have more species than temperate or polar areas. Colombia (near equator) has about 1,400 species of birds.
- **New York (41° N):** 105 species of birds.
- **Greenland (71° N):** 56 species of birds.
- **India (tropical latitudes):** More than 1,200 species of birds. Tropical forest region like Ecuador has upto 10 times more species of vascular plants as compared to a forest of equal area in a temperate region like the Midwest of USA the Tropical Amazonian rain forest (South America) has the greatest biodiversity on earth.
- It contains more than 40,000 species of plants, 3000 species of fishes, 1300 species of birds, 427 species of mammals, 427 species of amphibians, 378 species of reptiles and more than 1,25,000 species of invertebrates.
- **Biodiversity (species richness) is highest in tropics because:**
  - **(a)** Tropical latitudes have remained relatively undisturbed for millions of years and thus had a long evolutionary time for species diversification.

(b) Tropical regions are relatively more constant and predictable (less seasonal).
(c) They receive more solar energy which contributes to greater productivity.

(b) Altitudinal gradient relationship

- Biodiversity decreases when we move from lower to higher altitudes on the mountain.
- Lower temperature and greater seasonal variations reduce biodiversity.
- Higher altitudes have less biodiversity than lower altitudes.

(c) Species–Area Relationship

- According to the study of Alexander von Humboldt "within a region, species richness increases with increasing explored area, but only up to a limit".
- Relation between species richness and area for a wide variety of taxa gives a rectangular hyperbola.
- On a logarithmic scale, the relationship is a straight line described by the equation:

$$\log S = \log C + Z \log A$$

where, S = Species richness, A = Area, C = Y-intercept, Z = Slope of the line (regression co-efficient).

- The value of Z lies in the range of 0.1 to 0.2.
- In species–area relationship among very large areas like entire continents, slope of the line is steeper (Z value: 0.6 to 1.2).

  Example: For frugivorous birds and mammals in the tropical forests of different continents, the slope is 1.15.

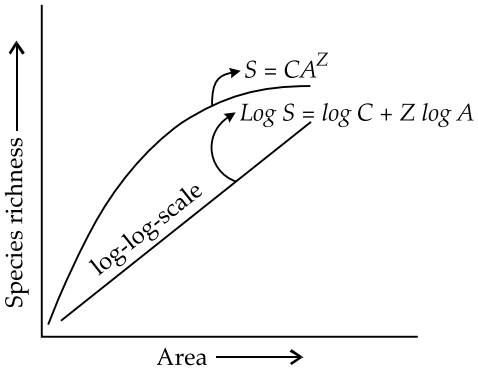


Fig. 15.1: Graph showing species–area relationship

Importance of Species Diversity to the Ecosystem

- The communities with more species are generally more stable than those with less species.
- A stable community should not show too much variation in productivity from year to year.
- According to David Tilman, increased diversity contributed to higher productivity.
- **Rivet popper hypothesis:** This hypothesis was used by Stanford ecologist Paul Ehrlich. In an airplane, all parts are joined together using thousands of rivets (species). If every passenger travelling in airplane starts popping a rivet to take home (causing a species to become extinct), it may not affect flight safety (proper functioning of ecosystem) initially, but as more and more rivets are removed, the planes become dangerously weak over a period of time. Loss of rivets on the wings (key species that drives major ecosystem functions) is more serious threat to flight safety than the loss of a few rivets on the seats or windows inside the plane.

Loss of Biodiversity

- The biological wealth of our planet has been declining rapidly due to human activities.
- In last 20 years, 27 species have been disappeared.
- IUCN Red List (2004) says that 784 species (338 vertebrates, 359 invertebrates and 87 plants) were extinct in the last 500 years. Example: Dodo (Mauritius), Quagga (Africa), Thylacine (Australia), Stellar's Sea Cow (Russia) and 3 subspecies (Bali, Javan, Caspian) of tiger.
- 27 species have been disappeared in the last 20 years.
- More than 15,500 species are facing the threat of extinction.
- 12% of all birds, 23% of all mammals, 32% of all amphibians and 31% of all gymnosperm species face the threat of extinction.
- The current extinction rate is 100–1,000 times faster than in the pre-human times.
- If this trend continues, nearly 50% species might be extinct within the next 100 years.

Impacts of Loss of Biodiversity

(a) Decline in plant production.
(b) Lowered resistance to environmental perturbations such as drought.
(c) Increased variability in ecosystem processes such as plant productivity, water use and pest and disease cycles.

Causes of Biodiversity Losses ('The Evil Quartet')

(a) Habitat Loss and Fragmentation:

- It is the most important cause.

  For example, Tropical rain forests (loss from 14% to 6%).
- Thousands hectares of rain forests are being lost within hours.
- The Amazon rain forest is being cut for cultivating soya beans or for the conversion of grasslands for cattle. Due to fragmentation, animals requiring large territories and migratory animals are badly affected.

(b) Over-exploitation

- Due to over-hunting and over-exploitation of various plants and animals by humans, many species have become endangered or extinct.
- Many species like Stellar's sea cow, Passenger pigeon, etc., are extinct due to over-exploitation by humans.

(c) Alien Species Invasions

- Some of the alien species turn invasive and cause decline or extinction of indigenous species.
  For example, The Nile Perch introduced in Lake Victoria (East Africa) caused extinction of more than 200 species of cichlid fish.
- Invasive weed species like carrot grass (*Parthenium*), *Lantana* and water hyacinth (*Eichhornia*) caused damage to our native species.
- The illegal introduction of the African catfish (*Clarias gariepinus*) for aquaculture is posing a threat to the indigenous catfishes in our rivers.

(d) Co-extinction

- When a species becomes extinct, the plant and animal species associated with it also become extinct.
- Example: Extinction of the parasites when the host is extinct.
- Co-evolved plant-pollinator mutualism where the extinction of one leads to the extinction of the other.

(e) Types of extinction processes

(a) **Natural extinction:** It is a natural and gradual disappearance of some species with changes in natural environmental conditions.

(b) **Mass extinction:** It refers to the extinction of a large number of species at certain periods in the Earth's geological history due to sudden catastrophes

Key Terms

- **Biodiversity:** Biodiversity is the variety of living forms present in various ecosystems.
- **Ecological/ecosystem diversity:** Diversity at the ecosystem level is called ecological diversity.
- **Genetic diversity:** It refers to the diversity of genes within a species.
- **Species diversity:** It refers to the variety of species within a region.
- **Latitudinal gradient:** It is the diversity index used to show the distribution of flora and fauna from the poles to the tropics.
- **Co-extinction:** It refers to the simultaneous extinction of multiple species where one is dependent on other species.
- **Exotic/Alien species:** These are species which are introduced into an ecosystem to which they are not native.

Mnemonics

1. Concept: Causes of Biodiversity loss (Evil Quartet)

Trick: CHO Aldehyde

Interpretation:

C - Co Extinction
H - Habitat loss and Fragmentation
O - Over exploitation
A - Alien species invasions

2. Concept: Animals extinct due to Over-Exploitation

Mnemonics: Please **S**top Over Exploitation

Interpretation:

P - Passenger pigeon
S - Stellar's sea cow

3. Concept: Alien Species invasion

Trick: NA PLEASE

Interpretation:

N - Nile Perch
A - African Catfish (*Clarias gariepinus*)
P - *Parthenium* (Carrot grass)
L - *Lantana*
E - *Eichhornia* (Water hyacinth)
AS - Alien Species

Topic-2 Conservation of Biodiversity

Concepts Covered • *Reason for Conservation* • *Methods of Conservation of Biodiversity*

Revision Notes

Reasons for Conservation

(a) Narrowly Utilitarian Arguments

- Human derive economic benefits from nature such as food, firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and medicines.
- Other indirect benefits are pest control, climate moderation and flood control.
- More than 25% of the drugs are derived from plants.
- 25,000 species of plants have medicinal value.
- Exploring molecular, genetic and species-level diversity, i.e., 'bioprospecting' for products of economic importance may enormously benefit nations with rich biodiversity.

(b) Broadly Utilitarian Arguments

- Biodiversity has many ecosystem services.
- Amazon forest produces 20% of total O_2 in the Earth's atmosphere by the process of photosynthesis.
- Pollination service takes place through bees, bumble bees, birds and bats.
- We derive aesthetic pleasures such as walking through thick woods, watching spring flowers in full bloom or waking up to a bulbul's song in the morning.

(c) Ethical Arguments

- Every species has an intrinsic value.
- We have a moral duty to care for their well-being.

Conservation of Biodiversity

(a) In situ conservation (on site)

- It is the conservation of genetic resources within natural or human-made ecosystem in which they occur. For example, protected areas such as National Parks, Sanctuaries, Biosphere reserves, cultural landscapes, natural monuments.

(i) National Park

- Strictly reserved for the welfare of the wildlife where private ownership, cultivation, grazing, etc., are prohibited.
- There are 104 national parks in India.

(ii) Sanctuary

- Here, protection is given only to the animals/fauna.
- Collection of timbers, minor forest products and private ownership are allowed as long as they do not harm the animals.
- There are 553 wildlife sanctuaries in India.

(iii) Biosphere Reserves

- Areas of land or coastal environments to conserve ecosystem and genetic resources contained therein.
- There are 18 biosphere reserves in India.

There are three zones in each biosphere reserves.

(a) **Core zone:** No human activity is allowed.

(b) **Buffer zone:** It surrounds the core zone. Human activities such as resource consumption, strategy development and education are restricted.

(c) **Transition zone:** It is the outer most of the biosphere reserves where active cooperation is present between reserve management and local people.

(iv) Sacred Forests (Sacred Groves)

- Sacred groves are highly protected forests because of religious and cultural traditions.
- Sacred groves are found in Khasi and Jaintia Hills in Meghalaya, Aravalli Hills of Rajasthan, Western Ghat regions of Karnataka and Maharashtra and Sarguja, Chanda and Bastar areas of Madhya Pradesh.

– In Meghalaya, the sacred groves are the last refuges for a large number of rare and threatened plants.

(v) Hotspots

– These are the richest and the most threatened reservoirs of plant and animal life on Earth.

– In total all the biodiversity hotspots cover less than 2% of the earth's land area but could reduce the ongoing extinctions by almost 30%.

– There are 36 hotspots in the world.

– Three main hotspots (Western Ghats and Sri Lanka, Indo-Burma and Himalaya) cover India's biodiversity regions.

(b) Ex situ conservation (off site)

- It is the conservation of organisms outside their habitats.
- **Gene banks:** Some institutes maintain stock of viable seeds, live growing plants, tissue culture and frozen germplasm with the whole range of genetic variability.
- In this approach, threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care, e.g., genetic resource centres, zoological parks, botanical gardens, gene banks, etc.
- In recent years, ex-situ conservation has advanced by preserving the gametes of threatened species in viable and fertile condition for long period using cryopreservation techniques, eggs can be fertilised in-vitro, and plants can be propagated using tissue culture methods.
- Seeds of different genetic strains of commercially important plants can be kept for a long period in seed banks.

International Efforts for Conserving Biodiversity

- **The Earth Summit (Rio de Jeneiro, 1992) – Three objectives:**
  (a) Conservation of biodiversity
  (b) Sustainable use of biodiversity
  (c) Sharing of benefits in the utilisation of genetic resources.
- **The World Summit on Sustainable Development** (Johannesburg, South Africa, 2002): 190 countries pledged to reduce the current rate of biodiversity loss.
- **Red data book:** Record of the threatened species of plants and animals is maintained by IUCN. It has 8 categories and those are Extinct, Extinct in wild, critically endangered, Vulnerable, lowest risk, data deficient, not evaluated.
- **The Biological Diversity act, 2002:** Through this act, India has responded to the conservation of biological diversity. The main objectives of this act are as follows:
  1. Conservation of biological diversity.
  2. Sustainable use of its components.
  3. Fair and equitable sharing of the benefits arising out of utilisation of genetic resources.
- **Ramsar sites:** It is named after Ramsar city in Iran where the Ramsar convention was signed in 1971 to develop awareness about the importance of wetlands.
- **Wet lands:** These are the areas where water is the primary factor, controlling the environment and the plants and animals life existing there in. They occur where the water table is at or near the surface of land or where the land is covered by water.
- **Threats to wetlands:** Loss of vegetation, Salinisation, excessive inundation, water pollution, invasive species, excessive development and road building are the main threat to wetlands.

Key Terms

- **Biosphere Reserves:** These are a kind of protected areas of land and coastal environment having unique biodiversity.
- **Cryopreservation:** It is the method of storage of materials at ultra-low temperature either by very rapid cooling or by gradual cooling and simultaneous dehydration at low temperature.
- **Exotic/Alien species:** These are species which are introduced into an ecosystem to which they are not native.
- **Hot Spots:** These are the priority areas of conservation that are extremely rich in species which have high endemism and are under constant threat of extinction.

Key Terms

- **Sacred Forests/groves:** These are the forest protected by tribal communities due to religious sanctity.
- **Ex situ conservation:** The conservation of components of species outside their natural habitats.
- **In situ conservation:** The conservation of species in their natural habitats.
- **Endemic species:** The species which are found only in a particular area because of isolation and climatic condition.
- **Sanctuary**: Protected area only for the fauna.
- **Red list:** A catalogue highlighting the challenged taxa that are on the verge of global extinction.

❑❑

CHAPTER-16

ENVIRONMENTAL ISSUES

Topic-1

Pollution and Waste Management

Concepts Covered • *Definition of pollution and pollutant; environmental issues: air pollution and its control, major sources of gaseous and particulate pollutants, control devices for air pollution such as: scrubbers and electrostatic precipitators, catalytic converter, CNG, Bharat stages, noise pollution: harmful effects and control; Water pollution, major sources and its control, composition of waste water, thermal pollution, eutrophication - cultural or accelerated, BOD, effect of sewage discharge on BOD and dissolved oxygen content in river; case studies of waste water treatment (FOAM and EcoSan); Soil pollution – sources, effects and control, agrochemicals and their harmful effects, integrated organic farming, contribution of Ramesh Chandra Dagar, biomagnification and bioconcentration; solid waste management, Radioactive waste management, e-waste.*

Revision Notes

Pollution

- Human population explosion increases the demand for food, water, home, electricity, roads, automobiles etc.
- It leads to pollution of air, water and soil and depletion of valuable natural resources.
- The Government of India has passed the Environment (Protection) Act, 1986 to control environmental pollution and protect and improve the quality of our environment.

Air Pollution and its control

- The air pollution is caused due to undesirable change in the physical, chemical and biological characteristics of air.
- **Factors Involved in Air Pollution**
  (a) Concentration of pollutants.
  (b) Duration of exposure to the pollutants.
  (c) Type of organism it affects.
- **Causes of Air Pollution:**
  (a) Particulate and gaseous air pollutants from smokestacks of thermal power plants, smelters, etc.
  (b) Pollutants from automobiles.
  (c) Usage of leaded petrol.
  (d) Garbage decomposition.
- **Effects of Air Pollution**
  (a) Humans and Animals
  - According to Central Pollution Control Board (CPCB), particulate size of less than 2.5 μm in diameter (PM 2.5) causes greatest harm such as respiratory problems, irritation, inflammations and damage to lungs and premature deaths.
  - It also causes cancer and genetic mutations.

(b) Plants

- It causes fruit damage and various leaf diseases like necrosis, chlorosis, etc.
- It decreases the crop yield resulting in premature death of plants.
- It increases infestation by pests.

➢ **Control of Air Pollution**

(a) Electrostatic precipitator

- It is the device widely used in industries to remove particulate matter.
- It can remove over 99% particulate matter present in the exhaust from a thermal power plant.
- It has electrode wires maintained at high voltage which produces electrons.
- These electrons get attached to the dust particles, giving them negative charge.
- The collecting plate grounded being positive charge attracts the negatively charged dust particles.
- When the air passes through the collecting plate, it gets cleaned.
- The velocity of air between the plates is maintained at low value to allow the dust to fall on the collecting plate.

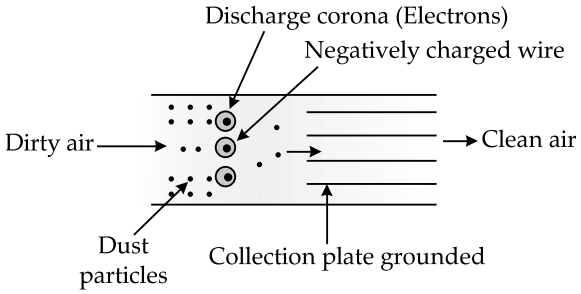


Fig. 16.1. Electrostatic precipitator

(b) Scrubber

- It is a device used to remove harmful gases like sulphur dioxide from the industrial exhausts.
- The exhausts are passed through a spray of lime or water.
- The water dissolves the gases and lime (CaO) reacts with sulphur dioxide to form a precipitate of calcium sulphate and sulphide.
- There are two types of scrubber namely, wet scrubber and dry scrubber.

(c) Catalytic Converters

- It is made up of expensive metals like platinum, palladium and rhodium.
- These are fitted into the automobiles for reducing emission of poisonous gases such as carbon monoxide, nitrogen dioxide, etc.

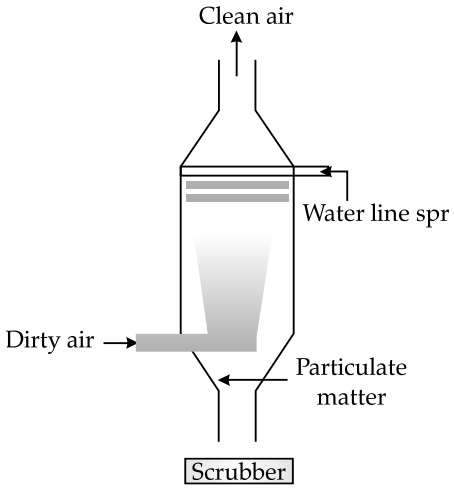


Fig. 16.2. Scrubber

➢ **When the exhaust emission passes through the catalytic converter:**

(a) Nitric oxide splits into nitrogen and oxygen.

(b) Carbon monoxide gets oxidised into carbon dioxide.

(c) Unburnt hydrocarbons get burnt completely into carbon dioxide and water.

➢ **Impact of Air Pollution on Environment**

(a) Higher energy efficient.

(b) Greater fuel economy.

(c) Hybrid vehicles reduce emissions even lower than recommended level set by the Environment Protection Agency.

➢ **Measures Taken by the Government to Control Air Pollution**

(a) Use of catalytic converters.

(b) Use of lead-free petrol or diesel.

(c) Phasing out of old vehicles.

(d) Using low-sulphur petrol and diesel.

(e) Application of pollution-level norms for vehicles, etc.

- **Laws and policies in India to control vehicular pollution**

(a) Application of Euro IV norms in vehicles. According to this, sulphur must be controlled at 350 ppm in diesel and 150 ppm in petrol.

(b) Application of Bharat Stage IV for all automobiles throughout the country.

- **Controlling Vehicular Air Pollution: (A Case Study of Delhi)**
  - With its very large population of vehicular traffic, Delhi leads the country in its levels of air-pollution. In the 1990s, Delhi ranked fourth among the 41 most polluted cities of the world. Air pollution problems in Delhi became so serious that a public interest litigation (PIL) was filed in the Supreme Court of India. After being censured very strongly by the Supreme Court, under its directives, the government was asked to take appropriate measures, including switching over the entire fleet of public transport, i.e., buses, from diesel to compressed natural gas (CNG). All the buses of Delhi were converted to run on CNG by the end of 2002. Now, electric buses are being deployed.
  - **Advantages of CNG:**

(a) CNG burns most efficiently leaving no unburnt remain behind.

(b) CNG is cheaper than petrol or diesel, cannot be siphoned off by thieves and adulterated like petrol or diesel.

- **Disadvantage of CNG:**

(a) CNG has difficulty in laying down pipelines to deliver CNG through distribution points / pumps and ensuring uninterrupted supply.

Noise Pollution and its Control

- In India, the Air (Prevention & Control of Pollution) Act (1981) was amended in 1987 to include noise as an air pollutant.
- Noise is undesired high level of sound.
- The sound level above 150 dB, generated by take off of a jet plane or rocket may damage ear drums.
- Causes of Noise Pollution

(a) Use of music instruments, loudspeaker, crackers, etc.

(b) Jet planes or rockets take off.

(c) Industrial, factory and traffic noises.

- Harmful Effects of Noise Pollution

(a) Noise causes psychological and physiological disorders.

(b) Sleeplessness and increased heartbeat.

(c) Altered breathing pattern, stress, etc.

(d) Hearing disability.

- Control of Noise Pollution

(a) Using sound absorbent materials in industries and buildings.

(b) Creating horn-free zones around hospitals and schools.

(c) Sticking to permissible sound-levels of crackers and loudspeakers.

(d) Delimit the timings of using loudspeakers by framing laws.

(e) Silencers for automobiles, industries, etc.

Water Pollution and its Control

- Water bodies are lifeline of all living organisms.
- Water pollution refers to the contamination of water bodies due to changes in physical, chemical and biological properties of water that affect the living beings.
- Due to human activities, the ponds, lakes, stream, rivers, estuaries and oceans are becoming polluted.
- The Government of India has passed the Water (Prevention and Control of Pollution) Act, 1974 to safeguard our water resources.
- **Sources of Water Pollution**

(a) Domestic sewage and industrial effluents

- Domestic sewage contains biodegradable organic matter.

- It is decomposed by microorganisms, which can multiply using these organic substances as substrates and hence utilise some of the components of sewage.
- A mere 0.1% impurities make domestic sewage unfit for human use.
- They include suspended solids such as sand, silt, clay, colloidal materials such as faecal matter, bacteria, cloth, paper, fibres and dissolved materials like nitrate, ammonia, phosphate, sodium, calcium, etc.
- Solids are easy to remove while removal of dissolved materials, organic compounds and toxic metal ions are most difficult.
- Domestic sewage from home and hospitals contain pathogen and cause diseases like typhoid, dysentery ,etc.

(b) Industrial wastes

- The industrial effluents from petroleum, paper and chemical manufacturing industries contain toxic heavy metals like mercury and organic compounds leading to biomagnification (biological magnification).
- Heated (thermal) waste water from electricity-generating units (e.g., thermal power plants) eliminates organisms sensitive to high temperature.
- It may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

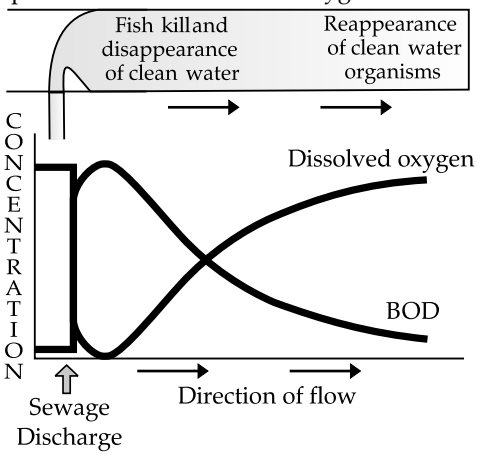
(c) Agricultural run-off

- The run-off from agricultural land is polluted with pesticides and fertilisers.
- It enters water sources by seeping into ground water or streams.

➢ **Effects of Water Pollution**

(a) Biological Oxygen Demand

- The amount of biodegradable organic matter in sewage water is estimated by measuring Biochemical Oxygen Demand (BOD).
- During biodegradation, micro-organisms consume a lot of oxygen.
- It results in a sharp decline in dissolved oxygen causing death of aquatic organisms.
- The prime contaminants are nitrates and phosphates, which act as plant nutrients.
- They overstimulate the growth of algae, causing scum and unpleasant odours, and robbing the water of dissolved oxygen vital to other aquatic life.
- At the same time, other pollutants flowing into a lake may poison whole populations of fish; whose decomposing remains, further deplete the water's dissolved oxygen content.



(b) Eutrophication

- It is the natural ageing of a lake by nutrient enrichment of its water.
- In a young lake, the water is cold and clear.
- With time, due to introduction of nutrients such as nitrogen, phosphorus, etc., which encourage the growth of aquatic organisms.
- As the lake's fertility increases, plants and animals grow rapidly, and organic remains are deposited on the lake bottom.
- Slowly, the slit and organic debris pile up and the lake grows shallower and warmer, with warm-water organisms.

- Marsh plants take root in the shallows and fill in the original lake basin and eventually the lake gets converted into land.
- **Cultural or accelerated eutrophication:** The acceleration of ageing process due to heavy discharge of pollutants from the industries and home is known as cultural or accelerated eutrophication.

(c) Algal bloom

- The presence of large amounts of nutrients in water causes excessive growth of planktonic algae or algal bloom.
- It imparts a distinct colour to the water bodies and deteriorates the water quality resulting in death of fishes. Some bloom-forming algae are extremely toxic to human beings and animals.
- For example, the water hyacinth *(Eichhornia crassipes)* is the most problematic aquatic weed (Terror of Bengal').
- They grow faster than our ability to remove them.
- It leads to an imbalance in the ecosystem dynamics of the water body.

➢ **Control of Water Pollution**

(a) Sewage contains a large quantity of human excreta, organic matter and microbes which should be treated first in sewage treatment plant before discharging into water bodies.

(b) Judicious use of small doses of fertilisers and manure.

- **A Case Study of Integrated Waste Water Treatment**
  - It includes artificial and natural processes.
  - An example of such an initiative is the town of Arcata, situated along the northern coast of California.
  - Collaborating with biologists from the Humboldt State University, the town people created an integrated waste water treatment process within a natural system.
- **The cleaning occurs in two stages:**

(a) Sedimentation, filtering and chlorine treatments.

- After this stage, lots of dangerous pollutants like dissolved heavy metals still remain.
- To combat this, an innovative approach was taken.

(b) The biologists developed a series of six connected marshes over 60 hectares of marshland.

- Appropriate plants, algae, fungi and bacteria were seeded into this area, which neutralise, absorb and assimilate the pollutants.
- Hence, as the water flows through the marshes, it gets purified naturally.
- The marshes also constitute a sanctuary, with a high level of biodiversity in the form of fishes, animals and birds that now reside there.
- A citizens group called **Friends of the Arcata Marsh** (FOAM) is responsible for the upkeep and safeguarding of this wonderful project.

Ecological Sanitation [EcoSan]

➢ It is a sustainable system for handling human excreta, using dry composting toilets.
➢ Ecological sanitation is a sustainable system for handling human excreta using dry composting toilets.
➢ There are 'EcoSan' toilets in many areas of Kerala and Sri Lanka.
➢ Advantages of EcoSan

(a) This is a practical, hygienic, efficient and cost-effective solution of human waste disposal.

(b) Human excreta can be recycled into a resource (as natural fertiliser), which reduces the need for chemical fertilisers.

Solid Wastes

➢ Solid wastes refer to everything that goes out in trash.
➢ Sources of Solid Wastes

(a) Municipal solid wastes

- These are wastes from homes, offices, stores, schools, hospitals, etc., that are collected and disposed by the municipality.
- It includes paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc.

(b) Industrial wastes

- These are wastes from industries.
- It includes scraps, toxic heavy metals and oxides of iron, silica and aluminium.

(c) Hospital wastes

- These are the wastes from hospitals.
- It includes disinfectants and other harmful chemicals.

(d) E-wastes
- These are the wastes from electronic goods.
- It includes damaged electronic goods and irreparable computers.
- Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process.

➢ Methods of Solid Wastes Disposal

(a) Open burning
- Open burning reduces the volume of the wastes, although it is generally not burnt to completion and open dumps often serve as the breeding ground for rats and flies.

(b) Sanitary landfills
- This method was adopted as the substitute for open-burning dumps.
- In this method, wastes are dumped in a depression or trench after compaction, and covered with dirt every day.

(c) Incineration
- Hospitals generate hazardous wastes that contain disinfectants and other harmful chemicals, and also pathogenic micro-organisms.
- The incinerators are used to dispose hospital wastes.

(d) Recycling
- It is the only way to manage e-wastes. It is done in an eco-friendly way.
- It can be done in specifically built factories or manually.

(e) Rag-pickers and Kabadiwallas
- It helps to collect and separate out wastes into reusable or recyclable.

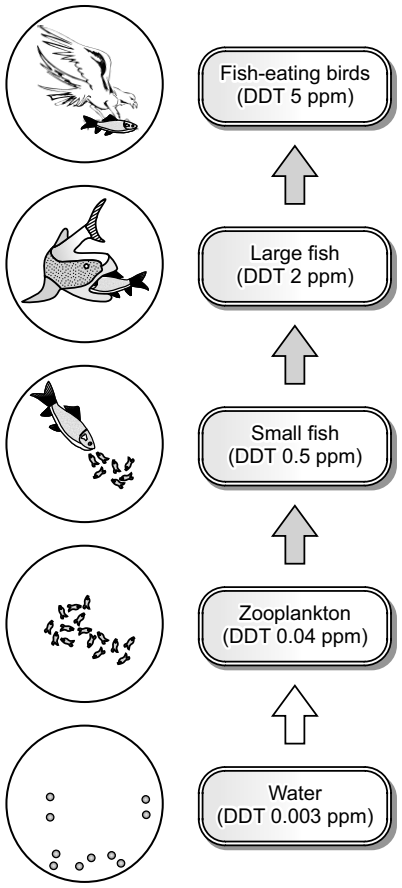


Fig. 16.4. Biomagnification of DDT in an aquatic food chain

Classification of Wastes

➢ All wastes can be categorised into three types namely,
(a) Bio-degradable.
(b) Recyclable.
(c) Non-biodegradable.

➢ The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown, that leaves only the non-biodegradable to be disposed-off. *For example,* – Compost, sewage, livestock waste, etc.

➢ The non-biodegradable materials cannot be decomposed or degraded by microbes and hence becomes complex and toxic. *For example,* – DDT, BHC, polythene bags

➢ State Governments are trying to push for reduction in use of plastics and use of eco-friendly packaging.

➢ We can use cloth or other natural fibre carry-bags instead of polythene bags for shopping.

A Case Study of Remedy for Plastic Waste

➢ **Ahmed Khan**, a plastic sack manufacturer in Bangalore developed Polyblend.

➢ It is a fine powder of recycled modified plastic.

➢ Polyblend is mixed with the bitumen and is used to lay roads.

➢ Blend of Polyblend and bitumen enhances the bitumen's water repellent properties and helps to increase road life.

Case Study of Organic Farming

➢ Ramesh Chandra Dagar, a farmer in Sonipat, Haryana included bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes, which support each other and allow an extremely economical and sustainable venture.

➢ There is no need of chemical fertilisers, as cattle excreta (dung) are used as manure.

➢ Crop waste is used to create compost, which can be used as a natural fertiliser or can be used to generate natural gas for satisfying the energy needs of the farm.

➢ Dagar has created the Haryana Kisan Welfare Club, with a membership of 5000 farmers to spread information on the practice of integrated organic farming.

Radioactive Wastes

- Nuclear energy was thought to be a non-polluting way of producing energy.
- But, the use of nuclear energy was found to have two serious problems namely,
  (a) Accidental leakage. *For example,* –Incident in the Three Mile Island and Chernobyl incidents.
  (b) Safe-disposal
- **Effects of Radioactive Wastes**
  (a) Radiation from nuclear waste is causing an extreme damage to organisms, as it causes mutations at a very high rate.
  (b) At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders.
- **Disposal Method**
  (a) It has been recommended that storage of nuclear waste, after sufficient pre-treatment, should be done in suitably shielded containers buried within the rocks, about 500 m deep below the Earth's surface.
  (b) However, this method of disposal is meeting stiff opposition from the public.

Key Terms

- **Algal Bloom:** The excess proliferation of planktonic algae imparting distinct colour and odour to the water is called algal bloom.
- **Biodegradable Pollutants:** Those pollutants which can be broken into simpler and harmless substances by the action of decomposers or microbes are called biodegradable pollutants.
- **Biological / Biochemical Oxygen Demand [BOD]:** It is a measure of oxygen required by aerobic decomposers for the biochemical degradation of biodegradable organic wastes.
- **Biomagnification:** It refers to increase in concentration of the toxicant at successive trophic levels.
- **DDT:** Dichloro diphenyl trichloroethane.
- **CNG:** Compressed Natural Gas
- **Decibel (dB):** A unit used to measure the intensity of a sound
- **Deforestation:** It is the conversion of forested areas into non-forested ones.
- **Desertification:** It is the degradation of fertile land into barren land.
- **Electronic Wastes (E-wastes):** The irreparable computers and other electronic goods are known as electronic wastes.
- **Eutrophication:** It is the natural aging of a lake by nutrient enrichment of its water.
- **Noise:** It is undesirable high level of sound.
- **Non-biodegradable pollutants:** Pollutants which cannot be broken into simpler and harmless substances by the action of decomposers or microbes are called non-biodegradable pollutants.
- **Oil spill:** Spontaneous discharge of oil, petroleum in estuaries and oceans.

Topic-2 Deforestation, Climate Change, Environment Protection

Revision Notes

Degradation By Improper Resource Utilisation and Maintenance

- The degradation of natural resources can occur by the action of pollutants as well as by improper resource utilisation practices.
  (a) Soil erosion and desertification
  - Human activities like over-cultivation, deforestation, grazing and poor irrigation practices, leads to soil erosion.
  - It results in arid patches of land and desertification.
  - Increased urbanisation also creates desertification.

  (b) Water logging and soil salinity
  - These are the problems as a part of Green Revolution.

- Irrigation without proper drainage of water leads to water logging in the soil.
- It draws salt to the surface of the soil.
- The salt is deposited on the land surface or collects at the plant roots damaging the agriculture.

Deforestation

- It is the conversion of forested areas to non-forested ones.
- Almost 40% forests have been lost in the tropics, compared to only 1% in the temperate region.
- National Forest Policy (1988) of India has recommended 33% forest cover for the plains and 67% for the hills.
- **Slash and Burn Agriculture (Jhum Cultivation):** It is practiced in the north-eastern states of India.
- In this method, the farmers cut down the trees of the forest and burn the plant remains.
- The ash is used as a fertiliser and the land is then used for farming or cattle grazing.
- After cultivation, the area is left for several years so as to allow its recovery.
- In earlier days, enough time-gap was given for recovery.
- With increasing population and repeated cultivation, this recovery phase is done away with, resulting in deforestation.
- **Reasons of Deforestation**
  (a) Forest fires.
  (b) Demand for forest products such as timber, wood, etc.
  (c) Overgrazing of animals.
  (d) Urbanisation.
- **Effects of Deforestation**
  (a) Increase in the concentration of carbon dioxide in the atmosphere.
  (b) Loss of biodiversity due to habitat destruction.
  (c) Disturbs hydrological cycle
  (d) Soil erosion and desertification

Reforestation

- The process of restoring a forest that once existed in the past is known as reforestation.
- It may occur naturally or can be planted in a deforested area.

Case Study of People's Participation in Conservation of Forests

(a) Bishnoi movement
- In 1731, the king of Jodhpur in Rajasthan asked to arrange wood for constructing a new palace.
- The minister and workers went to a forest near a village, inhabited by Bishnois.
- The Bishnois thwarted them from cutting down the trees.
- A Bishnoi woman, Amrita Devi hugged a tree and dared king 5 men to cut her first before cutting the tree.
- Sadly, the king's men cut down the tree along with Amrita Devi.
- Her three daughters and hundreds of other Bishnois followed her, and thus lost their lives saving trees.
- Government of India has instituted the Amrita Devi Bishnoi Wildlife Protection Award for individuals or communities from rural areas for extraordinary courage and dedication in protecting wildlife.

(b) Chipko Movement of Garhwal Himalayas
- In 1974, local women participated to protect trees from the axe of contractors by hugging them.
- Realising the significance of participation by local communities, the Government of India in 1980s has introduced the concept of Joint Forest Management (JFM) so as to work closely with the local communities for protecting and managing forests.
- In return for their services to the forest, the communities get benefit of various forest products (e.g., fruits, gum, rubber, medicine, etc.), and thus the forest can be conserved in a sustainable manner.

(c) Ozone depletion
- Ozone layer depletion is the gradual thinning of the Earth's ozone layer in the upper atmosphere caused due to the release of chemical compounds containing gaseous bromine or chlorine from industries or other human activities."
- Montreal Protocol (an international treaty in Canada) was signed in 1987 to control the emission of ozone depleting substances.
- Many more efforts have been made and protocols have laid down definite road maps, separately for developed and developing countries, for reducing the emission of CFCs and other ozone depleting chemicals.

(d) Global warming and green house effect

- Some of the infrared radiation from the Sun passes through the atmosphere, but most is absorbed and re-emitted in all directions by greenhouse gas (CO_2, Methane, etc.) molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
- Excess of these gases in atmosphere due to pollution increases this effect manifolds causing the increase in overall temperature of the Earth, called global warming.
- Global warming is causing melting of glaciers and ice caps on poles, rise in sea levels, disturbed natural cycles, increased flood and droughts, disturbed species composition , habitat loss, etc.
- Global warming is affecting El Nino effect. What causes the El Niño?
- Image result for El Nino effect
- An El Niño condition occurs when surface water in the equatorial Pacific becomes warmer than average and east winds blow weaker than normal. El Nino effect increases droughts and floods.

(e) Environment protection acts

- Time to time, government has made laws to improve the quality of environment. Some of these are:
- Image result for environment protection acts in India
- Water (Prevention And Control Of Pollution) Act, 1974. Air (Prevention and Control of Pollution) Act, 1977. Forest Conservation Act, 1980. Environmental Protection Act, 1986.

Key Terms

- **Soil Erosion:** It is the removal of the fertile top soil by wind and water action, human interventions like modern agricultural practices, deforestation, etc.
- **Soil Salinity/Water Logging:** It refers to the irrigation without proper drainage that leads to water logging. It brings underground salts to the surface.
- **CFC:** Chlorofluorocarbon.
- **JFM:** Joint Forest Management
- **Green house effect**: Trapping of heat by atmosphere
- **Global warming:** Increase in global temperature due to green house effect

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