UNIT - VI : Reproduction

Chapter - 1 : Reproduction in Organisms

TOPIC-1
Asexual Reproduction

Quick Review

- **Life Span :** It is the period from birth to the natural death of an organism.
- **Reproduction :** It is a process in which an organism gives rise to young ones (offspring) similar to itself.
- **Types of Reproduction :** Asexual reproduction and Sexual reproduction.
- **Asexual Reproduction :** The production of offspring by a single parent is known as asexual reproduction. The offspring produced asexually are identical to one another and also to their parent. Such morphologically and genetically similar individuals are known as clones. It is usually found in unicellular organisms and also in simple plants and animals.
- **Different Methods of Asexual reproduction**

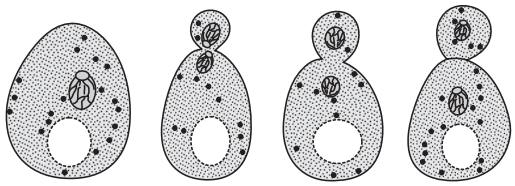
(i) Fission : In this, the parent cell divides into two or more individuals. Examples - Protists and Monerans.

Fission is of two types :

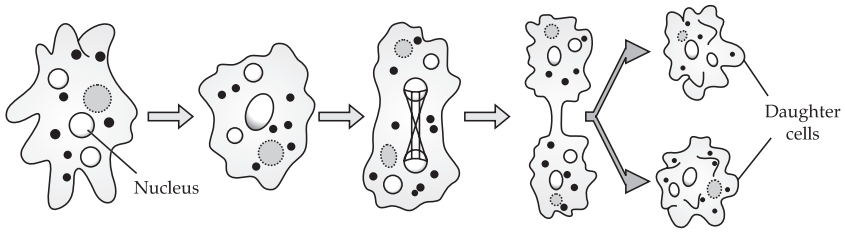
(a) Binary fission : It is the division of parent cell into two individuals. Examples - *Amoeba, Paramoecium.*

(b) Multiple fission : It is the division of parent cell into many individuals. Example – *Plasmodium*.

(ii) Budding : The formation of a daughter individual from a small projection, the bud, arising on the parent body is called budding. It occurs in Yeasts, sponges and *Hydra*.



Budding in yeast



Binary Fission in *Amoeba*

- **Other Reproductive Structures :**
  - **(a) Zoospores (motile spores)—**Found in some algae, fungi and protists.
  - **(b) Conidia (non-motile spores)—***Penicillium*.
  - **(c) Gemmules (internal buds of sponges)—**Sponges (*Spongilla*).
- **Vegetative Propagation :** In certain plants, vegetative propagules (the units of vegetative propagation such as runner, rhizome, sucker, tuber, offset and bulb) arise from the nodes of modified stems. When the nodes come in contact with damp soil or water, they produce roots and new plants. Examples,

(a) Eyes in potato—Emergence of small plants from the buds ('eyes') of the potato tuber.

(b) Rhizomes of banana and ginger.

(c) Adventitious buds—Arise from the notches present at margins of leaves of *Bryophyllum*.

(d) Bulbil—Fleshy bulb which function as vegetative propagules.

- **Sporulation :** During unfavourable conditions, some organisms get surrounded by a resistant, three layered, hard covering called cyst. The cyst consists of number of spores. These spores get liberated during favourable conditions and this process is called sporulation. *e.g.*, *Amoeba*.
- **Fragmentation :** A type of asexual reproduction, where an organism splits into fragments and each fragment develops into a new organism *e.g.*, *Spirogyra*, sponges etc.
- **Terror of Bengal :** Water hyacinth is known as terror of Bengal because it grows rapidly and enormously and hampers the growth of the native species and eliminates them. It is also known as "blue devil".

TOPIC-2
Sexual Reproduction

Quick Review

- The sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex. It results in offsprings that are not exactly identical to the parents or amongst themselves.
- All living organisms pass through three stages : Juvenile phase, Reproductive phase and Senescent phase.
  - **(i) Juvenile phase :** It is period of growth of an individual organism after its birth and before it reaches its reproductive maturity. It is known as vegetative phase in plants. It is the early phase of life cycle.
  - **(ii) Reproductive phase :** It is the phase of life cycle where the growth of the individual is slowed down but it develops the potentiality to reproduce.
  - **(iii) Senescent phase :** It is the period when an organism grows old and loses its ability to reproduce.
- In higher plants, flowering indicates the end of vegetative phase and the beginning of the reproductive phase.
- Annual and biennial plants show clear cut vegetative, reproductive and senescent phases, but in perennial species it is very difficult to identify these phases.
- Some plants exhibit unusual flowering phenomenon. They flower only once in their life time and are called **monocarpic**. Examples,
  (a) Bamboo species flower only once in their lifetime (after 50-100 years), produce large number of fruits and die.
  (b) *Strobilanthus kunthiana* (vern. Neelakuranji) flowers once in 12 years.
- In animals, juvenile phase is followed by morphological and physiological changes prior to active reproductive behaviour.
- Birds living in nature lay eggs only seasonally. However, birds in captivity (e. g. poultry) can be made to lay eggs throughout the year.
- **Oestrus cycle :** The females of placental mammals exhibit cyclic changes in the activities of ovaries, accessory ducts and hormones during the reproductive phase. These cyclic changes are called oestrus cycle. It is seen in non-primates such as cows, sheep, rat, deer, dog, tiger etc. It is menstrual cycle in primates such as monkeys, apes and humans.
- **Seasonal breeders :** The mammals which live in natural conditions exhibit reproductive cycles only during favourable seasons and are called seasonal breeders.
- **Continuous breeders :** The mammals that are reproductively active throughout their reproductive phase are called continuous breeders.

Senescence (Old age) :

- It is the last phase of life span and the end of reproductive phase.
- During this stage, the metabolism slows down which ultimately leads to death.
- In plants and animals, hormones are responsible for transition between juvenile, reproductive and senescence phases.

Events in Sexual Reproduction

(i) PRE-FERTILISATION EVENTS

- This includes all events prior to the fusion of gametes.
- It comprises : (a) Gametogenesis and (b) Gamete transfer.

(a) Gametogenesis

- It is the process of formation of male and female gametes (haploid sex cells).
- **Homogametes/Isogametes :** In this type, all gametes are similar *i.e.,* gametes cannot be categorized into male and female gametes. The fusion of two such gametes is called isogamy *i.e.,* Algae.
- **Heterogametes :** In this type, the male and female gametes can be distinguished. Male gamete is called the antherozoids or sperm and the female gamete is called the egg (ovum or oosphere) a.g. Humans.
- Union between non-motile egg or ovum or oosphere and motile sperm or antherozoid is called oogamy.

Sexuality in Organisms

- **Bisexual/Monoecious plants :** In these plants, male and female reproductive structures are found in the same plant.
- **Unisexual/Dioecious plants :** In these plants, the male and female reproductive structures are found on different plants.
- In unisexual/monoecious/flowering plants, the male and female flowers are present on the same individual. *e.g.*, Cucurbits & coconuts.
- Fungi may be homothallic (bisexual) or heterothallic (unisexual).
- Bisexual animals (hermaphrodites) : Earthworms, leech, sponge, tapeworm, etc.
- Unisexual animals : Cockroach, higher animals, etc.

Cell Division during Formation of Gametes

- Haploid parental body produces haploid gametes by mitosis. It is seen in Monera, Fungi, Algae and Bryophytes.
- Diploid parental body produces haploid gametes by meiosis of meiocytes (gamete mother cell). It is seen in Pteridophytes, Gymnosperms, Angiosperms & animals.

(b) Gamete Transfer

- Male gametes need a medium to move towards female gametes for fertilisation.
- In simple plants such as Algae, Bryophytes and Pteridophytes, the transfer of gamete takes place through water medium.
- To compensate the loss of male gametes during transport, a large number of male gametes is produced.
- In seed plants, pollen grains containing male gametes are transferred from anthers to stigma where they germinate to form pollen tube. Pollen tube carries male gamete to the egg or female gamete for fertilization.
- In bisexual or self-fertilizing plants, the transfer of pollen grains to the stigma is easy as anthers and stigma are located close to each other. Example – pea.
- In unisexual or cross pollinating plants, the pollinating agencies help in transfer of pollen grains to the stigma. Pollen grains germinate on the stigma and the pollen tube carrying the male gametes reach the ovule and discharge male gametes near the egg.
- In Dioecious animals, male and female gametes are formed in different individuals, organisms usually bear a specific method for gamete transfer.

(ii) FERTILISATION EVENTS

- It is the fusion of gametes to form a diploid zygote. It is also known as syngamy.
- **Parthenogenesis :** It is a phenomenon whereby egg formation takes place without fertilization. The adults produced by parthenogenesis are often haploid, and their cells do not undergo meiosis in forming new gametes. E.g. Rotifers, honeybees, some lizards and birds (turkey).

Types of Fertilisation :

- Depending upon the site of syngamy, fertilization is of the following two types :

(1) External fertilisation

- In this type, fertilisation or syngamy occurs in the external medium (water), *i.e.* outside the body of the organism. Examples - Aquatic organisms like algae, bony fishes and amphibians.
- Disadvantage : The offspring are extremely vulnerable to predators, threatening their survival up to adulthood.

(2) Internal fertilisation

- In this type, fertilisation or syngamy occurs inside the body. *e.g.*, terrestrial organisms, belonging to fungi, animals like reptiles, birds, mammals and plants like Bryophytes, Pteridophytes, Gymnosperms & Angiosperms. Large number of sperms are produced but the number of eggs is very low.

(iii) POST-FERTILISATION EVENTS

- It includes the events after the formation of zygote.

Zygote

- Every sexually reproducing organism begins its life as a zygote.
- It is the vital link between organisms of one generation to the next.
- The development of zygote depends on the type of life cycle of the organism and the nature of environment.
- In fungi and algae, zygote secretes a thick wall around itself which provide resistant to desiccation and damage. It undergoes a period of rest before germination.
- In organisms with haplontic life cycle, zygote divides by meiosis into haploid spores that grow into haploid individuals. In organisms with diplontic cycle, zygote divides by mitosis and develops into diploid embryo.

Embryogenesis

- It is the process of the development of embryo from the zygote.
- The zygote undergoes cell division (mitosis) and cell differentiation.
- The cell division increases the number of cells in the embryo.
- Cell differentiation causes the modifications of groups of cells into various tissues and organs to form an organism.

Types of Animals based on site of development of embryo

(i) **Oviparous :** Here, animals lay fertilized/unfertilized eggs. Examples – In reptiles & birds, the fertilized eggs covered by hard calcareous shell are laid in a safe place. After incubation, young ones hatches out. In most amphibians, unfertilized eggs are laid in water by female where they are fertilized by sperms produced by male.

(ii) **Viviparous :** Here, the zygote develops into a young one inside the female body. Later, the young ones are delivered out from the body. Example - mammals. Because of proper care and protection, the chances of survival of young ones are greater in viviparous animals.

(iii) In flowering plants, zygote is formed inside the ovule. After fertilisation, sepals, petals and stamens of flower wither and fall off. The zygote develops into embryo and ovules develop into seeds. The ovary develops into fruits which develop a thick wall called pericarp, which is protective in function. After dispersal, seeds germinate under favourable condition to produce new plants.

Know the Terms

- **Juvenile phase :** It is the period of growth of an individual organism after its birth and before it reaches its reproductive maturity.
- **Reproductive phase :** It is the phase in which an individual can give maximum number of births.
- **Ageing or senescence phase :** It is the period when an organism grows old and loses the ability to reproduce.
- **Reproduction :** Reproduction is the process of formation of new individuals of a species from the pre-existing ones.
- **Clone :** Morhologically and genetically similar individuals are called clone.
- **Gametogenesis :** Process of formation of gametes is gametaogenesis.
- **Pollination :** Transfer of pollen grains from anther to stigma is pollination.
- **Meiocytes :** These are specialized cells of diploid organisms which undergo meiosis to produce gametes.

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Chapter - 2 : Sexual Reproduction in Flowering Plants

TOPIC-1
Sexual Reproduction in Flowering Plants

Quick Review

- Flowers are the site of sexual reproduction in flowering plants.
- Parts of a typical angiospermic flower are : sepals, petals, stamens and pistils.
- The four whorls of the flower are attached on a central axis called thalamus.
- A flower can be bisexual (contains both male and female reproductive parts) or unisexual (Only either of the reproductive parts are present).

Male Reproductive Structures

Androecium (Whorl of Stamens)

- Androecium consists of a whorl of stamens.
- The number and length of the stamens are variable in flowers of different species.
- A stamen has three parts namely, Anther, Filament and Connective.

(a) Anther

- It is the terminal and bilobed part of stamens attached with filament. A bilobed anther is called dithecous.
- Each lobe has two pollen sacs or microsporangia. Therefore the anther is tetrasporangiate.
- A longitudinal groove runs lengthwise separating the theca.

(b) Filament
- It is the long and slender stalk part of the stamen.
- Its proximal end is attached to the thalamus or petals of the flower.

(c) Connective
- The structure which connects the anther lobes together is known as connective.

Transverse section of an anther
- The anther is tetragonal in structure consisting of four microsporangia or pollen sacs located at the corners, two in each lobe.
- The microsporangia develop to become pollen sacs.
- They extend longitudinally throughout the length of an anther.
- These are packed with pollen grains.

Structure of microsporangium or Pollen sac
- It is circular and is generally surrounded by wall layers namely,
  (a) Epidermis **(b)** Endothecium
  (c) 2 or 3 Middle layers **(d)** Tapetum
- The first two layers perform the function of protection and help in dehiscence of anther to release the pollens.
- The middle layers and the innermost layer, (tapetum) nourishes the developing pollen grains.
- The cells of the tapetum possess dense cytoplasm and more than one nuclei.
- When the anther is young, a group of compactly arranged homogenous cells called sporogenous tissues occupies the centre of each 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.

Dehiscence of anther
- The microspores get arranged in a group of four cells and hence are microspore tetrad.
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains.
- From each microsporangium, thousands of pollen grains are formed and released due to the dehiscence of anther.

Pollen grain (Male gametophyte)
- Pollen grain germinate and give rise to male gametophyte.
- These are spherical, measuring about 25-50 micrometers in diameter.
- Pollen grains are well preserved as fossils due to the presence of sporopollenin, a tough, resistant and stable material.
- A pollen grain has a two-layered wall namely, Exine and Intine.

(a) Exine :
- Exine 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 temperature and strong acids and alkali.
- It cannot be degraded by enzymes.
- The exine has 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 contain 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 to give rise the 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 **Leguminoseae, Rosaceae & Solanaceae** have viability for months.
- Pollen grains of some plants like *Parthenium* 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.

Female Reproductive Structure

Gynoecium (Pistil)

- It represents the female reproductive part of the flower.
- If it consists of a single pistil or carpel, it is known as monocarpellary or if it has more than one pistil or carpel, it is called multicarpellary.
- When there is more than one carpels they may be fused together then the pistil is known as syncarpous or may be free then it is known as apocarpous.
- Each carpel has three parts namely, Stigma, Style and Ovary.

(a) Stigma

- It is a landing platform for pollen grains.

(b) Style

- It is an elongated slender part beneath the stigma.

(c) Ovary

- It is the basal swollen part of the carpel.
- Inside the ovary is the ovarian cavity called locule where the placenta is located.
- Placenta contains the ovules or megasporangia.
- The number of ovules in an ovary may be one as seen in wheat, paddy, mango etc., or many as seen in papaya, watermelon, orchids, etc.

Megasporangium (Ovule)

- It 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 some times three protective coverings called integuments.
- Integuments encircle the ovule except at the tip where a small opening called micropyle is organized.
- 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 which contains reserve food materials.
- Inside the nucellus there is embryo sac, which is also called as the female gametophyte.
- An ovule has a single embryo sac usually formed from a single haploid megaspore.

Megasporogenesis

- The formation of haploid megaspores from the diploid megaspore mother cell (MMC) as a results 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.

Female gametophyte (Embryo sac)

- In most of the flowering plants, only one megaspore 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.

Development of Female gametophyte

- The nucleus of the functional megaspore divides mitotically to form two nuclei which move towards the opposite poles, forming two-nucleated embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the four-nucleated and later the eight-nucleated stages of the embryo sac.
- These divisions are strictly free nuclear, *i.e.* nuclear divisions are not followed immediately by cell wall formation.
- After eight-nucleate stage, the organization of the typical female gametophyte or embryo sac takes place.
- Generally six of the eight nuclei are surrounded by cell walls and organized 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 tubes into the synergid.
- Three cells at the chalazal end organize as the antipodals.
- Thus, a typical mature angiosperm embryo sac at maturity is eight-nucleate but seven-celled.

TOPIC-2

Pollination and Fertilization

Quick Review

- The process of transfer of pollen grains from the anther to the stigma of a pistil is known as pollination.
- There are few external agents which help the plants for pollination to take place.
- The Pollination is of three types based on the source of pollens namely,
  (a) Autogamy **(b)** Geitonogamy **(c)** Xenogamy

Autogamy

- When the pollen grains are transferred from the anther to the stigma of the same flower, it is known as autogamy.
- In flowers with exposed anthers and stigma, a complete autogamy is rare and hence the anthers and stigma should lie close to each other to enable self-pollination. Alongwith this there should be synchrony in pollen release and stigma receptivity.
- Plants like *Viola* (common pansy), *Oxalis* and *Commelina* produce two types of flowers namely Chasmogamous flowers and Cleistogamous flowers.

(a) Chasmogamous flowers

- They are similar to flowers of other species with exposed anthers and stigma.

(b) Cleistogamous flowers

- They do not open at all.
- Anthers and stigma lie close to each other.
- They are autogamous as there is no chance of cross-pollination.
- When anthers dehisce in the flower buds, pollen grains come in contact with the stigma for pollination.
- Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

Geitonogamy

- When the pollen grains are transferred from the anther to the stigma of another flower of the same plant, it is known as geitonogamy.
- It involves pollination with the help of a pollinating agent. It is structurally cross-pollination but genetically self-pollination.
- It is genetically similar to autogamy because the pollen grains come from the same plant.

Xenogamy

- When the pollen grains are transferred from anther to the stigma of a different plant, it is known as xenogamy. It brings about genetically different types of pollen grains to the stigma.

Agents of pollination :

- There are two type of agents of pollination namely :
  (a) Biotic agents **(b)** Abiotic agents

Abiotic Agents

- There are two abiotic agents namely, wind and water which help pollination to takes place.

Pollination by Wind

- The pollination taking place by wind is called anemophily.
- Wind and water pollinated flowers are not very colourful and do not produce nectar.
- Wind pollinated flowers often have a single ovule in each ovary.
- Numerous flowers remain packed into an inflorescence.
- Examples – In Corn cob, the tassels are the stigma and style which wave in the wind to trap pollen grains, and also seen in grasses.

Characteristics of Anemophilous flowers

- The flowers produce enormous amount of pollen.
- The pollen grains are light and non-sticky so that they can be transported in wind currents.
- They often possess well-exposed stamens for easy dispersal of pollens into wind currents.
- They have large, feathery and sticky stigma to trap air-borne pollen grains.

Pollination by Water

- The pollination taking place by water is called hydrophily.
- It is limited to about 30 genera, mostly monocotyledons.
- In *Vallisneria*, the female flowers reach the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water. These male flowers or pollen grains are carried by water currents and reach the female flowers.

- In sea grasses, the female flowers remain submerged in water and the long, ribbon-like pollen grains are carried inside the water and reach the stigma.
- The pollen grains of most of the water-pollinated species have a mucilaginous covering to protect from wetting.
- Not all aquatic plants use hydrophily. For example, in aquatic plants like water hyacinth, water lily, etc., the flowers emerge above the level of water for entomophily or anemophily *i.e.*, for pollination to takes place by insects or wind.
- It is seen in *Vallisneria* & *Hydrilla* (fresh water), *Zostera* (marine sea-grasses) etc.

Biotic Agents

- Some flowering plants use animals as pollinating agents like Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) bats, some primates (lemurs), arboreal (tree-dwelling) rodents, reptiles (gecko lizard & garden lizard) etc.
- When the pollination takes place by insects, it is known as entomophily.
- Often flowers of animal pollinated plants are specifically adapted for a particular species of animal.
- When the animal comes in contact with the anthers and the stigma, its body gets a coating of pollen grains and when it comes in contact with the stigma, it results in pollination.
- Some plants provide safe places as floral reward to lay eggs as seen in *Amorphophallus*, the tallest flower.
- There is a very close obligatory symbiotic relationship between the species of moth (*Pronuba*) and the plant *Yucca*. They cannot complete their life cycles without each other. The moth deposits its eggs in the locule of the ovary and the flower gets pollinated by the moth. The larvae of the moth come out of the eggs as the seeds start developing.
- There are many insects which consume pollen or nectar without bringing about pollination. They are called pollen/nectar robbers.

Characteristics of Entomophilous Flowers

- Flowers are large, colourful, fragrant and rich in nectar.
- When the flowers are small, they form inflorescence to make them visible.
- The flowers pollinated by flies and beetles secrete foul odours to attract these animals.
- The pollen grains are generally sticky.

Outbreeding Devices (Devices for promoting Cross Pollination)

- In order to avoid self-pollination, cross-pollination is encouraged in plants as follows :

(a) Avoiding Synchronization

- In some species, pollen release and stigma receptivity are not synchronized.
- Either the pollen is released before the stigma becomes receptive or stigma becomes receptive before the release of pollen *i.e.*, the anther and stigma mature at different times. This phenomenon is called dichogamy. It prevents autogamy.

(b) Arrangement of Anther and Stigma at different Positions

- In some species, the arrangement of anther and stigma at different positions prevents autogamy.

(c) Self-incompatibility

- It is a genetic mechanism which prevents pollen of one flower to germinate on the stigma of the same flower on of the same plant due to the presence of similar sterile genes in pollen and stigma.

(d) Production of Unisexual Flowers (Decliny)

- Monoecious plants such as castor and maize, where the male and the female flowers are present on the same plant prevents autogamy but not geitonogamy. On the other hand, dioecious plants like papaya, where the male and female flowers are present on different plants prevents both autogamy and geitonogamy.

Pollen-pistil Interaction

- It is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.
- This interaction takes place through the chemical components produced by them.
- If the pollen is compatible, then the pistil accepts it and promotes post-pollination events.
- 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.
- The pollen tube grows through the tissues of the stigma and style and reaches the ovary.
- If the pollen is incompatible, then the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
- In some plants, the pollen grains are shed at two-celled stage, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma.
- In plants which shed pollen in the three-celled stage, the pollen tubes carries two male gametes from the beginning.

- The pollen tube, after reaching the ovary, enters the ovule through the micropyle chalaza/integuments and then enters one of the synergids through the filiform apparatus.
- The filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.
- A plant breeder can manipulate pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

Artificial Hybridisation

- It is one of the major approaches of crop improvement programme by using desired pollen grains for pollination.
- This is achieved by emasculation and bagging techniques.
- Emasculation is the removal of anthers by using forceps from the bisexual flower bud of female parent before the anther dehisces.
- The emasculated flowers are then covered with a suitable bag made up of butter paper to prevent contamination of its stigma with unwanted pollen. This is called bagging.
- When the stigma attains receptivity, the mature pollen grains collected from anthers of the male parent are dusted on the stigma. Then the flowers are rebagged and allowed to develop the fruits.
- If the female parent produces unisexual flowers, there is no need for emasculation.
- The female flower buds are bagged before the flowers open.
- When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

Double Fertilisation

- The pollen tube after entering one of the synergids releases its contents including 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 by the process of syngamy to form a diploid cell called zygote.
- The other male gamete moves towards the two polar nuclei located 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, it is called triple fusion.
- Since two types of fusions viz. syngamy and triple fusion take place in an embryo sac, it is called double fertilisation.
- The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote develops into an embryo.
- It is an event unique in flowering plants.

TOPIC-3

Post-Fertilization Changes and Special Modes of Reproduction

Quick Review

Post-fertilisation Events

- The development of endosperm and embryo development and the maturation of ovule(s) into seed(s) and ovary into fruit are post-fertilisation events.

Endosperm Development

- The primary endosperm cell divides repeatedly by mitosis to form a triploid endosperm tissue.
- Endosperm cells are filled with reserve food materials which are used for the nutrition of the developing embryo.
- During the endosperm development, the primary endosperm nucleus undergoes successive mitotic nuclear divisions to give rise to free nuclei. This stage is called free-nuclear endosperm.
- Then the endosperm becomes cellular due to the cell wall formation.
- For example, the tender coconut water is a free-nuclear endosperm which is made up of thousands of nuclei and the surrounding white kernel is the cellular endosperm.

Embryo Development

- The embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- The zygotes divides only after the formation of certain amount of endosperm in order to provide nutrition to the developing embryo.
- The development of embryo is similar in monocotyledons and dicotyledons upto octant stage.
- The zygote gives rise to the proembryo and subsequently to the globular, heart-shaped and mature embryo.

Dicotyledonous Embryo

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

Monocotyledonous Embryo

- They possess only one cotyledon.
- In the grass family, the cotyledon is called scutellum which is situated lateral to the embryonal axis.
- At its lower end, the embryonal axis has the radicle and root cap enclosed in an undifferentiated sheath called coleorhizae.
- The portion of embryonal axis above the level of attachment of scutellum is the epicotyl.
- It has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure called coleoptile.

Seed

- Seed is the final product of sexual reproduction.
- It is the fertilized ovule formed inside fruits.
- It consists of seed coat(s), cotyledon(s) and an embryonal axis.
- The cotyledons are simple, thick and swollen due to storage of food as seen in most of the dicots.
- Mature seeds may be non-albuminous or albuminous.

Non-albuminous or Non-endospermic Seeds

- These seeds have no residual endosperm as it is completely consumed during embryo development.
- Examples - pea, groundnut, beans.

Albuminous or Endospermic Seeds

- These seeds retain a part of endosperm as it is not completely used up during embryo development.
- Examples, wheat, maize, barley, castor, coconut, sunflower.
- In some seeds like black pepper, beet etc., the remnants of nucellus is also persistent. It is called perisperm.
- Integuments of ovules harden as tough protective seed coats.
- It has a small pore (micropyle) through which oxygen and water enter into the seed during germination.
- As the seed matures, its water content gets reduced and the seeds become dry (10-15 % moisture by mass). The general metabolic activity of the embryo slows down.
- The embryo may enter a state of inactivity (dormancy).
- If favourable conditions are available such as adequate moisture,oxygen and suitable temperature, they germinate.

Fruit

- The ovary develops into a fruit after pollination and fertilization.
- The transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
- The wall of ovary develops into pericarp.
- The fruits may be fleshy as seen in guava, orange, mango, etc., or may be dry as seen in groundnut, mustard, etc.,
- Many fruits have mechanisms for dispersal of seeds.
- Fruits are of two types namely :
  (a) True fruits
  (b) False fruits

True Fruits

- When the fruit develops only from the ovary and other floral parts degenerate and fall off, they are called true fruits.

False Fruits

- When parts of flower other than ovary also contribute to the fruit formation, they are called false fruits. Examples – apple, strawberry, cashew, etc.
- In some species such as banana, the fruits develop without fertilisation, these fruits are called parthenocarpic fruits.
- Parthenocarpy can be induced through the application of growth hormones. Such fruits are seedless.

Advantages of Seeds

- The pollination and fertilisation processes are independent of water while the seed formation is more dependable.
- Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonize in other areas.
- They have food reserves and so young seedlings are nourished until they are capable of photosynthesis.
- The hard seed coat protects the young embryo.
- Since seeds are the products of sexual reproduction, they generate new genetic combinations leading to variations.
- The dehydration and dormancy of mature seeds are crucial for storage of seeds.
- It can be used as food throughout the year and also to raise crop in the next season.

Viability of Seeds after Dispersal

- In a few species the seeds lose viability within a few months or live for several years.
- Some seeds remain alive for hundreds of years.
- The oldest is lupine (*Lupinus arcticus*) excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy.
- 2000 years old viable seed is of the date palm (*Phoenix dactylifera*) discovered during the archeological excavation at King Herod's palace near the Dead Sea.

Apomixis and Polyembryony

- Apomixis is (apo = with out; mixis = mixing together) means the production of seeds without fertilisation.
- It is seen in some species of Asteraceae and grasses.
- Apomixis is a form of asexual reproduction that mimics sexual reproduction.
- Occurrence of more than one embryos in a seed is called as polyembryony.

Development of Apomictic Seeds

- In some species, the diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.
- In species like Citrus and Mango varieties, some of the nucellar cells surrounding the embryo sac divide and protrude into the embryo sac and develop into the embryos. Hence, in these species each ovule contains many embryos.

Importance of Apomixis in Hybrid Seed Industry

- Hybrid seeds have to be produced every year.
- If the seeds collected from hybrids are sown, the plants in the progeny will segregate and lose hybrid characters.
- The production of hybrid seeds is costly. Hence the cost of hybrid seeds is also expensive for the farmers.
- If the hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. This helps farmers to use the hybrid seeds to raise new crop year after year without losing hybrid characteristics.

Know the Terms

- **Microsporogenesis :** It is process of formation of mircospores from a pollen mother cell (PMC) through meiosis.
- **Megasporogenesis :** It is the process of formation of the four megaspores from the megaspore mother cell (MMC) in the region of nucellus through meiosis.
- **Self-Pollination or autogamy :** It is the transfer of pollen from anther to the stigma of the same flower.
- **Geitonogamy :** It is the transfer of pollen grains from the anther to the stigma of another flower of the same plant.
- **Xenogamy :** It is the transfer of pollen grains from anther to the stigma of a different plant.
- **Anemophily :** Pollination by wind is called anemophily.
- **Hydrophily :** Pollination by water is called hydrophily.
- **Ornithophily :** Pollination by bird is called ornithophily.
- **Chiropterophily :** Pollination by bat is called chiropterophily.
- **Entomophily :** Pollination by insects is called entomophily.
- **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.
- **Emasculation :** It is the process of removal of anthers (using forceps) from the bisexual flower bud without affecting the female reproductive part *i.e.,* pistil.
- **Coleorrhiza :** It is undifferentiated sheath that encloses the radicle and root cap in a monocot seed.
- **Perisperm :** Remnants of nucellus in matured seed are known as perisperm.
- **True fruits :** Fruits that develop from the ovary are called true fruits.
- **False fruits :** Fruits that develop from the thalamus are called as false fruits.
- **Parthenocarpic fruits :** Fruits that develop without fertilisation are called parthenocarpic fruits.
- **Apomixis :** It is production of seeds without involving the process of meiosis and syngamy.

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Chapter - 3 : Human Reproduction

TOPIC-1
Male and Female Reproduction System

Quick Review

Male Reproductive System

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

Testes

- Testes are the primary sex organs that produce sperms and testosterone.
- Testes are contained in the scrotum located between 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 sperm are produced.
- Seminiferous tubule is lined internally with spermatogenic cells called spermatogonia or primary male germ cells and sertoli cells, or supporting cells.
- Spermotogonia undergo meiotic divisions and leads to sperm formation.
- Sertoli cells give shape and nourishment to developing spermatogenic cells and therefore also called as **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 open into epididymis.
- The epididymis leads to vas deferens that ascends into the abdomen and loops over the urinary bladder.
- It receives a duct from 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, prostate 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 is rich in mucus. It helps in the lubrication of the penis, supplies nutrient to sperms and provides an alkaline medium to counteract the acidity of the uterus.

External Genitalia

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

The Female Reproductive System

- It includes a pair of **Ovaries, Accessory ducts and External genitalia**.

Ovaries

- They are the primary female sex organs which produce ova or the female gametes and having a number of steroid ovarian hormones such as estrogen and progesterone.
- Ovaries are located on both side in the lower abdomen.
- 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 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 fimbriae for catching 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 oviduct which passes into the uterus.

Uterus

- It is single and also called a 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 vagina through a narrow cervix.
- The cavity of the cervix is called cervical canal which along with 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 menstrual cycle while the myometrium exhibits strong contraction during delivery of the 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 penis 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 partially by a membrane called hymen.
- The hymen is often torn during the first coitus (intercourse) or accidentally.
- 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 tissue and fat, is 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 sucked out.

TOPIC-2
Gametogenesis and Menstrual Cycle

Quick Review

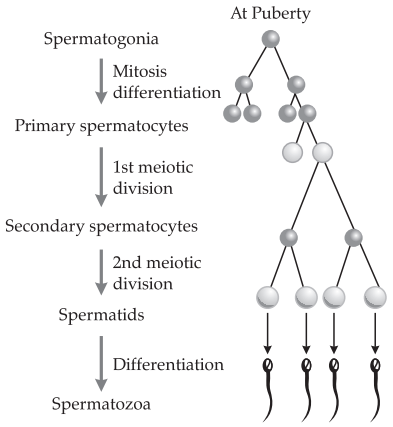
Gametogenesis

- The process of formation of gametes or sex cells is known as gametogenesis.
- It includes spermatogenesis and oogenesis.

Spermatogenesis

- It is the process of formation of sperms in seminiferous tubules of testes.
- It has two stages namely,
  (a) Formation of spermatids **(b)** Spermiogenesis
- During the formation of spermatids, the spermatogonia *i.e.*, Sperm mother cells or immature male germ cells produce spermatids.
- In spermiogenesis, the spermatids are transformed into sperm.

Schematic Representation of Spermatogenesis



- Each primary spermatocyte undergoes meiosis-I and produces two haploid secondary spermatocytes.
- Each secondary spermatocyte divides by meiosis-II and produces two haploid spermatids.
- Thus, four spermatids are formed from each primary spermatocyte.
- The spermatids, under the influence of FSH of anterior pituitary are converted into spermatozoa. The process is called spermiogenesis.
- After spermiogenesis, sperm head become embedded in the Sertoli cells and are finally released from seminiferous tubules. The process of release of mature spermatozoa from the sertoli cells into the lumen of seminiferous tubules is known as spermiation.

Hormones in Spermatogenesis

- Hypothalamus releases large amount of Gonadotropin releasing hormone (GnRH).
- GnRH stimulates the anterior pituitary gland to secrete two gonadotropins namely Luteinizing hormone (LH) and follicle stimulating hormone (FSH).
- LH acts on the Leydig cells and stimulates synthesis and secretion of androgens which in turn stimulate the spermatogenesis.
- FSH acts on the Sertoli cells and stimulates secretion of some spermogenic factors which help in the process of spermiogenesis.

Structure of Sperm

- It is a microscopic structure.
- A mature sperm measures about 60 μm (0.06 mm) long.
- A plasma membrane envelops the whole body of sperm.
- Sperm consists of four parts namely, head, neck, a middle piece and a tail region.

(a) Head

- It is oval shaped, consisting of nucleus and acrosome.
- Acrosome is formed from golgi complex which contains lytic enzymes, that help in fertilisation of the ovum.

(b) Neck

- Behind the head is a neck containing proximal and distal centrioles.
- The distal centriole of the neck is connected to axial filament.

(c) Middle Piece

- It is composed of axial filament surrounded by numerous mitochondria and cytoplasm.
- Mitochondria produce energy for the sperm motility.

(d) Tail

- It consists of a central axial filament.
- The sperm moves in fluid medium and female genital tract by the undulating movement of the tail.
- Sperms are transported through the accessory ducts.
- The secretions of epididymis, vas deferens, seminal vesicle and prostate are essential for maturation and motility of sperms.
- The seminal plasma and sperms together constitute the semen.
- The human male ejaculates about 200-300 million sperms during a coitus ejaculation.
- For normal fertility at least 60% sperms must have normal shape and size and 40% of them must show vigorous motility.

Oogenesis

- It is the process of formation and maturation of ovum.
- It takes place in Graafian follicles.
- It is initiated in embryonic stage when millions of egg mother cells (oogonia) are formed within each ovary.
- No oogonia are formed and added after birth.
- Oogonia multiply to form primary oocytes which enter into prophase-I of the meiosis and get temporarily arrested at that stage.
- Each primary oocyte gets surrounded by a layer of granulosa cells to form primary follicle.
- A large number of primary 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 to form secondary follicles.
- The secondary follicles get transformed into a tertiary follicle.
- It has a fluid filled cavity (antrum).
- The theca layer forms an inner theca interna and an outer theca externa.
- The primary oocyte within the tertiary follicle grows in size and undergoes first unequal meiotic division to form a large haploid secondary oocyte and a tiny first polar body.
- The secondary oocyte retains the nutrient rich cytoplasm of the primary oocyte.
- It is unknown, whether the first polar body divides further or degenerates.
- The tertiary follicle further changes into the mature follicle (Graafian follicle).
- The secondary oocyte forms a new membrane (zona pellucida).
- The Graafian follicle now ruptures to release the secondary oocyte (ovum) from the ovary. This is called ovulation.

Structure of Ovum

- It is spherical or oval and non-motile female gamete.
- It is about 0.2 mm in diameter.
- Human ovum is non cleidoic (without shell) and alecithal (with out yolk).
- Ovum has four membranes namely,
  - **(a) Plasma membrane (Oolemma) :** Innermost layer.
  - **(b) Vitelline membrane :** Attached to plasma membrane.
  - **(c) Zona pellucida :** Transparent non-cellular, thick, glycoprotein rich layer found outer to the vitelline membrane.
  - **(d) Corona radiata :** Outer layer formed of follicle cells. These cells are held together by mucopolysaccharide called hyaluronic acid.

Menstrual Cycle

- The reproductive cycle in the human female and related primates is called menstrual cycle.
- The first menstruation begins at puberty (at the age of 10-12 years) 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 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.
- The menstrual flow results due to breakdown of endometrial lining of the uterus and its blood vessels which form the liquid that comes out through vagina.
- Menstruation occurs only if the released ovum is not fertilised.
- Lack of menstruation may be indicative of pregnancy or may also be caused due to some other underlying causes like stress, poor health etc.
- The menstrual phase is followed by the follicular phase.
- During follicular 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 gradually during the follicular phase, and stimulates follicular development as well as secretion of estrogens by the growing follicles.
- Both LH and FSH attain a peak level in the middle of cycle (about 14^{th} 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 (ovulatory phase) is followed by the luteal phase during which the remaining parts of the Graafian follicle transform as the corpus luteum.

- The corpus luteum secretes large amounts of progesterone which is essential for maintenance of the endometrium.
- During pregnancy, all events of the menstrual cycle stop and there is no menstruation.
- In the absence of fertilisation, the corpus luteum degenerates. This causes disintegration of the endometrium leading to menstruation, marking a new cycle.
- In human beings, menstrual cycle ceases at around 50 years of age and is termed as menopause.
- Cyclic menstruation is an indicator of normal reproductive phase and extends between menarche and menopause.

TOPIC-3
Fertilization and Post-Fertilization Events

Quick Review

Fertilization

- The process of fusion of male gamete (sperm) with the female gamete (ovum) is called fertilization.
- During copulation, semen is released through the penis into the vagina (insemination).
- After insemination, the sperms swim through the cervix and enter into the uterus and reach the ampullary-isthmic junction of the oviduct where fertilization takes place.
- The process of fertilization takes place as follows :

Sperms → vagina → cervical canal → uterus → isthmus
↓
Fertilization ← Ampullary-isthmic Junction
↑
Ovum (from ovary) → fimbriae → infundibulum → ampulla

- Fertilization (sperm + ovum → zygote) occurs only if ovum & sperms are transported simultaneously. So all copulations do not lead to fertilization and pregnancy.
- As a sperm contacts with zona pellucida, it induces changes in the membrane that block entry of additional sperms.
- With the help of enzymes of the acrosome, which dissolve the zona pellucida and plasma membrane of the ovum, the sperm enters into the cytoplasm of the ovum. This induces second meiotic division of the secondary oocyte to form a second polar body and a haploid ovum (ootid).
- The haploid nuclei of the sperm and ovum fuse together to form a diploid zygote.

Implantation

- The mitotic division (cleavage) starts as the zygote moves through the isthmus of oviduct towards the uterus and forms 2, 4, 8, 16 daughter cells called blastomeres.
- The embryo with 8-16 blastomeres is called a morula.
- Morula continues to divide and transforms into a large mass of cells called blastocyst, which moves further towards the uterus.
- The blastomeres in the blastocyst are arranged into an outer layer (trophoblast) and an inner group of cells (inner cell mass) attached to trophoblast.
- The trophoblast layer then gets attached to endometrium and the inner cell mass gets differentiated to three germ layers namely, outer ectoderm, middle mesoderm and inner endoderm forming 3-layered structure (gastrula) leading to the formation of embryo.
- After attachment, 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.

Pregnancy and Embryonic Development

- After implantation, the finger-like projections called chorionic villi appear on the trophoblast which is surrounded by the uterine tissue and maternal blood.
- The chorionic villi and uterine tissue become interdigitated with each other and form a structural and functional unit between developing embryo and the maternal body called placenta.
- The placenta is a structural and functional unit between embryo (foetus) and maternal body.
- Placenta is connected to the embryo by an umbilical cord.
- The umbilical cord helps to transport substances to and from the embryo.

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 the gas 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

- During pregnancy, levels of estrogen, progestogen, cortisol, prolactin, thyroxine etc are also increased in maternal blood.
- They support the fetal growth, metabolic changes in the mother and maintain pregnancy.
- Three germ layers (ectoderm, endoderm, mesoderm) give rise to all tissues (organs) in adults.
- The stem cells in inner cell mass have the potency to give rise to all the tissues and organs.
- Human pregnancy (gestation period) lasts 9 months (for cats : 2 months, dogs : 2 months, elephants : 21 months).

Changes in Embryo during Pregnancy

- After one month of pregnancy : Heart is formed.
- End of second month : Limbs and digits are developed.
- End of 12 weeks (first trimester) : The major organs such as limbs, external genital organs etc., are well developed.
- During 5th month : First movement of foetus and appearance of hair on the head.
- End of 24 weeks (second trimester) : Body is covered with fine hair, eyelids separate and eye lashes are formed.
- End of 9 months : Ready for delivery.

Parturition (Labour) and Lactation

- The process of giving birth to young ones after the gestation period of nine months is known as parturition.
- Parturition is induced by neuroendocrine mechanism.
- The signals originating from the foetus and placenta induce mild uterine contractions (fetal ejection reflex). This causes the release of oxytocin from maternal pituitary.
- Oxytocin causes stronger uterine muscle contractions which in turn stimulate further secretion of oxytocin. This process is continued leading to expulsion of the baby out of the uterus through the birth canal.
- After parturition, the umbilical cord is cut off.
- The placenta and remnants of umbilical cord are expelled from the maternal body after parturition. This is called "after birth".

Lactation

- The mammary glands produce milk towards the end of pregnancy by the process called lactation.
- The yellowish milk produced during the initial few days of lactation is called colostrum.
- The colostrum contains several antibodies essential to develop resistance for the new born babies.

Know the Terms

- **Spermatogenesis :** It is the process of 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 female.
- **Menstrual cycle :** The cyclic events starting from one menstruation till the next that take place during the reproductive period is called menstrual cycle.
- **Fertilisation :** The process of fusion of sperm and the ovum to form a single cell called zygote is called fertilization.
- **Morula :** The embryo with 8-16 blastomeres is called a Morula.
- **Parturition :** The birth of the fully developed foetus is termed as parturition.

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Chapter - 4 : Reproductive Health

Quick Review

- The term 'reproductive health' simply refers to healthy reproductive organs with normal functions. According to WHO (World Health Organisation), the word 'reproductive health' means a total well-being in all aspects of reproduction *i.e.,* physical, emotional, behavioural and social.
- Thus, a society with people having physically and functionally normal reproductive organs and normal emotional and behavioural interactions among them in all sex-related aspects might be called reproductively healthy.
- **Problems Associated with Reproductive Health :**
  - **(a)** Rapid increase in human population called population explosion.
  - **(b)** Lack of awareness and sex education in people.
  - **(c)** A number of myths and misconceptions about sex related aspects.
  - **(d)** Common occurrence of sexually transmitted diseases due to lack of knowledge of hygiene of reproductive organs.
  - **(e)** Illegal abortions and female foeticides.
  - **(f)** Sex abuse and sex related crime.
  - **(g)** Myths and misconceptions about sex related issues.
- **Strategies of Reproductive Health Programmes :** To ensure total reproductive health, several programmes like reproductive health programmes and family planning were started in 1951.
- **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) Prevent and control sexually transmitted diseases** by providing 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 infantile mortality rates.
  - **(g)** Lessen the problem of infertility by promoting the Assisted Reproductive Techniques (ARTs).
- **Steps Taken to Maintain a Reproductively Healthy Society**
  1. Imposing a statutory ban on amniocentesis (analysis of aminotic fluid-Foetal Sex Determination.)
  2. To legally check implementation of immunization programs.
  3. Creation of specialized health centers like infertility clinic for diagnosis and corrective treatment of some infertility disorders.
  4. Better awareness about sex related matters and sex-related problems etc.
  5. Increase in the number of medically assisted deliveries and better post-natal care.
  6. Increase in number of couples with small families.
  7. Better detection and cure of STDs.
- **Reasons for Population Explosion :** Tremendous increase in size and growth rate of population is called population explosion. It is due to :
  1. Rapid decline in death rate
  2. More longevity, longer life span
  3. Advanced medical facilities.
  4. Prevention of diseases
  5. Developed techniques in agriculture
  6. Better transport facilities.
  7. Protection from natural factors.
  8. Increase in number of people in reproductive age.

- **Consequences of Population Explosion :** Poverty, unemployment, shortage of food, unhygienic conditions, education problems, residential problems, pollution, crime, excessive consumption of natural resources etc.
- **How to Control Over Population ?**
  1. People should be given education regarding advantages of small family and family planning methods.
  2. Increasing the age of marriage.
  3. Incentives to those families, which are adopting family planning methods.
  4. Birth control through vasectomy and tubectomy.
  5. Family planning programmes with the slogan '**Hum Do Hamare Do**'.
- **Birth Control Measures :**

  The most important step to overcome this problem is to encourage smaller families by using various contraceptive methods. The contraceptive methods help to prevent unwanted pregnancies.
- **An ideal contraceptive should be**
  - User-friendly, easily available, effective and reversible.
  - With no or least side-effects.
  - Non-interfering with sexual drive, desire & sexual act.
- **They are grouped as follows :**

  1. Natural or Traditional Methods : These methods of birth control depend upon the natural rhythms of a woman. These include the following methods :

  (a) Coitus interruptus : This involves withdrawing penis by male partner before ejaculation so that semen is not deposited in the vagina. It is oldest method of voluntary fertility control. This method has certain limitations:
  - Some sperms may be deposited in the vagina even before the sexual climax.
  - May develop physiological and psychological problems to both the partners.

  (b) Periodic abstinence: A week before and a week after the menstrual phase are supposed to be safe periods for sexual intercourse. It reduces the chances of pregnancy by about 80 percent.

  The period from 12^{th} to 18^{th} day (both days inclusive of the menstrual cycle is called danger or risk or fertile period and unprotected sexual intercourse should be avoided during this period.

  (c) Lactational amenorrhoea : It has been noticed that during the period of intense lactation after the parturition, the mother does not undergo menstruation and ovulation so the chances of conception are nearly nil. It also has no side effects but is effective only upto a maximum period of six months after parturition.

  2. Artificial Methods : This involves mechanical or barrier methods.

  (a) Condoms : These are rubber or latex sheaths which are put on penis before starting coital activity (copulation). These are popularly called 'Nirodh'. These check pregnancy by preventing deposition of sperms in the vagina. These can be self-inserted so as to give privacy to the user. These also prevent the spread of sexually transmitted diseases (STDs) including AIDS, syphilis etc. Female condoms are also available called femidoms.

  (b) Diaphragms and cervical caps : These are mechanical barriers made of rubber and fitted in vagina of female to check the entry of sperms in uterus. These are reusable.

  (c) Intra Uterine Devices (IUDs) : These are inserted by doctors or expert nurses in the uterus through vagina. These include :
  - Non-medicated IUDs (*e.g.,* Lippes loop)
  - Copper releasing IUDs (*e.g.,* Copper T)
  - Hormone releasing IUDs (***e.g.,*** Progestasert) : Make the uterus unsuitable for implantation and the cervix hostile to the sperms.
  - IUDs increase phagocytosis of sperms. The Cu ions suppress motility and fertilising capacity of sperms.
  - IUDs are ideal contraceptives for the females who want to delay pregnancy or spacing in children.

  3. Chemical Methods : These are of the following types :

  (i) Spermicidal tablets, jellies, paste and creams introduced in the vagina before coital activity. These kill sperms. Common spermicidal chemicals used are lactic acid, citric acid, potassium permanganate, zinc sulphate etc.

  (ii) Physiological (Oral) Devices : These are the hormonal preparation in the form of pills for females.
  - The pills are usually small doses of progestogens or progestogen–estrogen combinations in the form of tablets (pills).
  - Pills are taken daily for 21 days starting within the first five days of menstrual cycle. After a gap of 7 days (during which menstruation occurs) it has to be repeated in the same pattern as long as the female desires to prevent conception.
  - They inhibit ovulation and implantation as well as alter the quality of cervical mucus to prevent entry of sperms.
  - Pills are very effective with lesser side effects.
  - **Saheli :** It is a new oral contraceptive for the females. It was developed by Central Drug Research Institute (CDRI) Lucknow. It 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.

(iii) Injectables/Implants

- Progesterone alone or in combination with oestrogen is used by females as injections or implants under skin.
- Their mode of action is similar to that of pills and they are effective within 72 hours of coitus.

4. Sterilization or Surgical Methods : These methods block the gamete transport and so prevent conception. These include the following measures :

(a) Male sterilization : It is a permanent method of birth control in which either testes are surgically removed, called castration, or cutting of the vas deferens, called Vasectomy. The vas deferens is exposed and cut through a small incision on the scrotum to prevent the passage of sperms.

(b) Female sterilization : Methods of female sterilization include :

(i) Ovariectomy involves surgical removal of ovaries.

(ii) Tubectomy involves cutting of fallopian tubes.

(iii) Tubal ligation involves blocking of fallopian tubes by an instrument called laparoscope.

➢ **Medical Termination of Pregnancy (MTP)**

- Intentional or voluntary termination of pregnancy before full term is called MTP or induced abortion.
- 45 to 50 million MTPs are performed in a year all over the world (*i.e.* 1/5th of total number of conceived pregnancies).
- MTP helps to decrease the population.
- Because of emotional, ethical, religious and social issues many countries have not legalised MTP.
- Government of India legalised MTP in 1971 with some strict conditions to check indiscriminate and illegal female foeticides which are reported to be high in India.

➢ **Importance of MTP**

- To avoid unwanted pregnancies due to casual intercourse or failure of the contraceptive used during coitus or rapes.
- Essential in cases where continuation of the pregnancy could be harmful to the mother or to the foetus or both.
- MTPs are safe during the first trimester, (up to 12 weeks of pregnancy). 2nd trimester abortions are very risky.

➢ **Problems Related with MTPs**

- Majority of the MTPs are performed illegally.
- Misuse of amniocentesis (a foetal sex determination test based on the chromosomal pattern in the amniotic fluid).
- MTP for female child causes sex imbalance in society.

➢ **Amniocentesis**

- It is a pre-natal diagnostic method to determine the sex of the developing baby. This method has both positive and negative application. This method is legally banned in India.

(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 female foeticide, which causes a sex--imbalance in the society.

➢ **Sexually Transmitted Diseases (STDs)**

➢ Diseases transmitted through sexual intercourse are called Sexually transmitted diseases (STDs)/Venereal diseases (VD) or Reproductive tract infections (RTI). *E.g.* Gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B and HIV leading to AIDS.

➢ **Hepatitis-B and HIV are also transmitted**

(a) By sharing of injection needles, surgical instruments etc.

(b) By transfusion of blood.

(c) From infected mother to foetus.

➢ Except Hepatitis B, genital herpes, HIV and other diseases are completely curable if detected early and treated properly.

➢ **Early symptoms :** Itching, fluid discharge, slight pain, swellings, etc., in the genital region.

➢ Absence or less significant early symptoms and the social stigma deter the infected persons to consult a doctor. This leads to pelvic inflammatory diseases (PID), abortions, still births, ectopic pregnancies, infertility, cancer of the reproductive tract etc.

➢ All persons are vulnerable to STDs. These are very high among persons in the age group of 15-24 years.

- **Prevention :**
  - **(a)** Avoid sex with unknown partners/multiple partners.
  - **(b)** Always use condoms during coitus.
  - **(c)** In case of doubt, go to a qualified doctor for early detection and get complete treatment.
- **Infertility**
  - It is the inability of male or female to produce children.
  - The reasons for this may be physical, congenital, diseases, drugs, immunological or even psychological.
- **Assisted Reproductive Technologies (ART)**

(1) ***In vitro*** **fertilisation (IVF– test tube baby programme) :** In this method, ova from the wife/donor and sperms from the husband/donor are collected and are induced to form zygote under simulated conditions in the laboratory. This is followed by Embryo transfer (ET). It is of 2 types :

(a) Zygote Intra Fallopian Transfer (ZIFT) : Transfer of zygote or early embryos (with up to 8 blastomeres) into fallopian tube.

(b) Intra Uterine Transfer (IUT) : Transfer of embryos with more than 8 blastomeres into the uterus. Embryo formed by in vivo fertilisation (fertilisation within the female) is also used for such transfer to assist those females who cannot conceive.

(2) Gamete Intra Fallopian Transfer (GIFT) : Transfer of an ovum from a donor into the fallopian tube of another female who cannot produce ovum, but can provide suitable environment for fertilization and development.

(3) Intra Cytoplasmic Sperm Injection (ICSI) : A laboratory procedure in which a single sperm (from male partner) is injected directly into an egg (from female partner). Then the fertilised egg is implanted into the woman's uterus.

(4) Artificial Insemination (AI) technique

- The semen collected from the husband or a healthy donor is artificially introduced into the vagina or the uterus (IUI– intra-uterine insemination) of the female.
- This technique is useful for the male partner having inability to inseminate female or low sperm counts etc.

(5) Surrogacy

- Here, a woman (surrogate mother) bears a child for a couple unable to produce children, because the wife is infertile or unable to carry.
- The surrogate is impregnated either through artificial insemination or through implantation of an embryo produced by in vitro fertilisation.

- **Problems of ART**

- It requires high precision handling by specialized professionals and expensive instrumentation. Therefore, these facilities are available only in very few centres.
- Emotional, religious and social problems.
- Legal adoption is one of the best methods for couples looking for parenthood.

Know the Terms

- **Medical Termination of Pregnancy :** The Intentional or voluntary termination of pregnancy before full term is known as MTP.
- **Amniocentesis :** It is a prenatal diagnostic technique that is used to determine the sex and metabolic disorders of the developing foetus in the mother's uterus through the observation of the chromosomal pattern.
- **Sexually transmitted diseases :** Diseases transmitted through sexual intercourse are called sexually transmitted diseases (STDs).
- **Infertility :** It is the inability of couple to produce baby even after unprotected intercourse.
- **Zygote Intra Fallopian Transfer (ZIFT) :** It involves transfer of zygote or early embryos (with up to 8 blastomeres) into fallopian tube.
- **Intra Uterine Transfer (IUT) :** It involves transfer of embryos with more than 8 blastomeres into the uterus.
- **Artificial insemination (AI) technique :** It is the method of transferring semen (sperm) collected from the husband or a healthy donor into the vagina or the uterus (IUI – intra-uterine insemination) of the recipient female.

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UNIT - VII : Genetics and Evolution

Chapter - 5 : Principles of Inheritance and Variation

TOPIC-1
Mendelian Laws of Inheritance and Chromosomal Theory of Inheritance

Quick Review

Mendel's Laws of Inheritance

- **Hybridization Experiments on Garden Peas (*Pisum sativum*)**
  - Mendel selected 7 pairs of true breeding pea varieties

S. No.	Characters	Dominant	Recessive
1.	**Height of the stem**	Tall (T)	Dwarf (t)
2.	**Colour of the flower**	Violet/Red (R)	White (r)
3.	**Position of the flower**	Axial (A)	Terminal (a)
4.	**Shape of pod**	Full/Inflated (I)	Constricted (i)
5.	**Colour of pod**	Green (G)	Yellow (g)
6.	**Shape of seed**	Round (R)	Wrinkled (r)
7.	**Colour of seed/cotyledons**	Yellow (Y)	Green (y)

Inheritance of One Gene

- **Monohybrid Cross :**
  - A cross involving two plants differing in one pair of contrasting characters.
  - *e.g.* Mendel crossed tall and dwarf pea plants to study the inheritance of one gene.
- **Steps in Making a Cross in Pea :**
  - Selection of two pea plants with contrasting characters.
  - Removal of anthers (emasculation) of one plant to avoid self pollination. This is female parent.
  - Collection of pollen grains from the other plant (male parent) and transfer to female parent (pollination).
  - Collection of seeds and production of offspring.
  - Mendel made similar observations for other pairs of traits and proposed that some factors were inherited from parent to offspring. Now they are called as genes.
  - The F_1 (Tt) when self pollinated, produces gametes T and t in equal proportion.
  - Mendel self-pollinated the F_2 plants.
  - He found that dwarf F_2 plants continued to generate dwarf plants in F_3 & F_4.
  - He concluded that genotype of the dwarfs was homozygous- tt.
- **Monohybrid Phenotypic Ratio :**
  3 Tall : 1 Dwarf = 3 : 1
- **Monohybrid Genotypic Ratio :**
  Homozygous tall (TT) : 1, Heterozygous tall (Tt) : 2, Homozygous dwarf (tt) : 1= 1 : 2 : 1
- **Backcross and Testcross**
  - **Backcross :** Crossing of F_1 hybrid with its any of parent.
  - **Testcross :** Crossing of an F_1 hybrid with its recessive parent (Test cross ratio=1:1). It is used to find out the unknown genotype. Mendel conducted test cross to determine the F_2 genotype.

Mendel's Principles or Laws of Inheritance

1. **Principle of Dominance**
   - Characters are controlled by discrete units called factors.
   - Factors occur in pairs.

- In a dissimilar pair of factors or contrasting alleles *i.e.*, in heterozygous condition, only one member of the pair expresses its effect in the hybrid and is called as dominant while the manifestation of the other is masked and is called as recessive.

2. First Law (Law of Segregation)

States that allelic pairs separate or segregate during gamete formation, and randomly unite at fertilization, thus homozygous parent produces similar gametes. Heterozygous parent produces two kinds of gametes, each having one allele in equal proportion.

The Concept of Dominance

- In heterozygotes, there are dominant and recessive alleles.
- The normal (unmodified or functioning) allele of a gene produces a normal enzyme that is needed for the transformation of a substrate.
- **The modified allele is responsible for production of**
  (i) The normal/less efficient enzyme or
  (ii) A non-functional enzyme or
  (iii) No enzyme at all
- **In the first case :** The modified allele will produce the same phenotype like unmodified allele. It becomes dominant.
- **In 2nd and 3rd cases :** The phenotype is dependent only on the functioning of the unmodified allele. Here, the modified allele becomes recessive.

Non-Mendelian Inheritance

(a) Incomplete Dominance

- It is an inheritance in which heterozygous offspring shows intermediate character between two parental characteristics. *e.g.* Flower colour in snapdragon (dog flower or *Antirrhinum* sp.) and *Mirabilis jalapa* (4'O clock plant).
- 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.

(b) Co-dominance

- It is the inheritance in which both alleles of a gene are expressed equally and independently in a hybrid. *i.e.* both the alleles are dominant,. *e.g.* ABO blood grouping in humans.
- ABO blood groups are controlled by the gene I.
- The gene (I) has three alleles I^A, I^B and i. However a person can have any two of these three alleles. I^A and I^B both are dominant alleles while *i* is a recessive allele.
- The alleles I^A and I^B produce antigen A and antigen B respectively on the RBC surface while allele *i* doesn't produce any antigen.
- When I^A and I^B are present together they both express their own types of surface antigen A and B. This is due to co-dominance.

(c) Multiple Allelism

- Here more than two alleles govern the same character.
- Since in an individual only two alleles are present, multiple alleles can be found only when population studies are made. *e.g.* ABO blood grouping (3 alleles : I^A, I^B & i). Skin colour and height of humans are also examples of multiple alleles.

(d) Pleiotropy

- Pleiotropy is the phenomenon in which one gene controls many traits. For example, the gene in pea plants that controls the round and wrinkled texture of seeds also influences the phenotypic expression of starch grain size.
- So, if starch grain size is considered as the phenotype, then from this angle, 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 as much on the gene product and the production of a particular phenotype.

Inheritance of Two Genes

➢ **Dihybrid Cross**

- A cross between two parents differing in two pairs of contrasting characters.
- Mendel made some dihybrid crosses. *e.g.* Cross between pea plant with round shaped and yellow coloured seeds (RRYY) and wrinkled shaped and green coloured seeds (rryy).
- On observing the F_2, Mendel found that the yellow and green colour segregated in a 3:1 ratio.

- Round and wrinkled seed shape also segregated in a 3:1 ratio.

  Thus, the segregation of one pair of contrasting characters (Round and wrinkled shape) is independent of the segregation of another pair of contrasting character (yellow and green) colour and also that some new combinations of character appear in F_2 generation as the alleles get randomly rearranged in the off springs at the time of fertilization.
- **Dihybrid genotypic ratio:** 1 : 2 : 1 : 2 : 4 : 2 : 1 : 2 : 1

  RRYY =1; RRYy =2; RrYY = 2; RrYy = 4; RRyy = 1; Rryy = 2; rrYY = 1; rrYy = 2; rryy = 1
- **Dihybrid Phenotypic ratio**

  Round yellow 9 : Round green 3 : Wrinkled yellow 3 : Wrinkled green 1, *i.e.* 9 : 3 : 3 : 1

  The ratio of 9 : 3 : 3 : 1 can be derived as a combination series of 3 yellow : 1 green, with 3 round : 1 wrinkled.

  i.e. (3 : 1) (3 : 1) = 9 : 3 : 3 : 1

3. **Second Law (Mendel's Law of Independent Assortment) :**
   - It states that 'when more than one pair of characters are involved in a cross, the segregation of one pair of contrasting characters is independent of the segregation of other pair of contrasting characters and also that new recombination of characters alongwith the parental type also appear in F_2 generation.

➢ **Non-recognition of Mendel's work**

- Mendel's work remained unrecognized till 1900 because,
  - **(a)** Communication was not easy.
  - **(b)** Non recognition of mendel as a scientists.
  - **(c)** His mathematical approach was new and unacceptable.
  - **(d)** He used statistical calculations which were beyond the comprehension of the biologist of his time.
  - **(e)** Chromosomes, and mitosis and meiosis were not known in Mendel's time.
  - **(f)** The concept of genes (factors) as stable and discrete units was not accepted. (Mendel could not explain the continuous variations seen in nature).
  - **(g)** Mendel could not provide any physical proof for the existence of factors.
- In 1900, de Vries of Holland, Correns of Germany & von Tschermak of Austria independently rediscovered Mendel's results and proclaimed his conclusions as the Mendel's Laws of inheritance.

➢ **Chromosomal Theory (1902)**

- The chromosomal Theory was proposed independently by Walter Sutton and Theodore Boveri in 1902.
- Walter Sutton & Theodore Boveri proposed that the pairing and separation of a pair of chromosomes during meiosis lead to segregation of pair of factors.
- Sutton united chromosomal segregation with Mendelian principles and called it as Chromosomal Theory of Inheritance.
- It states that—
  - **(a)** Chromosomes are vehicles of heredity *i.e.*, they are transmitted from parents to offspring.
  - **(b)** Two identical chromosomes form a homologous pair. Gametes are present in a linear fashion on chromosomes.
  - **(c)** They segregate at the time of gamete formation.
  - **(d)** Independent pairs segregate independently of each other.
  - **(e)** Chromosomes are mutable.
  - **(f)** Sex chromosomes determine sex of individual.

Parallism between genes (Mendelian factors) & Chromosomes :

- Mendelian factors as well as chromosomes are transferred from generation to generation.
- The chromosomes occurs in homologous pairs. The genes also occurs in pairs (allele pairs).
- Both chromosomes and genes segregate at the time of gamete formation in such a way that gametes receive only one chromosome & similarly one allele of each pair.
- Different pairs of chromosomes segregate independently of each other. Similarly one pair of alleles segregate independently of another pair.
- Fusion of two (male & female) gametes brings about the diploid chromosome number as well as the allelic pairs in the offsprings.
- Thomas Hunt Morgan proved Chromosomal Theory of Inheritance using fruit flies (*Drosophila melanogaster*).
- He took fruit flies as the suitable material because,
  - **(a)** It breeds very quickly.
  - **(b)** Short generation time (life cycle : 12-14 days).
  - **(c)** Breeding can be done throughout the year.
  - **(d)** Hundreds of progenies are produced per mating.

(e) They can grow on simple synthetic medium.

(f) Male and female flies are easily distinguishable.

➢ **Linkage and Recombination**

- **Recombination :** It is the generation of non-parental gene combinations.
- **Linkage :** Physical association of two or more genes on a chromosome, Which show tendency to inherit together. They do not show independent assortment.

  Morgan et. al crossed yellow body and white eyed females with wild type brown body and red eyed in ales and inter-crossed F_1 offsprings. He found that the two genes did not segregate independently, resulted in deviation from normal dihybrid ratio 9 : 3 : 3 : 1 in F_2 generation because the appearance of parental combinations were higher than the non-parental and new recombinations.
- Morgan further carried out several dihybrid test crosses in *Drosophila* to study sex-linked genes.

  Cross A : Double recessive Yellow-bodied, white-eyed females YW/YW X Hybrid Brown-bodied, red-eyed males Y'W'/YW (wild type)

  Cross B : Double recessive White-eyed, miniature winged (Wm/Wm) X Hybrid Red eyed, large winged (W'm/Wm) (wild type)
- **Morgan in the above crosses found that,**

  (a) The two genes did not segregate independently of each other and the F_2 ratio deviated from the 9 : 3 : 3 : 1 ratio.

  (b) Genes were located on the X chromosome.

  (c) 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 linkage.

  (d) Genes for white and yellow were very tightly linked and showed only 1.3% new recombination while white and miniature wings showed 37.2% recombination (loosely linked).

  (e) Tightly linked genes show low recombination.

  (f) Loosely linked genes show high recombination.

  Strength of linkage is inversely proportional to the distance between two linked genes. Thus, the linkage between y & w alleles is stronger than the linkage between w & m alleles.
- **Linkage groups :** All the genes present together on a single chromosome make up a linkage group. The total number of linkage groups is an organism is equal to its haploid number of chromosomes or number of homologous pairs in diploid organisms.
- Alfred Sturtevant used the recombination frequency between gene pairs as a measure of the distance between genes and 'mapped' their position on the chromosome.
- Recombination frequency or the cross over value (COV) can be calculated by following formula.

$$\text{COV} = \frac{\text{Number of recombinants}}{\text{Total number of offsprings}} \times 100$$

- Genetic maps are used as a starting point in the sequencing of genomes as was done in Human Genome Project.

TOPIC-2
Sex Determination and Chromosomal Disorder

Quick Review

➢ **Sex determination**

- The method by which the distinction between male and female is established in a species is called sex determination.
- Sex of an individual is finalized at the time of zygote formation.

➢ **Autosomes and Sex chromosomes (allosomes)**

- Autosomes are chromosomes other than sex chromosomes. They contain genes which determine somatic characteristics.
- Number of autosomes is same in males and females.
- Sex chromosomes (X & Y) are the chromosomes which are involved in 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 was called as **X-chromosome**).

- **Mechanism of Sex Determination**

  Chromosomal sex determination

  It is based on heterogamety *i.e.*, occurrence of two types of gametes in one of the two sexes. It is of following types :

  (a) XX-XO mechanism :

  Here, male is heterogametic, *i.e.*, XO besides autosomes (Gametes with X and gametes without X) and female is homogametic, *i.e.* XX (all gametes are with X chromosomes). *e.g.* Many insects such as grasshopper.

  (b) XX-XY mechanism :

  Male is heterogametic (X & Y) and female is homogametic (X only). *e.g.* Human and *Drosophila.*

  (c) ZZ-ZW mechanism :

  Male is homogametic (ZZ) and female is heterogametic (Z & W). *e.g.* Birds.

  (d) ZO-ZZ mechanism : Females have only Z-chromosomes besides autosomes and males have a pair of Z-chromosomes *e.g.* in cockroaches.

  XX-XO & XX-XY mechanisms show male heterogamety. ZZ-ZW mechanism shows female heterogamety.

  Females have only Z chromosome besides autosomes and males have a pair of Z chromosome as seen in cockroaches.

- **Sex Determination in Humans (XX-XY type)**
  - Human has 23 pairs of chromosomes (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 males produce 2 types of gametes *i.e.*, 50 % with X-chromosome and 50 % with Y-chromosome.
  - Females produce only ovum with an X-chromosome.
  - There is an equal probability of fertilization of the ovum with the sperm carrying either X or Y chromosome.
  - The sperm determines whether the offspring will be male or female.
  - **Environmental Sex-determination :** Determination of sex depends upon the environmental condition. The environmental factors like temperature etc determine whether the zygote will develop into male or female. *e.g.* turtles and crocodile.
  - **Genetic balance mechanism of sex determination :** Sex of the individual is decided by the ratio of X-chromosome and autosome as is found in ***Drosophila***.
  - **Cytoplasmic Sex-determination :** Cytoplasmic or fertility factor called as F^+ factor located in plasmid determines the sex as in found is some bacteria.
- **Mutation**
  - It is a sudden heritable change in DNA sequences resulting in changes in the genotype and the phenotype of an organism. The term mutation was given by Hugo de vries (1901).
  - It is caused either by loss or gain or change in a single base pair of DNA.
  - **Frame-shift mutation :** Loss (deletions) or gain (insertion/ duplication) in DNA segment so that the whole frame of codons is changed.
  - **Point mutation :** Mutation due to change in a single base pair of DNA. *e.g.* sickle cell anaemia.
  - Mutation results in Chromosomal abnormalities (aberrations).
  - Chromosomal aberrations are seen in **cancer cells**.
  - **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 representation or chart showing family history is called **family tree (pedigree).**
  - Thus, an analysis of traits in several generations of a family is called **pedigree analysis.**
  - In humans, control crosses are not possible.
  - So, the study of family history about inheritance is used.
  - In human genetics, pedigree study is utilized to trace the inheritance of a specific trait, abnormality or disease.
- **Genetic Disorders**
  - There are two types of genetic disorders namely,
    - **(a)** Mendelian disorders
    - **(b)** Chromosomal disorders

(1) 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.

  e.g. 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.

➢ Pedigree Analysis of Autosomal Dominant Trait *e.g.* – Myotonic dystrophy

➢ **Myotonic Dystrophy**

- It is an autosomal dominant disorder which is characterized by increasing contractility of muscles with decreasing relaxation. This leads to atrophy of muscles particularly of face and neck. Hypogonadism, balding and cardiac irregularities may also be caused due to this disorder.

➢ **Pedigree Analysis of Autosomal Recessive Trait *e.g.* –** Sickle cell anaemia

➢ **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.
- Homozygous dominant (Hb^AHb^A) : normal Heterozygous (Hb^AHb^S): carrier; sickle cell trait Homozygous recessive (Hb^SHb^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).
- This is due to the single base substitution at the sixth codon of the β-globin gene from GAG to GUG.
- The mutant Hb molecule undergoes polymerization under low oxygen tension causing the change in shape of the RBC from biconcave disc to elongated sickle like structure.

➢ **Haemophilia (Royal disease)**

- Sex linked recessive disease.
- In this, a protein involved in the blood clotting is affected.
- A simple cut results in non-stop bleeding.
- The heterozygous female (carrier) for haemophilia may transmit the disease to sons.
- The possibility of a female becoming a haemophilic is very rare because mother has to be at least carrier and father should be haemophilic (unavailable in the later stage of life).
- Queen Victoria was a carrier of the disease. So her family pedigree shows a number of haemophilic descendents.

➢ **Phenylketonuria**

- An inborn error of metabolism.
- 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.

(2) Chromosomal Disorders

- They are caused due to absence or excess or abnormal arrangement of one or more chromosomes.
- These are of two types namely,
  (a) Aneuploidy **(b)** Euploidy.

(a) Aneuploidy

- The gain or loss of chromosomes due to failure of segregation of chromatids during cell division.
  It includes,
  (a) Nullisomy (2n-2): A complete homologous 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, so that one chromosome occurs in triplicate.
  (d) Tetrasomy (2n+2):2 chromosomes are added to diploid set, so that a chromosome is found in quadripulate

(b) Polyploidy (Euploidy)

- It is an increase in number of chromosomes sets beyond diploid X condition (2n)
- This is often seen in plants.
- **On the basis of number of chromosome sets, the polyploids are of following types :** triploids (3n), tetraploids (4n), pentaploids (5n), hexaploids (6n) etc.
  (a) Autopolyploidy : It is an increase in number of the same genome. *e.g.* AAA (autotriploid), AAAA (autotetraploid) etc.
  (b) Allopolyploidy : It is the increase in number of sets of chromosome due to coming together of diploid genomes of two or more than two individuals of different species. *e.g.* AABB, AABBDD. Bread wheat is allohexaploid (AABBDD). Triticale is the man made cereal formed by hybridization between durum wheat and rye. It is allohexaploid.

- **Autoallopolyploidy :** It is a kind of polyploidy where the genomes of two species come together in which one has double set of chromosomes. *e.g. Helianthus tuberosus* which is autoallohexaploid.
- **Chromosomal aberrations :** These are the changes in morphology and structure of chromosome resulting in the change in number and sequence of genes on them without any change in ploidy. They are of following types :

1. **Deletion :** It is the loss of a terminal segment of a chromosome or from within the a chromosome (interstitial segment) followed by reunion of its remaining parts.
2. **Inversion :** It is a change in a chromosome architecture due to breaking up, rotation through 180° of a segment and its reunion so that sequence of genes is revered in the inverted region.
3. **Duplication :** It is a change in chromosome structure in which a part of chromosome breaks up and unites with another homologous chromosome. This process repeats the chromosome segments because the same block of genes is present more than once in a haploid component
4. **Translocation :** It is a change in chromosome architecture which is due to breaking up of segment of chromosome and its union with another non-homologous chromosome. It may be due to breaking up of a segment of chromosome and its union with another non-homologous chromosome. It may also be due to mutual exchange of chromosomal segments between non-homologous chromosomes.

➢ **Examples for Chromosomal Disorders**

(a) Down's Syndrome (Mongolism)

- It is the presence of an additional copy of chromosome number 21 (trisomy of 21).
- Genetic constitution : 45 A + XX or 45 A + XY (*i.e.* 47 chromosomes).
- **Features :**
  - **(a)** They are short statured with small round head.
  - **(b)** Broad flat face.
  - **(c)** Furrowed big tongue and partially open mouth.
  - **(d)** Many "loops" on finger tips.
  - **(e)** Palm is broad with characteristic palm crease.
  - **(f)** Retarded physical, psychomotor & mental development.
  - **(g)** Congenital heart disease.

(b) Klinefelter's Syndrome

- It is the presence of an additional copy of X-chromosome in male.
- Genetic constitution: 44 A + XXY (*i.e.* 47 chromosomes).
- **Features :**
  - **(a)** Overall masculine development, however, the feminine development is also expressed. *e.g.* development of breast (Gynaecomastia).
  - **(b)** Sterile.
  - **(c)** Mentally retarded.

(c) Turner's Syndrome

- This is due to the absence of one of the X chromosomes in female.
- Genetic constitution: 44 A + XO (*i.e.* 45 chromosomes).
- **Features :**
  - **(a)** Sterile, Ovaries are rudimentary.
  - **(b)** Lack of other secondary sexual characters.
  - **(c)** Dwarf.
  - **(d)** Mentally retarded

Know the Terms

➢ **Genetics (GK. Genesis – decent) :** It is a branch of biology that deals with the study of principles and mechanism of heredity and variations. The term genetics was coined by Bateson (1906).

➢ **Heredity (L. Hereditas –** heirship or inheritance) : It is the tendency of similarity between parents and offsprings "Like begets like".

➢ **Offspring :** They are the products of sexual reproduction and are biparental in origin. Siblings are offspring of the same parents. *i.e.* brothers and sisters.

➢ **Inheritance :** Transmission of characters from parents to progeny.

➢ **Variation :** Tendency of differences in various traits of individuals of a progeny from one another and their parents.

➢ **Clone :** The group of organisms produced by asexual reproduction. They are morphologically and genetically similar to one another as well as their parents (The individuals of a clone are called rametes).

- **Haploid (Monoploid) :** An individual or cell containing a single complete set of chromosomes.
- **Diploid :** An individual or cell containing two complete sets of chromosomes.
- **Punnett square (Checker board) :** A grid that enables to calculate the results of simple genetic crosses.
- **Cross :** Deliberate mating of two parental types of organisms of the same species.
- **Trait :** A phenotypic characteristic of an inherited character.
- **Wild type :** The species variety showing normal phenotype.
- **Father of genetics :** Gregor Johann Mendel
- **Mendelian factor or gene :** It is a unit of inheritance which passes from one generation to the next through the gamete and controls the expression of a character in the organisms.
- **Alleles or allelomorphs :** A pair of Mendelian factors or genes located on the same locus of two homologous chromosomes of an individual which control the expression of a trait or character are called alleles or allelomorphs.
- **Gene locus :** A particular portion or region of the chromosomes representing a single gene is called gene locus.
- **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 is originally present in the population and is dominant, usually widespread. Recessive allele is less common and is believed to be formed through mutation of wild allele.
- **Homozygote (homozygous) :** It is an individual which contains identical alleles of a gene or factor of a character on its homologous chromosomes. *e.g.* TT or tt.
- **Heterozygote (heterozygous) :** It is an individual which contain the two contrasting factors of a character or two different alleles of a gene on the same locus of its homologous chromosomes. It is not pure and is called hybrid for that character. *e.g. Tt*.
- **Hybrid :** The organisms produced after crossing two genetically different individuals is called hybrid. Also called heterozygote or heterozygous individuals.
- **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.
- **F_2 generation :** It is the generation of individuals which arises as a result of interbreeding or selfing amongst individuals of F_1 generation.
- **Genotype :** (GK. Geno- race; typos – image). It is the genetic constitution of individual with regard to one or more characters irrespective that whether the genes are expressed or not, for *e.g.* genotype of hybrid tall pea plant is *Tt*, pure tall *TT* and pure dwarf *tt*.
- **Phenotype :** (GK. Pheno – to appear, typos – image): It is observable or measurable distinctive structural or functional characteristic of an individual. *e.g.* phenotypic tall pea plant can be genotypically *TT* ot *Tt*.
- **Genome :** It is a complete set of chromosomes where every gene/chromosome is represented singly as in a gamete.
- **Gene pool :** Aggregate of all the genes and their alleles present in an interbreeding population is known as gene pool.
- **Reciprocal cross :** Cross which involves two types of individual where the male of one type is crossed with female of the second type and vice versa.
- **Back cross :** Cross between hybrid and one of its parent.
- **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.
- **Dysgenics :** Study of undesirable traits of human race and the genes that cause them.
- **Ishihara cards :** Cards used for checking colour blindness.
- **Diplotene chromosomes :** Lampbrush Chromosomes.
- **Bernstein :** Discovered multiple alleles, co-dominance and dominant recessive relationship in determination of human blood groups.
- **W. Johannsen :** Coined the term pure line (1900), gene (1909), genotype and phenotype.

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Chapter - 6 : Molecular Basis of Inheritance

TOPIC-1
Nucleic Acid – DNA and RNA

Quick Review

- **The DNA**
  - DNA and RNA are the two types of nucleic acids.
  - DNA is the genetic material in all the organisms except some viruses.
  - RNA is the genetic material in some viruses.
  - RNA mostly functions as messengers.
- **Structure of Polynucleotide Chain**
  - Polynucleotides are the polymers of nucleotides.
  - DNA and RNA are polynucleotides.
  - **A nucleotide has 3 components :**
    1. A nitrogenous base
    2. A pentose sugar (ribose in RNA and deoxyribose in DNA)
    3. A phosphate group
  - **Nitrogen bases are of 2 types :**
    (a) Purines : It includes Adenine (A) and Guanine (G).
    (b) Pyrimidines : It includes Cytosine (C), Thymine (T) and Uracil (U). Thymine (5-methyl Uracil) present only in DNA) and Uracil only in RNA.
  - A nitrogenous base is linked to the pentose sugar through an N-glycosidic linkage to form nucleoside.

Nucleosides in RNA	Nucleosides in DNA
Adenosine	*Deoxyadenosine*
Guanosine	*Deoxyguanosine*
Cytidine	*Deoxycytidine*
Uridine	*Deoxythymidine*

  - Nitrogen base + sugar + phosphate group = Nucleotide (deoxyribonucleotide). In RNA, every nucleotide residue has an additional – OH group present at 2′-position in the ribose.
  - 2 nucleotides are linked through **3′ – 5′ phosphodiester** bond to form dinucleotide.
  - When more nucleotides are linked, it forms polynucleotide.
- **Structure of DNA**
  - **Friedrich Meischer (1869) :** Identified DNA and named it as 'Nuclein'.
  - **James Watson & Francis Crick** proposed double helix model of DNA. It was based on the X-ray diffraction data produced by **Maurice Wilkins & Rosalind Franklin**.
  - DNA is made of two polynucleotide chains coiled in a right handed fashion. Its backbone is formed of sugar and phosphates. The bases project inside.
  - The two chains have anti-parallel polarity, *i.e.* one chain has the polarity 5′ → 3′ and the other has 3′ → 5′.
  - Nitrogen bases of opposite chains are held together by hydrogen bonds forming base pairs (bp).
  - There are two hydrogen bonds between A and T (A = T) and three H-bonds between C and G (C ≡ G).
  - Purine comes opposite to a pyrimidine. This generates uniform distance between the two strands.
- **Erwin Chargaff's Rule**
  - Purines and pyrimidines are always in equal amounts *i.e.*, A + G = T + C.
  - In DNA, the proportion of A is equal to T and the proportion of G is equal to C. *i.e.*, A = T and G = C.
  - The base ratio A + T/G + C may vary from species to species but constant for a given species.
  - Length of DNA = number of base pairs × distance between two adjacent base pairs.
  - Φ 174 (a bacteriophage) has 5386 nucleotides.
  - Bacteriophage lambda has 48502 base pairs (bp).
  - *E. coli* has 4.6×10^6 bp.
  - Haploid content of human DNA = 3.3×10^9 bp.

- Number of base pairs in human = 6.6×10^9
- Length of DNA in humans = $6.6 \times 10^9 \times 0.34 \times 10^{-9} = 2.2$ m
- Length of DNA in **E-coli** =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

➢ **Packaging of DNA Helix**

- In prokaryotes (*e.g. E. coli*), the DNA, being negatively charged, is held with some positively charged non-histone basic proteins like polyamines and form 'nucleoid'.
- In eukaryotes, there is a set of positively charged, basic proteins called histones.
- Histones are rich in positively charged basic amino acid residues lysines and arginines.
- There are five types of histones-H_1, H_2A, H_2B, H_3 and H_4.
- Two molecules each of H_2A, H_2B, H_3 and H_4 organize to form a unit of eight molecules called as histone octamer.
- Negatively charged DNA is wrapped around positively charged histone octamer to form a structure called nucleosome.
- Nucleosomes are connected with one another with the help of linker DNA on which H_1 Histone is present.

➢ **Nucleosome**

- A typical nucleosome contains 200 bp of DNA helix.
- Therefore, the total number of nucleosomes in human = 6.6×10^9 bp/200 = 3.3×10^7
- Nucleosomes constitute the repeating unit to form chromatin.
- Chromatin is the thread-like stained bodies.
- Nucleosomes in chromatin appear as "beads-on-string".
- Chromatin is packed to form a solenoid structure.
- Further supercoiling constitute looped structure called chromatin fibre.
  These chromatin fibers further coil and condense at metaphase stage of cell division to form chromosomes.
- Chromatin is packaged → solenoid → chromatin fibres → coiled and condensed at metaphase stage → chromosomes.
- Higher level packaging of chromatin requires non-histone chromosomal (NHC) proteins.
- Two types of chromatin are :
  (a) Euchromatin : Loosely packed and transcriptionally active chromatin and stains light.
  (b) Heterochromatin : Densely packed and inactive region of chromatin and stains dark.

➢ **The Search for Genetic Material**

Griffith's Experiment - Transforming Principle

- **Griffith** (1928) used mice and *Streptococcus pneumoniae*.
- ***Streptococcus pneumoniae* has two strains :**
  (a) Smooth (S) strain (Virulent) : Has polysaccharide mucous coat. Causes Pneumonia.
  (b) Rough (R) strain (Non-virulent) : No mucous coat. Does not cause Pneumonia.

➢ **Experiment**

- S-strain → Inject into mice → Mice die
- R-strain → Inject into mice → Mice live
- S-strain (Heat killed) → Inject into mice → Mice live
- S-strain (Hk) + R-strain (live) → Inject into mice → Mice die
- He concluded that some 'transforming principle', transferred from heat-killed S-strain to R-strain. It enabled R-strain to synthesize smooth polysaccharide coat and become virulent. This must be due to the transfer of genetic material.

➢ **Biochemical Characterization of Transforming Principle**

- Oswald Avery, Colin MacLeod & Maclyn McCarty worked to determine the biochemical nature of 'transforming principle' in Griffith's experiment.
- They purified biochemicals (proteins, DNA, RNA etc.) from heat killed S cells using suitable enzymes.
- They discovered that —
  (a) Digestion of protein and RNA (using Proteases and RNases) did not affect transformation. So the transforming substance was not a protein or RNA.
  (b) Digestion of DNA with DNase inhibited transformation. It means that DNA caused transformation of R cells to S cells, i.e. DNA was the transforming substance.

➢ **The Genetic Material is DNA**

The fact that DNA is the genetic material also came from the experiments of Alfred Hershey and Martha Chase (1952).

They worked with viruses that infect bacteria and are called bacteriophages.

➢ **Hershey-Chase Experiment — Blender Experiment**

- Hershey and Chase made two preparations of bacteriophage - In one, proteins were labelled with S-35 by putting in medium containing radioactive sulphur (S-35). In the second, DNA was labelled with P-32 by putting in a medium containing radioactive Phosphorous (P-32).
- These preparations were used separately to infect *E. coli*.

- After infection, the *E. coli* cells were gently agitated in a blender to separate the phage particles from the bacteria.
- Then the culture was centrifuged. Heavier bacterial cells were formed as a pellet at the bottom. Lighter viral components outside the bacterial cells remained in the supernatant.
- They found that,
  (a) Supernatant contains viral protein labelled with S-35, *i.e.* the viral protein had not entered the bacterial cells.
  (b) The bacterial pellet contains radioactive P. This shows that viral DNA labelled with P-32 had entered the bacterial cells. This proves that DNA is the genetic material.

➢ **Properties of Genetic Material**

- A molecule that can act as a genetic material must fulfill the following criteria :
  (a) Be able to generate its replica by the process of (Replication).
  (b) Chemically and structurally be stable.
  (c) Provide the mutations that are required for evolution. It should be able to store genetic information which can be inherited.
  (d) Be able to express itself as 'Mendelian Characters'.

DNA v/s RNA

➢ **DNA is a Better Genetic Material than RNA due to following reasons :**

- DNA is chemically less reactive and structurally more stable. It has the capacity to undergo repair.
- Due to unstable nature of RNA, RNA viruses (*e.g. Q.B bacteriophage, Tobacco mosaic virus etc.*) mutate and evolve faster.
- For the storage of genetic information DNA is better due to its stability. But for the transmission of genetic information, RNA is better.
- RNA can directly code for the protein synthesis, hence can easily express the characters. DNA is dependent on RNA for protein synthesis.

Reasons for stability (less reactivity) of DNA	Reasons for mutability (high reactivity) of RNA
Double stranded	*Single stranded*
Presence of thymine	*Presence of Uracil*
Absence of 2'-OH	*Presence of 2'-OH*

- The two DNA strands are complementary. On heating, they separate. When appropriate conditions are provided they come together. (In Griffith's experiment, when the bacteria were heat killed, some properties of DNA did not destroy).

➢ **RNA World**

- RNA is a single stranded structure but it is often folded back upon itself forming helices. Nitrogenous bases are like those of DNA except that there is uracil in place of thymine.
- RNA was the first regulatory chemical and genetic material in early life forms.
- It acts as genetic material and bio catalyst.
- Essential life processes (metabolism, translation, splicing etc) evolved around RNA.
- DNA has evolved from RNA with chemical modifications that make it more stable.

➢ **Central Dogma of Molecular Biology**

- It was proposed by Francis Crick (1948). It states that the genetic information flows unidirectionally from DNA → RNA → Protein.

➢ **Teminism :** H. Temin and Baltimore gave the concept of reverse flow of genetic information, *i.e.*, the formation of DNA from RNA. This is called as Reverse Central Dogma or Teminism or reverse transcription. This takes place in some of the viruses in the presence of an enzyme called reverse transcriptase.

➢ **Types of RNA**

- RNA is of 3 types –mRNA, tRNA and rRNA.
- mRNA constitutes 2–5% of the total cellular RNA, tRNA is about 15% and rRNA is about 70–80%.
- **mRNA (messenger RNA) :** Provides template for translation (protein synthesis), and is transcribed from DNA.
- **rRNA (ribosomal RNA) :** Structural and catalytic role during translation. *e.g.* 23S rRNA in bacteria acts as ribozyme.
  It is the component of ribosome and is the most stable type of RNA.
- t**RNA (transfer RNA or sRNA or soluble RNA or adaptor RNA) :** Brings amino acids for protein synthesis and reads the genetic code.
- tRNA are smallest amongst all the RNA and contains 70–80 nucleotides only.

- **DNA Replication**
  - Replication is the copying of DNA from parental DNA.
  - Watson & Crick proposed Semi-conservative model of replication.
  - It suggests that the parental DNA strands act as template for the synthesis of new complementary strands. After the completion of replication, each DNA molecule would have one parental and one new strand.
- **Experimental Proof**
  - **Mathew Messelson & Franklin Stahl (1958)** experimentally proved Semi-conservative model.
  - **Messelson & Stahl's Experiment :**
  - They cultured *E. coli* in a medium containing $N^{15}H_4Cl$ (N^{15} : heavy isotope of N). N^{15} was incorporated into both strands of bacterial DNA and the DNA became heavier.
  - Another preparation containing N salts labelled with N^{14} was also made. N^{14} was also incorporated in both strands of DNA and became lighter.
  - These two types of DNA can be separated by centrifugation in a CsCl density gradient.
  - They took *E. coli* cells from N^{15} medium and transferred to N^{14} medium.
  - After one generation (*i.e.* after 20 minutes), they isolated and centrifuged the DNA. Its density was intermediate (hybrid) between ^{15}N DNA and ^{14}N DNA. This showed that in the newly formed DNA, one strand is old (N^{15} type) and one strand is new (N^{14} type). This confirms semi-conservative replication.
  - After II generation (*i.e.* after 40 minutes), there was an equal amounts of hybrid DNA and light DNA.
  - Taylor & colleagues (1958) performed similar experiments on *Vicia faba* (faba beans) using radioactive thymidine to detect distribution of newly synthesized DNA in the chromosomes. It proved that the DNA in chromosomes also replicate semi-conservatively.
- **The Machinery and Enzymes for Replication**
  - DNA replication starts at a point called *origin* (*ori*).
  - A unit of replication with one origin is called a *replicon*.
  - During replication, the two strands unwind and separate by breaking H-bonds in presence of an enzyme, *Helicase*.
  - Unwinding of the DNA molecule at a point forms a 'Y'-shaped structure called replication fork.
  - The separated strands act as templates for the synthesis of new strands.
  - DNA replicates in the 5′→3′ direction.
  - *Deoxyribonucleoside triphosphates* (dATP, dGTP, dCTP& TTP) act as substrate and also provide energy for polymerization.
  - Firstly, a small RNA primer is synthesized in presence of an enzyme, *primase*.
  - In the presence of an enzyme, DNA dependent *DNA polymerase*, many nucleotides join with one another to primer strand and form a polynucleotide chain (new strand).
  - The DNA polymerase forms one new strand (leading strand) in a continuous stretch in the 5′→3′ direction (Continuous synthesis).
  - The other new strand is formed in small stretches (Okazaki fragments) in 5′→3′ direction (Discontinuous synthesis).
  - The Okazaki fragments are then joined together to form a new strand by an enzyme, *DNA ligase*. This new strand is called lagging strand.
  - If a wrong base is introduced in the new strand, DNA polymerase can do proof reading.
  - *E. coli* completes replication within 38 minutes. *i.e.* 2000 bp per second.
  - In eukaryotes, the replication of DNA takes place at S-phase of the cell cycle. Failure in cell division after DNA replication results in polyploidy.
- **Transcription**
  - It is the process of copying genetic information from one strand of the DNA into RNA.
  - Here, adenine pairs with uracil instead of thymine.
  - Both strands are not copied during transcription, because
    - **(a)** The code for protein is different in both strands. This complicates the translation.
    - **(b)** If two RNA molecules are produced simultaneously they would be complimentary to each other, hence form a double stranded RNA. This prevents translation.
- **Transcription Unit**
  - It is the segment of DNA between the sites of initiation and termination of transcription.
  - It consists of 3 regions :
    - **(a) A promoter (Transcription start site) :** Binding site for RNA polymerase.
    - **(b) Structural gene :** The region between promoter and terminator where transcription takes place.
    - **(c) A terminator :** The site where transcription stops.
  - The DNA- dependent RNA polymerase catalyzes the polymerization only in 5′→3′direction.

- 3′→5′ acts as template strand. 5′→3′ acts as coding strand.
- 3′–ATGCATGCATGCATGCATGCATGC–5′ template strand.
  5′–TACGTACGTACGTACGTACGTACG–3′ coding strand.

➢ **Transcription Unit and the Gene**

- **Gene :** Functional unit of inheritance. It is the DNA sequence coding for RNA molecule.
- **Cistron :** A segment of DNA coding for a polypeptide.
- Structural gene in a transcription unit is 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.
- **Exons and Introns**
  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 sequences that appear in mature or processed RNA. The exons are interrupted by introns. Introns or intervening sequences do not appear in mature or processed RNA.

➢ **Process of Transcription**

Steps of transcription in prokaryotes

- **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.
- **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.
- **Termination :** A termination factor (ρ factor) binds to the RNA polymerase and terminates the transcription.
- In bacteria (Prokaryotes), transcription and translation can be coupled (Translation can begin before mRNA is fully transcribed) because mRNA requires no processing to become active.
- Transcription and translation take place in the same compartment (no separation of cytosol and nucleus).
- In eukaryotes, there are 2 additional complexities :

(a) There are three RNA polymerases :

- **RNA polymerase I :** Transcribes rRNAs (28S, 18S & 5.8S).
- **RNA polymerase II :** Transcribes the heterogeneous nuclear RNA (hnRNA). It is the precursor of mRNA.
- **RNA polymerase III :** Transcribes tRNA, 5S rRNA and snRNAs (small nuclear RNAs).

(b) The primary transcripts (hnRNA) : They contain both the exons and introns and are non-functional. Hence introns have to be removed. For this, it undergoes the following processes :

- **Splicing :** From hnRNA, introns are removed (by the spliceosome) and exons are spliced (joined) together.
- **Capping :** Here, a nucleotide methyl guanosine triphosphate (cap) is added to the 5′ end of hnRNA.
- **Tailing (Polyadenylation) :** Here, adenylate residues (200-300) are added at 3′-end. It is the fully processed hnRNA, now called mRNA.

TOPIC-2

Genetic Code, Translation, Lac Operon, Human Genome Project and DNA Fingerprinting

Quick Review

➢ **Genetic Code**

It is the sequence of nucleotides in mRNA that contains information for protein synthesis (translation).

➢ **There are 20 amino acids that are involved in translation.**

- **George Gamow :** Suggested that for coding 20 amino acids, the code should be made up of 3 consecutive nucleotides.
- **HarGobind Khorana :** Developed the chemical method in synthesizing RNA molecules with defined combinations of bases (homopolymers and co-polymers).
- **Marshall Nirenberg :** Developed cell-free system for protein synthesis.
- Severo Ochoa (polynucleotide phosphorylase) enzyme is used to polymerize RNA with defined sequences in a template independent manner.

➢ **Salient Features of Genetic Code**

- The genetic code is a triplet code (three-letter code) where three adjacent nitrogen bases code for a single amino acid.
- 61 codons code for amino acids. 3 codons (UAA, UAG and UGA) do not code for any amino acids. They function as stop codons (Termination codons or non-sense codons).
- 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.
- No punctuations between adjacent codons (comma less code). The codon is read in mRNA in a continuous fashion.
- Genetic code is non-overlapping.
- A single amino acid is represented by many codons (except AUG for methionine and UGG for tryptophan). Such codons are called degenerate codons.
- Genetic code is unambiguous and specific. *i.e*. one codon specifies only one amino acid.
- The codon is read in 5′ → 3′ direction.
- AUG has dual functions. It codes for Methionine (met), and also acts as initiator codon. In eukaryotes, methionine is the first amino acid and formyl methionine in prokaryotes.

➢ **Mutations and Genetic Code**

- The relationships between genes and DNA are best understood by mutation studies.
- Effects of large deletions and rearrangements in a segment of DNA may result in loss or gain of a gene and so a function.
- A classical example of point mutation is a change of single base pair in the gene for beta globin chain of haemoglobin that results in the change of amino acid residue glutamate to valine. It results into a diseased condition called as sickle cell anaemia.
- 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 multiple codon hence one or multiple amino acids, and reading frame remains unaltered from that point onwards. Such mutations are referred to as frame-shift insertion or deletion mutations.
- This forms the genetic basis of proof that codon is a triplet and it is read in a contiguous manner.

➢ **The Adapter Molecule – tRNA**

- The tRNA is a molecule has about 6% of its part double stranded and the rest remains single stranded which has unpaired bases.
- The tRNA has
  - **(a)** An anticodon (NODOC) loop that has bases complementary to the CODON with which it gets attached in mRNA.
  - **(b)** An amino acid acceptor end to which amino acid binds. This end or site lies at (3′ end & CCA–OH group. The 5′ end bears G.
  - **(c)** **T Ψ C loop :** This is the site for attaching with ribosome.
    This has some unusual bases like Ψ (pseudouridine) and ripothymidine.
  - **(d)** **DHU-Loop :** It is the binding site for the enzyme aminoacyl synthetase. It is the largest loop and has Dihydrouridine.
  - **(e)** **Extra arm :** It is a variable side arm lying between T Ψ C and anticodon loop.
    tRNA is called adapter molecule because it picks up amino acids from cytoplasm and transfers them to ribosomes during protein synthesis.
- For initiation, there is another tRNA called initiator tRNA.
- There are no tRNAs for stop codons.
- (2-D) structure of tRNA looks like a clover-leaf according to Robert Holly (1965). 3-D structure looks like inverted 'L' according to Klug (1974).

➢ **Translation – Protein Synthesis**

It takes place in ribosomes. It includes 4 steps :

1. **Charging of tRNA (aminoacylation of tRNA)**
   - Formation of peptide bond requires energy obtained from ATP.
   - For this, amino acids are activated (amino acid + ATP) and linked to their cognate tRNA in the presence of aminoacyl tRNA synthetase. So, the tRNA becomes charged.
2. **Initiation**
   - It begins at the 5′-end of mRNA in the presence of an *initiation factor*.
   - The mRNA binds to the small subunit of ribosome. Now the large subunit binds to the small subunit to complete the initiation complex.
   - Large subunit has 2 binding sites for tRNA- aminoacyl tRNA binding site (A site) and peptidyl site (P site).
   - Initiation codon for methionine is AUG. So,methionyl tRNAcomplex would have UAC at the Anticodon site.

3. **Elongation**
   - At the P-site the first codon of mRNA binds with anticodon of methionyl tRNA complex.
   - Another aminoacyl tRNA complex with an appropriate amino acid enters the ribosome and attaches to A site.
   - Its anticodon binds to the second codon on the mRNA and a peptide bond is formed between first and second amino acids in presence of an enzyme, *peptidyl transferase*.
   - First amino acid and its tRNA are broken. This tRNA is removed from P site and second tRNA at the A site is pulled to P site along with mRNA. This is called translocation.
   - Then 3rd codon comes into A site and a suitable tRNA with 3rd amino acid binds at the A site. This process is repeated.
   - A group of ribosomes associated with a single mRNA for translation is called a polyribosome (polysomes).
4. **Termination**
   - When aminoacyl tRNA reaches the termination codon like UAA, UAG & UGA, the termination of translation occurs. The polypeptide and tRNA are released from the ribosomes.
   - The ribosome dissociates into large and small subunits at the end of protein synthesis.

     An mRNA has additional sequences that are not translated (untranslated regions or UTR). UTRs are present at both 5′-end (before start codon) and 3′-end (after stop codon). They are required for efficient translation process.

➢ **Regulation of Gene Expression**

Gene expression results in the formation of a polypeptide. In eukaryotes, the regulation includes the following levels:

- Transcriptional level (formation of primary transcript)
- Processing level (regulation of splicing)
- Transport of mRNA from nucleus to the cytoplasm
- Translational level.

The metabolic, physiological and environmental conditions regulate expression of genes. *E.g.*

- In *E. coli*, the enzyme, *beta-galactosidase* hydrolyses lactose into galactose and glucose. In the absence of lactose, the synthesis of beta-galactosidase stops.
- The development and differentiation of embryo into adult are result of the expression of several set of genes.

➢ **Operon Concept**

- "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.

➢ **The Lac Operon**

- **Lac operon in *E. coli* :** The operon controlling lactose metabolism. It consists of a regulator gene 3-structural genes, an operator gene, Promoter gene, a repressor and an inducer.
  - **(a) A regulatory or inhibitor (i) gene :** Codes for the repressor.
  - **(b) 3 structural genes :**
    - **(i) z gene :** Codes for β-*galactosidase* (hydrolyze lactose to galactose and glucose).
    - **(ii) y gene :** Codes for *permease* (increase permeability of the cell to lactose).
    - **(iii) 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.
- 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.
- So, repressor protein cannot bind to **operator gene**. The operator gene becomes free and induces the RNA polymerase to bind with **promoter gene** then transcription starts. Regulation of lac operon by repressor is called negative regulation.

➢ **Human Genome Project (HGP)**

- 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 (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.

➢ **Goals of HGP**

(a) To identify all the estimated genes in human DNA
(b) To determine the sequences of the 3 billion chemical base pairs that make up human DNA.
(c) To store this information in databases.
(d) To improve tools for data analysis.
(e) To transfer related technologies developed during the project of society to other sectors of society.
(f) To address the ethical, legal and social issues (ELSI) that may arise from the project.

➢ **HGP was Closely Associated with Bioinformatics**

Application of computer science and information technology to the field of biology and medicine helps in analyzing DNA sequence data.

➢ **Methodologies of HGP**

There are two major approaches namely, ESTs and sequence annotation.

- **Expressed Sequence Tags (ESTs) :** Focused on identifying all the genes that are expressed as RNA and sequencing the same.
- **Sequence annotation :** Sequencing whole set of genome containing all the coding & non-coding regions and later assigning functions to different regions.

Procedure

Isolate total DNA from a cell → Convert into random fragments of smaller size → Clone in suitable host (*e.g.* BAC – bacterial artificial chromosomes & YAC – yeast artificial chromosomes) for amplification through PCR (polymerase chain reaction) → Fragments are sequenced using Automated DNA sequencers (using Frederick Sanger method) → Sequences are arranged based on the overlapping regions → Alignment of sequences using 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 (micro-satellites).

➢ **Salient Features of Human Genome**

(a) Human genome contains 3164.7 million nucleotide bases pairs.
(b) Total number of genes = about 25,000.
(c) Average gene consists of 3000 bases, but sizes vary. Largest known human gene (dystrophin on X-chromosome) contains 2.4 million bases.
(d) 99.9% nucleotide bases are identical in all people. It is 0.1% what makes each of us unique.
(e) Functions of over 50% of discovered genes are unknown.
(f) Chromosome I has most genes (2968) and Y has the fewest (231).
(g) Less than 2% of the genome codes for proteins.
(h) Repeated sequences make up very large portion of human genome. Repetitive sequences are stretches of DNA sequences that are repeated many times. They have no direct coding functions, but they shed light on chromosome structure, dynamics and evolution.
(i) About 1.4 million locations where single-base DNA differences (SNPs- Single nucleotide polymorphism or 'snips') occur in humans.

➢ **DNA Fingerprinting (DNA profiling)**

- It is the technique to identify the similarities of the DNA fragments of two individuals.
- Developed by **Alec Jeffreys (1985)**. He is considered as the father of DNA finger printing. Lalji Singh is the Father of Indian DNA finger printing.

➢ **Basis of DNA Fingerprinting**

- DNA carries some non-coding sequences called repetitive sequence [Variable Number Tandem Repeats (VNTR)].
- Number of repeats is specific. It varies from person to person and is specific to a person.
- The size of VNTR varies from 0.1 to 20 kb.
- Repetitive DNA are 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 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. For evolution & speciation, polymorphisms play important role.

➢ **Steps of DNA Fingerprinting (Southern Blotting Technique)**

(a) Isolate DNA (from any cells like blood stains, semen stains or hair roots).
(b) Make copies (amplification) of DNA by Polymerase Chain Reaction (PCR) if the amount of isolated DNA is small.
(c) Digest DNA by restriction endonucleases.
(d) Separate DNA fragments by gel electrophoresis over agarose polymer gel.
(e) Treat with alkali solution (NaOH) to denature DNA bonds so as to split them into single stranded DNAs in the gel into single strands.
(f) Transfer (blotting) single stranded DNA fragments to synthetic membranes such as nitrocellulose or nylon, and then baked in a vacuum oven at 80°C for 3-5 hours (to fix the DNA fragment on the membrane).
(g) Nitrocellulose filter paper is placed in a solution containing radioactive labelled single stranded DNA probe. The DNA probes are small radio active synthetic DNA segments of known sequences of nitrogen bases. These DNA probe binds with the complimentary sequences of the DNA fragment on the membrane to form a hybridized DNA.
(h) The filter paper is washed to remove unbound probe.
(i) The hybridized DNA is photographed on to an X-ray film by autoradiography. The image (in the form of dark & light bands) obtained is called DNA fingerprint. This gives the characteristic pattern of an individual's DNA.

➢ **Application of DNA Fingerprinting**

- Forensic tool to solve paternity, rape, murder etc.
- For the diagnosis of genetic diseases.
- To determine phylogenetic status of animals.

Know the Terms

➢ **VNTR :** Variable Number Tandem Repeats
➢ **YAC :** Yeast Artificial Chromosome
➢ **BAC :** Bacterial Artificial Chromosome
➢ **SNPs :** Single Nucleotide Polymorphism
➢ **HGP :** Human Genome Project, a mega project.
➢ **hnRNA :** Heterogeneous nuclear RNA. It is precursor of mRNA.
➢ **Replication fork :** The Y shaped structure formed when double stranded DNA is unwound upto a point during its replication.
➢ **Transformation :** The phenomenon by which the DNA isolated from one type of a cell, when introduced into another type, is able to express some of the properties of the former into the latter.
➢ **Transcription :** The process of copying genetic information from one strand of DNA into RNA.
➢ **Translation :** The process of polymerisation of amino-acids to form a polypeptide as dictated by mRNA.
➢ **Anticodon :** A sequence of three nitrogeneous bases on tRNA which is complementary to the codon on mRNA.
➢ **Exons :** The regions of a gene which become part of mRNA and code for different regions of proteins.
➢ **Introns :** The regions of a gene which are removed during the processing of mRNA.
➢ **Euchromatin :** The region of chromatin which is loosely packed and genetically active.
➢ **Heterochromatin :** The chromatin that is more densely packed, stains dark and is genetically inactive.
➢ **Capping :** Adding of methyl guanosine triphosphate to the 5′ end of hnRNA.
➢ **Splicing :** The process in eukaryotic genes in which introns are removed and the exons are joined together to form mRNA.
➢ **Nucleosome :** The structure formed when negatively charged DNA is wrapped around positively charged histone octamer.
➢ **DNA Polymorphism :** The variations at genetic level, where an inheritable mutation is observed.
➢ **Satellite DNA :** The repetitive DNA sequences which form a large portion of genome and have high degree of polymorphism but do not code for any proteins.
➢ **Operon :** A group of genes which control a metabolic pathway.
➢ **IRGSP :** International Rice Genome sequencing Project.

❑❑

Chapter - 7 : Evolution

TOPIC-1
Origin of Life on Earth and Various Related Evidences

Quick Review

- **Introduction**
  - Evolution is an orderly change from one form to another.
  - Evolutionary Biology : Study of history of development of newer life forms from pre-existing ones.
- **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 4.5–5 billion years ago.
  - There was no atmosphere on early earth.
  - Water vapour, CH_4, CO_2 & NH_3 released from molten mass covered the surface.

    $H_2O \rightarrow H_2 + O_2$

    $NH_3 + O_2 \rightarrow$ water

    $CH_4 + O_2 \rightarrow CO_2$
  - Then the ozone layer was formed.
  - As it cooled, the water vapour fell as rain to form oceans.
- **Theories of Origin of Life**
- **Theory of Spontaneous Generation (Abiogenesis)**
  1. It states that, life came out of decaying and rotting matter like straw, mud etc.
  2. Louis Pasteur (1864) demonstrated that life comes from pre-existing life and dismissed abiogenesis theory.
  3. He showed that in pre-sterilized flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose.
- **Biogenesis**
  1. It was proposed by **Francisco Redi, Spallanzani** and **Louis Pasteur**.
  2. It states that, life originates from pre-existing life.
- **Cosmic Theory (Theory of Panspermia)**
  - It states that the units of life (spores) were transferred to different planets including earth.
- Theory of Special Creation
  - It states that, living & non-living things are created by some supernatural power (God).
- **Theory of Chemical Evolution of life**
  - It was proposed by **Oparin and Haldane**.
  - It states that, the first form of life was originated from non-living inorganic and organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, nucleic acids etc.
  - "Abiogenesis first, but biogenesis ever since".
  - Two hypothetical proposals of Oparin-Haldane's theory are :
    (i) Chemical evolution from inorganic to organic molecules.
    (ii) First life formed by assembly and interaction of organic molecules.
  - The theory is also known as primary abiogenesis. It took place only once.
- **Urey-Miller Experiment**
  - **Harold Urey & Stanley 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 devoid of oxygen but containing compounds of carbon, hydrogen, nitrogen and water.
  - They made 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 formation of sugars, nitrogen bases, pigments and fats.
  - First non-cellular form of life originated 3 billion years ago.
  - They were RNA, proteins, polysaccharides etc.

➢ **Evolution of Life Forms – Various Theory**

- Based on observations made during a sea voyage in a survey 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 history of earth.
- There has been 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 or fitness of the individual or population.
- 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 earth.
- The geological history of earth closely correlates with the biological history of earth.

➢ **Evidences for Evolution**

1. Paleontological Evidences

Paleontology
- The study of fossils is known as paleontology.

Fossils
- These are remnants of life forms or the parts found preserved in rocks (earth crust).
- Fossils are written documents of evolution.

Significance of Fossils

(a) To study phylogeny (evolutionary history or race history). *e.g*. Horse evolution.

(b) To study the connecting link between two groups of organisms. *e.g*. *Archaeopteryx* having reptilian and avian characteristics.

(c) To study about extinct animals. *e.g*. Dinosaurs.

(d) To study about geological period by analyzing 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.

2. Morphological and Anatomical Evidences

- Comparative anatomy and morphology evidences showed that different forms of animals have some common structural features.

This can be explained as follows :

(a) Homologous Organs and Homology

- Homologous organs are the organs having fundamental similarity in structure and origin but different in functions. This phenomenon is called homology. *e.g*. Human hand, Whale's flippers, Bat's wings, and Cheetah's foot.
- All these perform different functions, but are constructed on the same fundamental plan.
- Homology can be seen in skeleton (*e.g*. humerus, radius, ulna, carpals, meta-carpals & phalanges), heart, blood vessels, excretory system, brain etc.

➢ **Homology in Plants**

- The thorns of *Bougainvillea* and tendrils of *Cucurbita*.
- The origin of homologous organs is due to Divergent evolution.
- The divergent evolution is the process by which related species become less similar in order to survive and adapt in different environmental conditions.
- Homology indicates common ancestry.

(b) Analogous Organs and Analogy

- Analogous organs are the organs having similar function but different structure and origin. This phenomenon is called analogy.
- Examples
  - **(i)** Wings of insects (formed of a thin flap of chitin) and wings of birds (modified forelimbs).
  - **(ii)** Eyes of Octopus (retina from skin) and 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 conditions.

3. **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. *e.g.*
     (a) Darwin's finches (seen in Galapagos Islands).
     (b) Australian marsupials.
     (c) Placental mammals in Australia.

➢ **Placental Mammals**
   - Mole, Anteater, Mouse, Lemur, Flying squirrel, Bobcat, Wolf.
   - When more than one adaptive radiation occur in an isolated geographical area, this leads to convergent evolution. *e.g.* Australian Marsupials and Placental mammals.

4. **Biochemical Evidences**
   - Similarities in proteins and genes.
   - Similarities in other biomolecules and metabolism.

5. **Evidences for Evolution by Natural Selection**
   - Natural selection is the process by which the organisms that are best suited for their environment survive and reproduce.
   - **Examples of natural selection :**

(a) Industrial Melanism (In England)

Before Industrialization (1850s):
   - There were more white winged moths (*Biston betularia*) on trees than dark winged or melanised moths (*Biston carbonaria*).
   - **Reason :** White coloured lichen covered the trees. In that background the white winged moths survived but the dark coloured moths were easily spotted out and picked out by predators.

After industrialization (1920) :
   - More dark winged moths and less white winged moths.
   - **Reason :** The tree trunks became dark due to pollution by industrial smoke and soot. No growth of lichens. Under this condition the white winged moth did not survive because the predators identified them easily against dark background. Dark winged moth survived because of suitable dark background.
   - Excess use of herbicides, pesticides, antibiotics or drugs etc. resulted in selection of resistant varieties (Natural selection by anthropogenic action).

TOPIC-2
Evolutionary Theories, It's Mechanism and Evolution of Man

Quick Review

➢ **Theories of Biological Evolution**

1. **Lamarckism (Theory of Inheritance of Acquired Characters)**
   - It was proposed by Lamarck in 1801 and was explained in his book *Philosophic Zoologique*.
   - It states that evolution of life forms occurred by use and disuse of organs. Continued use of an organ makes it larger, more elaborate and continued disuse of an organ causes its gradual decrease in size, degeneration and finally its elimination. The new character so acquired is passed on to next generation *e.g.*
     (a) Evolution by Use of Organs : Long neck of giraffe is due to continuous elongation to forage leaves on tall trees. This acquired character was inherited by succeeding generations.
     (b) Evolution by Disuse : Disappearance of limbs in snakes. This theory was eliminated out because, it is proved that the characters are inherited only through genes.

2. **Darwinism (Theory of Natural Selection)**
   - It was proposed by Charles Darwin (1859) in his book "Origin of Species".
   - It is based on two key concepts namely,
     (a) Branching descent (Adaptive radiation) **(b)** Natural selection (Convergent evolution)

(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 conditions. 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 principle of populations (1794) influenced Darwin.
- Natural selection is based on the following facts :
  (a) Heritable minor variations
  (b) Over production by organisms
  (c) Limited natural resources
  (d) Struggle for existence for food and space
  (e) 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 survives (Survival of the fittest).
- Darwin said that the organisms with heritable variations make resource utilization better.
- They 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 (1901)** proposed Mutation Theory of evolution in his book "Mutation theory".
- 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 for deVries it is a discontinuous process. He believed mutation caused speciation and hence called it saltation (single step large mutation).

➢ **Differences between Darwinian Variation & Mutation**

Darwinian Variation	Mutation
It shows minor variation.	It shows large variation.
It is slow and directional.	It is random, sudden and directionless.
It showed gradual evolution.	It showed discontinuous evolution and speciation by saltation.
It is caused by reshuffling of genes.	It is caused by change in the genetic material.

➢ **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 a constant. This is called genetic equilibrium (Hardy-Weinberg equilibrium).
- Sum total of all the allelic frequencies = 1. *e.g.*, 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 Aa = 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. This is due to evolution.

➢ **Factors Affecting Hardy-Weinberg Equilibrium :** There are fine basic processes which may bring about the change in Hardy Weinberg equilibrium and bring about the variations at the genetic level as follows :

(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
- The accidental gene flow causing change in frequency.
- Sometimes, the change in 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
- Mutations result in formation of new phenotypes.
- Over few generations, this leads to speciation.

(d) Genetic Recombination
- It is the reshuffling of gene combinations during crossing over resulting in genetic variation.

(e) Natural Selection : It is the major factor which adds variations in the population, change the gene frequencies in the gene pool resulting in the formation new gene pool.
- These are of three types namely, Stabilizing selection, Directional selection and Disruptive selection.

(i) Stabilizing Selection : Here, more individuals acquire average character value and variation is reduced.

(ii) Directional Selection : Here, individuals of one extreme are more favoured.

(iii) Disruptive Selection : Individuals of both the extremes are favoured. It produces two peaks that may lead to the development of two different populations.

➢ **Account on Evolution**

(a) Proterozoic Era - 2000 Million Years Ago (Mya)
- First cellular forms of life.
- Some of the cells had the ability to release O_2 as the light reaction in photosynthesis.
- Single celled organisms → Multicellular organisms

(b) Paleozoic Era
- **500 mya :** Invertebrates.
- **400-600 mya :** First land organisms (plants).
- **400 mya :** Arthropods invaded the land.
- **350 mya :** Jawless fish. Fish with stout and strong fins could move on land and go back to water.
- **320 mya :** Sea weeds and few plants.
- **Amphibians to reptiles :** They lay thick-shelled eggs which do not dry up in sun unlike those of amphibians.
- In the next 200 million years reptiles dominated on earth. Giant ferns (Pteridophytes) were present but they all fell to form coal deposits slowly.

(c) Mesozoic Era
- **200 mya :** Some of the land reptiles went back into water to evolve into fish-like reptiles (*e.g.,* Ichthyosaurs).
- The land reptiles were dinosaurs.
- They include
  - **(i)** ***Tyrannosaurus rex :*** Largest dinosaur (20 feet in height, huge fearsome dagger-like teeth).
  - **(ii)** Triceratops
  - **(iii)** Pteranodon
  - **(iv)** Stegosaurus
  - **(v)** Brachiosaurus

(d) Cenozoic Era
- **65 mya :** Dinosaurs suddenly disappeared.
- First mammals (shrew-like). Their fossils are small sized.
- In South America, there were mammals resembling horse, hippopotamus, bear, rabbit etc.
- Due to continental drift, when South America joined North America, these animals were over ridden by North American fauna.
- Due to continental drift, Australian marsupials survived because of lack of competition from any other mammals.

➢ **Origin and Evolution of Man (Human ancestry)**

(i) Dryopithecus & (ii) Ramapithecus (15 mya)
- **(a)** Hairy.
- **(b)** Walked like gorillas and chimpanzee.
- **(c)** Dryopithecus : ape-like.
- **(d)** Ramapithecus : man-like.
- **(e)** Fossils of man-like bones found in Ethiopia and Tanzania.
- **(f)** Man-like primates (3-4 mya) : Height up to 4 feet.

(ii) Australo-pithecus (2 mya)
- In East African grasslands.
- Hunted with stone weapons.
- Ate fruits.

(iii) ***Homo habilis***
- First human-like being (hominid).
- Brain capacity : 650-800 cc.
- Did not eat meat.

(iv) ***Homo erectus*** **(1.5 mya)**
- Large brain (900 cc). Ate meat.

(v) Neanderthal man : 40,000- 1 lakh yrs ago :
- Brain 1400 cc.
- Lived in East and Central Asia.
- Used hides to protect their body.
- Buried their dead.

(vi) ***Homo sapiens*** **(Modern man) :** Evolution took place during 10,000 to 75,000 years ago.
- Prehistoric cave art developed about 18,000 years ago.
- Agriculture and settlements : 10,000 years ago.

Know the Terms

- **Abiogenesis :** Origin of life form 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.
- **Bio-geography :** The study of patterns of distribution of plants and animals in different parts of earth.
- **Gene Pool :** Sum total of all the genes in a population.
- **Panspermia :** Units of life in the forms of so called spores, which were transferred to earth from outer space (as believed by some scientists).
- **Saltation :** Single step large mutations.
- **Speciation :** It is the formation of new species from the pre-existing ones.
- **Organic (Biological) Evolution :** Changes in the characteristics/features of organisms or groups of such populations over a number of generations.

- **Gene Pool :** Sum total of all the genes in a population. `

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UNIT - VIII : Biology in Human Welfare

Chapter - 8 : Human Health and Diseases

TOPIC-1
Health and Related Aspects, Common Human Diseases and Immunity

Quick Review

- Health is a state of complete physical, mental & social well-being.
- Health is affected by genetic disorders, infections, sedentary life style (Junk food, lack of exercise, habits, etc).
- **Disease :** A disease can be defined as any condition that may lead to discomfort, distress, health problems, or death of the affected person.
- Infectious Diseases are caused by microscopic organisms (such as bacteria or viruses) that get into the body and cause problems. *e.g.*, Influenza, TB.
- **Congenital Diseases:** These are diseases which are present since birth. For instance, hole in the heart of an infant. They are caused by some genetic abnormalities or metabolic disorder or malfunctioning of an organ.
- **Acquired Diseases :** These are diseases which may occur after birth during one's lifetime.
- Based on their ability or inability to spread from one individual to another, acquired diseases are of two types :
  (a) Infectious or Communicable diseases : The diseases which can be transmitted from diseased person to healthy person by means of infectious agents are known as infectious or communicable diseases. For example, tuberculosis, measles, malaria etc.
  (b) Non-infectious or Non-communicable diseases : The diseases which cannot be transmitted from an affected individual to a healthy person are known as non-infectious or non-communicable diseases. For example, high blood pressure, Cancer, Allergy, Obesity etc.
- Among non-infectious diseases, cancer is the major cause of death.
- Pathogens are disease causing organisms.
- Parasites are pathogens as they harm the host by living in or on them.
- Pathogens have to adapt to life within the environment of the host.

- **Common Infectious Diseases in Man**

1. BACTERIAL DISEASES

(a) Typhoid

- **Pathogen** : *Salmonella typhi*.
- **Mode of transmission** : It enters the small intestine through food and water and migrates to other organs through blood.
- **Symptoms** : Sustained high fever (39°- 40°C), weakness, stomach pain, constipation, headache & loss of appetite. Intestinal perforation and death may occur.
- **Confirmation** : Widal test is used for confirmation of the disease.

(**b) Pneumonia**

- **Pathogen** : *Streptococcus or Diplococcus pneumoniae & Haemophilus influenzae.*
- **Mode of transmission** : Inhaling the droplets/aerosols released by an infected person. Sharing glasses and utensils with an infected person.
- **Symptoms** : Infects lung alveoli. The alveoli get filled with fluid leading to respiratory problems. Fever, chills, cough, headache.
- **Severe cases** : Lips and finger nails turn gray to bluish colour.
- Dysentery, plague, diphtheria are some other bacterial diseases in humans.

2. VIRAL DISEASES

(a) Common cold

- **Pathogen** : Rhino Viruses
- **Mode of transmission** : Inhaling droplets resulting from cough or sneezes. Through contaminated objects.
- **Symptoms** : Infects nose & respiratory passage. Nasal congestion and discharge, sore throat, hoarseness, cough, headache, tiredness etc. Last for 3-7 days.

3. PROTOZOAN DISEASES

(a) Malaria

- **Pathogen :** *Plasmodium* sp. *(P. vivax, P. malariae, P. ovale. and P. falciparum).*
- **Mode of transmission :** Biting of *Anopheles* mosquito.
- **Symptoms :** Haemozoin causes chill and high fever recurring every 3-4 days.

Life cycle of *Plasmodium*

- Life cycle of *Plasmodium* has three phases - *Schizogony*, *gamogony* and *sporogony*. Female *Anopheles* mosquito is the primary host while man is the secondary host.

Life Cycle of *Plasmodium* in Man

(a) The infective stage of *Plasmodium* is the sporozoite, which is injected in to the blood of the human by the female *Anopheles* mosquito.

(b) From the human blood, sporozoites reach the liver cells where they multiply.

(c) The liver cells rupture to liberate the parasites in to the blood where they attack the RBCs, multiply and cause their rupture.

(d) The rupture is associated with the release of a toxin called haemozoin, which is responsible for the recurring chill and high fever within 3 - 4 days.

(e) The development of gametocytes takes place in the RBCs, which are of two types : male gametocytes or microgametocytes, and female gametocytes or macrogametocytes.

Life cycle of *Plasmodium* in Female *Anopheles* Mosquito

(a) When a female *Anopheles* mosquito sucks the blood of an infected human host, it receives the RBCs including gametocytes.

(b) Further development occurs in the stomach wall of the mosquito, the gametes fuse to form a zygote.

(c) The zygote undergoes further development to form sporozoites.

(d) The sporozoites after liberation from the stomach wall move to different organs in the body cavity, but many of them penetrate the salivary glands.

(e) The mosquito now becomes infective; when the female *Anopheles* mosquito bites a healthy person the sporozoites are injected in his/her blood along with saliva.

(b) Amoebiasis (Amoebic dysentery) or Enteritis.

- **Pathogen** : *Entamoeba histolytica.* Found in the large intestine of humans.
- **Mode of transmission** : Houseflies (mechanical carriers) transmit parasites from faeces of infected person, to food and water and thereby contaminating it.
- **Symptoms** : Constipation, abdominal pain and cramps, stools with excess mucous and blood clots.

4. HELMINTH DISEASES

(a) Ascariasis

- **Pathogen** : *Ascaris* (Intestinal parasite).
- **Mode of transmission** : Soil, water, vegetables, fruits etc. contaminated with faeces containing eggs of parasites.
- **Symptoms** : Internal bleeding, muscular pain, fever, anaemia and blockage of intestinal passage.

(b) Filariasis (Elephantiasis)

- **Pathogen** : Filarial worms or *Wuchereria* (*W. bancrofti* & *W. malayi*).
- **Mode of transmission** : Bite of female *Culex* mosquito.
- **Symptoms** : Filarial worms live in lymphatic vessels (usually of lower limbs). It causes chronic inflammation of the organs in which they live for many years. Limbs and genital organs may be deformed.

5. FUNGAL DISEASES

(a) Ring worms

- **Pathogens** : *Microsporum, Trichophyton & Epidermophyton*. They are seen in groin, between the toes etc.
- **Mode of transmission** : From soil or by using towels, cloths, comb etc. Heat and moisture help fungi to grow.
- **Symptoms** : Appearance of dry, scaly lesions on various body parts such as skin, nails and scalp. Intense itching.

Other Infectious Diseases

Bacterial Diseases

Disease	Pathogen	Transmission
Dysentery	*Shigella*	Contact, Contaminated food and water
Plague	*Pasteurella pestis*	Rat fleas
Diphtheria	*Corynebacterium diphtheriae*	Contaminated food, Direct contact
Cholera	*Vibrio cholerae*	Food & 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

Disease	Pathogen	Transmission
Rabies	*Rabies virus*	Rabid dogs etc
Dengue	*Dengue virus*	*Aedes* mosquito
Influenza	*Influenza virus*	Coughing & sneezing
Measles	*Rubeola virus*	Droplets
German measles	*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 & Air
Chikungunya	*CHIK virus*	Aedes mosquito
Avian flu	*H5N1 virus*	Contact with infected poultry. Air borne spread
H1N1 (Swine flu)	*H1N1 virus*	Contact with pigs, cough & sneeze of infected person.

Prevention and Control of Diseases

1. Personal Hygiene : Keep the body clean. 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) Standard practices of hygiene in public catering.
(e) Control and eliminate the vectors (*e.g.*, mosquitoes) and their breeding places by following methods:
  (i) Avoid stagnation of water.
  (ii) Regular cleaning of household coolers.
  (iii) Use of mosquito nets.
  (iv) Introduce larvivorous fishes like *Gambusia* in ponds.
  (v) Spraying insecticides in ditches, drainage and swamps.
  (vi) Doors and windows should be provided with wire mesh to prevent entry of mosquitoes.

- These precautions can avoid vector borne diseases like Malaria, Filariasis, Dengue and Chikungunya.

➢ **Immune System**

- It is the system that gives immunity to the body by recognizing, responding and remembering foreign antigens.
- It plays an important 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 occurs.
- These are of two types namely, primary lymphoid organs and secondary lymphoid organs.

(a) Primary Lymphoid Organs

- Here, immature lymphocytes differentiate into antigen-sensitive lymphocytes. *e.g.*, Bone marrow and thymus.
- Bone marrow is the main lymphoid organ and is the site of formation of all the blood cells including lymphocytes.
- Thymus is large during birth but gradually reduces in size and becomes very small size in puberty.
- Growth and maturation of T-lymphocytes taken place here.

(b) Secondary Lymphoid Organs

- The organs, to which matured lymphocytes migrate, interact with antigens and then proliferate to become effector cells. *e.g.*, Spleen, lymph nodes, tonsils, Peyer's patches, MALT and appendix. Secondary lymphoid organs are:

(i) Spleen :

(i) It is a bean-shaped organ.

(ii) It contains lymphocytes and phagocytes.

(iii) It removes worn-out RBCs and microorganisms from blood.

(iv) It is a reservoir of erythrocytes in foetus.

(ii) Lymph Nodes

(i) These are found in lymphatic system.

(ii) They trap microorganisms or other antigens that enter the lymph and tissue fluid.

(iii) The trapped antigens activate lymphocytes and cause immune response.

(iii) Mucosal Associated Lymphoid Tissue (MALT) :

(i) It is located within the lining of respiratory, digestive and urinogenital tracts.

(ii) It constitutes 50% of lymphoid tissue in human body.

➢ **Immunity**

- It is the ability of the immune system of the body to fight against the disease-causing organisms.
- It is of two types namely, Innate immunity and Acquired immunity.

(a) Innate Immunity

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

(i) Physical Barriers

- Skin on our body is the first and main barrier which prevents entry of the micro-organisms. It is the first line of defence.
- Mucus coating of the epithelium lining the respiratory, gastrointestinal and urogenital tracts also help in trapping microbes entering our body.

(ii) Physiological Barriers : Acid in the stomach, saliva in the mouth, tears from eyes–all prevent microbial growth.

(iii) Cellular Barriers : Certain types of leukocytes (WBC) of our body like polymorpho-nuclear leukocytes (PMNL-neutrophils) and monocytes and natural killer (type of lymphocytes) in the blood as well as macrophages in tissues can phagocytose and destroy microbes.

(iv) Cytokine Barriers : Virus infected cells secrete proteins called *interferon* which protect non-infected cells from further viral infection.

(b) Acquired Immunity

- It is a pathogen specific immunity.
- It is not present since birth but develops during the life time of an individual.
- 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 B-lymphocytes and T-lymphocytes.
  (a) B-lymphocytes (B-cells) : Produce antibodies.
  (b) T-lymphocytes : Help B-cells to produce antibodies.

➢ **Structure of an Antibody Molecule**

- Each antibody has 4 polypeptide chains namely, 2 small light chains and 2 large heavy chains (H_2L_2).
- In our body different types of antibodies : Such as IgG, IgA, IgM, IgE & IgD are produced.
- Acquired immune response is of two types namely,
  (a) Humoral mediated response
  (b) Cell mediated response

➢ **Humoral or Antibody Mediated Response/Antibody Mediated Immunity (AMI)**

- Antibodies are found in blood plasma. So, it is called as humoral immune response.
- It includes B-lymphocytes and T-lymphocytes. The later help the former to produce antibodies.

➢ **Cell Mediated Response/Cell Mediated Immunity (CMI)**

- It is T-lymphocytes (T-cells) mediated CMI.
- CMI causes Graft rejection.
- The body is able to differentiate '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.

➢ **Acquired immunity is of two type *i.e.*, Active and Passive Immunity**

(a) Active Immunity

- The immunity in which antibodies are produced in a host body when the host is exposed to antigens (*e.g.*, living or dead microbes or other proteins) is known as active immunity.
- It is a slow process.
- It is produced by 2 ways :
  (a) Natural Active Immunity : During natural infection by microbes.
  (b) Artificial Active Immunity : Injecting the microbes deliberately during immunization.

(b) Passive Immunity :

- Here, readymade antibodies are directly given to protect body.
- It is of two types :
  (a) Natural Passive Immunity : *e.g.*, Antibodies (IgG) from mother → Placenta → Foetus and → Antibodies (IgA) in colostrum → infants
  (b) Artificial Passive Immunity : *e.g.*, Anti-tetanus serum (ATS)

➢ **Immunization**

- This is based on 'memory' of the immune system.
- It is of two types namely,
  (a) Active immunization
  (b) Passive immunization

(a) **Active Immunization (Vaccination)**

- A preparation of vaccine (antigenic proteins of pathogen or inactivated pathogen) is introduced into body.
- The antibodies produced in the body against the antigens neutralize the pathogenic agents during actual infection.
- The vaccines also generate memory B and T-cells that recognize 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). Such vaccines are called as second generation vaccines.
- The vaccines produced by conventional methods *e.g.* small pox-vaccines are called first generation vaccine and those which are synthetic vaccine are the third generation vaccine.

(b) Passive Immunization

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

➢ **Allergies**

- It is the exaggerated or hypersensitive response of the immune system to certain antigens present in the environment.
- Allergens are substances causing allergy. *e.g.*, mites in dust, pollens, animal dander, fur etc.
- Antibodies produced against the allergens are of IgE type.
- Allergy is due to the release of chemicals like histamine and serotonin from the mast cells.
- **Symptoms :** Sneezing, watery eyes, running nose, difficulty in breathing, etc.

- **Determination of cause of allergy :** The patient is exposed to or injected with very small doses of possible allergens, and the reactions studied.
- Treatment, Drugs like anti-histamine, adrenaline and steroids quickly reduce the symptoms of allergy.
- Modern-day life style results lowering of immunity and more sensitivity to allergens.
- Asthma is a respiratory disease due to allergy.

➢ **Auto Immunity**

- It is caused due to genetic and other unknown reasons. Body attacks self cells. This results in auto-immune disease.
- It is memory-based acquired immunity evolved in higher vertebrates based on the ability to differentiate foreign organisms (*e.g.,* pathogens) from self-cells. *e.g.,* Rheumatoid arthritis.

➢ **AIDS (Acquired Immunodeficiency Syndrome)**

- Syndrome is a group of symptoms.
- AIDS is the deficiency of immune system.
- It is caused by HIV (Human Immunodeficiency Virus), a retrovirus having RNA genome.
- AIDS was first reported in America (1981).
- **Mode of Transmission :**

  (a) Sexual contact with infected person.

  (b) Transfusion of contaminated blood and blood products.

  (c) Sharing of infected needles.

  (d) From infected mother to her child through placenta.

➢ **High risk of getting HIV includes**

(a) Individuals with multiple sexual partners

(b) Drug addicts who take drugs intravenously using infected syringes.

(c) Individuals who require repeated blood transfusion

(d) Children born to an HIV infected mother

➢ HIV does not spread by touch or physical contact.

- It spreads only through body fluids.
- There is always a time-lag (from few months to 5-10 years) between the infection and appearance of symptoms.

➢ **Life Cycle of HIV Virus :**

- HIV enters into body → To macrophages (acts as HIV factory) → RNA genome replicates in presence of *Reverse transcriptase* to form viral DNA → Viral DNA incorporates into host DNA → Infected cells produce virus particles → HIV enters into helper T-cells (T_H) → Replicates & produce progeny viruses → Attack other helper T-cells → T-cells decrease → Weaken immunity.
- HIV infected person may be infected with *Mycobacterium*, viruses, fungi and parasites like *Toxoplasma*.

➢ **Diagnosis of AIDS**

ELISA test (Enzyme-linked immune-sorbent Assay) PCR-Test, western blotting etc.

➢ **Treatment of AIDS**

- Anti-viral drugs partially effective.
- They can only prolong the life of the patient.

➢ **Prevention of AIDS**

- Educate peoples about AIDS.
- Making blood (from blood banks) safe from HIV.
- Use of disposable needles and syringes.
- Advocating safe sex and free distribution of condoms.
- Controlling drug abuse.
- Regular check-ups for HIV in susceptible population.

➢ **Cancer**

- Cancer is an abnormal and uncontrolled multiplication of cells resulting in the formation of tumor (masses of cells).
- Normal cells show a contact inhibition (contact with the other cells inhibits their uncontrolled growth). Cancer cells do not have this property.
- Tumors are of two types namely, Benign tumor and Malignant tumor.

(a) Benign Tumor

- It is confined to the place of its origin and do not spread to other parts of the body.
- It is harmless or causes less damage to the body.

(b) Malignant Tumor
- It spread and invades nearby tissues.
- It is harmful.

➢ **Metastasis :** The spread of cancer cells from one part of the body to another.

➢ **Types of Cancer**
- **Carcinoma :** cancer of epithelial cells
- **Sarcoma :** cancer of connective tissues.
- **Melanomas :** cancer of melanocytes
- **Leukemia :** blood cancer
- **Lymphomas :** cancer of spleen and lymph nodes.

➢ **Causes of Cancer (Carcinogens)**

(a) Physical agents : *e.g.* Ionizing radiations like X-rays and gamma rays and non-ionizing radiations like UV.

(b) Chemical agents : Tobacco smoke (major cause of lung cancer), vinyl chloride, caffeine, nicotine, mustard gas etc.

(c) Biological agents : *e.g.,* oncogenic viruses, cellular oncogenes (e-onc or proto oncogenes) etc. When C-onc in normal cells is activated the cells becomes oncogenic.

➢ **Cancer Detection and Diagnosis**

(a) Biopsy : A thin piece of the suspected tissue is stained and examined under microscope (histopathological studies).

(b) In case of leukemia : Biopsy and histopathological studies. Blood & bone marrow tests for increased cell counts.

(c) Radiography (use of X-rays) : CT (Computerized tomo-graphy) scan and MRI (Magnetic Resonance Imaging).

(d) Use of Antibodies against cancer-specific antigens.

(e) Techniques of molecular biology to detect genes related to cancer. Such individuals may be advised to avoid exposure to particular carcinogens (*e.g.* tobacco smoke).

➢ **Treatment of Cancer**

Most cancers are treated by combination of surgery, radiotherapy and chemotherapy.

(a) Radiation therapy : Tumor cells are irradiated lethally, without damaging surrounding normal tissues.

(b) Chemotherapy : Use of chemotherapeutic drugs. Many drugs have side effects like hair loss, anaemia etc.

(c) Immunotherapy : The patients are given biological response modifiers (*e.g.* ∝- interferon) which activates their immune system and helps in destroying the tumor.

TOPIC-2
Drugs and Adolescence

Quick Review

➢ **Drugs**
- These have ability to alter the activity of nervous system.
- They are also called as psychotropic drugs or mood altering drugs or neurological drugs.
- These drugs change the mood, feeling behaviour and power of perception.
- The sources of most of the drugs are mainly flowering plants and some fungi.

➢ **Types of Drugs**
- The drugs, which are commonly abused are opioids, cannabinoids and coca alkaloids.
- These drugs are of following main types :

1. Depressants
- Depress brain activity.
- They include

(a) Sedatives : Give calmness and relaxation. High doses induce sleep. *e.g., Barbiturates* (*sleeping pills*).

(b) Tranquilizers : Lower tension and anxiety without inducing sleep. *e.g., Benzodiazepines* (*e.g. Valium*).

2. Opiate Narcotics (Pain Killers)
- Drugs which bind to specific opioid receptors in CNS and gastrointestinal tract.
- They are analgesic & depressant (lower tension, anxiety, B.P and respiration rate and reduce visual activity). *e.g.,* Opium and its derivatives (Opiates or Opioids).
- Opium is obtained from dried latex of unripe capsules of Poppy plant (*Papaver somniferum*).

➢ **Opium Derivatives**

(a) ***Morphine:*** Strong analgesic and sedative extracted from the latex of poppy plant. Useful during surgery.

(b) Brown sugar

(c) ***Heroin* (*Diacetyl morphine*/*smack*) :** Most dangerous, white, odourless, bitter crystalline compound produced by acetylation of morphine. It is a depressant and slows down body functions. It is taken by snorting & injection.

(d) ***Codeine* :** Mild analgesic. Used in cough syrups.

3. Stimulants

- Stimulates CNS. *e.g., Cocaine, Caffeine* (cardiac stimulant), *amphetamines* (synthetic)
- *Amphetamines* & *anabolic steroids* are misused by some athletes.
- Coca alkaloid (Cocaine or coke/crack) : Obtained from *coca plant* (*Erythroxylum coca*)
- Interferes the transport of neurotransmitter dopamine.
- Cocaine is usually snorted.
- Stimulate CNS producing euphoria and energy.
- Excessive dosage causes hallucination.

4. Hallucinogens

- Cause hallucinations, changing thoughts, feelings and perceptions. *e.g., Mescaline, Psilocybin, Cannabinoids* & LSD (Lysergic Acid diethylamide).
- *Atropa belladonna* & *Datura* are plants with hallucinogenic property.

5. Cannabinoids

- Drugs (a group of chemicals) that interact with cannabinoid receptors in brain.
- Generally taken by inhalation and oral ingestion.
- Natural cannabinoids are obtained from *Cannabis sativa* (Hemp plant). Its flower tops, leaves & resin are used to produce *bhang, ganja, charas* (*hashish*), *marijuana* etc.
- Affects cardiovascular system.

➢ **Alcoholism**

- Alcohols include beverages and spirits.

(a) Beverages : Wine, beer and toddy (5-15% alcohol).

(b) Spirits : Whisky, brandy, rum, gin, arrack, etc (more than 50% alcohol).

- The victims of alcoholism are known as alcoholics.

➢ **Effects of Alcoholism**

(a) Affects thinking ability, speech, movements, reflexes etc.
(b) Amnesia, blurred vision, loss of body balance, nausea, vomiting, headache etc.
(c) Cirrhosis and fatty liver.
(d) Alcoholic polyneuritis and loss of appetite
(e) Cardiovascular diseases and hypertension.
(f) Ulcer, pancreatitis and gastritis.
(g) Loss of sexual drive and necrospermia.
(h) Foetal alcohol syndrome (FAS or Alcohol Embryopathy).
(i) Family and social problems.

➢ **Effects of Alcoholism on Traffic Accidents**

(a) Affects co-ordination and correct judgment of distance.
(b) Affects vision causing Tunnel vision.
(c) Increases reaction time.
(d) Affects behaviour.

➢ **De-alcoholism**

- Medical treatment.
- Social methods of treatment (Group therapy).
- Aversion therapy (Behavioural treatment).

➢ **Smoking**

- Tobacco is smoked, chewed or used as a snuff.
- Tobacco contains nicotine (an alkaloid) which stimulates adrenal gland to release adrenaline and nor-adrenaline, causing high BP and heart rate.
- Smoking causes cancers of lung, urinary bladder and throat, bronchitis, emphysema, coronary heart disease, gastric ulcer etc. Tobacco chewing causes oral cancer.
- Smoking increases CO (Carbon monoxie) content in blood and reduces oxyhaemoglobin. This causes O_2 deficiency in the body.

Adolescence and Drugs

➢ **Adolescence**

- It is 'a period' and 'a process' during which a child becomes mature in terms of his/her attitudes and beliefs for effective participation in society.
- Adolescence is a bridge linking childhood and adulthood (period of 12-18 years of age). It is very vulnerable phase of mental and psychological development.

Causes of Drug or Alcohol use in Adolescence Period

(a) Curiosity and Experimentation.
(b) Need for adventure and excitement.
(c) To escape facing problems.
(d) Stress from pressure to excel in academics or examination.
(e) Television, movies, news papers, internet etc.
(f) Unstable or unsupportive family structures and peer pressure.

Addiction and Dependence

➢ **Addiction**

- It is a psychological attachment (euphoria and a temporary feeling of well being) with drugs and alcohol.
- With repeated use of drugs, the tolerance level of the receptors increases. Thus the receptors respond only to higher doses leading to greater intake and addiction.

➢ **Dependence**

- It is the tendency of the body to manifest a characteristic and unpleasant withdrawal syndrome if regular dose of drugs/alcohol is abruptly discontinued.
- This results in anxiety, shakiness, nausea and sweating.
- Dependence leads to social adjustment problems.

➢ **Effects of Drug or Alcohol Abuse**

(a) Reckless behaviour, vandalism and violence.
(b) Coma and death due to respiratory failure, heart failure or cerebral hemorrhage.
(c) Drugs together with alcohol may cause death.
(d) Drop in academic performance and absence from school.
(e) Lack of interest in personal hygiene.
(f) Withdrawal and isolation.
(g) Depression, fatigue, aggressive and rebellious behaviour, deteriorating relationship between family and friends.
(h) Loss of interest in hobbies.
(i) Fluctuations in sleeping, eating habits, weight, appetite etc.
(j) Social problems like stealing and spread of infectious diseases (*e.g.* AIDS, hepatitis B).
(k) Damage of nervous system and cirrhosis.
(l) Use of drugs and alcohol by pregnant woman adversely affects the foetus.
(m) Misuse of drugs by athletes (*e.g.* narcotic analgesics, anabolic steroids, diuretics and certain hormones to increase muscle strength and bulk and to promote aggressiveness).

➢ **Side Effects of Anabolic Steroid in Females**

(a) Masculinisation
(b) Mood swings and depression
(c) Excessive hair growth
(d) Deepening of voice
(e) Increased aggressiveness
(f) Abnormal menstrual cycle
(g) Enlargement of clitoris

➢ **Side Effects of Anabolic Steroid in Males**

(a) Acne
(b) Mood swings and depression
(c) Increased aggressiveness
(d) Reduced testicles
(e) Decreased sperm
(f) Kidney and liver dysfunction
(g) Breast enlargement
(h) Premature baldness
(i) Enlargement of prostate gland

- **Side Effects in the Adolescent, Male and Female**
  - Severe facial and body acne
  - Premature closure of the growth centres of the long bones resulting in stunted growth.
- **Prevention and Control**

(a) Avoid undue peer pressure.
(b) Education and counselling.
(c) Seeking help from parents and peers.
(d) Looking for danger signs.
(e) Seeking professional and medical help.
(f) Psychologists and psychiatrists.
(g) De-addiction and rehabilitation programs.

Know the Terms

- **Health :** It is a state of complete physical, mental and social well-being.
- **Disease :** A disease can be defined as any condition that may lead to discomfort, distress, health problems, or death of the affected person.
- **Congenital Diseases :** Diseases which are present since birth.
- **Acquired Diseases :** Diseases which may occur after birth during one's lifetime.
- **Infectious or Communicable diseases :** The diseases which can be transmitted from diseased person to healthy person by means of infectious agents.
- **Non-infectious or Non-communicable diseases :** The diseases which cannot be transmitted from an affected individual to a healthy person.
- **Pathogens :** Pathogens are disease causing organisms.
- **Immune system :** It is the system that gives immunity to the body by recognizing, responding and remembering foreign antigens.
- **Immunity :** It is the ability of body to protect itself from infection and disease.
- **Innate (non-specific) immunity :** It is the non-specific type of defence that is present at the time of birth.
- **Acquired (specific) immunity :** It is pathogen specific immunity.
- **Active immunity :** It is a type of acquired immunity in which the body produces its own antibodies against disease-causing antigens.
- **Passive immunity :** It is a type of acquired immunity in which readymade antibodies are transferred from one individual to another.
- **Vaccination :** It is defined as protection of the body from communicable diseases by the administration of some agents that mimic the microbe.
- **Allergy :** Allergy is the exaggerated response of the immune system to certain antigens present in the environment.
- **Autoimmunity :** It is the memory based acquired immunity, which is able to distinguish foreign molecules or cells (pathogen) from self-cells.
- **Cancer :** Cancer is an abnormal and uncontrolled multiplication of cells resulting in the formation of tumor.
- **Metastasis :** Metastasis is the pathological process of spreading cancerous cells to the different part of the body.
- **Addiction :** It is a psychological attachment to certain effects such as euphoria and a temporary feeling 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/alcohol is abruptly discontinued.

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Chapter - 9 : Strategies for enhancement in Food Production

TOPIC-1
Animal Husbandry

Quick Review

- With ever-increasing population of the world, enhancement of food production is a major necessity. Biological principles as applied to animal husbandry and plant breeding have a major role in our efforts to increase food production. Several new techniques like embryo transfer technology and tissue culture techniques are going to play a pivotal role in further enhancing food production.

Animal Husbandry

- It is the agricultural practice of breeding and raising livestock by applying scientific principles.
- It deals with the care and breeding of livestock such as buffaloes, cows, pigs, horses, cattle, sheep, camels, goats, bees, silkworms etc and poultry farming and fisheries, which are useful to humans.
- More than 70% of the world livestock population is in India and China.
- However, the contribution to the world farm produce is only 25%, *i.e.,* the productivity per unit is very low. Hence, the new technologies have to be applied to achieve improvement in quality and productivity.

Management of Farms and Farm Animals

Dairy Farm Management (Dairying)

- It is the management of animals for increasing yield and quality of milk and its products for human consumption.
- It deals with the processes and systems to improve quality and quantity of milk.
- Milk yield depends on the quality of breeds in the farm.
- The selection of good breeds having high yielding potential and resistance to diseases is important.
- For the yield potential :
  - The cattle have to be well looked after *i.e.,* they have to be housed well, should have adequate water and be maintained disease free.
  - The feeding of cattle should be carried out in a scientific manner i.e., with special emphasis on the quality and quantity of fodder.
  - Stringent cleanliness and hygiene of cattle and handlers while milking, storage and transport of the milk.
- Now-a-days, these processes have mechanized and so the chance of direct contact of the produce with the handler has been reduced.
- To ensure stringent measures there should be
  (i) Regular inspections, with proper record keeping which helps to identify and rectify the problems.
  (ii) Regular visits by a veterinary doctor.

Poultry Farm Management

- Poultry is the domesticated fowls (birds) used for food or eggs. Examples – chicken, ducks, turkey and geese.

Important Parameters of poultry farm management :

- Selection of disease free and suitable breeds.
- Proper feed and water.
- Proper and safe farm conditions.
- Hygiene and health care of birds.

Animal Breeding

- A breed is a group of animals related by descent and similar in general appearance, features, size etc.
- Breeding is the modification of genotype of an organism to make that organism more useful to humans.
- The objective of animal breeding is to increase the animal yield and to improve the desirable qualities of the produce.

Types of Breeding

- Breeding is of two types namely,
  (a) Inbreeding **(b)** Out-breeding

(a) Inbreeding

- It is the mating of more closely related individuals within the same breed for 4-6 generations.
- The procedure of inbreeding is as follows :
- 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 cow that produces more milk per lactation.
- A superior male (bull) gives rise to superior progenies.

Advantages of Inbreeding

- It increases homozygosity to evolve a pure line animal.
- It exposes harmful recessive genes that are eliminated by selection.
- It helps in accumulation of superior genes and elimination of less desirable genes. This approach increases the productivity of inbred population.

Disadvantages of Inbreeding

- Continued inbreeding, especially close inbreeding, may reduce fertility and productivity. This is called inbreeding **depression.** To solve this problem, selected animals should be mated with unrelated superior animals of the same breed.

(b) Out-breeding

- It is the breeding of the unrelated animals.
- It is of three types namely, out-crossing, cross-breeding and inter-specific hybridization.

(i) Out-crossing

- It involves mating of animals within the same breed, that have no common ancestors on either side of their pedigree up to 4-6 generations.
- The offspring of such a mating is known as out-cross.
- It is the best method for animals having low milk productivity to increase 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.
- The desirable qualities of 2 different breeds are combined into a progeny.
- The hybrid progeny animals may be used for commercial production or may be subjected to inbreeding and selection to develop new stable superior breeds. *e.g.,* Hisardale (sheep) developed in Punjab by crossing *Bikaneri ewes* and *Marino rams*.

(iii) Interspecific hybridization

- It involves the mating of male and female animals of two different species, which produces interspecific hybrids.
- In some cases, the progeny may combine desirable features of both the parents, and may be of considerable economic value. *e.g.,* Mule, a cross between male ass with female horse.

Artificial insemination

- In this method, the semen collected from selected 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.
- The success rate of crossing mature male and female animals is low even though artificial insemination is carried out.

Multiple Ovulation Embryo Transfer (MOET) Technology

- It is a programme for herd improvement in animals like cattle, sheep, buffaloes etc.
- In this, a cow is administered hormones, with FSH-like activity, to induce follicular maturation and super ovulation *i.e.,* production of 6-8 eggs instead of one egg per cycle.
- The animal is either mated with an elite bull or artificially inseminated.
- Fertilised eggs at 8–32 cells stages are recovered non surgically 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, meat-yielding bulls have been bred successfully to increase herd size in a short time.

Bee-keeping (Apiculture)

- It is the maintenance of hives of honeybees for the production of honey and beeswax.
- Honey is a food of high nutritive and medicinal value.
- Beeswax is used for preparation of cosmetics, polishes etc.
- Bee-keeping can be practiced in any 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*.
- 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. It improves both crop yield and honey yield.
- **A successful bee keeping requires :**
  - **(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 beeswax.

Fisheries

- Fishery is an industry of catching, processing or selling of fish, shellfish or other aquatic animals such as prawn, crab, lobster, edible oyster etc.
- The freshwater fishes include *Catla, Rohu*, common carp, etc.
- The edible marine fishes include *Hilsa*, Sardines, Mackerel, Pomfrets, etc.
- Fisheries provide income and employment to millions of fishermen and farmers particularly of coastal region.

Techniques to Increase the Production of Aquatic Plants and Animals

(a) Aquaculture : Rearing and management of useful aquatic plants and animals like fish, oysters and prawn etc. is called aquaculture.

(b) Pisciculture : It is the rearing, catching and management of fish. It has led to the development of fishery industry.

- **Blue Revolution :** It is the increased production of fish and fish produce which has led to the development and flourishing of the fishery industry. It was started in our country India during about 1960 along with the Green revolution and white revolution.

TOPIC-2
Plant Breeding

Quick Review

- It is the purposeful manipulation of plant species in order to create desired plant types that are better suited for cultivation, give better yields and are disease resistant.

Green Revolution

- During mid 1960s, several high yielding varieties of wheat and rice were developed as a result of various types of breeding techniques. This has resulted in the dramatic increase in food production not only in our country but in the whole world. This phase of enhanced food production is referred to as **Green revolution.**
- It is dependent on plant breeding.
- Norman E. Borlaug is the father of Green revolution
- Dr. M.S. Swaminathan is known as the father of green revolution in India.

Classical Plant Breeding

- It involves hybridization of pure lines and artificial selection of progenic plants to produce desirable traits of higher yield nutrition and disease resistance.
- The plant breeding is carried out by using molecular genetic tools.

Desirable Traits Need to be Incorporated

- Increased crop yield.
- Improved quality.
- Increased tolerance to environmental stresses such as salinity, extreme temperatures and drought, resistance to pathogens.
- Increased tolerance to insect pests.

Steps of Breeding

(i) Collection of Genetic Variability

- In many crops, pre-existing genetic variability is available from wild relatives of the crop.
- Collection and preservation of all the different wild varieties, species and relatives of the cultivated species is a prerequisite for effective exploitation of natural genes.
- The entire collection of plants/seeds having all the alleles for all genes in a given crop is called germ plasm collection.

(ii) Evaluation and Selection of Parents

- The germ plasm is evaluated so as to identify plants with desirable combination of characters.
- The selected plants are multiplied and used for hybridisation.
- The pure lines are created wherever desirable and possible.

(iii) Cross Hybridisation Among the Selected Parents

- The desired characters have to be combined in the hybrid from two different plants (parents). e.g., high protein quality of one parent is combined with disease resistance from another parent.
- This is possible by cross hybridizing the two parents to produce hybrids that genetically combine the desired characters in one plant.

Limitations

- This is a very time-consuming and tedious process.
- The hybrids may not combine the desirable characters.
- Usually only one in a few hundred to a thousand crosses shows the desirable combination.

(iv) Selection and Testing of Superior Recombinants

- 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. This is called hybrid vigour or heterosis.
- These are self-pollinated for several generations till they reach a state of uniformity (homozygosity), so that the characters will not segregate in the future progeny.

(v) Testing, Release and Commercialization of new cultivars.

- The newly selected lines are evaluated for their yield and other agronomic traits of quality, disease resistance, etc.
- This is done by growing them in the research fields and recording their performance under ideal fertiliser application, irrigation and other crop management practices.
- The evaluation is followed by testing the materials in farmers' fields, for at least three growing seasons at several locations in the country, representing all the agro climatic zones.
- The material is evaluated in comparison to the best available local crop cultivar (a check or reference cultivar).
- The variety tested is selected, certified and is released as a new variety.

Wheat and Rice

- The development of high yielding varieties of wheat and rice in the mid-1960s, through plant breeding techniques has increased food production in our country. This phase is known as the Green Revolution.
- During the period 1960-2000, wheat production increased from 11 million tons to 75 million tons. The rice production went up from 35 million tons to 89.5 million tons.
- Nobel laureate Norman E. Borlaug (International Centre for Wheat and Maize Improvement, Mexico) developed semi-dwarf wheat. In 1963, 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 developed in India.

Sugarcane

- ***Saccharum barberi*** which is grown in north India has poor sugar content and yield.
- It was crossed with ***Saccharum officinarum*** which grows in south India.
- This hybrid possess thicker stems and higher sugar content but does not grow well in north India.

Millets

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

Plant Breeding for Disease Resistance

- It enhances food production and helps to reduce the use of fungicides and bacteriocides.
- Resistance of the host plant is the genetic ability to prevent the pathogens from disease.

Plant Diseases : Plant diseases may be caused by fungi, bacteria or viruses.

- **Fungal diseases :** Rusts (*e.g.*, brown rust of wheat and black rust of wheat), Red rot (Red rot of sugarcane and late blight of potato).
- **Bacterial diseases :** Black rot of crucifers, blight of rice and citrus canker etc.
- **Viral :** Tobacco mosaic, turnip mosaic, etc.

Methods of Breeding for Disease Resistance

- **It includes,**
  (a) Conventional breeding techniques
  (b) Mutation breeding

Conventional Method

- The steps are :
  (a) Screening germ plasm for disease resistance.
  (b) Hybridisation of selected parents.
  (c) Selection and evaluation of the hybrids.
  (d) Testing and release of new varieties.

Demerits of conventional method :

- Conventional breeding is constrained by the availability of limited number of disease resistance genes.
- Only a limited number of genes resistant to diseases have been identified in crop variation or their wild relatives.

Mutation Breeding

- Mutation is the creation of genetic variations through changes in the base sequences within the genes ***i.e.,*** which can create new desirable characters not found in the parental type.
- Plants having these desirable characters can be multiplied directly or can be used in breeding.
- Mutation breeding is the breeding by artificially inducing mutation through the use of chemicals or radiations like gamma radiations, and selecting and using the plants that have desirable character as a source in breeding.
  Example - In mung bean, resistance to yellow mosaic virus and powdery mildew were induced by mutations.
- Resistant genes from wild species are introduced into the high-yielding cultivated varieties.
  Example - Resistance to yellow mosaic virus in bhindi (*Abelmoschus esculentus*) was introduced from a wild species and resulted in a new variety called *Parbhani kranti*.
- Transfer of resistant genes is achieved by sexual hybridisation between the target and the source plant.
- **Mutation breeding is carried out in following steps.**
  (i) Inducing mutation in plants artificially by chemicals or radiations.
  (ii) Screening plants for desired variations.
  (iii) Selecting plants with desired traits for multiplication and further breeding.

Plant Breeding for Developing Resistance to Insect Pests

- Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics.
- **Some important characteristics that lead to insect pest resistance are :**
  (i) Hairy leaves : *e.g.,* resistance to jassids in cotton and cereal leaf beetle in wheat.
  (ii) Solid stems in wheat : lead to non-preference by the stem sawfly.
  (iii) Smooth leaved and nectar-less cotton varieties do not attract bollworms.
  (iv) High aspartic acid, low nitrogen and sugar content in maize leads to resistance to maize stem borers.
- The steps of breeding methods are the same as for other agronomic traits.

Plant Breeding for Improved Food Quality

- More than 840 million people in the world do not have adequate food. 3 billion people suffer from micronutrient, protein and vitamin deficiencies *i.e.,* 'hidden hunger'.
- Therefore, breeding of crops for improvement in quality of food produced is essential and a most important aspect.
- Biofortification is the method of breeding crops with higher levels of nutrients, which help to improve public health.

Objectives of Biofortification or Breeding for Improved Nutritional Quality

- To improve protein content and quality.
- To improve oil content and quality.
- To improve vitamin content.
- To improve micronutrient and mineral content.

Examples for Hybrids with Improved Nutritional Quality

- Maize hybrids having twice the amount of amino acids, lysine and tryptophan compared to existing maize hybrids.
- Wheat variety, Atlas 66, having high protein content.
- Iron-fortified rice variety containing over five times as much iron as in common varieties.

Vegetable Crops Rich in Vitamins and Minerals

- Indian Agricultural Research Institute, New Delhi has produced variety of vegetable crops rich in vitamin and minerals such as 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

- It is an alternative source of proteins for animal and human nutrition derived from certain beneficial microorganisms 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, 250g of a micro-organism like *Methylophilus methylotrophus* produce 25 tonnes of protein.
- Microbes are being grown commercially as a source of SCP. They are :
  - **(i)** *Spirulina*—a cyanobacterium or blue green alga.
  - **(ii)** *Chlorella*—a green alga
  - **(iii)** *Yeast—Saccharomyces cerevisiae*—a fungus
  - **(iv)** *Methylophilus methylotrophus*—a bacterium
  - **(v)** *Fusarium graminearum*—a fungus.

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 which is free of virus from infected plant is removed and grown *in vitro* to obtain virus-free plants.
- Scientists have cultured meristems of banana, sugarcane, potato, etc.

Somatic Hybridization

- 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 hybridization.
- Protoplasts can be isolated after digesting the cell walls of single cells of plants.
- A protoplast of tomato has been fused with that of potato, to form new hybrid plants with the characteristics of tomato and potato.
- But it does not have all the desired characteristics for its commercial utilization.

Know the Terms

- **Breed :** It is a group of animals related by descent and similar general appearance, features, size etc.
- **Classical Plant Breeding :** It involves hybridization of pure lines and artificial selection to produce desirable traits.
- **Animal husbandry :** It is the agricultural practice of breeding and raising livestock by applying scientific principles.
- **Breeding :** It is the modification of genotype of an organism to make that organism more useful to humans.
- **Inbreeding :** It is the mating of more closely related individuals within the same breed for 4-6 generations.
- **Out-breeding :** Breeding between animals of different breeds is known as out-breeding.
- **Apiculture :** It is the practice of bee-keeping for production of various products such as honey and beeswax.
- **Pisciculture :** It refers to the breeding, hatching, and rearing of fish under controlled conditions.
- **Aquaculture :** It is the cultivation of aquatic organisms.
- **Mariculture :** It refers to aquaculture practiced in marine environments.
- **Green Revolution :** It is the development and flourishing of the agriculture.
- **Mutation breeding :** It 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.
- **Bio fortification :** It is the process of breeding crops with higher levels of vitamins, minerals, proteins and fat content.
- **Tissue culture :** It is the process of developing a complete plant from a part of a plant. The plant part is called an explant.
- **Micro propagation :** It is a method of producing new plants in a short duration through tissue culture.

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Chapter - 10 : Microbes in Human Welfare

TOPIC-1
Microbes-in Household Products, Industrial Products and in Sewage Treatment and Biogas

Quick Review

- Microbes are the major components of biological system on the earth.
- They are the organism which can not be seen with the naked eyes but are viewed under the microscope.
- Microbes are present everywhere such as in soil, water, air, inside our bodies and that of other animals and plants.
- They are also present where no other life-form could possibly exist such as deep inside the geysers (thermal vents) where the temperature may be as high as 1000°C, deep in the soil, under the layers of snow several metres thick, and in highly acidic environments.
- Microbes are diverse–protozoa, bacteria, fungi and microscopic plants.
- Viruses, viroids and also prions are 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. Such cultures are useful in studies on micro-organisms.
- Most microbes are harmful to the mankind, causing a number of infectious diseases, but some are important in many ways for human welfare.

Microbes in household products.

- ***Lactobacillus* or Lactic Acid Bacteria (LAB)**
  - It converts milk into curd.
  - It produces lactic acid that coagulates and partially digests the milk protein casein.
  - A small amount of curd containing LAB converts fresh milk into curd.
  - It also increases vitamin B_{12}.
  - In stomach, it helps to inhibit pathogens.
- **Bacterial Fermentation (Anaerobic Respiration)**
  - The dough which is formed by fermentative activity of bacteria is used to make foods such as dosa, idli etc.
  - The puffed up appearance of dough is due to the production of CO_2 gas.
  - Toddy is made by fermenting sap from palms by bacteria.
  - Microbes are used to ferment fish, soya bean and bamboo-shoots to make foods.
  - Microbes are used to produce cheeses differing in flavour, taste and texture. *e.g.*, Large holes in 'Swiss cheese' are due to production of large amount of CO_2 by *Propionibacterium sharmanii* (a bacterium).
  - 'Roquefort cheese' is ripened by growing a specific fungus (*Penicillium roqueforti*) on them that gives them a particular flavour.
- **Baker's Yeast (*Saccharomyces cerevisiae*) :**
  - It is used to make bread by fermenting dough.

Microbes in Industrial Products

- The large scale production of beverages, antibiotics etc. on an industrial scale, requires growing microbes in very large vessels called fermentors or bioreactors.

- **Fermented Beverages**
  - *Saccharomyces cerevisiae* (Brewer's yeast) is used in the production of beverages by fermenting malted cereals and fruit juices to produce ethanol.
  - Wine and Beer are produced without distillation.
  - Whisky, Brandy and Rum are produced by distillation of fermented broth.
- **Antibiotics**
  - The chemical substances produced by some microbes that can kill or inhibit the growth of other disease-causing microbes.
  - They are used to treat plague, whooping cough, diphtheria, leprosy and many other infectious diseases.
- **Penicillin**
  - First antibiotic discovered by Alexander Fleming in 1929.
  - He observed that a mould (*Penicillium notatum*) growing in unwashed culture plates around which *Staphylococci* could not grow.
  - He extracted penicillin from it.
  - Ernst Chain and Howard Florey established its full potential as an effective antibiotic.
  - Fleming, Chain and Florey were awarded Nobel Prize (1945).

Chemicals, enzymes and other bioactive molecules

1. Organic Acids : *e.g.,*

- ***Aspergillus niger* (a fungus) :** Citric acid
- ***Acetobacter aceti* (a bacterium) :** Acetic acid
- ***Clostridium butylicum* (a bacterium) :** Butyric acid
- ***Lactobacillus* (a bacterium) :** Lactic acid

2. Alcohol :

- Yeast (*Saccharomyces cerevisiae*) is used to produce ethanol.

3. Enzymes :

- **Lipases :** Used in detergent formulations. Help to remove oily stains from the laundry.
- **Pectinases and Proteases :** To clarify bottled juices.
- **Streptokinase :** Produced by *Streptococcus*. Used as a 'clot buster' to remove clots from the blood vessels of patients who have myocardial infection.

4. Cyclosporin A :

- It is produced by *Trichoderma polysporum* (fungus).
- It is used as an immunosuppressive agent in organ transplant patients.

5. Statins :

- It is produced by *Monascus purpureus* (a yeast).
- It is used as blood-cholesterol lowering agent.
- It inhibits the enzymes responsible for synthesis of cholesterol.

Microbes in Sewage Treatment

- Sewage (municipal waste-water) contains large amount of human excreta and organic matter and microbes.
- Sewage is treated in Sewage Treatment Plants to make it less polluting. It includes stages namely, primary treatment 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 form the primary sludge and the supernatant form the primary effluent.
  - The effluent is taken for secondary treatments.

(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 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 $20^{\circ}C$.
- 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.

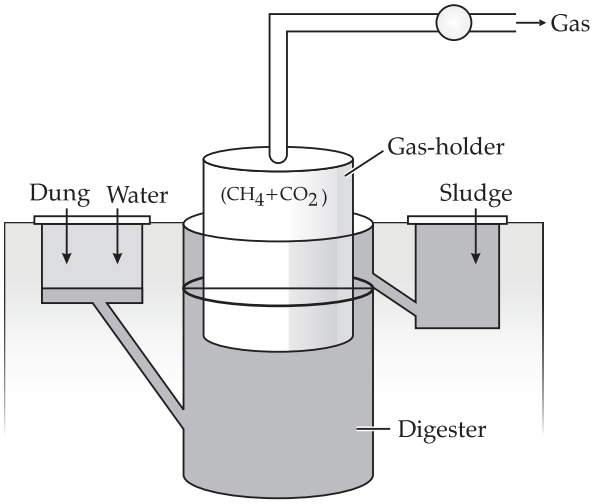
Microbes in the Production of Biogas

Biogas :

- It is a mixture of inflammable gases (mainly CH_4) produced by the microbial activity.
- Biogas is used for cooking and lighting.
- Methanogens grow anaerobically on cellulosic material and produce CH_4. *e.g., Methanobacterium*.

- *Methanobacterium* is found in the anaerobic sludge and rumen of cattle (for cellulose digestion).
- The dung of cattle (gobar) is rich in these bacteria.
- Dung can be used for generation of biogas (Gobar gas).

The Biogas plant



A Biogas Plant

- It consists of
  - **(a)** A concrete tank
  - **(b)** Floating cover
  - **(c)** An outlet
- The concrete tank (10-15 feet deep) collects 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 which is connected to a pipe to supply biogas.
- An outlet to remove spent slurry (used as fertilizer).

  Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC) developed technology of biogas production in India.

TOPIC-2
Microbes as Biocontrol Agents and Bio-fertilisers

Quick Review

- **Biocontrol**
  - It is the use of biological methods for controlling plant diseases and pests.
- **Chemical Pesticides and Insecticides**
  - These are toxic and harmful to all organisms including human beings and cause pollution.
  - Chemical pesticide kills both useful and harmful life forms.
  - Weedicides used to eliminate weeds cause soil pollution.
- **Microbial biocontrol agents**

  (a) ***Bacillus thuringiensis*** **(Bt) :**
  - This is to control butterfly caterpillar. These are available in sachets as dried spores which are mixed with water and sprayed on to vulnerable plants such as brassicas and fruit trees, where these are eaten by the insect larvae. In the gut of the larvae, the toxin is released and the larvae get killed. The scientists have introduced *B. thuringiensis* toxin genes into plants. *e.g.,* Bt cotton.

  (b) ***Trichoderma sp*** **(Fungus) :**
  - These are free livings species that are seen in the root ecosystems. They are effective biocontrol agents of several plant pathogens.

  (c) ***Baculoviruses*** **(Especially genus** ***Nucleopolyhedrovirus*****) :**
  - It attacks insects and other arthropods. These are suitable for species-specific, narrow spectrum insecticidal applications. This is desirable in IPM program to conserve beneficial insects.
- **Microbes as Biofertilisers**
  - Biofertilisers are the micro-organisms that enrich nutrient quality of the soil. *e.g.* Bacteria, fungi, cyanobacteria etc.

- ***Rhizobium***
  - It is a symbiotic bacteria found in root nodules of leguminous plants that fixes atmospheric N_2.
  - Free-living bacteria in the soil such as *Azospirillum* and *Azotobacter* enrich the nitrogen content of the soil.
- **Mycorrhiza**
  - It is a symbiotic association of fungi (*e.g.* the genus of *Glomus*) with the roots of higher plants.
  - The fungus gets food from the plant.
  - The fungal symbiont help to absorb phosphorous from soil and passes it to the plant, give resistance to root-borne pathogens and tolerance, to salinity and drought and also gives an overall increase in plant growth and development.
- **Cyanobacteria (Blue green algae) :**
  - They are autotrophic microbes that fixes atmospheric nitrogen. *e.g., Anabaena, Nostoc, Oscillatoria,* etc.
  - In paddy fields, Cyanobacteria serve as an important biofertilisers.
  - It also adds organic matter to the soil and increases its fertility.

Know the Terms

- **BOD :** Biochemical oxygen Demand
- **KVIC :** Khadi and Village Industries Commission
- **GAP :** Ganga Action Plan
- **LAB :** Lactic acid Bacteria
- **YAP :** Yamuna Action Plan
- **STPs :** Sewage Treatment Plants
- **IPM :** Integrated Pest Management
- **IPM :** Integrated Pest Management
- **Primary sewage treatment:** It is a mechanical process involving the removal of coarse solid materials.
- **Secondary sewage treatment:** It is a biological process involving the action of microbes.
- **Flocs:** They are masses of bacteria associated with fungal filaments to form mesh-like structures.
- **Biological Oxygen Demand (BOD):** It is the method of determining the amount of oxygen required by microorganisms to decompose the waste present in the water supply.
- **Biocontrol:** It refers to the use of biological methods for controlling plant diseases and pests.
- **Biopesticides:** The biological agent which are used to control weeds, insects and pathogen are called biopesticides.
- **Methanogens:** Micro-organisms that produce methane along with CO2 and H2 under anaerobic conditions are called methanogens.

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UNIT - IX : Biotechnology and its Application

Chapter - 11 : Biotechnology: Principles and Processes

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

Quick Review

Introduction

- **Biotechnology** deals with techniques of using live organisms or their enzymes for products and processes useful to humans.
- The term biotechnology was given by Karl Ereky (1919).
- 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'.
- **Biotechnology deals with :**
  - Microbe-mediated processes (making curd, bread, wine etc).
  - *In vitro* fertilisation ('test-tube' baby programme)

- Synthesis and using of a gene
- Preparation of a DNA vaccine
- Correcting a defective gene

Principles of Biotechnology

The two core techniques of modern biotechnology are :

(a) Genetic engineering : The technique in which the genetic material (DNA and RNA) is chemically altered and introduced into host organisms to change the phenotype is known as genetic engineering.

(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.

- Traditional hybridisation techniques lead to inclusion and multiplication of undesirable genes along with desired genes.
- Genetic engineering helps to isolate and introduce only 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 inherits along with the host DNA.
- First recombinant DNA was emerged from the possibility of linking a gene of antibiotic resistance with a native plasmid of *Salmonella typhimurium*. Plasmid is an autonomously replicating circular extra chromosomal DNA.
- Stanley Cohen and Herbert Boyer (1972) constructed first recombinant DNA. They isolated the antibiotic resistance gene by cutting out a piece of DNA from a plasmid.

Steps in Genetically Modifying an Organism

- There are three basic steps 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

1. Restriction Enzymes ('molecular scissors')

- The restriction enzymes are called molecular scissors and are responsible for cutting DNA.
- In 1963, two enzymes responsible for restricting the growth of bacteriophage in E. coli were isolated. One of these added methyl groups to DNA. The other (restriction endonuclease) cut DNA.
- The first restriction endonuclease is Hind II. Isolated by Smith, Wileox and Kelley (1968) from Haemophilus influenzae bacterium. It always cuts DNA molecules at a particular point by recognizing a specific sequence of six base pairs. This is known as the recognition sequence for Hind II.
- Today more than 900 restriction enzymes have been isolated from over 230 strains of bacteria.

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. *e.g. EcoRI* comes from *E. coli* RY 13, where R = the strain, Roman numbers = the order in which the enzymes were isolated from that strain of bacteria.
- Restriction enzymes belong to a class of enzymes called nucleases.
- The nucleases include **exonucleases** and **endonucleases**.

(i) Exonucleases

They remove nucleotides from the ends of the DNA.

(ii) Endonucleases

- They cut at specific positions within the DNA.
- Each restriction endonuclease can bind to specific recognition sequence of the DNA and cut each of the two strands at specific points in their sugar-phosphate backbones.
- Each restriction endonuclease recognizes a specific palindromic nucleotide sequences in the DNA.
- The palindrome in DNA is a sequence of base pairs that read the same on the two strands in 5′ → 3′ direction and in 3′ → 5′ direction. *e.g.*

  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 overhanging stretches at the ends. They are called sticky ends.
- They form H-bonds with their complementary cut counterparts. This stickiness facilitates action 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 the enzyme DNA ligases.

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. So, they can be separated by moving them towards the anode under an electric field through a medium/matrix such as agarose (which a natural polymer of D-galactose and 3, 6 anhydro L-galactose and which is extracted from sea weeds).

- The DNA fragments separate (resolve) according to their size through sieving effect provided by the agarose gel.
- The smaller sized fragments move farther.
- The separated DNA fragments can be visualized 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.

2. Cloning Vectors

- They 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 (high number per cell) 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 is also multiplied to the numbers equal to the copy number of the vectors.

Features of cloning vector :

(a) Origin of replication (*ori*)

- This is a DNA sequence from where replication starts. A piece of DNA linked to *ori* can replicate within the host cells. This also controls the copy number of the linked DNA. So, for getting many copies of the target DNA it should be cloned in a vector whose origin support 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

- In order 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.
- 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 Bam HI site of tetracycline resistance gene in the vector pBR322.
- The recombinant plasmids lose tetracycline resistance due to 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 on tetracycline medium.
- The recombinants grow in 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 insertion of alien DNA, and helps in selection of recombinants.
- Selection of recombinants due to inactivation of antibiotics requires simultaneous plating on two plates having different antibiotics.
- Therefore, alternative selectable markers have 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, α-galactosidase. So, the enzyme is inactivated. It is called insertional inactivation. Such colonies do not produce any colour. These are identified as recombinant colonies.
- If the plasmid in bacteria do not have any insert it gives blue coloured colonies in presence of chromogenic substrate.

(d) Vectors for cloning genes in plants and animals

- Genetic tools of some pathogens can be transformed into useful vectors for delivering genes to plants and animals. E.g. *Agrobacterium tumefaciens* (a pathogen of many dicot plants) can deliver a piece of DNA (T-DNA) to transform normal plant cells into a tumor.
- These tumor cells produce the chemicals required by the pathogen.
- The tumor 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 interest into plants.
- Retroviruses in animals can transform normal cells into cancerous cells. So, they are used to deliver desirable genes into animal cells.

3. Competent Host (For Transformation with Recombinant DNA)

- DNA is a hydrophilic molecule. So it cannot pass through cell membranes.
- To avoid this problem, bacterial cells are treated with a specific concentration of a divalent cation (*e.g.* calcium), so as to increase the pore size in the cell wall.
- So, DNA enters the bacterium through pores in cell wall. Such cells are incubated with recombinant DNA on ice.
- They are then placed briefly at 42°C (heat shock) and then put them back on ice. This enables the bacteria to take up the recombinant DNA.

Other methods to introduce alien DNA into host cells :

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

(b) Biolistics (gene gun) method : In this, 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 : These vectors, when infect the cell, transfer the recombinant DNA into the host.

TOPIC-2
Process of Recombinant DNA Technology

Quick Review

1. **Isolation of the Genetic Material (DNA)**
   - To get pure DNA (free from other macro-molecules), 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 macro-molecules (RNA,proteins, polysaccharides and lipids).
   - Genes (DNA) are interwined 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.
   - When chilled ethanol is added, purified DNA precipitates out as a collection of fine threads in the suspension.
2. **Cutting of DNA at Specific Locations**
   - Restriction enzyme digestions are performed by incubating purified DNA with the restriction enzyme, at the optimal conditions.
3. **Isolation of derived DNA fragments.**
   - **Agarose gel electrophoresis** is employed to check the progression of a restriction enzyme digestion. As 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.
4. **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.**
   - The technique was developed by *Kary Mullis* in 1985 and for this he was awarded the Nobel Prize in 1993.
   - Primers are small chemically synthesized oligonucleotides that are complementary to the regions of DNA.
   - The enzyme extends the primers using the nucleotides and the genomic DNA (template).
   - For amplification a thermostable DNA polymerase (isolated from a Thermophilic bacterium, *Thermus aquaticus*) is used.
   - It remains active at high temperature during the denaturation of double stranded DNA.
   - Source DNA and vector DNA are cut with the same endonuclease so as to obtain the sticky ends.
   - These are then ligated by mixing the gene of interest vector DNA in presence of the enzyme DNA ligase to form recombinant DNA.
   - The amplified fragment can be used to ligate with a vector for further cloning.
5. **Insertion of Recombinant DNA into the Host Cell/Organism**
   - There are several methods of introducing the ligated DNA into recipient cells.
   - Recipient cells take up DNA present in its surrounding.
   - If a recombinant DNA bearing a**mpicillin resistant gene** (a selectable marker gene) is transferred into ***E. coli*** cells,the host cells become ampicillin-resistant cells.
   - If the transformed cells are spread on agar plates containing ampicillin, only transformants will grow, untransformed recipient cells will die.
6. **Obtaining the Foreign Gene Product**
   - The ultimate aim of recombinant DNA technology is to produce a desirable protein.
   - The foreign gene gets expressed 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 purified using different separation techniques.

- The cells can also be multiplied on large scale in a continuous culture system.
- Here, 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.

➢ **Bioreactors**

- To produce large quantities of products, the bioreactors are used where large volumes (100-1000 litres) of culture can be processed.
- 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 (temperature, pH, substrate, salts, vitamins, oxygen) for achieving the desired product.
- There are two types of bioreactors namely,
  (a) Simple stirred-tank bioreactor
  (b) Sparged stirred-tank bioreactor
- The most commonly used bioreactors are of stirring type.

➢ **Stirred-tank Reactor**

- It is usually cylindrical or with a curved base to facilitate the proper mixing of the reacting contents.
- The stirrer facilitates even mixing and oxygen availability throughout the bioreactor.
- 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)
  (g) The contents are mixed by stirrer. This makes the oxygen available throughout the bioreactor.

7. **Downstream Processing :** All the processes to which the product is subjected to before being marketed as a final and finished product are called as downstream processing.
   - It includes 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 through 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.

Know the Terms

- **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.
- **Restriction enzymes :** Enzymes that are used to cut DNA segment at a specific site are called restriction enzymes.
- **Exonucleases :** Remove nucleotides from the ends of the DNA molecule.
- **Endonucleases :** Make cuts at specific positions within the DNA molecule.
- **Plasmid :** Autonomously replicating circular extra-chromosomal DNA of any bacteria.
- **Origin of replication :** A specific DNA sequence which is responsible for initiating replication is called origin of replication.
- **Vectors :** These are plasmid DNA or viruses that act as vehicle to transfer the piece of DNA attached to it.
- **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.
- **Gel electrophoresis :** A technique which is used to separate the fragments of DNA is known as gel electrophoresis.
- **Transformation :** It is a procedure through which a piece of DNA is introduced in a host bacterium.
- **Insertional inactivation :** The procedure of inserting a recombinant DNA within coding sequence of a functional gene which makes that gene inactive (unable to express) is called insertional inactivation.
- **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.
- **Micro-injection :** A technique in which recombinant DNA is directly injected into the nucleus of an animal's cell.
- **Biolistics or Gene gun :** Plant cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA in a method known as biolistics or gene gun.
- **Bioreactors :** Bioreactors are vessels in which raw materials are biologically converted into specific products, enzymes, etc., using microbial plants, animal or human cells.

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Chapter - 12 : Biotechnology and its Application

TOPIC-1
Application of Biotechnology in Agriculture and Medicine

Quick Review

- Biotechnology essentially deals with industrial scale production of biopharmaceuticals using genetically modified microbes, fungi, plants and animals.
- The applications of biotechnology include therapeutics, diagnostics, and genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production.
- Three critical research areas of biotechnology are :
  - **(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.

➢ **Biotechnological Applications in Agriculture**

- Three options for increasing food production
  - **(a)** Agro-chemical based agriculture
  - **(b)** Organic agriculture
  - **(c)** Genetically engineered crop-based agriculture
- The Green Revolution succeeded in tripling the food supply.
- Increased yields have partly been due to the use of improved crop varieties, but mainly due to the use of better management practices and use of agrochemicals (fertilisers and pesticides).
- Genetically Modified Organisms (GMO) or transgenic organisms 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)** It helps to reduce post-harvest losses.
- **(c)** It increases efficiency of mineral usage by plants (this prevents early exhaustion of fertility of soil).
- **(d)** It enhances nutritional value of food. *e.g*. Vitamin 'A' enriched rice.
- **(e)** GM is used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

➢ **Pest Resistant Plants**

- Pest Resistant Plants reduce the use of chemical pesticide.
- It reduces the need for insecticides. *e.g*. Bt cotton, Bt corn, rice, tomato, potato, soyabean etc.

➢ **Bt Cotton**

- Some strains of *Bacillus thuringiensis* produce proteins that kill insects like coleopterans (beetles), lepidopterans (tobacco, budworm, armyworm) and dipterans (flies, mosquitoes).
- *B. thuringiensis* forms a toxic insecticidal protein (Bt toxin) crystal 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 solubilise the crystals.
- The toxin binds to the surface of midgut epithelial cells and creates pores.
- It causes cells to swell and undergo lysis and ultimately leading to 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 and that of cryI Ab controls corn borer.

- **Nematode resistance in tobacco plant**
  - A nematode *Meloidegyne incognitia* 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 defense in all eukaryotic organisms.
  - It prevents translation of a specific mRNA (silencing) due to a complementary dsRNA molecule.
  - The source of this complementary RNA is from an infection by RNA viruses or mobile genetic elements (transposons) that replicate via an RNA intermediate.
  - Using *Agrobacterium* vectors, nematode-specific genes (DNA) were introduced into the host plant.
  - It produces both sense and anti-sense RNA in host cells.
  - These two RNA's being complementary to each other form a double stranded RNA (dsRNA) that initiated RNAi and thus,silenced the specific mRNA of nematode.
  - Thus, the parasite cannot survive in a transgenic host expressing specific interfering RNA.
- **Biotechnological Applications in Medicine**
  - The recombinant DNA technology helps for the mass production of safe and more effective therapeutic drugs.
  - The recombinant therapeutics does not induce unwanted immunological responses as is common in case of similar products isolated from non-human sources.
  - At present, about 30 recombinant therapeutics have been approved for human-use in the would including India.
  - In India, 12 of these are presently being marketed.
- **Genetically Engineered Insulin**
  - The 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 from the pancreas of animals (cattle and pigs) causes allergy or other types of reactions to the foreign protein.
  - Insulin consists of two short polypeptide chains (chain A and chain B) that are linked together by disulphide bridges.
  - In mammals, insulin is synthesized as a pro-hormone.
  - The pro-hormone needs processing before it becomes a fully mature and functional hormone.
  - The pro-hormone contains an extra stretch called the C peptide.
  - This is removed during maturation into insulin.
  - In 1983, Eli Lily 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.
  - The chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.
- **Gene Therapy :**
  - It is a method to correct a gene defect diagnosed in a child/embryo.
  - Here, genes are inserted into a person's cells and tissues to treat a hereditary disease.
  - It compensates for the non-functional gene.
  - First clinical gene therapy was given in 1990 to a four 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 (injection of functional ADA). But these approaches are not completely curative.
  - In gene therapy, lymphocytes from the patient's blood are grown in a culture.
  - Then, 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 bone 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 techniques for early diagnosis.
  - The presence of a pathogen is normally suspected only when the pathogen has produced a symptom.

- By this time, the concentration of pathogen will be already 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 other genetic disorders.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridise to 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 synthesized against the pathogen.

TOPIC-2
Transgenic Animals and Bioethical Issues

Quick Review

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

➢ **Advantages or Benefits of Transgenic Animals**
- **To study normal physiology and development :**
  - **(a)** Transgenic animals are used to study how genes are regulated, and how they affect the normal body functions and its development.
  - **(b)** *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.
- **To Study the contribution of genes in the development of a disease :**
  - **(a)** Transgenic models help for investigation of new treatments for human diseases.
  - **(b)** *E.g.* transgenic models for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.
- **Biological products :**
  - **(a)** Some medicines contain biological products, but they are often expensive.
  - **(b)** Transgenic animals are used to produce useful biological products by introducing genes which codes for a particular product. *e.g.* human protein (α-1-antitrypsin) used to treat emphysema, products for treatment of phenylketonuria (PKU) and cystic fibrosis etc.
  - **(c)** In 1997, *Rosie* (first transgenic cow) produced human protein-enriched milk (2.4 gm per litre).
  - **(d)** It contains the human alpha-lactalbumin and is nutritionally more balanced product for human babies than natural cow-milk.
- **Vaccine safety testing:** Transgenic mice are being developed and used in testing the safety of vaccines before they are used for humans. Polio vaccine is tested in mice.
- **Chemical safety testing (toxicity testing) :** Transgenic animals are made to know the effect of toxic chemicals. This is also known as toxicity/safety testing.

➢ **Ethical Issues**
- **Problem of unpredictable results**
  - **(a)** Genetic modification may cause unpredictable results when such organisms are introduced into the ecosystem.
  - **(b)** Therefore, Indian Government has set up organizations like GEAC (Genetic Engineering Approval Committee), which makes decisions about the validity of GM research and the safety of GM-organisms for public services.

- **Problems of patent**
  - **(a)** 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 country.
  - **(b)** *E.g.* Basmati rice, herbal medicines like turmeric, neem etc.
  - **(c)** Basmati rice has unique aroma and flavour.
  - **(d)** India has 27 varieties of Basmati.
  - **(e)** In 1997, an American company got patent rights on Basmati rice through the US Patent and Trademark Office.
  - **(f)** This allowed the company to sell a 'new' variety of Basmati which had actually been derived from Indian farmer's varieties.
  - **(g)** Indian Basmati was crossed with semi-dwarf varieties and claimed as a novelty.
  - **(h)** Other people selling Basmati rice could be restricted by the patent.
- **Biopiracy :**
  - **(a)** It is the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned.

Know the Terms

- **ELISA :** Enzyme linked immunosorbent Assay.
- **GEAC :** Genetic Engineering Approval committee.
- **ADA :** Adenosine deaminase deficiency. This enzyme is crucial for the functioning of the immune system.
- **Probe :** A probe is a piece of single-stranded DNA that is tagged with a radioactive molecule.
- **Vaccines :** It is a liquid containing dead or attenuated pathogen or it is an antigen that provides temporary or permanent immunity to a disease.
- **Transgenic animals :** Animals that have their DNA manipulated to possess and express an extra or a foreign gene are known as transgenic animals.
- **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 organizations and multinational companies exploit biological resources or bioresources of other nations, without proper authorization from the countries concerned. This is called biopiracy.
- **SCID :** Severe Combined Immuno-deficiency. It is caused by a defect in the gene for the enzyme adenosine deaminase (ADA).
- **GMO :** Genetically modified organisms.
- **RNAi :** RNA Interference.

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UNIT - X : Ecology and Environment

Chapter - 13 : Organisms and Population

TOPIC-1
Organisms and Its Environment

Quick Review

- **Ecology :** It is the branch of biology that deals with the inter-relationship amongst the organisms and their environment. Study of ecology is important to strike a balance between development and maintenance of natural environmental and biotic communities, use and conservation of resources, solve local, regional and global environmental problems.
- **Environment :** The sum total of all biotic and abiotic factors, substances and conditions that surround and potentially influence organisms without becoming their constituent part is called environment.

- **Organism and its Environment :** At organism level, physiological ecology tries to understand how different organisms are adapted to their environment in terms of survival and reproduction. The variation in the intensity and duration of temperature along with annual variations in precipitation results in formation of major biomes like desert, rain forest and tundra.
- Regional and local variation within each biome lead to the formation of different kinds of habitats like tropical rain forest, deciduous forest, desert, sea coast etc.
- The habitat includes biotic components like pathogens, parasites, predators and competitors of the organism with which they interact constantly.
- **Major Abiotic Factors**

(a) **Temperature :** It is the most important ecological factor to determine the bio-mass of a place. Average temperature on land varies seasonally and decreases progressively from the equator towards the poles and from plains to mountain tops. Temperature affects the kinetics of enzymes and basal metabolism along with physiological functions of the organisms. The organisms that can tolerate wide range of temperature are called **eurythermal** and those organism restricted to a narrow range of temperatures are called **stenothermal.**

(b) **Water :** Life on earth is unsustainable without water. Productivity and distribution of plants is heavily dependent on water. Some organisms which are tolerant to wide range of salinities are called **euryhaline** and others which are restricted to a narrow range are called **stenohaline.** Fresh water animals cannot live for long in sea water because of the osmotic problems they would face.

(c) **Light :** Plants produce food through photosynthesis in presence of sunlight. Some plants are adapted to low light conditions because they are overshadowed by tall canopied trees. Flowering in some plants occurs only in presence of critical day light called photoperiodism. The availability of light and land is closely linked to that of temperature as the sun is the source of both. UV component of sunlight is harmful to plants and animals.

(b) **Soil :** Types of soil depends upon climate, weathering process, or sedimentary and how soil development occurred. Soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils along with pH, mineral, composition and topography determine the vegetation in any area.

- **Responses to Abiotic Factor :** In the course of evolution, many species have evolved constant internal environment to permit all biochemical reactions and physiological functions to work with maximum efficiency to have overall fitness of species. Organisms try to maintain the constancy of its internal environment (homeostasis) inspite of varying external environment. There are various ways to establish homeostasis :

(i) **Regulate :** Certain animals have the ability to maintain a constant temperature and constant osmolarity to keep up their homeostasis. E.g. All birds and mammals, very few lower vertebrates and invertebrates.
Thermoregulation and osmoregulation is the source of success of these organisms in all the environmental conditions. In winter thermoregulation by means of sweating reduce the body temperature.

(ii) **Conform :** In most of animals and plants, their body temperature change with ambient temperature. Such animals are called conformers. For example, in aquatic animals osmotic concentration of the body fluid changes with that of the ambient water osmotic concentration. Conformers are not able to bear the energetic expenses to maintain the constant body temperature. Heat loss or heat gain is the surface phenomenon. The conformers have more surface area in comparison to their volume.

(iii) **Migrate :** Many animals like birds move away temporarily from stressful habitat to a more hospitable area and return when stressful condition is over. For example, Siberian birds migrate to Keoladeo National park, Bharatpur, India.

(iv) **Suspend :** In microorganisms like bacteria, fungi and lower plants, a thick walled spores are formed which helps them to survive unfavourable conditions. Spores germinate when conditions are favourable. In higher plants, seeds and some other vegetative reproductive structures serves to tide over periods of stress. They reduce their metabolic activity and go into a state dormancy. They germinate under favourable moisture and temperature.

(v) **Adaptation** is the attribute of organism's morphological, physiological and behavioural changes that enables the organisms to survive and reproduce in its habitat. For example, Kangaroo rats fulfill the water requirement by internal oxidation of fat in the absence of water. Thick cuticle in many plants also prevents loss of water. CAM plants open their stomata during night to reduce the loss of water during photosynthesis.

Adaptation of Mammals :

(a) Mammals from colder climates have shorter ears and limbs to minimize heat loss. This is called **Allen's Rule.**

(b) In polar seas aquatic mammals like seals have a thick layer of fat called **blubber,** below their skin that acts as an insulator and reduces loss of body heat.

Physiological and biochemical adaptations :

(a) Altitude sickness is observed at higher altitude that includes symptoms like nausea, fatigue, heart palpitations due to less oxygen and atmospheric pressure. The person gradually get acclimatized and stop experiencing altitude sickness. This is type of physiological adaptation.

(b) A number of marine invertebrate and fish live in temperature always less then zero and some lives deep inside ocean where pressure is very high by array of biochemical adaptations.

Behavioural adaptation :

(a) Some organisms like desert lizard lack the physiological ability that mammals have, but deal with high temperature of their habitat by behavioural means. They bask in the sun and absorb heat when their body temperature is low, but move into shade when the ambient temperature starts increasing.

TOPIC-2
Population and Population Interactions

Quick Review

- **Populations :** A population is defined as a group of individuals of the same species that live in a particular geographical area at a particular time and functioning as a unit.
- A population has certain attributes that an individual organism does not have. For example individual may have births and deaths, but a population has birth rates and death rates.
- **The birth and death rates** are referred as per capita births or deaths respectively, which increases and decreases with respect to members of the population.
- **Sex ratio** is another attributes of population. An individual may be male or female but population has sex ratio.
- A population at given time is composed of different individuals of different ages. If the age distribution is plotted for the population, the resulting structure is called age pyramids. The shape of pyramids reflects the shape of growth status of population.
- **Population size or population density** (N) is measured in terms of number.
- **Population Growth :** The size of population is not static. It keeps changing with time, depending upon food availability, predation pressure and reduced weather. The main factors that determine the population growth are :

(i) Natality (number of births)
(ii) Mortality (number of deaths)
(iii) Immigration (individuals that come into habitat)
(iv) Emigration (individual that leaves the habitat)

- **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.	Number of individuals in a population decreases with the death of the individuals.
2.	Natality shows the number of offsprings produced per unit time per unit population.	Population density and its size is decreased by death rate.

If 'N' is population density at time 't', then its density at t +1 is

$$N_{(t+1)} = N_t + [(B + I) - (D + E)]$$

- **Growth model :** Growth of population takes place according to availability of food, habit condition and presence of other biotic and abiotic factors. There are two main types of models :

(i) Exponential Growth : This kind of growth occurs when food and space is available in sufficient amount. The population grows in an exponential or geometric fashion. If the size of population is N, the birth rate is represented as 'b' and death rate as 'd', then increase and decrease in N during unit period time 't' will be

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

Let $(b - d) = r$.

Then $dN/dt = rN$

The r in this equation is called 'intrinsic rate of natural increase'.

(ii) Logistic Growth : There is a competition between the individuals of a population for food and space. The fittest organism survives and reproduces. This type of growth initially shows a lag phase followed by phases of acceleration and de-acceleration.

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

- **Population interaction :** All animals, plants and microbes in a biological community interact with each other. These interactions may be beneficial, detrimental or neutral to one species or both. Following types of interaction is seen :

(a) Predation : It is the interaction between two species members in which the members of one species capture, kill and eat up the members of other species.

(b) Parasitism : It is the relationship between two living organisms of different species in which one organism called parasite obtains its food directly from another living organism called host.

(c) **Amensalism :** It is the interaction between two living individuals of different species in which one organism does not allow other organism to grow or live near.
(d) **Commensalism :** It is the relationship between two living individuals of different species in which one is benefitted, while the other is neither harmed nor benefitted.
(e) **Proto-cooperation :** It is the interaction between two living organisms of different species in which both are mutually benefitted but they can live without each other.
(f) **Competition :** It is the rivalry between two or more organisms for obtaining the same resources.
(g) **Mutualism :** It is the interaction between two organisms of different species where both the partners are benefitted but cannot live separately.

Know the Terms

- **Adaptations :** These are certain characteristics that organism develop in order to survive and reproduce better in their habitat.
- **Population :** It is defined as a group of individuals of the same species that live in a particular geographical area at a particular time and functioning as a unit.
- **Birth rate (Natality) :** It is the ratio of live births in an area to the population of an area.
- **Death rate (Mortality) :** It is the ratio of deaths in an area to the population of an area.
- **Sex ratio :** It is the number of males or females per thousand individuals.
- **Population density :** It is defined as the number of individuals of a population present per unit area at a given time.
- **Natality (B) :** It is the number of births during a given period in a population.
- **Mortality (D) :** It is the number of deaths in a population during a given period.
- **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.
- **Emigration (E) :** It is the number of individuals of the population who left the habitat and gone elsewhere during a given time period.
- **Mutualism :** Both the species are benefitted (+).
- **Competition :** Both the species are harmed (-).
- **Parasitism :** One species (parasite) is benefitted and other species (host) is harmed.
- **Predation :** One species (predator) is benefitted and other species (prey) is harmed.
- **Commensalism :** One species is benefitted and the other is neither benefitted nor harmed (0).
- **Amensalism :** One species is harmed and the other is unaffected.

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Chapter - 14 : Respiration in Plants

TOPIC-1
Ecosystem – Structure and Function, Productivity and Decomposition

Quick Review

- **Introduction**
  (a) An ecosystem is a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
  (b) The entire biosphere can be regarded as a global ecosystem.
- **Types of Ecosystems**
  (a) **Terrestrial ecosystem :** Forest, grassland, desert etc
  (b) **Aquatic ecosystem :** Pond, lake, wetland, river, estuary and ocean.
  (c) **Man-made ecosystem :** Crop fields and aquarium
- **Ecosystem : Structure and Function**
  (a) An ecosystem, consists of biotic and abiotic components. These components function as a unit. Unidirectional flow of energy taken place within these components of ecosystem.
  (b) Vertical distribution of different species occupying different levels is called stratification. *E.g.* 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 main functions of ecosystem.

(i) Productivity **(ii)** Decomposition
(iii) Energy flow **(iv)** Nutrient cycling

- **Pond - Aquatic Ecosystem**

(a) A pond is a shallow, simple, self-sustainable water body that exhibits all basic components of an ecosystem.
(b) Abiotic components in pond : water and the soil, which is deposited at the bottom.
(c) Climatic conditions : The solar input, the cycle of temperature, day-length etc.
(d) Autotrophic components : Phytoplankton, some algae and the floating, submerged and marginal plants.
(e) Consumers (heterotrophs) : Zooplankton, free swimming and bottom dwelling forms.
(f) Decomposers : Fungi, bacteria and flagellates.
(g) Pond performs all the functions of an ecosystem such as :
(i) Conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs.
(ii) Consumption of the autotrophs by heterotrophs.
(iii) Decomposition and mineralization of the dead matter to release them back for reuse by the autotrophs.
(h) There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment.

- **Productivity**

(a) A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.
(b) The rate of biomass production is called productivity.
(c) The productivity is expressed in terms of $g^{-2}yr^{-1}$ or (kcal m^{-2}) yr^{-1}.
(d) It can be divided into gross primary productivity (GPP) and net primary productivity (NPP).

- **Primary Productivity**

(a) The amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis is called primary production.
(b) The primary production is expressed in terms of weight (g^{-2}) or energy (kcal m^{-2}).

- **Gross Primary Productivity**

(a) It is the rate of production of organic matter during photosynthesis.
(b) A considerable amount of GPP is utilized by plants in respiration.
(c) Gross primary productivity minus respiration losses (R) is the net primary productivity (NPP), *i.e.* NPP is the available biomass for the consumption of heterotrophs (herbivores and decomposers).

$$NPP = GPP - R$$

(d) Primary productivity depends on
(i) The plant species inhabiting a particular area
(ii) Environmental factors
(iii) Availability of nutrients
(iv) Photosynthetic capacity of plants
Therefore, it varies in different types of ecosystems.
(e) The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter.
(f) Of this, despite occupying about 70% of the surface, the productivity of the oceans is only 55 billion tons. Rest of course, is on land.

- **Secondary Productivity**

It is the rate of formation of new organic matter by consumers.

- **Decomposition :**

(a) It is the breakdown of complex organic matter by decomposers into inorganic substances like carbon dioxide, water and nutrients.
(b) It is largely an oxygen-requiring process.
(c) **Detritus** (dead plant remains such as leaves, bark, flowers and dead remains of animals, including faecal matter) is the raw material for decomposition.

- **Steps in decomposition**

The important steps in the process of decomposition are fragmentation, leaching, catabolism, humification and mineralisation.

(a) Fragmentation

It is the breakdown of detritus into smaller particles by detritivores (*e.g.* Earthworm).

(b) Leaching

In this process, water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.

(c) Catabolism

(i) Here, the degradation of detritus into simpler inorganic substances takes place by bacterial and fungal enzymes.

(ii) Fragmentation, leaching and catabolism operate simultaneously on the detritus.

(d) Humification

(i) It is the accumulation of humus (dark amorphous substance) in soil.

(ii) Humus is resistant to microbial action and so decomposes very slowly.

(ii) Being colloidal in nature, it serves as a reservoir of nutrients.

(e) Mineralization

It is the release of inorganic nutrients due to the degradation of humus by some microbes.

➢ **Factors Influencing Decomposition**

The rate of decomposition is controlled by chemical composition of detritus and climatic factors.

(a) 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.

(b) Climatic factors like temperature and soil moisture :

– Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes.

– Warm and moist environment favours decomposition whereas low temperature and anaerobic conditions inhibits decomposition resulting in build up of organic materials.

TOPIC-2
Energy Flow and Ecological Succession

Quick Review

➢ **Energy Flow**

- Sun is the only source of energy for all ecosystems the earth.
- Of the incident solar radiation less than 50% of it is photosynthetically active radiation (PAR).
- Plants and photosynthetic and chemosynthetic bacteria (autotrophs), fix solar radiant energy to make food.
- Plants capture only 2-10% of the PAR and this small amount of energy sustains the entire living world. So, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem.
- Ecosystem obeys 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.

➢ **Producers**

- The green plants in the ecosystem which capture the solar energy and convert it into chemically bound energy are called producers.
- 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 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 **(b)** Secondary consumers **(c)** Tertiary consumers

➢ **Primary Consumers**

- These are herbivores that feed on plants.
- *E.g.* Insects, birds and mammals in terrestrial ecosystem and molluscs in aquatic ecosystem.

- **Secondary Consumers**
  - These are primary carnivores that feed on herbivores. *e.g.,* Frog, fox, man etc.
- **Tertiary Consumers**
  - These are secondary carnivores that feed on primary carnivores.
- **Grazing Food Chain**
  - 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 (saprotrophs) which are heterotrophic organisms. *e.g.,* 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 animals (cockroaches, crows etc.) are omnivores.
  - These interconnections of food chains make a food web.
  - Organisms occupy a place in the natural surroundings or in a community according to their feeding relationship.
  - 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.
  - The standing crop 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 –only 10% of the energy is transferred to each trophic level from the lower trophic level.
  - In nature, it is possible to have so many levels – producer, herbivore, primary carnivore, secondary carnivore in the grazing food chain.
- **Ecological Pyramids**
  - The representation of a food chain in the form of a pyramid is called ecological pyramid. It is the relationship between the producers and consumers of various order represented graphically.
  - The base of each pyramid represents the producers (first trophic level) while the apex represents tertiary or top level consumer or the last trophic level.
  - **Ecological pyramids are of three types :**
    (a) Pyramid of number
    (b) Pyramid of biomass
    (c) Pyramid of energy
  - Any calculations of energy content, biomass, or numbers has to include all organisms at that trophic level.
  - The trophic level represents a functional level, not a species as such.
  - A given species may occupy more than one trophic level in the same ecosystem at the same time. *E.g.,* A sparrow is a primary consumer when it eats seeds, fruits, peas, and a secondary consumer when it eats insects and worms.
  - In most ecosystems, all the pyramids are upright, *i.e.*, producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores.
  - Also energy at a lower trophic level is always more than at a higher level.
  - Example of inverted pyramids includes insects feeding on a big tree.
  - Pyramid of biomass in sea is generally inverted because the biomass of fishes far exceeds that of phytoplankton.
  - Pyramid of energy is always upright, because when energy flows from a trophic level to the next trophic level, as some energy is always lost as heat at each step.

➢ **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 Succession**

- It is a gradual, slow and predictable change in the species composition of an area leading to a climax community (community that is in equilibrium with the environment).
- During succession some species colonize an area and become more numerous, whereas populations of other species decline and disappear.
- The entire sequences of communities that successively change in a given area are called sere.
- The individual transitional communities are termed seral stages (seral communities).
- In the successive seral stages, there is a change in the diversity of species, increase in the number of species and organisms and an increase in the total biomass.
- The present day communities are the results of succession that occurred over millions of years.
- Succession and evolution would have been parallel processes at that time.

➢ **Types of Succession**

- Succession is of two types namely,

(a) primary succession **(b)** secondary succession

➢ **Primary Succession**

- The succession taking place in areas where no living organisms ever existed is known as primary succession.
- *E.g.* newly cooled lava, bare rock, newly created pond or reservoir.
- Before a biotic community is established, there must be formation of fertile soil through natural processes. So, the primary succession is a very slow process.

➢ **Secondary Succession**

- The succession taking place in an area after the existed organisms are lost is known as secondary succession.
- *E.g.* abandoned farm lands, burned or cut forests, lands that have been flooded.
- Since some soil or sediment is present, succession is faster than primary succession.
- The species that invade depends on the condition of the soil, availability of water etc.
- In succession, changes in vegetation affect food and shelter of various animals.
- Thus, as succession proceeds, the number and types of animals and decomposers also change.
- Natural or human induced disturbances (deforestation, fire etc.), can convert a particular seral stage of succession to an earlier stage.
- Such disturbances create new conditions that encourage some species and discourage or eliminate other species.

➢ **Succession of Plants**

- Based on the nature of the habitat, succession of plants is of two types namely,

(a) Hydrarch **(b)** Xerarch

(a) Hydrarch Succession

- It takes place in wetter areas.
- The successional series progress from hydric to mesic conditions.

(b) Xerarch Succession

- It takes place in dry areas.
- The series progress from xeric to mesic conditions.
- Hence, all successions (both hydrarch and xerarch) lead to medium water conditions (mesic, the climax community).
- The species invading a bare area are called pioneer species.

➢ **Primary Succession on Rocks (Xerophytic Habitat)**

- The species that invade a bare area are called pioneer species.
- In primary succession on rocks, lichens are the pioneer species which secrete acids to dissolve rock, helping in weathering and soil formation.
- These result in some very small plants like bryophytes, which take hold in the small amount of soil.
- With the passage of time, these are succeeded by bigger plants, and after several more stages, ultimately as stable climax forest community is formed.
- The climax community remains stable as long as the environment remains unchanged.
- With time, the xerophytic habitat gets converted into a mesophytic one.

➢ **Primary Succession in Water**

- In primary succession in water, the pioneer species are the small phytoplanktons.
- With the time, these are replaced by free-floating angiosperms, then by rooted hydrophytes, sedges, grasses and finally the trees.
- The climax again would be a forest.
- With time, the water body is converted into land.

- **Secondary Succession**
  - In secondary succession, the species that invade depend on the condition of the soil, availability of water, the environment as also the seeds or other propagules present.
  - Since soil is already present, the rate of succession is much faster and hence, climax is also reached more quickly.

TOPIC-3
Nutrient Cycling and Ecosystem Services

Quick Review

- **Nutrient Cycling :** The movement of nutrient elements through the various abiotic and biotic components of an ecosystem is called nutrient cycling. It is also called as biogeochemical cycles. The total amount of nutrients present in soil at anytime is called standing state. This varies with the type of ecosystem and season. There are two types of nutrient cycles :
  (i) Gaseous – exist in atmosphere.
  (ii) Sedimentary – exists in earth crust.
- Environmental factors like soil, moisture, pH, temperature regulate the rate of release of nutrients into the atmosphere. The function of reservoir is to meet with the deficit which occurs due to imbalance in the rate of influx and efflux.
- **Carbon Cycle :** Carbon cycling occurs through atmosphere, ocean and through living and dead organisms. Most of carbon is fixed by plants during the process of photosynthesis and returned to atmosphere in form of CO_2 during respiration. Burning of wood, forest fire and combustion of organic matter, fossil fuel, and volcanic activity are other sources of releasing CO_2 in the atmosphere.
- **Phosphorus Cycle :** The natural reservoir of phosphorus is rock which contains phosphorus in the form of phosphates. On weathering, minute amount of phosphates dissolve in soil solution and is absorbed by the roots of the plants. The waste products of dead organisms are decomposed by bacteria to release phosphorus. Gaseous exchange between organism and environment is negligible as compared to carbon.
- **Ecosystem Services**
  The products of ecosystem processes are called ecosystem services. It includes :
  (i) The healthy forest ecosystem which purify air and water
  (ii) Mitigates floods and droughts.
  (iii) Cycle nutrients
  (iv) Generate fertile soil
  (v) Provide wildlife habitat
  (vi) Maintain biodiversity, etc.
  These fundamental ecosystem services are taken for granted because they are free although its value is twice the total global Gross National Product (GNP). Soil formation accounts for about 50% of total ecosystem services.

Know the Terms

- **Ecosystem :** It is a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
- **Scavengers :** These are animals which eat dead bodies of other animals. The rate of biomass production is called productivity.
- **Primary productivity :** It is the amount of biomass produced per unit area in a given time period by plants during photosynthesis.
- **Gross primary productivity :** It is the rate of production of organic matter during photosynthesis.
- **Net primary productivity :** Gross primary productivity minus respiration losses (R) is the net primary productivity (NPP).
- **Detritus :** Dead remains of plants and animals are called detritus.
- **Detrivores :** Animals that feed on decaying organic matter (detritus). Examples: earthworms, termites, snails etc.
- **Ten percent law :** It states that during transfer of energy from one trophic level to another, only about 10% is stored at higher levels; remaining 90% is lost in respiration (heat).
- **Grazing food chains :** It extends from producers through herbivores to carnivores.
- **Detritus food chains :** It begins with dead organic matter to the detrivores organisms which in turn make food for protozoan to carnivores.
- **Trophic level :** A specific place of organisms in the food chain is known as their trophic level.
- **Food chain :** It is a single linear sequence of organisms.
- **Food web :** It contains a number of interconnected food chain.
- **Ecological pyramids :** The representation of a food chain in the form of a pyramid is called ecological pyramid.

- **Pyramid of numbers :** It the graphical representation of the number of individuals present at each trophic level in a food chain of an ecosystem.
- **Pyramid of biomass :** A pyramid of biomass is a graphical representation of the total amount of living matter present at each trophic level of an ecosystem.
- **Pyramid of energy :** A pyramid of biomass is a graphical representation of the amount of energy trapped per unit time and area in different trophic level of a food chain with producers forming the base and the top carnivores at the tip.
- **Ecological succession :** It is a gradual, slow and predictable change in the species composition of an area leading to a climax community.
- **Primary succession :** The succession that takes place in areas where no living organisms ever existed.
- **Secondary succession :** The succession that takes place in areas which have lost all life forms due to destructions and floods.
- **Hydrarch succession :** It takes place in water areas.
- **Xerarch succession :** It takes place in dry areas.
- **Biogeochemical cycle :** The cyclic flow of nutrients between non-living environment (soil, air and water) and the living organisms is called biogeochemical cycle.
- **Carbon cycle :** The cyclic flow of carbon in biosphere between its abiotic (soil, air and water) and biotic (plants and animals) components is called carbon cycle.
- **Ecosystem services :** The products of ecosystem processes are called ecosystem services.

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Chapter - 15 : Biodiversity and its Conservation

TOPIC-1
Biodiversity and Its Patterns

Quick Review

- **Biodiversity :** It is the diversity of biological organisation ranging from cellular macromolecules to biomes.
- **Edward Wilson :** Popularized the term 'biodiversity' to describe the combined diversity at all levels of biological organization.

Levels of Biodiversity

- Biodiversity has been divided into three hierarchical levels of biological organization.

1. **Genetic diversity**
   - **(a)** Diversity shown by a single species at genetic level. *e.g.*, *Rauwolfia vomitoria* (Himalaya) shows genetic variation in the potency and concentration of the chemical reserpine.
   - **(b)** India has more than 50,000 different strains of rice and 1000 varieties of mango.
2. **Species diversity**
   Diversity at species level. *e.g.*, Western Ghats have greater amphibian species than Eastern Ghats.
3. **Ecological diversity**
   Diversity at ecosystem level. *e.g.*, In India, deserts, rain forests, mangroves, coral reefs, wet lands, estuaries & alpine meadows are seen.

Number of Species on Earth (Global Species Diversity)

- According to IUCN or International Union for Conservation of Nature & Natural Resources (2004) more than 1.5 million species have been described so far.
- According to Robert May, Global estimate is about 7 million (considering the species are to be discovered in the tropics. *i.e.* only 22% of the total species have been recorded so far).
- Animals are more diverse (above 70%) than plants including Plantae and Fungi (22%).
- Most species rich taxonomic group among animals are: Insects (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 and 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 are not culturable under laboratory conditions.
- 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.
- Applying May's global estimate, India would have more than 1 lakh plant species and 3 lakh animal species.

Patterns of Biodiversity

- Biodiversity is not uniform throughout the world. It varies with the change in latitude and attitude, it is affected by latitudinal gradients species area relationship. Following are the main 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.
  - **(i)** Colombia (near equator) has about 1400 species of birds.
  - **(ii)** New York (41° N) : 105 species of birds
  - **(iii)** Greenland (71° N) : 56 species of birds
  - **(iv)** India (tropical latitudes) : > 1200 species
- Tropical forest region like Ecuador has up to 10 times species of vascular plants as compared to a forest of equal area in a temperate region like the Midwest of USA.
- Tropical Amazonian rain forest (South America) has the greatest biodiversity on earth. It contains :
  - **(i)** 40000 species of plants
  - **(ii)** 3000 species of fishes
  - **(iii)** 1300 species of birds
  - **(iv)** 427 species of mammals
  - **(v)** 427 species of amphibians
  - **(vi)** 378 species of reptiles
  - **(vii)** 1,25,000 species of invertebrates
- Biodiversity (species richness) is highest in tropics because
  - **(i)** Tropics had more evolutionary time.
  - **(ii)** Relatively constant environment (less seasonal).
  - **(iii)** They receive more solar energy which contributes to greater productivity.

(b) Species- Area Relationship

- According to the study of *Alexander von Humboldt* (German naturalist & geographer) in South American jungles, 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 or linear, 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 the large areas like entire continents, slope of the line is steeper (Z value : 0.6 to 1.2). *e.g.,* for frugivorous birds and mammals in the tropical forests of different continents, the slope is 1.15.

Importance of Species Diversity to the Ecosystem

- For many decades, ecologists believed that communities with more species, generally, tend to be more stable than those with less species.
- A stable community should not show too much variation in productivity from year to year; it must be either resistant or resilient to occasional disturbances (natural or man-made), and it must also be resistant to invasions by alien species.
- **David Tilman** found that plots with more species showed less year-to-year variation in total biomass.
- He also showed that in his experiments, increased diversity contributed to higher productivity.
- A rich biodiversity is not only essential for ecosystem health but imperative for the survival of the human race on this planet.

Loss of Biodiversity

- IUCN Red List (2004) says that 784 species (338 vertebrates, 359 invertebrates and 87 plants) became extinct in the last 500 years. *e.g., Dodo* (Mauritius), *Quagga* (Africa), *Thylacine* (Australia), *Stellar's sea cow* (Russia) and 3 subspecies (Bali, Javan, Caspian) of tiger.
- 27 species have disappeared in the last 20 years.
- More than 15,500 species are facing threat of extinction.
- 12% birds, 23% mammals, 32% amphibians, 31% gymnosperm species face the threat of extinction.
- The current extinction rate is 100 - 1000 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) 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')

- There are four major causes of biodiversity loss. These are popularly called as the evil quartet.

- **Habitat Loss and Fragmentation**
  - It is the most important cause. *e.g.*, Tropical rain forests (loss from 14% to 6%).
  - Thousands of hectares of rain forests is being lost within hours.
  - The Amazon rain forest (lungs of the planet) is being cut for cultivating soya beans or for conversion of grass lands for cattle.
  - When large habitats are broken up into small fragments due to various human activities, mammals and birds requiring large territories and certain animals with migratory habits are badly affected, leading to population declines.
  - Due to fragmentation, animals requiring large territories and migratory animals are badly affected.
- **Over-exploitation**
  - The dependence of humans on nature for food and shelter led to over-exploitation of natural resources.
  - **Example :** Many species like Stellar's sea cow, Passenger pigeon etc became extinct due to over exploitation.
  - Many marine fish populations around the world are over harvested, endangering the continued existence of some commercially important species.
- **Alien Species Invasions**
  - When alien species are introduced unintentionally or deliberately, some of them turn invasive, and cause decline or extinction of indigenous species.
  - These alien species cause decline or extinction of indigenous species.
  - **Example : (a)** The Nile Perch introduced in Lake Victoria (East Africa) caused extinction of more than 200 species of cichlid fish.

  (b) Invasive weed species like carrot grass (*Parthenium*), Lantana and water hyacinth (*Eichhornia*) caused damage to our native species.

  (c) The illegal introduction of the African Catfish (*Clarias gariepinus*) for aquaculture is posing a threat to the indigenous catfishes in our rivers.
- **Co-extinction**
  - When a species becomes extinct, the plant and animal species associated with it also become extinct.
  - **Example : (a)** Extinction of the parasites takes place when the host is extinct.

  (b) Co-evolved plant-pollinator mutualism where extinction of one leads to the extinction of the other.

TOPIC-2
Conservation of Biodiversity

Quick Review

There are three main reasons for conserving the biodiversity which are categorized as follows :

(a) Narrowly Utilitarian Arguments
- Humans derive economic benefits from nature such as food, firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and medicines.
- 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 for products of economic importance with increasing resources.

(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, bumblebees, birds and bats.
- Aesthetic pleasures such as walking through thick woods, watching spring flowers in full bloom or waking by hearing a bulbul's song in the morning.

(c) Ethical Arguments
- Every species has an intrinsic value.
- We have a moral duty to take care for their well-being.

CONSERVATION BIODIVERSITY

Types of Conservation

(a) *In situ* **conservation (on site)**

- It is the conservation of genetic resources within natural or human-made ecosystems in which they occur.
- E.g. Protected areas such as National Parks, Sanctuaries, Biosphere reserves, cultural landscapes, national monuments.

National Park

- Strictly reserved for the welfare of the wildlife where private ownership, cultivation, grazing etc are prohibited.
- There are 90 national parks in India.

Sanctuary

- Here, protection is given only to the animals.
- Collection of timbers, minor forest products and private ownership are allowed so long as they do not harm the animals.
- There are 448 wildlife sanctuaries in India.

Biosphere Reserves

- Areas of land or coastal environments to conserve ecosystem and genetic resources contained therein.
- There are 14 biosphere reserves in India.

Sacred Forests (Sacred Groves)

- Sacred groves in Khasi and Jaintia Hills in Meghalaya
- Aravalli Hills of Rajasthan
- Western Ghat regions of Karnataka & Maharashtra
- Sarguja, Chanda and Bastar areas (Madhya Pradesh).
- In Meghalaya, the sacred groves are the last refuges for a large number of rare and threatened plants.

Hotspots

- These are the richest and the most threatened reservoirs of plant and animal life on earth.
- There are 34 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.
- 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 periods 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 long periods in seed banks.

International Efforts for Conserving Biodiversity

- The Earth Summit (Rio de Janeiro, 1992) - Three objectives :
  (a) Conservation of biodiversity
  (b) Sustainable use of biodiversity
  (c) Sharing of benefits in the utilization of genetic resources.
- The World Summit on Sustainable Development (Johannesburg, South Africa, 2002) : 190 countries pledged to reduce the current rate of biodiversity loss.

Know the Terms

- **Exotic species :** They are known as alien species that are introduced into a habitat by humans.
- **Biosphere reserve :** A reserve area for multiple use of land but having many zones.
- **Red list :** A catalogue highlighting the challenged taxons that are on the verge of global extinction.
- **WCU :** World Conservation Union (formerly called IUCN).
- **IUCN :** International Union for Conservation of Nature and Natural resource.
- **Biodiversity :** It is the variety of living forms present in various ecosystems.
- **Genetic diversity :** Diversity shown by a single species at genetic level.
- **Species diversity :** Diversity at the species level.
- **Ecological diversity :** Diversity at the ecosystem level.
- **Hot spots :** These are the areas or regions of high endemism and very high levels of species richness.
- **Extinct species :** Species that no longer exist on earth.
- **In situ conservation (on site) :** It is the conservation of genetic resources within natural or human-made ecosystems in which they occur.
- **Ex situ conservation (off site) :** It is the conservation of organisms outside their habitats.

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Chapter - 16 : Environmental Issues

TOPIC-1
Pollution, Solid and Radioactive Wastes

Quick Review

➢ **Introduction**
- Human population explosion increases the demand for food, water, home, electricity, roads, automobiles etc.
- It leads to pollution of air, water and soil.
- **Pollution** is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil.
- Agents that cause pollution.
- 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

➢ **Causes of Air Pollution**
- Particulate and gaseous air pollutants from smoke stacks of thermal power plants, smelters and other industries release particulate and gaseous air pollutants.
- According to Central Pollution Control Board (CPCB), particulate size of less than 2.5 mm in diameter (PM 2.5) causes greatest harm to human health.
- Pollutants from automobiles.
- Use of leaded petrol.

➢ **Harmful Effects of Air Pollution**
- Air pollutants cause injury to all living organisms.
- They reduce growth and yield of crops and cause premature death of plants.
- Air pollutants affect the human respiratory system.
- It causes respiratory problems, irritation, inflammations and damage to lungs and premature deaths.

➢ **Control of Air Pollution**

(a) Particulate matters must be separated/filtered out before releasing the harmless gases into the atmosphere.

(b) Use of catalytic converters (having Platinum-Palladium & Rhodium as the catalysts).
- It reduces emission of poisonous gases.
- This converts unburnt hydrocarbons to CO_2 and water, and carbon monoxide and nitric oxide to CO_2 and nitrogen gas, respectively.
- Motor vehicles having catalytic converter should use unleaded petrol because lead in the petrol inactivates the catalyst.

(c) Proper maintenance of automobiles along with use of lead-free petrol or diesel can reduce the pollutants they emit.

(d) Catalytic converters, having expensive metals namely platinum-palladium and rhodium as the catalysts, are fitted into automobiles for reducing emission of poisonous gases.

(e) Phasing out of old vehicles

(f) Use of low-sulphur petrol and diesel

(g) Application of pollution-level norms for vehicles, etc.

➢ **Controlling Vehicular Air Pollution :** A Case Study of Delhi
- In Delhi, compressed natural gas (CNG) in public transport (buses) is used.
- CNG is better than petrol and diesel because—

(a) CNG burns most efficiently and very little of it is left unburnt.

(b) CNG is cheaper than petrol or diesel, cannot be siphoned off by thieves and adulterated like petrol or diesel.

- The main problem with CNG is
  (a) The difficulty of laying down pipelines to deliver
  (b) Distribution points/pumps and ensuring uninterrupted supply.

➢ **Electrostatic Precipitator**

- It is the electrical device widely used to remove particulate matter present in the exhaust of thermal power plants and vehicular exhaust.
- It can remove over 99% particulate matter present in the exhaust from a thermal power plant.
- The electrons released from electrode wires (maintained at several thousand volts) attach to dust particles and give a negative charge.
- The collecting plates are earthed so that they attract the charged dust particles.
- The velocity of air between the plates must be low enough to allow the dust to fall.
- A scrubber removes gases like SO_2.
- In a scrubber, the exhaust is passed through a spray of water or lime.
- Very small particulates are not removed by this precipitator.

Laws & policies in India to control vehicular pollution

(a) Auto fuel policy

- It has laid out a roadmap to cut down vehicular pollution in Indian cities. It has steadily reduced the sulphur and aromatic content in petrol and diesel fuels.

(b) Euro II norms

- It stipulates that sulphur should be at 350 parts-per-million (ppm) in diesel and 150 ppm in petrol.
- Aromatic hydrocarbons are to be contained at 42%of the concerned fuel.
- The goal is to reduce sulphur to 50 ppm in petrol and diesel and bring down the level to 35%.
- Vehicle engines will also need to be upgraded.

(c) The Bharat Stage II

- All automobiles and fuel have to meet the Euro III emission specifications in 11 cities from 1 April 2005 and had to meet the Euro-IV norms by 1 April 2010.
- The rest of the country have Euro-III emission norm compliant automobiles and fuels by 2010.

Noise Pollution

- 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.

➢ **Sources of Noise Pollution**

- Music instruments, loudspeaker, crackers, industries etc.

➢ **Harmful Effects of Noise**

- Noise causes psychological and physiological disorders.
- The sound level above 150 dB (generated by take off of a jet plane or rocket) may damage ear drums.
- Chronic exposure to relatively lower noise may damage hearing abilities of humans.
- It causes sleeplessness, increased heartbeat and hypertension and breathing problem, stress etc.

➢ **Control of Noise Pollution**

- Use of sound absorbent materials in industries.
- Delimitation of horn-free zones around hospitals and schools.
- Permissible sound-levels of crackers and loudspeakers.
- Delimit the timings of using loudspeakers.

➢ **Water Pollution and Its Control**

- Water bodies are lifeline of all living organisms.
- 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.

➢ **Domestic Sewage and Industrial Effluents**

- A mere 0.1 % impurities make domestic sewage unfit for human use.
- The composition of waste water contains suspended solids (sand, silt, clay etc), colloidal materials (faecal matter, bacteria, cloth, paper, fibres etc.) and dissolved materials (nutrients like nitrate, NH_3, phosphate, Na, Ca etc).
- Solids are easy to remove.
- Removal of dissolved materials, organic compounds and toxic metal ions are most difficult.
- Domestic sewage contains biodegradable organic matter.
- It is decomposed by microorganisms, which can multiply using these organic substances as substrates and hence utilize some of the components of sewage.

- Sewage from homes and hospitals may contain undesirable pathogens and its disposal into water causes serious diseases like dysentery, typhoid, jaundice, cholera, etc.
- Industrial (petroleum, metal, paper manufacturing, chemical manufacturing, etc.) waste water contains toxic substances like heavy metals such as mercury, cadmium, copper, lead, etc. and organic compounds.
- Some toxic substances (mercury, DDT etc) present in industrial waste water, cause biological magnification (biomagnification) in the aquatic food chain.

➢ **Biochemical Oxygen Demand - BOD**

- The amount of biodegradable organic matter in sewage water is estimated by measuring Biochemical Oxygen Demand (BOD).
- During biodegradation, microorganisms consume a lot of O_2.
- It results in a sharp decline in dissolved O_2. This causes death of aquatic organisms.

➢ **Algal Bloom**

- Presence of large amounts of nutrients in water also causes excessive growth of planktonic algae (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.
- The water hyacinth (*Eichhornia crassipes*) is the most problematic aquatic weed (Terror of Bengal').
- They grow faster than our ability to remove them.
- They grow abundantly in eutrophic water bodies.
- It leads to an imbalance in the ecosystem dynamics of the water body.

➢ **Biomagnification**

- Biomagnification is the accumulation of the toxicant at successive trophic levels.
- The organism in each trophic level cannot metabolize or excrete the toxicant, and is thus passed on to the next trophic level.

➢ **Biomagnification of DDT in an Aquatic Food Chain**

- Water (DDT : 0.003 ppm) → zooplankton (0.04 ppm) → small fish (0.5 ppm) → large fish (2 ppm) → birds (5 ppm).
- DDT disturbs calcium metabolism in birds, which causes thinning of egg shell and their premature breaking.
- It causes decline in bird populations.

➢ **Eutrophication**

- It is the natural ageing of a lake by nutrient enrichment of water.
- In a young lake the water is cold and clear.
- With time,streams draining into the lake introduce nutrients like N_2, P 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.
- Thus, the lake grows shallower and warmer, with warm-water organisms.
- Marsh plants take root in the shallows and fill in the original lake basin.
- Eventually, the lake becomes a bog, finally converting into land.
- Depending on climate, size of the lake and other factors, the eutrophication may span thousands of years.
- However, pollutants like effluents from the industries and homes accelerate the ageing process. This phenomenon is called **Cultural** or Accelerated Eutrophication.
- The prime contaminants are nitrates and phosphates, which act as plant nutrients.
- They over stimulate the growth of algae, causing unsightly scum and unpleasant odors, 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 decomposed remains further deplete the water's dissolved oxygen content.

➢ **Thermal Waste Water**

- Heated (thermal) wastewater 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.

➢ **A Case Study of Integrated Waste Water Treatment**

- It includes artificial and natural processes.
- An example 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 neutralize, 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**
- It is a sustainable system for handling human excreta, using dry composting toilets.
- This is a practical, hygienic, efficient and cost-effective solution to human waste disposal.
- The key point to note here is that with this composting method, human excreta can be recycled into a resource (as natural fertiliser), which reduces the need for chemical fertilisers.
- There are 'EcoSan' toilets in many areas of Kerala and Sri Lanka.

➢ **Solid Wastes**
- Solid wastes refer to everything that goes out in trash.
- These are discarded solid materials which are produced due to various human activities.
- Municipal solid wastes are wastes from homes, offices, stores, schools, hospitals, etc., that are collected and disposed by the municipality.
- The municipal solid wastes include paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc.
- 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.

➢ **Sanitary Landfills**
- These were adopted as the substitute for open-burning dumps.
- In a sanitary landfill, wastes are dumped in a depression or trench after compaction, and covered with dirt every day.
- Landfills are also not really much of a solution since the amount of garbage generation especially in the metros has increased so much that these sites are getting filled too.
- Also there is danger of seepage of chemicals, etc., from these landfills polluting the underground water resources.

➢ **Types of Solid Wastes**
- All wastes can be categorized into three types namely :

  (a) Bio-degradable

  (b) Recyclable

  (c) Non-biodegradable

➢ **Plastic Wastes**
- It is important that all garbage generated is sorted in order to recycle or reuse.
- Kabadiwallahs and rag-pickers help to separate materials for recycling.
- The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown.
- This leaves only the non-biodegradable to be disposed off.
- We are increasing the use of non-biodegradable products. *e.g.,* plastic packets of eatables such as biscuit packet, milk and water in polybags, packed fruits and vegetables (in polystyrene and plastic packaging) etc.
- State Governments are trying to push for reduction in use of plastics and encouraging use of eco-friendly packaging.
- We can use carrying cloth or other natural fibre carry-bags instead of polythene bags for shopping.

➢ **Hospital Wastes**
- Hospital wastes contain disinfectants and other harmful chemicals, and also pathogenic micro-organisms.
- The incinerators are used to dispose hospital wastes.

➢ **E-wastes**
- Irreparable computers and other electronic goods are known as electronic wastes (e-wastes).
- They are buried in landfills or incinerated.

- 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.
- Developed countries have specifically built facilities for recycling of e-wastes.
- Recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-wastes.
- Recycling is the only solution for the treatment of e-waste, provided it is carried out in an environment friendly manner.

➢ **Polyblend :** A 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 repellant properties and helps to increase road life.

➢ **Agro-Chemicals and Their Effects**
- In the wake of green revolution, use of inorganic fertilisers, pesticides, herbicides, fungicides, etc. has increased manifold for enhancing crop production.
- These are toxic to non-target organisms that are important components of the soil ecosystem.
- These can be biomagnified in the terrestrial ecosystems.
- Chemical fertilisers cause eutrophication.

➢ **Integrated Organic Farming**
- It is a cyclical, zero-waste procedure, where waste products from one process are cycled in as nutrients for other processes.
- This allows the maximum utilization of resource and increases the efficiency of production.
- 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 fertilizer 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**
- Radiation from nuclear waste has an adverse effect on living organisms, because it causes mutations at a very high rate.
- At high doses, nuclear radiation is lethal but at lower doses, it creates various disorders, such as cancer.
- 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.
- However, this method of disposal is meeting stiff opposition from the public.
- **Use of nuclear energy has two very serious problems:**
  (a) Accidental leakage. *e.g.,* incident in the Three Mile Island and Chernobyl incidents
  (b) Safe disposal of radioactive wastes.

TOPIC-2
Greenhouse Effect, Global Warming and Ozone Depletion

Quick Review

➢ **Greenhouse Effect & Global Warming**
- Greenhouse is a small glass house used for growing plants during winter under controlled conditions.
- The glass panel lets the light in, but does not allow heat to escape.
- Therefore, the greenhouse warms up.
- Greenhouse effect is a natural phenomenon responsible for heating of Earth's surface and atmosphere.
- It maintains the present average temperature (15°C).
- Without greenhouse effect, the average temperature at Earth surface would have been very cold. (–18°C).

- Clouds and gases reflect about 1/4th of the incoming solar radiation, and absorb some of it.
- But almost half of incoming solar radiation falls on Earth's surface heating it, while a small proportion is reflected back.
- Earth's surface re-emits heat as infrared radiation.
- But a part of infrared is absorbed by atmospheric gases (CO_2, CH_4 etc.) and so cannot escape into space.
- These gases (greenhouse gases) radiate heat energy, and a major part of which again comes to Earth's surface, thus heating it up again.
- These gases cause the greenhouse effect.
- Increase in the level of greenhouse gases has led to global warming (overheating of Earth land).
- During the past century, the temperature of Earth has increased by 0.6°C, most of it during the last 3 decades.

➢ **Global Warming**
- The gradual rise in temperature of earth surface due the accumulation of green house gases is called as global warming. It has led to deleterious changes in the environment resulting in odd climatic changes (E.g. El Nino effect).

➢ **Impacts of Climate Change :**

(a) It has been observed that in the past three decades, the average temperature of the Earth has increased upto 0.6ºC. As a result, the natural water cycle has been disturbed, which has resulted an abrupt changes in the pattern of rainfall. It also changed the amount of rain water.

(b) Melting of Polar ice caps and mountain glaciers. This has caused a rise in the sea level, leading to the inundation of coastal regions.

(c) The upper parts of atmosphere have become cooler due to reduced passage of long wave radiations. This in turn had led to shrinkage of atmosphere.

➢ **Climate Change mitigation : (a)** Climate change is a real and serious issue. We need to act promptly to mitigate its effects.

(b) Mitigation means reducing the severity, seriousness or painfulness of something.

(c) Climate change mitigation consists of actions to limit the magnitude or rate of long-term climate change. It generally involves reductions in human (anthropogenic) emissions of greenhouse gases (GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation.

(d) Mitigation policies can substantially reduce the risks associated with human-induced global warming.

➢ **Examples of mitigation:**

(a) Phasing out fossil fuels by switching to low-carbon energy sources, such as renewable and nuclear energy

(b) Expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.

➢ **Goals of mitigation :**

(a) To avoid significant human interference with the climate system.

(b) To stabilize greenhouse gas levels in a time frame sufficient to allow ecosystems to adapt naturally to climate change

(c) To ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

➢ **Ozone Depletion in the Stratosphere**
- 'Bad' ozone is formed in the lower atmosphere **(troposphere)**.
- It harms plants and animals.
- The 'good' ozone is found in the **stratosphere**.
- It acts as a shield absorbing ultraviolet radiation from the sun.
- UV rays are highly injurious since they cause mutation.
- The thickness of the ozone (O_3) in a column of air from the ground to the top of the atmosphere is measured in terms of Dobson units (DU).
- Ozone is continuously formed by the action of UV rays on molecular oxygen, and also degraded into molecular oxygen in the stratosphere.
- Production and degradation of ozone in the stratosphere should be balanced.
- But the balance is disrupted due to ozone degradation by **chlorofluorocarbons (CFCs)**.
- CFCs (used as refrigerants) move upward and reach stratosphere. UV rays act on them releasing Cl atoms.
- In the presence of Cl (catalyst), ozone degrades releasing molecular oxygen (O_2) causing ozone depletion.
- It has formed ozone hole over the Antarctic region.
- UV radiation of wavelengths shorter than UV-B, are almost completely absorbed by Earth's atmosphere.

- **Effects of UV-B**
  - **(a)** UV-B causes mutation of DNA.
  - **(b)** It causes ageing of skin, damage to skin cells and skin cancers.
  - **(c)** A high dose of UV-B causes inflammation of cornea (snow-blindness), cataract, etc.
  - **(d)** It permanently damages the cornea.
- **Montreal Protocol**
  - The Montreal Protocol (an international treaty in Canada, 1987) was signed 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.
- **Soil Erosion and Desertification**
  - Human activities like over-cultivation, deforestation, grazing and poor irrigation practices, lead to soil erosion.
  - It results in arid patches of land and desertification.
  - Increase in urbanization also creates desertification.
- **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.
  - This damages 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.
  - We have only 19.4% of forest cover (it was about 30% at the beginning of 20th century).
- **Reasons of Deforestation**
  - **(a)** Conversion of forest to agricultural land.
  - **(b)** For timber, firewood, cattle ranching etc.
  - **(c)** Slash & burn agriculture (Jhum cultivation) in the north-eastern states of India. In this, 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 decreased, resulting in deforestation.
- **Consequences of Deforestation**
  - **(a)** CO_2 concentration in the atmosphere is enhanced because trees that could hold a lot of carbon in their biomass are lost with deforestation
  - **(b)** Loss of biodiversity due to habitat destruction
  - **(c)** Disturbs hydrologic cycle
  - **(d)** Soil erosion and desertification
- **Reforestation**
  - **(a)** The process of restoring a forest that once existed in the past is known as reforestation.
  - **(b)** It may occur naturally in a deforested area.
  - **(c)** We can speed it up by planting trees.

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.
  - 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 extra ordinary 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.
- Realizing 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.

Know the Terms

- **FOAM :** Friend of Arcata Marsh
- **Ecosan :** Ecological sanitation (Sustainable handling of human excreta)
- **Polar Vertex :** Complete separation of Antarctica air from rest of the world by natural circulation of wind.
- **Defunct Ships :** A type of solid waste that need proper disposal.
- **Oil spill :** Spontaneous discharge of oil, petroleum in estuaries and oceans.
- **Mulching :** Artificial cover used to save the land.
- **DU :** Dobson unit, PIL Public Interest Litigation
- **Pollution :** It defined as any undesirable change in physical, chemical or biological characteristics of air, land, water or soil.
- **Pollutants :** Agents that cause pollution are called as pollutants.
- **Acid rain :** It is caused by presence of excess of nitrogen oxides, sulphur dioxide and chlorides in the atmosphere.
- **Smog :** Smog a dark brown smoky mist that occurs in cold weather. It is a mixture of smoke, dust particles and small drops of fog.
- **Catalytic converters :** These are devices fitted in automobiles to reduce vehicular pollution.
- **Electrostatic precipitator :** It is the device widely used to remove particulate matter such as dust, smoke etc. from air using force of an electrostatic charge.
- **Noise :** It is undesired high level of sound.
- **Bio magnification :** Increase in the concentration of pollutants or harmful chemicals with an increase in the trophic level.
- **Eutrophication :** It is the natural ageing process of a lake caused due to nutrient enrichment.
- **Ecological sanitation :** It is a sustainable system for handling human excreta, using dry composting toilets.
- **E wastes :** These are electronic wastes that generally include electronic good such as computers etc.
- **Greenhouse effect :** The greenhouse effect refers to an overall increase in the average temperature of the Earth due to the presence of greenhouse gases.
- **Global warming :** It is defined as an increase in the average temperature of the Earth's surface.
- **Ozone depletion :** It is the reduction in concentration of ozone layer.

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