Sexual Reproduction in Flowering Plants

SHORT NOTES

Parts of flower

- All flowering plants show sexual reproduction.
- A complete flower consists of calyx, corolla, androecium and gynoecium.
- Androecium is the male reproductive structure that consists of a whorl of stamens.
- Gynoecium is the female reproductive structure that consists of a whorl of carples (pistils).
- Each pistil has three parts.
  - **Stigma:** Landing platform for pollen grains.
  - **Ovary:** Basal bulged part of pistil, has ovarian cavity (locule). Placenta is located inside ovarian caviity.
- A typical stamen is composed of filament and anther.
  - **Filament:** It is a long slender stalk. The proximal end of the filament is attached to the thalamus or the petal of the flower.
  - **Anther** is terminal and generally bilobed structure and each lobe having two theca i.e., they are dithecous.
- The anther is a four-sided (tetragonal) structure consisting of four microsporangia located at the corners two in each lobe.
- The microsporangia develop further & become pollen sacs. They extend longitudinally all through the length of an anther and are packed with pollen grains.

Structure of Microsporangium

- A typical microsporangium near circular, which is generally surrounded by four wall layers.
- The outer 3 wall layers perform the function of protection and help in dehiscence of anther to release the pollen. The innermost wall layer tapetum nourishes the developing pollen grains.
- **Microsporogenesis** is a process of formation of microspores from PMC (Pollen Mother Cell).

Pollen Grain

- It represents the male gametophyte.
- It has prominent two layered wall-exine and intine.
- The outer layer exine is made up of sporopollenin and the intine is made up of pectin and cellulose.
- Pollen grains of many species causes severe allergies.
- Pollen grains are rich in nutrients.
- **Pollen variability:** depends on both temperature and humidity.
- Pollen of a large number of species can be stored for years in **liquid nitrogen (–196°C)** in pollen banks for crop breeding programmes.

Female Gametophyte/Embryo Sac

- Ovules generally differentiate a single megaspore mother cell (MMC) in micropylar region of nucellus.
- In majority of flowering plants, one megaspore remains functional and 3 degenerate. The functional megaspore develops in to the female gametophyte (embryo sac).
- The typical angiosperm embryo sac (female gametophyte) possess **8-nucleate and 7-celled** condition at maturity.

Pollination

- Pollination is the transfer of pollen grain from anther to the stigma of the same flower (self pollination) or of different flower (cross pollination) of the same species.
- Self pollination is of two types i.e, autogamy and geitonogomy.
- Autogamy can be promoted by cleistogamy.
- Xenogomy (cross pollination) is the only type of pollination which brings genetically different types of pollen grains on the stigma.
- Geitonogamy functionally similar to cross pollination and genetically it is similar to autogamy (self pollination).
- Wind and water are common abiotic pollinating agents.
- **Wind Pollination** requires **light, non-stickly pollen** so that they can be transported by wind currents. Well exposed stamens and large often **feathery stigma** to trap air borne pollen, single ovule in each ovary and numerous flowers in an inflorescence.
- In majority of aquatic plants like **water hyacinth** and **water lily**, flowers emerge above water & are pollinated by **insects or wind**.
- In most **water-pollinated** species, **pollen grains** are protected from wetting by a **mucilaginous covering**.
- **Insect-pollinating flowers** are **large, colourful, fragrant** and **rich in nectar**.
- Nectar & pollen grains are usual **floral rewards**.
- In some species, floral rewards are in providing safe places to lay eggs, eg, *Amorphophallus*. A species of **moth and *Yucca*** cannot complete their life cycles without each other.

Outbreeding Devices

- Flowering plants have developed many out breeding devices to discourage self pollination and to encourage cross pollination. For example:
  - Pollen release and stigma receptivity are not synchronised.
  - Anther and stigma are placed at different positions so that pollen cannot come in contact with stigma of the same flower.
  - **Self-incompatibility** is a genetic mechanism which prevents self-pollen from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil.
  - Production of unisexual flowers.

Pollen-pistil Interaction

- Pollen-pistil interaction is a chemical-mediated dynamic process.
- Following compatible pollination, pollen tube grows through the tissues of the stigma and style, the contents of pollen grain move into pollen tube.
- The growing pollen tube carrying **two non-motile male gametes**, reaches the ovary, enters the ovule through micropyle & then enters one of the synergids through the filiform apparatus, which guides the entry of pollen tube.
- One male gamete fuses with egg cell and other with PEN.
- In **artificial hybridisation**, desired pollen are used for pollination and stigma is protected from contamination from unwanted pollen by emasculation and bagging.
- If female flowers are unisexual, there is no need of emasculation.

Double Fertilisation

- **Syngamy & triple fusion are called double fertilisation**, an event unique to flowering plants.
- The central cell after triple fusion becomes primary endosperm cell (PEC) and develop into **endosperm**.

Endosperm

- Endosperm development precedes embryo development.
- As it is filled with reserve food materials and used by developing embryo.

Embryo

- **Embryo** develops at micropylar end of embryo sac where the zygote is situated.
- Early stages of embryo development (**Embryogeny**) are similar in both monocotyledons and dicotyledons.
- In dicots, the zygote forms → prombryo → globular → heart-shaped → mature embryo.
- Embryos of monocot has only one cotyledon called **scutellum** Radicle or root cap is enclosed with undifferentiated sheath called **coleorhiza**. Epicotyl has shoot apex & a few leaf primordia enclosed in foliar structure **coleoptile**.

Seed

- In angiosperms, seed (fertilised ovule) is the final product of sexual reproduction, formed inside fruits. A seed typically consists of seed coats, cotyledon(s) & an embryo axis.
- Mature seeds may be non-abuminous or ex-albuminous, having no residual endosperm, which is consumed completely during embryo development (eg. Pea, groundnut). **Albuminous seeds** retain a part of endosperm (eg. Wheat, maize, barley, castor, coconut).
- In black pepper & beet, remnants of nucellus are also persistent, called **perisperm**.
- True fruits develop from ovary.
- In apple, strawberry, cashew, etc., thalamus also contributes to form fruit called **false fruit**.
- **Parthenocarpic fruit** develop without fertilisation eg., Banana.
- *Lupinus arcticus* seed germinated and flowered after estimated record 10,000 years of dormancy. *Phoenix dactytifera* (date palm) seed remained viable for 2000 years.

Apomixis and Polyembryony

- Some species of **Asteraceae & grasses** have evolved a special mechanism to produce seeds without fertilisation called apomixis.
- In ***Citrus* and mango**, nucellar cells protrude into embryo sac & develops into embryos, so each ovule contains many **embryos (polyembryony)**.

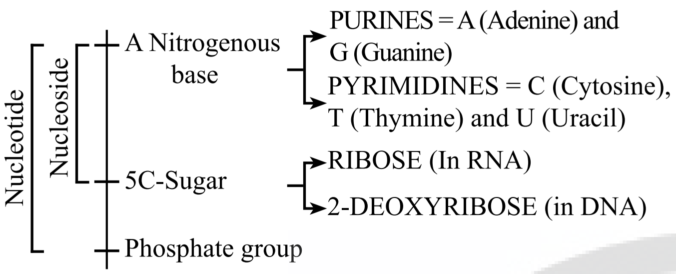
Molecular Basis of Inheritance

SHORT NOTES

DNA is a long polymer of deoxyribonucleotides. The length of DNA is usually defined as number of nucleotides present and is also characteristic of an organism.

Structure of Polynucleotide Chain

Nucleotide (Basic unit of Polynucleotide chain)



- Uracil is present in RNA; Thymine (5-methyl uracil) in DNA

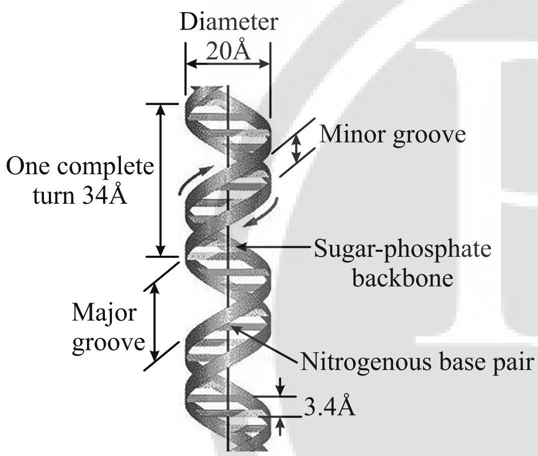


Fig.: Dimension of DNA double helix

CENTRAL DOGMA OF MOLECULAR BIOLOGY

Proposed by FRANCIS CRICK.

- Only applicable to dsDNA.

  DNA (Replication) —Transcription→ mRNA —Translation→ Protein

  In some viruses, the flow of information is in reverse direction, i.e. from RNA to DNA. It is called reverse central dogma.

PACKAGING OF DNA HELIX

- In prokaryote (*E.coli*), the DNA (negatively charged) is held with some proteins (positive charges) in the **"Nucleoid"**. The DNA in nucleoid is organised in large loops held by proteins.
- In eukaryotes, it is much more complex.
  - **Histone Octamer:** Positively charged set of basic proteins, Histone (rich in lysine and arginine) are organised to form a unit of eight molecules, called Histone octamer.
  - **Nucleosome:** Negatively charged DNA is wrapped around positively charged histone octamer. A typical nucleosome contains 200 bp of DNA helix.
- Nucleosomes constitute the repeating unit of a structure in nucleus called chromatin, thread like stained bodies seen in nucleus.
- Nucleosomes in chromatin are seen as **beads-on-string** structure under electron microscope. Packaged to form chromatin fibres that are further coiled and condensed at metaphase stage to form chromosomes.

In a typical NUCLEUS (regions of chromatin)

Euchromatin	Heterochromatin
1. Loosely packed	1. More densely packed
2. Stains light	2. Stains dark
3. Transcriptionally active	3. Transcriptionally inactive

SEARCH FOR GENETIC MATERIAL

Transforming Principle

- In 1928, Frederick Griffith, in a series of experiments with *Streptococcus pneumoniae*, witnessed a miraculous transformation in **Bacteria**.
- Griffith concluded that R-strain was somehow transformed by heat-killed S-strain. It must be due to the transfer of genetic material (transforming principle).

Biochemical Nature of Transforming Principle

- Oswald Avery, Colin MacLeod and Maclyn McCarty (1933-44) discovered that DNA is the genetic material.
- DNA of S bacteria caused R bacteria to become transformed.
- As proteases and RNAse did not affect transformation but DNAase inhibit transformation.

Genetic Material is DNA

The Unequivocal proof that DNA is the genetic material came from the experiments of Alfred Hershey and Martha Chase (1952), on **bacteriophages**, using radioactive phosphorus ^{32}P and sulphur ^{35}S in separation medium with *E. coli*.

RNA WORLD (genetic material of some viruses like TMV)

- RNA was the first genetic material.
- The essential life processes like metabolism, translation, splicing evolved around RNA.
- RNA used to act as a genetic material as well as a catalyst, so was reactive and hence unstable. (DNA has evolved from RNA with chemical modifications that make it more stable.)

REPLICATION

- Watson and Crick proposed a scheme for replication of DNA while proposing the double helix structure of DNA.
- Semi conservative DNA replication: Two strands would separate and act as a template for the synthesis of new

complementary strands. After completion of replication, each DNA molecule would have one parental and one newly synthesised strand.

EXPERIMENTAL PROOF

- Semi-conservative DNA replication was shown first in *Escherichia coli*, then in higher organisms like plants and human cells.
- **Matthew Meselson** and **Franklin Stahl**, performed the experiment (1958) to prove semi conservative nature of DNA by using normal ^{14}N and heavy ^{15}N isotope of Nitrogen.
- **Taylor** and colleagues (1958) used **radioactive thymidine** and *Vicia faba* **(Faba beans)** to prove that DNA in chromosomes also replicate semi-conservatively.

TRANSCRIPTION

- Process of copying genetic information from one strand of DNA into RNA.
- Principle of complementarity governs transcription (except, adenine forms pair with uracil instead of thymine). In transcription, only a segment of DNA and only one of the two strands is copied into RNA.

TRANSCRIPTION UNIT AND GENE

- **Cistron** is defined as a segment of DNA coding for polypeptide.
- The structural gene is **monocistronic** (mostly in eukaryotes) or **polycistronic** (mostly in bacteria or prokaryotes).
- In eukaryote, genes are split between coding sequences or **Exons**, which appear in mature RNA and **Introns** or intervening sequence.
- **Regulatory sequences** are defined as regulatory genes, even though they do not code for any RNA or protein.
- In bacteria, mRNA does not require any processing, so transcription and translation are coupled.
- In eukaryotes there are three RNA polymerases in the nucleus, and capping and tailing is required to form mature RNA.

GENETIC CODE (GEORGE GAMOW)

- Genetic code should be triplet.
- 61 codons code for amino acids and 3 codons are stop codons.
- The code is degenerate, contiguous and universal.
- AUG has dual function. It codes for methionine and act as initiator codon.
- UAA, UAG and UGA- Stop terminator codons.

tRNA-Adapter Molecule

- **Francis Crick** postulated the presence of an adapter molecule that would read the code and bind to specific amino acid.
- tRNA has an **anti-codon loop** that has bases complementary to the code and it also has an amino acid acceptor end to which it binds to amino acids, tRNAs are specific for each amino acid.
- For initiation, there is a specific tRNA that is called **initiator tRNA**. There are no tRNAs for stop codons.
- Secondary structure of tRNA looks like a **cloverleaf**, though the actual structure is a compact molecule which looks like **inverted L**.

TRANSLATION

- Translation refers to the process of polymerisation of amino acids to form a polypeptide. The order and sequence of amino acids are defined by the sequence of bases in the mRNA.
- A translational unit in mRNA is flanked by a start codon (AUG) and the stop codon.
- Untranslated regions, **(UTRs)** are present at both 5'-end (before start codon)and at 3'-end (after stop codons). UTRs are required for efficient translation.
- The ribosome moves from codon to codon along the mRNA. Amino acids are added one by one and translated into polypeptide sequences.

REGULATION OF GENE EXPRESSION

Gene expression results in formation of a polypeptide. It can be regulated at several levels. In eukaryotes, the regulation could be exerted at

1. Transcriptional level (Formation of primary transcript).
2. Processing level (Regulation of splicing).
3. Transport of mRNA from nucleus to cytoplasm.
4. Translational level.

Lac OPERON

- Francois Jacob and Jacque Monod were the first to elucidate a transcriptionally regulated system, the *lac* operon (*lac* refers to lactose), **a polycistronic structural gene** regulated by a common promoter and regulatory gene called operon.

Lac operon consists of:

One regulatory gene *i*, three structural genes (*z*, *y* and *a*), gene (*i* refers to inhibitor) and codes for repressor, *z*-for β-galactosidase (β-gal), *y*-for permease and gene a codes for transacetylase.

- Lactose is the substrate of β-galactosidase and it regulates switching on/off of operon, so called **inducer**.
- *lac* operon is negatively regulated and is inducible

HUMAN GENOME PROJECT - (HGP)

- Launched in 1990, a 13 year project was co-ordinated by U.S. department of energy and National Institute of Health, Wellcome trust (UK), Japan, France, Germany, China participated. It was completed in 2003.
- Human genome has approximately 3×10^9 bp and the cost of sequencing in the beginning was US $3 per bp, i.e. 9 billion US dollars. HGP lead to the rapid development of a new area in biology called bioinformatics.
- Many non-human model organisms like bacteria, Yeast, *Caenorhabditis elegans*, *Drosophila*, plant (rice and *Arabidopsis*) have also been sequenced.

METHODOLOGIES

- **Expressed sequence tags (ESTs) identification:** Focussed on identifying all genes that expressed as RNA.
- **Sequence annotation:** Sequencing the whole genome containing coding and non-coding sequences, needing vectors like BAC (Bacterial artificial chromosomes) and YAC (Yeast Artificial Chromosomes).

DNA FINGERPRINTING

- 99.9% base sequence among humans is same. 0.1% differences in sequence of DNA make every individual unique in their phenotype.
- It involves identifying difference in repetitive DNA, a small stretch of DNA repeated many times, called **satellite DNA**.
- Depending on base composition (A:Tor G:C rich), length of segment and number of repetitive units, the satellite DNA is classified into micro-statellites and mini satellites. They do not code for any proteins. They form large portion of human genome and show high degree of polymorphism and form the **basis of DNA fingerprinting**.
- Polymorphisms are inheritable from parent to child so DNA fingerprinting solves paternity disputes.
- The technique of DNA finger printing was initially developed by **Alec Jeffreys**.

Steps = Isolation of DNA (I) → Digestion by restriction endonuclease (II) → Separation of DNA fragments by Electrophoresis (III)
↓
Blotting on nitrocellulose or Nylon membrane (IV) → Hybridisation Using labelled VNTR probe (V) → Detection of hybridised DNA Fragments by autoradiography (VI)

Significance

- VNTR are called mini-satellite, a small DNA sequence arranged tandomly in many copies. The size of VNTR varies from 0.1 to 20 kb. After hybridisation with VNTR probe, the autoradiogram gives many bands of differing sizes. These bands give a characteristic pattern for an individual DNA. It differs from individual to individual in a population except in monozygotic twins.
- The sensitivity of the technique has been increased by use of polymerase chain reaction **(PCR)**.
- DNA fingerprinting has much wider application in determining population and genetic diversities. Currently, many different probes are used to generate DNA fingerprints.

Principles of Inheritance and Variation

SHORT NOTES

- Genetics deals with inheritance and variation of characters from parents to offsprings.
- **Inheritance** is the process by which characters are passed on from parent to progeny.
- **Variation** is the degree by which progeny differ from their parents and is caused due to sexual reproduction.
- Gregor Mendel conducted hybridisation experiments on **garden peas** for seven years (**1856-1863**) and proposed the laws of inheritance.
- Mendel selected **14-true breeding** pea plant varieties as pairs which were similar except for one character with contrasting traits.
- The characters studied by Mendel were stem height, flower colour and position, pod shape and colour, seed shape and colour.
- **Law of dominance** explains the expression of only one parental character in F_1 of monohybrid cross. It also explains the proportion of 3 : 1 obtained at the F_2.
- Monohybrid cross is a cross between two organisms which is made to study the in heritance of a single pair of alleles of character.
- Monohybrid phenotypic ratio is 3:1 and genotypic ratio is 1:2:1.
- Dihybrid cross is a cross between two organisms which is made to study the inheritance of two pairs of alleles belonging to two different genes.
- Dihybrid phenotypic ratio is 9:3:3:1 and genotypic ratio is 1:2:1:2:4:2:1:2:1.
- **Law of segregation explains,** the factors or alleles of a pair segregate from each other such that gametes receive only one of the two factors. **Law of independent assortment** explains when two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair of characters.
- If F_1 did not resemble either of the parents and was in between the two this type of interaction is called as incomplete dominance, e.g., dog flower (Snapdragon or *Antirrhinum sp.*).
- The genotypic and phenotypic ratio of incomplete dominance is 1:2:1.
- Genes are units of inheritance. They contain information required to express a particular trait an organism.
- British geneticist R.C Punnett developed a graphical representation call Punnett square to calculate **possibility of all possible genotypes** of offsprings in a genetic cross.
- The alleles which do not show dominance-recessive relationship and are able to express themselves independently and equally when present together. This type of allele interaction is called codominance.
- ABO blood group in humans is an example of codominance.
- ABO blood group in human being is controlled by Gene-I, having three alleles I^A, I^B and *i*. I^A and I^B produce slightly different form of sugar, while *i* does not produce any sugar.
- I^A and I^B are completely dominant over *i*, but when I^A and I^B are present together, they express their own sugars, because of co-dominance hence RBC have both sugars.
- There are **6 genotypes** and **4 phenotypes** in human ABO blood types.
- ABO blood grouping is a very good example of multiple allelism in which **more than two** alleles govern the **same** character.
- Pleiotropy is a condition in which a single gene can exhibit multiple phenotypic expression. It is the effect of a gene on metabolic pathways which contribute towards different phenotypes, e.g., Phenylketonuria.
- **Walter Sutton** and **Theodore Boveri** noted that the behaviour of chromosomes was parallel to behaviour of genes and they used chromosome movement to explain Mendel's Laws.
- Sutton united the knowledge of chromosomal segregation with Mendelian principles and proposed chromosomal theory of inheritance.
- Linkage is the phenomenon of genes staying together during inheritance without any seperation due to their being present on the same chromosome.
- Morgan proved and defined linkage on the basis of his breeding experiments in *Drosophila melanogaster*.
- Morgan's student Alfred Sturtevant used **frequency of recombination** between genes on same chromosome as a measure of distance between genes and mapped their position on chromosomes.
- If traits are controlled by three or more genes then the traits are called as polygenic traits. It also takes into account influence of environment.
- The phenotype reflects the contribution of each allele, i.e., the effect of each allele is additive, e.g. Human Skin Colour
- Types of sex-determination.
  - XO-Type = Male heterogamete
    e.g. = Grasshopper
  - XY-Type = Male heterogamete
    e.g. = Insects, Man
  - ZW-Type = Female heterogamete
    e.g. = Birds
- Genetic make-up of sperm determines sex of the child and in each pregnancy, there is always **50%** probability of a male or female child.
- In honey bees, sex-determination is haplo-diploid type in which unfertilised egg develops as male (**drone**) i.e. **haploid** and Queen and worker bees (females) are **diploid**.
- Mutation is caused due to alteration in chromosomes which result in abnormailities or aberrations. Chromosomal aberrations are commonly observed in cancer cells.
- **Mutagens are** Chemical and physical factors that induce mutations, e.g. UV radiations, X-rays etc.
- Pedigree analysis is a study of family history about inheritance of a particular trait or disease.
- A few chromosomal aberrations are colour-blindness, Haemophilia, Thalassemia, S.C anaemia and phenylketonuria.
- A few disorders are dons's syndrome, klinefelter's syndrome. Turner's syndrome

Microbes in Human Welfare

SHORT NOTES

MICROBES IN HOUSEHOLD PRODUCTS

- A common example is the production of curd from milk. Micro-organisms such as Lactobacillus and others commonly called Lactic Acid Bacteria **(LAB)** grow in milk and convert it to curd. During growth, the LAB produces acids that coagulate and partially digest the milk proteins. It also improves its nutritional quality by increasing vitamin B12. In our stomach too, the LAB play very beneficial role in checking disease causing microbes.
- The dough, which is used for making bread, is fermented by using **baker's yeast** (*Saccharomyces cerevisiae*).
- **"Toddy",** a traditional drink of some parts of southern India is made by fermenting sap from palms.
- Microbes are also used to ferment fish, soya-bean and bamboo-shoots to make foods. Cheese, is one of the oldest food items in which microbes were used. The large holes in **'Swiss cheese'** are due to production of a large amount of CO_2 by a bacterium named *Propionibacterium sharmanii*. The **'Roquefort cheese'** is ripened by growing a specific fungus on them for a particular flavour.

MICROBES IN INDUSTRIAL PRODUCTS

Production on an industrial scale requires growing microbes in very large vessels called Fermentors.

(a) Fermented Beverages

The yeast *Saccharomyces cerevisiae* used for bread making and commonly called brewer's yeast, is used for fermenting malted cereals and fruit juices to produce ethanol. Wine and beer are produced without distillation whereas whisky, brandy and rum are produced by distillation of the fermented broth.

(b) Antibiotics

Antibiotics are chemical substances, which are produced by some microbes and can kill or retard the growth of other disease causing microbes.

Pencillin was the first antibiotic to be discovered and it was a chance discovery. **Alexander Fleming** while working on *Staphylococci* bacteria, once observed a mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He found out that it was due to a chemical produced by the mould and he named it Pencillin after the mould *Pencillium notatum*. Later, **Ernest Chain** and **Howard Florey** made its full potential effective antibiotic.

(c) Chemicals, Enzymes and other Bioactive Molecules

- *Aspergillus niger* (fungus) - Citric acid
- *Acetobacter aceti* (bacterium) - Acetic acid
- *Clostridium butylicum* (bacterium) - Butyric acid
- *Lactobacillus* (bacterium) - Lactic acid
- *Saccharomyces cerevisiae* - Ethanol

Enzymes

- Lipase - used in laundry detergents
- Pectinase and protease - used in bottled juices
- Streptokinase (*Streptococcus bacterium*) - used as clot buster (to remove clots)

Bioactive molecules

- Cyclosporin A (*Trichoderma polysporum* fungi) - used as immunosuppressive agent (for organ transplant patients).
- Statins (*Monascus purpureus* yeast) - used as blood cholesterol lowering agents.

MICROBES IN SEWAGE TREATMENT

Treatment of waste waster is done by heterotrophic microbes naturally present in the sewage. This treatment is carried out in two stages;

(a) Primary treatment/Physical treatment

It involves physical removal of particles from the sewage through filtration and sedimentation.

- Sequential filtration - to remove floating debris
- Sedimentation - to remove grit (soil and small pebbles)

All solids that settle form the primary sludge, and the supernatant forms the effluent. The effluent from the primary settling tank is taken for secondary treatment.

(b) Secondary treatment/Biological treatment

- The primary effluent is passed into large aeration tanks, this allows vigorous growth of aerobic microbes into flocs. While growing, these microbes consume the major part of the organic matter in the effluent. This significantly reduces the BOD **(biochemical oxygen demand)** of the effluent. BOD is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.
- Once the BOD of sewage water is reduced significantly, 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 this 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.
- During this digestion, bacteria produce a mixture of gases such as **methane, hydrogen sulphide** and **carbon dioxide.** These gases form biogas.
- The effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams.

MICROBES IN PRODUCTION OF BIOGAS

Biogas is mixture of gases produced by the microbial activity and which may be used as fuel. Certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with CO_2 and H_2S. These bacteria are collectively called Methanogens (*Methanobacterium*).

These bacteria are also present in the rumen of cattle. A lot of cellulosic material present in the food of cattle is also present in the rumen. In rumen, these bacteria help in the breakdown of cellulose and play an important role in the nutrition of cattle. Thus, the excreta (dung) of cattle, commonly called Gobar, is rich in these bacteria. Dung can be used for generation of biogas commonly called gobar gas.

Biogas Plant

The technology of biogas production was developed in India mainly due to the efforts of Indian Agricultural Research Institute **(IARI)** and Khadi and Village Industries Commission **(KVIC).**

The biogas plant consists of a concrete tank in which bio-wastes are collected and slurry of dung is fed.

A floating cover is placed over the slurry, which keeps on rising as the gas is produced in the tank due to the microbial activity.

The biogas plant has an outlet, which is connected to a pipe to supply biogas to nearby houses.

The spent slurry is removed through another outlet and may be used as fertilizer.

The biogas thus produced is used for cooking and lighting.

MICROBES AS BIOFERTILISERS

Biofertilizers are organisms that enrich the nutrient quality of the soil. The main sources of biofertilisers are bacteria, fungi and cyanobacteria.

Bacteria

- Symbiosis - *Rhizobium* with root nodules of leguminous plants
- Free living (in the soil) - *Azotobacter* and *Azospirillum.*

Fungi

- Symbiosis - Mycorrhiza with root system of genus Glomus and absorb phosphorus and water from the soil for the plant growth.

Cyanobacteria

- Symbiosis - *Anabaena* and *Azolla.*
- Free living - *Nostoc, Oscillatoria* and Blue green algae.

MICROBES AS BIOCONTROL AGENTS

Biological control of pests and diseases

- Lady bird to control aphids
- Dragon fly - to control mosquitoes
- Bacillus thuringiensis ***(Bt-Cotton)*** - to control wide range insects
- *Trichoderma* (fungi) - protects root system and control plant pathogens.
- Baculoviruses *(Nucleopolyhedrovirus)* - to attack insects and other arthropods.

Organisms and Populations

SHORT NOTES

- Ecology (at organismic and population level) studies interactions among organisms and between organism and its physical (abiotic) environment.
- Ecology is basically concerned with four levels of biological organisation-**organisms, populations, communities and biomes**.

ORGANISMS AND ITS ENVIRONMENT

- Ecology, at the organismic level, is essentially physiological ecology.
- The rotation of our planet around the sun and the tilt of its axis cause annual variations in the intensity and duration of temperature, resulting in distinct seasons.
- **Habitat** of an organism is characterised by physico-chemical (abiotic) components and biotic components like-pathogens, parasites, predators and competitors of the organism with which they interact constantly.

MAJOR ABIOTIC FACTORS

Temperature

- Is the ecologically most important factor.
- Affects enzyme kinetics, metabolic activity and physiology.
- **Eurythermals** tolerate wide temperature fluctuations.
- **Stenothermals** restricted to narrow range.
- Thermal tolerance determines geographical distribution.

Water

- Life originated in water.
- Productivity and distribution of plants is dependent on water.
- **Salinity** measured in ppt is:
  < 5 in inland water, 30-35 in sea,
  and >100 in some hypersaline lagoons.

Light

- Plants need light for photosynthesis and photoperiod for flowering.
- Animals also need light for foraging, reproduction & migration.
- Red algae are found in deepest water.

Soil

- Nature and properties of soil depends on climate, weathering and transportation.
- Composition, grain size, pH, minerals and topography determine vegetation which dictates the type of animals supported.

RESPONSE TO ABIOTIC FACTORS

Abiotic conditions of many habitats vary drastically in time and organisms living in such habitats need to evolve strategies to survive or manage with the stressful conditions.

ORGANISMIC RESPONSE TO ABIOTIC STRESS

Regulate

- Maintain homeostasis by physiological (or behavioural) means.
- All birds, mammals and very few lower vertebrates and invertebrates are capable of this.
- Success of mammals is largely due to their ability to maintain constant body temperature and thrive in antarctica or in Sahara desert.

Conform

- 99% animals and nearly all plants are conformers.
- Body temperature changes with the ambient temperature.

Suspend

- Thick walled spore in bacteria, fungi and lower plants.
- Dormancy in higher plants, hibernation in bears, aestivation in snails and fish, diapause or suspended development in zooplanktons.

ADAPTATIONS TO COPE WITH EXTREME ENVIRONMENT

Morphological

- Kangaroo rat in North American deserts is capable of meeting all its water requirements through internal fat-oxidation and ability to concentrate urine.
- CAM plants like *Opuntia* have thick cuticle, sunken stomata and photosynthetic stems.
- **Allen's Rule:** Shorter extremities of mammals in cold climate to reduce heat loss. (Thick blubber in seal).

Physiological

- Altitude sickness. Symptoms-Nausea, fatigue & heart palpitations.
- Gradually, the body compensates low oxygen by increasing RBC production, decreasing the binding affinity of haemoglobin and increasing the breathing rate.

Behavioural

- Responses to cope up with variations in environment.
- Desert lizards-bask in the sun & absorb heat when their body temperature drops below comfort zone, but move away into shade when ambient temperature starts increasing
- Some species hide in burrow to escape from the above-ground heat.

POPULATION

Population Attributes

- **Birth rates and Death Rates:** Refer to per capita births and deaths, respectively.
- **Sex-ratio**

- **Age-pyramids:** Shows percent individuals of a given age or age group. The shape of the pyramids reflects the **growth status** of the population. It is of three types: Expanding, stable and declining.
- Evolutionary changes through natural selection takes place at population level.

POPULATION GROWTH

- Food availability, predation pressure and adverse weather are the factors which affect population.
- Population density, in a given habitat during a given period, fluctuates due to changes in **four** base processes.
  - **Natality, immigration** increase it.
  - **Mortality, emigration** decrease it.
- Tiger census in our national parks & tiger reserves is often based on **pug marks and fecal pellets**
- If N is the population density at time t, then its density at time t + 1. $N_{t+1} = N_t [(B + I) – (D + E)]$
  - If births plus immigration (B + I) is more than deaths plus emigration (D + E), population density will increase
  - Under normal conditions, births & deaths are most important factors influencing population density
  - If a new habitat is just being colonised, immigration is more significant to population growth than birth rates.

GROWTH-MODELS

Exponential Growth

- When resources in the habitat are unlimited, then the population grows in an exponential or geometric fashion. It is given by the equation, $N_t = N_o e^{rt}$.
- It results in J-shaped curve.

Logistic Growth

- The natural resources are limited in nature, this leads to competition.
- The population growing in a habitat with limited resources shows, lag, acceleration, deceleration and finally asymptote.
- It results in S-shaped or sigmoid curve also called as **Verhulst**-Pearl **logistic** curve.
- Logistic growth model is realistic.
- **Asymptote**-When population density reaches the carrying capacity.

LIFE HISTORY VARIATION

- Populations evolve to maximise their reproductive fitness, also called **Darwinian fitness** (high 'r' value), in the habitat in which they live and evolve towards the most effective reproductive strategy.

Reproductive Strategies in Organisms

- Breed only once in their life time. e.g., Pacific salmon fish, Bamboo.
- Breed many times during lifetime. e.g., Most birds & Mammals.
- Some produce large number of small-sized off springs e.g., Oysters, Pelagic fishes.
- Others produce a small number of large-sized off springs. e.g., Birds & Mammals.

POPULATION INTERACTIONS

Predation (+; –)

- One species benefits and other is harmed.
- Used as biological control method for pest-control.
- Maintain species diversity by reducing competition among prey.
- Prey species evolved defenses: Camouflage - Insects & frogs, monarch butterfly- Chemcal defense, thorns-*Cactus, Acacia.*
- Many plants produce and store chemicals that make herbivore sick when they are eaten, e g., *Calotropis* produces cardiac glycosides.

Competition (–; –)

- Both the species are negatively affected.
- Totally unrelated species can compete for same resources.
- The fitness (**'r' the intrinsic rate of increase**) of one species is significantly lower in presence of another species.
- **Competitive release** - The distributional range increase dramatically when the superior species is removed., eg. *Balanus & Chathamalus.*
- **Gause's competitive exclusion principle** states two closely related species competing for the same resources cannot co-exist. e.g., Abingdon tortoise and Goats in galapagos island.
- Two species compete for the same resource could avoid competition by **resource partitioning** eg. 5 closely related species of warblers.

Parasitism (+; –)

- One species benefits and other is harmed.
- Free lodging and meals.
- Parasites are host specific, i.e., **co-evolve.**
- Human liver fluke depends on a snail and a fish to complete its life cycle.
- Parasites reduce survival, growth and reproduction of host make them weak
- **Brood parasitism** in birds eg. Cuckoo and crow. The eggs of parasitic bird had evolved to resemble host's egg in colour and size.
- Ectoparasites feed on external surface of host (Ex. ticks, lice, *Cuscuta*) and endoparasites live inside the host (e.g., *Ascaris* lives in intestine)

Commensalism (+; 0)

- One species benefits and the other is neither harmed nor benefited.
- An orchid growing as an epiphyte on a mango branch, barnacles growing on back of a whale, cattle egret and grazing cattle, sea anemone that has stinging tentacles and clown fish that lives among them are few examples.

Amensalism (–; 0)

- One species is harmed whereas the other is unaffected.

Mutualism (+; +)

- Both the species get benefits by this interaction.
- Lichens, mycorrhiza, plant - animal relationships for pollination.
- Plants offer rewards or fees like pollen, nectar for pollinators and fruits for seed dispersal.
- Mediterranean orchid ***Ophrys*** employs **sexual deceit** to get pollination done by a species of bee by **pseudo copulation**.
- Shows co-evolution and one to one relationship like fig and partner wasp.

Ecosystem

SHORT NOTES

INTRODUCTION

- Ecosystem is a functional unit of nature.
- Forest, grassland and desert are **terrestrial ecosystems**.
- Pond, lake, wetland, river and estuary are **aquatic**.
- Crop fields and an aquarium are **man-made ecosystems**.

ECOSYSTEM-STRUCTURE

Stratification: Vertical distribution of different species occupying different levels, like trees at top vertical strata, shrubs second and herbs and grasses occupy bottom layers.

ECOSYSTEM-FUNCTIONS

Productivity

- **Primary production:** Amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis.
- Expressed in terms of weight (gm^{-2}) or energy ($K\ cal\ m^{-2}$).
- Rate of biomass production is productivity, expressed as $gm^{-2}\ yr^{-1}$ or ($K\ cal\ m^{-2}$) yr^{-1}. It can be divided into:
  - (*i*) **Gross primary productivity (GPP):** Rate of production of organic matter during photosynthesis.
  - (*ii*) **Net primary productivity (NPP):** Available biomass for the consumption to heterotrophs (herbivores and decomposers).

NPP = GPP - R (respirator loss)

- Varies in different ecosystems:
  - Annual net primary productivity of whole biosphere is approximately = **170 billion tons** (dry wt.) of organic matter.
  - Productivity of oceans (70% of surface) = **55 billion tons**, rest is on land.
- **Secondary productivity:** Rate of formation of new organic matter by consumers.

DECOMPOSITION

- Breakdown of complex organic matter into inorganic substances like CO_2, water and nutrients.
- **Raw material:** Detritus, i.e., dead plant remains like leaves, bark, flowers and dead remains of animals, including fecal matter.

DECOMPOSITION	
Fragmentation	Break down of detritus into smaller particles by detritivores (e.g., earthworm).
Leaching	Water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
Catabolism	Bacterial and fungal enzymes degrade detritus into simpler inorganic substances.
Humification	Accumulation of dark, amorphous humus which is highly resistant to microbial action. Humus undergoes decomposition at an extremely slow rate in soil.
Mineralisation	Humus is further degraded by microbes to release inorganic nutrients.

ENERGY FLOW

- Unidirectional from sun to producers and then to consumers.

TROPHIC LEVELS IN AN ECOSYSTEM

- Amount of energy decreases at successive trophic levels.
- Only 10% of the energy is transferred to each trophic level from the lower trophic level (10% Law).

HETEROTROPH	Tertiary consumer →	Fourth trophic level (T_4) (secondary carnivores)	Man, lion	Large fishes
HETEROTROPH	Secondary consumer →	Third trophic level (T_3) (primary carnivores)	Birds, wolf	Fishes
HETEROTROPH	Primary consumer →	Second trophic level (T_2) (herbivores)	Insects, birds, mammals	Zooplanktons, molluscs
	Primary producer Autotrophs →	First trophic level (T_1) (green plants)	Herbaceous, woody plants	Algae, phytoplanktons and higher plants

DETRITUS FOOD CHAIN	GRAZING FOOD CHAIN
❍ Begins with dead organic matter. ❍ Made up of decomposers which are **heterotrophic organisms**, mainly fungi and bacteria. ❍ Present in a terrestrial ecosystem.	❍ Sun is the source of energy. ❍ Autotrophs assimilate food using simple inorganic materials and radiant solar energy. ❍ The energy flows from autotrophs to heterotrophs as per the law of thermodynamics. ❍ Present in an aquatic ecosystem.

ECOLOGICAL PYRAMIDS

- Food or energy relationship between organisms at different trophic levels is expressed in terms of **number**, **biomass** or **energy**.
- Three types of ecological pyramids are usually studied: (*a*) pyramid of number (*b*) pyramid of biomass (*c*) pyramid of energy.
- Pyramid of energy is always upright.
- It assumes a simple food chain that never exists in nature. It does not accommodate a food web.
- Saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

Pyramid of Number

- Upright in most ecosystems.

Biodiversity and Conservation

SHORT NOTES

BIODIVERSITY

- Biodiversity or biological diversity is the variety and variability of life on Earth, popularised by the socio-biologist **Edward Wilson.**
- A conservative and scientifically sound estimate made by Robert May places the global species diversity at about 7 million.
- Among animals, insects make more than 70% of total, i.e., out of every 10 animals on this planet, 7 are insects.
- Although, India has only 2.4% of world's land area, its share of the global species diversity is an impressive 8.1 percent.

PATTERNS OF BIODIVERSITY

- Species diversity decreases as we move away from equator towards the poles.
- Species richness within a region increased with increasing explored area, but only upto a limit.
- The relation between species richness and area for a wide variety of taxa (angiosperms, birds, bats, freshwater fishes) is a rectangular hyperbola. On a logarithmic scale, it is a straight line.
- The value of Z lies in the range of 0.1 to 0.2 regardless of region or taxa.
- Slope of the line is much steeper in very large areas like the entire continents.

IMPORTANCE OF SPECIES DIVERSITY TO THE ECOSYSTEM

- Communities with more species, tend to be more stable than those with less species.
- **David Tilman's** long-term ecosystem experiments using outdoor plots show that plots with more species showed less year-to-year variation in total biomass and increased diversity contributed to higher productivity.
- The **'rivet popper hypothesis'** of Paul Ehrlich states that loss of rivets on the wings (Key species, that drive major ecosystem functions) will be serious. So, each species is important for the ecosystem.

LOSS OF BIODIVERSITY

- The **IUCN red list (2004)** documents extinction of 784 species (including 338 vertebrates, 359 invertebrates and 87 plants) in the last 500 years.
- There were five episodes of mass extinction of species in the past, before humans appeared.
- The Sixth Extinction presently in progress is 100 to 1000 times faster than pre-human times and our activities are responsible for the faster rates.

CAUSES OF BIODIVERSITY LOSSES

- Habitat loss and fragmentation, over-exploitation, alien species invasions and co-extinctions are four major causes (The Evil Quartet) of biodiversity losses.

BIODIVERSITY CONSERVATION

- The reasons for why should we conserve biodiversity can be grouped into three categories: narrowly utilitarian, broadly utilitarian, and ethical.

Narrowly Utilitarian Arguments

- Humans derive countless direct economic benefits from nature — food, firewood, fibre, construction material, industrial products and medicinal products.

Broadly Utilitarian Arguments

- Biodiversity plays a major role in many **ecosystem services** that nature provides.

Ethical Arguments

- We have a moral duty to care for their well-being.

TYPES OF BIODIVERSITY CONSERVATION

In-situ Conservation

- It is a type of conservation that performs inside the natural habitat it conserves biodiversity at all levels.
- Biodiversity hotspots are the regions with very high levels of species richness and high degree of endemism.
- Biodiversity hotspots and sacred groves are *in situ* conservation strategies.
- 14 biosphere reserves, 90 National Parks and 448 wild life sanctuaries provide legal protection in India.

Ex-situ Conservation

- It is conservation of selected rare threatened plants/animals outside their natural habitat.
- Zoological Parks, Botanical gardens and wild-life Safari parks includes under *ex- situ* conservation.
- 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.
- Cryopreservation is a method to protect and preserve gametes of threatened species in viable and fertile condition.

INTERNATIONAL EFFORTS FOR CONSERVING BIODIVERSITY

- The Earth Summit was held in Rio de Janeiro (1992) for biodiversity conservation and sustainable utilisation of benefits.
- World Summit on sustainable development held in 2002 in Johannesburg, South Africa, 190 countries pledged for significant reduction in current rate of biodiversity loss at global, regional and local levels by 2010.