BIO-TONIC

Building Strong Foundations in Biology
Simplified Theory, Key Concepts & Exam-Focused Practice

COMPLETELY UPDATED AS PER NCERT BIOLOGY SYLLABUS
(SESSION 2026–27)

PUCII /KCET AND NEET

INOLU CHINNA MALLIKARJUNA

BlueRose ONE .com
Stories Matter
NewDelhi • London

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BLUEROSE PUBLISHERS
www.BlueRoseONE.com
info@bluerosepublishers.com
+91 8882 898 898
+4407342408967

ISBN: 978-81-6744-233-8

First Edition: November 2026

BIOLOGY

Completely Updated as per NCERT Biology Syllabus (Session 2026–27)

PUCII /KCET and NEET

12th

I.Mallikarjun

- Structured as per rationalisedl contents
- Strict NCERT Alignment
- Diversified MCQs, Fill in the Blanks
- Short and Long Answer type Questions with Answers are upgraded as per HOTS
- Exam-Centric Preparation Strategy

SYLLABUS

FOR 2026-27 BOARD EXAMINATIONS

Authored by: I. MALLIKARJUN

Features of this Edition:

- **NCERT Integration:** Strictly based on the rationalized 13-chapter NCERT syllabus.
- **Competency-Focused:** Extensive collection of Case-based, MCQ, and Assertion-Reason questions.
- **Rapid Recap:** Crucial points to remember at the end of every chapter.
- **Exam Ready:** Previous Year Questions (PYQs) and Sample Paper analysis.

UPDATED SYLLABUS & MARKS WEIGHTAGE

Time : 3 hours **Max. Marks : 70**

Unit	Title	Marks
VI	Reproduction	**27**
VII	Genetics and Evolution	**33**
VIII	Biology and Human Welfare	18
IX	Biotechnology and its Applications	13
X	Ecology and Environment	14
	Total	105

UNIT VI: REPRODUCTION

Chapter 1: Sexual Reproduction in Flowering Plants – Flower structure, development of gametophytes, pollination, double fertilisation, and seed development.

Chapter 2: Human Reproduction – Male & female systems, gametogenesis, menstrual cycle, fertilisation, and pregnancy.

Chapter 3: Reproductive Health – Birth control, prevention of STDs, MTP, and Assisted Reproductive Technologies (IVF, ZIFT, GIFT).

UNIT VII: GENETICS AND EVOLUTION

Chapter 4: Principles of Inheritance and Variation – Mendelian inheritance, sex determination, and genetic disorders.

Chapter 5: Molecular Basis of Inheritance – Structure of DNA/RNA, replication, transcription, translation, and DNA fingerprinting.

Chapter 6: Evolution – Origin of life, Darwinism, natural selection, and human evolution.

UNIT VIII: BIOLOGY AND HUMAN WELFARE

Chapter 7: Human Health and Diseases – Pathogens, immunity, vaccines, Cancer, and HIV/AIDS.

Chapter 8: Microbes in Human Welfare – Microbes in food, industrial production, sewage treatment, and bio-fertilizers.

UNIT IX: BIOTECHNOLOGY

Chapter 9: Biotechnology: Principles and Processes – Genetic Engineering (Recombinant DNA technology).

Chapter 10: Biotechnology and its Applications – Applications in health and agriculture, human insulin, and gene therapy.

UNIT X: ECOLOGY AND ENVIRONMENT

Chapter 11: Organisms and Populations – Population interactions, growth, and age distribution.

Chapter 12: Ecosystem – Productivity, decomposition, and energy flow.

Chapter 13: Biodiversity and its Conservation – Importance, loss, and conservation strategies (Hotspots, National Parks).

EXAMINATION BLUEPRINT

Section	Type of Questions	No. of Que.	Marks
Section A	MCQs & Fill in the blanks	20	20
Section B	Very Short Answer (VSA)	5	10
Section C	Short Answer (SA)	5	15
Section D	Long Answer (LA)	4	20
Section E	HOTS Questions	1	5
	Total	**35**	**70**

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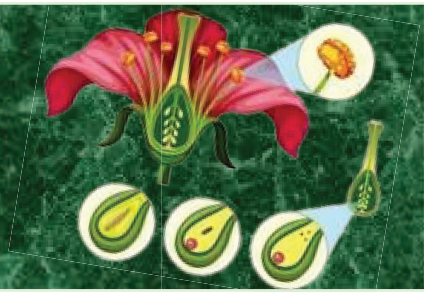
Chapter 1

Sexual Reproduction in Flowering Plants



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1.5. APOMIXIS AND POLYEMBRYONY

Theory

INTRODUCTION:

- **Sexual Reproduction:** It involves the formation of male and female gametes, either in the same individual or in different individuals, followed by fusion of the male and female gametes.

1.1. Flower - A Fascinating Organ Of Angiosperms

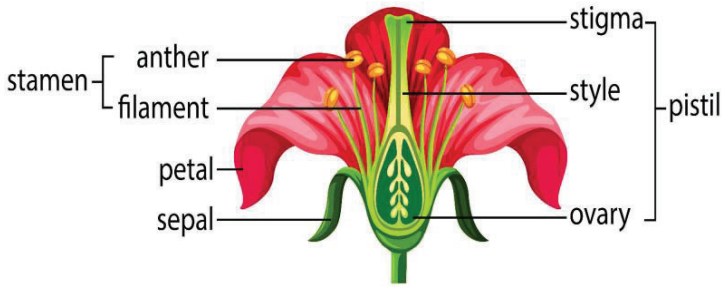
- A flower is a modified shoot with highly condensed nodes and internodes, specialised for reproduction.
- Biologists consider flowers morphological and embryological marvels and the sites of sexual **reproduction.**
- Flowers are objects of aesthetic, ornamental, social, religious and cultural value.
- Floral biology deals with the study of flowers.
- **Floriculture** - Science of cultivation, breeding and marketing of flowers.

Parts of Flower :-

- Flower has a stalk called **pedicel.**
- Free end of pedicel is flattened or dome shaped which is called **thalamus.**
- Thalamus is a type of modified stem, on which nodes & internodes are present.
- All four floral whorls arise from the nodes of thalamus.
- A typical flower consists of four important whorls, namely **calyx**, **corolla**, **androecium** and **gynoecium**.

1. **Calyx** :-
   - It is the first whorl of the flower.
   - It is composed of a group of sepals. They may be free or fused.
   - It protects the flower during the bud stage.

2. **Corolla** :-
   - ➢ It is the second whorl of the flower
   - ➢ It is composed of a group of petals. They may be free or fused.
   - ➢ It helps attract insects and other pollinators.
3. **Androecium**:-
   - ➢ It is the third whorl of the flower
   - ➢ It is composed of stamens, the male reproductive organs. They may be free or fused.
4. **Gynoecium:-**
   - ➢ It is the fourth whorl of the flower
   - ➢ It is composed of carpels, the female reproductive organs. They may be free or fused.



Sexual reproduction involves the following events:

1. **Pre-fertilization events:** i.e., development of pollen grains, development of ovules and pollination.
2. **Fertilization:** Fusion of male and female gametes.
3. **Post-fertilization events:** i.e., development of embryo and endosperm and formation of fruit and seed.

1.2. Pre- Fertilisation: Structures And Events

- ❖ Several hormonal and structural changes are initiated which lead to the development of **flowers.**
- ❖ Flowers contain the male reproductive whorl, androecium, and the female reproductive whorl, gynoecium. These are the main structures involved in pre-fertilisation events.

Stamen, Microsporangium, Microsporogenesis, Pollen grains

- ❖ Male reproductive organ is called **androecium**, consists of a whorl of **stamens.**

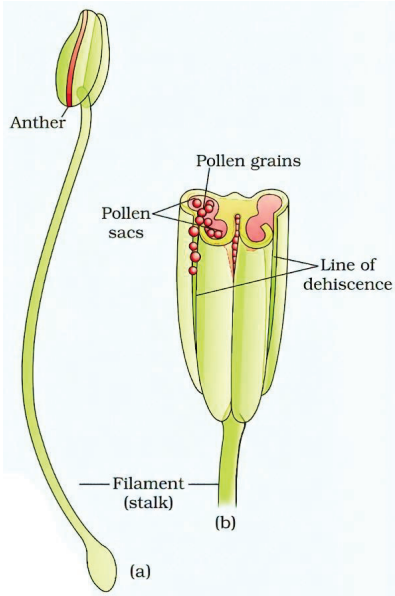
Stamen (microsporophyll) :-

- ❖ A typical stamen is differentiated into two parts –

a. 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.
connective.

b. Anther :- A typical anther is bilobed and dithecous, with two thecae in each lobe. A longitudinal groove runs lengthwise, separating the thecae.

- ❖ The proximal end of filament is attached to the **thalamus** or the **petal**.
- ❖ The two anther lobes are connected by a tissue called the connective.



2 (a) A typical stamen; (b) three–dimensional cut section of an anther

- A typical angiosperm anther is bilobed with each lobe having two theca i.e. they are **dithecous**. Often a **longitudinal groove** runs lengthwise separating the theca.
- The anther consists of four microsporangia, two in each lobe.
- The microsporangia develop into pollen sacs that extend longitudinally through the length of the anther and are packed with pollen grains.
- A typical anther has four microsporangia i.e. **tetrasporangiate**.

Structure of microsporangium :-

- In transverse section, a typical microsporangium appears nearly circular in outline.
- Microsporangium is generally surrounded by four different wall layers namely the **epidermis, endothecium, middle layers** and **tapetum.**

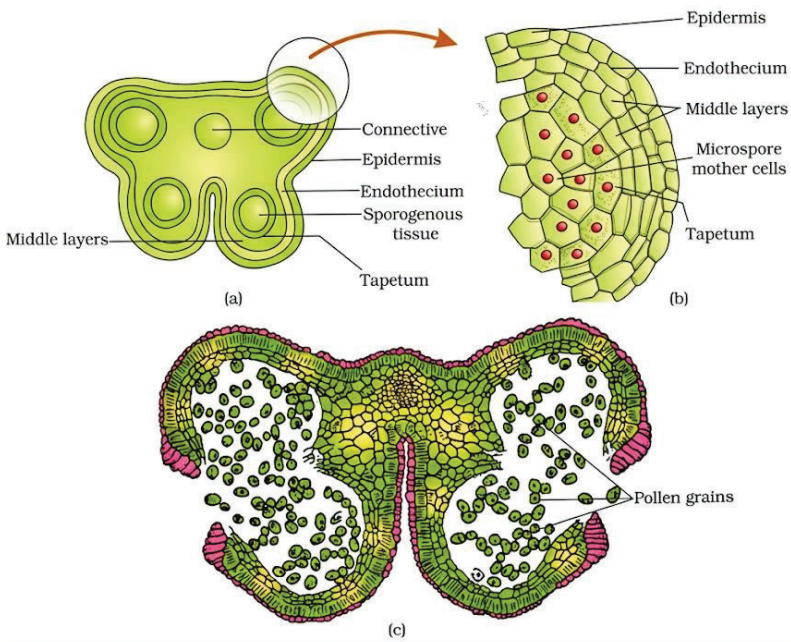


Figure 1.3 (a) Transverse section of a young anther; (b) Enlarged view of one microsporangium showing wall layers; (c) A mature dehisced anther

a) **Epidermis:** - It is the outermost layer of the anther and consists of a single layer of cells. It forms the outermost protective layer.

b) Endothecium: - It is a single cell layer below the epidermis and helps in **dehiscence of anther.**

c) **Middle layer:-** The middle layers consist of 1-3 layers of cells and mainly provide protection.

Note:The outer three wall layers perform the function of protection and help in dehiscence of anther.

d) **Tapetum: -** It is the innermost wall layer; its cells have dense cytoplasm and often more than one nucleus. It provides nourishment to the developing microspores.

❖ When the anther is young a group of compactly arranged homogenous cells called the **sporogenous tissue** occupies the centre of each microsporangium.

Pollen sacs:

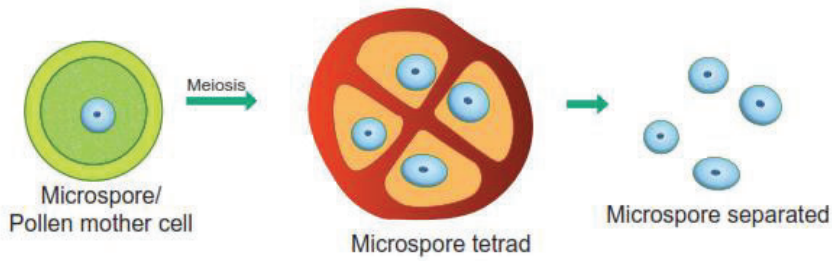
❖ Four pollen sacs are present in the anther. Inside the pollen sacs, microspores (pollen grains) are formed by the meiotic division of microspore mother cells (pollen mother cells).

❖ Each cell of the sporogenous tissue is capable of giving rise to a microspore tetrad and is a

❖ potential pollen mother cell (PMC).

Microsporogenesis:-

❖ The process of formation of microspore from pollen mother cell (PMC) through meiosis is called **Microsporogenesis.**



(a)

❖ The sporogenous tissue of a microsporangium differentiates into pollen mother cells (PMCs), also called microspore mother cells.

❖ Each microspore mother cell undergoes meiosis to form four haploid microspores.

❖ The four microspores are initially arranged as a microspore tetrad.

❖ As the anther matures and dehydrates, the microspores dissociate and develop into pollen grains.

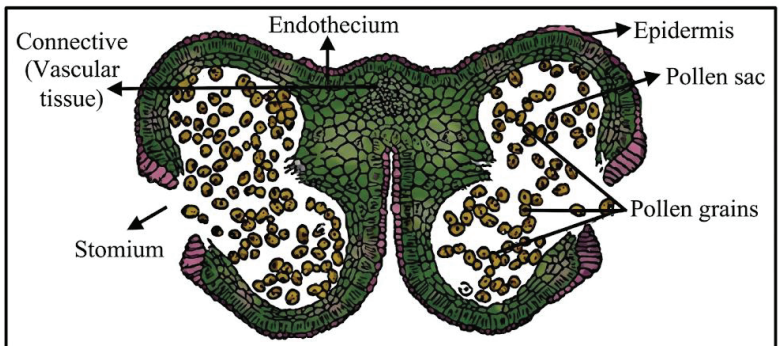


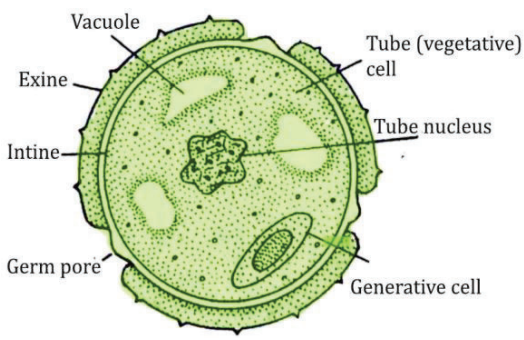
Fig. : A Mature Dehisced Anther

Anther dehiscence is facilitated by dehydration of the mature anther wall, particularly the endothecium.

Structure of Pollen Grain :

- Pollen grains are generally spherical, measuring about **25-50 micrometers** in diameter.
- It has a prominent two-layered wall. The outer wall layer is thick, rigid and ornamented, called **exine.** This layer is formed mainly by **sporopollenin.**
- Sporopollenin is one of the most resistant organic materials withstand high temperatures, strong acids and alkali. No enzyme that degrades sporopollenin is known. known.
- Because sporopollenin is highly resistant, pollen grains may be well preserved as fossils.

- The inner wall of pollen grain is thin, continuous, soft and elastic in nature. It is called **intine**. It is made up of pectin and **cellulose** or **pecto- cellulose.**
- At certain places, sporopollenin is absent from the exine; these apertures are called germ pores. During pollen germination, the intine protrudes through a germ pore and forms the pollen tube.
- The cytoplasm of pollen grain is surrounded by a **plasma membrane.**
- At the 2-celled stage, a pollen grain contains a vegetative cell and a generative cell.
- The **vegetative cell** is bigger, has abundant food reserve and a large irregularly shaped nucleus.
- The generative cell is small, spindle-shaped and floats in the cytoplasm of the vegetative cell. It has dense cytoplasm and a nucleus.



- In over 60% of angiosperms, pollen grains are shed at the 2-celled stage. In the remaining species, the generative cell divides mitotically to form two male gametes before the pollen grains are shed (**3-celled stage**).

Pollen allergy -

1. Air-borne pollen grains of many species can cause allergies and bronchial problems, sometimes leading to chronic respiratory disorders such as asthma and bronchitis.
2. Parthenium, introduced into India as a contaminant with imported wheat, has become widespread and can cause pollen allergy.

Pollen Product - Pollen Tablets and **Syrups**

- Pollen grains are rich in nutrients.
- It has become a fashion in recent years to use pollen tablets as food supplements.
- In western countries, a large number of pollen products in the form of tablets and syrups are available in the market.
- Pollen consumption has been claimed to increase the performance of athletes and race horses.

Viability of pollen grains:

- In some cereals such as rice and wheat, pollen grains lose viability within 30 minutes of their release, and in some members of Rosaceae, Leguminoseae and Solanaceae, they maintain viability for months.
- The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.

Pollen Banks:

- It is possible to store pollen grains of a large number of species **for years** in liquid nitrogen ($-196^{\circ}C$). Such stored pollen can be used as **pollen banks**, similar to **seed banks**, in crop breeding programmes.

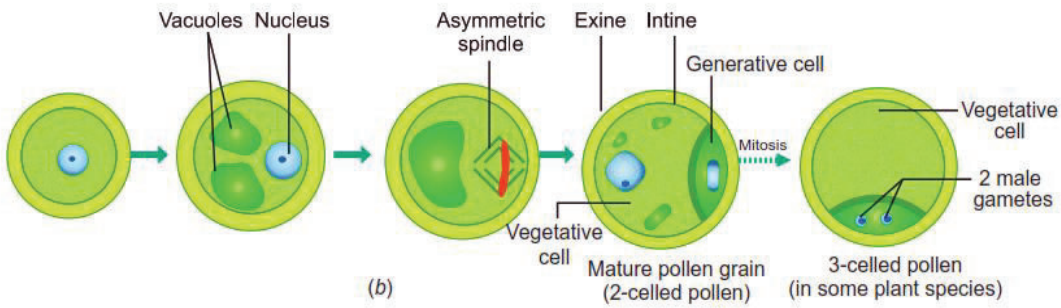
Micro-Gametogenesis Or Development Of Male Gametophyte

- In flowering plants, microspore or pollen grain is considered as first cell of male gametophyte.

(i) Pre-pollination development:

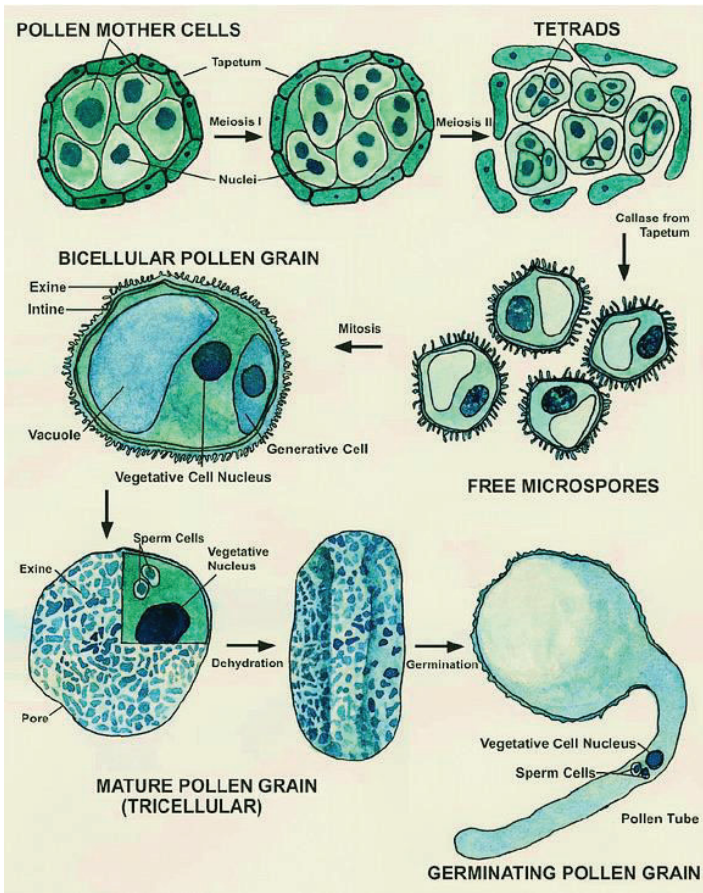
- Pollen grain or microspore is the first cell of male gametophyte and represents immature male gametophyte.
- Development of male gametophyte is precocious, that is, it begins inside the **microsporangium** or **pollen sac.**

- When first formed the microspore or young pollen grain has a centrally placed nucleus embedded in dense cytoplasm covered by plasma membrane.
- It grows in size with the inflow of nutrients. Vacuoles develop and bring about rapid growth of pollen grain.
- The vacuoles push the pollen grain nucleus to one side near the wall.
- The protoplast then divides mitotically to form two unequal cells- small **generative cell** and large **tube** or **vegetative cell.**
- A layer of callose develops around the generative cell which separates the cell from the pollen grain wall. Later on, callose dissolves and the naked generative cell comes to float freely in the cytoplasm of the tube cell.
- A 2-celled pollen grain consists of a vegetative cell and a generative cell.
- **Vegetative cell**:- Bigger, has food reserve and irregularly shaped nucleus.
- **Generative cell:-** Small, floats in cytoplasm of vegetative cell, spindle shaped, dense cytoplasm and nucleus.



(ii) Post-pollination development :

- Further development of pollen grain takes place on the stigma of carpel after pollination.
- Pollen grains absorb water and nutrients from the stigma. Their cytoplasm increases in volume, and the intine protrudes through a germ pore to form a pollen tube.
- The vegetative (tube) nucleus enters the pollen tube first. It is followed by the generative cell, which enters the pollen tube.
- Inside the pollen tube, the generative cell divides mitotically to form two non-motile male gametes. The mature male gametophyte therefore consists of one vegetative (tube) cell and two male gametes. This 3-celled stage



represents the mature male gametophyte of angiosperms.

- ❖ Male gametophyte of angiosperms is highly reduced and completely depends on sporophyte. The pollen grain represents the **male gametophyte.**
- ❖ For the formation of mature pollen grain from microspore mother cell or pollen mother cell, one meiotic and one mitotic division are required. For the formation of mature male gametophyte, one meiotic and two mitotic divisions are required.

Female Reproductive Whorl-Gynoecium

- ❖ The gynoecium is the female reproductive whorl of a flower. Its basic unit is the carpel.
- ❖ The Gynoecium may be

1. **Monocarpellary :-** Gynoecium may consist of a single pistil (**monocarpellary**).
2. **Multicarpellary:-** Gynoecium with more than one pistil (**multicarpellary**).
3. **Apocarpous :-** Gynoecium with free carpels or free pistils. **E.g**., Rose, lotus, Michelia.
4. **Syncarpous** :- Gynoecium with fused carpels or fused pistils.E.g.,Papaver, Hibiscus

1. **Carpel** (megasporophyll) :-

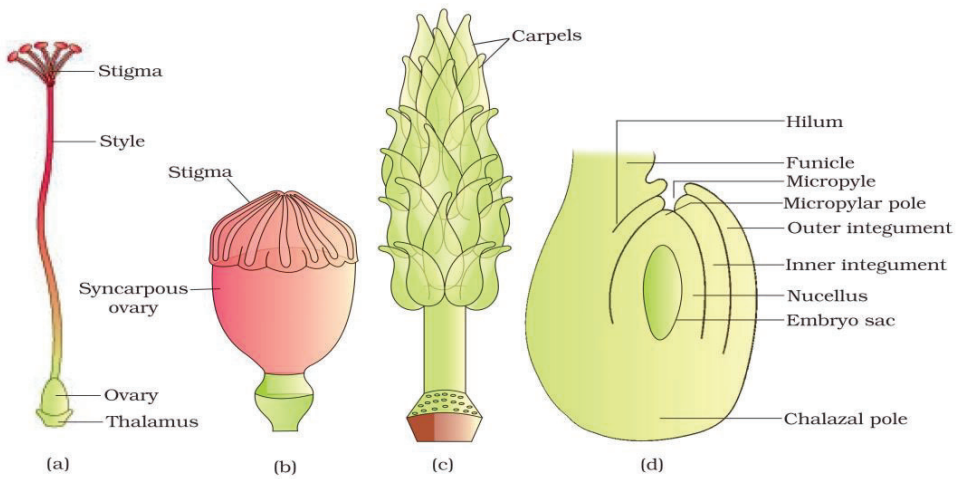


Figure 1.7 (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*; (d) A diagrammatic view of a typical anatropous ovule

- ❖ A carpel has three main parts:

[1] Stigma [2] Style [3] Ovary

1. **Stigma :-** It is the terminal receptive region of the carpel and serves as a landing platform for pollen grains.
2. **Style:-** It is the elongated, narrow region between the stigma and the ovary.
3. **Ovary :-** It is the basal swollen part of the carpel and contains the ovarian cavity (locule).

- ❖ The carpel or pistil has three parts namely;
- ❖ The ovules are also known as integumented Megasporangia which are borne on a cushion-like tissue called **placenta** in the ovarian cavity.

- The placenta is located inside the ovarian cavity
- Arising from the placenta are the megasporangia, commonly called **ovules.**
- The number of ovules in an ovary may be one (e.g., wheat, paddy, mango) or more than one
- (e.g., papaya, watermelon, orchids).

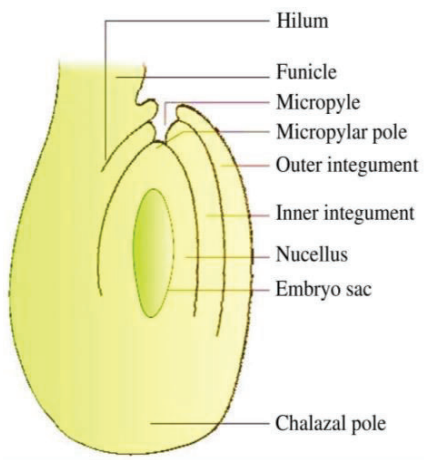
Structure Of Ovule Or Megasporangium

- An ovule is an integumented megasporangium borne on the placenta inside the ovary.

- **It consists of following parts :**

1. **Funicle:-** The ovule is a small structure attached to the placenta by means of a thin stalk called **funicle.**
2. **Hilum:-** The body of the ovule fuses with funicle in the region called **hilum**. Thus, hilum represents the junction between ovule and funicle.
3. **Raphe:-** It is an extended part of funicle at one side of the Ovule up to the chalaza.
4. **Integuments:-** Each ovule has one or two protective envelopes called **Integuments.**
5. **Micropyle:-** Integuments encircle the ovule except at the tip where a small opening called the micropyle is organised.
6. **Chalaza :-** Opposite the micropylar end, is the chalaza , representing the basal part of the Ovule.
7. **Nucellus:-** The main body of the ovule contains a mass of parenchymatous cells with abundant reserve food material, called the nucellus.
8. **Embryo sac :-** Located in the nucellus is the embryo sac or female a single embryo sac that develops from a functional megaspore through mitotic divisions.

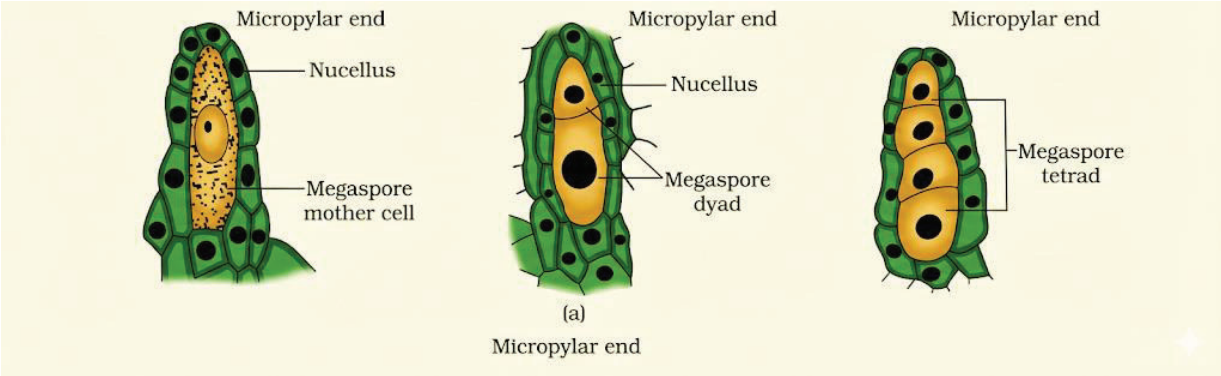
An ovule generally contains



Megasporogenesis

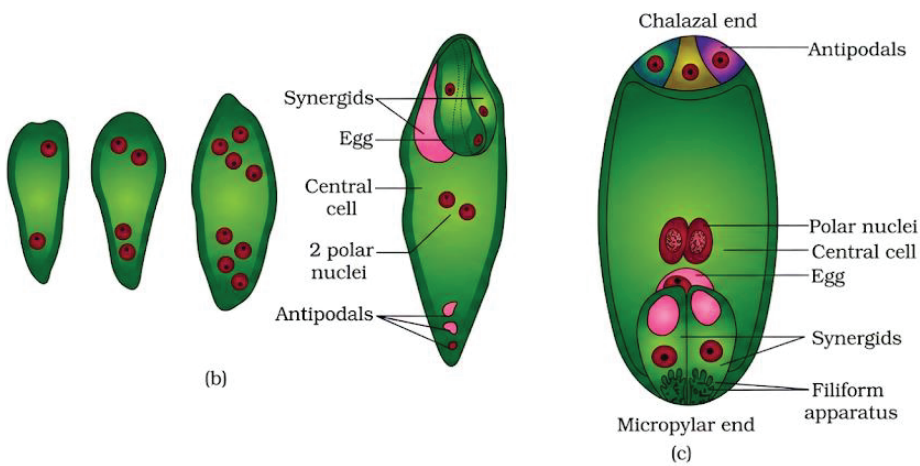
- The process of formation of **haploid megaspores** from **megaspore mother cell (MMC)** is called **megasporogenesis.**
- The Ovule has a central mass of diploid tissue called **nucellus.**
- A nucellar cell towards the micropylar end differentiates into the megaspore mother cell (MMC).

- The megaspore mother cell (MMC) is a large diploid cell with dense cytoplasm and a prominent nucleus.
- The megaspore mother cell (MMC) undergoes meiosis to form four haploid megaspores.
- The four haploid megaspores are generally arranged in linear tetrad.
- Ploidy of the cells: Nucellus (2n), MMC (2n), Functional megaspore (n), Female gametophyte (n).



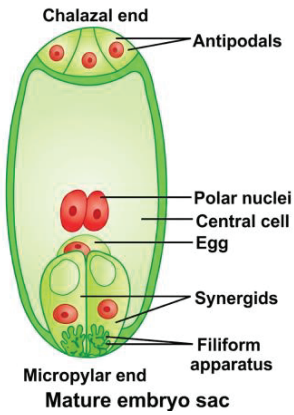
Development of embryo sac or female gametophyte

- The chalazal megaspore is functional and the other three megaspores degenerate.
- The functional megaspore develops into the female gametophyte or embryo sac.
- Development of the embryo sac from a single functional megaspore is called monosporic development.
- The nucleus of the functional megaspore divides mitotically; the two nuclei migrate to opposite poles, forming the 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the **4-nucleate** and later the **8 - nucleate** stages of the embryo sac.
- It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation.
- At the 8-nucleate stage, one nucleus from each pole migrates to the centre; these are the two polar nuclei. Three nuclei remain at the micropylar end and three at the chalazal end. Cellular organisation then produces the egg apparatus at the micropylar end and three antipodal cells at the chalazal end.
- Thus, the mature embryo sac is 7-celled and 8-nucleate.



Structure of female gametophyte :-

- After the **8-nucleate stage**, cell walls are laid down leading to the organization of the typical **female gametophyte** or **embryo sac.**
- Six of the eight nuclei become surrounded by cell walls and are organised into six cells.
- Three cells are formed towards the micropyle end in which one cell is large and more distinct out of three cells. This is called **egg cell** and remaining two smaller cells are known as **synergids.**
- These three cells are collectively known as **egg-apparatus. [1 Egg cell + 2 Synergids].**
- The three cells at the chalazal end are called antipodals or antipodal cells.
- Both the **polar nuclei** are present in the **large central cell.** Polar nuclei are present below the egg apparatus in central cell.
- Just before the process of fertilization they unite or fuse together in the centre to form **secondary nucleus** or **definitive nucleus**. It is diploid in nature [2 n] and one in number.
- After 3 mitoses in megaspore, seven celled and eight nucleated structure is formed.
- This **eight nucleated and seven celled** structure is called **female gametophyte or embryo-sac of angiosperms.**
- The synergids have fingers like structures (special cellular thickenings) at the micropylar tip called **filiform apparatus.**
- The filiform apparatus plays an important role in guiding the pollen tube into a synergid.

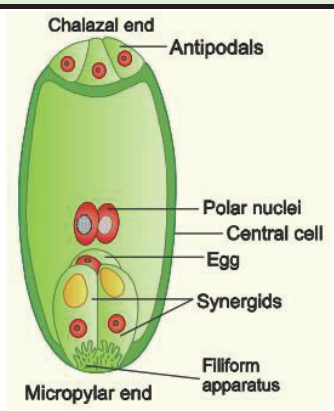
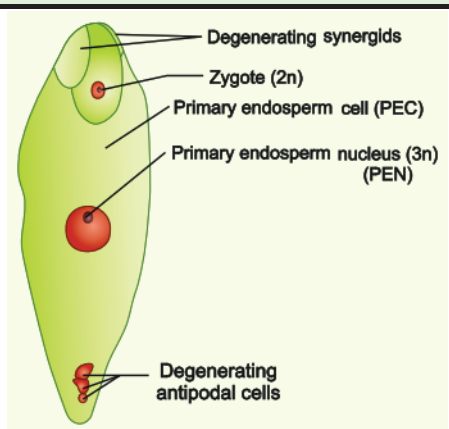


Mature embryo sac

Differences between Microsporogenesis and Megasporogenesis

Microsporogenesis	Megasporogenesis
1. The Process of formation of microspores	1. The Process of formation of megaspores
2. It occurs in the microsporangia.	2. It occurs in the ovule.
3. Sporogenous cells differentiate into pollen mother cells (PMCs).	Usually one nucellar cell differentiates into the megaspore mother cell (MMC).
4. Each microspore mother cell gives rise to four functional haploid microspore.	4. Each megaspore mother cell gives rise to one functional haploid megaspore

Differences between unfertilized embryo sac and fertilized embryo sac

Unfertilised Embryo Sac	Fertilised Embryo Sac
	
1. All the cells are haploid	1. Zygote is diploid, PEN is triploid and other cells are haploid
2. Antipodals and synergids are distinctly present	2. Degenerating of Antipodals and synergids
3. The haploid polar nuclei may fuse to form a diploid secondary nucleus	3. Diploid secondary nucleus fertilizes with a haploid male gamete to form a triploid PEN
4. Egg cell is haploid	4. Egg cell fertilizes with the male gamete to form a diploid zygote.

Pollination

- Pollination is the transfer of pollen grains from the anther to the stigma of a flower of the same plant or another plant of the same species.
- In flowering plant both types of gametes (male gamete and female gamete) are non-motile and brought together for fertilization by pollination.

Kinds Of Pollination

Depending on the source of pollen, pollination is of three types: 1. Autogamy, 2. Geitonogamy and 3. Xenogamy.

1. AUTOGAMY OR SELF POLLINATION:

- If pollen grains are transferred from the anther to the stigma of the same flower, it is called autogamy or self-pollination. E.g., pea, wheat and rice.
- In a normal flower which opens and exposes the anthers and stigma, complete autogamy is rather rare. In these flowers

a. Shedding of pollens and receptivity of stigma should occur simultaneously.

b. Anther and stigma should lie close to each other. Continued self-pollination may result in inbreeding depression.

2. **GEITONOGAMY:**

- Transfer of pollen grains from anther of one flower to the stigma of another flower on the same plant is called **Geitonogamy.**
- From the **genetical point** of view geitonogamy is similar to self-pollination (Autogamy) because pollen grains come from the same plant.
- But **functionally or ecologically,** it is considered as cross pollination involving a pollinating agent.

3. **XENOGAMY OR CROSS POLLINATION OR ALLOGAMY:**

- Transfer of pollen grains from the anther to the stigma of a flower on a different plant of the same species is called xenogamy.
- It is commonly called as **cross-pollination** (Allogamy).
- Genetically, as well as ecologically, it is cross pollination. This is the only type of pollination in which genetically different types of pollen reach to the stigma.

Differences between Geitonogamy and Xenogamy

Geitonogamy	Xenogamy
The process of transfer of pollen grains from the anther to Stigma of another flower of the same plant.	The process of transfer of pollen grains from anther to stigma of a different plant
This pollination brings genetically similar pollen grains to stigma	This pollination brings genetically different type of pollen grains to the stigma
Eg. Cucurbita, Castor etc.	Eg. Papaya, Maize etc.

Adaptations for Self-Pollination :

1. **Monocliny (Bisexuality):**- It means flowers are bisexual (hermaphrodite). eg. Pea
2. **Homogamy**:- When both the sex organs of a flower mature at the same time (synchrony in pollen release and stigma receptivity). It is called **homogamy**. It increases chances for self-pollination. E.g. Pea
3. **Cleistogamy :-**

- In some plants bisexual flowers are formed which never open throughout the life. Such flowers are called **Cleistogamous flowers**, such as **Commelina, Viola** (Common pansy), **Oxalis.**
- All the above plants have two types of flowers. One type of flowers are **Cleistogamous** and another are **chasmogamous flowers.**
- In Cleistogamous flowers the anthers and stigma lie close to each other.
- When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect Pollination.
- Thus, Cleistogamous flowers are invariably autogamous as there is no chance of cross pollen landing on the stigma.
- Cleistogamous flowers produce assured seed set even in the absence of pollinators.

4. **Chasmogamy**

- Flowers that open and expose the anthers and stigma for pollination are chasmogamous.
- In some chasmogamous flowers, anthers and stigma may be positioned close enough for self-pollination. Examples include Oxalis and Viola.

Differences between Cleistogamous flower and Chasmogamous flower:

Cleistogamous flower	Chasmogamous flower
These flowers are bisexual and never open.	These flowers are bisexual and open just before pollination.
These flowers undergo self pollination	These flowers can undergo self or cross pollination
These flowers are inconspicuous	These flowers are prominent (conspicuous)
These flowers do not require pollinators.	These flowers may require pollinating agents.

Adaptations For Cross Pollination (Outbreeding Devices)

❖ The **methods** or **devices** that discourage self-pollination and encourage cross-pollination are called **out breeding devices.**

1. **Dicliny (Unisexuality) :-** A device to prevent self-pollination is the production of unisexual flowers. Unisexuality prevents autogamy. In monoecious plants geitonogamy is still possible, whereas in dioecious plants both autogamy and geitonogamy are prevented. E.g., papaya (dioecious).
2. **Dichogamy :-** In many bisexual flowers of the plants, stamens and carpels of a flower do not mature at the same time, so pollen release and stigma receptivity are not synchronised. Either pollen is released before the stigma is receptive (protandry) or the stigma becomes receptive before pollen release (protogyny).

   Dichogamy is of two types :-

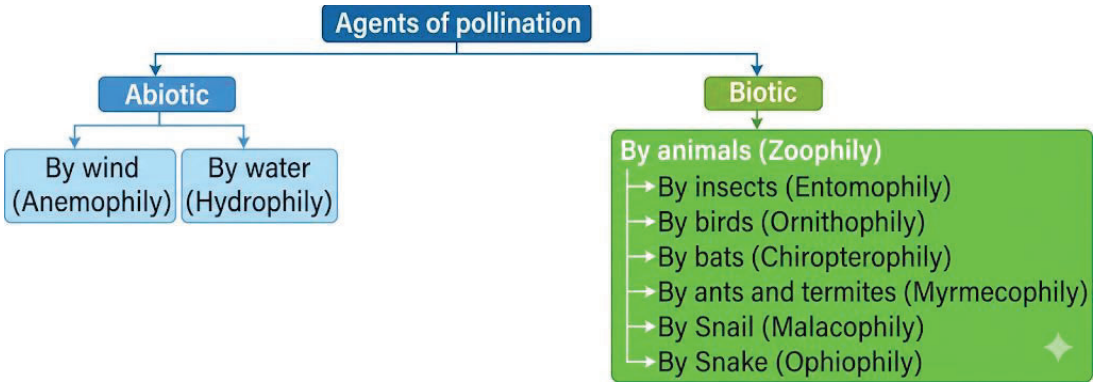
   a. **Protandry :-** When the anthers of a flower mature earlier than carpels, then it is called **Protandry**. In protandry, the anthers mature before the stigma becomes receptive.

   b. **Protogyny :-** In protogyny, the stigma becomes receptive before the anthers mature.
3. **Chasmogamy or Anthesis :-** Opening [blooming] of the floral bud in the form of a flower is called anthesis. Chasmogamous flowers have exposed anthers and stigma.
4. **Heterostyly :-** In heterostyly, stamens and styles occur at different heights, reducing the chance of self-pollination. E.g., Primula.
5. **Herkogamy :-**Presence of a physical barrier between Anther and Stigma to avoid self-pollination. **E.g.,** Calotropis
6. **Self sterility or self-incompatibility :-** Failure in the germination of pollen grains on stigma of same flowers called **self-sterility or self-incompatibility .**This is a genetic mechanism and prevents self-pollen (from the same flower or other flower of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil. **e.g.** Tobacco

AGENTS OF POLLINATION:- Plants use two types of agents for pollination are namely ;

❖ **Abiotic** :- wind and water (used by only few plants).

❖ **biotic** :- animals agents (used by majority of the plants) to achieve pollination.



ABIOTIC AGENTS:

- Only a small proportion of plants use abiotic agents.
- Pollen grains coming in contact with stigma is a chance factor in both **wind** and **water pollination.**
- To compensate for these uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen grains when compared to the number of ovules available for pollination.
- Both **wind** and **water** pollinated flowers are not very colourful and do not produce nectar.

(A) ANEMOPHILY(Pollination by Wind) :-

- Transfer of pollen grains from one flower to another by wind is called anemophily.
- Flowers pollinated by wind are called anemophilous flowers.

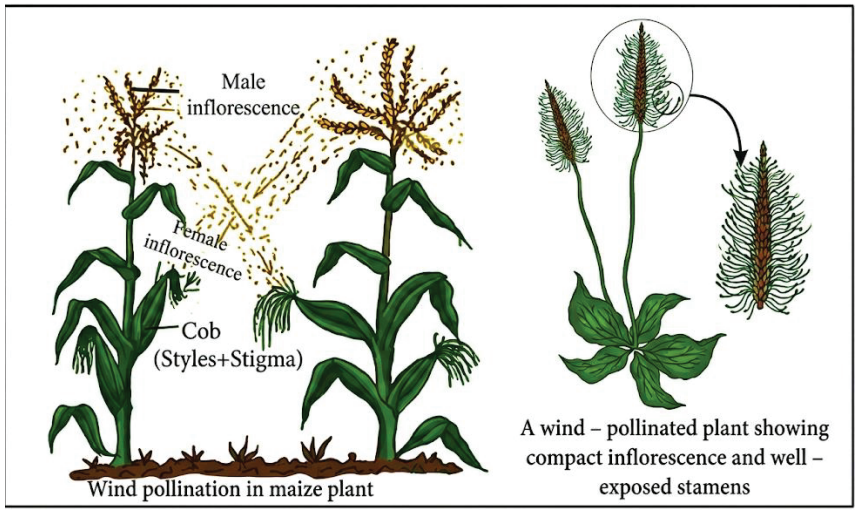
Characters of Anemophilous flower

- They produce a large number of pollen grains.
- They Possess(have) **well exposed stamens** so, that the pollens are easily dispersed into wind currents
- Neither attractive nor with **fragrance**.
- Flowers are small , inconspicuous, colourless and nectarless.
- Flowers may be unisexual in many wind-pollinated species.

Characters of pollens :- The pollen grains are small, light and dry (non-sticky), so they can be easily carried by wind.

Characters of stigma:-

- Stigmas are often large and feathery, helping them trap airborne pollen grains.
- Maximum loss of pollen grains takes place in this type of pollination.
- It is completely non directional process.
- Wind pollinated flowers often have a **single ovule** in each ovary and numerous flowers are packed into an **inflorescence. E.g.,** Maize ,Rice ,Grasses ect
- In maize, the long silks are the styles and stigmas that wave in the wind and trap pollen grains; the tassel is the male inflorescence.
- Pollination by wind is more common amongst abiotic pollinations.
- Wind pollination is quite common in grasses.



Wind pollination in maize plant

A wind – pollinated plant showing compact inflorescence and well – exposed stamens

(B) HYDROPHILY(Pollination by Water) :-

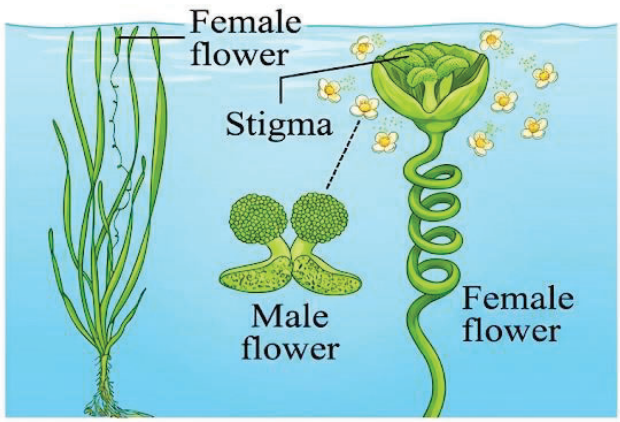
- Pollination brought about by water is called hydrophily.
- Flowers pollinated by water are called hydrophilous. Examples include Vallisneria, Hydrilla (Fresh water) **and Zostera** (Marine water)**.**
- Pollination by water is quite rare in flowering plants and is limited to about **30 genera**, mostly **monocotyledons.**
- Water is a regular mode of transport for the male gametes among the **algae , bryophytes and pteridophytes.**
- The distribution of some bryophytes and pteridophytes, on earth is limited because they need water for the transport of male gametes and fertilization.
- Not all aquatic plants use water for pollination such **water hyacinth** and **water lily** show pollination by insects or Wind because the flowers emerge above the level of water.
- Hydrophily is of two types.

(i) Epihydrophily **(ii) Hypohydrophily**

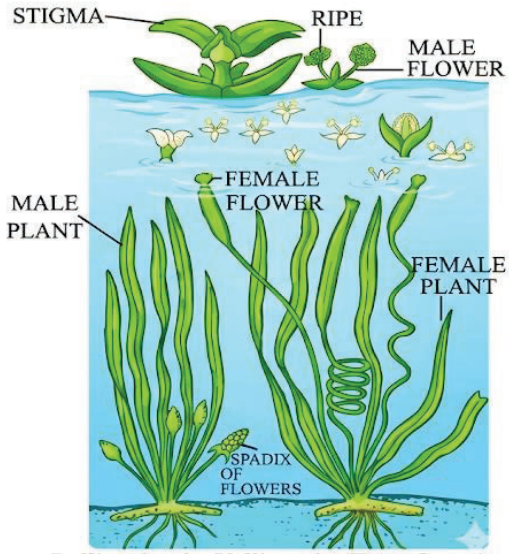
(i) Epihydrophily:- When the pollination takes place on the surface of water then it is called **Epihydrophily.** e.g., Vallisneria.

- Vallisneria is a dioecious plant and flowers are unisexual.
- Pedicel (Stalk) of female flowers are **long** and **coiled**.
- But at maturity due to uncoiling they also reach the water surface.
- Male flowers are released onto the water surface and are carried by water currents towards the female flowers.
- Some eventually reach the stigma and bring about pollination.

- All activities of Vallisneria take place inside the water except pollination.



Pollination by water in *Vallisneria*



Pollination in *Vallisneria* (Tape Grass)

(ii) Hypohydrophily

- When pollination takes place below the water surface, it is called hypohydrophily. E.g., Zostera (sea grass) and Hydrilla.
- In Zostera **female flowers** remain **submerged** in water and the **long ribbon like pollen grain** are **released inside the water** and they are **carried passively inside the water,** some of them reach the stigma and achieve pollination.
- **Vallisneria** and **Hydrilla** are **fresh water plants**, while **Zostera** is a **marine water plant.**
- In most of the water pollinated species, pollen grains are protected from wetting by a **mucilaginous covering.**

(C) ZOOPHILY:

- When the pollination brings about by animals then it is called **zoophily.**
- Majority of flowering plants use a range of animals as pollinating agents. **Bees, butterflies, bettles, wasps, ants, moths, birds** and **bats** are common pollinating agents.
- Among the animals, insects, particularly bees are the dominant biotic pollinating agents.
- Larger animals such as some **primates (Lemurs), arboreal (tree-dwelling) rodents,** or even **reptiles (Gecko lizard and garden lizard)** have also been reported as pollinators in some species.
- Generally in zoophillous plants, **flowers are large**, **attractive** and **nectar glands** are present.
- Often flowers of animal pollinated plants are specifically adapted for a particular species of animals.

ENTOMOPHILY:

- The pollination which takes place with the help of insects is known as **entomophily.**
- Among insects, bees are important and dominant pollinating agents.
- Insect-pollinated flowers often use colour, fragrance and nectar to attract pollinators.

Characters of Entamophillous flower

- Most insect-pollinated flowers are conspicuous, colourful and attractive.
- Many are fragrant and provide nectar as a floral reward.
- The pollen grains of insect pollinated flowers are sticky due to presence of pollen kitt.
- When flowers are small, a number of flowers are clustered into inflorescence to make them conspicuous.
- The flowers pollinated by flies and beetles secrete foul odour to attract these animals.
- **Rewards to pollinators:-** To sustain animals visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are usual floral rewards. In some species floral rewards are in providing safe places to lay eggs . **eg.** Yucca, Amorphophallus
- Nectar, Pollen grains and Safe egg laying places.

A. **Nectar and pollen grains** are the usual floral **rewards** to pollinating insects.

- For harvesting the reward from the flower ,the animal visitor come in contact with the anther and the stigma.
- The body of animal gets a coating of pollen grains, which are generally sticky in animal pollinated flowers.
- When the animal carrying pollen on its body comes in contact with the stigma of same or different flower it brings about pollination.

B. **Flowers also provide safe places to lay eggs :-**

- **Eg-1 :** In tallest flower of Amorphophallus (the flower itself is about 6 feet in height), process of pollination is same as Yucca means it provides space (safe place) for laying eggs.
- **Eg-2 :** Yucca shows a close association with a specialised yucca moth pollinator.
- The moth pollinates the Yucca flower and lays eggs in the ovary; the developing larvae use some of the developing seeds, while the plant receives pollination.
- The association is highly specialised and the moth and Yucca depend on each other for reproduction.

- **Pollen / Nectar robbers :** Many insects may consume pollen or the nectar without bringing about pollination, such floral visitors are referred to as pollen / nectar robbers.

Pollen - Pistil Interaction

- All the events of deposition, germination of pollen on stigma, growth of pollen tube through the style and entry of pollen tubes into the ovule are together called **pollen pistil interaction.**

a. Recognition of compatible pollen

- There is no guarantee for the transfer of right type of pollen grain to the right type of stigma during pollination.
- The pistil has the ability to recognize the **compatible** or **incompatible pollens** due to the interaction of chemicals like **proteins** and **polysaccharides.**
- If it is **right type**, the stigma accepts and hydrates the pollens to germinate.
- If it is **wrong type** the stigma rejects pollen by preventing germination.

b. Germination of pollen grains

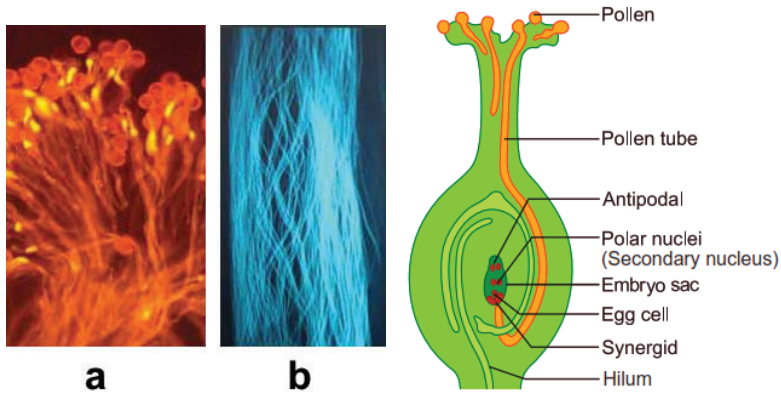


Figure 1.12 (a) Pollen grains germinating on the stigma; (b) Pollen tubes growing through the style; (c) L.S. of pistil showing path of pollen tube growth;

- Compatible pollination is followed by the germination of pollen grain to produce pollen tube through the germ pore.
- The content of the pollen grain move into the pollen tube.
- Pollen tube grows through the tissues of the stigma and style and reaches the ovary.

c. Development of Male Gametes

- In some plants, pollen grains are shed at **two-celled** condition (a vegetative cell and a generative cell). In such plants, 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** condition, pollen tubes carry the two male gametes from the beginning

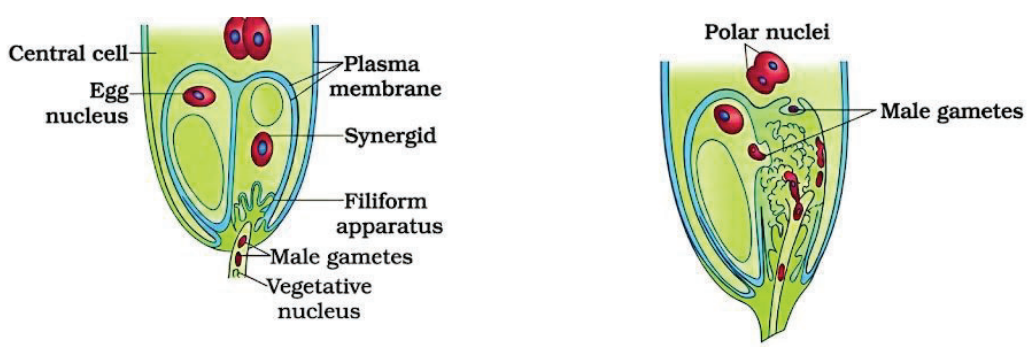
d. Entry of pollen tube into ovule

- **Porogamy:-** It is the most common type in which pollen tube enters in ovule through micropyle.
- **Chalazogamy:-** Pollen tube enters in ovule through chalaza end.
- **Mesogamy:-** Pollen tube enters in the ovule either through integuments or through funicle.

e. Entry of pollen tube into Embryo sac

- Pollen tube can enter into the ovule through any passage but inside embryo sac, it enter only through the egg apparatus at micropylar end.
- After entering the ovule, the pollen tube grows towards the egg apparatus, guided by chemical signals associated with the synergids and the filiform apparatus.

- One of the synergid starts degenerating when the pollen tube comes near egg apparatus. enter into the embryo sac through the degenerating synergids.
- On entering the synergid, the pollen tube releases its contents, including the two male gametes.



(a) enlarged view of an egg apparatus showing entry of pollen tube into a synergid; (b) Discharge

of male gametes into a synergid & the movement of the sperms, one into the egg and the other into the central cell

f. Fusion of Gametes

Before or after the entrance of pollen tube into the embryo sac, both polar nuclei of the central cell fused together to form a **diploid nucleus**. It is known as secondary nucleus.

Artificial Hybridisation

❖ Artificial hybridisation is the controlled crossing of selected parents to combine desirable characters and produce improved varieties.

❖ This is achieved by the following techniques namely:

a. Emasculation:

- Removal of anthers from a **bisexual flower** bud before dehiscence of anther is called **emasculation**. It is done by using a pair of forceps.
- It is to prevent self pollination.
- In unisexual female flower there is no need of emasculation

b. Bagging:

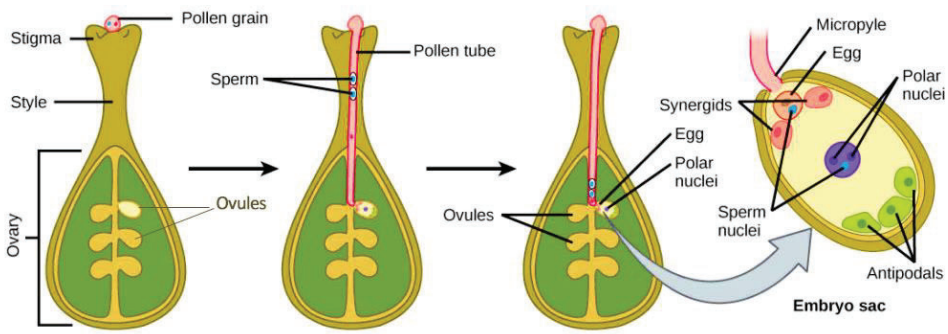
- Covering the emasculated flower with a suitable bag, commonly butter paper, is called bagging.
- It is to prevent contamination of stigma of emasculated flower with unwanted pollen.
- Mature pollen grains collected from anthers of **desired male parent** and dusted on the stigma and the flowers are rebagged and allowed for fruits and seeds to develop.

c. Labeling:

- It involves attaching a label to the emasculated and pollinated flower.
- The label should contain details such as the date of crossing and the male and female parents.

1.3. Fertilisation

❖ Fusion of male & female gametes to form diploid zygote is called **Fertilization.**



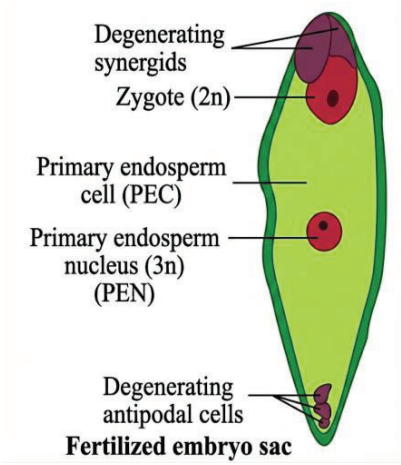
❖ After entering the synergid, the pollen tube releases 2 male gametes into the cytoplasm of the synergid.

❖ The fusion of two male gametes with two different components of the embryo sac like egg and secondary nucleus is called double fertilization or the occurrence of two types of fusions namely syngamy and triple fusion in an embryo sac is termed as double fertilization an event unique to flowering plants.

a. Syngamy - It is the fusion of one of the male gamete with the egg to form a diploid zygote. It is also called **genetic fertilization**. It is the first fertilization.

b. Triple fusion - It is the fusion of **second male gamet**e with the diploid **secondary nucleus** to form a triploid nucleus called **Primary Endosperm Nucleus (PEN)** in the embryo sac is called **triple fusion or vegetative fertilization** .It involves the fusion of three haploid nuclei (1 male gamete and two haploid polar nuclei).The central cell after triple fusion become the **primary endosperm cell (PEC)** and develops

into the **endosperm while the zygote develops into an embryo.** Antipodal cells and remaining synergid degenerate after the fertilization. The developing embryo is nourished mainly by the endosperm.



1.4. Post-Fertilisation : Structures And Events

❖ Following double fertilization, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit, are collectively termed as **post-fertilisation events.**

a. ***Ovary*** *develops into fruit*

b. ***Ovary wall*** *develops into fruit wall or pericarp*

c. Ovules develop into seeds

d. Outer integument develops into the outer seed *coat/testa.*

e. Inner integument develops into the inner seed *coat /tegmen*

f. ***Funiculus*** *develops into stalk of seed*

g. ***Hilum*** *develops into scar of the seed*

h. ***Micropyle*** *develops into seed pore*

i. ***Zygote*** *develops into embryo*

j. ***PEN*** *develops into Endosperm*

k. Nucellus may persist as perisperm in some seeds

l. ***Synergids*** *degenerate*

m. ***Antipodals*** *degenerate*

n. Sepals, petals and stamens usually fall off

o. Style and stigma usually fall off

Development Of Endosperm

❖ Endosperm development precedes embryo development.

❖ The PEC divides repeatedly and forms a triploid endosperm tissue.

❖ Endosperm is a nutritive tissue that develops from the primary endosperm cell after triple fusion.

❖ The cells of this tissue are filled with **reserve food materials** and are used for the **nutrition** of the **developing embryo.**

❖ The endosperm is of three types based on their development:-

Types of endosperm

(a) Nuclear
- Free nuclear divisions
- no wall formation
- Large central vacuole
- wall formation at later stage
- e.g. coconut, wheat, sunflower

(b) Cellular
- Divisions of PEN followed by wall formation
- e.g. *Petunia*, *Adoxa*, Balsam

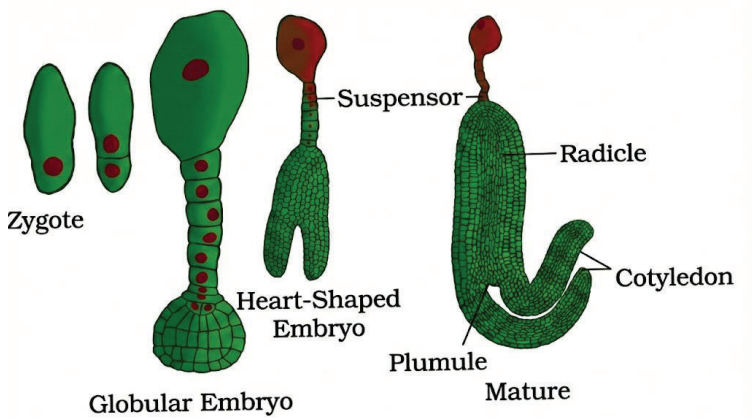
(c) Helobial
- First division of PEN followed by wall formation
- 2 celled unequal, smaller chalazal cell and larger micropylar cell
- Further free nuclear divisions
- e.g. order Helobiales *Asphodelus*

Note :- The drinking portion (coconut water) is nuclear endosperm and edible portion (white kernel) is the cellular endosperm in coconut.

Development Of Embryo In Dicot

- The young sporophytic plant developed from the zygote is called **embryo**.
- **Embryogenesis** is the formation of embryo from zygote.
- Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- Most zygotes divide only after certain amount of **endosperm is formed.** This is an adaptation to provide assured **nutrition** to the developing embryo.
- The zygote divides mitotically and gives rise to the **proembryo or 2 celled embryo.** Further divisions subsequently give rise to the globular, heart-shaped and mature embryo.

Sequence Based Sample Q's **Proembryo → Globular embryo → Heart shaped embryo → Mature embryo**



STRUCTURE OF DICOT EMBRYO

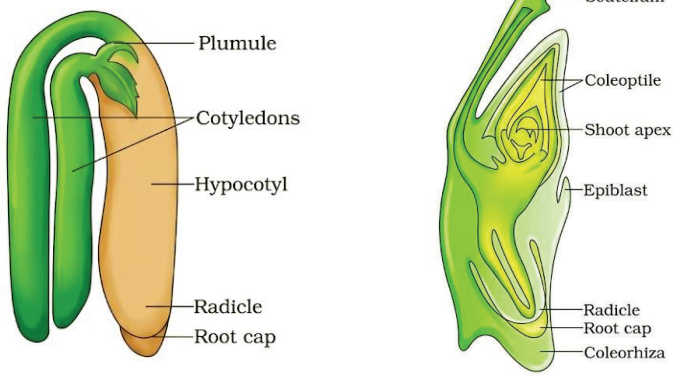
- A typical Dicotyledonous embryo consists of an embryonal axis and two cotyledons.
- The portion of embryonal axis above the level of cotyledons is the epicotyl, which terminates with the **plumule**.
- The portion of the embryonal axis below the cotyledons is the hypocotyl, which terminates in the radicle or root tip.
- The root tip is covered with a **root cap (Calyptra).**

STRUCTURE OF MONOCOT EMBRYO

- Embryos of monocotyledons possess only **one cotyledon.**

- In the grass family, the cotyledon is called **scutellum** that is situated towards one side (lateral) of the embryonal axis.
- At its lower end, the embryonal axis has the radicle and root cap.
- The radicle and root cap are enclosed in an undifferentiated sheath called the coleorrhiza.
- The portion of the embryonal axis above the level of attachment of scutellum is the **epicotyl**.
- **Epicotyl** has a shoot apex and a few leaf primordia enclosed in a hollow foliar sheath called coleoptile.

L.S. of an embryo of grass



Differentiate between Coleoptile and Coleorhizae.

Coleoptile	Coleorhizae
It is a protective sheath that encloses young plumule and its apical meristem in germinating monocot seeds	It is a protective undifferentiated sheath covering the radicle and root cap in monocot seeds.

Angiospermic Seed

STRUCTURE OF SEED

- In angiosperms, the seed is the final product of sexual reproduction.
- Fertilized ovule is known as seed. In other words, seed is a mature fertilized, integumented megasporangium (Ovule).
- All the structures, which are present inside the seed coat are collectively termed as kernel.
- A typical seed has a seed coat and an embryo; endosperm may persist in albuminous seeds.

Types of Seeds

- The angiospermic seeds are classified into two categories on the basis of presence or absence of endosperm in seeds -

1. Non Endospermic seeds or Ex-albuminous seeds or Non albuminous seeds :

- Such type of seeds do not have an endosperm at maturity, therefore they are called **non endospermic or Ex-albuminous seeds.**

- In non-albuminous seeds, the endosperm is consumed during embryo development and food is stored mainly in the cotyledons.
- **Examples:** Capsella and most of dicotyledons. e.g. gram, pea, bean, ground nut. But in castor, seeds are endospermic.

2. Endospermic seeds or Albuminous seeds :

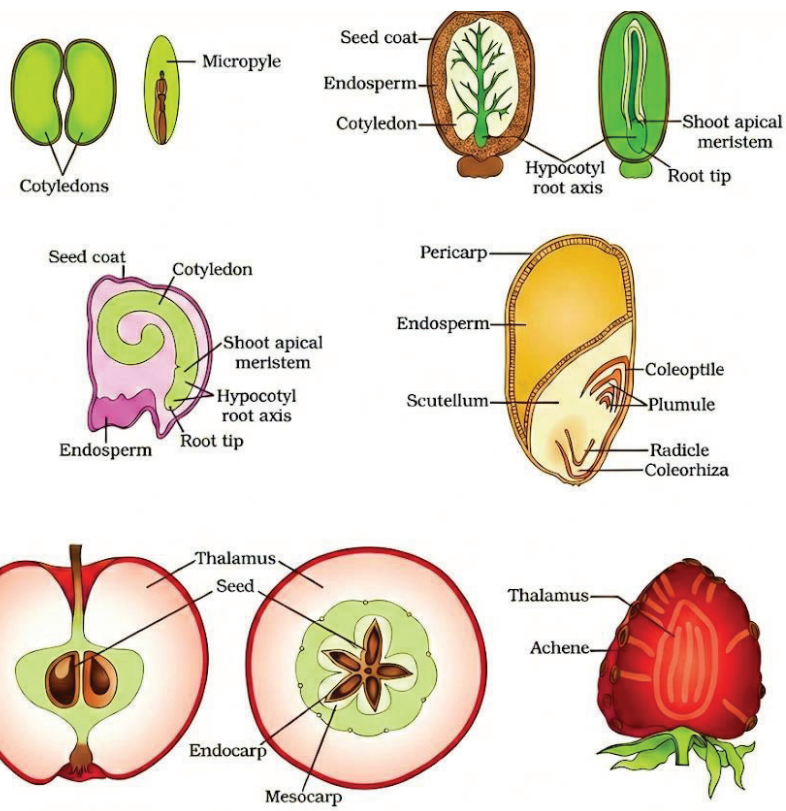
- These seeds retain a part of endosperm as it is not completely used up during embryo development.
- In this type of seeds, food is stored in endosperm.
- In albuminous seeds, the persistent endosperm serves as a food reserve and the cotyledons are often thin or membranous.

Examples : wheat, rice, coconut, barley ,maize and Castor etc. But in orchid seeds are non-endospermic.

- In some seeds, remnants of nucellus are observed. This residual, persistent nucellus present in the seed is called **Perisperm**. **E.g.,** Black pepper.

Differentiate between Albuminous seeds and Exalbuminous seeds with examples

Albuminous seeds (Endospermic seeds)	Exalbuminous seed (Non -endospermic seeds)
1. Endosperm is present in the matured seed 2.Endosperm is not utilized completely during the germination of seed **Examples :** Castor, Maize, Coconut	1. Endosperm is absent in the matured seed 2.Endosperm utilized completely by the developing embryo **Examples :** Pea, Beans, Ground nut.



- ❖ After fertilization **integuments** of ovules harden as tough protective **seed coats.**
- ❖ **The micropyle** remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination.
- ❖ As the seed matures, its water content is reduced and seeds become relatively dry (10-15 per cent moisture by mass).
- ❖ The general **metabolic activity** of the embryo slows down.
- ❖ The **embryo** may enter a state of inactivity called **dormancy**, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.
- ❖ As Ovules mature into seeds, the ovary develops into a fruit i.e., the transformation of ovules into seeds and ovary into fruit proceeds simultaneously.

Note **Viability of seeds:**

- Seed viability is the period for which a seed retains the ability to germinate.
- Some seeds remain viable for hundreds or even thousands of years.
- The old Lupinus arcticus germination claim is disputed and should not be treated as a confirmed record.
- A well-documented example is an about 2,000-year-old date-palm seed (Phoenix dactylifera) recovered near the Dead Sea that germinated successfully.

Advantage Of Seed

Since reproductive processes such as pollination and fertilisation are independent of water, seed formation is more dependable (reliable).

1. **Dispersal:** Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonise in other areas.
2. **Variations:** Being products of sexual reproduction, they generate new genetic combinations leading to variations.
3. **Agriculture:** Seed is the basis of our agriculture.
4. **Perennation:** Seeds are suited to survive unfavourable periods because they have:
   a) A tough protective covering.
   b) A dormant embryo.
   c) Low water content.
   d) Low metabolic activity.
5. **Food :** Seeds are the major source of human diet. They can be stored and used as food throughout the year and also to raise crop in the next season.
6. The hard seed coat provides protection to the young embryo. Dehydration and dormancy of mature seeds are crucial for storage of seeds.
7. Seeds have sufficient food reserves. so, young seedlings are nourished until they are capable of photosynthesis on their own.

Fruits :-

1. A fruit usually develops from the ovary after fertilisation. Fruits may be classified as follows:
2. **True Fruit -** The fruits develop from the ovary.
3. False fruits - In some species, floral parts in addition to the ovary contribute to fruit formation, e.g., apple, strawberry, cashew, etc., the thalamus also contributes to fruit formation. Such fruits are called false fruits.
4. **Parthenocarpic Fruits -** There are a few species in which fruits develop without fertilisation. Such fruits are called **parthenocarpic fruits.** Banana is one such example.

Differentiate between the following:

Hypocotyl	Epicotyl
The cylindrical portion of the embryonic axis below the level of cotyledon is called hypocotyl that terminates in radicle.	The portion of the embryonic axis above the level of cotyledon is called epicotyl that terminates in plumule.
Coleoptile	**Coleorhiza**
In monocot seeds, plumule or shoot apex is covered by a hollow foliar structure called coleoptile	In monocot seeds, the radicle and root cap are covered by a protective sheath called coleorhizae.
Integument	**Testa**
The protective envelop of the ovule is called integument.	The outer protective seed layer is called testa.
Perisperm	**Pericarp**
The remnants of persistent nucellus in a seed is called perisperm.	The wall of ripened ovary or fruit is called pericarp.

1.5. Apomixis And Polyembryony

- The process of formation of seeds without fertilization is called **apomixis or agamospermy.** The term apomixis was coined by **Winkler**.
- Apomixis is a type of asexual reproduction but mimics sexual reproduction.
- **Examples:-** Asteraceae and grasses have evolved a special mechanism, to produce seeds without fertilization, called apomixis.

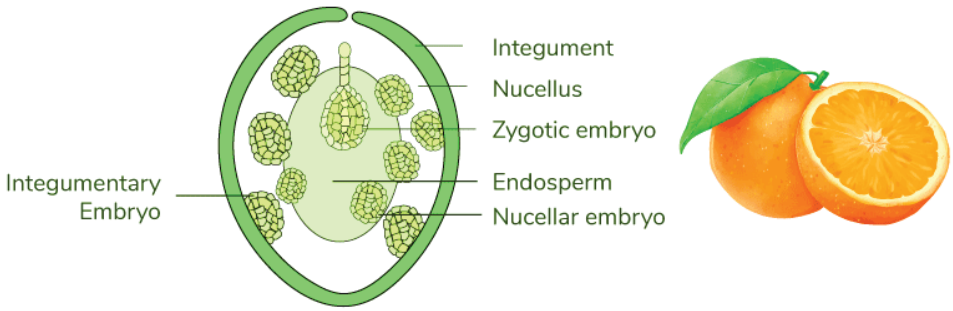
Importance of Apomixis :-

1. Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity.
2. One of the problems of hybrids is that hybrid seeds have to be produced every year.
3. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters.
4. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers.
5. If hybrid plants could be made apomictic, farmers could reuse the seeds year after year without having to buy new hybrid seed each season.

Polyembryony:-

- Occurrence of more than one embryo in a seed is referred as **polyembryony.**
- Examples include Citrus (orange, lemon) and mango.

❖ Polyembryony may arise when more than one embryo develops within a seed; in some plants, additional embryos can arise from nucellar cells in addition to the zygotic embryo.



EXERCISE

PART – A

I. Multiple Choice Questions: 1 Mark Each:

1. The function of tapetum in microsporangium is

a) it nourishes the developing pollen grains

b) helps in dehiscence of anther to release the pollen

c) helps in protection

d) helps in division

2. Select the correct sequence of anther wall layers.

a) Epidermis → Middle layers → Endothecium → Tapetum

b) Epidermis → Endothecium → Middle layers → Tapetum

c) Epidermis → Tapetum → Middle layers → Endothecium

d) Tapetum → Middle layers → Epidermis → Endothecium

3. Select the correct sequence of events in microsporogenesis.

a) Sporogenous tissue → Microspore mother cell → Microspore tetrad → Microspores

b) Microspores → Microspore mother cell → Microspore tetrad → Sporogenous tissue

c) Sporogenous tissue → Microspore tetrad → Microspores → Microspore mother cell

d) Microspores → Sporogenous tissue → Microspore tetrad → Microspore mother cell

4. Most resistant organic material present on exine of pollen grain is

a) Tapetum b) Pectin c) Sporopollenin d) Cellulose

5. Which of the following has proved helpful in preserving pollen as fossils?

a) Pollen kit b) Cellulosic intine c) Oil content d) Sporopollenin

6. Select the incorrect statement with respect to vegetative cell of pollen grain.

a) Bigger than generative cell

b) Has abundant food reserve

c) Has a large irregularly shaped nucleus

d) Floats in the cytoplasm of generative cell

7. Which one of the following statements is not true?

a) Pollen grains of many species cause severe allergies.

b) Stored pollen in liquid nitrogen can be used in the crop breeding programmes.

c) Tapetum helps in the dehiscence of anther.

d) Exine of pollen grains is made up of sporopollenin

8. Pollen grains can be stored for several years in liquid nitrogen having a temperature of

a) $-120^{\circ}C$ b) $-80^{\circ}C$ c) $-160^{\circ}C$ d) -196°

9. Functional megaspore in an angiosperm develops into an

a) Endosperm b) embryo sac c) embryo d) ovule

10. In angiosperms, microsporogenesis and megasporogenesis

a) Involve meiosis b) occur in ovule

c) Occur in anther d) form gametes without further division

11. Function of filiform apparatus is to

a) recognise the suitable pollen at stigma b) stimulate division of generative cell

c) produce nectar d) guide the entry of pollen tube

12. From the statements given below choose the option that is true for a typical female gametophyte of a flowering plant.

A) It is 8-nucleate and 7-celled at maturity

B) It is free-nuclear during the development

C) It is situated inside the integument but outside the nucellus

D) It has an egg apparatus situated at the chalazal end

a) A) and D b) B) and C. c) A) and B d) B) and D)

13. Identify the correct sequence of arrangement of cells in the mature embryo sac from the micropylar end.

a) Synergids → Egg Cell → Central cell → Antipodals

b) Antipodals → Central Cell → Egg cell → Synergids

c) Synergids → Central Cell → Egg cell → Antipodals

d) Antipodals → Egg cell → Central Cell → Synergids

14. Which of the following is not a correct statement?

a) Placenta is located outside the ovarian cavity.

b) Central cell develops into PEC after fertilization.

c) Orchids contain more than one ovule in an ovary.

d) Egg apparatus consists of one egg cell and two synergid cells.

15. Even in the absence of pollinating agents, seed setting is assured in

a) Cucurbita b) Papaya c) Commelina d) Maize

16. Transfer of pollen grains from the anther to stigma of another flower of the same plant is known as

a) Autogamy b) Xenogamy c) Cleistogam d) Geitonogamy

17. Which pollination brings genetically different types of pollen grains to the stigma?

a) Geitonogamy b) Xenogamy c) Autogamy d) Cleistogamy

18. Dioecious plants are

a) Autogamous only b) Both autogamous and geitonogamous

c) Both geitonogamous and xenogamous d) Xenogamous only

19. Statement I: In Viola, both autogamy and geitonogamy is prevented.
Statement II: Geitonogamy is similar to autogamy since pollen grains comes from the same plant.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

20. Which is not a characteristic feature of wind pollinated flowers?

a) Feathery stigma
b) Presence of single ovule in ovary
c) Pollen grains are non-sticky
d) Flowers are very colourful

21. Wind pollination is common in

a) Legumes b) lilies c) grasses d) orchids

22. Double fertilization is

a) Fusion of two male gametes of a pollen tube with two different eggs
b) Fusion of one male gamete with two polar nuclei
c) Fusion of two male gametes with one egg
d) Syngamy and triple fusion

23. In a fertilized embryo sac, the haploid, diploid and triploid structures are-

a) Synergid, zygote and primary endosperm nucleus
b) Synergid, antipodal and polar nuclei
c) Antipodal, synergid and primary endosperm nucleus
d) Synergid, polar nuclei and zygote

24. Haploid condition is not observed in which of the following cells

a) Synergids and Egg
b) Zygote and PEN
c) Antipodal and Egg
d)Antipodal and Synergids

25. Endosperm persist in the mature seed in

a) Groundnut b) Castor c) Pea d) Beans

26. Coconut water from a tender coconut is

(a) Innermost layers of the seed coat
(b) degenerated nucellus
(c) Immature embryo
(d) free nuclear endospersm

27. In a monocot embryo, shoot apex and leaf primordia are enclosed in a hollow foliar structure called

a) Pericarp b) Coleoptile c) Endosperm d) Coleorrhiza

28. Perisperm differs from endosperm in

a) being a diploid tissue
b) being a haploid tissue
c) having no reserve food
d) its formation by fusion of secondary nucleus with several sperm

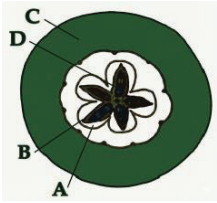
29. Non-albuminous seed is produced in

a) Maize b) castor c) wheat d) pea

30. Which one of the following fruits is parthenocarpic?

a) Jackfruit b) Banana c) Brinjal d) Apple

31. Which part of the fruit, labelled in the given figure makes it a false fruit?



a) D-Seed b) A-Mesocarp c) B-endocarp d) C-Thalamus

32. Occurrence of more than one embryo in a seed is seen in

a) Grasses b) Asteraceae c) Citrus d) Both grasses and asteraceae

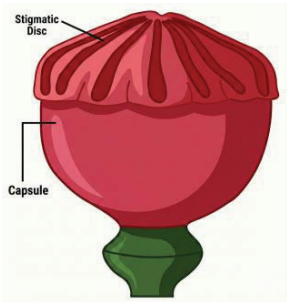
33. Statement I: Apomixis is the production of seeds from unfertilized ovules.
Statement II: Embryos produced from apomictic seeds are not generally identical to the parent plant.

a) Statement I is true, statement II is false
b) Statement I is false, statement II is true
c) Statement I and statement II both are true
d) Statement I and statement II both are false

34. Statement I: Formation of fruit without fertilization is called apomixis.
Statement II: In some species of Asteraceae and grasses seeds are formed without fertilization.

a) Both Statement I and Statement II are correct
b) Both Statement I and Statement II are incorrect
c) Statement I is correct and Statement II is incorrect
d) Statement I is incorrect and Statement II is correct

35. The following picture is an example for



a) Multicarpellary, apocarpous gynoecium b) Multicarpellary, syncarpous gynoecium
c) Monocarpellary gynoecium d) Apocarpous gynoecium

Answer Key

1. A.	**2.** B.	**3.** A.	**4.** C.	**5.** D.	**6.** D.
7. C.	**8.** D.	**9.** B.	**10.** A.	**11.** D.	**12.** C.
13. A.	**14.** A.	**15.** C.	**16.** D.	**17.** B.	**18.** D.
19. D.	**20.** D.	**21.** C.	**22.** D.	**23.** A.	**24.** B.
25. B.	**26.** D.	**27.** B.	**28.** A.	**29.** D.	**30.** B.
31. D.	**32.** C.	**33.** A.	**34.** D.	**35.** A.	

II. Fill in the blanks: 1 Mark Each:

(Embryogeny, Amorphophallus, Self-incompatibility, Micropyle, Perisperm, Polyembryony, Zostera, Tapetum, Strawberry, Microsporogenesis, Lupine, Pollen grain, Scutellum, Emasculation, Castor)

1. The process of formation of microspores from a pollen mother cell through meiosis is called _____.

2. _____ is the innermost wall layer of microsporangium.
3. Embryo sac is to ovule as _____ is to an anther.
4. The opening of the angiosperm ovule where the integument is absent is known as _____
5. _____ is an example for water pollinated plant.
6. An example for plant that gives floral reward by providing safe place to lay insect eggs is _____.
7. The genetic mechanism which prevents self-pollen from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil is known as _____ .
8. The removal of anthers from the flower bud before the anther dehiscence in bisexual flower is referred as _____ .
9. The early stages of embryo development are called _____ .
10. An example for albuminous seed is _____ .
11. The residual persistent nucellus present in some seeds is called _____。
12. In the grass family the cotyledon of embryo is called_____.
13. _____ is an example for false fruit.
14. An example for oldest viable seed is _____ .
15. If more than one embryo occurs in a seed then it is known as _____ .

Answer Key		
1. Microsporogenesis	2. Tapetum	3. Pollen grain
4. Micropyle	5. Zostera	6. Amorphophallus
7. Self-incompatibility	8. Emasculation	9. Embryogeny
10. Castor	11. Perisperm	12. Scutellum
13. Strawberry	14. Lupine	15. Polyembryony

PART – B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each:

Q1. Mention four wall layers of microsporangium

Ans: Epidermis, endothecium, middle layers and tapetum.

Q2. Write a note on tapetum.

Ans:

1. It is the innermost layer of the microsporangium.
2. Generally the cells have more than one nucleus.
3. It has **dense cytoplasm** and **nourishes** the developing microspores.
4. It also secretes chemicals that can form **sporopollenin** of pollen grain exine.

Q3. Complete the tabular column given below with respect to the male gametophyte of angiosperms.

Ans:

Cells of the gametophyte	Shape of the Nucleus
Vegetative	Irregular
Generative	Oval

Q4. Write the significance of sporopollenin or sporopollenin is one of the most resistant organic material known. Justify?

Ans:

1. It is one of the most resistant organic materials known and can withstand high temperatures, strong acids, alkalis and enzymatic degradation.
2. Fossilization of pollen grains.

Q5. What is the filiform apparatus? Write its significance.

Ans:

1. Special cellular thickening of synergids at the micropylar tip is called **filiform apparatus.**
2. It plays an important role in guiding the pollen tube into a synergid.

Q6. Differentiate between chasmogamous and Cleistogamous flowers.

Ans:

1. The flowers that open upon maturity are chasmogamous.
2. Whereas the Cleistogamous flowers remain closed even at maturity.

Q7. What are Cleistogamous flowers? Give an example

Ans:

1. The flowers remain closed even at maturity are called **Cleistogamous flowers.**
2. **Example:** Commelina, Viola, Oxalis.

Q8. What are cleistogamous flowers? Mention two advantages of cleistogamy.

Ans: Flowers do not open at all and their anthers and stigma lie close to each other.

Advantages

1. It does not need pollinating agents.
2. It ensures definite seed formation.

Q9. Mention one advantage and one disadvantage each of cleistogamy.

Ans:

1. The advantage of cleistogamy is it ensures seed formation even in the absence of pollinators.
2. The disadvantage is it results in inbreeding depression.

Q10. Differentiate between geitonogamy and xenogamy.

Ans:

1. **Geitonogamy** is the transfer of pollen grains from the anther of flower to the stigma of another flower of the same plant.
2. **Xenogamy** is the transfer of pollen grains from anther to the stigma of different plants of the same species.

Q11. List the characteristic features of wind pollinated flowers.

Ans:

1. Flowers are not showy.
2. Absence of scent and nectar.
3. Inflorescence generally pendant or swinging.
4. In monoecious flowers male flowers are more than female flowers.
5. They produce large quantities of pollen.
6. Pollen grains are dry, very small, non-sticky, and non-absorbent.
7. Stigma may be large and feathery or bushy.
8. Plants grow in large groups.

9. Perianth reduced or absent.
10. Anthers are versatile.

Q12. Mention any two floral rewards offered by insect pollinated flowers to their pollinators.

Ans:

1. Nectar and pollen grains.
2. Safe place to lay eggs.

Q13. Define: a) Emasculation b) Bagging.

Ans:

a) **Emasculation:** is the removal of anthers from a flower before the maturation or dehiscence of anthers in a bisexual flower.

b) **Bagging:** The process of covering the stigmas of emasculated flowers with a bag of suitable size is known as bagging.

Q14. Define : a) syngamy b) triple fusion.

Ans:

1. The fusion of haploid male gamete with a haploid egg to form diploid zygote is called **syngamy**.

2. The fusion of haploid male gamete with two haploid polar nuclei to form a triploid primary endosperm nucleus is called **triple fusion**.

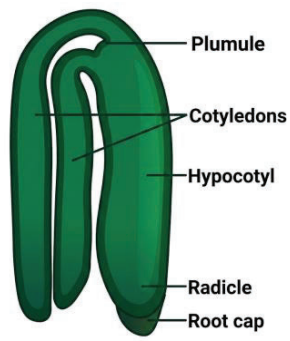
Q15. Name the four stages in development of dicotyledonous embryo in angiosperms.

Ans: The different stages in the early development of embryos in flowering plants are as follows:

1. Proembryo
2. Globular embryo
3. Heart shaped embryo
4. Mature embryo

Q16. Draw a neat labelled diagram of a typical dicotyledonous embryo.

Ans:



Dicot embryo

Q17. Differentiate between Albuminous and Non–albuminous seeds.

Ans:

1. **Albuminous seeds:** Seeds that retain residual endosperm at maturity are called albuminous seeds.

2. **Non-albuminous seeds:** Seeds in which the endosperm is completely consumed during embryo development are called non-albuminous seeds. Examples: pea, bean and groundnut.

Q18. What is perisperm? Give an example.
Ans: The residual, persistent nucellus is called the perisperm.
E. g., Beet and Black pepper.

Q19. Differentiate between true fruits and false fruits.
Ans: 1. **True fruits:** The fruits that develop only from the ovary are called true fruits.
2. **False fruits:** The fruits that develop from ovary as well as other floral parts are called false fruits.

Q20. Why apple is called a false fruit? Which part(s) of the flower forms the fruit?
Ans: Apple is called a false fruit because the thalamus/receptacle also contributes to fruit formation in addition to the ovary; the fleshy edible part is mainly derived from the thalamus.

Q21. What is parthenocarpy? Give an example.
Ans: The fruits that develop from unfertilized ovary are called parthenocarpic fruits**. E. g.,** Banana.

Q22. Name the phenomenon of formation of seed without fertilization in angiosperms. Give an example of a plant which exhibits this phenomenon.
Ans: The phenomenon is called **Apomixis** E. g., Aster

Q23. What is Apomixis? Mention its significance

Ans : Production of seeds without fertilization is known as **apomixis.**

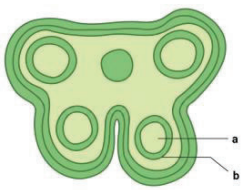
Significance

- Apomictic seeds are developed to retain the parental characters together in the hybrids for many generations.
- They reduce the cost of producing hybrid seeds and buying of hybrid seeds every year by farmers.

Q24. Define polyembryony. Mention the plants which exhibit polyembryony.
Ans: The phenomenon of having more than one embryo in a seed is known as **polyembryony**. **Ex**: Citrus, Mango.

Q25. How are parthenocarpic fruits produced by some plants and apomictic seeds by some others?
Ans: 1. **Parthenocarpic fruits** are formed without the fertilization of ovaries.
2. **Apomictic seeds** are formed without the fertilization of ovules.

Q26. In the T.S. of an anther given below, identify "a" and "b" and mention their function.



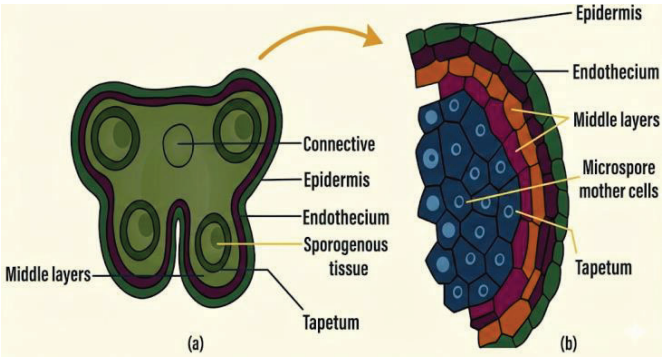
Ans: a – Sporogenous tissue: Each cell of this tissue is capable of giving rise to a pollen tetrad.
b – Tapetum: Provide nourishment to the developing pollen grains.

PART – C

IV. Answer the following questions in 40 – 80 words each: 3 Marks Each:

Q1. Draw a labelled diagram of transverse section of a young anther.

Ans:



Q2. Describe the structure of microsporangium.

Ans:

1. In a transverse section, a typical microsporangium appears near circular in outline.
2. It is surrounded by four wall layers: the epidermis (single layered), endothecium (single layered), middle layers (1 – 4 number) and the tapetum (single layered).
3. The outer three wall layers perform the function of protection and help in dehiscence of anther to release the pollen.
4. The innermost wall layer is the tapetum which nourishes the developing pollen grains.
5. When the anther is young, a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.

Q3. Explain the structure of pollen grain.

- The pollen grains represent the **male gametophyte.**
- **General Shape and Size :** Generally **spherical** in shape and measuring about **25-50 µm** in diameter.
- **Wall Layers:** It has **pollen wall** or **sporoderm** enclosing the protoplasm.
  a. **Exine:** It is a hard outer layer made up of **sporopollenin**. Which is one of the **most resistant organic material**.
  ✓ It can withstand in **high temperature** and **Strong acids** and **alkali**. Pollen grains are well preserved as fossils because of the presence of **Sporopollenin**.
  ✓ It has apertures called **germ pores** where sporopollenin is absent.
  b. **Intine:** It is a thin and continuous layer made up of **cellulose** and **pectin**.
- At the 2-celled stage, a pollen grain has a large vegetative cell and a small generative cell.
  a. **Vegetative cell:** Bigger, has abundant food reserve and a large irregularly shaped nucleus.
  b. **Generative cell:** Small and floats in the cytoplasm of the vegetative cell. It is spindle-shaped with dense cytoplasm and a nucleus.

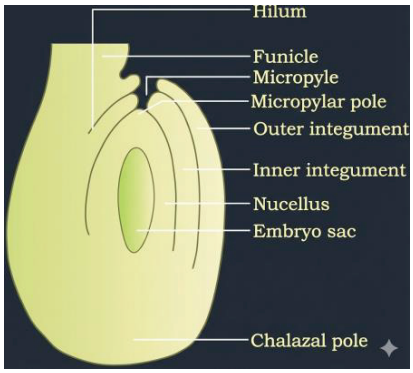
Q4. Write any two commercial uses of pollen grains and mention the viability period of pollen grains of Solanaceae members.

Ans:

1. **Commercial Uses:** Pollen grains can be used as pollen tablets and syrup as nutritional supplements to increase the performance of athletes and race horses.
2. **Viability:** Solanaceae members – For months.

Q5. Draw a neat labelled diagram of a typical anatropous ovule.

Ans:



Q6. Describe the structure of megasporangium.

Ans:

1. Ovule is attached to the placenta by a stalk (funicle).
2. Junction between the body of ovule and funicle is called hilum.
3. Each ovule has 1 or 2 protective envelopes (integuments) except at the tip where a small opening (micropyle) is present.
4. Opposite the micropylar end is the chalaza (basal part).
5. Enclosed within the integuments, there is a mass of cells called nucellus. Its cells contain reserve food materials.
6. Inside the nucellus is embryo sac (female gametophyte).

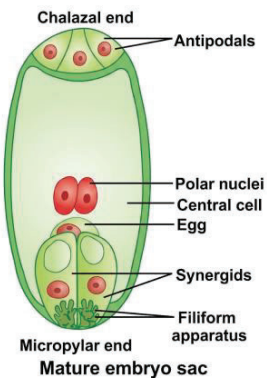
Q7. Explain the structure of a mature female gametophyte in flowering plants.

Ans:

1. A typical mature embryo sac is 7-celled and 8-nucleate.
2. 3 cells (2 synergids + one egg cell) are grouped at the micropylar end and form egg apparatus.
3. Synergids have special cellular thickenings at the micropylar tip called filiform apparatus.
4. 3 cells at the chalazal end are the antipodals.
5. A large central cell with two polar nuclei is present in the centre.

Q8. Draw a neat labelled diagram of a mature embryo sac.

Ans:



Mature embryo sac

Q9. List the characters of insect pollinated flowers. March -2022

Ans:

1. They produce **nectar** by **nectariferous glands** of flowers.
2. Some flowers produce **edible pollen grains.**
3. Flowers are **fragrant**, **emit scent** or **odour.**
4. Flowers are **showy** and **bright colored.**

5. Flowers occur in groups and are conspicuous.
6. Pollen grains are **sticky in nature.**
7. Stigma is sticky due to release of exudates.
8. The flowers pollinated by flies and beetles secrete **foul odour** to attract these.

Q10. What is artificial hybridization? Name the techniques that are employed to achieve this?.

Ans: Definition: The process of obtaining plants with desired traits through controlled pollination and fertilization.

Techniques:

1. **Emasculation:** Removal of anthers from the bisexual flower bud of female parent before the anther dehisces.
2. **Bagging:** Emasculated flowers are covered with a bag (butter paper) to prevent its stigma from pollination by unwanted pollen.
3. **Pollination:** When stigma attains receptivity, pollen grains collected from desired male parent are dusted on the stigma.
4. **Rebagging:** Pollinated stigmas of flowers are covered again to prevent further contamination.

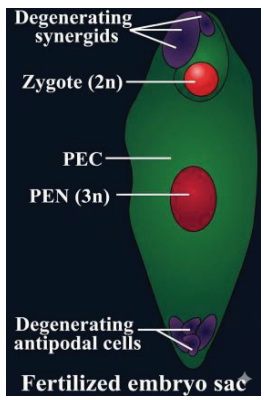
Q11. What is triple fusion? Where does it take place in the megasporangium? Name the nuclei involved in triple fusion.

Ans:

1. **Definition:** The fusion of three haploid nuclei is termed triple fusion.
2. **Location:** It occurs inside the embryo sac.
3. **Nuclei involved:** One male gamete nucleus and two polar nuclei.

Q12. Draw a labelled diagram of the fertilized female gametophyte and mention the ploidy of any one of the products of double fertilization.

Ans:



Ploidy: Zygote – Diploid (2n) / PEN or PEC - Triploid (3n).

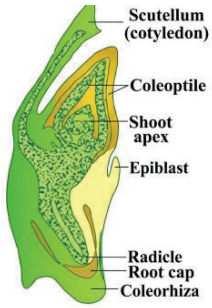
Q13. Name the product of fertilisation that forms the kernel of coconut. How does the kernel differ from coconut water?

Ans:

1. **Product:** PEC – Primary endosperm cell.
2. **Difference:** Kernel is a cellular endosperm, while coconut water is free-nuclear endosperm.

Q14. Draw a L.S. of grass embryo and label the following parts: a) Scutellum b) Coleoptile c) Shoot apex d) Radicle e) Root cap f) Coleorrhiza g) Epiblast.

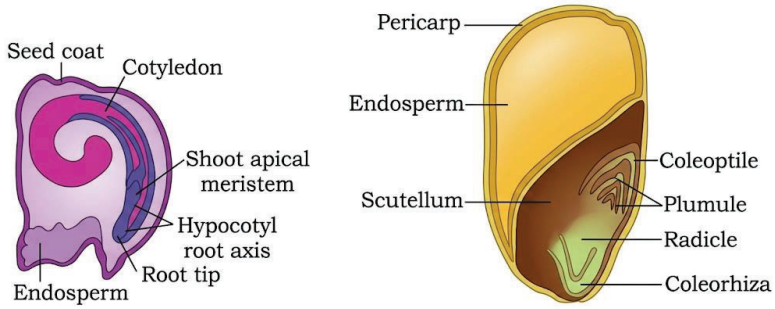
Ans:



LS of grass embryo (monocot)

Q15. Draw a neat labelled diagram of a monocot seed.

Ans:



Q16. 'Fertilization is not an obligatory event for fruit production in certain plants'. Justify the statement.

Ans:

- In certain plants like Banana, fruit formation does not involve fertilization.
- The fruits develop from the ovary without fertilisation by a phenomenon called parthenocarpy, and the seeds are generally absent.

Q17. Explain any three advantages the seeds offer to angiosperms.

Ans:

1. **Dispersal:** Better adaptive strategies for dispersal to new habitats and colonization.
2. **Nourishment:** They have food reserves; seedlings are nourished until they are capable of photosynthesis.
3. **Protection:** The hard seed coat protects the young embryo.
4. **Variation:** Being products of sexual reproduction, they generate new genetic combinations and variations.
5. **Survival:** Dehydration & dormancy help seeds to overcome unfavourable conditions.

Q18. Why are some seeds referred to as apomictic seeds? Mention its advantages to a farmer who uses them.

Ans:

- **Apomictic seeds:** These seeds develop without the fertilization of ovules.
- **Advantages to Farmers:**
  - ✓ In hybrids, progeny normally segregate and lose hybrid characters. Apomixis prevents this segregation.
  - ✓ Production of hybrid seeds is costly. If hybrids are made into apomicts, farmers can keep using the seeds to raise new crops year after year without buying expensive hybrid seeds every season.

PART- D

V. Answer the following questions in 200-250 words each: 5 Marks Each:

Q1. Mention any five differences between microsporogenesis and megasporogenesis.

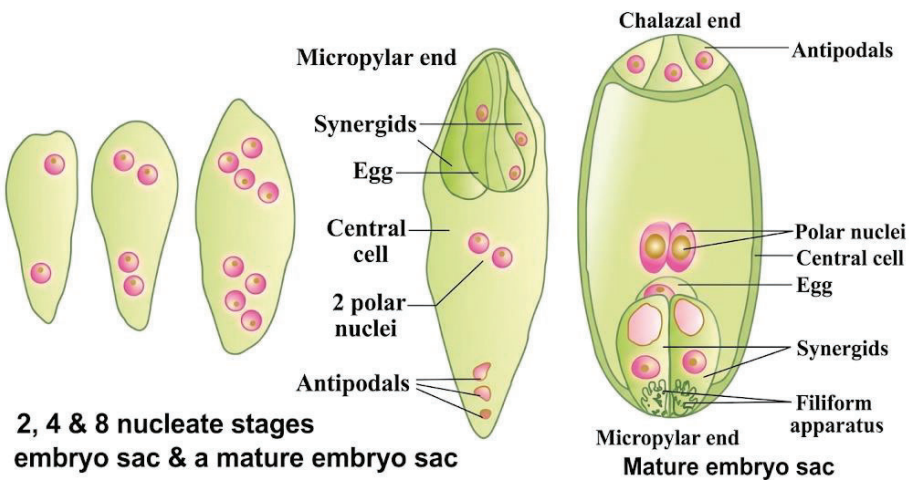
Ans.

Microsporogenesis	Megasporogenesis
Occurs in microsporangium.	Occurs in megasporangium.
Involves the formation of microspores from microspore mother cells by meiosis.	Involves the formation of megaspore from megaspore mother cell by meiosis.
Many microspore mother cells are differentiated in microsporangium.	Usually one megaspore mother cell differentiates in megasporangium.
Four microspores are formed from each microspore mother cells as microspore tetrads of different types.	Four megaspores are formed from one megaspore mother cell as linear tetrad.
All the four cells of microspore tetrad are functional.	Among the four cells of megaspore tetrad, three degenerate and one remains functional.

Q2. Explain the structure of pollen grain.

- **General Shape:** Generally spherical, 25-50 µm in diameter.
- **Wall Layers:** It has pollen wall or sporoderm enclosing the protoplasm.
  c. **Exine:** Hard outer layer made up of sporopollenin. It has apertures called germ pores where sporopollenin is absent.
  d. **Intine:** A thin and continuous layer made up of cellulose and pectin.
- **Matured Pollen Cells:**
  c. **Vegetative cell:** Bigger, has abundant food reserve and a large irregularly shaped nucleus.
  d. **Generative cell:** Small and floats in the cytoplasm of the vegetative cell. It is spindle-shaped with dense cytoplasm and a nucleus.

Q3. Diagrammatically represent the development of a female gametophyte in angiosperms.



Q4. Answer the following:

a) Explain different types of pollination based on the source of pollen. (3 Marks)

Ans,

1. **Autogamy:** Transfer of pollen grain from anther to stigma of the same flower on the same plant.
2. **Geitonogamy:** Transfer of pollen grains from the anther of a flower to the stigma of another flower of the same plant.

3. **Xenogamy:** Transfer of pollen grains from anther to the stigma of a different plant of the same species.

b) List the characteristic features of water-pollinated flowers. (2 Marks)

Ans.

- Pollen grains are long and ribbon-like. They are carried inside the water to reach the stigma.
- Pollen grains have a mucilaginous covering to protect them from wetting.

Q5. How does pollination occur in Vallisneria and Zostera?

Ans.

1. **Vallisneria:** A dioecious hydrophyte. Female flowers reach the surface of water by a long stalk. Male flowers or pollen grains are released on the surface and carried passively by water currents to reach the female stigma.
2. **Zostera:** Female flowers remain submerged in water. Pollen grains are long and ribbon-like, released inside the water, and carried passively to reach the submerged stigma.

Q6. Pollen-Pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition. Explain.

Ans.

1. It includes all events from pollen deposition on stigma to pollen tube entry into the ovule.
2. The pistil has the ability to recognize compatible (right type) or incompatible (wrong type) pollen.
3. This recognition is the result of a continuous dialogue mediated by chemicals produced by both pollen and pistil.
4. If compatible, the pistil accepts the pollen and promotes post-pollination events; if incompatible, it rejects the pollen by preventing germination or tube growth.

Q7. Flowering plants have developed many devices to discourage self-pollination and encourage cross-pollination. Comment.

Ans.

1. **Dichogamy:** Male and female parts mature at different times (Protandry or Protogyny). E.g., *Gossypium*, *Solanum*.
2. **Dicliny (Unisexuality):** Production of unisexual flowers. E.g., Papaya, Castor.
3. **Herkogamy:** Physical barriers prevent self-pollination. E.g., *Calotropis*.
4. **Heterostyly:** Styles of different lengths. E.g., *Oxalis*, *Primula*.
5. **Self-incompatibility:** Genetic mechanism preventing self-pollen germination. E.g., Potato, Tobacco.
6. **Pollen pre-potency:** Foreign pollen germinates faster than self-pollen. E.g., Pear, Apple.

Q8. Answer the following:

a) Double fertilization is a unique event in flowering plants. Briefly explain. (3 Marks)

Ans.

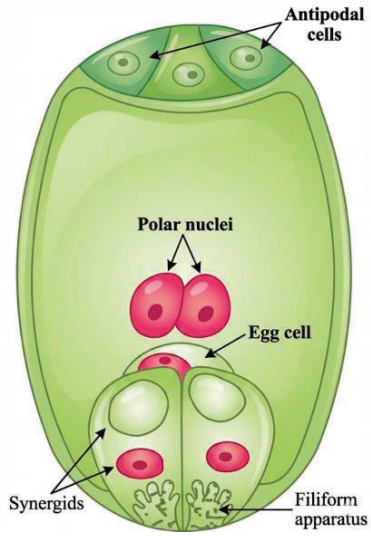
1. **Syngamy:** One male gamete fuses with the egg cell nucleus to form a diploid zygote.
2. **Triple Fusion:** The second male gamete fuses with two polar nuclei to produce a triploid Primary Endosperm Nucleus (PEN).
3. **Double Fertilization:** Since two types of fusion (syngamy and triple fusion) occur in one embryo sac, it is called double fertilization.

b) Arrange the following terms in the correct developmental sequence: Pollen grain, Sporogenous tissue, Microspore tetrad, Pollen mother cell, Male gametes. (2 Marks)

Ans. Sequence: Sporogenous tissue → Pollen mother cell → Microspore tetrad → Pollen grain → Male gametes.

VI. Answer the following questions in 200-250 words each: 5 Marks Each:

Q1. A picture of a mature angiosperm embryo sac is given below, answer the question that follow.



a) Which cells or nuclei of the embryo sac produce zygote and primary endosperm nucleus? (2 Marks)

• Zygote: egg + one male gamete; PEN: two polar nuclei/secondary nucleus + the second male gamete.

b) What is the ploidy of antipodal cells and primary endosperm nucleus? (2 Marks)

- Antipodal cells – haploid (n).
- Primary endosperm nucleus – Triploid (3n).

c) Why the endosperm development precedes embryo development? (1 Mark)

- To provide assured nourishment to the developing embryo.

Q2. Answer the below given questions in relation the picture.

Ans.

a) Does pollination necessarily confirm fertilisation?

• No. Pollination alone does not guarantee fertilisation. A compatible pollen grain must germinate, form a pollen tube, reach the embryo sac and complete gamete fusion.

b) What are the floral rewards provided by the plant?

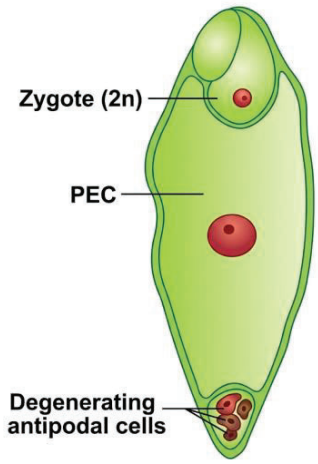
• Nectar and pollen grains.

c) Mention the characteristics of flower in this pollination other than floral rewards.

- The flowers are showy, scented.

Q3. Write the name of the following

a. **Three cells present at the chalazal end in the embryo sac -Antipodals**
b. **A small pore in the Ovule through which the pollen tube enters - Micropyle**
c. **Wall of the fruit having mesocarp, endocarp,epicarp – Pericarp**
d. **Two cells present on either side of egg cell in an embryo sac – Synergids**
e. **Mass of cells enclosed within the integument – Nucellus**



Q4.Answer the following:

Ans.

a) Plan an experiment and prepare the flow chart of the steps you follow to ensure that the seeds are formed only from the desired sets of pollen grain.

- Emasculation - Bagging - desired pollen dusting - Rebagging - Tagging.

b) Name the type of experiment that you carried out.

- Artificial hybridisation.

c) Write the importance of such an experiment.

• To obtain crop plants with desired combinations of characters and improved cultivation value.

Q5. Double fertilization is the unique feature of angiosperms and the products of the double fertilization are zygote and PEN. In context of this when a hexaploid plant is pollinated by a tetraploid plant find out the ploidy of zygote and PEN through a schematic illustration.

Ans.
Hexaploid plant (Female - 6n) x Tetraploid plant (Male - 4n)

- **Female Gametes:** Egg (3n), Polar nuclei (3n + 3n = 6n).
- **Male Gametes:** Male gamete (2n).

Schematic Result:

- **Syngamy:** Egg (3n) + Male gamete (2n) = **Zygote (5n)**.
- **Triple fusion:** Polar nuclei (3n+3n) + Male gamete (2n) = **PEN (8n)**.

Q6. Why the process of fertilization in angiosperms is termed double fertilization? Draw a diagram of an angiosperm embryo sac where fertilization is just completed and label the following parts:

Ans.

- Reason: Since two fusions, syngamy and triple fusion, take place in the same embryo sac, the process is called double fertilisation.
- **Labels for Diagram:**

  a) The part that develops into an embryo (Zygote).

  b) The part that develops into an endosperm (PEN/PEC).

c) Degenerating cells at the chalazal end (Antipodals).

Q7. Answer the following:

a) Double fertilization is reported in the plants Castor and Groundnut. However the mature seeds of groundnut are non-albuminous while castors are albuminous. Explain the post-fertilisation event responsible for this.

Ans.

The relevant post-fertilisation event is the fate of the endosperm during embryo development. Groundnut seeds are non-albuminous because the endosperm is completely used up during embryo development, leaving no residual endosperm. In castor, some endosperm persists in the mature seed.

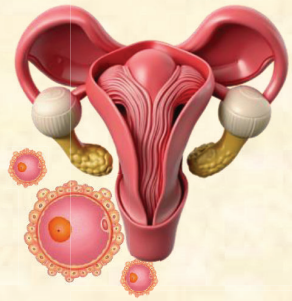
b) Banana is a parthenocarpic fruit whereas oranges show polyembryony. How are they different from each other with respect to seeds?

Ans.

Banana fruits are generally seedless because the ovary develops into a fruit without fertilisation (parthenocarpy). In oranges, seeds are present, but a seed may contain more than one embryo (polyembryony), often because additional embryos arise from nucellar cells in addition to the zygotic embryo.

Chapter 2

HUMAN REPRODUCTION



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2.6. EMBRYONIC DEVELOPMENT
2.7. PARTURITION

Theory

INTRODUCTION:

Human reproduction is a biological process in which an organism gives rise to young ones similar to itself. In humans, this process is called human reproduction.

1. Sexual reproduction - It involves fusion of male and female gametes.
2. Diploid organism (2n) - Humans have two sets of chromosomes, one from each parent.
3. Viviparous - The embryo and foetus develop inside the female body.

Major events in human reproduction are:

1. Gametogenesis - Formation of gametes: sperm in males and ova in females.
2. Insemination - Transfer of sperm into the female reproductive tract.
3. Fertilisation - Fusion of male and female gametes to form a zygote.
4. Cleavage - Rapid mitotic divisions of the zygote that produce blastomeres and later a blastocyst.
5. Implantation - Attachment and embedding of the blastocyst in the uterine endometrium.
6. Gestation - The period of development in the uterus from fertilisation to parturition.
7. Parturition - Delivery of the fully developed foetus.

- These reproductive events occur **after puberty.**
- There are remarkable differences between the reproductive events in the **male** and in the **female**, for example, **sperm formation** continues even in old men, but formation of ovum ceases in women around the age of **fifty years.**

2.1. The Male Reproductive System

- The male reproductive system is located in the pelvic region.
- It includes a **pair of testes** along with **accessory ducts, glands** and the **external genitalia.**

Primary reproductive organs - Gamete-forming organs.

1. A PAIR OF TESTES - They have two major functions:

(i) Formation of sperm.

(ii) Secretion of androgens, mainly testosterone.

- The testes develop in the abdominal region and normally descend into the scrotum through the inguinal canals during foetal life.
- The scrotum maintains the testes about 2-2.5 C below internal body temperature, which is necessary for spermatogenesis.

Structure of testis

- Each testis is oval, about 4-5 cm long and 2-3 cm wide, and lies in the scrotum.
- It is covered by three layers:

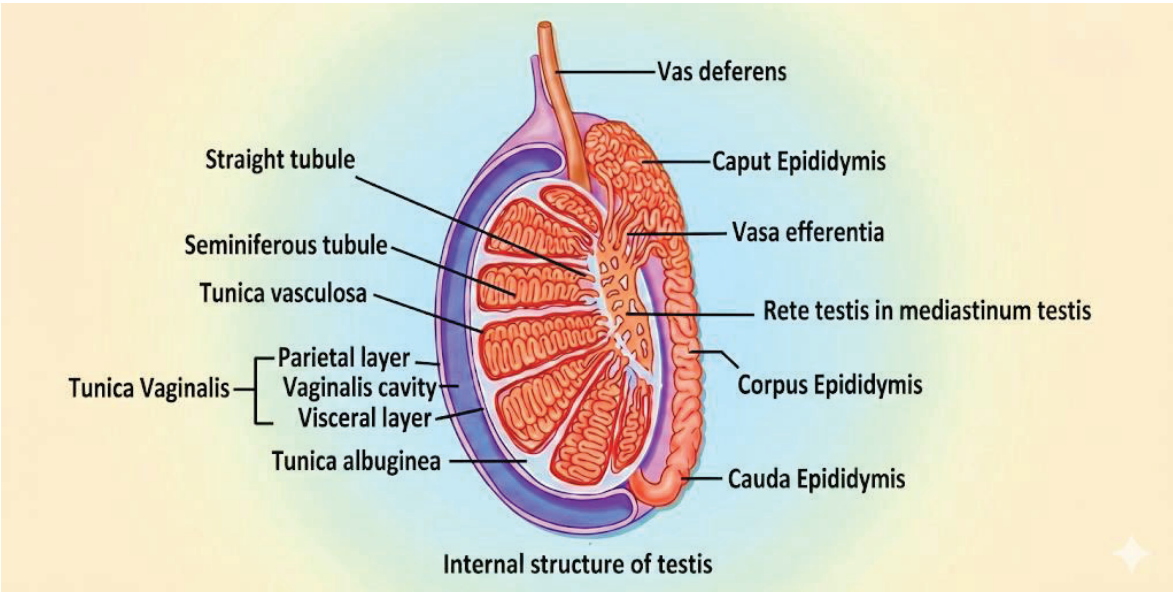
(i) Tunica vaginalis - The outer serous covering.

(ii) Tunica albuginea - A dense fibrous connective-tissue layer.

(iii) Tunica vasculosa - The vascular inner layer containing blood vessels and connective tissue.

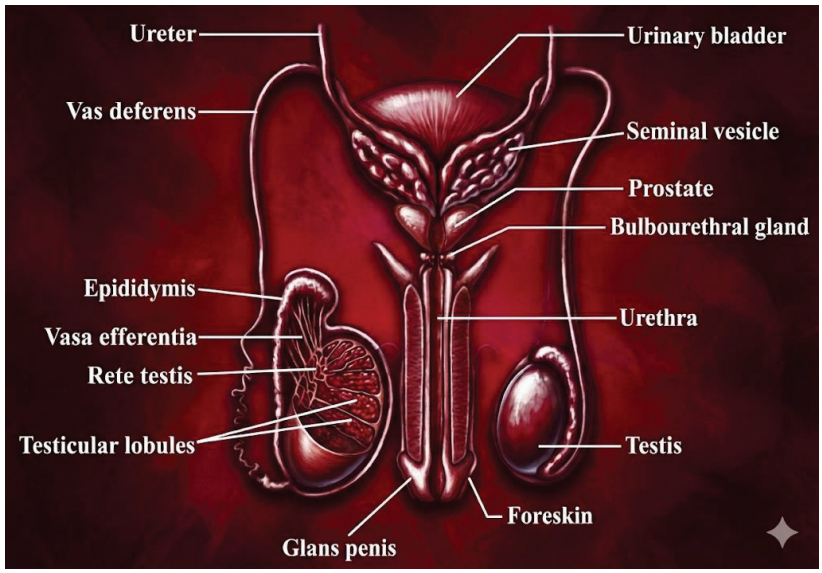
Internal structure of Testis

- Testicular lobules - Each testis is divided into about 250 compartments called testicular lobules.



Internal structure of testis

- **Seminiferous tubules - Each lobule contains one to three highly coiled seminiferous tubules in which sperm are** produced.



Diagrammatic view of male reproductive system (part of testis is open to show inner details)

❖ Each seminiferous tubule is lined on its inside by germinal epithelium which has two types of cells called **male germ cells (spermatogonia) and supporting Sertoli cells (sustentacular cells).**

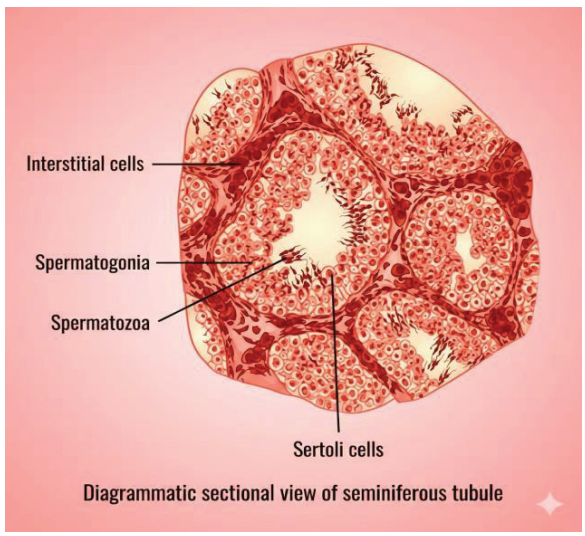
Male germ cells/Spermatogonia - The male germ cells undergo meiotic divisions finally leading to sperm formation.

2. **Sertoli cells (Nurse cell)** - Sertoli cells provide nutrition to the germ cells. (Therefore, these cells are also known as nurse cells.)

❖ The interstitial spaces outside the seminiferous tubules contain blood vessels and interstitial cells, including the following:

(a) Leydig (interstitial) cells - They synthesise and secrete testicular androgens.

sperm formation.



B. Secondary/accessory reproductive organs - These do not produce gametes but provide passage, storage and support for reproduction.

1. Accessory ducts - Help in storage, transport and maturation of sperm.

a. Rete testis

b. Vasa efferentia

c. Epididymis

d. Vas deferens

Rete testes : -All the seminiferous tubules are join to form dense network of tubules in posterior part of rete testis.

Vasa -efferentia :-About **10-12** fine ducts that are arises from rete testis and opens into epididymis are They carry sperm from the testis to the epididymis.

c. **Epididymis :-**It is a highly coiled long tubule present along the posterior surface of each testis. It helps in maturation of sperms. It is divided into three parts - (i) Head (ii) Body (iii) Tail

Vas deferens:-The epididymis continues into straight tubule known as **vas deferens** that ascends to the urinary bladder. It joins the duct of the seminal vesicle to form the ejaculatory duct.

Ejaculatory duct :-The Ampulla of vas deferens and duct of seminal vesicle combine to form a common duct that opens into the urethra.

Urethra:-It originate from the base of urinary bladder and extend through penis to its external opening **called the urethral meatus.**

2.Accessory Glands :- It includes;

1. Seminal vesicle – **Paired**
2. Prostate- **Unpaired/ Single**
3. Cowper's/ Bulbourethral - **Paired**

Seminal Vesicle – These the paired structures. These glands secrete **seminal fluid** which makes **60 to 70%** fructose, calcium and other substances that support sperm function.

Prostate gland – It is single. It secrete **prostatic fluid** which make **20 to 30%** part of semen. It contains

Cowper's Gland – These are paired, pea-sized glands present on either side of membranous urethra. Their helps lubricate the penis and urethral passage.

- Secretions of the male accessory glands form seminal plasma, which is rich in fructose, calcium and certain **enzymes.**
- **Seminal plasma together with sperm constitutes semen.**
- **Secretions of the accessory ducts and glands support the maturation, motility and transport of sperm.**

3.External Genitalia:-

a. **Penis-** Male copulatory organ-Helps in insemination.

b. **Scrotum-** Supports the testes.

a. **Penis -**

- The penis is the male external genitalia in human being and act as a copulatory organ.

- It is made up of erectile spongy tissue. When spongy tissue filled with blood that helps in erection of the penis to facilitate **insemination.**
- The enlarged terminal end is the glans penis, which is covered by a loose fold of skin called the **foreskin.**

b. **Scrotum:-** The scrotum is a pouch outside the abdominal cavity that contains the testes.

- During foetal life, the testes normally descend from the abdominal region into the scrotum through **^{h}month** of the the inguinal canals.
- The scrotum helps in maintaining the low temperature of the testes ($\mathbf{2-2.5}^{\circ}\mathrm{C}$ lower than the normal internal body temperature) necessary for **spermatogenesis.**

2.2. The Female Reproductive System

The female reproductive system consists of a pair of ovaries, a pair of oviducts, the uterus, cervix, **vagina and external genitalia, mainly located in the pelvic region.**

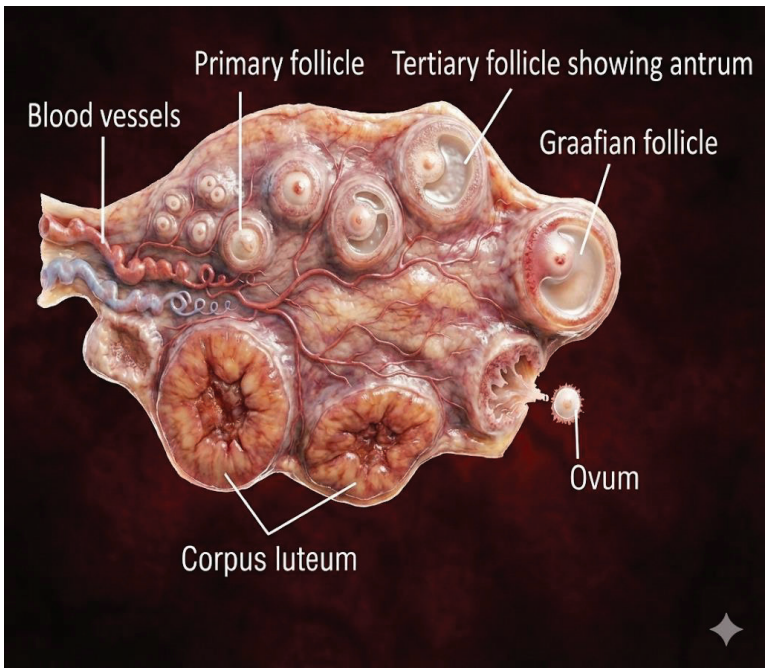
A. Primary reproductive organs :-

A pair of Ovaries - It has two functions ;

(i) Formation of female gametes (ova).

(ii) Secretion of ovarian hormones such as estrogens and progesterone.

- The ovaries are located one on each side of the lower abdomen.
- Each ovary is about **2 to 4 cm** in **length** and **2cm in width.** It is connected to pelvic wall and uterus by **ligaments.**
- Usually one secondary oocyte is ovulated during each menstrual cycle.
- Each ovary is covered by a thin epithelium which encloses the **ovarian stroma.**
- The stroma is divided into two zones - a **peripheral cortex** and an **inner medulla.**



B. Secondary/Accessory reproductive organs:-

1. **Accessory Ducts:-**It includes ;
   (i) Fallopian tube/Oviduct
   (ii) Uterus/Womb
   (iii) Vagina

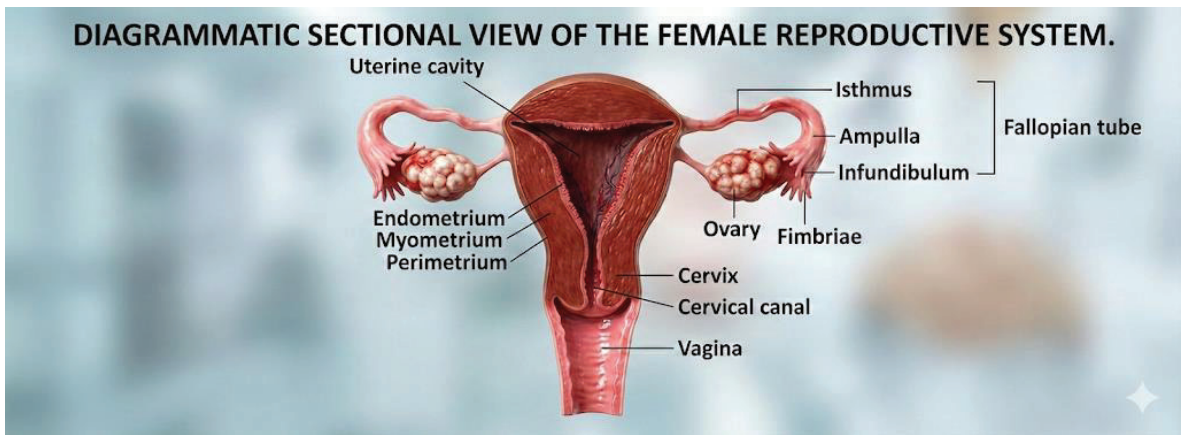
Fallopian tube/Oviduct –

- A pair of fallopian tubes are present in a female reproductive system.
- Each fallopian tube is ciliated, musucular tube and is measuring about **10 to 12 cm** in length.
- It extends from the **periphery of each ovary to the uterus.**
- It is divided into three parts – **Infundibulum, Isthmus, ampulla**

a. **Infundibulum –** It is a funnel shaped structure present near to ovary. The edges of the Infundibulum poses finger-like projections called **fimbriae**. It helps in collection of **2° oocyte** released by ovary.

b. **Ampulla -**It is the middle wider part of oviduct, where fertilization will occur.

c. **Isthmus** – It is the last part of oviduct close to uterus, which has a narrow lumen and it joins with the uterus.



UTERUS OR WOMB

- The uterus is **single** and it is also called **womb** or **hystera**.
- The shape of the uterus is like an **inverted pear.**
- It is present in the pelvis between the **bladder** and the **rectum**.
- It is highly vascularised organ and it is supported by **ligaments** attached to the **pelvic wall.**
- It is divided into three parts namely; **Fundus or body ,Uterine cavity** and **Cervix.**

a. **Fundus –** It is the upper dome shaped part present between to fallopian tubes.

b. Uterine cavity– It is a central main portion of uterus

c. Cervix -It is the lower cylindrical part of uterus. The cavity of cervix is called **cervical canal.**

- The uterus opens into vagina through this narrow **cervix.** The **Cervical canal along with vagina** forms the **birth canal.**
- The wall of the uterus has three layers of tissue namely;

a. **Perimetrium –** It is a external thin membranous layer.

b. **Myometrium -** Middle thick layer of smooth muscle, exhibits strong contraction during delivery of the baby.

c. **Endometrium -** Inner glandular layer, that lines the uterine cavity. It undergoes cyclical changes during menstrual cycle.

VAGINA

It is long tube extend from cervix to the outside of body. It opens to the exterior between **urethra** and **rectum**.It act as a **copulatory chamber.**

Functions of vagina:-

- ❖ It provide passage for menstrual flow.
- ❖ It receive sperms during intercourse.
- ❖ Also form the part of birth canal during delivery of baby.

2. Accessory Glands :-

a. **Bartholin's gland :-**The **Bartholin's glands** are located posterior to the left and right of the opening of the vagina. They secrete **mucus** to **lubricate the vagina** and are homologous to the bulbourethral glands of the male.

b. Skene's gland :-The **Skene's glands** are located on the anterior wall of the vagina and around the lower end of the urethra. They secrete a lubricating fluid to lubricate vagina.

3. External Genitalia/Vulva:-The female external genitalia include **mons pubis, labia majora, labia minora, hymen and clitoris.** They are collectively known as **vulva.**

a) Mons pubis : Mons pubis or mons veneris is a **cushion of fatty tissue** covered by **skin** and **pubic hair.** It lies over pubic symphysis.

b) Labia majora : The labia majora are **fleshy folds of tissue,** which extend down from the mons pubis and **surround the vaginal** and **urethral openings.**

c) Labia minora : The labia minora are **paired fleshy folds of tissue under the labia majora.**

d) Clitoris : The clitoris is a **small erectile tiny finger-like structure** which lies at the upper junction of the **two labia minora** above the urethral opening.

e) Hymen - The opening of the vagina is often covered partially by a perforated membrane called **hymen**. The hymen is **often torn during the first coitus (intercourse).**

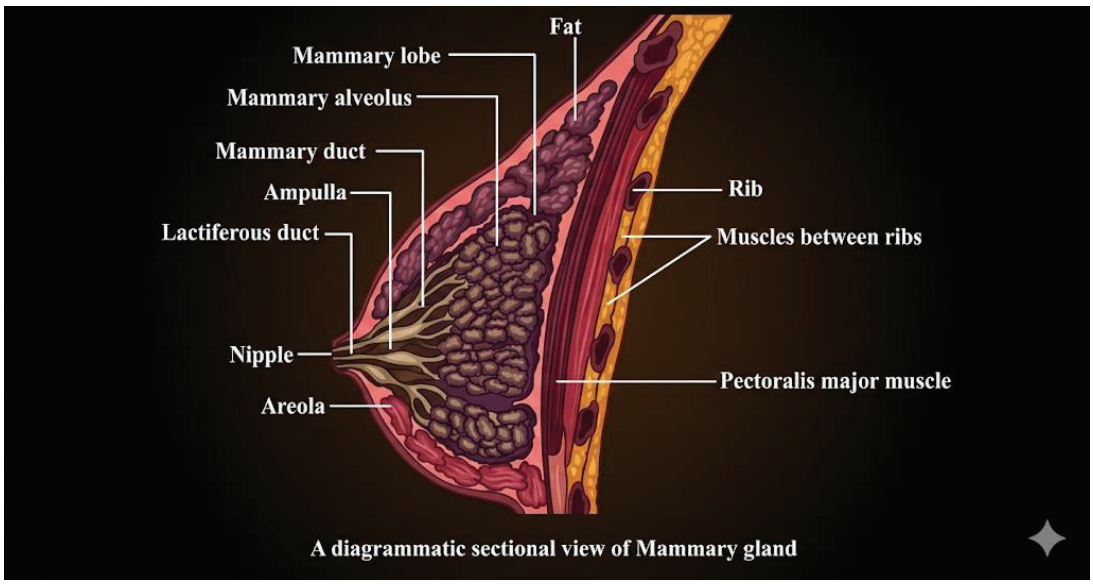
❖ **Why the presence or absence of hymen is not a reliable indicator of virginity or sexual experience?**

Because it can also be broken by a **sudden fall or jolt, insertion of a vaginal tampon, active participation in some sports like horse riding, cycling,** etc. In some women the hymen persists even after coitus.

4. Mammary Glands:- Presence of **functional mammary gland** is characteristic of all **female mammals.**

- ❖ They begin to develop at the time of puberty, under the influence of **estrogen** and **progesterone** hormones.
- ❖ They commonly called as **breasts.**

- ❖ Externally each breast has a projection known as ***nipple*** and which is surrounded by a circular pigmented area of skin known as ***areola.***
- ❖ The mammary glands contain **glandular tissue** and a **variable amount of fat.**
- ❖ The glandular tissue of each breast is divided into **15–20** ***mammary lobes*** containing clusters of cells called ***alveoli.***
- ❖ The **cells of alveoli secrete milk**, which is stored in the **cavities (lumens) of alveoli**. *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.**



A diagrammatic sectional view of Mammary gland

Functions of Mammary Glands

1. Secretion and ejection of milk which is known as lactation.
2. Lactation is associated with pregnancy and child birth.
3. Helps the mother in feeding the new born.

Hormonal influence

1. **Estrogen** and **progesterone**- Stimulate the development of mammary gland.
2. **Prolactin -** Stimulate milk production.
3. **Oxytocin -** Stimulate ejection of milk.

Note :- **Colostrum**

★ The milk produced in the initial few days of lactation ,it contain antibodies(IgA) essential to develops resistance for new born.

★ Highly recommended by doctors in initial period of infant growth for bringing healthy baby.

2.3. GAMETOGENESIS

- ❖ It is a process of **formation and diff**erentiation of haploid **gametes** in diploid gonads. It include **spermatogenesis** (in males) and **oogenesis (**in females **).**

1. **SPERMATOGENESIS:-** The process of formation of haploid sperm in males from diploid spermatogonia in Seminiferous tubules of testis is called **spermatogenesis.**
2. **OOGENESIS :-** The process of formation of haploid ovum from oogonia in the ovary is **Oogenesis**.
   - ❖ Both sperm and ovum originate from primordial germ cells.
   - ❖ The gametogenesis divided into three stage –
     a. Multiplication phase
     b. Growth phase
     c. Maturation phase- longest phase
   - ❖ Gametogenesis is regulated by three hormones - GnRH, LH and FSH

1. SPERMATOGENESIS

- ❖ In testis, the immature male germ cells (spermatogonia) produce sperms by spermatogenesis that begins at puberty.
- ❖ It is the process of formation of haploid sperms in seminiferous tubules of testis is called
- ❖ **spermatogenesis.** It begins at **puberty.**
- ❖ Male can produce sperms through its entire life.
- ❖ The process of Spermatogenesis can be studied under two steps namely; **(1) Formation of spermatids** and **(2) Formation of sperms from spermatid (**Spermiogenesis**)**

(1) Formation of spermatids **Spermatocytogenesis** **:-**

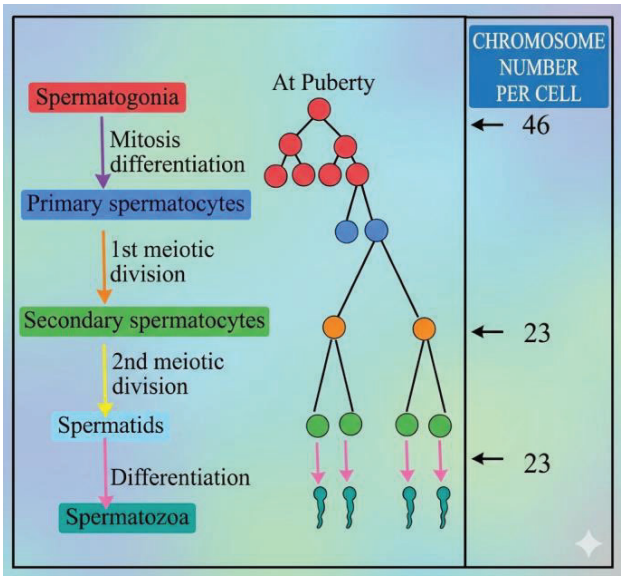
a. **Phase of Multiplication -** In this phase ,the **spermatogonial mother cells** present Inside the **seminiferous tubules** are divides several times by **mitosis** to produce large number of **spermatogonia.** Each cell is diploid with 46 chromosomes.

b. **Growth phase –** In this phase some spermatogonia **actively grows** by obtaining nourishment from **Sertoli cells** and **increase in size** to form a large **primary spermatocytes**. Each primary Spermatocyte is **diploid cell** and **have 46 chromosome**.

c. **Maturation phase –** In this phase some of the primary spermatocytes periodically undergo meiosis.
   - A primary spermatocyte completes the **first meiotic division** (reduction division) leading to formation of two equal, haploid cells called **secondary spermatocytes,** which have only 23 chromosomes in each.
   - The secondary spermatocytes undergo the **second meiotic division** to produce four equal **haploid cells** called **spermatids.**

(2) Formation of sperm from spermatid (Spermiogenesis):-

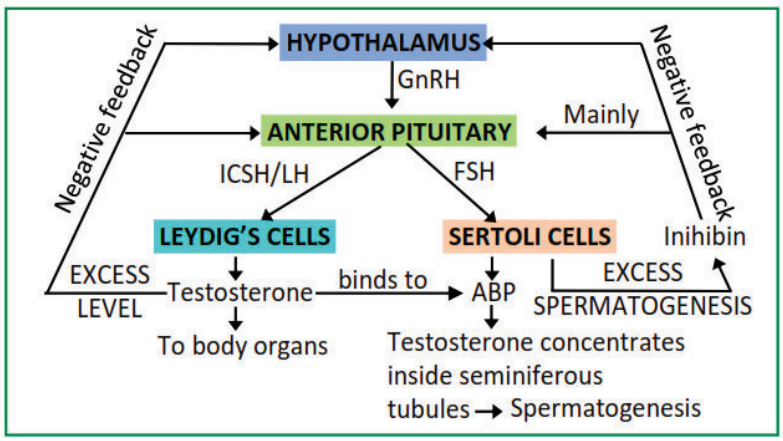
- ❖ The process of transformation of spherical non-motile spermatids into tad-pole like spermatozoa (Sperms) is called **Spermiogenesis**.
- ❖ After Spermiogenesis, sperm heads become embedded in the Sertoli cells, and are finally released into the seminiferous tubules by the process called **spermiation.**



Schematic representation of Spermatogenesis

Hormonal regulation of Spermatogenesis

- Around 7 million oogonia are formed upto 25th week of intrauterine life/ foetal life.
- Hypothalamus releases **Gonadotropin releasing hormone (GnRH).**
- GnRH stimulates the anterior pituitary gland to secrete 2 **gonadotropins** such as **Luteinizing hormone (LH)** and **follicle stimulating hormone (FSH).**
- **LH/ICSH** acts on the **Leydig cells** and stimulates secretion of **androgens**.
- Androgens stimulate the process of **spermatogenesis.**
- FSH acts on the **Sertoli cells** and stimulates secretion of some factors helps in the process of **Spermiogenesis.**



STRUCTURE OF SPERM

- It is a microscopic haploid motile structure. A mature sperm is about **0.06 mm** long.
- A plasma membrane envelops the whole body of sperm.
- It is consists of a **head**, **neck**, a **middle piece** and a **tail.**

1.Head :– It is a large pear shaped part. It contains an large **haploid nucleus** with parental chromosomes.

- The nucleus of sperm anteriorly contains a cap like structure called **acrosome.** It is derived from **Golgi complex of spermatid.**

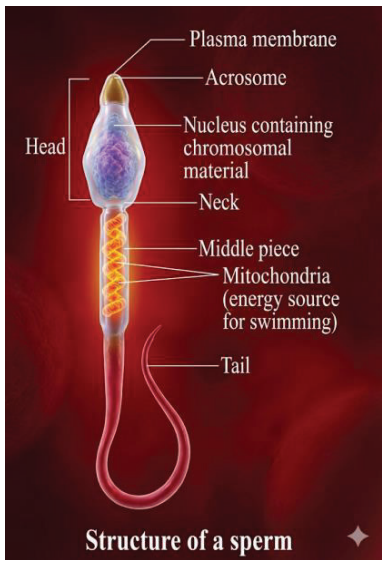
- The acrosome is filled with **enzymes (sperm lysins)** that help **fertilisation of the ovum.**

2.Neck :- It is a small constriction present between head and middle piece .

- It contain **proximal** and **distal centriole** .The proximal centriole plays a role in the first division of the zygote.
- The distal centriole produce **axial filament** or **axoneme.** It runs throughout the length of the sperms forming the central axis of the tail.

3.Middle piece :- It is the middle part of the sperm. It contains numerous **mitochondria**, which **produce energy** for the movement of tail that **facilitate sperm motility** essential for **fertilisation.**

4.Tail – It is the longest part of the sperm. Its vibratory action helps in movement of sperm.



- The human male ejaculates about **200** to **300** million sperms during a coitus of which, for normal fertility,
  1. At least **60 percent** sperms must have normal shape and size
  2. At least **40 percent** of them must show vigorous motility.
- Seminal plasma along with sperms constitute **Semen.**

Note : About 3-5 ml of semen is ejaculated at each coitus in man. 1 ml of semen has nearly 100 million sperms. The count below 20 million/ml leads to infertility(oligospermia).The absence of sperms in semen is called **Azoospermia.**

2. OOGENESIS

- The process of formation of a mature female gamete is called **oogenesis** which is markedly different from spermatogenesis.
- Oogenesis is initiated during the embryonic development stage.
- The diploid cells of germinal epithelium (oogonia) gets converted into haploid ovum. It involves following phases :

A. Multiplication Phase-

- In this phase ,the diploid primordial germ cells repeatedly divide by mitosis to form large number of **diploid oogonia** or **egg mother cells** (2n) in each foetal ovary.

- ❖ Around **7 million oogonia** are formed upto **25th week** of intrauterine life/ foetal life.
- ❖ No more oogonia are formed after birth.
- ❖ Oogenesis in female only continues upto the age of around **50 years** the period after this is known as **menopause.**

B. **Growth Phase –** In this phase ,the oogonia grow in size (due to accumulation of food materials) and form **primary oocytes.**

C. **Maturation phase –** In this phase, the primary oocytes begins the **first meiotic division** which proceed upto **diplotene stage of prophase - I** and **get arrested in this phase till the puberty.**

- ❖ **At the puberty** the primary oocytes **complete the meiosis - I,** by **unequal cytokinesis** results in forming a **large secondary oocytes** (Contain large amount of cytoplasm) and a **smaller first polar body** (Contain less amount of cytoplasm).
- ❖ **The first polar body may degenerate or may divide.**
- ❖ The secondary oocyte enters meiosis II and is arrested at metaphase II until fertilisation.

- ❖ At ovulation, a secondary oocyte arrested at metaphase II is released from the ovary.

- ❖ After ovulation the secondary oocytes reaches the **ampulla of fallopian** tube and for further development the secondary oocyte has to wait for arrival of spermatozoa for completion of second meiotic division.

Fate of secondary oocytes in fallopian tube which was arrested in metaphase - II.

1. **If the sperm arrives, then it resume the cell cycle** -The meiosis-II completes and divide the secondary oocyte by unequal cytokinesis into ovum (Contain large amount of cytoplasm) and second polar body (Contain less amount of cytoplasm).
2. **If the sperm did not arrives**, then the second meiotic division will not complete and secondary oocyte degenerates in fallopian tube in its arrested stage.

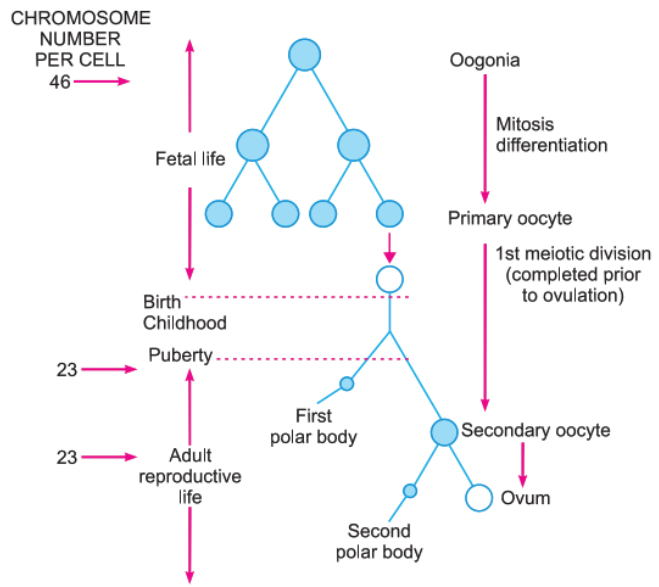


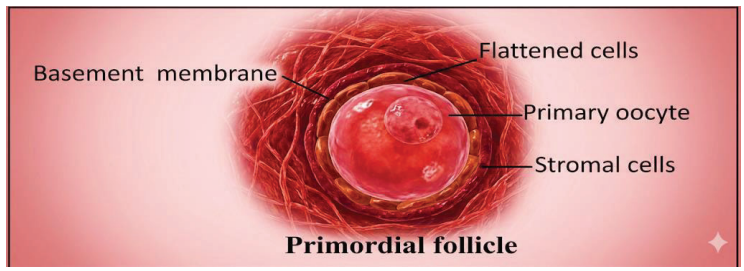
Fig. 2.11 Systematic representation of oogenesis

Folliculogenesis -

- Ova develops from oogonia in the cortex of ovary, during this development **oogonia are surrounded by cells of stroma** for the purpose of **nutrition** and **protection.**
- The stromal cells will form the **ovarian or Graafian follicle** that surround the oocyte. This process of formation of follicles around the oocytes is known as **folliculogenesis.**

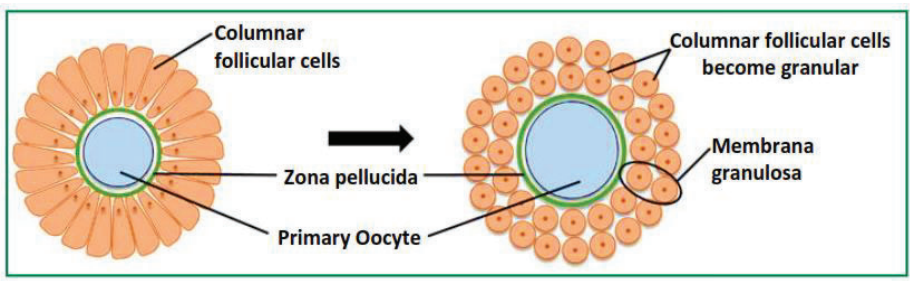
Developing stages of follicle -

1. **Primodial follicle -** During the embryonic development some of the stromal cells (Follicular cells) surround the primary oocyte known as **primordial follicle.**



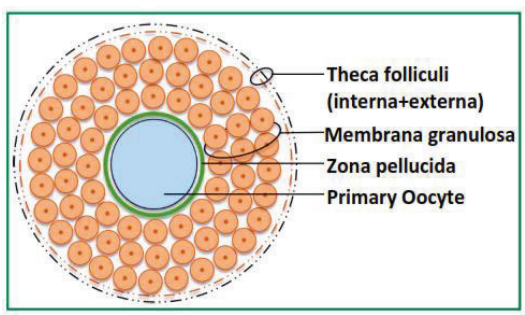
2. **Primary follicle –**

- **Formation of zona pellucida-** A glycoprotein membrane appear between the primary oocyte and follicular cells is known as zona pellucida.
- **Formation of membrana granulosa-** The follicular cells proliferate to forms several layers of cells (and now known as granulosa cells) to form **membrana granulosa.**
- A large number of these **follicles degenerate** during this phase from **birth to puberty**.
- Primary oocyte surrounded by a layer of granulosa cells is called the **primary follicle.**
- **At puberty only $60,000 - 80,000$ primary follicles are left in each ovary.**



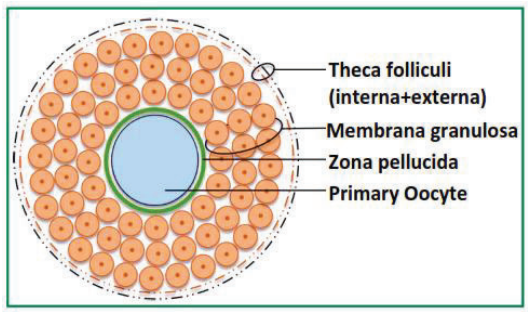
3. **Secondary follicle –**

- At puberty under the **influence of gonadotropic hormones,** in each menstrual cycle some of the **primary follicle** transform into **secondary follicle.**
- The follicles surrounded by more layers of granulosa cells and a new theca and are called **secondary follicles.**
- Formation of **theca layer**, it release **estrogen hormone.**



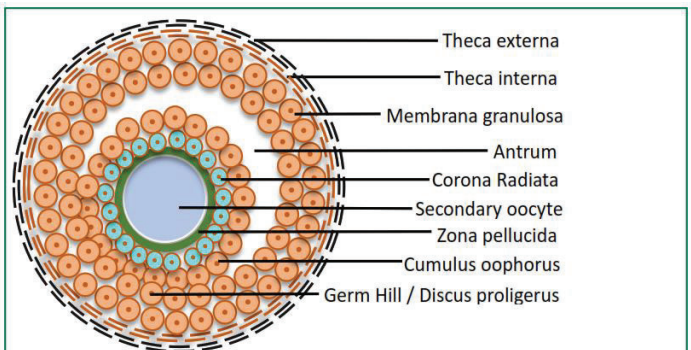
4. **Tertiary follicle –**

- The **secondary follicle soon transforms into a tertiary follicle** which is characterised by a fluid filled cavity within the membrana granulosa called **antrum**, filled with liquid.
- The theca layer is clearly organised into an **inner theca (interna)** and an **outer theca(externa).**



5. **Mature Tertiary/ Graafian follicle –**

- The tertiary follicle further changes into the mature follicle **called Graafian follicle.**
- The cavity of follicle rapidly increase in size and get fill with liquid.
- It is externally covered by a **outer fibrous theca externa** and **inner theca interna** with **connective tissue** and **blood capillaries.** Inner to the theca **multilayered membrane granulosa** is present**.**
- A fluid filled cavity called **antrum (**Secreted by memberane of granulosa cells**)** is present Inside the Graafian Follicle.
- The Graafian Follicle contains Ovum.It is **with very little yolk type.**
- The Ovum contains haploid nucleus, ooplasm. It is surrounded by **plasma membrane** (Vitelline memberane), **Zona pellucida** (both are primary egg membranes) ,**Corona radiata** (secondary egg membrane).The cells of corona radiata are held together by **hyaluronic acid.**
- The projection of granulosa cells covering the oocyte into antrum is called **cumulus oophorus (germ hill).**
- Due to increase in size of cavity the wall of follicle became thin.
- At this stage the primary oocyte converts into secondary oocyte by completing its first meiotic division.



Note : Corona radiata formed by follicle cells before it leaves the ovarian follicle

6. **Rupture Graafian follicle -** After 13th day of menstrual cycle (on the 14th day of ideal cycle) The Graafian follicle now ruptures to release the **secondary oocyte** from the ovary by the process called **ovulation.** due to maximum level attained by LH (LH surge).

7. **Corpus luteum –** After ovulation, the granulosa cells of ruptured Graafian follicle proliferate and filled with yellow pigment known **lutein** and **become luteal cells.** This yellow structure which is made up of luteal cells is known as **corpus luteum.**

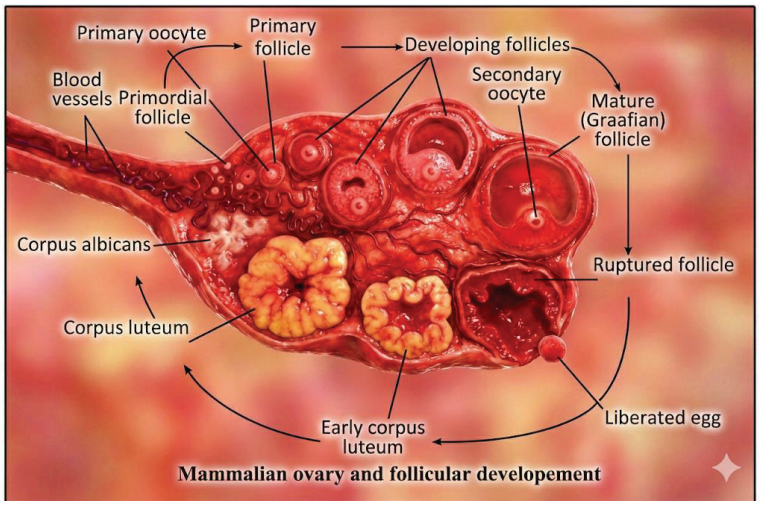
Note - Corpus luteum act as temporary endocrine structure which secrete progesterone, estrogen, relaxin and inhibin.

Fate of Corpus luteum -

- If pregnancy does not occur, the corpus luteum remains functional for about 10-14 days after ovulation.
- Its continued maintenance in early pregnancy depends mainly on hCG after implantation.

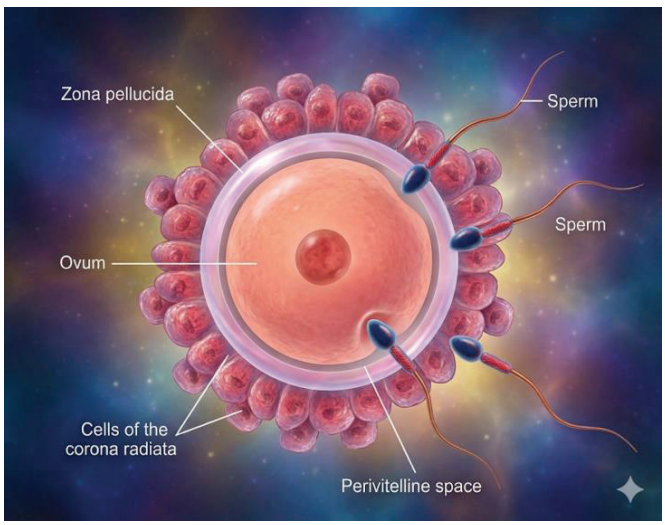
(1) If pregnancy occurs, hCG maintains the corpus luteum during early pregnancy; the placenta later becomes the major endocrine source.

(2) If pregnancy does not occur, the corpus luteum degenerates and forms the corpus albicans.



Mammalian ovary and follicular developement

Structure of mature egg or Ovum



- It is a haploid non-motile female gamete. About **0.2 mm** in diameter.
- Human egg is spherical in shape and surrounded by oolemma, in which enclosed ooplama is present.
- The peripheral ooplasm contains cortical granules.
- The central ooplasm contains cytoplasmic organelles but lacks centrioles.

❖ The secondary oocyte is haploid and arrested at metaphase II. It contains very little yolk; glycogen and lipid globules are present.

❖ It has 3 membranes namely;

a. Oolemma or plasma membrane.

b. Zona pellucida

c. Corona radiata.

a. **plasma membrane:** Innermost layer

b. **zona pellucida:**It is the primary egg membrane and is a non-cellular structure lies outside the plasma membrane. There is a narrow space between zona pellucida and plasma membrane is called perivitelline space.

c. **Corona radiata:** It is composed of granular cells found external to zona pellucida, their cells project finger like microvilli to guard the egg.

Table 3.7. Differences between Sperm and Egg

Sperm	Egg
1. Male gamete	1. Female gamete
2. Motile	2. Non- motile
3. Smaller in size	3. Larger in size
4. Tadpole shaped	4. Spherical in shaped
5. Acrosome is present	5. Acrosome is absent
6. No extra protective membranes	6. Has additional protective membranes
7. Axial filament is present	7. Absent
8. Centrioles are present	8. Centrioles are absent
9. Nebenkern sheath is present.	9. Absent.
10. Has a single set of paternal chromosomes.	10.It has single set of maternal Chromosomes

Table 3.8. Differences between Spermatogenesis and Oogenesis

Spermatogenesis	Oogenesis
1. It is the process of formation of sperms.	1. It is the process of formation of ova or eggs.
2. It Occurs in the seminiferous tubules of the testis	2. It occurs in ovaries.
3. Polar bodies are not formed.	3. Polar bodies are formed during oogenesis.
4. Cytokinesis is equal	4. Cytokinesis is unequal
5. Growth phase is insignificant.	5. Growth phase is significant
6. Each spermatocyte produces 4 sperms	6. Each oocyte produces one functional ootid and 3 polar bodies.

2.4. Menstrual Cycle

❖ The reproductive cycle in the female primates (e.g., monkeys, apes and human beings) is called **menstrual cycle** or The cyclical changes in the activities of ovaries and accessory ducts as well as hormones during reproductive phase of primate mammals is called **menstrual cycle.**

❖ In human females, menstruation is repeated at an average interval of about **28/29 days.**

- The first menstruation begins at puberty and is called **menarche.**
- Menstrual cycles cease around **50 years of age**; it is termed as **menopause.**
- One egg or ovum is released during the middle of menstrual cycle. Pregnancy inhibits the ovulation.
- Lack of menstruation can be due to **-Pregnancy, Stress, Poor health** etc.

The major phases or events of the menstrual cycle :-The menstrual cycle consist of four phases namely ;

1. **Menstrual/Bleeding phase**
2. **Pre-Ovulatory/Follicular/Proliferative phase**
3. **Ovulatory phase**
4. **Post-Ovulatory phase**
5. **Post Ovulatory phase /Luteal phase /Secretory phase**

1. Menstrual /Bleeding Phase(1 –5th day)

- The first menstruation begins at puberty and is called **menarche.**
- The amount of **gonadotropins (**FSH and LH **)** and **ovarian hormone** (Progestorone and estrogen) is considerably low.
- There is no significant changes. There is no corpus luteum in ovary, it gets already degenerated. As there is no corpus luteum progesterone and estrogen reduces considerably.
- Low level of progesterone and estrogen causes breakdown of endometrial lining of uterus and its blood vessels which forms liquid that comes out through vagina, this is known as menstrual flow. Menstrual flow occurs and it last for **3 to 5 days.**
- Next menstruation occurs only if the released ovum is not fertilized.
- Lack of menstruation is the indication of pregnancy.

2. Pre-ovulatory / Follicular / Proliferative / Estrogenic Phase (Between 6th – 13th day)

- It starts from **5th day** after menstruation and completed within **8-12 days.**
- In this phase under the influence of **GnRH** secreted by **hypothalamus**, the level of **gonadotropins (FSH and LH)** and **ovarian hormone (Estrogen)** begin to rise.
- The secretion of **FSH/LH** from **anterior pituitary gland** stimulate the **primary follicles** in the ovary to grow and become a fully mature **Graafian follicle**. This stimulate the secretion of estrogen from developing follicles. Growing follicles secrete **estrogen.**
- **Oestrogen stimulate:**
- The endometrium of uterus regenerates through proliferation (endometrial hyperplasia caused by estogen). Ultimately, thickness of uterine wall is gradually increased.
- Development of secondary sexual characters.
- Suppression of FSH secretion and Secretion of LH

3. Ovulatory Phase - It is the phase of **rupturing of follicle** and **releasing of gamete.**

- Estrogen secretion in the previous phase stimulate the anterior pituitary for the secretion of **LH** and **FSH,** due to which LH and FSH attains a peak level in the **middle of cycle (About 14th day).**

- ❖ The peak level of LH (LH Surge) induce the **rupturing of Graafian follicle,** thereby releasing the gamete, it is known as **ovulation.**
- ❖ The released gamete reaches ampulla of fallopian tube, expected to get fertilized.
- ❖ The uterine wall became more thick.

4. Post-ovulatory / Luteal / Secretory / Progesterone Phase -

- ❖ In an ideal menstrual cycle of **28 days**, this phase usually include the cycle days between 15^{th} to 28^{th} day.
- ❖ Between **15^{th} to 23^{rd} day,** it has high level of **progesterone** and **comparatively mild level of estrogen** and, the level considerably reduced between **23^{rd} to 28^{th} day.**
- ❖ The **amount of GnRH, FSH and LH reduces** significantly **throughout the phase.**
- ❖ After **ovulation**, the remaining parts of the **Graafian follicle** (or ruptured Graafian follicle) transform as the corpus luteum. This corpus luteum releases large amount of progesterone and comparatively small amount of estrogen.

Functions of Progesterone:-

- ❖ Makes the endometrium maximum **vascular, thick and soft**. Thus ,the uterus gets ready for implantation.
- ❖ It inhibits the further secretion of **GnRH** from hypothalamus and **FSH** and **LH** from anterior pituitary.
- ❖ In the **absence of fertilisation** (pregnancy), due to declining level of **estrogen** and **progesterone**, the thickness of uterine wall decreases in terminal stage of this phase.
- ❖ **During pregnancy** all events of the **menstrual cycle stop** and there is **no menstruation.**
- ❖ **Menstruation only occurs** if the released **ovum is not fertilised.**
- ❖ **Lack of menstruation** may be **indicative of pregnancy.** However, it may also be caused due to some other underlying causes like stress, poor health etc.

Menstrual Hygiene

- ❖ **Maintenance of hygiene** and **sanitation** during menstruation is very important.
- ❖ Take bath and clean yourself regularly.
- ❖ Use sanitary napkins or clean homemade pads.
- ❖ Change **sanitary napkins** or **homemade pads** after **every $4-5$ hours** as per the requirement.
- ❖ Dispose of the used sanitary napkins properly wrapping it with a used paper. Do not throw the used napkins in the drainpipe of toilets or in the open area.
- ❖ After handling the napkin wash hands with soap.

2.5. Fertilisation

- ❖ The process of fusion of male gamete (sperm) and female gamete (ovum) and result in formation of **diploid zygote** known as **fertilisation.**
- ❖ During copulation (coitus) semen is released by the penis into the vagina (**insemination**).
- ❖ The **motile sperms swim rapidly,** pass through the cervix, enter into the uterus and finally **reach the ampullary region** of the fallopian tube.

- The **ovum released by the ovary** is also transported to the **ampullary region** where fertilisation takes place.
- Fertilisation can only occur if the **ovum** and **sperms** are **transported simultaneously** to the **ampullaryisthmic junction.** This is the reason why not all copulations lead to **fertilisation** and **pregnancy.**

Mechanism of Fertilisation -

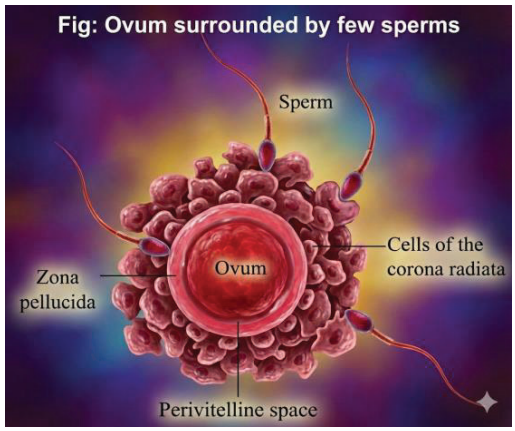
1. Movement of sperm toward the secondary oocyte.
2. Penetration of corona radiata and zona pellucida by releasing sperm lysins present in
3. the acrosome of sperm, providing passage to secondary oocyte.
4. After penetrating zona pellucida, sperm fuse with the plasma membrane of secondary oocyte.
5. Phagocytosis of sperm by secondary oocyte.

a) completion of meiosis - II resulting in the formation of **ovum** and **second polar body.**

b) Once the sperm enters the secondary oocyte, it causes the **cortical reaction,** which produces changes in the **zona pellucida** that **block the entry of additional sperms(polyspermy)** .Thus, it ensures that only one sperm can fertilize an ovum.

6. After formation of ovum, the nucleus of sperm fuse with the nucleus of ovum resulting in formation of **diploid zygote.**

Fig: Ovum surrounded by few sperms



SEX DETERMINATION

- Determination of the sex at the time of fertilization.
- The chromosome pattern in the human female is XX and that in the male is XY.
- Therefore, all the haploid gametes produced by the female (ova) have the sex chromosome X whereas in the male gametes (sperms) the sex chromosome could be either X or Y .
- Hence, in male 50% of sperms carry the X chromosome while the other 50% carry the Y chromosome, while Female has 100 % X chromosome in its every gamete.
- After fusion of the male and female gametes the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum. The zygote carrying XX would develop into a female baby and XY would form a male.

❖ That is why, scientifically it is correct to say that the sex of the baby is determined by the father and not by the mother.

CLEAVAGE AND IMPLANTATION

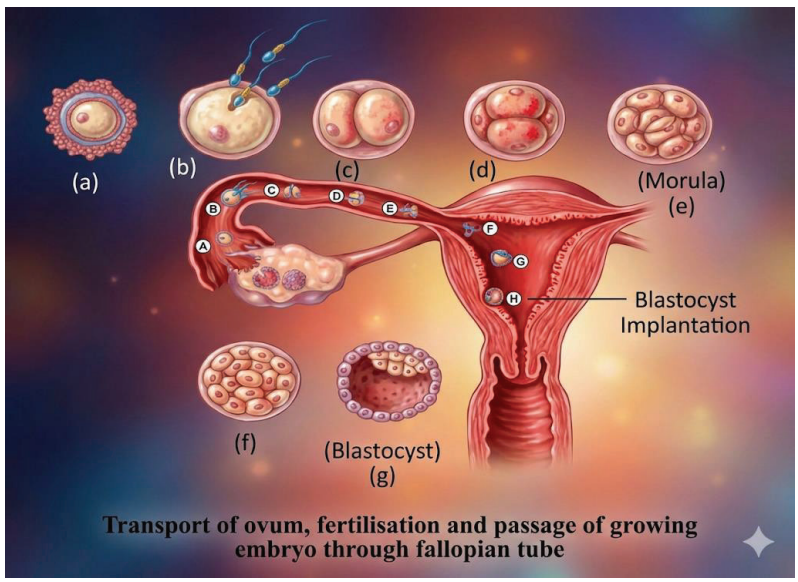
a. Cleavage

✓ The process through which a single celled **zygote** undergoes repeated mitotic division and changes into a complex multicellular structure without increasing its size known as **cleavage.**

✓ Due to the process of cleavage, a single celled **zygote**, through a successive mitotic cell divisions changes into a complex multicellular structure. Cells produced as a result of cleavage are termed as **blastomeres.**

b. Morulation :-

✓ Cleavage start as the zygotes moves through the isthmus of oviduct toward the uterus, resulting in the formation of 2, 4, 8, and 16 blastomeres which look like **mulberry.** This stage is termed as **morula stage.** The embryo with 8 to 16 blastomeres is called a **morula.**



Transport of ovum, fertilisation and passage of growing embryo through fallopian tube

c. Blastulation :-

✓ As the morula continues to divide a cavity appears between the cells called as **blastocoel**, after the formation of blastocoel the morula transforms into **blastocyst** as it moves further into the uterus.

✓ In blastocyst, blastomeres are arranged into **trophoblast** (outer layer) and an **inner cell mass** attached to trophoblast.

✓ The trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the **embryo.**

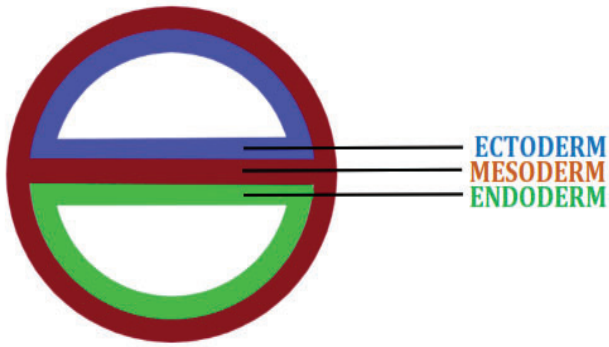
✓ In human being, the blastocyst gets attached with the uterine endometrium in about **four days** after entering in uterus.

d. Implantation :-

✓ After attachment, uterine cells divide rapidly and cover the blastocyst. Thus, the blastocyst becomes embedded in the endometrium. This is called **implantation**.

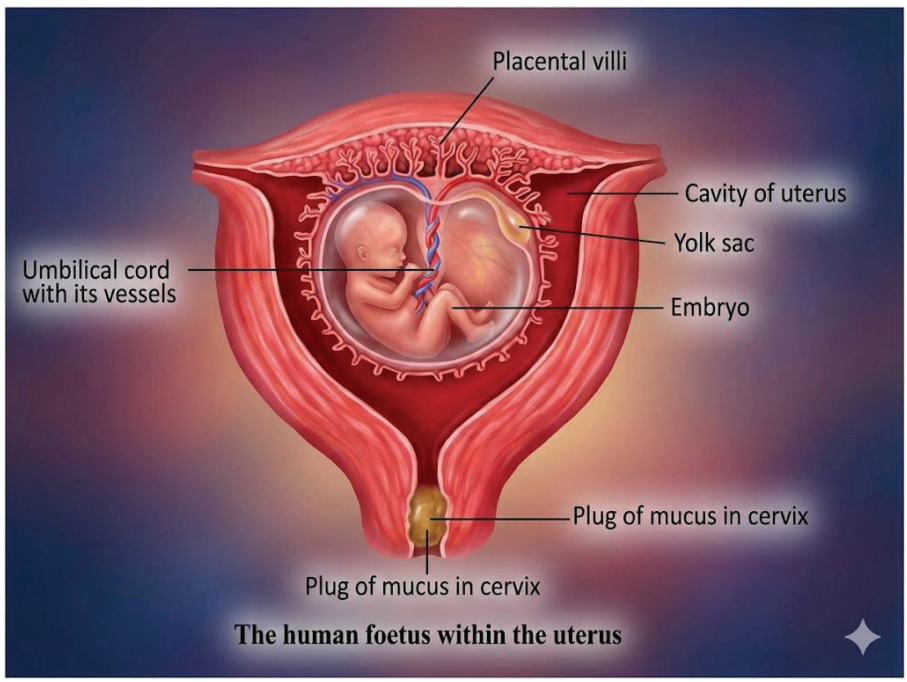
e. Gastrulation :-

✓ In this, the inner cell mass gets differentiated to **three germ layers** (outer **ectoderm**, middle **mesoderm** & inner **endoderm**).This three layered structure (**gastrula**) forms the embryo.



PREGNANCY AND EMBRYONIC DEVELOPMENT

- Pregnancy is the duration between conception and child birh. In human it is approximately **nine months** and **seven days.** This period varies in different animals. In **Cats** and **Dogs** it is **63 days** while in elephant it goes upto **623 days.**
- After implantation, finger-like projections appear on the trophoblast called **chorionic villi** which are surrounded by the **uterine tissue** and **maternal blood.**
- The chorionic villi and uterine tissue become interdigitated with each other and jointly form a **structural** and **functional unit** between developing embryo (foetus) and maternal body called **placenta.**
- The placenta is connected to the embryo through an umbilical cord which helps in the transport of substances to and from the embryo.



Function of Placenta -

Nutrition - The placenta facilitates the supply of nutrients to developing embryo.

Respiration- The placenta facilitates supply of oxygen to the embryo and also removal of carbon dioxide

3. **Excretion-** It help in removal of waste materials produced by the embryo.
4. **Provide passage for antibody -** IgG.
5. **Formation of Hormone -**

Placenta also acts as a temporary endocrine tissue and produces several hormones like

a. Human Chorionic Gonadotropin (HCG),

b. Human Placental lactogen (hPL),

c. estrogens,

d. progestogens etc.

Note : Relaxin hormone secreted by ovary.

Hormones for foetal growth and maintenance of pregnancy

- **hCG,hPL** and **relaxin** are produced in women only during pregnancy.
- During pregnancy the levels of other hormones like **estrogens**, **progestogens, cortisol, prolactin, thyroxine**, etc., are increased several folds in the maternal blood.
- Increased production of these hormones is essential for **supporting the fetal growth, metabolic** changes in the **mother and maintenance of pregnancy.**

2.6. Embryonic Development

- **Gestation** - The average duration of human pregnancy is about 9 months which is called the gestation period.
- Immediately after implantation, the inner cell mass (embryo) differentiates into an outer layer called **ectoderm** and an inner layer called **endoderm.**
- A **mesoderm** soon appears between the ectoderm and the endoderm.
- These **three layers give rise** to **all tissues (organs) in adults.**
- It needs to be mentioned here that the **inner cell mass** contains certain cells called **stem cells** which have the potency to give rise to **all the tissues** and **organs.**

The major features of embryonic development at various months of pregnancy:

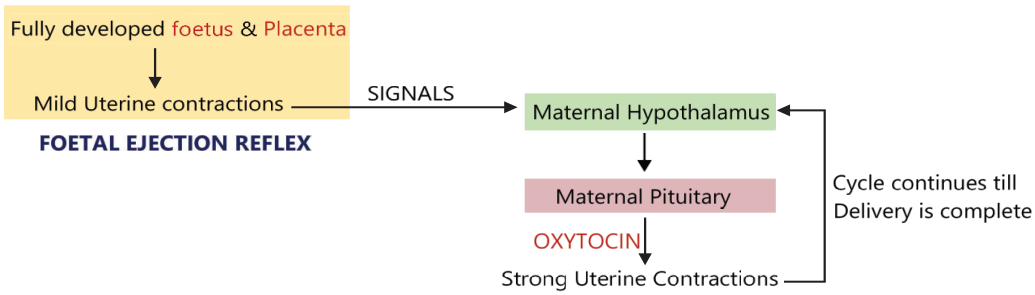
- The human pregnancy lasts **9 months** is called the **gestation period.**
- In human beings, after one month of pregnancy, the embryo's heart is formed. The first sign of growing foetus may be noticed by listening to the heart sound through the stethoscope.
- By the end of the second month of pregnancy, the foetus develops limbs and digits.
- By the end of **12 weeks** (first trimester), the limbs and external genital organs are well-developed.
- By the fifth month the first movements of the foetus and appearance of hair on the head are observed.
- By the end of **24 weeks** (second trimester), the body is covered with fine hair, eye-lids separate, and eyelashes are formed.
- By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

2.7. Parturition

- The process of delivery of the foetus (child birth) is called **parturition.**
- Parturition is induced by a complex **neuroendocrine mechanism** involving many hormones like corticotrophin releasing hormone, cortisol, estrogens, oxytocin, relaxin, etc.

- The signals for parturition originate from the **fully developed foetus** and the **placenta** which induce mild uterine contractions called **foetal ejection reflex.**
- This triggers release of oxytocin from the maternal pituitary. **Oxytocin(child birth hormone)** acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin.
- The stimulatory reflex between the uterine contraction and oxytocin secretion continues resulting in **stronger** and **stronger contractions**. This leads to expulsion of the baby out of the uterus through the **birth canal.**
- In short, vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus.
- Soon after the infant is delivered, the **placenta** is also expelled out of the uterus.
- Oxytocin strengthens uterine contractions during labour through a positive-feedback mechanism.
- Relaxin helps relax pelvic ligaments and facilitates parturition.

- After parturition, oxytocin stimulates milk ejection (milk let-down).
- **Note :- The average duration of human pregnancy is about 9 months (= 270 – 290 days).**



Lactation -

- Lactation is the production and secretion of milk by the mammary glands after childbirth.

- The mammary glands of the female undergo differentiation during pregnancy.
- The alveolar epithelium of mammary glands **synthesizes milk** and is stimulated by **prolactin of pituitary gland.**
- Suckling stimulates neural signals that promote prolactin secretion for milk production and oxytocin release for milk ejection.
- causes contraction of muscles cells around the alveoli of mammary glands resulting in the **milk ejection.**
- The milk produced during the initial few days of lactation is called **colostrum.** It contains several antibodies (**IgA**) absolutely essential to develop resistance [passive immunity] for the **new-born babies.**
- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

EXERCISE

PART - A

I. Select the correct alternative from the choices given: 1 Mark Each:

1. Scrotum helps in maintaining the temperature of testes which is A lower than the normal body temperature. Each of testes has about B compartments and measures C in length. Select the option that fills the blanks correctly.

A	B	C
a) $1-3°C$	250	4 – 6
b) $2-2.5°C$	250	4 – 5
c) $3-3.5°C$	300	2 – 3
d) $2-2.5°C$	250	2 – 3

2. Spot the odd one out from the following structures with reference to the male reproductive system.
a) Rete testis b) Epididymis c) Vasa efferentia d) Isthmus

3. Which of the following is not a male accessory gland?
a) Seminal vesicle b) Ampulla c) Prostate d) Bulbourethral gland

4. The vas deferens receives duct from the seminal vesicle and opens into urethra as
a) epididymis b) ejaculatory duct c) efferent ductile d) ureter

5. The function of myometrium layer present in the uterine wall is to
a) Undergo cyclical changes during menstrual cycle.
b) Exhibit strong uterine contraction during parturition.
c) Give protection to the uterus.
d) Help in the implantation process.

6. Sertoli cells are found in
a) ovaries and secrete progesterone
b) adrenal cortex and secrete adrenaline
c) seminiferous tubules and provide nutrition to germ cells
d) pancreas and secrete cholecystokinin

7. The cells that secrete testicular hormones (androgens) are ___ .
a) Sertoli cells b) Leydig cells c) Germ cells d) Spermatogonia

8. Seminal plasma in human males is rich in
a) Fructose and calcium b) glucose and calcium
c) DNA and testosterone d) ribose and potassium

9. Statement I: The process of release of sperms from the seminiferous tubule is called spermatogenesis.
Statement II: The spermatids are transformed into spermatozoa by the process called Spermiogenesis.
Choose the correct answer from the options given below:
a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect
c) Statement I is correct but statement II is incorrect
d) Statement I is incorrect but statement II is correct

10. In spermatogenesis, if FSH hormone is not secreted from the anterior pituitary gland, which stage is affected?

a) Formation of primary spermatocyte b) formation of spermatozoa
c) Formation of spermatid d) formation of secondary spermatocyte

11. To produce 2000 sperm and 400 ova, how many spermatogonia and oogonia are required?

a) 500 spermatogonia and 200 oogonia b) 500 spermatogonia and 400 oogonia
c) 250 spermatogonia and 250 oogonia d) 250 spermatogonia and 400 oogonia

12. Diploid number of chromosomes in a primary spermatocyte is 46. What is the total number of chromatids in each of its secondary spermatocyte?

a) 46 b) 23 c) 92 d) 69

13. The secondary spermatocytes undergo the second meiotic division to produce four equal, haploid

a) Spermatogonium b) Spermatids
c) Primary spermatocyte d) Secondary spermatocyte

14. The process of transformation of spermatids into sperm is

a) Spermiation b) Spermatogenesis
c) Spermiogenesis d) Insemination

15. The release of sperms from the seminiferous tubules is called ___ .

a) Spermiation b) Spermatogenesis
c) Spermiogenesis d) Spermioteliosis

16. What is the correct sequence of sperm formation?

a) Spermatogonia, spermatozoa, spermatocytes, spermatids
b) Spermatogonia, spermatocytes, spermatids, spermatozoa
c) Spermatids, spermatocytes, spermatogonia, spermatozoa
d) Spermatogonia, spermatocytes, spermatozoa, spermatids

17. In female oogenesis is initiated during

a) Ovulation b) Puberty
c) Childhood d) Embryonic development stage

18. Which among the following has 23 chromosomes?

a) Spermatogonia b) Zygote c) Secondary oocyte d) Oogonia

19. Gonadotropin Releasing Hormone (GnRH) is a hypothalamic hormone which stimulates pituitary gland to secrete

a) LH and FSH b) FSH and Oxytocin
c) LH and Oxytocin d) Progestorone

20. Identify the wrong pair with respect to menstrual cycle:

a) Formation of corpus luteum- 15^{th} to 28^{th} day
b) Secretion of progesterone -15^{th} to 28^{th} day
c) Regeneration of endometrium- 5^{th} to 13^{th} day
d) Disintegration of endometrium- 5^{th} to 13^{th} day

21. The corpus luteum secretes large amounts of progesterone, which is essential for maintenance of

a) Perimetrium b) Myometrium c) Endometrium d) Cervical canal

22. Progesterone hormone is secreted by

a) Testis b) Pituitary gland c) Corpus luteum d) Graafian follicle

23. Which of the following statement is true?

a) LH surge induces menstruation.

b) Regression of corpus luteum increases progesterone.

c) Diploid egg is formed after second meiotic division.

d) Embryo differentiates from the inner cell mass of blastocyst.

24. Match the items given in column I with those in column II and select the correct option given below.

Column I	Column II
A. Proliferative phase	(i) Breakdown of endometrial lining
B. Secretory phase	(ii) Follicular phase
C. Menstruation	(iii) Luteal phase

A B C

a) (iii) (ii) (i)

b) (i) (iii) (ii)

c) (ii) (iii) (i)

d) (iii) (i) (ii)

25. When does the second meiotic division occur in the secondary oocyte?

a) At the time of birth b) at the time of fertilization

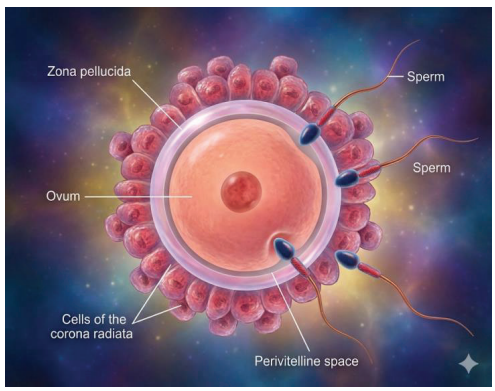
c) At the time of puberty d) at the time of ovulation

26. The secondary oocyte after ovulation is covered by a non-cellular layer of

a) Cumulus oophorus b) Corona radiata

c) Zona pellucida d) Cortical layer

27. Choose the correct option from the table given below for the formation and dissolution of the labeled part in the given diagram Formed by and dissolved.



a) Primary oocyte before fertilisation b) Primary oocyte after fertilisation

c) Secondary oocyte before fertilisation d) Secondary oocyte during fertilisation

28. Which of the following hormones is produced only during pregnancy?

a) hCG b) LH c) Estrogen d) FSH

29. The ___ hormone is secreted by the ovary in the later phase of pregnancy.

a) Androgens b) Estrogens c) Relaxin d) Progestogens

30. Which of the following hormones is not secreted by human placenta?

a) hCG b) Estrogens c) Progesterone d) LH

31. Morula is a developmental stage

a) Between the zygote and blastocyst

b) between the blastocyst and gastrula

c) After the implantation

d) between implantation and parturition

32. Which one of the following is not the function of placenta?

a) Facilitates removal of carbon dioxide and waste material from embryo

b) Secretes oxytocin during parturition
c) Facilitates supply of oxygen and nutrients to embryo
d) Secretes estrogen

33. During pregnancy the fetus develops limbs and digits

a) After three weeks b) after eight weeks
c) After six weeks d) after nine weeks

34. The first movements of the fetus and appearance of hair on its head are usually observed during which month of pregnancy?

a) Fourth month b) Fifth month c) Sixth month d) Third month

35. During embryonic development embryo's heart formed at the end of

a) First trimester b) Second trimester c) First month d) Third month

36. Signals for parturition originate from

a) Both placenta as well as fully developed fetus
b) oxytocin released from maternal pituitary
c) Placenta only
d) fully developed fetus only

Answer Key					
1. B	2. D	3. B	4. B	5. B	6. C
7. B	8. A	9. D	10. B	11. B	12. A
13. B	14. C	15. A	16. B	17. D	18. C
19. A	20. D	21. C	22. C	23. D	24. C
25. B	26. C	27. D	28. A	29. C	30. D
31. A	32. B	33. B	34. B	35. C	36. A

II. Fill in the blanks: 1 Mark Each:

(Oxytocin, Menarche, Placenta, Alveoli, Fimbriae, Ovulation, Antrum, Acrosome, Endometrium, Colostrum, Stem, Fertilization, Competent cells, Parturition, Blastocyst, Luteinising hormone)

1. The interstitial space in seminiferous tubules consists of immunologically ___ .

2. The edges of the infundibulum possess finger-like projections called ___ .

3. The cells of ___ secrete milk in the mammary glands.

4. The anterior portion of the sperm head is covered by a cap like structure called ___

5. Tertiary follicle is characterized by a fluid filled cavity called ___ .

6. The first menstruation begins at puberty is called ___ .

7. The glandular layer of uterus that undergoes cyclic changes during menstrual cycle is ___.

8. The process of release of ovum from a mature follicle is called ___ .

9. Ovulation is induced by a hormone called ___ .

10. Several hormones like hCG, hPL, estrogen and progesterone are produced by ___ .

11. The fusion of male and female gametes is called ___ .

12. The ___ cells of the inner mass of embryo have the potency to give rise to all the tissues and organs.

13. Zygote divides to form ___ which is implanted in the uterus.

14. The hormone which helps in parturition is ___ .

15. The process of delivery of the foetus is called ___ .

16. ___ contains several antibodies which is absolutely essential to develop resistance for the new-born babies.

Answer Key		
1. Competent cells	2. Fimbriae	3. Alveoli
4. Acrosome	5. Antrum	6. Menarche
7. Endometrium	8. Ovulation	9. Luteinising hormone
10.Placenta	11.Fertilization	12.Stem
13.Blastocyst	14.Oxytocin	15.Parturition
16.Colostrum		

PART - B

III. Answer the following questions in 3-5 sentence each: 2 Marks Each:

Q1. Why are the human testes located outside the abdominal cavity? Name the pouch in which they are present.

Ans.

- To maintain the 2–2.5°C temperature of the testes less than the normal internal body temperature necessary for spermatogenesis.
- Scrotum.

Q2. List the accessory ducts of male reproductive system in humans.

Ans.

- Rete testes
- Vasa efferentia
- Epididymis
- Vas deferens

Q3. Draw a neat labelled diagram of sectional view of seminiferous tubules.

(Space for Diagram)

Q4. Mention the two functions of Sertoli cells.

Ans.

- They provide nutrition to developing spermatogonia.
- They secrete hormones inhibin and androgen binding protein.

Q5. Name any two accessory ducts of the female reproductive system in humans.

Ans.

- Uterus
- Cervix
- Vagina
- Fallopian tube

Q6. What is the number of chromosomes in the following cells of a human female?

Ans.

a) Primary oocyte b) Secondary oocyte

a) Primary oocyte – 46 b) Secondary oocyte - 23

Q7. Mention any four parts of the external genitalia in human females.

Ans.

- Mons pubis
- labia majora

- labia minora
- hymen, clitoris

Q8. Mention the roles of LH and FSH during spermatogenesis.

Ans.

- LH stimulates the Leydig cells to secrete androgens.
- FSH stimulates the Sertoli cells to secrete androgen binding protein and inhibin.

Q9. Name the cells which synthesize the androgen. Mention the hormone which stimulates the cells to produce androgen.

Ans. Leydig cells/Interstitial cells. LH.

Q10. Write the function of each of the following : a) Seminal vesicle b) Acrosome of human sperm

Ans.

a) Seminal vesicle – Secretion of **fructose** and **prostaglandins**

b**) Acrosome of human sperm** –It helps in fertilization by releasing lytic enzymes like **hylauronidase** and **acrosin**, which helps to penetrate the sperm into ovum.

Q11. "Acrosome and middle piece of the sperm are very essential parts of the sperm without which fertilization does not occur". Justify the statement.

Ans. Acrosome secretes sperm lysins to dissolve egg membrane for penetration into egg and its fertilization. Middle piece contains numerous mitochondria that provide energy for sperm movement.

Q12. Differentiate Spermiogenesis from spermiation.

Ans.

- **Spermiogenesis** :- It is the process of formation of mature sperms from immature spermatids.
- **Spermiation** :- It is the process of release of sperms into duct system.

Q13. How is 'oogenesis' markedly different from 'spermatogenesis' with respect to the growth till puberty in the humans?

Ans.

- Production of sperms by spermatogenesis only begins at the puberty stage while oogenesis begins at the embryonic developmental stage itself.
- **In spermatogenesis**, the growth phase is **very short.** The spermatogonium actively grows into a larger primary spermatocyte by obtaining nourishment from the nursing cells.
- **In oogenesis**, the growth phase is **very long.** It may extend over many years. The oogonium grows into a large primary oocyte. It then gets surrounded by a layer of granulosa cells to form primary follicle. A large number of these follicles degenerate during the period from birth to puberty. So, at puberty only **60,000-80,000 primary follicles** are left in each ovary.

Q14. List the events of menstrual cycle.

Ans.

- Menstruation phase
- Follicular/Proliferative phase
- Ovulatory phase
- Luteal/Secretory phase

Q15. Differentiate between Menarche and Menopause.

Ans. The beginning of first menstrual cycle in human female is called **menarche.**

The cessation of menstrual cycle in human female at an age of 50 is called **menopause.**

Q16. Define ovulation?Mention the hormone that induces ovulation.

Ans. The process of rupture and release of secondary oocyte from Graafian follicle is called **ovulation.** LH

Q17. Mention two events that occur during the luteal phase of menstrual cycle.

Ans.

- It involves transformation of ruptured Graafian follicle into corpus luteum.
- Progesterone secreted by corpus luteum stimulates preparation of endometrium necessary for implantation and subsequent maintenance of pregnancy.

Q18. Mention the fate of corpus luteum and its effect on the uterus in absence of fertilisation of the ovum in a human female.

Ans. In the absence of fertilisation the corpus luteum degenerates to form corpus albicans. This results in the degeneration of endometrium of the uterus.

Q19. Define fertilisation. Where does fertilisation normally occur in the human oviduct?

Ans:

- Fertilisation is the fusion of a sperm with the secondary oocyte to form a zygote.

- It normally occurs at the ampullary-isthmic junction of the oviduct (fallopian tube).

Q20. Define the following terms : a) Cleavage b) Implantation

Ans.

a) **Cleavage:-**The series of **mitotic divisions** that occur in zygote to form blastomeres is called **cleavage**. The process transforms the zygote into a hollow, fluid-filled structure called a blastocyst

b) **Implantation** :- It is the embedment of blastocyst to uterine wall.

Q21. List any four hormones secreted by placenta.

Ans.

- Estrogen
- Progesterone
- Human chorionic gonadotropin (hCG)
- Human placental Lactogen (hPL)

Q22. Why is oxytocin necessary for parturition?

Ans.

- Oxytocin acts on the uterine smooth muscle (myometrium) and causes uterine contractions.
- This in turn stimulates further secretion of oxytocin and by the positive feedback results in parturition

Q23. What is parturition? Name the hormone released by the pituitary which induces parturition.

Ans.

- The process of delivery or the release of the baby from the mother's womb is called parturition.
- Oxytocin.

Q24. "Unless foetal ejection reflex is produced, normal parturition does not occur". Substantiate the statement.

Ans.

- Foetal ejection reflex triggers quick release of oxytocin from the mother's posterior lobe of pituitary.
- Oxytocin acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin. This by positive feedback induces stronger and stronger contractions.

Q25. What is colostrum? Mention its benefits.

Ans.

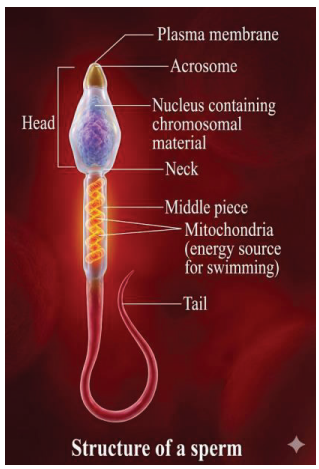
- The milk secreted during the initial few days of lactation is called COLOSTRUM
- This is yellowish fluid, which is rich in proteins, low in fats, IgA antibodies etc. fed to baby helps in bringing up the healthy baby.

PART- C

IV. Answer the following questions in 40-80 words each: 3 Marks Each:

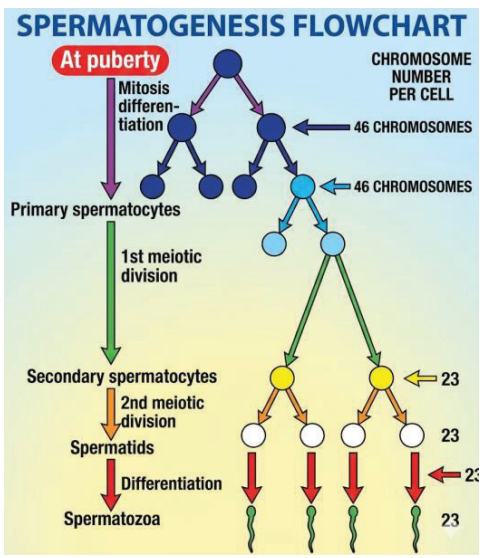
Q1. Draw a neat labelled diagram of human sperm.

Ans.



Q2. Write the schematic representation of spermatogenesis.

Ans.



Q3. Trace the path of spermatozoa from the testes up to the ejaculatory duct.

Ans. Seminiferous tubules ---- Rete testes --- Vasa efferentia ---- Epididymis ---- Vas deferens ---- Ejaculatory duct

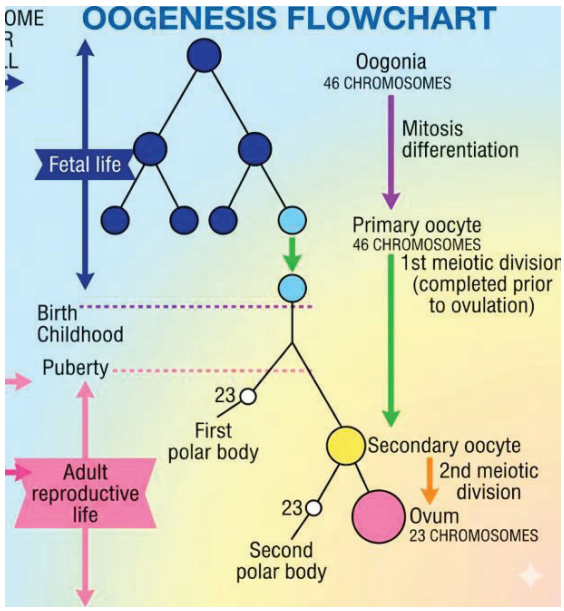
Q4. Explain the organization of glandular tissue in a breast of human females.

Ans.

- The mammary glands are enclosed in breasts that contain glandular tissue and variable amount of fat.
  The mammary glands are modified sweat glands. The glandular tissue of each breast is divided into 15-20 mammary lobes containing clusters of cells called alveoli.
- The cells of alveoli secrete milk, which is stored in the cavities (lumens) 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.

Q5. Give the schematic representation of oogenesis.

Ans.



Q6. Mention the events that occur during the follicular phase of menstrual cycle.

Ans.

- It involves the proliferation and thickening of endometrium.
- Formation of mature Graafian follicles from primary follicles.
- These changes in the ovary and the uterus are induced by changes in the levels of pituitary and ovarian hormones.

Q7. What is placenta? List the functions of the human placenta.

Ans: Placenta is a temporary structural and functional association between maternal and foetal tissues.

- Transfers oxygen and nutrients from maternal blood to the foetus.
- Transfers carbon dioxide and metabolic wastes from foetal blood to the mother.
- Allows transfer of some maternal IgG antibodies, providing passive immunity.
- Acts as an endocrine tissue and secretes hCG, hPL, estrogens and progesterone.

It acts as a barrier and prevents entry of certain bacteria and harmful materials from maternal blood.

It allows the of IgG antibodies to cross and provided passive immunity to foetus.

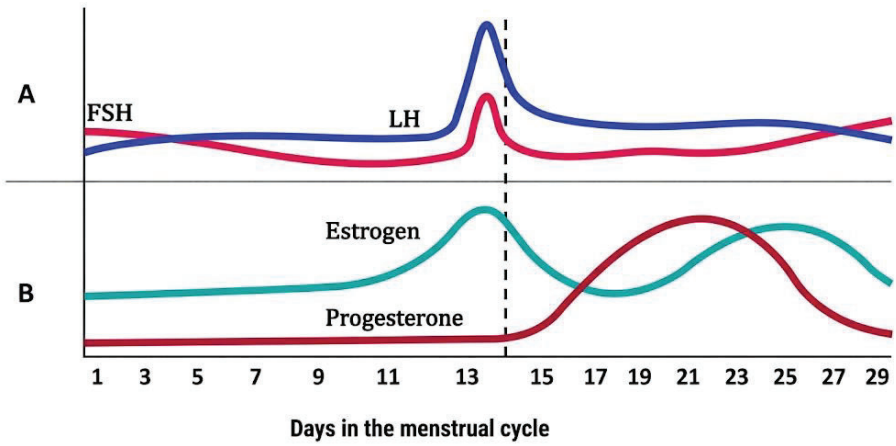
It acts as an endocrine tissue, producing estrogens, progesterone, human chorionic gonadotropin (hCG) and human placental lactogen (hPL).

Q8. Explain the changes that occur in ovary and uterus during luteal phase of menstrual cycle.

Ans.

- The Graafian follicle transform into corpus luteum to produce progesterone.
- Progesterone stimulates preparation of endometrium necessary for implantation and subsequent maintenance of pregnancy.
- In the absence of fertilization the corpus luteum degenerates into corpus albicans. This causes disintegration of endometrium leading to menstruation, making a new cycle.

Q9. In the figure given below, parts A and B show the level of hormones which influence the menstrual cycle. Study the figure and answer the questions that follow:



Ans.

- **a) Name the organs/glands which secrete the hormones represented in labelled parts A & B.**
  - A - Pituitary, B - Ovary.
- **b) State the role of hormones secreted from part B on the uterus of human female during menstrual cycle.**
  - It promotes proliferation of uterine endometrium.

Q10. Briefly explain the process of fertilization in humans.

Ans.

- During fertilization, a sperm comes in contact with zona pellucida of secondary oocyte and induces the changes the membrane that block the entry of additional sperm ensuring monospermy.
- The secretions of the acrosome help the sperm to enter into the cytoplasm of the secondary oocyte through the corona radiata, zona pellucida and plasma membrane. The secretions of sperm lysins include Hyaluronidase, Acrosin and corona penetrating enzyme.
  - The entry of sperm into cytoplasm of secondary oocyte induces the completion of the second meiotic division to form a haploid ovum or ootid and a second polar body. Soon the nucleus of the haploid sperm and egg fuse to form a diploid zygote.

Q11. In humans, sex of the baby is determined by the father and not the mother. Justify.

Ans.

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

Q12. When and where do chorionic villi appear in humans? State their function.

Ans.

- Chorionic villi appear during implantation.
- On the trophoblast of blastocyst.
- They surround the uterine tissue and maternal blood and become interdigitated with each other to form placenta.

Q13. Study the flow chart: Hypothalamus -> Pituitary -> Testes -> Sperms. Name the hormones and functions.

Ans:

- GnRH from the hypothalamus stimulates the anterior pituitary to release LH and FSH.
- LH acts on Leydig cells and stimulates secretion of androgens, mainly testosterone.
- FSH acts on Sertoli cells and stimulates secretion of factors that support spermiogenesis.

Q14. Parturition is induced by complex neuroendocrine mechanism. Comment.

Ans.

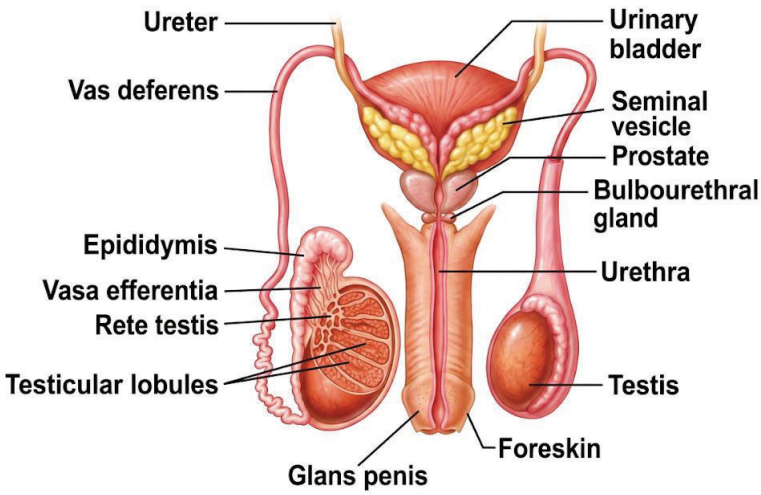
- The signals for parturition originate from the fully developed fetus and the placenta, which induce mild uterine contractions called foetal ejection reflex.
- Foetal ejection reflex triggers quick release of oxytocin from the mother's posterior lobe of pituitary.
- Oxytocin acts on the uterine muscle and causes stronger uterine contractions, which in turn stimulates further secretion of oxytocin.
- Hormone Relaxin released by the placenta helps dilate the uterine cervix during labour pains.
- With the continued forceful contractions, the amnion ruptures and the amniotic fluid flows out, lubricating the vagina.
- This leads to expulsion of the baby out of the uterus through birth canal.

PART-D

V. Answer the following questions as directed: **5 Marks Each**

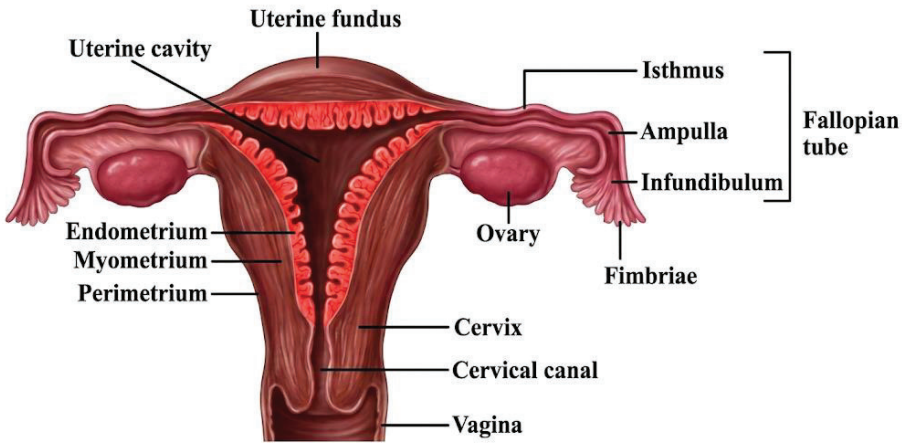
Q1. Draw a neat labelled diagram of human male reproductive system.

Ans.



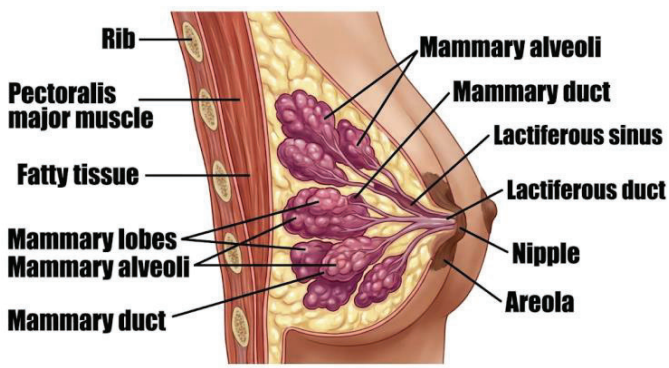
Q2. Draw a neat labelled diagram of the sectional view of human female reproductive system.

Ans.



Q3. Draw a neat labelled diagram of the sectional view of mammary gland.

Ans.



Q4. Differentiate between spermatogenesis and oogenesis.

Ans.

Spermatogenesis	Oogenesis
• It starts at puberty.	• It starts during embryonic development.
• Occurs in seminiferous tubules.	• Occurs in ovaries.
• Four sperms from one spermatocyte.	• One ova from one oocyte.
• Meiosis is symmetric.	• Meiosis is asymmetric.
• Occurs from puberty to end of life cycle.	• Occurs up to age of 50 to 55.

Q5. Trace the development of oocytes till ovulation in human female reproductive system in menstrual cycle.

Ans.

1. **Foetal Stage:** Oocytes formation begins in the foetal stage at the 25th week. Millions of oocytes are formed within each foetal ovary and no more oocytes are formed after birth.
2. **Primary Oocytes:** Oocytes undergo meiosis, but become temporarily arrested at the diplotene stage of prophase I and are called primary oocytes. Each primary oocyte is surrounded by granulose cells to form primary follicles. At puberty only 60,000 – 80,000 primary follicles are left in each ovary.
3. **Secondary Follicles:** After puberty primary follicles get surrounded by more layers of granulose and a new theca to form secondary follicles.
4. **Tertiary Follicles:** The secondary follicles transform into tertiary follicles by developing a fluid filled cavity called antrum and at this stage it completes its meiosis – I to form secondary oocytes.
5. **Ovulation:** The tertiary follicles finally get transformed into a mature ovarian follicle called Graafian follicle. The secondary oocyte is released from the Graafian follicle by a process called ovulation.

Q6. Describe the various events that occur during menstrual cycle.

Ans.

1. **Menstrual phase:** It involves periodic discharge of endometrial epithelium, blood tissues, mucus etc. It lasts for about 3 – 5 days. Menstruation occurs if the ovum is not fertilized after ovulation.
2. **Proliferative/Follicular phase:** It involves the proliferation and thickening of endometrium, formation of mature Graafian follicles from primary follicles. It lasts for about 6th to 13th day of the cycle.
3. **Ovulatory phase:** Usually occurs at the 14th to 16th day of the cycle in a regular cycle. Rapid secretion of LH in the middle of the cycle to maximum and is called LH surge. It induces the rupture of Graafian follicle and release of egg (secondary oocyte).
4. **Secretory/Luteal phase:** During which, ruptured Graafian follicle transform into corpus luteum to produce progesterone. Progesterone stimulates preparation of endometrium necessary for implantation and subsequent maintenance of pregnancy. In the absence of fertilization the corpus luteum degenerates into corpus albicans. This causes disintegration of endometrium leading to menstruation, making a new cycle. This phase lasts for about 17th to 28th days in a regular cycle.

Q7. Briefly explain the embryonic development in humans.

Ans.

1. **Cleavage:** About 30hrs after fertilization, the zygote undergoes a series of mitotic divisions and forms 2, 4, 8 and 16 cells called blastomeres.
2. **Morula & Blastocyst:** Cleavage in zygote occurs as it moves through the isthmus. The embryo with 8 – 16 blastomeres is called morula. The morula continues to divide and transforms into blastocyst as it moves further down into the uterus.
3. **Differentiation:** The blastomeres in the blastocyst are arranged into an outer layer called TROPHOBLAST and inner group of cells called EMBRYOBLAST CELLS. The trophoblast layer gets attached to the endometrium and the Embryoblast cells differentiate into embryo.
4. **Organogenesis:** Heart of the embryo is formed after one month of pregnancy. By the end of second month foetus develops limbs and digits. By the end of first trimester most of the major organ systems are well developed.
5. **Growth:** During 5th month movement of foetus and appearance of hair on head and by the end of second trimester hair appear on the entire body, eye lids separate and eye lashes are developed.
6. **Parturition:** By the end of 9 months of pregnancy the foetus is fully formed and is ready for parturition.

VI. Answer the following questions as directed: 5 Marks Each:

Q1. Draw a sectional view of seminiferous tubule of a human. Label the following cells in the seminiferous tubule:

Ans.

a. Cells that divide by mitosis to increase their number (Spermatogonia).

b. Cells that undergo Meiosis I (Primary spermatocytes).

c. Cells that undergo Meiosis II (Secondary spermatocytes).

d. Cells that help in the process of Spermiogenesis (Sertoli cells).

e. Cells produced due to Spermiogenesis (Spermatozoa/Sperms).

Q2. Answer the following:

a) Explain the hormonal control of ovarian changes.

- FSH stimulates growth and maturation of ovarian follicles.
- The mid-cycle LH surge induces ovulation; LH also supports formation and function of the corpus luteum.
- Estrogens promote proliferative changes in the endometrium.
- Progesterone from the corpus luteum maintains the secretory endometrium for implantation.

b) Define menarche and menopause.

Menarche is the first menstrual cycle at puberty. Menopause is the permanent cessation of menstrual cycles, usually around 45-50 years of age.

Q3. Answer the following:

a) Why does corpus luteum secrete large amount of progesterone during luteal/secretory phase?

- It is necessary for the maintenance of the endometrium. Such an endometrium is necessary for

implantation of the fertilized ovum and other events of pregnancy.

b) Why is breast feeding best for newborn babies?

- Yes, I agree. The milk secreted during the initial few days of lactation is called colostrum. This is a yellowish fluid, which is rich in proteins, low in fats, and contains **IgA antibodies**, which help develop resistance and bring up a healthy baby**.**

Chapter 3
Reproductive Health

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3.1. REPRODUCTIVE HEALTH - PROBLEMS AND STRATEGIES
3.2. POPULATION STABILISATION AND BIRTH CONTROL
3.3. MEDICAL TERMINATION OF PREGNANCY
3.4. SEXUALLY TRANSMITTED INFECTIONS (STIs)
3.5. INFERTILITY

Theory

INTRODUCTION:

Reproductive health - The term 'reproductive health' simply refers to healthy Reproductive organs with normal functions.

However, it has a broader perspective and includes the emotional and social aspects of reproduction also.

According to the World Health Organisation (WHO) –

The reproductive health means a total well-being in all aspects of reproduction, i.e., **physical**, **emotional**, **behavioural** and **social.**

Therefore, 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.**

3.1. Reproductive Health - Problems And Strategies

India was amongst the first countries in the world to initiate action plans and programmes at a national level to attain total reproductive health as a social goal. These programmes called **'family planning'** were initiated in **1951**.It focuses specifically on controlling family size, birth spacing, and contraceptive usage.

Reproductive and Child Health (RCH) care, launched later in **1997**, is a comprehensive, broader program that includes family planning alongside prenatal/postnatal care, child survival, and STI/STD management to ensure overall reproductive health.

Problems of Reproductive Health :-

♦ There are several problems associated with reproductive health which are as follows-

1. Lack of awareness in the people about various aspects of reproductive health like the use of contraceptives, hygienic sexual practices, etc.

2. The common occurrence of several Sexually Transmitted Diseases (STDs).
3. Early marriage as soon as the children attain puberty.
4. Misuse of amniocentesis in prenatal sex determination increases in female foeticide.
5. Infertility and related social stigma.
6. Ignorance about Assisted Reproductive Technologies (ARTs).
7. Population explosion.
8. Illegal abortions

Strategies of Reproductive Health :-

1. To Create Awareness about Reproductive health and reproduction related aspects –

- With the help of **audio-visual** and the **print-media governmental** and **non-governmental** agencies have taken various steps to create awareness among the people about reproduction-related aspects.
- **Parents, other close relatives, teachers** and **friends,** also have a major role in the dissemination of the above information.
- **Introduction of sex education** in schools should also be encouraged to provide right information to the young so as to discourage children from believing in myths and having misconceptions about sex-related aspects.
- Proper information about **reproductive organs, adolescence** and **related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS, etc.,** would help people, especially those in the adolescent age group to lead a reproductively healthy life.

2. To Educate the people - Especially fertile couple and Marriageable group members

- Educating people, especially fertile couples and those in marriageable age group, about available
- Birth control options.
- Care of pregnant mothers.
- Post-natal care of the mother and child.
- Importance of breast feeding.
- Equal opportunities for the male and the female child, etc., would address the importance of bringing up socially conscious healthy families of desired size.
- Awareness of problems due to uncontrolled population growth,
- Social evils like sex-abuse and sex-related crimes, etc.

3. Providing facilities and support for building up a reproductively healthy society

- Successful implementation of various action plans to attain reproductive health.
- Strong infrastructural facilities.
- Professional expertise and material support.
- These are essential to provide medical assistance and care to people in reproduction-related problems like. Pregnancy, delivery, STDs, abortions, contraception, menstrual problems, infertility, etc.
- **Implementation of better techniques and new strategies** from time to time are also required to provide more efficient care and assistance to people.

- Research on various reproduction-related areas are encouraged and supported by governmental and non-governmental agencies to find out new methods and/or to improve upon the existing ones.
- **Statutory ban on amniocentesis** for sex-determination to legally check increasing **female foeticides**.
- Massive **child immunisation**

Amniocentesis :- It is a pre-natal diagnostic technique used to detect genetic disorders, chromosomal abnormalities (e.g., Down syndrome),based on the chromosomal pattern in the amniotic fluid surrounding the uterus.

Significance :-

- It is used to detect the genetic abnormalities of the foetus
- Used to determine the sex of the foetus

3.2. Population Stabilization And Birth Control

- **Population:** A group of similar species present in a particular area in a given period of time.
- Rapid increase of population in a short period of time in an area is called **population exposion.**
- The scientific study of human population is called **Demography.**
- **Census :-** It is an official counting of population and a compiled data of **birth, death,sex-ratio , qualificatio** etc.
- The world population which was around **2 billion** (2000 million) in **1900** rocketed to about **6 billion** by **2000** and **7.2 billion** in **2011**. A similar trend was observed in India too.
- Our population which was approximately **350 million** at the time of our independence reached close to the billion mark by **2000** and crossed **1.2 billion** in **May 2011.**
- According to the **2001** census report, the population growth rate was less than 2 per cent**,** i.e., 20/1000/year, a rate at which our population could increase rapidly.

The population explosion is due to

1. A rapid decline in death rate
2. Increased health facilities
3. Better living conditions
4. Decrease in MMR(Maternal Mortality Rate)
5. Decrease in IMR (Infant Mortality Rate)
6. Increase in number of people in reproducible are probable reason for population explosion.

Consequences of population Exposion –

- Scarcity of food, shelter and Clothing
- Increased poverty
- It leads to unemployment
- Increase Illiteracy

Measures to control over population –

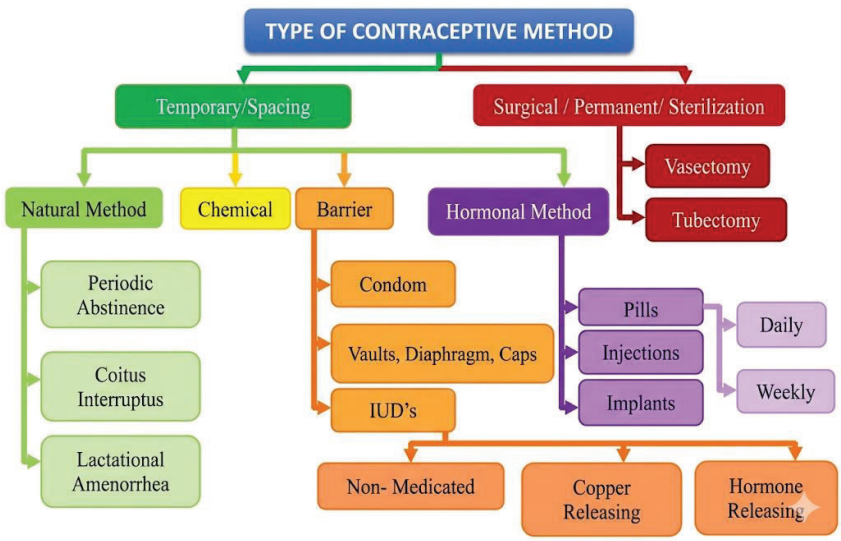
1. **By educating people -** The reproductive age group people should be educated about the advantage of small family. Government and Non-government organizations, Mass media and educational institutions can play an important role in this campaign. **"Hum Do Hamara Do"** (We two ours two) is the most common slogan on family planning which creates awareness about a small family.
2. **Rising of marriageable age** - The marriageable age of female and male should be raised to **18** years and that of males is **21** years.
3. **By providing incentives** - Government has to give incentives to families adopting one child norm. The incentives may be in the form of free education, monthly allowances, promotion to professionals etc.
4. **By family planning programmes** - The couple have to be motivated to plan small family by adopting birth control measures.

CONTRACEPTIVE METHODS:-

- **Contraception :-** The process of temporary or permanent prevention of pregnancy is called **contraception.**
- **Contraceptives :-** The devices or methods which will help to **prevent pregnancy** or **conception** without disturbing reproductive health are called **contraceptives.**

Characteristics features of Ideal contraceptives :- An Ideal contraceptive should be-

- Increase Illiteracy
- User-friendly.
- Easily available.
- Effective.
- Reversible.
- Least side-effects.
- It should not interfere with the sexual drive, desire and/or the sexual act of the user.



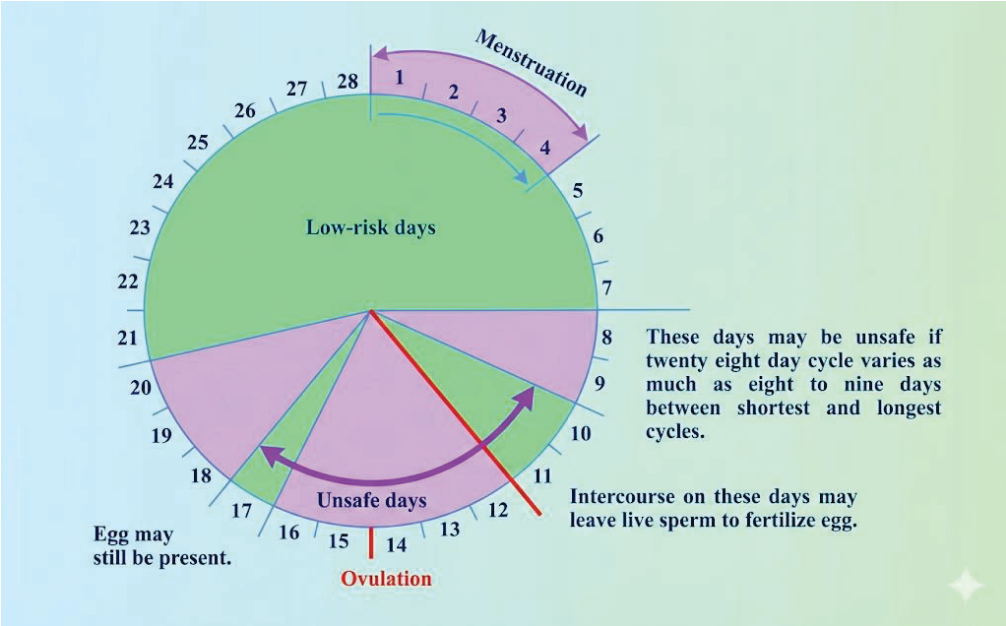
- No doubt, the widespread use of these methods has a significant role in checking uncontrolled growth of population. However, their possible ill-effects like nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding or even breast cancer, though not very significant, should not be totally ignored.

1. NATURAL METHODS

- These methods work on the principle of avoiding chances of **ovum** and **sperms** meeting. As no medicines or devices are used in these methods, side effects are almost nil.
- These methods are of following kinds :-

(A) Periodic Abstinence or Rhythm Method

- In which the couples **avoid** or **abstain** from coitus from day **10** to **17** of the menstrual cycle when ovulation could be expected.
- As chances of fertilisation are very high during this period, it is called the **fertile period.**
- Therefore, by abstaining from coitus during this period, conception could be prevented.



(B) Coitus Interruptus

- In which the **male partner withdraws his penis** from the vagina just **before ejaculation of sperms into the vagina** to avoid insemination.So there will be no conception.

(C) Lactational Amenorrhea

- It is the absence of **menstrual cycle** and **ovulation** due to intense lactation after Parturition.
- Therefore, as long as the mother breast-feeds the child fully, chances of conception are almost nil.
- However, this method has been reported to be effective only up to a maximum period of **six months** following parturition.
- As **no medicines or devices are used** in these methods, side effects are almost nil ,but Chances of failure, these method are also high.

2. CHEMICAL METHODS

- These contraceptives are introduced in vagina just before sexual activity.
- These include the contraceptives which contain spermicides.
- Spermicidal contraceptives are available in the form of **creams**(brand: 'Delfen'), **jellies** and **foams/foam tablets** (brand : 'Today').

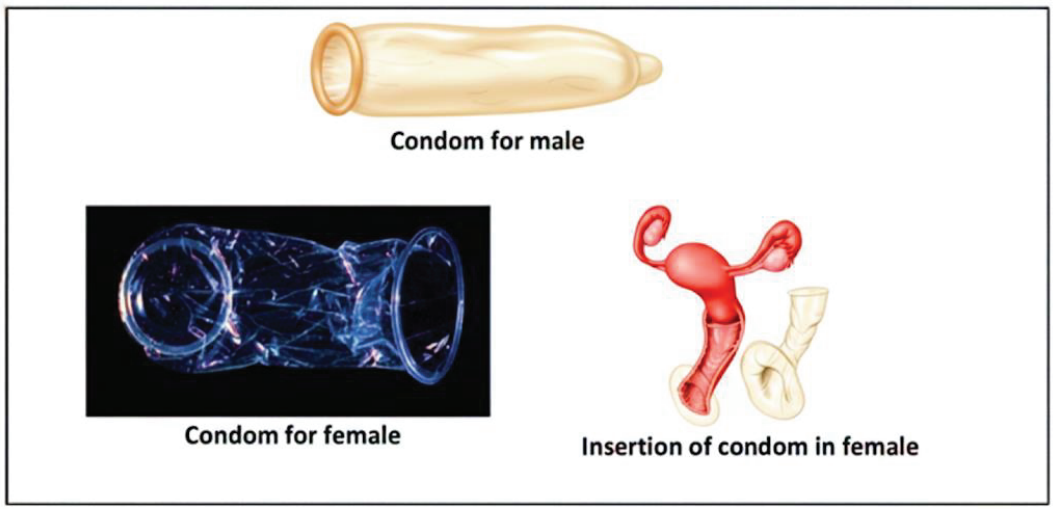
3. BARRIER METHODS

- The mechanical devices which Prevent physical meeting of **Sperms** and **Ovum** is called barriers.

These barrier methods available for both males and females :

(A) Condoms:

- Condoms are barriers made of thin **rubber/ latex sheath.**
- Condoms are used to cover the **penis** in the **male** or **vagina** and **cervix** in the **female**, just before coitus so that the ejaculated semen would not enter into the female reproductive tract. This can prevent conception.



- **Example:- 'Nirodh'** is a popular brand of condom for the **male** and **Femidome** is for females.
- Use of condoms has increased in recent years due to its additional benefit of **protecting the user from contracting STIs and AIDS.**
- Both the male and the female condoms are disposable, can be self-inserted and thereby gives privacy to the user.

(B) Diaphragms,Cervical Caps and Vaults :-

- These are also barriers made of rubber that are inserted into the female reproductive tract to cover the cervix during coitus.
- These prevent conception by blocking the entry of sperms through the cervix.

- These are reusable.
- Spermicidal **creams, jellies and foams** are usually used along with these barriers to increase their contraceptive efficiency.

4. INTRA UTERINE DEVICES (IUDs)

- These are the devices which are inserted by **doctors** or **expert nurses** in the uterus through vagina.
- IUDs increase phagocytosis of sperms within the uterus.

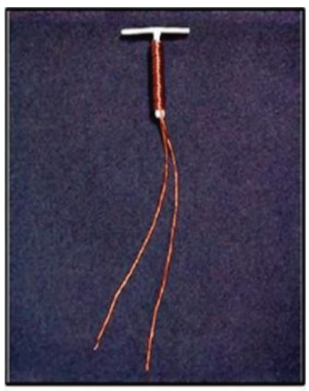
These Intra Uterine Devices are presently available as :

(A) Non-medicated or Inert IUDs

- These IUDs are made up of stainless steel or polyethylene. (e.g. Lippes loop)

(B) Copper releasing IUDs

- The Cu ions released from these IUDs suppress sperm motility and the fertilising capacity of sperms.
  Eg.CU-7,CU-T ,Multiload-250,380



Copper T (CuT)

(C) Hormone releasing IUDs

- These IUDs, in addition make the uterus unsuitable for implantation and the cervix hostile to the sperms. (e.g. Progestasert, LNG-20)

Lippes loop Copper-T Multiload-375 Hormone releasing IUD

- IUDs are ideal contraceptives for the females who want to delay pregnancy and/or space children.
- It is one of most widely accepted methods of contraception in India.

5. HORMONAL METHOD/ORAL CONTRACEPTIVES

- These are used orally in the form of tablets and hence are popularly called the oral pills.

Oral Contraceptives for females :

(A) Daily Pills or combination pills

- These are the preparations containing a combination of progestogen and estrogen.
- 'Mala D' and 'Mala N' are popular brands of combination pills.

- A pack of these pills contain 28 (21 hormonal and 7 non hormonal (iron)) pills.

- The hormonal pills have to be taken daily for a period of 21 days starting preferably within the first five days of menstrual cycle (during which menstruation occurs).
- After a gap of 7 days (during which iron pills are taken for recovery of blood loss in menstruation and to maintain regularity of hormonal pills), it has to be repeated in the same pattern till the female desires to prevent conception.
- These pills are very effective with lesser side effects and are well accepted by the females.

(B) Saheli :

- Weekly Pills :-

  'Saheli' - the new oral contraceptive for the females contains nonsteroidal preparation was developed by scientists at Central Drug

Research Institute (CDRI) in Lucknow, India.

- It is a 'once a week' pill (after an initial intake of twice a week dose for 3 months) with very few side effects and high contraceptive value.

Emergency Contraceptives

- These could be used to avoid possible pregnancy due to rape or casual unprotected intercourse.
- Administration of progestogens or progestogen estrogen combinations or IUDs within 72 hours of coitus have been found to be very effective as emergency contraceptives.
- e.g. 'Unwanted-72', 'i-pill', 'ezy pill', etc. are popular brands of emergency contraceptive pills.

Side effects of contraceptives -

Nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding, Even breast cancer, though not very significant, should not be totally ignored.

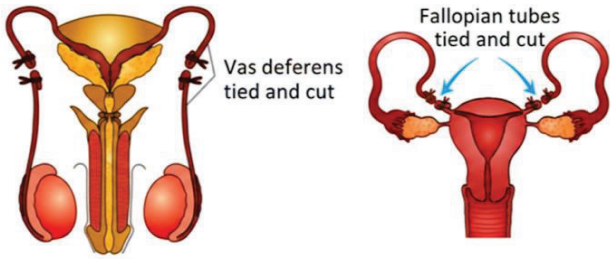
6. INJECTABLES AND IMPLANTS

- Progestogens alone or in combination with estrogen can also be used by females as injections or implants under the skin.
- Their mode of action is similar to that of pills and their effective periods are much longer.

Note- Injections and implants have high level of progesterone which inhibits the secretion of FSH, LH and ultimately inhibit the ovulation, so work as a contraceptive.

7. SURGICAL METHODS OR STERILISATION METHODS

- These are generally advised for the male/female partner as a terminal method to prevent any more pregnancies.
- Surgical intervention blocks gamete transport and thereby prevents conception.
- Sterilisation procedure in the male is called **'vasectomy'** and that in the female, **'tubectomy'**.



(a) Vasectomy **(b)** Tubectomy

- In vasectomy, a small part of the vas deferens is removed or tied up through a small incision on the scrotum.
- In tubectomy a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.

Note :- These techniques are highly effective but their reversibility is very poor.

3.3. Medical Termination of Pregnancy

- Intentional or voluntary termination of pregnancy before full term is called medical termination of pregnancy (MTP) or induced abortion.
- Nearly 45 to 50 million MTPs are performed in a year all over the world which accounts to $1/5^{th}$ of the total number of conceived pregnancies in a year.
- MTP is done to get rid of unwanted pregnancies either due to casual unprotected intercourse or failure of the contraceptive used during coitus or rapes.
- MTPs are also essential in certain cases where continuation of the pregnancy could be harmful or even fatal either to the mother or to the foetus or both.
- MTPs are considered relatively safe during the first trimester, i.e., up to 12 weeks of pregnancy. Second trimester abortions are much riskier.
- Government of India legalised MTP in 1971 with some strict conditions to avoid its misuse.
- Such restrictions are all the more important to check indiscriminate and illegal female

foeticides which are reported to be high in India.

- The Medical Termination of Pregnancy (Amendment) Act, 2017 was enacted by the government of India with the intension of reducing the incidence of illegal abortion and consequent maternal mortality and morbidity.

According to this Act :

- A pregnancy may be terminated on certain considered grounds within the first 12 weeks of pregnancy on the opinion of one registered medical practitioner.
- If the pregnancy has lasted more than 12 weeks, but fewer than 24 weeks, two registered medical practitioners must be of the opinion, formed in good faith, that the required ground exist.

The grounds for such termination of pregnancies are:

(i) The continuation of the pregnancy would involve a risk to the life of the pregnant woman or of grave injury physical or mental health; or

(ii) There is a substantial risk that of the child were born; it would suffer from such physical or mental abnormalities as to be seriously handicapped.

Disturbing/dangerous/unhealthy trends observed with MTPs are:

- A majority of the MTPs are performed illegally by unqualified quacks which are not only unsafe but could be fatal too.
- Amniocentesis is misused to determine the sex of the unborn child. Frequently, if the foetus is found to be female, it is followed by MTPs this is totally against what is legal.
- Such illegal practices should be avoided because these are dangerous both for the young mother and the foetus. Effective counselling on the need to avoid unprotected coitus and the risk factors involved in illegal abortions as well as providing more health care facilities could reverse the mentioned unhealthy trend.

Amniocentesis

- This procedure is performed most often between the 14^{th} and the 16^{th} week of pregnancy.
- In amniocentesis, some of the amniotic fluid of the developing foetus is taken to analyse the fetal cellsand dissolved substances.
- This procedure is used to test for the presence of certain genetic disorders such as, Down syndrome, haemophilia, sickle-cell anemia, etc. and obviously inherited metabolic disorders determine the survivability of the foetus.
- The sex of the fetus can also be determined (though it is a misuse of amniocentesis and it is also illegal) by examining the sex chromosomes (for the presence or absence of Barr body) of the fetal cells.

3.4. Sexually Transmitted Infections [STI's)

- Diseases or infections which are transmitted through sexual intercourse are collectively called sexually transmitted infections [STIs] or venereal diseases (VD) or reproductive tract infections (RTI).
- Gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B and of course, HIV leading to AIDS are some of the common STIs.

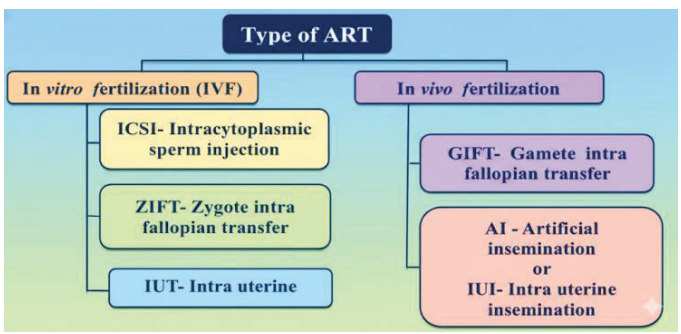
- Hepatitis-B and HIV can also be transmitted by sharing of injection needles, surgical instruments, with infected persons, transfusion of blood, or from an infected mother to the foetus too.
- Except for hepatitis-B, genital herpes and HIV infections, other diseases are completely curable if detected early and treated properly.
- Early symptoms of most of these are-
- Minor and Include itching, fluid discharge, slight pain, swellings, etc., in the genital region.
- Infected females may often be asymptomatic and hence, may remain undetected for long.
- Absence or less significant symptoms in the early stages of infection and the social stigma attached to the STIs, deter the infected persons from going for timely detection and proper treatment.
- Later complications, which include - Pelvic inflammatory diseases (PID), abortions, still births,ectopic pregnancies, infertility or even cancer of the reproductive tract.
- Incidence - Though all persons are vulnerable to these infections, their incidences are reported to be very high among persons in the age group of 15-24 year.

Precautions –

- Avoid sex with unknown partners/multiple partners.
- Always use condoms during coitus.
- In case of doubt, go to a qualified doctor for early detection and get complete treatment if diagnosed with disease.

3.5. Infertility

- A large number of couples all over the world including India are infertile, i.e. they are unable to produce children in spite of unprotected sexual co-habitation of 1-2 years.
- The reasons for this could be many-physical, congenital, diseases, drugs, immunological or even psychological.
- In India, often the female is blamed for the couple being childless, but more often than not, the problem lies in the male partner.
- Specialised health care units (infertility clinics, etc.) could help in diagnosis and corrective treatment of some of these disorders and enable these couples to have children. However, where such corrections are not possible, the couples could be assisted to have children through certain special techniques commonly known as Assisted Reproductive Technologies (ART).



Methods :

1. IN-VIVO FERTILISATION

- Fertilisation (fusion of the gametes) occurs within the female in natural conditions.

Techniques:

(A) Gamete Intra Fallopian Transfer (GIFT) :

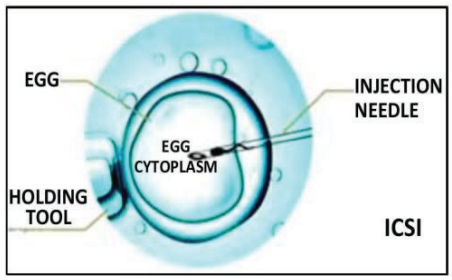
- In this technique, an ovum collected from a donor is transferred into the fallopian tube of another female who cannot produce one, but can provide suitable environment for fertilization and further development.

(B) Artificial Insemination (AI):

- Infertility cases either due to inability of the male partner to inseminate the female or due to very low sperm counts in the ejaculates, could be corrected by it.
- In this technique, the semen collected either from the husband or a healthy donor is artificially introduced either into the vagina or into the uterus (IUI - Intra-Uterine Insemination) of the female.

2. IN VITRO FERTILISATION (IVF) FOLLOWED BY EMBRYO TRANSFER (ET)

- In IVF, fertilisation occurs outside the body in almost similar conditions as that in the body.
- This method is popularly known as test tube baby programme.
- In this method, ova from the wife/donor (female) and sperms from the husband/donor (male) are collected and are induced to form zygote under simulated conditions in the laboratory.
- Intra cytoplasmic sperm injection (ICSI) is a specialised procedure to form an embryo in the laboratory in which a sperm is directly injected into the ovum.



- After IVF, the formed zygote (or early embryo developed from it) is transferred into the female (genetic or surrogate mother) to complete its further development.

Techniques of embryo transfer (ET) :

(A) Zygote Intra Fallopian Transfer (ZIFT) : In this technique, the zygote or early embryo (with up to 8 blastomeres) is transferred into the fallopian tube.

(B) Intra Uterine Transfer (IUT) : In this technique, embryo with more than 8 blastomeres is transferred into the uterus.

Note : Embryos formed by in-vivo fertilisation also could be used for such transfer to assist those females who cannot conceive.

- Though options are many, all these techniques require extremely high precision handling by specialised professionals and expensive instrumentation.
- Therefore, these facilities are presently available only in very few centres in the country.

- Obviously their benefits is affordable to only a limited number of people. Emotional, religious and social factors are also deterrents in the adoption of these methods.
- Since the ultimate aim of all these procedures is to have children, in India we have so many orphaned and destitute children, who would probably not survive till maturity, unless taken care of.
- Our laws permit legal adoption and it is as yet, one of the best methods for couples looking for parenthood.

EXERCISE

PART- A

I. Select the correct alternative from the choices given: 1 Mark Each:

1. **According to WHO, reproductive health means a total wellbeing in all aspects of reproduction like _____**

   a) Physical, Emotional, Behavioural, Social

   b) Physical, Emotional, Social, Life style

   c) Physical, Social, Behavioural, Life style

   d) Physical, Emotional, Behavioural, Life style

2. **Abbreviate 'Reproductive and Child Health Care' programme.**

   a) RACHC b) CDRI c) RCH d) RC

3. **What are the major tasks under reproductive and child health care programs?**

   a) Create awareness about reproductive health among people.

   b) Educate people about reproductive process

   c) Establish reproductive health care in hospitals

   d) Reproductive and child health.

4. **Statement I:Introduction of sex education in schools should be encouraged.**

   Statement II: This will encourage children to believe in myths about sex related aspects.

   a) Both Statement I and Statement II are correct

   b) Both Statement I and Statement II are incorrect

   c) Statement I is correct and Statement II is incorrect

   d) Statement I is incorrect and Statement II is correct

5. **Decreased MMR and IMR and increased people in reproductive age in a population will result in**

   a) Increase in growth rate b) Decrease in growth rate

   c) No significant change in growth rate d) Stable growth rate

6. **Which of the following is an indicator of a reproductively unhealthy society?**

   a) Increase in infant mortality rate

   b) Decline in maternal mortality rate

   c) Widespread awareness of contraceptive methods

   d) Detection and cure of sexually transmitted diseases

7. **Statement I: Amniocentesis is legally banned for sex determination.**

   Statement II: Amniocentesis was being misused for aborting normal female foetus.

   a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

8. Amniocentesis is a medical procedure where some of the amniotic fluid of the developing foetus is drawn to analyse the foetal cells and dissolved substances. It was banned in India in order to stop female foeticides. Which of the following highlight the importance of amniocentesis despite the ban?

a) Identification of a decline in sex ratio

b) Prevention of sexually transmitted diseases

c) Determination of biological sex of the unborn baby

d) Detection of genetic disorders

9. Which of the following cannot be detected in a developing foetus by amniocentesis?

a) Downs' syndrome b) Haemophilia

c) Sex of the foetus d) Hepatitis

10. CDRI stands for ___

a) Common Drug Research Institute b) Chandigarh Drug Research Institute

c) Calcutta Drug Research Institute d) Central Drug Research Institute

11. What is true for natural methods of contraception?

a) They increase phagocytosis of sperms

b) They act as barriers to prevent fertilisation

c) They avoid chances of ovum and sperms meeting.

d) They are terminal methods

12. Statement I: Lactational amenorrhea is absence of menstruation during intense lactation.
Statement II: This is a highly reliable method of contraception.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

13. Statement I: IUDs are ideal contraceptives for the females who want to delay pregnancy or space children.
Statement II: IUDs are most widely accepted methods contraception in India.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

14. Statement I: Use of condom is a safeguard against AIDS and sexual diseases besides checking pregnancy.

Statement II: Certain contraceptives are planted under the skin of the upper arm to prevent pregnancy.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

15. Choose the incorrect statement with regard to diaphragm

a) They are reusable

b) They block the entry of sperms

c) They are placed to cover the cervix

d) They prevent ovulation

16. Which of the following is not a copper-releasing IUD?

a) LNG 20 b) CuT c) Cu 7 d) Multiload 375

17. What makes the uterus unsuitable for implantation and the cervix hostile to sperms?

a) Cu 7 b) Lippe's loop c) Multiload 375 d) Progestasert

18. Select the correct statement with respect to IUDs.

a) Once inserted need not be replaced.

b) Inserted by user itself

c) Increase phagocytosis of sperms in the uterus

d) Suppress gametogenesis

19. Statement I: IUDs can cause excess menstrual bleeding and pain.

Statement II: IUDs can perforate uterus.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

20. Oral contraceptive pills mainly contain

a) Estrogen and luteinising hormone

21. Which statement about vasectomy is correct?

a) It stops spermatogenesis.

b) A small part of each vas deferens is cut or blocked, preventing sperm transport.

c) It prevents testosterone secretion.

d) It immediately removes sperm already present in the epididymis.

22. A widely accepted method of contraception in India is _____.

a) IUDs b) Diaphragms c) Tubectomy d) Cervical caps

23. Which of the following contraceptives involve a role of hormones?

a) Pills, Emergency contraceptives, Implants

b) Pills, IUDs, Vaults

c) Pills, Condoms, CuT

d) Pills, Implants, Diaphragms

24. Which of the following does not give the defined action of a contraceptive?

a) Hormonal method prevents or retards the entry of sperms, prevent ovulation and fertilisation

b) Vasectomy prevents spermatogenesis

c) Barrier method prevent fertilisation

d) Intra uterine devices increase phagocytosis of sperms, suppress sperm motility and fertilising capacity of sperms

25. Statement I: All contraceptives have the added advantage of protection against sexually transmitted diseases.

Statement II: Natural birth control methods have negligible side effects.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

26. Which of the following are not completely curable?

a) Hepatitis B, Chlamydiasis, HIV infection

b) Trichomoniasis, Chlamydiasis, HIV infection

c) Hepatitis B, Trichomoniasis, HIV infection

d) Hepatitis B, Genital herpes, HIV infection

27. The incidences of sexually transmitted infections are reported to be very high among persons in the age group of ___ years.

a) $05-14$ b) $15-24$ c) $25-34$ d) $35-44$

28. A specialised procedure to form a embryo in the laboratory is ___

a) Gamete Intra Fallopian Transfer b) Intra Cytoplasmic Sperm Injection

c) Artificial Insemination d) Intra Uterine Insemination

29. Statement I: GIFT is an in-vitro fertilisation technique.

Statement II: In GIFT, gametes are fertilised outside the female body.

a) Both Statement I and Statement II are correct

b) Both Statement I and Statement II are incorrect

c) Statement I is correct and Statement II is incorrect

d) Statement I is incorrect and Statement II is correct

30. In vivo fertilization occurs in

a) ZIFT b) GIFT c) ICSI d) IVF

Answer Key					
1. A.	**2.** C.	**3.** A.	**4.** C.	**5.** A.	**6.** A.
7. A.	**8.** D.	**9.** D.	**10.** D.	**11.** C.	**12.** A.
13. A.	**14.** A.	**15.** D.	**16.** A.	**17.** D.	**18.** C.

19. A.	**20.** B.	**21. B.**	**22.** A.	**23.** A.	**24.** B.
25. D.	**26.** D.	**27.** B.	**28.** B.	**29. B.**	**30.** B.

II. Fill in the blanks: 1 Mark Each:

(Family planning, Periodic abstinence, Coitus interrupts, Infertility, ICSI, surgical intervention, venereal, Saheli, 72, 12, Amniocentesis, Condom)

1. The programs to get total reproductive health as a social goal at the national level are called ___
2. A pre-natal diagnostic technique which was misused to illegally determine the sex of the developing foetus is ___
3. The collective term given to the diseases which are transmitted through sexual intercourse is ___ diseases
4. A natural method of contraception in which the couples avoid coitus during the period of menstrual cycle when ovulation could be expected is ___
5. ___ is a natural method of birth control based on the withdrawal of penis before ejaculation.
6. The contraceptive that protects the user from contracting STIs and AIDS is ___
7. ___ methods of contraception blocks gamete transport and thereby prevent conception.
8. ___ is an oral contraceptive for females, developed by scientists at the Central Drug Research Institute, Lucknow.
9. Administration of progestogens or progestogen-estrogen combinations or IUDs are effective as emergency contraceptives within ___ hours of coitus
10. MTPs are considered relatively safe upto ___ weeks of pregnancy
11. Inability of the couple to produce children inspite of unprotected sexual co-habitation is ___
12. An assisted reproductive technology in which a sperm is directly injected into the ovum to ensure conception is ___

Answer Key

1. Family Planning **Amniocentesis** **3. Venereal**

Answer Key		
1. Family Planning	2. Amniocentesis	3. Venereal
4. Periodic abstinence	5. Coitus interruptus	6. Condom
7. Surgical intervention	8. Saheli	9. 72
10. 12	11. Infertility	12. ICSI (Intracytoplasmic Sperm Injection)

PART - B

III. Answer the following questions in 3-5 sentences each. 2 Marks Each:

Q2. Introduction of sex education in schools should be encouraged. Why?

Ans: It discourages children from believing in myths and misconceptions about sex-related issues. Proper

information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS.

Q3. Which days of menstrual cycle are identified as "fertile period" and why?
Ans: Day 10 to Day 17 of the menstrual cycle is considered the fertile period. Ovulation occurs around this time and chances of fertilisation are high.

Q4. Mention two benefits of condoms which are used as contraceptive devices.
Ans: Condoms protect against sexually transmitted diseases (STDs). Condoms are disposable, can be self-inserted and prevent conception effectively.

Q5. What are IUDs? Give any two examples.
Ans: Intrauterine Devices (IUDs) are contraceptive devices inserted into the uterus. Examples: Copper-T, Lippes Loop.

Q6. Parents of one-year-old child wanted to space their second child. Their doctor suggested Cu-T. Explain its contraceptive actions.
Ans: Cu-T suppresses sperm motility and fertilising capacity of sperms. It is a copper-releasing IUD and is highly effective in preventing conception.

Q7. Mention any two events that are inhibited by the intake of oral contraceptive pills to prevent pregnancy in humans.
Ans: They inhibit ovulation and implantation. Alter the quality of cervical mucus to prevent/retard entry of sperms.

Q8. Why do women use 'Saheli', the oral contraceptive pill as a well-accepted method?
Ans: It is once-a-week pill with high contraceptive value. It is a non-steroidal preparation and with very few side effects.

Q9. What are emergency contraceptives? Write their hormonal combination.
Ans: Emergency contraceptives are hormonal pills used after unprotected intercourse. They contain a combination of Estrogen and Progestogen OR Progestogen only.

Q10. List one permanent contraceptive method each in males and females.
Ans: Male: Vasectomy. Female: Tubectomy.

Q11. Differentiate between vasectomy and tubectomy.
Ans: Vasectomy: a small part of the vas deferens is removed or tied up through a small incision on the scrotum. Tubectomy: a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.

Q12. List the possible ill-effects of various contraceptive methods.
Ans: Nausea, Abdominal pain, Breakthrough bleeding.

Q13. Mention four early symptoms of STD that occur in the genital region.
Ans: Itching, Fluid discharge, Slight pain, Swelling.

Q14. What are assisted reproductive technologies? Mention any two assisted reproductive technologies (ARTs).

fertilisation and embryo transfer) and GIFT (gamete intrafallopian transfer).

Q15. Suggest any two ARTs that may help an infertile couple where the female partner can support

tube.

tube.

Q16. Explain the technique that can help a woman who cannot produce viable ova but can support fertilisation and development in her reproductive tract and wishes to bear a child.

Ans: GIFT (Gamete Intra-Fallopian Transfer): an ovum collected from a donor is transferred into the recipient's fallopian tube, where fertilisation may occur in vivo.

PART - C

IV. Answer the following questions in 40 – 80 words each: 3 Marks Each:

Q1. Mention three strategies to promote reproductive health.

Ans:

1. **Family planning -** through awareness and access to contraceptive methods.
2. **Introduction of sex education in schools** to remove myths and misconceptions about sex-related aspects.
3. **Medical assistance and services to people** with reproductive problems like infertility, STDs, pregnancy care, etc.

Q2. How is amniocentesis performed? Why it is legally banned in our country?

Ans: Amniotic fluid is drawn from the amniotic sac using a syringe to analyse the foetal cells and dissolved substances. This procedure can be used to test for certain genetic disorders such as Down syndrome, haemophilia and sickle-cell anaemia. Prenatal sex determination using this technique is prohibited to prevent misuse for sex-selective practices.

Q3. Mention the parameters that indicate improved reproductive health of the society.

Ans: Decrease in maternal mortality rates and infant mortality rates. Better awareness about contraceptives. The young, urban, working ones have even adopted a 'one child norm' the most important step to overcome population explosion.

Q4. List the measures taken by the government to check the population growth rate.

Ans:

1. Motivate smaller families by using various contraceptive methods.
2. Create awareness about small-family norms and responsible family planning.
3. Promote adherence to the legally prescribed minimum age at marriage.
4. Incentives given to couples with small families.

Q5. What are contraceptives? Mention the qualities of an ideal contraceptive.

Ans: Contraceptives are methods to prevent pregnancy. An ideal contraceptive should be User-friendly. Easily available. Effective. Reversible with no or least side-effects. Should not interfere with the sexual drive, desire and sexual act.

Q6. Explain natural methods of contraception.

Ans: Natural methods are based on avoiding chances of ovum and sperm meeting. Methods include:

1. **Periodic abstinence** – avoiding coitus during fertile days.
2. **Withdrawal method** – withdrawal of penis before ejaculation.
3. **Lactational amenorrhoea** – absence of menstruation during intense lactation after parturition.

Q7. Explain barrier methods of contraception.

Ans: These methods prevent physical meeting of sperm and ovum. Condoms (for both sexes), diaphragms, and cervical caps are examples. Spermicidal creams, jellies, and foams can be used along with barriers for better efficacy.

Q8. List the types of intrauterine devices with one example for each.

Ans:

1. Non-medicated IUDs – e.g., Lippes Loop
2. Copper-releasing IUDs – e.g., CuT, Cu7, Multiload 375
3. Hormone-releasing IUDs – e.g., LNG-20, Progestasert

Q9. Categorise the following into different kinds of IUDs:

Ans:

a) Progestasert – Hormone-releasing
b) Lippes Loop – Non-medicated
c) CuT – Copper-releasing
d) LNG-20 – Hormone-releasing
e) Cu7 – Copper-releasing
f) Multiload 375 – Copper-releasing

Q10. Name any two-copper releasing intra-uterine devices (IUDs). List two reasons that make them effective contraceptives.

Ans: Examples: CuT, Multiload 375

Reasons:

1. Increase phagocytosis of sperms
2. Suppress sperm motility and fertilising capacity of sperms

Q11. a) Identify the contraceptive device shown in the picture. b) Mention how it prevents fertilization and conception.

Ans:

a) CuT (Copper-T)
b) It suppresses sperm motility and the fertilising capacity of sperm.

Q12. At the time of independence, India's population was 350 million. It exploded to over 1 billion by May 2000. List any three reasons for this rise and two steps taken by the government to check it.

Ans:

Reasons:

1. Increased health facilities along with better living conditions.
2. A rapid decline in death rate, maternal mortality rate (MMR) and infant mortality rate (IMR).
3. Increase in number of people in reproductive age

Steps:

4. Motivate smaller families by using various contraceptive methods.
5. Statutory raising of marriageable age of the female to 18 years and that of males to 21 years.

Q13. a) Give the technical term for the process shown in male surgical contraception. b) What is the principle behind it? c) How is the process carried out?

Ans:

a. Vasectomy
b. Blocks gamete transport and thereby prevent conception
c. A small part of the vas deferens is removed or tied up through a small incision on the scrotum.

Q14. a) Give the technical term for the process shown in female surgical contraception. b) How is the process carried out? c) Principle behind it:

Ans:

a) Tubectomy

b) A small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.

c) Blocks gamete transport and thereby prevent conception.

Q15. Name the hormonal composition of oral contraception used by human females. Explain how it acts as contraceptive.

Ans: It contains estrogen and progesterone (or progesterone alone). It inhibits ovulation and alters cervical mucus. Also changes uterine lining making it unsuitable for implantation.

Q16. List any six reproductive tract infections or sexually transmitted diseases.

Ans:

1. Gonorrhoea
2. Syphilis
3. Genital herpes
4. Chlamydiasis
5. Genital warts
6. HIV-AIDS

Q17. List three principles through which one could be free of STDs.

Ans:

(i) Avoid sex with unknown partners/multiple partners.

(ii) Always try to use condoms during coitus.

(iii) In case of doubt, one should go to a qualified doctor for early detection and get complete treatment if diagnosed with infection.

Q18. Define venereal disease. Mention the modes of transmission of HIV / Hepatitis B virus.

Ans: Venereal diseases (STDs) are infections transmitted through sexual contact.

Modes of transmission:

a) Sexual contact

b) Blood transfusion

Q19. Suggest any three ARTs that may help when the problem is with the male partner.

Ans: 1. AI/IUI - processed semen from the husband or a donor is introduced into the female reproductive tract/uterus.
2. ICSI - a single sperm is injected directly into the ovum.
3. IVF-ET - fertilisation occurs outside the body, followed by embryo transfer.

Q20. Explain IVF and embryo transfer (test-tube baby technique).

Ans: Ova and sperm are collected and fertilisation is carried out in vitro. A zygote or embryo up to 8 blastomeres is transferred into the fallopian tube (ZIFT); an embryo with more than 8 blastomeres is transferred into the uterus (IUT).

Q21. A woman cannot produce viable ova but can support fertilisation and development. Name a suitable ART.

Ans: GIFT - gametes from a donor can be transferred into the fallopian tube of the recipient.

Q22. Give the technical term for the ARTs described below:

Ans:

a) Transfer of donor ovum into another female → **GIFT**

b) Artificial introduction of semen into uterus → **IUI** (Intra Uterine Insemination)

c) Direct injection of sperm into ovum → **ICSI** (Intracytoplasmic Sperm Injection)

V. Answer the following questions in 100 – 150 words each: 5 Marks Each:

Q1. Explain five measures that can be taken to build up a socially responsible and reproductively healthy society.

Ans: 1. 'family planning' were initiated in 1951 and were periodically assessed over the past decades. Improved programmes covering wider reproduction-related areas are currently in operation under the popular name 'Reproductive and Child Health Care (RCH) programmes.

2. Awareness Programs: create awareness among the people about reproduction-related aspects. Government and NGOs should educate people about reproductive health, hygiene, and family planning through schools, mass media, and community programs.

3. Sex Education in school: Introduction of sex education in schools should also be encouraged to provide right information to the young so as to discourage children from believing in myths and having misconceptions about sex-related aspects. Proper information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS.

4. Social Support: Successful implementation of strong infrastructural facilities, professional expertise and material support.

5. Educating people: especially fertile couples and those in marriageable age group, about available birth control options, care of pregnant mothers, post-natal care of the mother and child, importance of breast feeding, equal opportunities for the male and the female child.

Q2. A wide range of contraceptive methods are presently available. Broadly group them into different categories.

Ans: 1. Natural/Traditional Methods: Periodic abstinence, Coitus interruptus, Lactational amenorrhoea.

2. Barrier Methods: Male and female condoms, Diaphragms, cervical caps, and vaults, Spermicidal jellies and foams.

3. Intrauterine Devices (IUDs): Non-medicated: Lippes loop; Copper releasing: CuT, Cu7; Hormone releasing: LNG-20, Progestasert.

4. Oral Contraceptives: Combined pills (estrogen + progesterone), Saheli (non-steroidal).

5. Injectables and Implants: Progestogen or combination of estrogen and progesterone.

6. Surgical Methods (Sterilization): Vasectomy in males, Tubectomy in females.

Q3. a) What is Medical Termination of Pregnancy? b) Mention two reasons for a woman to undergo medical termination of pregnancy. c) Mention any two medical grounds on which pregnancy can be terminated.

Ans: a) It is the voluntary termination of pregnancy before full term using surgical or chemical methods.

b) 1. Failure of contraceptive methods.
2. Pregnancy resulting from rape.

c) 1. When continuation of pregnancy could be harmful or even fatal either to the mother or to the foetus or both.
2. If the foetus is diagnosed with severe physical or mental abnormalities.

Q4. Medical termination of pregnancy is termination of pregnancy before the foetus becomes viable. a) When was MTP legalized by government of India? b) When is MTP relatively safe? c) What is the significance of MTP?

Ans:

a) In 1971 under the MTP Act.

b) During the first trimester, i.e., up to 12 weeks of pregnancy.

c) 1. To reduce unwanted pregnancies, especially in cases of contraceptive failure.
2. To support women who are victims of rape.
3. To reduce maternal mortality due to unsafe and illegal abortions.

Q5. What are IUDs? Mention any two types with an example for each. How do IUDs help in preventing conception?

Ans: IUDs (Intra Uterine Devices) are contraceptive devices inserted into the uterus to prevent pregnancy. They are inserted by doctors or trained nurses.
Types and examples:

1. **Non-medicated IUDs –** Lippes's loop
2. **Copper-releasing IUDs –** CuT
3. **Hormone-releasing IUDs –** LNG-20
   Mode of action: Increase phagocytosis of sperms. Suppress sperm motility and fertilising capacity. Hormonal IUDs make the uterus unsuitable for implantation and cervical mucus hostile to sperms.

Q6. Intrauterine devices are most widely accepted methods of contraception. a) How does CuT prevent conception? b) Which IUD makes uterus unsuitable for implantation? c) Name two hormone releasing IUDs.

Ans: a) CuT releases copper ions that suppress sperm motility and fertilising capacity of the sperms. It also increases phagocytosis of sperms within the uterus.

b) Hormone-releasing IUDs like LNG-20 make uterus unsuitable for implantation.

c) 1. LNG-20, 2. Progestasert.

Q7. Explain how oral contraceptives and sterilization help in contraception.

Ans: Oral Contraceptives (OCs): Contain small doses of estrogen and progesterone (or progesterone alone). They inhibit ovulation, thicken cervical mucus, and alter endometrial lining to prevent implantation.
Sterilization: It is a permanent method of contraception. In males (Vasectomy), a small part of vas deferens is

Q8. What are sexually transmitted diseases? Mention four early symptoms and four complications.

Ans: Sexually transmitted diseases (STDs/STIs) are infections mainly transmitted through sexual contact. Early symptoms may include itching, unusual discharge, pain or swelling, and sores/lesions. Possible complications include pelvic inflammatory disease, infertility, pregnancy-related complications and increased risk of some reproductive tract cancers.

Q9. What are assisted reproductive technologies? How can infertility be treated using ART?

Ans: Assisted Reproductive Technologies (ARTs) are medical techniques used to help achieve pregnancy. Examples include:
- IVF-ET: fertilisation outside the body followed by embryo transfer.
- ZIFT: zygote/early embryo (up to 8 blastomeres) transferred to the fallopian tube.
- IUT: embryo with more than 8 blastomeres transferred to the uterus.
- GIFT: gametes transferred to the fallopian tube.
- ICSI: a single sperm is injected into an ovum.
- AI/IUI: processed semen is introduced into the female reproductive tract/uterus.

technologies?

Ans: Assisted Reproductive Technologies (ARTs): Techniques that assist infertile couples to have children.

b) ZIFT: Zygote formed in vitro is transferred into the fallopian tube.

c) GIFT: Ovum is collected from donor and transferred into fallopian tube of recipient.
These methods help couples who are unable to conceive naturally.

Q10. a) What is infertility? Mention any two causes for infertility. b) How is infertility treated by ICSI and AI?

Ans: a) Infertility is the inability of a couple to conceive even after 1–2 years of unprotected sexual cohabitation. Causes: Low sperm count, poor sperm motility (males); Blockage of fallopian tubes, hormonal imbalance (females).

b) ICSI (Intracytoplasmic Sperm Injection): A single sperm is injected directly into the ovum. AI (Artificial Insemination): Semen is collected from husband or donor and introduced into the female reproductive tract.

VI. Answer the following questions as directed: 5 Marks Each:

Q1. Based on the picture related to contraceptives answer the question given below given below.

Ans: a) Identify the male and the female contraceptive devices, A and B.

A – Condom B – Female condom

b) How do they prevent conception?

By preventing the physical meeting of sperm and egg.

c) Mention two advantages (other than contraception), why they are preferred.

1. Easy to use
2. Prevent STIs.

Q2. Explain natural method and sterilization method of contraception.

Ans: 1. Periodic abstinence – Periodic abstinence is one such method in which the couples avoid or abstain from coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected.

2. Withdrawal method – male partner withdraws his penis from the vagina just before ejaculation so as to avoid insemination.

3. Lactational amenorrhoea – absence of menstruation during intense lactation after parturition.
sterilization method In males (Vasectomy):

1. A small part of vas deferens is removed or tied.
2. Prevents transport of sperm.
   In females (Tubectomy):
3. A small section of fallopian tube is cut or tied.
4. Prevents ovum from meeting sperm.
5. These are highly effective and irreversible methods of contraception.

Q3. The picture shows the contraceptive device used by women.

Ans: a) Identify the contraceptive device shown in the picture.

Implant.

b) What does it contain?

Progestogens alone or in combination with estrogen.

c) How is it used?

It is implanted below the skin.

d) How does it function as a contraceptive?

1. They inhibit ovulation
2. Inhibits implantation
3. Alter the quality of cervical mucus to prevent/retard entry of sperms.

Chapter 4

PRINCIPLES OF INHERITANCE AND VARIATION

TABLE OF CONTENTS

4.1. MENDELISM

4.2. INHERITANCE OF ONE GENE

4.3. INHERITANCE OF TWO GENES

4.4. SEX DETERMINATION

4.5. MUTATION

4.6. GENETIC DISORDERS

Theory

INTRODUCTION:

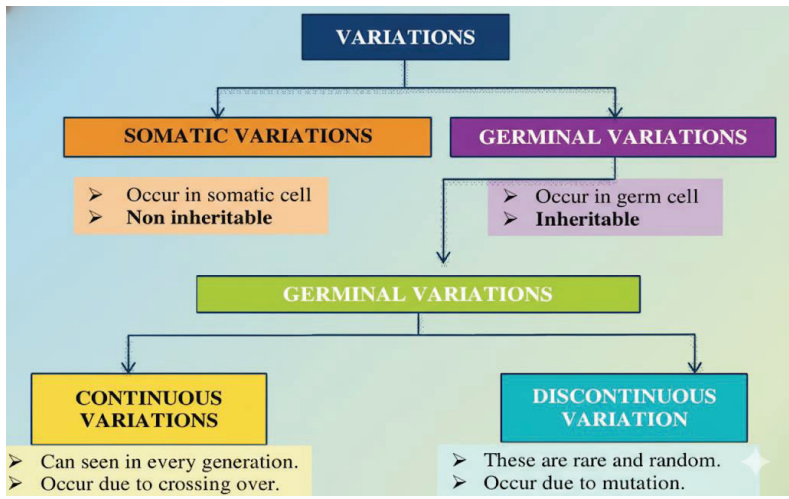
- **Genetics: -** Collective study of **heredity** and **variation**.
- The term genetics was coined by W. Bateson.

HEREDITY

- "Like begets like " i.e. offspring are identical to their parents.
- Heredity - Transmission of genetic characters from parents to offspring.
- **Inheritance**:- It is the process by which characters are passed on from parent to progeny; It is the basis of heredity.

VARIATIONS

- Variation is the degree by which progeny differ from their parents.
- Humans knew from as early as **8000 – 1000** B.C. that one of the causes of variation was hidden in sexual reproduction.
- Humans exploited the variations that were naturally present in the wild populations of plants and animals to selectively breed and select for organisms that possessed desirable characters.
- For example, through artificial selection and domestication from ancestral wild cows, we have well-known Indian breeds, e.g., **Sahiwal cows in Punjab.**



HISTORY

History of researches in genetics

- **G.J. Mendel:-** Father of Genetics.
- **W. Bateson:-**Father of Modern Genetics.
- **Morgan:-** Father of Experimental genetics
- He performed experiment on Drosophila & proposed various concepts, like Linkage, Sex linkage.

SOME TERMS USED IN GENETICS

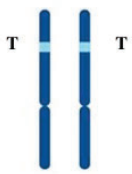
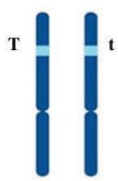
1. **Character -** Any feature of an organism. **Eg**. Plant height, Flower colour.
2. **Trait -** Different forms of character.
3. **Factors :-** The Units of heredity were called as **factors** by **Mendel**.(Now the factors of Mendel are called genes).
4. **Gene -**

- Unit of **heredity** which is responsible for **inheritance** and **appearance of characters.**
- These units were referred as **genes** by **Johannsen (1909).**

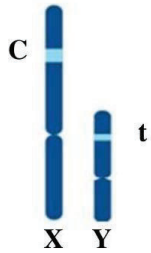
5. **Allele**

- Gene which code for a pair of contrasting traits are known as **alleles.**
- They are slightly different forms of same gene located on same locus of homologous chromosome.
- Alternative forms of a gene.
- T and t are the alleles of a gene that controls the character **height.**
- R and r are the alleles of a gene that controls the character **shape** of a seed.
- **Y** and **y** are the alleles of a gene that controls the character **colour** of cotyledon.

6. **Homozygous** and **Heterozygous**

HOMOZYGOUS	HETEROZYGOUS
☛ In diploid individual, if similar alleles of a gene is present then it is said to be homozygous. ☛ Also termed as Pure /true breeding.	☛ In diploid individual, if dissimilar alleles of a gene is present then it is said to be Heterozygous. ☛ Also termed as Impure /Hybrid
	

7. **Hybridization:-** A crossing experiment in which two parents are involved differing in one or more contrasting characters.
8. **Hybrid:-** A plant or animal obtained by crossing two homozygous individuals differing in one or more contrasting characters.
9. **Hemizygous -** Presence of only one allele of a gene in a diploid individual.
   eg. Male individual is hemizygous for gene present on *X* and *Y* chromosome.



10. Phenotype and Genotype

PHENOTYPE	GENOTYPE
☛ External and morphological appearance of an organism is called **phenotype.**	☛ Genetic constitution of an organism is called **genotype.**

11. Dominant allele and Recessive allele

Dominant allele	Recessive allele
Allele which can express itself both in homozygous and heterozygous condition is known as dominant allele.	Allele which can express itself only in homozygous condition is known as recessive allele.

12. **Monohybrid -** A plant or animal obtained by crossing two homozygous individuals differing in one contrasting character.
13. **Filial 1 progeny (First filial generation) :-** The first hybrid generation obtained by crossing two parents differing in one or more contrasting characters. It is represented as F1 generation.
14. **Filial 2 progeny/Second filial generation:-** The individual obtained by self pollinating two F1 hybrids is called second filial generation. It is also called **F2 generation.**
15. **Back cross :-** A cross between F1 hybrid with either of the two parents.
16. **Punnet square:-** It is a graphical representation to calculate the possible genotypes of offspring in a genetic cross. It was developed by **RC Punnett.**

MENDEL'S AMD HIS WORK

- Gregor Johann Mendel was born in the **village of Heinzendorf,** in a region called **Moravia of czechoslovakia.**
- He joined the church **overrun** with a hope to get an opportunity for learning. He became the **priest** in **1847.**
- In 1851 Mendel was deputed to the **university of vienna** for studying science (natural history) and mathematics for teacher certification.
- It is surprising to learn that Mendel never passed the examination but still taught physics and natural history at the technical high school in Brunn from 1854, after returning from the University.
- Mendel selected **garden pea plant** as an experimental material and conducted hybridization experiments from 1857for a period of **eight years.**
- On 8th of February 1865, Mendel presented the results of his pains taking research on pea plant before the Society for the study of natural science in Brunn.

- Mendel's work went unrecognized by the scientific world and he **died in 1884.**
- Mendel's work was rediscovered in 1900 by three biologists namely **Correns** of Germany, **Hugo de Vries** of **Holland** and **Tschemark of Austria.**
- They conducted experiments independently and obtained similar results to those of Mendel.
- With the rediscovery of Mendel's work, the scientific community recognized the significance of an outstanding contribution of Mendel to understand the mechanism of inheritance of characters from generation to generation.
- Since then, he is called the **"Father of Genetics".**
- The scientific world has honored him as scientist and recognized him as Father of Genetics.

REDISCOVERY OF MENDEL'S WORK

After 16 yrs of Mendel's death, in 1900, his postulates were rediscovered by 3 scientists [Working independently].

1. **Carl Correns; [Germany]** Experiment on Maize .
2. **Hugo de Vries; [Holland]** Experiment on Evening primrose .
3. **Erich von Tschermak;** [Austria] Experiment on different flowering plants .

Why Mendel's work remained unrecognised till 1900 ?

- Mendel published his work on inheritance of characters **in 1865** but, it remained unrecognised till 1900.
- **Some of the reasons** are as follows :

1. Communication was not easy in those days and hence work could not be widely published.
2. His concept of genes as stable and discrete alleles which did not 'blend' with each other, was not accepted by his contemporaries.
3. The mathematical terms and symbols used by **Mendel** to explain **biological phenomena** were totally not understood by many of the biologists of his time.
4. Mendel fail to provide any physical proof for the existence of factors as units of inheritance.
5. Scientists showed more interest on the book **"origin of species"** published by **Charles Darwin** during 1865.

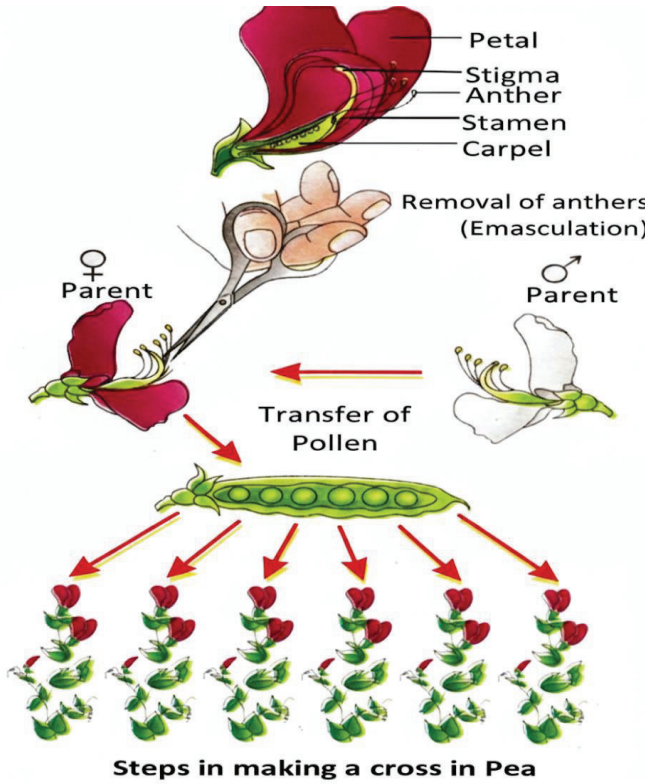
REASONS FOR MENDEL'S SUCCESS:

1. Mendel studied the inheritance of one or two character at a time unlike his predecessors who had considered many characters at a time.
2. He maintained the statistical records of all the experiments.
3. His experiments had a large sampling size. Which gave great or credibility to the data that he collected.
4. Mendel analyze the inheritance of qualitative characters i.e. Intermediate results are not present.
5. Selection of garden pea.

Why Mendel selected pea plants for his experiment ?

1. The plants exhibit different contrasting **phenotypic characters.**
2. The plants are annuals, **easy to cultivate** and **maintain**.

3. Flowers are **bisexual** and **naturally self-pollinating, but cross pollination is possible** manually.
4. It produces large number of **seeds.**



Steps in making a cross in Pea

Gregor Johann Mendel

- Conducted **hybridization experiments on garden pea plants for eight years** (1856-1863) and proposed the laws of inheritance in living organisms.
- Mendel observed characters in garden pea plants that display two opposing traits, **e.g.,** tall or dwarf plants, yellow or green seeds.
- Mendel conducted artificial pollination / cross pollination experiments using several **true-breeding pea lines.**
- The plants are **continuous self-pollinated** and shows the stable trait inheritance and expression for several generations is called **true-breeding.**
- Mendel selected 14 true-breeding pea plant varieties, as pairs which were similar except for one character with contrasting traits (**seven pairs of contrasting characters).**

Contrasting traits studied by Mendel in Pea:

Sl. No.	Characters	Dominant	Recessive
1	Stem height	Tall (T)	dwarf (t)
2	Flower colour	Violet (C)	white (c)
3	Flower position	Axial (A)	terminal (a)
4	Pod shape	Inflated (I)	constricted (i)
5	Pod colour	Green (G)	yellow (g)
6	Seed shape	Round (R)	wrinkled (r)
7	Seed colour	Yellow (Y)	green (y)

TECHNIQUES OF MENDEL

1. **Selection of pure parental plant- [True breeding plants]**

❖ It is done by continuous selfing and selection.

❖ Inbreeding increases homozygosity.

❖ 14 true breeding pea plant varieties [pure lines] are formed by Mendel for his experiments.

2. **Hybridization between pure plants**

It is done by **emasculation** and **bagging.**

a. **Emasculation-** Removal of anther from a bisexual flower in immature stage, it is done to prevent self-pollination.

b. **Bagging -** Covering of emasculated flower, it is

done to prevent undesirable cross pollination.

3. **Selfing of F_1 hybrid**

4.2. Inheritance Of One Gene

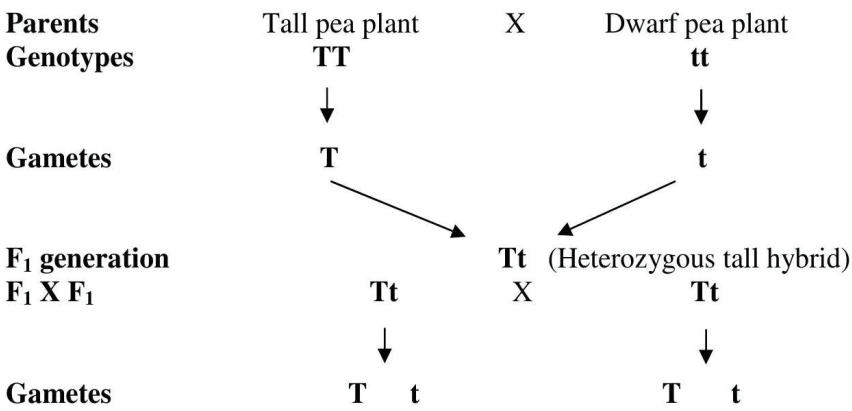
MONOHYBRID CROSS

Definition :- A cross between two parents that differ in only one contrasting character is called **monohybrid cross. Example:-** Mendel crossed tall and dwarf pea plants to study the inheritance one one gene.

Explanation:-

- When a homozygous tall pea plant was crossed with a homozygous dwarf plant, in the F1 progeny all plants were tall ,like one of its parents; none were dwarf. It is because **tallness is dominant** over **dwarfness**.
- Then the tall F1 tall plants were self crossed and found that in the F2 generation some offsprings were tall and some were dwarf in the ratio of 3:1 where 3 are tall and 1 is dwarf.

Diagrammatic representation of monohybrid cross (one gene inheritance):



F_2 generation: (Checker board) / Punnett square

	T	t
T	TT(Tall)	Tt(Tall)
t	Tt(Tall)	tt(dwarf)

Results of F_2 generation

- Phenotypic ratio = tall: dwarf
  3: 1
- Genotypic ratio = TT: Tt: tt
  1: 2: 1
- Types of phenotypes = 2^n [n is no. of heterozygous pair]
  $2^1 = 2$ phenotypes
  i.e. tall and dwarf

- Types of genotypes $= 3^n$ i.e. $3^1 = 3$ genotypes

  [TT, Tt , tt]

- Number of zygote $= 4^n$ i.e. $4^1 = 4$ zygotes

  Pure tall plants $= 1/4$

  Impure tall plants $= 2/4$

  Tall plants $= 3/4$

  Dwarf plant $= 1/4$

CONCLUSION OF MONOHYBRID CROSS

Law of dominance { 1. Conclusion of dominance

Law of segregation {2. Conclusion of segregation

LAW OF DOMINANCE

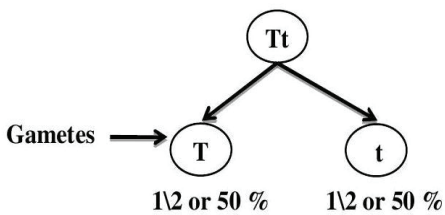
- According to Mendel characters are controlled by discrete units called **factors.**
- Factors occur in pairs.

  Eg. Tall-TT, Tt, Dwarf-tt
- In F_1 generation when two dissimilar factors are present together then factor which express itself over another is called **dominant factor** and which one is not express is known as **recessive factor.**
- Here F_1 generation resembles only one of the parents' i.e. **dominant parent.**

Exceptions: - Incomplete Dominance, Co-dominance

LAW OF SEGREGATION

- Dwarfness which appear in F_2 generation shows that allele do not show any blending and both the Characters are recovered as such in the F_2 generation though one of these is not seen at the F_1 stage.
- During gamete formation; the unit **factors** or **alleles** a pair segregate randomly and transfer inside different gamete.
- Each gamete receives only one factor of a pair; so gametes are pure for a particular trait. It is known as **Law of purity of gametes.**



- This law is also universal in nature because chromosome always segregate or separate at the time of meiosis Anaphase I.

  Rare exception of segregation: - Non disjunction of chromosome.

TEST CROSS

TEST CROSS

A test cross is a cross between an individual showing a dominant phenotype (genotype unknown) and a homozygous recessive individual. It is used to determine whether the dominant individual is homozygous or heterozygous.

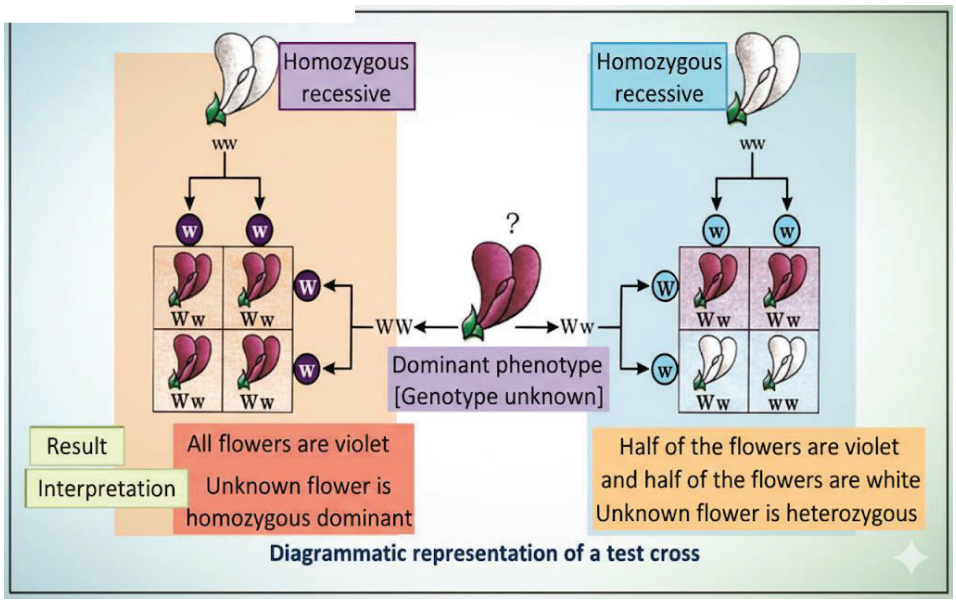
MONOHYBRID TEST CROSS

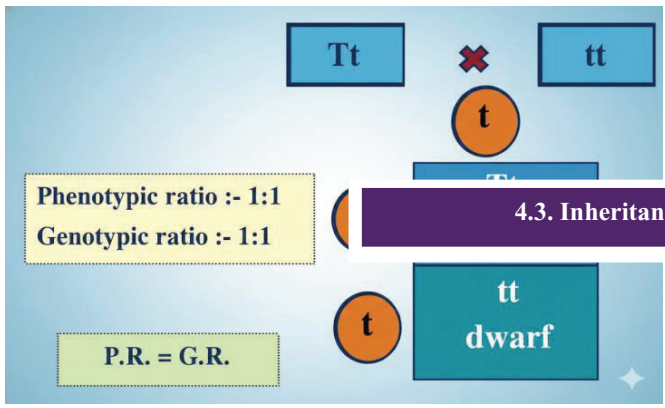
Example: T_ x tt. If the unknown plant is TT, all offspring are tall (Tt). If it is Tt, tall and dwarf offspring appear in a 1:1 ratio. Thus, the progeny reveal the unknown genotype.

ssive parent tt of monohybrid

ts here) showing a dominant phenotype (and whose genotype

ssive parent instead of self-crossing.



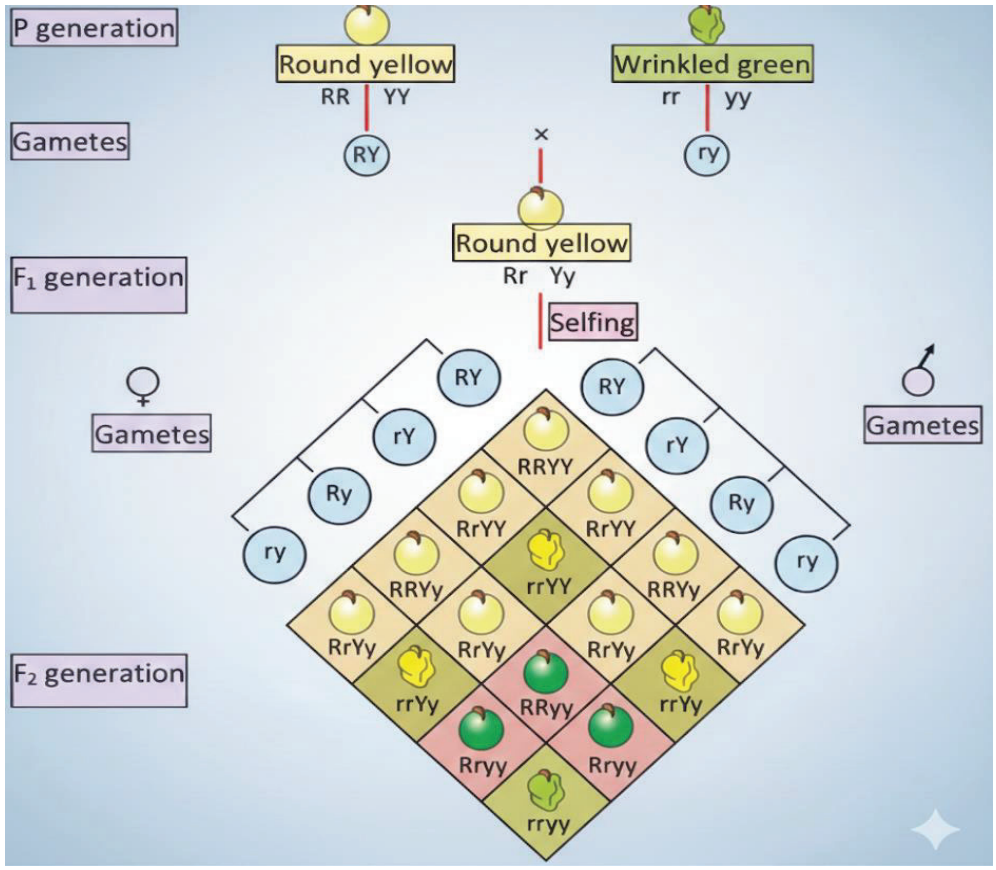


4.3. Inheritance Of Two Gene

DIHYBRID CROSS

- A cross between two individuals differing in two pairs of Contrasting traits is called **dihybrid cross.**
- Dihybrid cross explains the inheritance of two genes at a time.
- Mendel selected two varieties of pea plants – a pea plant with round & yellow seeds and other with wrinkled & green seeds.
- When a homozygous round and yellow seeded plant was crossed with a wrinkled and green seeded plant, heterozygous round and yellow seeded plants were produced in the **F1 generation**. It is because round and yellow are dominant over wrinkled and green.

- When F1 plants are self pollinated, four types of plants were produced in the **F2 generation.** They appeared in the ratio of 9:3:3:1 where 9 are round & yellow, 3 are round & green, 3 are wrinkled & yellow and 1 is wrinkled & green.



Phenotypic ratio

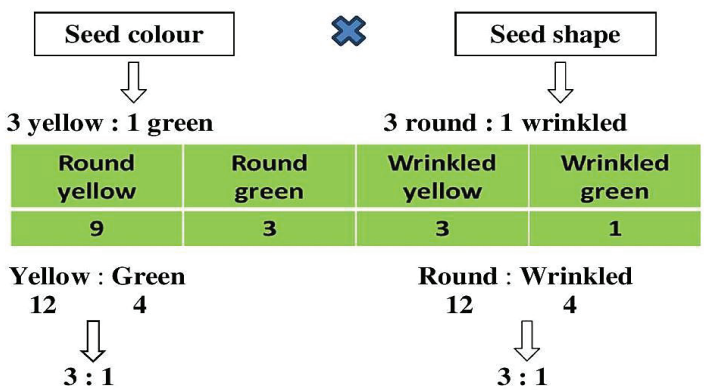
Round yellow	Round green	Wrinkled yellow	Wrinkled green
9	3	3	1

Genotypic ratio

RRYY	RRYy	RRyy	RrYY	RrYy	Rryy	rrYY	rrYy	rryy
1	2	1	2	4	2	1	2	1

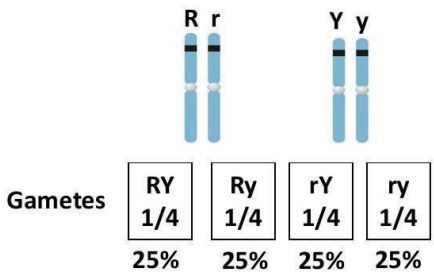
LAW OF INDEPENDENT ASSORTMENT

- It is based on F2 – generation of **Dihybrid cross.**
- Dihybrid cross is a product of 2 monohybrid crosses



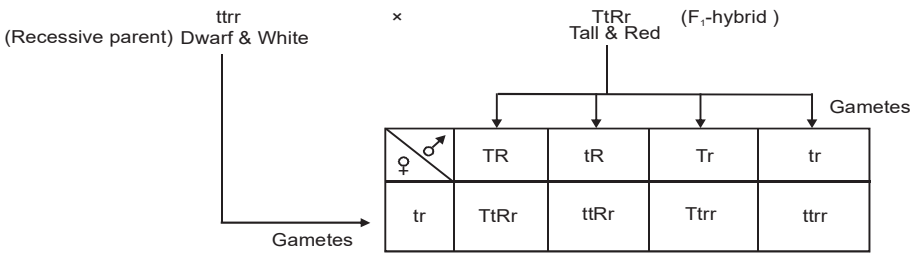
- The law states that "When two pairs of alleles are combined in a hybrid, segregation of one pair of allele is independent of the other pair of allele ."
- It explains the independent segregation of two pairs of genes during meiosis and the production of eggs and pollen in the F1 generation (RrYy plant).
- It is evident from dihybrid cross during gamete formation that ;
  1. The factors for yellow colour assort out independently of the factors for round shape.
  2. The **gene Y** may combine with the dominant **gene R** or the receive gene **r** of other character and enters a gamete.
  3. Similarly the **gene y** may combine with the dominant **gene R** or recessive **gene r** and enter a gamete.
  4. Hence the F1 dihybrid plant produces four types of gametes and they are **YR,Yr, yR** and **yr.**

  Exception: Linkage



DIHYBRID TEST CROSS

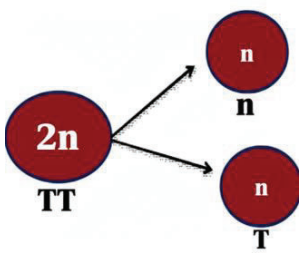
A cross between a heterozygous F1 individual with its recessive parent is called **test cross**.



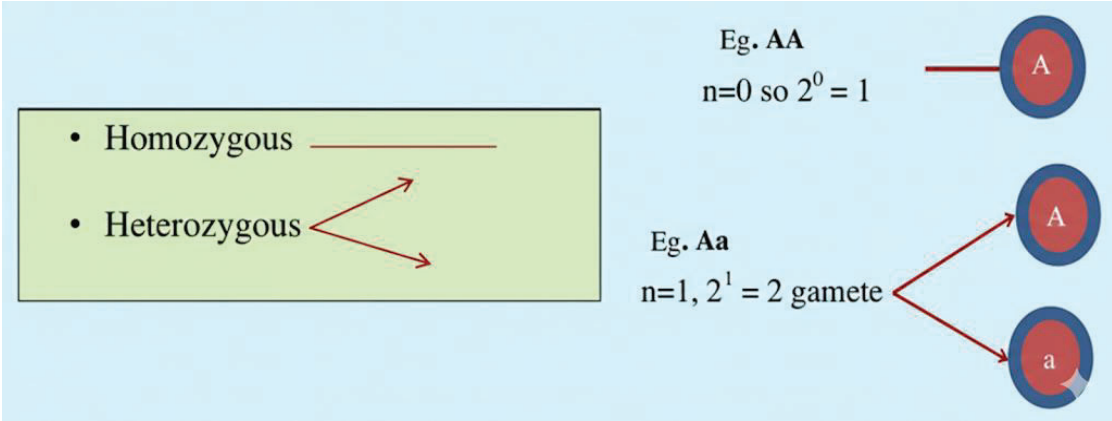
Ratio : RrYy x rryy (Dihybrid test cross ratio is 1: 1: 1: 1)

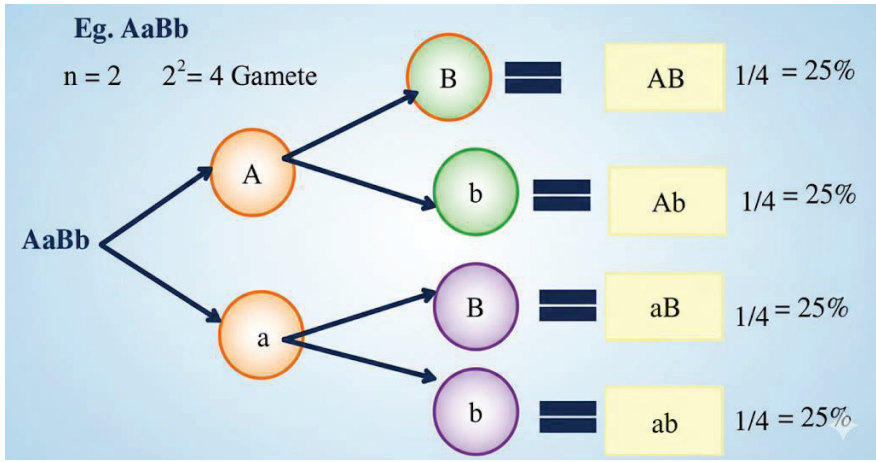
GAMETE FORMATION

- At the time of meiosis.



- Types of gametes $= 2^n$
- where n is no. of heterozygous pair or hybrid character.
- **Fork line method:-** To find out the composition of factors inside the gamete, we use fork line method.





IMPORTANT FORMULA'S FOR SELFING

Formula's	Monohybrid Aa	Dihybrid AaBb	Trihybrid AaBbCc
Types of phenotypes 2^n	2	4	8
Types of genotype 3^n	3	9	27
Number of zygote 4^n	4	16	64

Explanation of the concept of dominance

- Every gene contains information to express a particular trait.
- **In heterozygotes, there are 2 types of alleles :-**

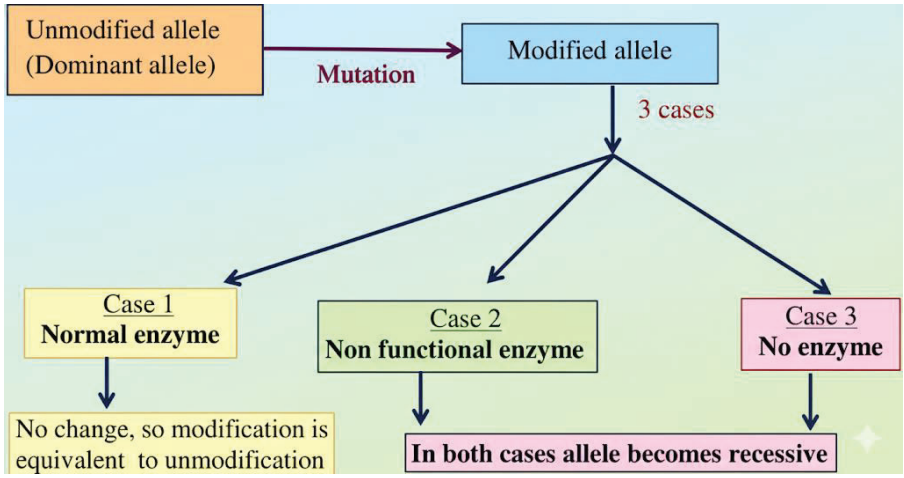
a. **Unmodified (normal or functioning) allele**: It is generally dominant and represents original phenotype.

b. **Modified allele:** It is generally recessive. **E.g.** consider a gene that contains information for producing an enzyme. Normal allele of that gene produces a normal enzyme. Modified allele is responsible for production of

1. Normal/less efficient enzyme or
2. A non-functional enzyme or
3. No enzyme at all

➢ **In the first case:** The modified allele will produce the same phenotype like unmodified allele. Thus, modified allele is equivalent to unmodified allele.

➢ **In 2nd and 3rd cases:** The phenotype will dependent only on the functioning of the unmodified allele. Thus the modified allele becomes recessive.



NON-MENDIIAN INHERITANCETHE

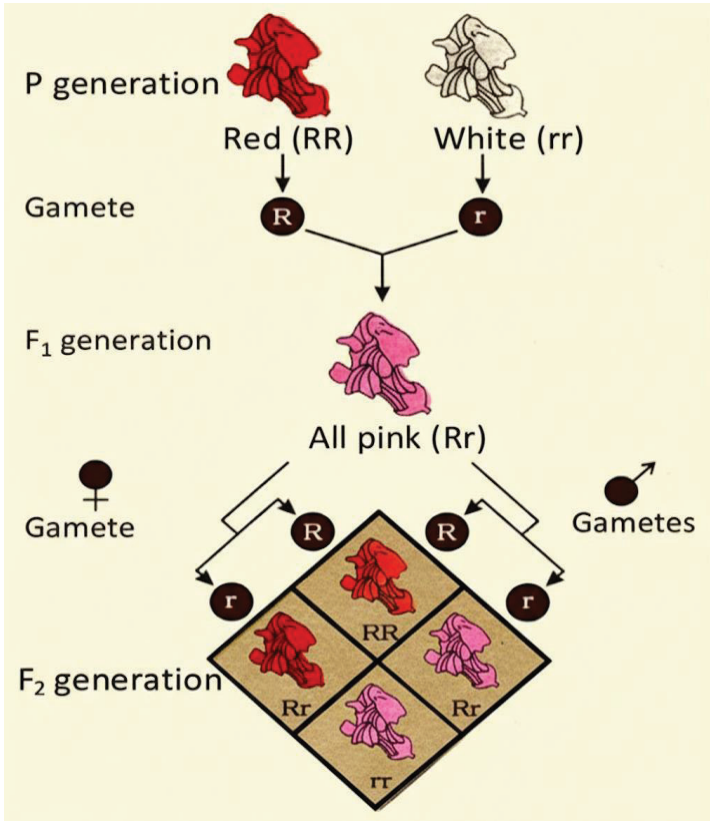
➢ Inheritance pattern that do not follow mendel's law of complete dominance.

INCOMPLETE DOMINANCE

- When in heterozygous condition, dominant allele cannot express completely over recessive allele this is known as **Incomplete dominance.**
- It is the **exception of law of dominance.**
- In case of incomplete dominance, the $\mathbf{F_1}$ had a phenotype that did not resemble either of the two parents and was in between the two.
- In heterozygous condition intermediate form appears.
- The inheritance of flower colour in the dog flower (snapdragon or Antirrhinum majus) is a good example to understand incomplete dominance.
- Incomplete dominance was first discovered by **Carl Correns** for flower colour in Mirabilis jalapa.
- Incomplete dominance is found in **Snapdragon** is similar to **Mirabilis**.
- Intermediate starch grain size in pea plant is also example of incomplete dominance.

Explanation :-

- When a homozygous red flowered plant is crossed with a homozygous white flowered plant, all the F1 plants shows pink flowers. This is due to **incomplete dominance.**
- When F1 Pink flowered plants are self pollinated,three types of plants are produced in the F2 generation. They are red ,pink and white. They appear in the ratio of **1:2:1** where one is red, two are pink and one is white.



Phenotypic ratio :- red : pink :white

1 : 2 : 1

Genotype ratio :- Rr : Rr : rr

1 : 2. : 1

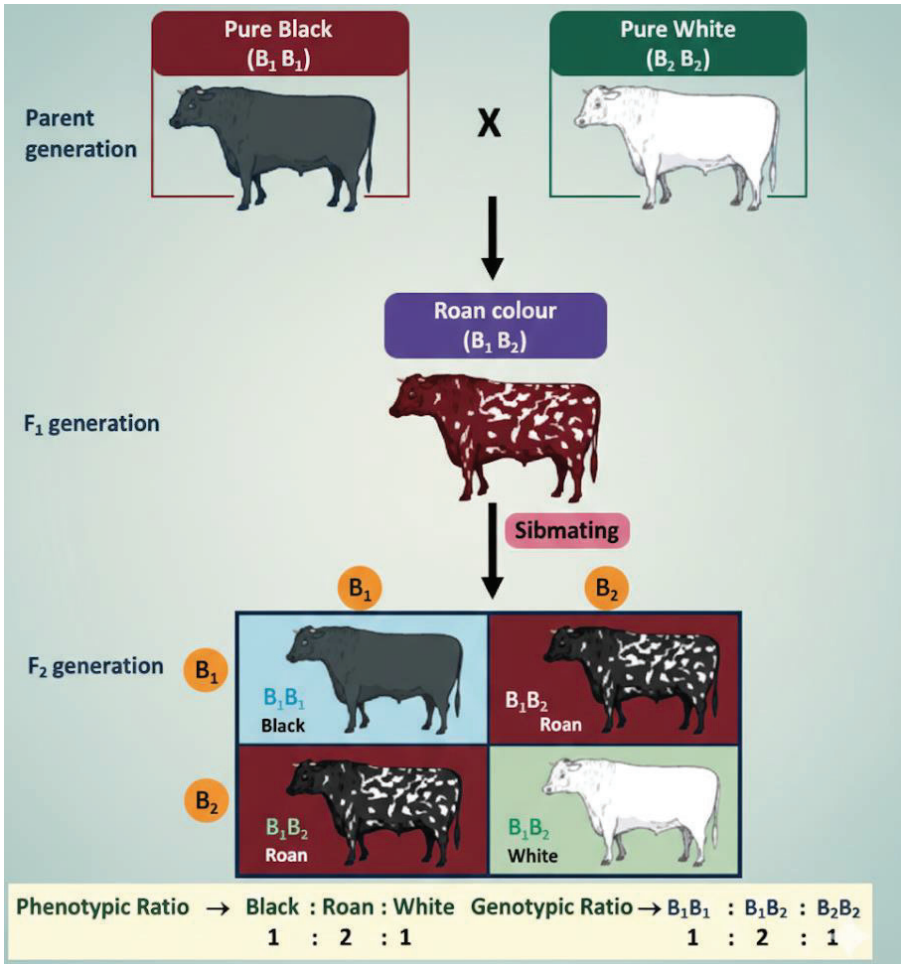
Dominance	Incomplete dominance
Here F_1 gen. resembles only one of the parent i.e. dominant parent.	Here F_1 gen. resembles none of the parent and the result was between the two.

CO-DOMINANCE

- Another exception of law of dominance.
- When both the allele of a gene express themselves simultaneously in a heterozygote, this condition is known as Co-dominance.
- In case of co-dominance the F_1 generation resembles both the parents.

Examples: -

1. AB blood group inheritance (AB blood group) - ($I^{A}I^{B}$)
2. Carrier of Sickle cell anaemia ($Hb^{A}Hb^{S}$)
3. Coat colour in Cattles



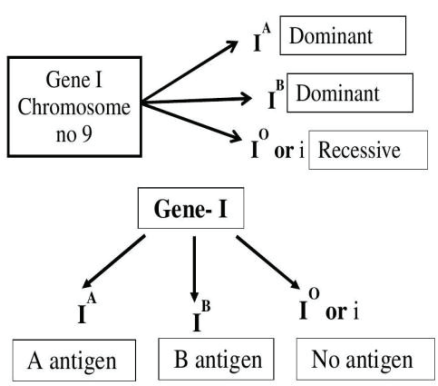
MULTIPLE ALLELES

- More than 2 alternative forms(alleles) of same gene are is called **multiple alleles.**
- Multiple alleles formed due to mutation.
- In a diploid organism only two alleles of a gene can be present and rest other allele of a same gene will be present in other members of population. So population study is essential for the study of multiple allele.

  Example :- ABO Blood group in humans

ABO BLOOD GROUP

- ABO blood group in humans beings comprises of four blood groups i.e. **A, B, AB, O**
- These blood groups are due to the presence of special antigens on the surface of RBC.
- Blood groups in man are controlled by a single gene called I.
- The gene **I** has three alleles called I^A, I^B and **i**.



ABO BLOOD GROUP

- The alleles I^A and I^B produce a slightly different antigen (sugar polymer) where as allele **i** do not produce any antigen.
- Because humans are diploid and each person possesses any two of the three I gene alleles.

Allele from Parent 1	Allele from Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	I^AI^A	A
I^A	I^B	I^AI^B	AB
I^A	i	I^Ai	A
I^B	I^A	I^AI^B	AB
I^B	I^B	I^BI^B	B
I^B	i	I^Bi	B
i	i	i i	O

- I^A and I^B are completely dominant over i, **i.e**. When I^A and **i** are present only I^A expresses and when I^B and **i** are present I^B expresses.
- When I^A and I^B are present together they both express their own types of sugars. It because of co-dominance. Hence RBC has both A and B types of sugars.
- Since there are three different alleles, there are six different combinations of these three alleles that are possible, a total of six different genotypes of the human ABO blood types.

PLEIOTROPY

- Gene which controls more than one character is called pleiotropic gene.
- This gene shows multiple phenotypic ef

EXAMPLES OF PLEIOTROPY

1. **Phenylketonuria :**

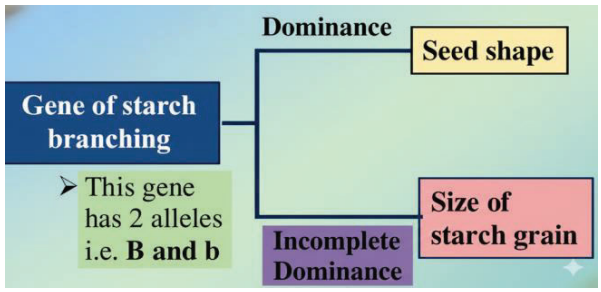
- It is an inborn error of metabolism and is inherited as autosomal recessive trait.
- PKU disease is caused due to mutation in the gene that code for the enzyme called **phenylalanine hydroxylase** that converts the amino acid **Phenylalanine** into **tyrosine** in liver.
- As a result of this phenylalanine is accumulated and converted into **phenyl-pyruvic** acid and **phenyl lactic acid.**
- Accumulation of these in brain results in **mental retardation.** Excess is eliminated through urine because of its poor absorption by kidney.
- **Symptoms :-**

1. Mental retardation
2. Reduction in hair pigmentation
3. Reduction in skin pigmentation

2. **Starch synthesis In Pea plant:** Seed shape and size of starch grains controlled by same gene located on chromosome.

- **Starch synthesis in pea seeds** is controlled by one gene. It has two alleles called **B** and **b**.
- Starch is synthesized effectively by **BB homozygote** & hence **large starch grains** are produced.
- **bb homozygote** have lesser efficiency in starch synthesis and produce **smaller starch grains**.

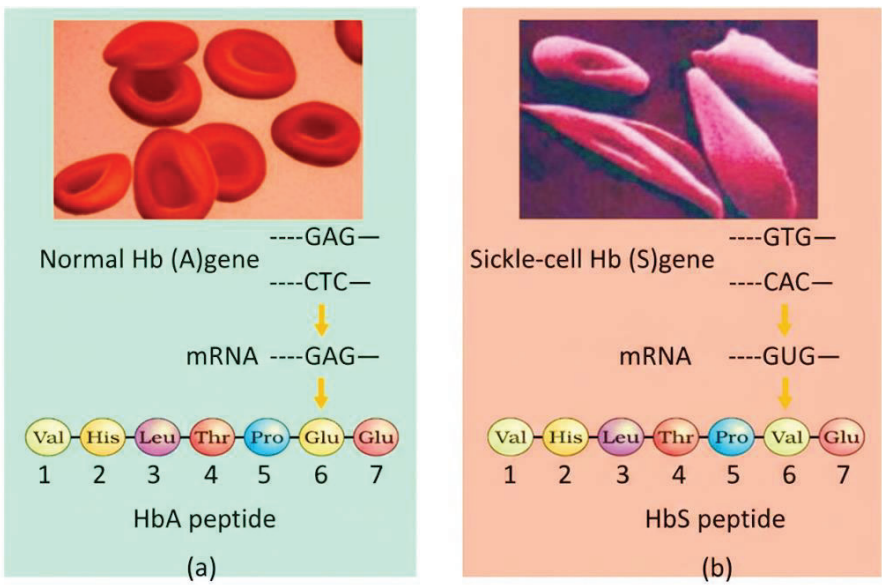
- After maturation **BB seeds are round** and **bb seeds are wrinkled.**
- Heterozygote produces round seeds because **B** is **dominant allele**. But the starch grains produced are of intermediate size in Bb seeds.
- When starch grain size is considered as the phenotype, then the alleles (Bb) show **incomplete dominance.**



	Seed shape	Size of starch grain
BB	Round	Large
Bb	Round	Medium
bb	Wrinkled	Small

3. Sickle cell anaemia (Autosomal linked recessive):-

- In this defect point mutation (change in single nitrogen base) occurs at beta chain of haemoglobin.
- In this defect glutamic acid (Glu) is replaced by valine (Val) at the sixth position of the beta globin chain of the haemoglobin molecule.
- The mutant haemoglobin molecule undergoes polymerization under low oxygen tension causing the change in the shape of the RBC from biconcave disc to elongated sickle like structure.
- Gene $\mathbf{Hb^S}$ provide a classical example of pleiotropy.
- It not only causes Haemolytic anaemia but also results increased resistance to one type of malaria that caused by the parasite Plasmodium falciparum.



Micrograph of the red blood cells and the amino acid composition of the relevant portion of β-chain of haemoglobin : (a) From a normal individual; (b) From an individual with sickle-cell anaemia

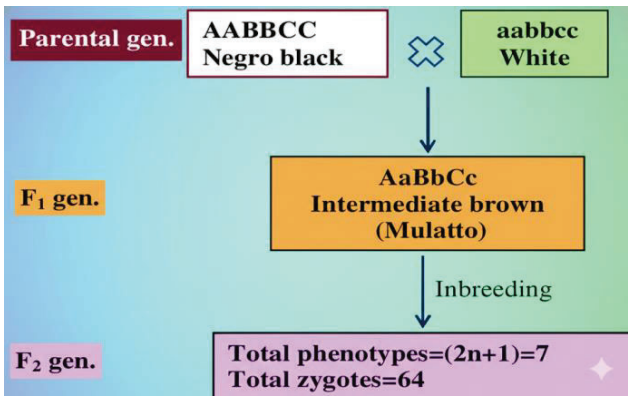
Genotype	Phenotype
Hb^AHb^A	Normal individual
Hb [CoHHb^S	Individuals appear apparently unaffected but they are carrier of the disease as there is 50 per cent probability of transmission of the mutant gene to the progeny, thus exhibiting sickle-cell trait
Hb^SHb^S	Diseased phenotype (person having sickle cell anaemia)

POLYGENIC INHERITANCE

- It is the inheritance in which some traits are controlled by several genes (**multiple genes**). **E.g.** human skin colour, human height etc.
- It is also known as **quantitative inheritance** in this inheritance when number of dominant allele increases then intensity of character also increases.
- Intermediate results are also produced.
- In this inheritance dominant allele is also known as contributory allele.
- Contribution of each dominant allele is equal.
- Quantitative inheritance are also affected by environment.

(1) Human skin colour :- controlled by 3 genes

- Assume that 3 genes **A, B, C** control human skin colour.
- The dominant forms **A, B & C** responsible for **dark skin** colour and recessive forms **a, b&c** for **light skin** colour. Genotype with all the dominant alleles (**AABBCC**) gives **darkest skin** colour.
- Genotype with all the recessive alleles (aabbcc) gives **lightest skin** colour.
- Therefore, genotype with **3 dominant alleles** and **3 recessive alleles** gives **an intermediate skin** colour. Thus, number of each type of alleles determines the darkness or lightness of the skin.



No. of Dominant allele	Phenotypic expression
6 Dominant allele	Negro black
5 Dominant allele	Very dark brown
4 Dominant allele	Dark brown
3 Dominant allele	Mulatto
2 Dominant allele	Light brown
1 Dominant allele	Very light brown
0 Dominant allele	White

CHROMOSOMAL THEORY OF INHERITANCE

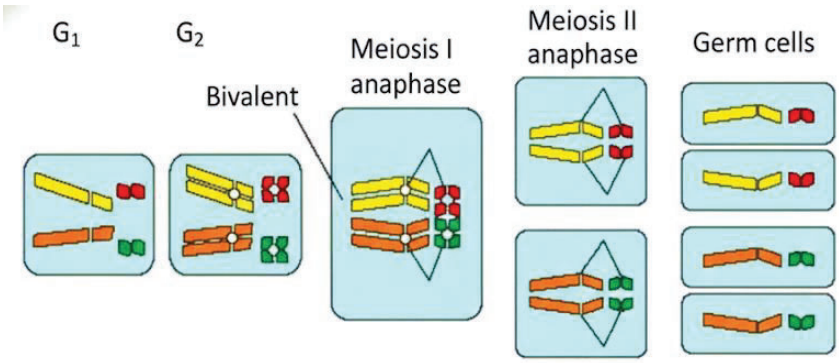
Rediscovery of Mendel's result:

- In 1990 **deVries, Correns** and **von Tschermak** independently rediscovered Mendel's result on the inheritance of character.

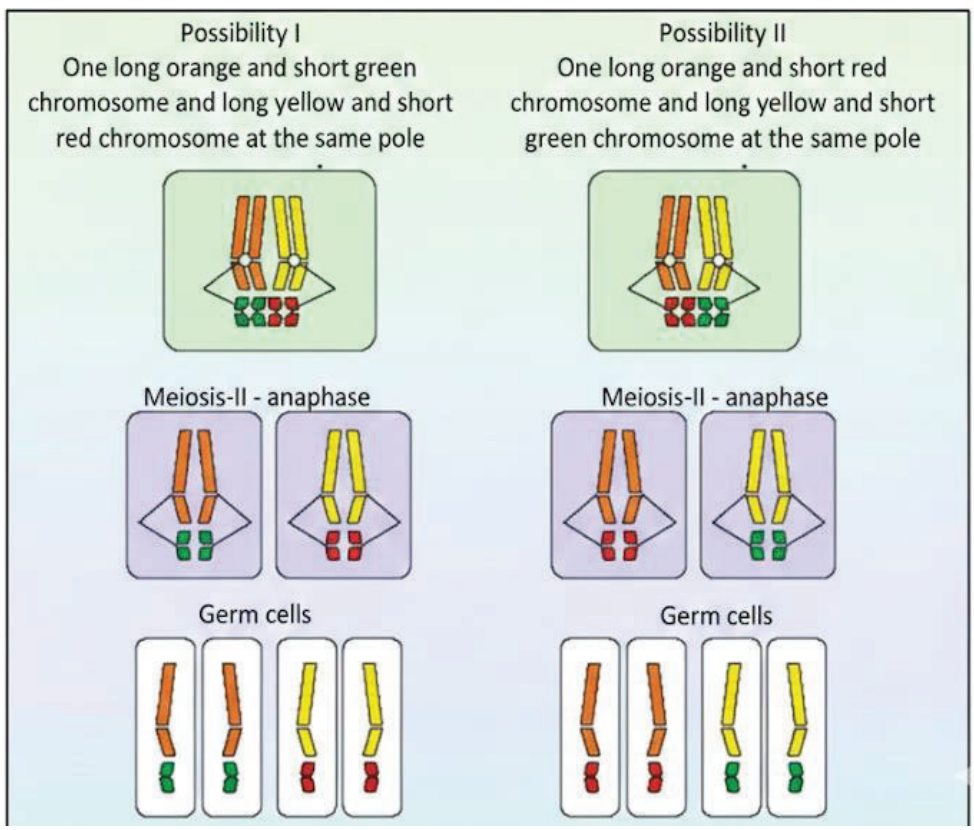
- By this time due to advancements in microscopy that were taking place, scientists were able to carefully observe cell division.
- This led to the discovery of structures in the nucleus that appeared to double and divide just before each cell division. These were called chromosomes (colored bodies, as they were visualised by staining).

✓ **Chromosomal Theory of Inheritance:**

- It was proposed by **Sutton** and **Boveri** in 1902.
- They discovered the structure in nucleus that appeared to double and divide just before each cell division.These were called Chromosomes.By 1902,the Chromosomes movement during meiosis had been worked out.
- They work out the chromosome movement during meiosis.
- They noticed that behavior of chromosomes was parallel to the behavior of genes and used chromosome movement to explain Mendel's laws.



Meiosis and germ cell formation in a cell with four chromosomes.
can you see how chromosomes segregate when germ cells are formed?



- Sutton combined the knowledge of **chromosomal segregation** with **Mendelian principles** and called it **the chromosomal theory of inheritance.**
- According to Sutton and Boveri the behavior of Mendelian factors (genes) was parallel to the behaviour of chromosomes during meiosis. It is as follows
  1. Chromosome and genes are present in pairs in diploid cells.
  2. Homologous chromosomes separate during gamete formation (meiosis)
  3. Fertilization restores the chromosome number to diploid condition.
  4. It is the chromosomes that segregate and assort independently.

A comparison between the behavior of chromosomes and genes:

	Gene	Chromosome
1.	Occurs in pairs **E.g;** Tall- TT,Tt , Dwarf -tt	Occurs in pairs
2.	Segregate at the time of formation of gametes such that only one of each pair is transmitted to a gamete.	Segregate at gametes formation and only one of each pair is transmitted to a gamete.
3.	Independent pairs segregate independently of each other	One pair segregate independently of each other.

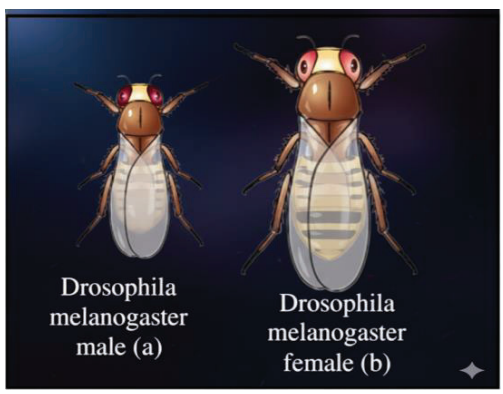
EXPERIMENTAL VERIFICATION OF CHROMOSOMAL THEORY:

- Experimental verification of chromosomal theory of inheritance was made by T.H.Morgan and his colleagues.
- Morgan worked on Drosophila melanogaster (fruit fly).

Why Drosophila is selected for experimental verification by T.H.Morgan?

Drosophila is suitable for genetic studies because;

1. They could be grown on simple synthetic medium in the laboratory.
2. They complete their life cycle in about two weeks,
3. A single mating could produce a large number of progeny flies.
4. There was a clear differentiation of the sexes - the male and female flies are easily distinguishable.
5. It has many types of hereditary variations that can be seen with low power microscopes.



Morgan carried out several hybridization experiments in drosophila to study genes that were sex-linked

- X chromosome of drosophila Dihybrid cross performed by Morgan:-

Experiment 1:

- Morgan hybridised yellow-bodied, white-eyed females to brown-bodied, red-eyed males.

- In the F_1 all females were brown-bodied, red-eyed and males were yellow-bodied, white-eyed.
- When F_1 female and male are crossed, the F_2 progeny consisted of 98.7% parental type and 1.3% of new combination.
- He observed that the two genes did not segregate independently of each other and the F_2 ratio deviated very significantly from the 9:3:3:1 ratio.

Experiment 2:

- In another experiment Morgan crossed white eyed and miniature winged female mutant with normal wild male with red eye and with normal wing.
- In the F_1 generation all females were wild type white males were white miniature wing.
- When F_1 male and female were crossed the F_2 consisted of 62.8% parental type and 37.2% recombinations or new combinations.
- **Note :-** The characters studied by Mendel were present only on the **X-chromosome.**
- **Conclusion:** He found that the genes for white eye and yellow body were very tightly linked and showed only 1.3 per cent recombination while genes for white eye and miniature wing showed 37.2 per cent recombination.
- Morgan and his group concluded that the genes were located on the *X* chromosome and when the two genes in a dihybrid cross were situated on the same chromosome, the proportion of parental gene combinations was much higher than non-parental type or new combinations. According to Morgan, this is due to linkage, i.e. physical association of genes on a Chromosomes.

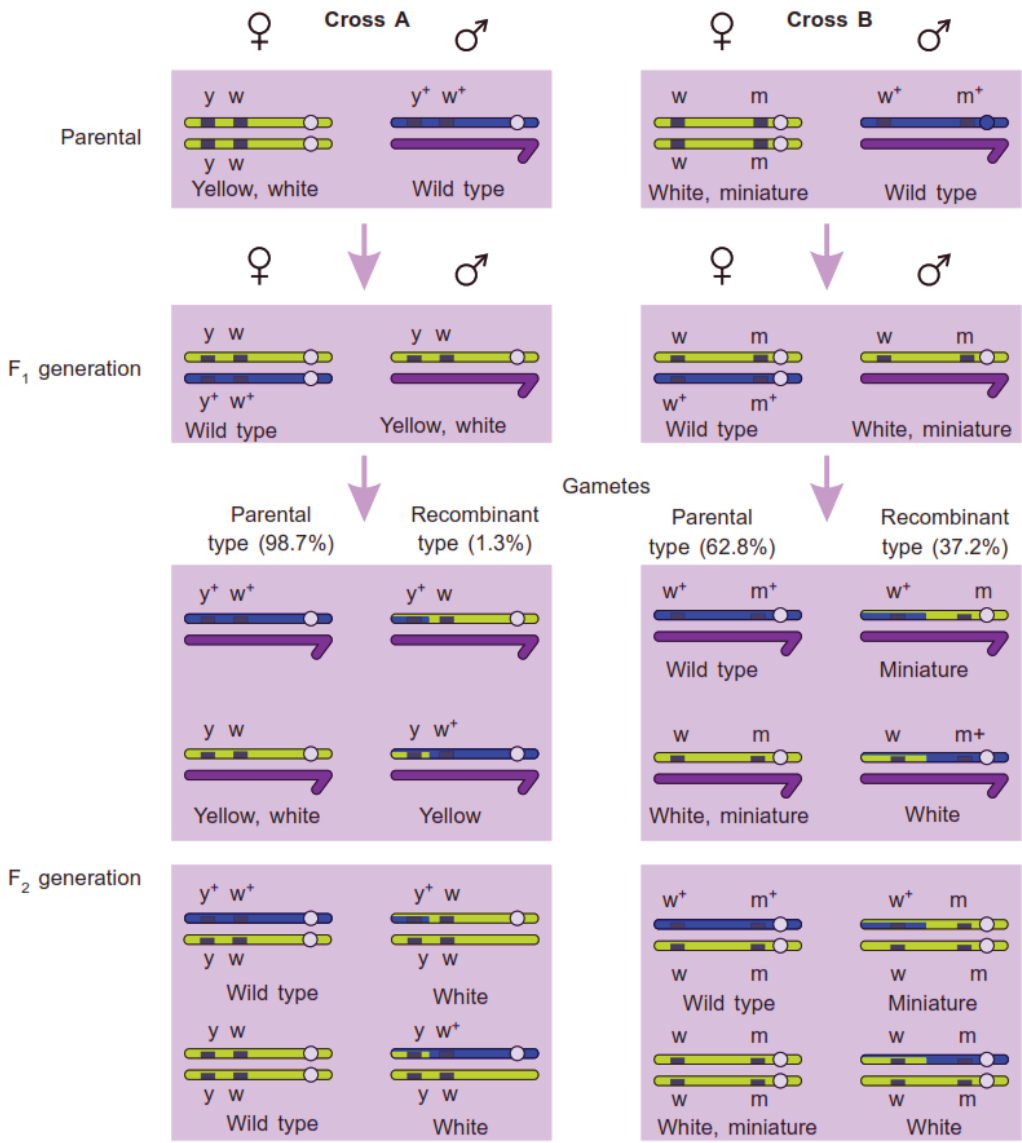


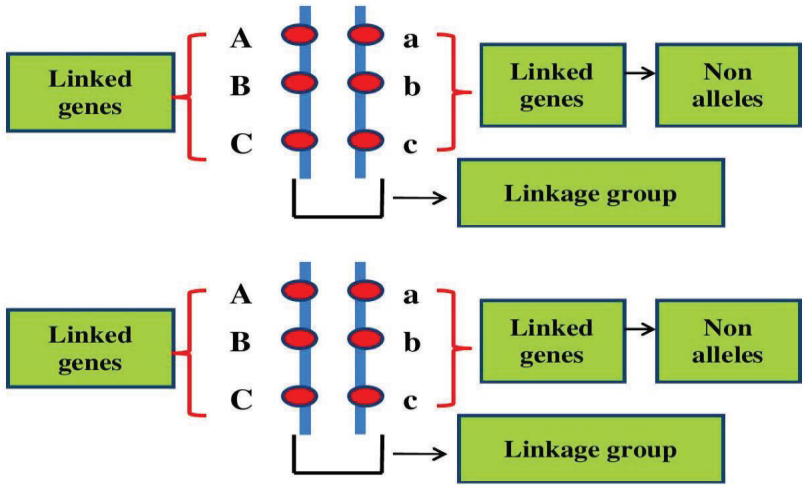
Fig : Result of two dihybrid crosses conducted by morgan. cross A shows crossng between gene y and w; cross B shows crossing between genes w and m here dominant wild type alleles are presented with (+) sign in superscript.

Note - The strength of linkage between y and w is higher than w and m.

LINKAGE AND RECOMBINATION

Linkage: Physical association of the two or more genes on chromosome is called **linkage**.

☛ The term linkage was coined by **Morgan**; he defined linkage on the basis of his breeding experiments on fruit fly (Drosophila melanogaster).



THEORY OF LINKAGE

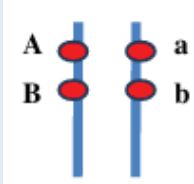
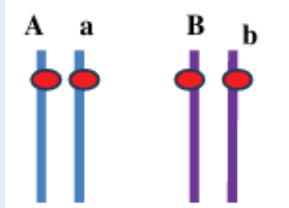
1. Linked genes are present on same chromosomes and do not show independent assortment at the time of gamete formation.
2. **Linkage is exception of independent assortment.**
3. Linked genes are linearly located on the same chromosome.
4. **They get separated if exchange (crossing over), takes place between them.**
5. **Strength of Linkage $\alpha 1/$ distance between the genes**
6. It means, if the distance between two genes is increased then strength of linkage is reduced and it proves that greater is the distance between genes, the greater is the probability of their crossing over.
7. Crossing over obviously disturbs or degenerates linkage. **Linked genes can be separated by crossing over.**
8. So on the basis of crossing over linkage is of 2 types:-

TYPES OF LINKAGE :-There are two types of linkages namely **complete** and **incomplete linkages.**

1. COMPLETE LINKAGE

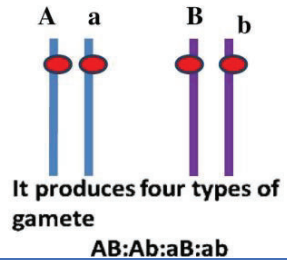
❖ When two genes are present close to each other on chromosome and are inherited together for number of generations then it is said to be **complete linkage.** Here there is no break and reunion of chromosome.

❖ The parental characters are inherited to the offsprings without any change i.e offsprings look almost similar to their parents. This type of linkage is rare in nature. e.g. male Drosophila, female silk moth.

Complete Linkage	Independent assortment
 **It produces two types of gametes. AB:ab**	 It produces four types of gametes. AB: Ab: aB: ab 1:1: 1: 1

2. **INCOMPLETE LINKAGE**

- ❖ When two genes are present far away from each other on chromosome, they tend to separate due to breakdown and reunion of chromosomes during crossing over at gametogenesis. This results in the formation of new combinations. This is called **incomplete linkage.**
- ❖ If genes are tightly linked then low recombination but if genes are loosely linked then more recombination.

Incomplete Linkage	Independent assortment
Here crossing over is present. ***AB*: *Ab*: *aB*: *ab***	 **It produces four types of gamete AB:Ab:aB:ab**
But here **R R P** **P > *R***	1:1: 1: 1

Linked gene	Independent gene
These genes are present on same chromosome.	These genes are present on different chromosome
They do not show independent assortment.	They show independent assortment.
They do not show 9:3:3:1 ratio in $\mathbf{F_2}$ generation of Dihybrid cross.	They show 9:3:3:1 in F_2 generation of Dihybrid cross.

APPLICATION OF LINKAGE

$$\textbf{Strength of Linkage } \alpha \frac{1}{\text{Distance between linked genes}} \alpha \frac{1}{\text{Crossing over}}$$

- ☛ Distance between linked genes can be identified.
- ☛ Unit of distance between gene is centi Morgan (cM).
- ☛ Formation of genetic map.

RECOMBINATION

- ❖ It means generation of non-parental gene combinations.

Genetic maps of chromosomes

- ❖ It is the graphical representation of sequential arrangement of genes on a Chromosomes
- ❖ The first genetic map was designed by **Alfred Sturtevant(student of Morgan) ,**in 1911.

- Alfred Sturtevant used the frequency of recombination between gene pairs on the same Chromosomes as a measure of the distance between genes and 'mapped' their position on the Chromosomes.
- Morgan thought that frequency of crossing-over is governed by distance between genes.It means crossing-over is directly proportional to distance between genes.
- The distance between the linked genes is referred as map unit or Morgan unit which is equal to one per cent of cross-over.

4.4. Sex Determination

Definition: The process by which male and female sex of an organism is decided by the presence of X or Y chromosome during fertilization is called **sex determination.**

- The chromosomes that are involved in sex determination are called **sex chromosomes (allosomes)**. They include **X & Y chromosomes.**
- **Autosomes** are chromosomes other than sex chromosomes. Number of autosomes is same in males and females. **Henking (1891)** studied spermatogenesis in some insects and observed that 50% of sperm received a nuclear structure after spermatogenesis, and other 50 % sperm did not receive it. **Henking** called this structure as the **X body** (now it is called as **X-chromosome**).

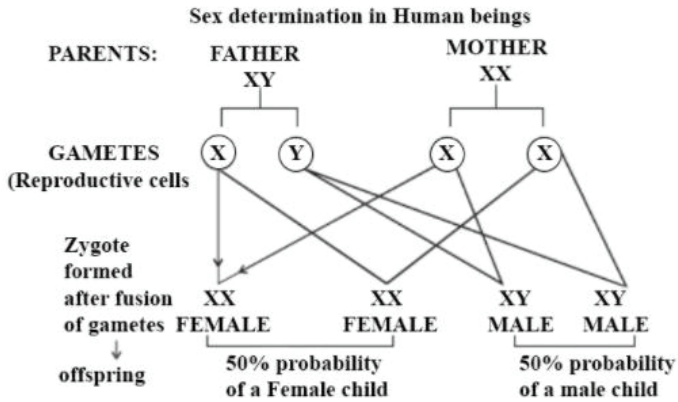
MECHANISM OF SEX DETERMINATION

1. **XX-XO mechanism:** Here, male is **heterogametic**, i.e. XO (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.
2. **XX-XY mechanism:** Male is heterogametic (X & Y) and female is homogametic (X only). **E.g.** Human & Drosophila.
3. **ZZ-ZW mechanism:** Male is homogametic (ZZ) and female is heterogametic (Z & W)**. E.g.** Birds.

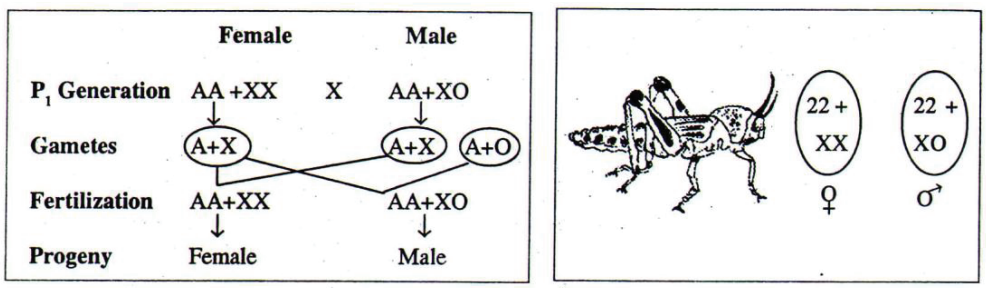
A. **Male heterogamety :-** Here males produces two types of sperms or gametes namely sperm with ' X ' chromosome and sperm with ' Y ' chromosome or sperm without X -chromosome. It includes XX -XY,XX - XO.

1. **XX-XY type of Sex-determination:- Eg.** Drosophila
   - Here males produce two types of sperms i.e. X-sperm-50%&Y-sperm 50% hence heterogametic.
   - Females produce only one type of egg i.e. X-egg.
   - Here the sex of the individual is decided by the type of sperm that fuses with the egg.
   - If X-sperm fuses with the egg it results in Female offspring& if Y sperm fuses with the egg results in male offspring.
2. **XX-XY type of Sex-determination:- Eg-** Humans
   - Sex determination in human beings is XX-XY type i.e. **Male heterogametic**
   - Human has **23 pairs** of chromosomes (22 pairs of autosomes and 1 pair of 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:** 50% with **Autosomes** and **X-chromosome (22AA+X)** and 50% with **Autosomes** and **Y- chromosome(22AA+Y) .** Females produce only ovum with **Autosomes** and **X-chromosome**.
   - If the ovum fertilizes with a sperm carrying X-chromosome the zygote develops into a female offspring (XX).
   - If the ovum fertilizes with a sperm carrying Y-chromosome results into a male offspring (XY).This ,it is the genetic makeup of the sperm that determines the sex of the baby.
   - It is evident that in an each pregnancy there is always 50 % probability of either a male or a female child.

- It is unfortunate that in our society women are blamed for producing female children because of this false opinion.



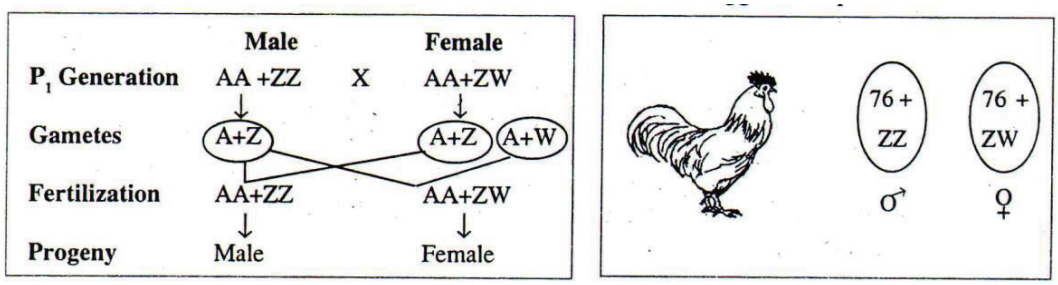
3. **XX-XO type of Sex-determination :- E.g-**It is seen in grasshopper
   - Here males are heterogametic and produce two types of sperms i.e.50% of sperms with X-chromosome (A+X) and 50% sperms without X-chromosome (A+O) homogametic.
   - Females produce only one type of eggs i.e.X-egg (A+X)
   - Here the sex of the individual is decided by the type of sperm that fuses with egg.
   - If the X-Sperm fuses with the egg it results in Female offspring and if Sperm without X (A+O) fuses with the egg results in male offspring.



XX-XO type of sex determination in *Grasshopper*

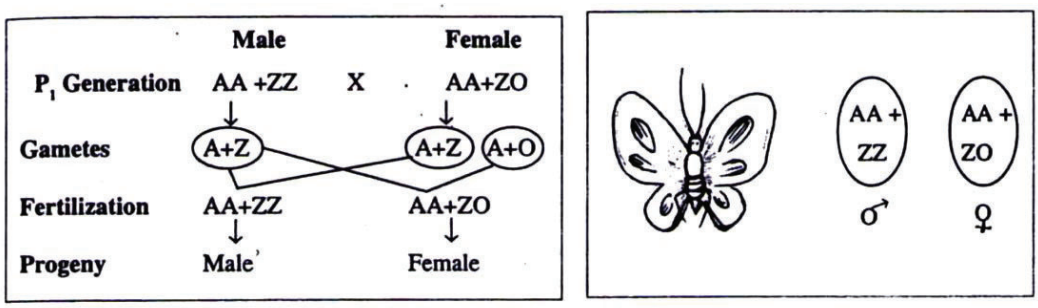
B. **Female heterogamety :-** Here females will produce two types of eggs. It includes Z-ZW and ZZ – ZO type of sex determination.

1. **ZX-ZW type of Sex-determinayion :- E.g.** It is seen in Birds(fowls)
   - Here females are heterogametic and produce two types of eggs namely egg with Autosomes and Z-chromosome (A+Z) and egg with Autosomes and W-chromosome (A+W).
   - Males are homogametic and produces only one type of sperm i.e. Z-Sperm with Autosomes and Z-chromosome (A+Z).
   - Here the sex of the individuals is decided by the type of egg that fuses with the sperm.
   - If the Z-egg (A+Z) fuses with the sperm (A+Z)it results in male offspring and if W-egg fuse with the Z-Sperm results in the female Offspring.



ZZ-ZW type of sex determination in birds

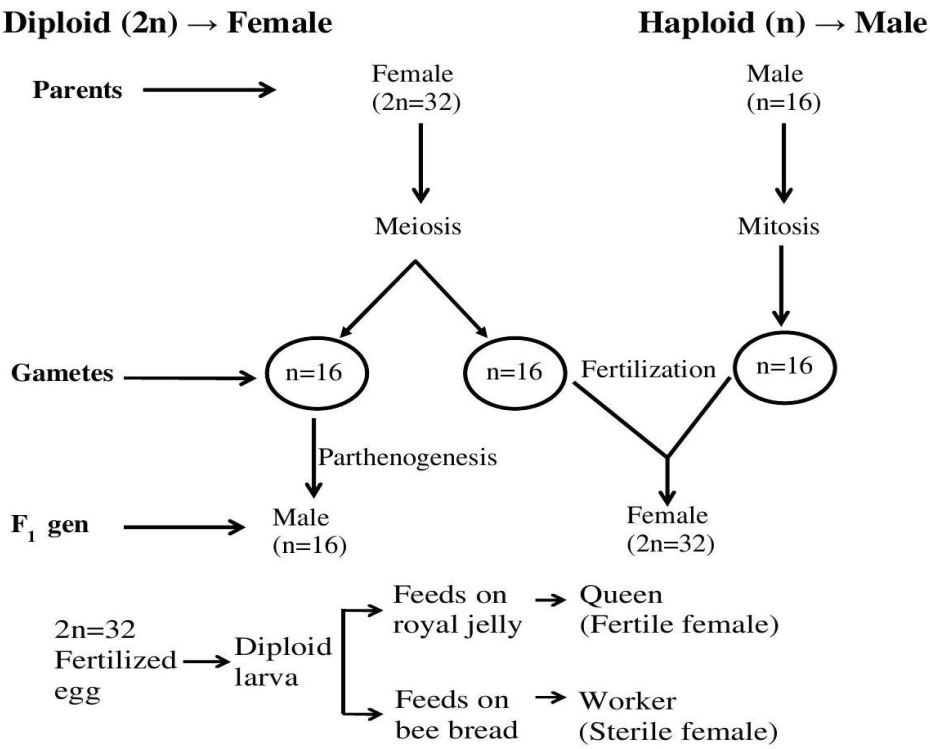
2. **ZZ-ZO type of Sex-determination :- E.g-** It is seen in butterflies
   - Here female is heterogametic and designated as ZO where in two types of eggs i.e 50% of eggs with Autosomes and Z-chromosome (A+Z) and 50% of eggs with Autosomes and without Z-chromosome (A+O).
   - The male is homogametic and produce only one type of sperm i.e. Z-Sperm (A+Z).
   - Here the sex of the individual is decided by the type of egg that fuses with the sperm.
   - If Z-egg fuses with the sperm it results in male offspring and if the egg with out Z-chromosome (A+O) fuses with the sperm results in female Offspring.



ZZ-ZO type of sex determination in butterflies

Haplo-Diplontic Sex-determination system:-E.g-It is seen in Honey bee.

- It is based on the number of sets of chromosomes an individual receives. **Fertilised egg** develops as a **female** (**queen or worker**). An **unfertilised egg** develops as a **male (drone).** It is called **parthenogenesis**.
- Therefore, the females are diploid (32 chromosomes) and males are haploid (16 chromosomes). This is called as **haplodiploid sex determination system**.
- In this system, the males produce sperms by mitosis.They do not have father and thus cannot have sons, but have a grandfather and can have grandsons.

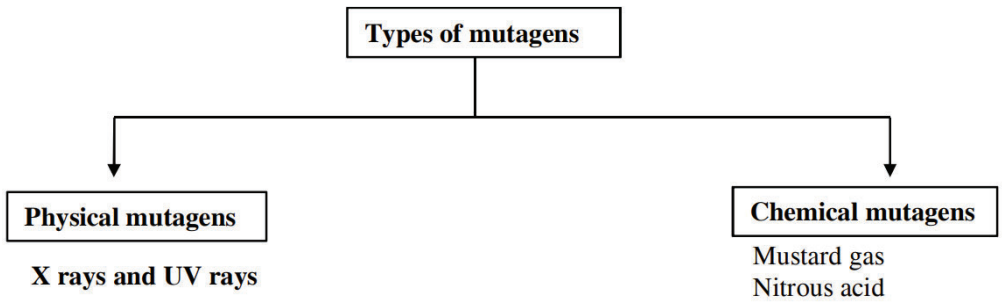


Special characteristic features of honey bee:-

- Males produce sperms by mitosis.
- Males do not have father and cannot have sons, but have a grandfather maternal and can have grandsons.

4.5. Mutation

- It is defined as the **sudden inheritable change** in the genetic material. or A phenomenon which **alters' the DNA sequences.** This in turn results in changes in the genotype and the phenotype of an organism is called **mutation**.
- In addition to **recombination**, **mutation** is another phenomenon that leads to **variation in DNA.**
- **Variations** are the tools for **organic evolution.**
- Mutations were discovered by Hugo devries in **Evening primrose (*Oenothera lamarkiana*).**
- The chemical and physical factors that induce mutations are called **mutagens**.



TYPES OF MUTATION

There are two types of mutations namely point mutation and chromosomal mutation.

1. **Gene mutation or Point mutation:-** It is the mutation in a single base pair, which is replaced by another base pair.
   E g., Sickle cell anaemia.In this **6th amino acid** of Normal haemoglobin i.e. **glutamine** is replaced by valine which results in **sickle shaped RBC.**This RBC **fails to carry enough oxygen** to their body tissues.
2. **Frame-shift mutation:-** It is the change in the reading frame because of insertion or deletion of base pairs.
   E.g., Deletion of one **X-chromosome** in humans results in **Turner's syndrome** and addition of one X-chromosome results in **Klinefelter's syndrome.**

a. **Insertion :-** It is the addition of one or more Nucleotides in the DNA segment.Insertion of three or its multiple bases do not change the reading frame but add new amino acid.

b. **Deletion:-** It is the removal of three or its multiple bases do not change the reading frame but remove one or more Amino acids.Loss of one or rarely more than one nitrogenous bases in structure of DNA.

EXAMPLE OF FRAME SHIFT MUTATION

RAM HAS RED CAP

CASE 1	CASE 2	CASE 3
If we insert a letter B in between HAS and RED.	If we insert two letter BI in between HAS and RED.	If we insert three letter BIG in between HAS and RED.
RAM HAS BRE DCA P Insertion or deletion of one or two bases changes the reading frame from the point of insertion or deletion.	**RAM HAS BIR EDC AP**	**RAM HAS BIG RED CAP** insert or delete one or multiple codon hence one or multiple amino acids, and reading frame remains unaltered from that point onwards.

PEDIGREE ANALYSIS

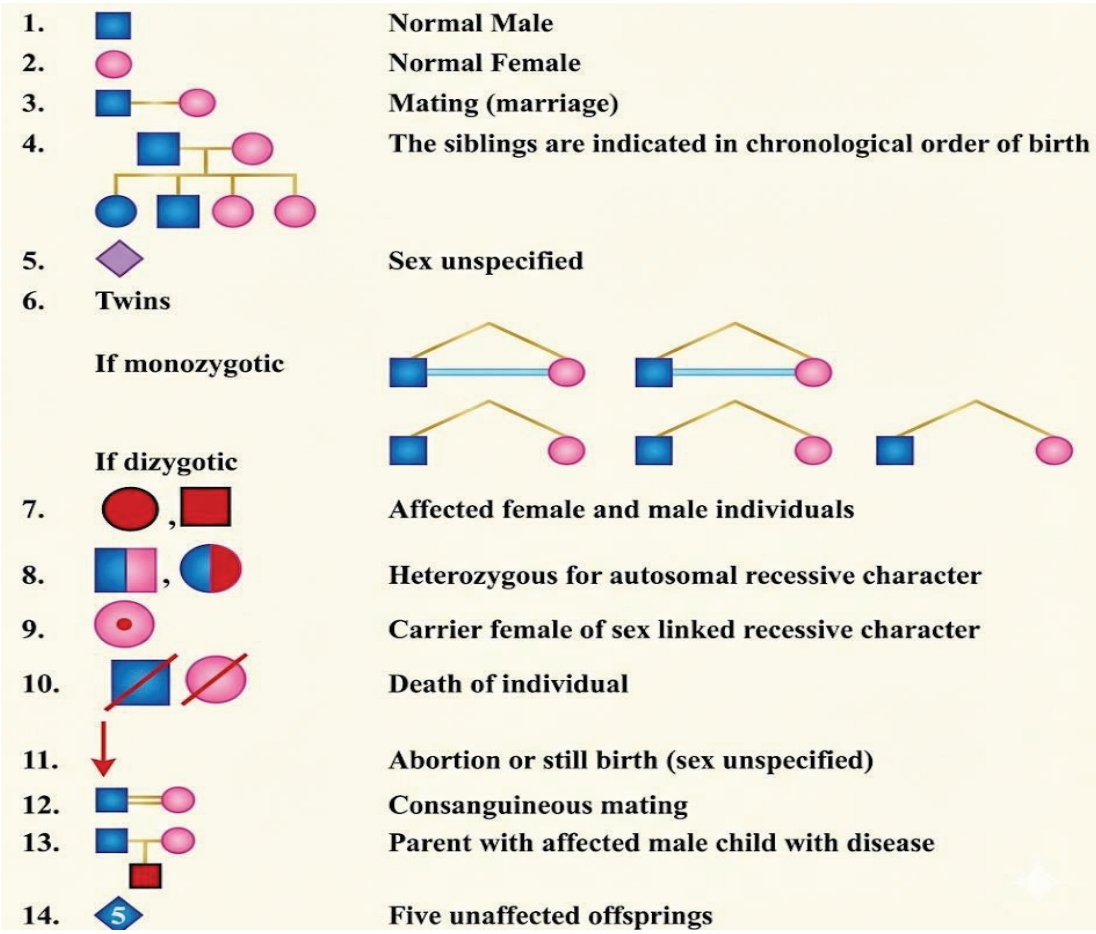
- Analysis of traits in several of generations of a family is called the pedigree analysis. or The record of inheritance of a trait or disorder in several generation of a family is called pedigree analysis.

- In the pedigree analysis the inheritance of a particular trait is represented as a tree called family tree over generations.

Significance :

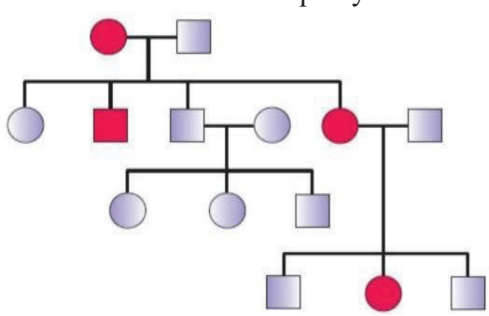
a. It is used to trace inheritance of a specific traits and genetic disorders.
b. It is used to trace the inheritance of Mendelian disorders like colour blindness, PKU sickle cell anaemia.
c. It helps to understand whether the trait is dominant or recessive.
d. It helps to know whether the trait is linked to the sex chromosome or autosome.

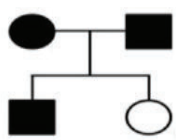
SYMBOLS OF PEDIGREE



A. Pedigree of autosomal dominant trait :- eg; Myotonic dystrophy

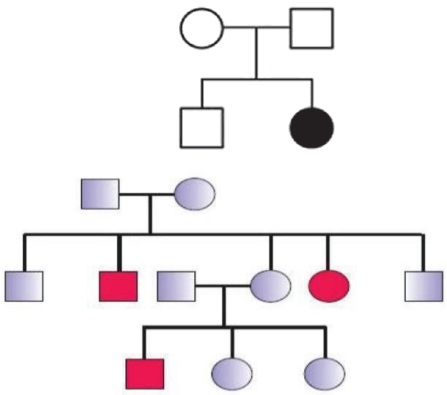
- The persons affected will have at least one affected parent.
- **Both affected parents may have normal child**
- The defect appears in every generation and no skip generation
- If both the parents are affected then all offsprings are affected.
- If both the parents are unaffected then all offsprings are also unaffected.
- Males and females are equally affected.





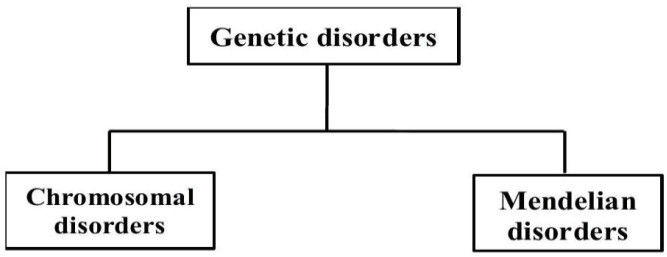
B. Pedigree of autosomal recessive trait eg: Sickle-cell anemia, Phenylketonuria, Thalassemia - Cystic fibrosis -

- This trait appears only in homozygous conditions.
- Normal heterozygous parents can have affected offsprings
- Trait may skip generations.
- Males and females are equally affected.
- Unaffected parents may have affected offspring.
- If both the parents are affected then all the offsprings are also affected



4.6. Genetic Disorders

The disorders caused due to defect either in **genes** or **chromosome** are called **genetic disorders. Types of genetic disorders :-** These are broadly grouped into two categories - **Mendelian disorders** and **chromosomal disorders.**



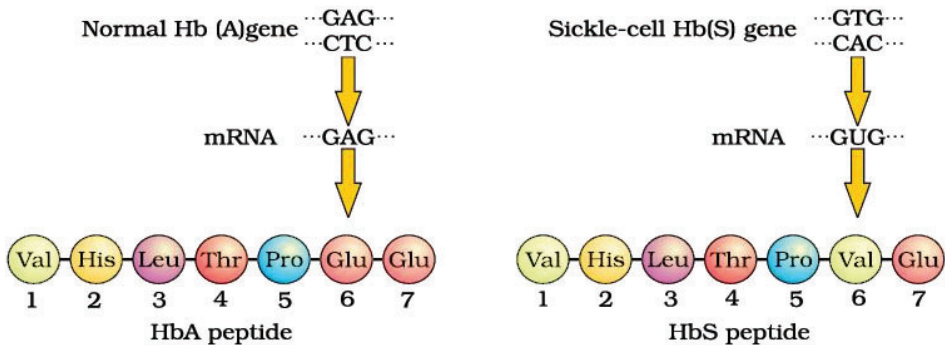
MENDELIAN DISORDER

- ❖ Mendelian disorders are mainly determined by alteration or mutation in the single gene.
- ❖ These disorders are transmitted to the offspring on the same lines of principle of inheritance. These disorders may be dominant or recessive.
- ❖ The pattern of inheritance of disorders can be traced in a family by the pedigree analysis.
- ❖ The trait may also be linked to the sex chromosome as in case of haemophilia.
- ❖ The X-linked recessive trait shows transmission from carrier female to male progeny.
- ❖ Examples -Sickle-cell anemia, Thalassemia, Haemophilia, Phenylketonuria, Cystic fibrosis, Colour blindness etc.

Sickle cell anaemia(SCA)

- ❖ A condition in which normal RBC become sickle shaped and fails to carry enough oxygen is called **sickle cell anaemia.**

- This is caused due to an autosome linked recessive trait
- It is transmitted from both the carrier parents to the offspring. (or heterozygous).
- The disease is controlled by a single pair of allele, ***HbA*** and HbS.



- Out of the three possible genotypes only homozygous individuals for ***HbS***($HbSHbS$) show the diseased phenotype.
- Heterozygous ($HbAHbS$) individuals appear unaffected but they are carrier of the disease.
- The defect is caused by the replacement of Glutamic acid (Glu) by Valine(Val) at the sixth position of the haemoglobin molecule.
- The replacement is due to mutation at sixth codon of the beta globin gene from GAG to GUG.
- The mutant haemoglobin molecule [HBS] undergoes polymerization under low oxygen tension causing the change in the shape of the RBC from biconcave disc to elongated sickle like structure.

Symptoms:

- Sickle celled RBC fails to transport enough oxygen to the body cells.
- Flow of blood is blocked by sickled RBC.
- Pain in abdomen and joints.
- It often causes childhood death.

Thalassemia

- It is an autosome linked recessive blood disease.
- A blood disease caused by a substitution mutation in the DNA sequence that controls the synthesis of the - or ß-chains of haemoglobin.
- Thalassemia is controlled by two closely linked genes HBA1 and HBA2 on chromosome 16 of each parent and it is due to mutation or deletion of one or more of the four genes.
- Thalassemia describes a group of inherited disorders characterized by reduced (or absent) amounts of haemoglobin, the oxygen - carrying protein inside the RBCs.

There are three basic groups of Thalassemia disorders

a. **α-Thalassemia :** Caused by defective formation of α-globin, controlled by two genes HBA1 andHBA2, present on chromosome 16.

b. **β - Thalassemia :** Decreased synthesis of β-globin. Defect is due to alleles of HBB genes present on chromosome 11.

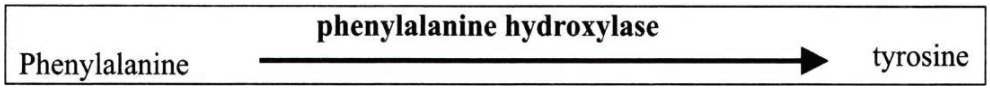
c. **δ-Thalassemia :** It occurs due to defective allele of HBF gene present on chromosome 11.

Symptoms : Thalassemia results in Anaemia and growth retardation.

Phenylketonuria (PKU)

- It is an inborn metabolic error caused due to the autosomal recessive trait.
- The affected individual lacks an enzyme phenylalanine hydroxylase that converts the amino acid phenylalanine into tyrosine.
- As a result of this phenylalanine is accumulated and converted into phenyl-pyruvic acid and phenyl lactic acid.
- Accumulation of these in brain results in mental retardation. Excess is eliminated through urine because of its poor absorption by kidney.

Symptoms:



- Mental retardation, Seizures, skin rashes, Light coloured hair and skin, Unusual positioning of hands.

Haemophilia (Bleeders Disease)

- Haemophilia A is a recessive X linked disorder due to lack of **clotting factor VIII** or **Anti-haemophilic** factor (AHF).
- Haemophilia **B** is also a recessive **X** linked genetic disorder due to lack of clotting factor **IX** or plasma thromoplastin component (PTC) or christmas factor.
- When a person with haemophilia is injured, bleeding is prolonged because a firm clot is slow to form.
- Haemophilia also follows criss cross pattern of inheritance.
- When a haemophilic man marries a normal woman, in their children daughters act as carriers and sons are normal.
- When a carrier woman marries a normal man, in their children 50% sons are normal and 50% sons are haemophilic.

Symptoms

- Bleeding in joints. - Pains and swelling at joints. - Bleeding at urinary tract.
- Prolonged bleeding from cuts, tooth extraction & surgery can also lead to death.

Colour Blindness

- It is a **sex-linked recessive disorder** due to defect in either **red** or **green cone** of eye resulting in failure
- to discriminate between **red** and **green** colour.
- This defect is due to mutation in certain genes present in the **X- chromosome.**
- It occurs in about **8 percent** of **males** and only about **0.4 percent** of **females**.
- This is because the genes that lead to red-green colour blindness are on the **X- chromosome**. Males have
- only one X-chromosome and females have two X-chromosomes.
- The son of a woman who carries the gene has a **50 percent** chance of being colour blind. The mother is
- not herself colour blind because the **gene is recessive**. That means that its effect is suppressed by her
- matching **dominant normal gene.**
- A daughter will not normally be colour blind, unless her mother is a carrier and her father is colour blind.

Genotypes: - Male - XY=normal

X^cY = affected

Female - XX = normal,

X^cX = normal but carrier

X^cX^c = affected

- ❖ When a woman with normal vision (homozygous) marries a colour-blind man, all the sons and daughters are normal, but daughters are carriers (heterozygous).
- ❖ If a carrier woman marries a man with normal vision, all the daughters and half of the sons are normal visioned, but half of the sons are colourblind.
- ❖ Colourblind trait is inherited from a male parent to his **grand son** through carrier daughter, which is an example of **criss cross pattern of inheritance.**

CHROMOSOMAL DISORDER

- The Diseases caused due to absence or excess or abnormal arrangement of one or more chromosomes are called **chromosomal disorders.**
- It is caused **due to failure of segregation of chromatids** during cell division.

1. **Aneuploidy** - The gain / loss of chromosome (s) due to failure of segregation of chromatids during cell division.
2. **Polyploidy** - An increase in a whole set of chromosome in an organism due to failure of cytokinesis after telophase.
3. **Trisomy:** Additional copy of a chromosome is included in an individual ($2n + 1$).
4. **Monosomy:** Lack of a single chromosome in any one pair of chromosomes ($2n - 1$)

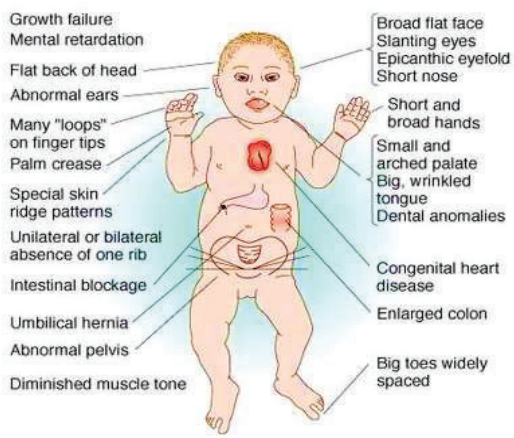
Examples of chromosomal disorders:

1. Down's syndrome
2. Klinefelter's Syndrome
3. Turner's syndrome

ANEUPLOIDY (EXAMPLE OF TRISOMY)

1. **Down's syndrome(Mongolism)**

- ❖ This syndrome was first reported by **Dr. Langdon Down**.
- ❖ It occurs in males or females due to the presence of an extra autosomal chromosome in the **21st autosomal pair**
- ❖ As a result the individual will have 47 chromosomes.
- ❖ The chromosomal complement of these persons is $\mathbf{45AA + XX = 47}$ in females and $\mathbf{45AA + XY = 47}$ or $\mathbf{2n + 1}$ in males.



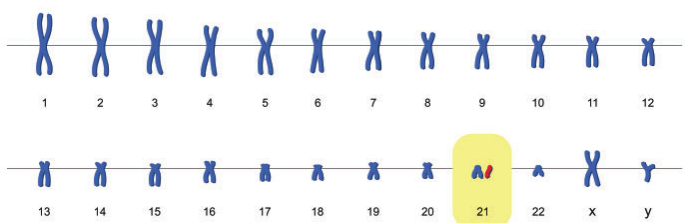


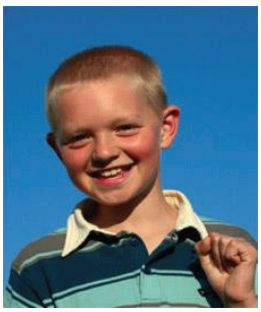
Fig 5.7.3 Down's syndrome karyotype

Symptoms:

1. Epicanthic [folded] eyelids,
2. Short statured with small round head,
3. Protruded tongue,
4. Open mouth with swollen lower lip,
5. Physical, psychomotor and mental development is retarded,
6. Palm is broad with characterized palm crease [single line in hand]

7. Enlarged fore head with flattened nose.

2. Klinefelter's syndrome



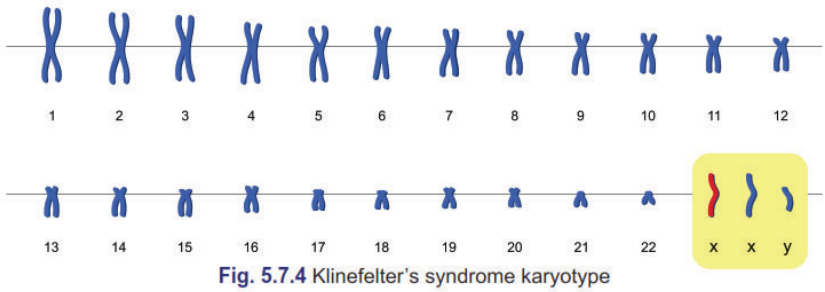


Fig. 5.7.4 Klinefelter's syndrome karyotype

- This syndrome was first reported by Dr.Harry E. Klinefelter.
- This syndrome is caused due to the addition of one extra sex chromosome and is due to chromosomal non-disjunction.
- The chromosomal complement of this person is $\mathbf{44AA + XXY = 47}$ or **47** with XXY.
- This individual is sterile male. It is an example for sex chromosomal trisomy.

Symptoms:

- Individual has overall masculine development.
- Feminine development [Gynaecomastia- breast development]
- They are sterile males with enlarged breasts.
- Scanty hairs on face, chest and underarm
- Underdeveloped testis and genital organ
- Tall stature with long limbs and short body

ANEUPLOIDY(EXAMPLE OF MONOSOMY)

Turner's Syndrome

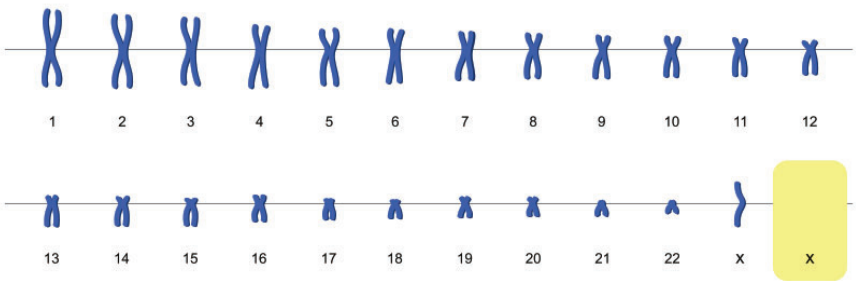


Fig 5.7.5 Turner's syndrome karyotype

- This syndrome was first reported by Dr. Henry Turner.
- It is an example of monosomy. This syndrome is caused due to the absence of X- chromosome.
- The chromosomal complement of this persons is $\mathbf{44AA + XO = 45}$ or **45** with XO.
- It is due to chromosomal non- disjunction during oogenesis.
- It is an example for sex chromosomal monosomy.

Symptoms.

1. These are sterile females.
2. Under developed ovaries without menstrual cycle
3. Broad & flat chest with infantile mammary glands.
4. They are short statured with webbed neck.
5. Quantity of female hormone is less.
6. Low mental capacity.

EXERCISE

PART - A

I. Select the correct alternative from the choices given: 1 Mark Each:

1. **A plant having the genotype AaBb will produce ___ kinds of gametes**
   a) 5 b) 4 c) 3 d) 2

2. **The colour based contrasting traits in seven contrasting pairs, studied by Mendel in pea plant were**
   a) 1 b) 2 c) 3 d) 4

3. **Which of the following characters was not chosen by Mendel?**
   a) Pod shape b) Pod colour c) Position of flower d) Position of pod

4. **Which of the following is not a pair of opposing characteristics Mendel studied?**
   a) Axial and terminal flowers b) Full and constricted pods
   c) Green and yellow pods d) Pink and white flowers.

5. **A cross between two tall plants resulted in tall and dwarf plants. What would be the genotypes of both the parents?**
   a) TT and Tt b) Tt and Tt c) TT and TT d) tt and tt

6. **In a monohybrid cross between two heterozygous individuals, percentage of pure homozygous individuals obtained in F_1 generation will be**
   a) 25% b) 50% c) 75% d) 100%

7. **What is the probability of production of dwarf offsprings in a cross between two heterozygous tall pea plants?**
   a) Zero b) 50% c) 25% d) 100%

8. **In the F_2 generation of a Mendelian dihybrid cross the number of phenotypes and genotypes are**
   a) Phenotypes - 4: Genotypes – 16 b) Phenotypes - 9: Genotypes - 4
   c) Phenotypes - 4: Genotypes – 8 d) Phenotypes - 4: Genotypes – 9

9. **Which of the following crosses will give tall and dwarf pea plants in same proportions?**
   a) TT × tt b) Tt × tt c) TT × Tt d) tt × tt

10. **Mendel's work was rediscovered by three scientists in the year**
    a) 1865 b) 1900 c) 1910 d) 1920

11. **Which three scientists independently rediscovered Mendel's work?**
    a) Avery, McLeod, McCarty b) Sutton, Morgan and Bridges
    c) Bateson, Punnet and Bridges d) De Vries, Correns and Tschemark

12. In Antirrhinum (Snapdragon), phenotypic ratio in F_2 generation for the inheritance of flower colour would be

a) 3: 1 b) 1: 2: 1 c) 1: 1 d) 2: 1

13. What is the possible blood group of a offspring when both parents have AB blood group?

a) AB only b) A, B and AB c) A, B, AB and O d) A and B only

14. Genes located very close to one another on same chromosome tend to be transmitted together and are called as

a) Allelomorphs b) Identical genes

c) Linked genes d) Recessive genes

15. Chromosome maps or genetic maps were first prepared by

a) Sutton and Boveri b) Bateson and Punnett

c) Morgan d) Sturtevant

16. Which of the following is incorrect regarding ZW - ZZ type of sex determination?

a) It occurs in birds

b) Females are homogametic and males are heterogametic.

c) Females are heterogametic and males are homogametic.

d) Total number of chromosomes is same in both male and female.

17. A couple has three daughters. What is the possibility of them having a son next time?

a) 0% b) 25% c) 50% d) 100%

18. Number of autosomes present in a normal human female cell is

a) 21 b) 22 pairs c) 23 d) 23 pairs

19. Haplodiploid sex determination is found in

a) Grasshoppers b) Birds c) Humans d) Honeybees

20. In XO type of sex determination

a) Females produce two different types of gametes

b) Males produce two different types of gametes

c) Females produce gametes with Y chromosome

d) Males produce gametes with Y chromosome.

21. Which of the following techniques may be used to identify an inheritance pattern within a family?

a) Pedigree analysis b) Chromosome analysis

c) Nuclear analysis d) Cytoplasm analysis

22. When is it possible for a woman to be colorblind?

a) The father has normal vision and the mother is a carrier

b) The father has normal vision and the mother is colorblind

c) The father is colorblind and the mother has a normal vision

d) The father is colorblind and the mother is a carrier.

23. A man marries a woman and both do not show any apparent traits of inherited disease. Five sons and two daughters are born, and three of their sons suffer from a disease. However, none of the daughters is affected. The following mode of inheritance for the disease is

a) Sex-linked recessive b) Sex-linked dominant

c)Autosomal dominant d) Autosomal recessive

24. In sickle cell anaemia Glutamic acid is replaced by

a) Valine b) Histidine c) Glutamate d) Aspartate

25. How many possible sickles cell genotypes are there in the population?

a) One b) Two c) Three d) Four

26. If both parents are unaffected carriers for Thalassemia, which is an autosomal recessive disorder, what are the chances of pregnancy resulting in an affected child?

a) 25% b) 100% c) 0% d)50%

27. Which of the following assertions about alpha-thalassemia is incorrect?

a) Involves the HBA1 and HBA2 genes

b) Is associated with the mutation or deletion of genes on chromosome 11

c) Is associated with the mutation or deletion of genes on chromosome 16

d) Leads to a reduction in the synthesis of globin

Answer Key					
1. B.	**2.** B.	**3.** D.	**4.** D.	**5.** B.	**6.** B.
7. C.	**8.** D.	**9.** B.	**10.** B.	**11.** D.	**12.** B.
13. B.	**14.** C.	**15.** D.	**16.** B.	**17.** C.	**18.** B.
19. D.	**20.** B.	**21.** A.	**22.** D.	**23.** A.	**24.** A.
25. C.	**26.** A.	**27.** B.			

II. Fill in the blanks: 1 Mark Each:

(Dominant, Consanguineous, Genotype, Sutton, Linkage, Incomplete dominance, Thomas Hunt Morgan, Aneuploidy, Phenylketonuria, Factors, Monohybrid cross, Test cross, Dihybrid cross, Thalassemia, Codominance, Alleles)

1. An individual's collection of genes is called ___
2. Genes which code for a pair of contrasting traits are known as ___
3. According to Mendel, characters are controlled by discrete units called ___
4. The ___ characters appear in the first filial generation in heterozygous condition in pea plants.
5. Mendel formulated the law of dominance on the basis of ___
6. Law of independent assortment can be explained with the help of ___
7. To determine the genotype of a tall plant of F1 generation, Mendel crossed this plant with a dwarf plant. This cross represents a ___
8. The inheritance of flower colour in dog flower is an example for ___
9. AB blood group is an example for ___

___ united the knowledge of chromosomal segregation with Mendelian principles.

11. Experimental verification of the chromosomal theory of inheritance was given by ___
12. The physical association of two genes is ___
13. The diseases caused by mutation in the gene that codes for the enzyme phenyl alanine hydroxylase is ___
14. An autosome linked recessive blood disease is ___
15. Failure of segregation of chromatids during cell division resulting in the gain or loss of chromosomes is called ___

Answer Key		
1. Genotype	2. Alleles	3. Factors
4. Dominant	5. Monohybrid Cross	6. Dihybrid cross
7. Test cross	8. Incomplete dominance	9. Codominance
10. Sutton	11. Thomas Hunt Morgan	12. Linkage
13. Phenylketonuria	14. Thalassemia	15. Aneuploidy

PART - B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each:

Q1. Differentiate between homozygous and heterozygous conditions.

Ans: Homozygous condition refers to the presence of two identical or similar alleles for a particular gene. Heterozygous conditions refer to the presence of two different or dissimilar alleles for a particular gene.

Q2. Differentiate between dominant and recessive alleles.

Ans: In a dissimilar pair of alleles, the allele which dominates the other is called dominant allele.
A recessive allele is expressed in the homozygous condition when the dominant allele is absent.

Q3. What is test cross? Write its significance.

TT or Tt.

Q4. State the law of segregation and law of independent assortment.

Ans: Law of segregation: The Law of Segregation states that during gamete formation, the two alleles for a trait separate, so each gamete only carries one allele for that trait.
Law of independent assortment: The law states that when two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair of characters.

Q3. What is a test cross? Write its significance.

Ans: A test cross is a cross between an individual showing a dominant phenotype and a homozygous recessive individual. It is used to determine the genotype of the dominant individual; for example, a tall pea plant may be TT or Tt.

Q6. A pea plant with purple flowers was crossed with plant having white flowers. The progeny

Q5. What is incomplete dominance? Give an example.

Ans: In incomplete dominance, neither allele is completely dominant, so the heterozygote has an intermediate phenotype. Example: in Antirrhinum (snapdragon), red x white flowers produce pink F1 flowers.

generation. In F2 generation both purple and white flowers appear in the ratio 3:1. Purple flower trait is dominant over white flower trait.

Q7. Name the respective pattern of inheritance where F1 phenotype

a) Does not resemble either of the two parents and is in between the two

b) Resembles only one of the two parents

Ans:

a) Incomplete dominance

b) Complete dominance

Q8. What is codominance? Give an example.

Ans: Codominance is a type of inheritance where the F1 generation resembles both parents.

Example: ABO blood grouping in human beings.

Q9. Distinguish between incomplete dominance and codominance.

Ans: In incomplete dominance, the F1 phenotype is intermediate and does not resemble either parent. In codominance, the F1 phenotype resembles both parents equally.

Q10. What are multiple alleles? Give an example.

Ans: Multiple alleles refer to the presence of more than two alleles controlling the same character in a population.

Example: ABO blood group system.

Q11. A child has blood group O. If the father has blood group A and mother blood group B, work out the genotypes of the parents and the possible genotypes of the other offspring.

Ans: Genotype of father I^Ai. Genotype of mother I^Bi.

Possible genotypes of other offsprings are I^AI^B, I^Bi, I^Ai and ii.

Q12. What is polygenic inheritance? Give an example.

Ans: Polygenic inheritance refers to inheritance of traits controlled by multiple genes.

Example: Human height and human skin colour.

Q13. ABO blood grouping in human population exhibits four possible phenotypes from six different genotypes. Explain.

Ans: This is due to the presence of three alleles I^A, I^B and i. I^A and I^B are codominant, while i is recessive, resulting in four phenotypes and six genotypes.

Q14. Define pleiotropy. Give an example.

Ans: Pleiotropy is a phenomenon in which a single gene influences multiple phenotypic traits.

Example: Phenylketonuria.

Q15. Differentiate between linkage and recombination.

Ans: Linkage is the physical association of genes on a chromosome.

Recombination is the formation of new gene combinations.

Q16. List two features of Drosophila melanogaster which make it suitable for genetic experiments.

Ans: They can be grown easily on simple synthetic medium.

They have a short life cycle and produce a large number of offspring.

Q17. Differentiate male heterogamety from female heterogamety.

Ans: In male heterogamety, males produce two types of gametes.
In female heterogamety, females produce two types of gametes.

Q18. Define mutation. What are mutation-causing agents called?

Ans: Mutation is a change in genetic material.
Mutation-causing agents are called mutagens.

Q19. What are mutagens? Give an example.

Ans: Mutagens are physical or chemical agents that induce mutations.
Example: UV radiation.

Q20. What is point mutation? Give an example.

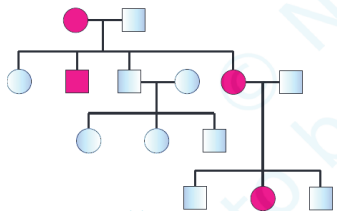
Ans: Point mutation is caused by a change in a single base pair of DNA.
Example: Sickle cell anaemia.

Q21. What are Mendelian disorders? Give an example.

Ans: Mendelian disorders are genetic disorders caused by mutation in a single gene.
Example: Haemophilia, cystic fibrosis, sickle cell anaemia, colour blindness, phenylketonuria and thalassemia.

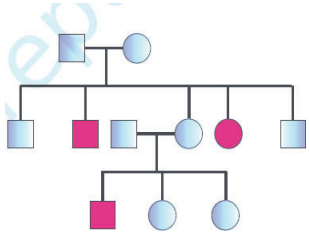
Q22. Schematically represent a pedigree chart of myotonic dystrophy.

Ans:



Q23. Schematically represent a pedigree chart of sickle cell anaemia.

Ans:



Q24. Mention the sixth codon of the beta globin chain in normal haemoglobin and in sickle cell anaemia.

Ans: Normal haemoglobin has GAG as the sixth codon.
Sickle cell anaemia haemoglobin has GUG as the sixth codon.

Q25. Distinguish between α thalassemia and β thalassemia.

Ans: In α thalassemia, synthesis of alpha globin chain is reduced.
In β thalassemia, synthesis of beta globin chain is reduced.

Q26. What is aneuploidy? Give an example.

Ans: Aneuploidy is the gain or loss of one or more chromosomes due to failure of segregation.
Example: Down's syndrome.

Q27. What is polyploidy? Give an example.

Ans: Polyploidy is the presence of more than two complete sets of chromosomes.
Example: Plants.

Q28. Distinguish between aneuploidy and polyploidy.

Ans: Aneuploidy involves gain or loss of individual chromosomes.
Polyploidy involves gain of entire sets of chromosomes.

Q29. Write the genotype of

a) An individual who is carrier of sickle-cell anaemia gene but apparently unaffected
b) An individual affected with sickle-cell anaemia

Ans:

a) HbA HbS
b) HbS HbS

Q30. Mention a Mendelian disorder and its types where there is reduced synthesis of haemoglobin.

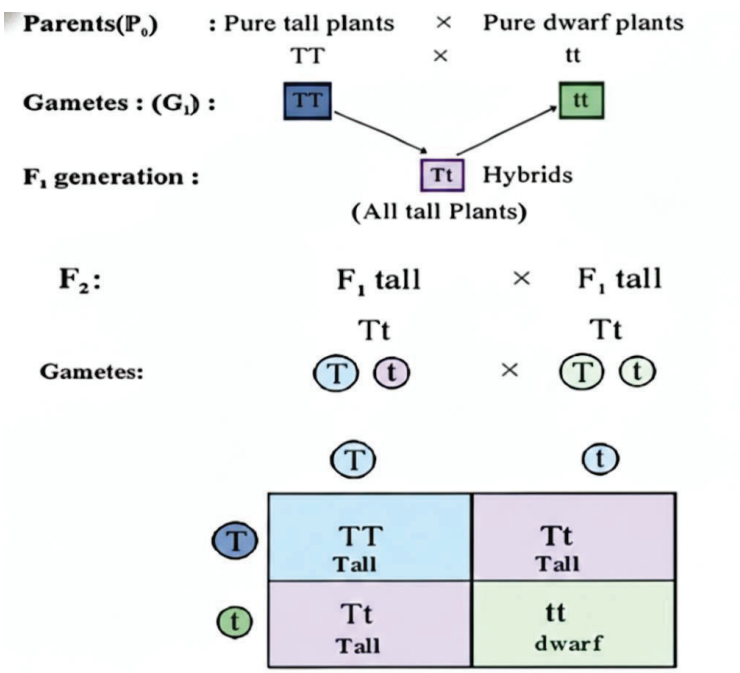
Ans: Thalassemia.
Types: α thalassemia and β thalassemia.

PART – C

IV Answer the following questions in 200-250 words each, wherever applicable: 3 Marks:

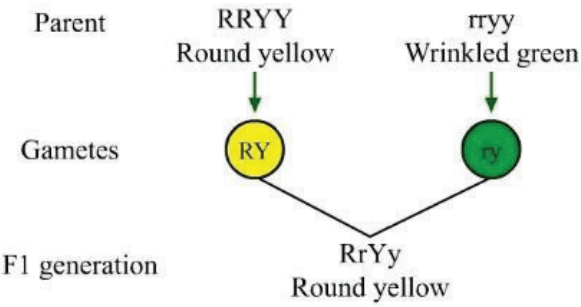
Q1. Schematically represent the inheritance of height in pea plant.

Ans:



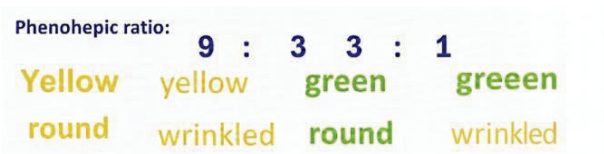
Phenotypic ratio: 3:1 (3 tall: 1 dwarf)
Genotypic ration: 1: 2 :1 (1 pure tall: 2 hybrid tall: 1 pure dwarf)

Q2. Schematically represent the inheritance of colour and shape of seed in pea plant.



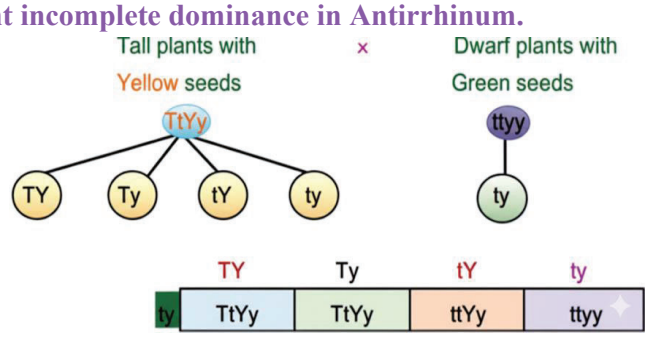
	RY	rY	Ry	ry
RY	RRYY Round yellow	RrYY Round yellow	RRYy Round yellow	RrYy Round yellow
rY	RrYY Round yellow	rrYY Wrinkled yellow	RrYy Round yellow	rrYy Wrinkled yellow
Ry	RRYy Round yellow	RrYy Round yellow	RRyy Round green	Rryy Round green
ry	RrYy Round yellow	rrYy Wrinkled yellow	Rryy Round green	rryy Wrinkled green

Ans:



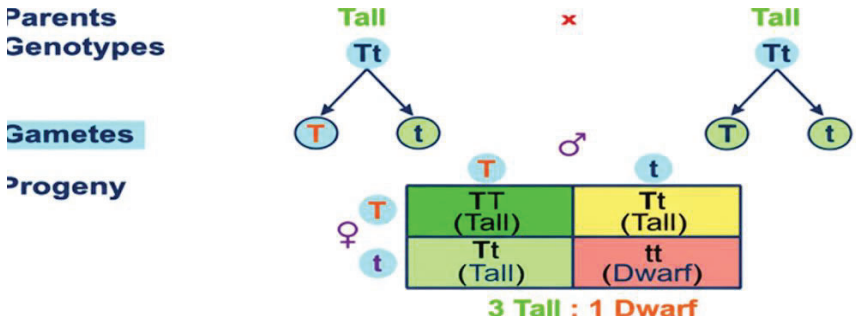
Q3. Schematically represent incomplete dominance in Antirrhinum.

Ans:



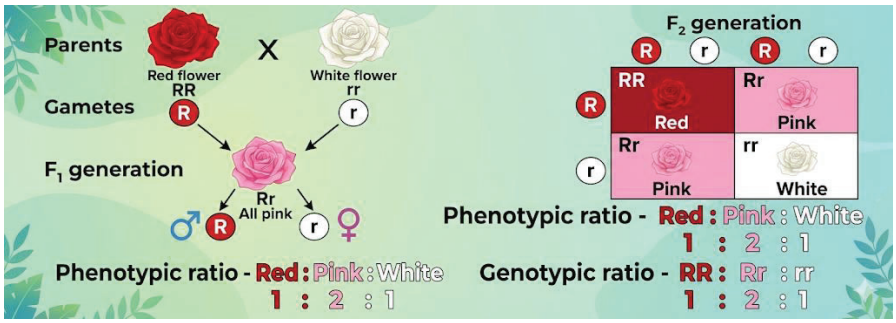
Q4. When a tall Pea plant was selfed, it produced one-fourth of its progeny as dwarf. Explain with the help of a cross.

Ans: Production of one-fourth dwarf progeny on selfing of a tall pea plant indicates that the plant is heterozygous. This can be explained with the cross as follows:



Q5. A tall Pea plant with yellow seeds (heterozygous for both) is crossed with a dwarf Pea plant with green seeds. Using a Punnet square work out the cross to show the phenotypes and the genotypes of F1 generation.

Ans: A tall pea plant with yellow seeds that is heterozygous for both traits (TtYy) crossed with a dwarf pea plant with green seeds (ttyy) will produce an F1 generation with a 1:1:1:1 phenotypic ratio of Tall Yellow, Tall Green, Dwarf Yellow, and Dwarf Green. The genotypes will also be in a 1:1:1:1 ratio: TtYy, Ttyy, ttYy, and ttyy respectively.



Q6. A woman with blood group O married a man with AB group. Show the possible blood groups of the progeny. List the alleles involved in this inheritance.

Ans:

Women with Blood group O married a man with Blood group AB

Hence the genotype of parents are

Mother - $I^O I^O$

Father – $I^A I^B$

Using the punnet square method, the possible blood groups in the progeny are as follows:

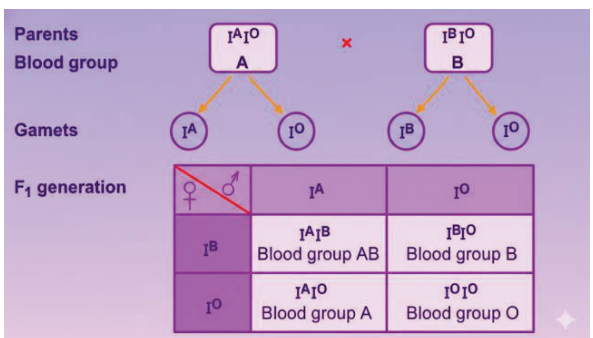
	I^O	I^O
I^A	$I^A I^O$	$I^A I^O$
I^B	$I^B I^O$	$I^B I^O$

Hence the possible genotype are – $I^A I^O$ and $I^B I^O$

possible phenotype are – Blood group A and Blood group B.

Q7. Four children with four different blood groups are born to parents where the mother has blood group 'A' and the father has blood group 'B'. Work out the cross to show the genotypes of the parents and all four children.

Ans: To have four children with blood groups A, B, AB, and O, the parents must have the genotypes IAIO (blood group A) and IBIO (blood group B).



Q8. "Mendel's work was not recognized during his time." Why?

Ans:

a. Communication was not easy (as it is now) in those days and his work could not be widely publicised.

b. His concept of genes (or factors, in Mendel's words) as stable and discrete units that controlled the expression of traits and, of the pair of alleles which did not 'blend' with each other, was not accepted by his contemporaries as an explanation for the apparently continuous variation seen in nature.

c. Mendel's approach of using mathematics to explain biological phenomena was totally new and unacceptable to many of the biologists of his time.

d. Finally, though Mendel's work suggested that factors (genes) were discrete units, he could not provide any physical proof for the existence of factors or say what they were made of.

Q9. Mention the similarities between the behaviours of chromosomes and genes according to chromosomal theory of inheritance.

Ans:

Chromosomes	Genes
Occur in pairs	Occur in pairs
Segregate at the time of gamete formation such that only one of each pair is transmitted to a gamete	Segregate at gamete formation and only one of each pair is transmitted to a gamete
Independent pairs segregate independently of each other	One pair segregates independently of another pair

Q10. During his studies on genes in Drosophila that were sex-linked T.H. Morgan found F2 population phenotypic ratios deviated from expected 9:3:3:1. Explain the conclusion he arrived at.

Ans: During his studies on sex-linked genes in Drosophila, T.H. Morgan observed that the F2 generation phenotypic ratios deviated from the expected 9:3:3:1 ratio. Because if the two genes in a dihybrid cross were situated on the same chromosome, the proportion of parental gene combinations were much higher than the non-parental type. This deviation led him to conclude that genes located on the same chromosome tend to be inherited together, a phenomenon known as genetic linkage.

a. Morgan attributed this due to the physical association or linkage of the two genes and coined the term linkage to describe this physical association of genes on a chromosome and the term recombination to describe the generation of non-parental gene combinations.

b. If two genes are tightly linked on the same chromosome showed very low recombination\

c. If two genes are loosely Linked on the same chromosome showed higher recombination

Q11. T H Morgan used Drosophila melanogaster for genetic experiments. Why?

Ans:

a. They could be grown on simple synthetic medium in the laboratory.

b. They complete their life cycle in about two weeks, and a single mating could produce a large number of progeny flies.

c. It has clear differentiation of the sexes – the male and female flies are easily distinguishable.

d. it has many types of hereditary variations that can be seen with low power microscopes

Q12. Study the figures given below and answer the question. Identify in which of the crosses, the strength of linkage between the genes is higher. Give reasons in support of your answer.

Ans: Strength of linkage between genes (y and w) is higher in cross A than that of cross B (w and m) because the two genes YW are located closely on the same chromosome. Tightly linked genes have less chance of recombination or separation during crossing over.

Q13. Explain sex determination in humans.

Ans:

a. Sex determining mechanism in case of humans is XY type.

b. 22 pairs i.e. autosomes are exactly same in both males and females, remaining two chromosomes are sex chromosomes X and Y are different.

c. A pair of X-chromosomes are present in the female whereas the presence of an X and Y chromosome are determinants of the male characteristics.

d. Females have 44+XX and males have 44+XY.

e. During spermatogenesis, male produces two types of gametes or sperms. 50 per cent of the total sperm produced carry the X-chromosome and the rest 50 per cent has Y-chromosome besides the autosomes. Females, however, produce only one type of ovum with an X-chromosome.

f. In case the ovum fertilises with a sperm carrying X-chromosome the zygote develops into a female (XX) and the fertilisation of ovum with Y-chromosome carrying sperm results into a male offspring. g. There is an equal probability of fertilisation of the ovum with the sperm carrying either X or Y chromosome.

Q14. Explain sex determination in Drosophila melanogaster.

Ans:

a. Sex determining mechanism in case of Drosophila is XY type, like humans.

b. Both males and females bear same number of autosomes.

c. Drosophila the males have one X and one Y chromosome, whereas females have a pair of X-chromosomes besides autosomes.

d. Males are heterogametic and produce two types of sperm. 50 per cent of the total

sperm produced carry the X-chromosome and the rest 50 per cent has Y-chromosome besides the autosomes.

e. Females are homogametic and produce one type of gamete (egg) carrying an X chromosome.

Q15. Explain sex determination in birds.

Ans:

a. In birds, sex determination is ZW type. Females have two different sex chromosomes (ZW), while males have two of the same sex chromosomes (ZZ) besides autosomes.

b. Female birds are heterogametic (ZW) and produce two types of eggs: Z-bearing and W-bearing. Male birds are homogametic (ZZ) and produce only Z-bearing sperm.

c. A Z-bearing egg fertilised by a Z-bearing sperm forms a ZZ male. A W-bearing egg fertilised by a Z-bearing sperm forms a ZW female.

Q16. Explain sex determination mechanism in grasshopper.

Ans:

a. In grasshoppers, sex determination is XO type.

b. Females have two X chromosomes (XX). They produce eggs with X-chromosome besides the other (autosomes).

c. Males have only one X chromosome (XO). They produce two types of gametes or sperms i.e. some with X-chromosome whereas some do not.

d. Eggs fertilised by sperm having an X-chromosome become females and, those fertilised by sperms that do not have an X-chromosome become males.

Q17. Explain sex determination mechanism in honey bees.

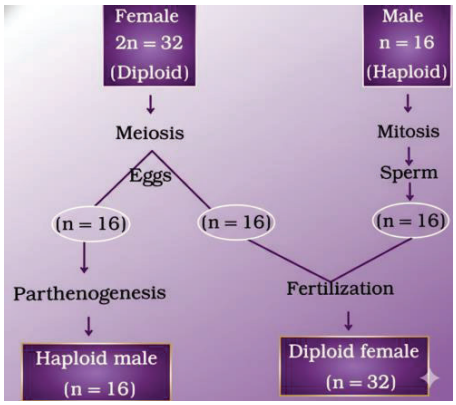
Ans:

a. sex determination mechanism in honey bees is haplodiploid sex-determination type.

b. The females are diploid having 32 chromosomes and males are haploid, i.e., having 16 chromosomes.
This means that the males have half the number of chromosomes than that of a female.

c. An offspring formed from the union of a sperm and an egg develops as a female (queen or worker), and an unfertilised egg develops as a male (drone) by means of parthenogenesis.

d. The sex determination in honey bee is based on the number of sets of chromosomes an individual receives.



Q18. What is pedigree analysis? Mention its significance.

Ans: Analysis of traits in several of generations of a family is called the pedigree analysis.

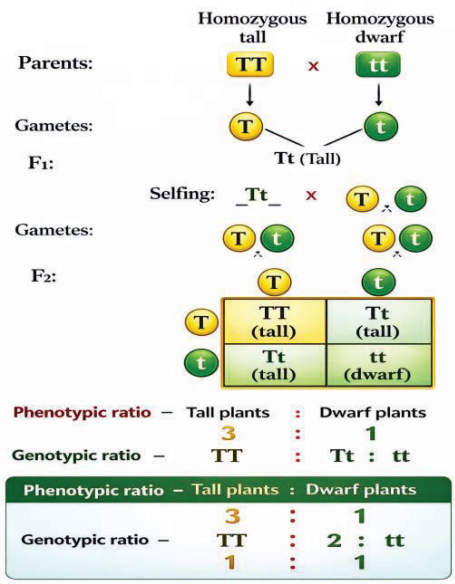
Significance: pedigree study provides a strong tool, which is utilised to trace the inheritance of a specific trait, abnormality or disease.

PART- D

V. Answer the following ☐uestions as directed☐

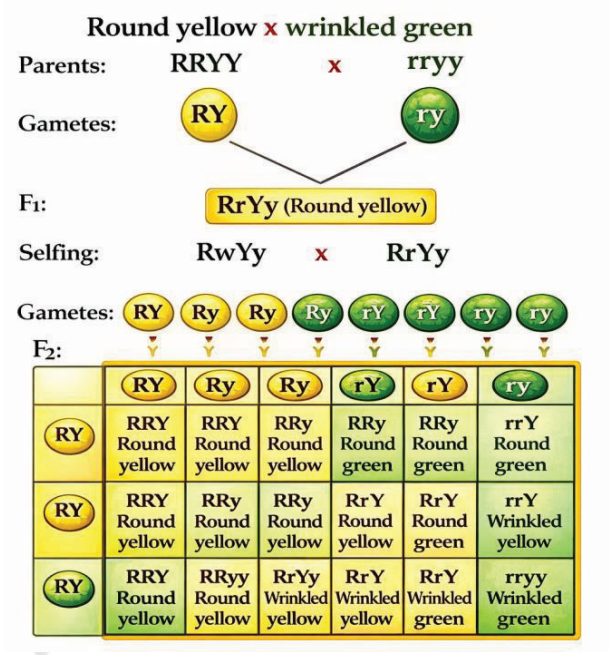
Q1. State law of segregation. Schematically represent it with reference to the inheritance of height in pea plants.

Ans: The law of segregation states that during gamete formation, the factors or alleles of a pair segregate from each other such that a gamete receives only one of the two factors.



Q2. Schematically represent inheritance of colour and shape of a seed in pea plant.

Ans:



	RY	Ry	Ry	rY	rY	ry
RY	RRY Round yellow	RRY Round yellow	RRy Round yellow	RRy Round green	RRy Round green	rrY Round green
RY	RRY Round yellow	RRy Round yellow	RRy Round yellow	RrY Round yellow	RrY Round green	rrY Wrinkled yellow
RY	RRY Round yellow	RRyy Round yellow	RrYy Wrinkled yellow	RrY Wrinkled yellow	RrY Wrinkled green	rryy Wrinkled green

Phenotypic ratio : round yellow : round green : wrinkled yellow : wrinkled green
9 3 3 1

Q3. What is incomplete dominance? Explain it with reference to flower colour in Snapdragon.

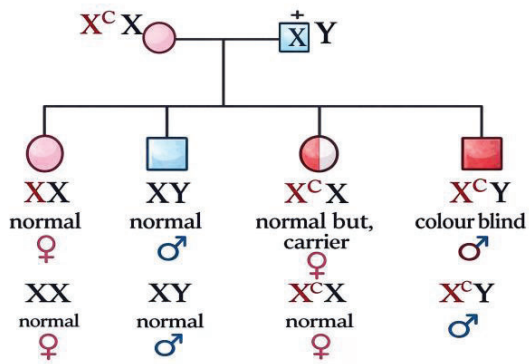
Ans: Incomplete dominance is a type of inheritance when neither allele in a gene pair is completely dominant and the F1 had a phenotype that did not resemble either of the two parents and was in between the two.

- When a true-breeding red-flowered (RR) snapdragon is crossed with true-breeding white-flowered plants (rr), all offspring in the F1 generation are heterozygous (Rr) and have pink flowers.
- When the F1 was self-pollinated, the F2 generation shows a genotypic ratio of 1:2:1 (RR : Rr : rr) and a phenotypic ratio of 1:2:1 (red : pink : white).

Q4. A colour-blind father has a daughter with normal vision. The daughter marries a man with a normal vision. What is the probability of her children to be colourblind? Explain with the help of a pedigree chart.

Ans: a. Colour blindness is often inherited in an X-linked recessive manner. b. Since the father is color-blind (XcY), the daughter has inherited one Xc chromosome from her father and one normal X chromosome from her mother, making her genotype XcX (carrier) but phenotypically normal. Probability of her children to be colour-blind is 25%.

	X	Y
X^c	X^cX Daughter: Carrier	X^cY Son: Colourblind
X	XX Daughter: Normal	XY Son: Normal



Q5. Write a note on Sickle cell anemia.

Ans:

- Sickle cell anemia is an autosome linked recessive trait transmitted when both parents are carriers.

- The disease is controlled by a single pair of alleles HbA and HbS. • HbSHbS individuals are affected, while HbAHbS individuals are carriers.
- It is caused by substitution of Glutamic acid by Valine at the sixth position of beta globin chain.
- The codon changes from GAG to GUG.
- Under low oxygen tension, RBCs become sickle shaped.

Q6. Write a note on haemophilia.

Ans:

- Haemophilia is a sex-linked recessive disorder.
- It affects blood clotting proteins.
- Minor injuries cause prolonged bleeding.
- Carrier females can transmit the disease to sons.
- Females rarely suffer from haemophilia.

Q7. Explain thalassemia as an example for Mendelian disorder.

Ans:

- Thalassemia is an autosomal recessive blood disorder.
- It causes reduced synthesis of globin chains.
- Two types exist: α-thalassemia and β-thalassemia.
- α-thalassemia affects alpha globin chains (chromosome 16).
- β-thalassemia affects beta globin chains (chromosome 11).
- It is a quantitative defect unlike sickle cell anemia.

V. Answer the following questions as directed: 5 Marks Each:

Q1. Observe the dihybrid cross and answer the questions given below.

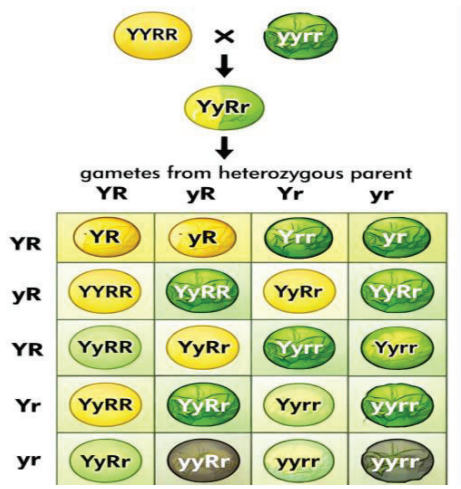
a) Write the phenotypic ratio.

b) Identify homozygous dominant genotype in progeny.

c) Identify recessive genotype in progeny.

d) Number of parental type progeny.

e) Number of recombinant type progeny.



Ans:

a) Phenotypic ratio: 9: 3: 3: 1

b) Homozygous dominant genotype – YYRR

c) Recessive genotype in progeny – yyrr

d) Number of parental type progeny = 9 + 1 = 10

e) Number of recombinant type progeny = 3 + 3 = 6

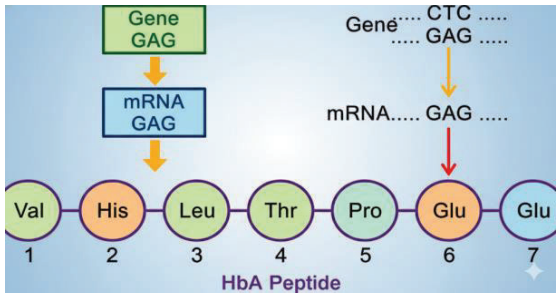
Q2. Given below is the representation of amino acid composition of the relevant translated portion of B chain of haemoglobin, related to the shape of human red cells.

a) Is this representation indicating a normal human or a sufferer from certain related genetic disease? Give reason in support of your answer.

b) What difference would be notice in the phenotype of the normal and the sufferer related to this gene?

c) Who are likely to suffer more from the defect related to the gene represented the males, the females or both males and females equally? Why?

Ans:



a) The representation indicates a normal human.

b) In normal condition, red blood cells have a biconcave shape which helps in efficient oxygen transport. In sufferers, red blood cells become sickle-shaped due to polymerisation of haemoglobin under low oxygen conditions.

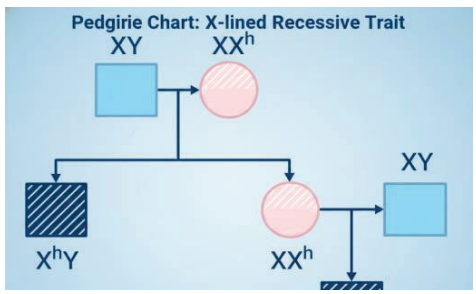
c) Both males and females are equally likely to suffer from sickle cell anaemia because it is an autosomal recessive disorder.

Q3. A normal couple had a haemophilic son and a phenotypically normal daughter. The daughter was married to a normal man. To their surprise, the grandson was also haemophilic.

a) Represent the cross in the form of a pedigree chart. Give the genotypes of the daughter and her husband. (3)

b) Write the conclusion you draw of the inheritance pattern of this disease. (2)

Ans:



Ans: a) The daughter is a carrier: X^H X^h. Her husband is normal: X^H Y. An affected son has genotype X^h Y.
b) Haemophilia shows X-linked recessive inheritance. Carrier females may transmit the allele to sons; affected males carry X^h Y.

Q4. Identify the genetic disorders given below:

a) Sex-linked recessive disorder occurring in about 8% of males and only about 0.4% of females leading to defect in cone of eye. (1)

b) Sex-linked recessive disorder affecting a single protein involved in the clotting of blood. (1)

c) Inborn error of metabolism, autosomal recessive trait, accumulation of phenylalanine. (1)

d) Autosome linked recessive blood disease, substitution of amino acid in beta globin chain of haemoglobin. (1)

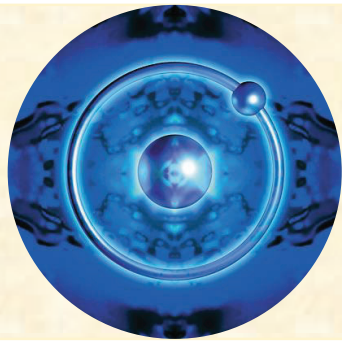
e) Autosome linked recessive blood disease, reduced rate of synthesis of globin chains of haemoglobin. (1)

Ans:

a) Colour blindness
b) Haemophilia
c) Phenylketonuria (PKU)
d) Sickle cell anaemia
e) Thalassemia

Chapter 5

MOLECULAR BASIS OF INHERITANCE



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THEORY

INTRODUCTION:

- **DNA** (deoxyribonucleic acid) and **RNA** (ribonucleic acid) are two types of nucleic acids found in living system.
- **DNA** acts as the genetic material in most of the organism.
- **RNA** also act as a genetic material in some viruses and also has additional role as well.

NUCLEIC ACID

Discovered by :- Friedrich Meischer

In nucleus of pus cell called it **'nuclein'**

Polymer of Nucleotides

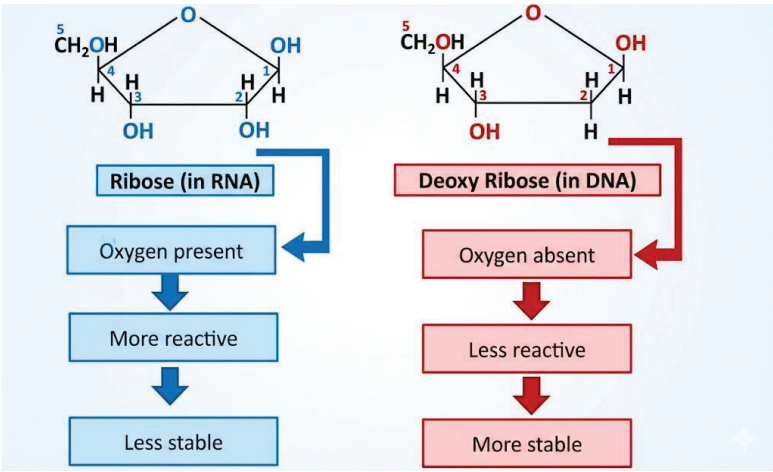
Nucleoside :- Nitrogen base + Pentose sugar.

Nucleotide :- Nitrogen Base + Pentose Sugar +Phosphate

1. **NITROGEN BASES:** Heterocyclic Nitrogenous compounds

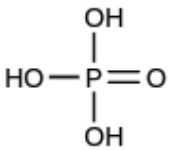
Purines	Pyrimidines
Adenine	Cytosine
Guanine	Thymine [DNA]
	Uracil [RNA]

2. PENTOSE SUGAR



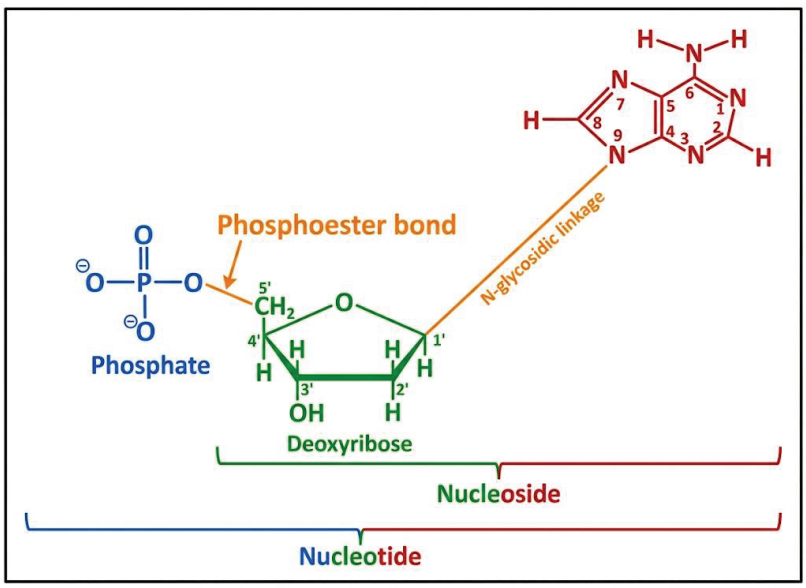
3. PHOSPHATE

❖ Due to phosphate both DNA and RNA show



1. **Acidic** properties and
2. Have **Negative** charge

NUCLEOTIDE FORMATION

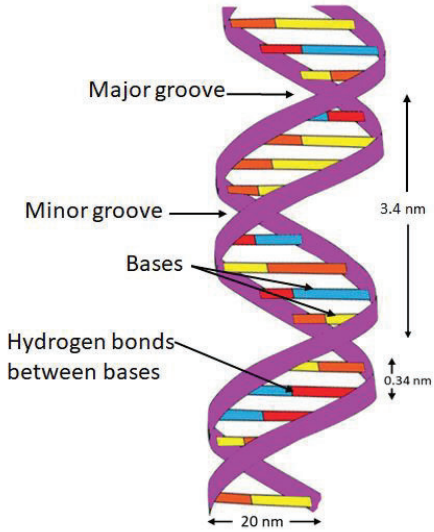


POLYNUCLEOTIDE CHAIN FORMATION

RIBONUCLEOTIDES (RNA)

N - base	Nucleosides = N base + Ribose sugar	Nucleotides = Nucleoside + P
Adenine	Adenosine	Adenylic acid
Guanine	Guanosine	Guanylic acid
Cytosine	Cytidine	Cytidylic acid
Uracil	Uridine	Uridylic acid

DEOXYRIBONUCLEOTIDES (DNA)



N - base	Nucleosides = N base + Deoxy Ribose Sugar	Nucleotides
Adenine	Deoxyadenosine	Deoxyadenylic acid
Guanine	Dioxyguanosine	Deoxyguanylic acid
Cytosine	Deoxycytidine	Deoxycytidylic acid
Thymine	Deoxy thymidine	Deoxythymidylic acid

5.1. The DNA

❖ DNA is a long polymer of deoxyribonucleotides.

Organisms	Number of Nucleotides
$\phi \times 174$ bacteriophage	5386 Nucleotides
λ bacteriophage	48502 base pairs
E.coli	4.6×10^6 base pairs
Human (Haploid cell)	3.3×10^9 base pairs

STRUCTURE OF DNA

1. **DNA** stores genetic information in the form of nucleotides and it is expressed in the form of protein.
2. **Wilkins and Franklin :-** Studied DNA molecule with the help of **X-ray crystallography** (diffraction experiment).
3. **Watson and Crick :-** Gave Double Helix Model (1953).
4. **Watson Crick and Wilkins were awarded by Noble Prize in 1962** for double helix model of **DNA.**

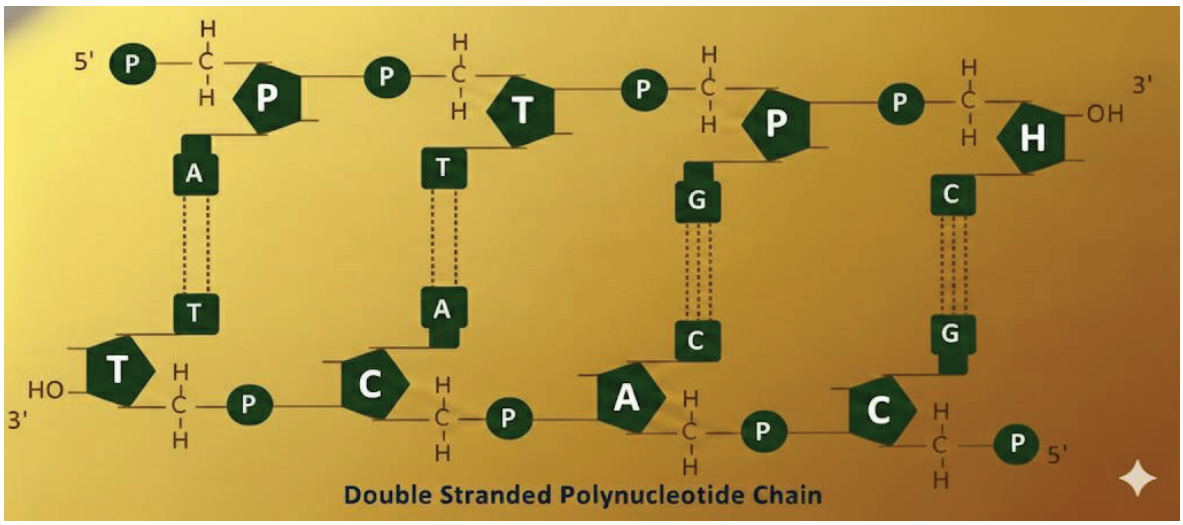
STRUCYURE OF DOUBLE HELIX MODEL OF DNA

❖ **Watson** and **Crick** (1953) proposed a double helix model for DNA.

❖ **The salient features of DNA are as following :-**

❖ DNA molecule is composed of **two polynucleotide strands,** which are twisted right-handedly like a **spiral staircase.**

- Each polynucleotide strand consists of number of **deoxyribonucleotides** attached to one another by **phosphodiester bonds.**
- The two polynucleotide strands are joined by the specific **base pairing** i.e. purines with pyrimidines and vice versa.
- The base pairing is specific among purines and pyrimidines. **Adenine** of one strand always pairs with **Thymine** of another strand. **Guanine** always pairs with **Cytosine**.
- The hydrogen bonds are also specific. There are **two hydrogen bonds** between adenine and thymine and **three hydrogen bonds** between guanine and cytosine i.e $A = T$ and $\mathbf{G \equiv C}$.
- In these two strands the **sugars** and **phosphates** form the backbone and nitrogen bases that are projected towards the inner side forms axis of the molecule.
- The two strands of the DNA are **antiparallel** and **complementary** i.e. One strand with $5'$ to $3'$ pairs with other strand in opposite manner [$3'$ to $5'$ manner].
- In a DNA molecule the amount of Purines is always equal to the amount of Pyrimidines i.e., $\mathbf{A = T}$ and $\mathbf{G \equiv C}$. This is called **Chargoff's rule or Equivalent base rule**. The base ratio $\mathbf{A + T/G + C = 1}$ unity.
- Each turn in the DNA molecule consists of ten nucleotide pairs. The length of each turn is $\mathbf{3.4\ nm}$ or $\mathbf{34A^0}$, the distance between each nucleotide in a strand is $\mathbf{0.34nm}$ or $\mathbf{3.4A^0}$.
- The distance between two strands is $\mathbf{2nm}$ or $\mathbf{20A^0}$(a nanometre is one billionth of a metre, that is $\mathbf{10^{-9}\ m}$)
- The DNA has two grooves namely **major deep groove and minor shallow groove.**



PACKAGING OF DNA HELIX

Question :- Calculate the length of DNA in a diploid cell of human(in meters)?

Solution :- Length of DNA = Total bp $\times$ 3.4Å

$= 6.6 \times 10^9 \text{bp} \times 0.34 \times 10^{-9} = \mathbf{2.2\ metres}$

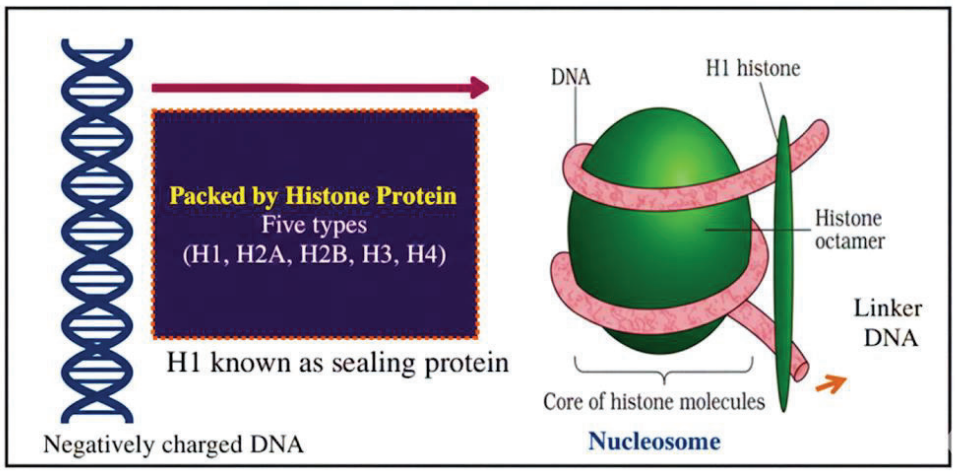
The length is far greater then dimension of a typical nucleus, so to fit this DNA we require packaging.

DNA packaging in Prokaryotes

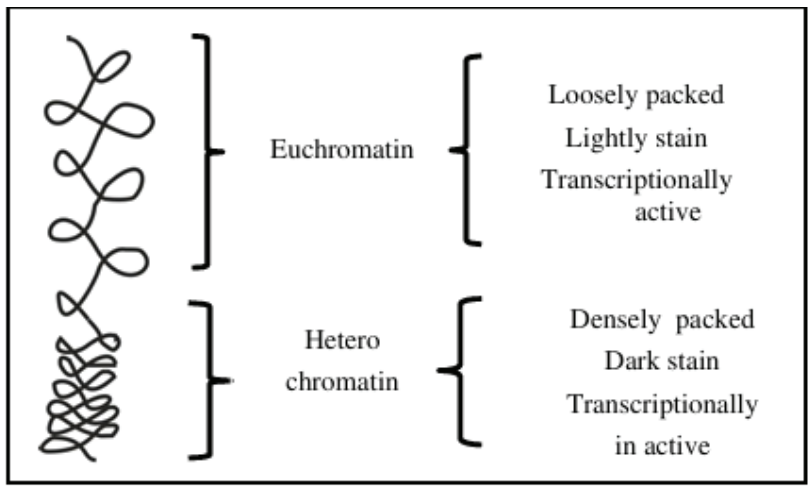
- ✕ Prokaryotes do not have definite nucleus.
- ✕ DNA is organized into a nucleoid.
- ✕ DNA is held together with some proteins in a region is called '**nucleoid**'.
- ✕ DNA in the nucleoid is organized in large loops held by **non-histone proteins.**

DNA packaging in Eukaryotes :

- It is carried out with the help of **lysine** and **arginine** rich basic proteins called **histone.**
- There are five types of histone proteins H1, H2A, H2B, H3 and H4.
- Four of them occur in pairs to produce histone octamer (2 copies of each - H2A, H2B, H3 and H4) called **core of Nucleosome**.Their positively charged ends are directed outside.
- The negatively charged DNA is wrapped around the positively charged histone octamer to form a structure called **nucleosome.**
- A typical nucleosome contains 200 bp of DNA Helix.



- DNA present between two adjacent nucleosomes is called **linker DNA.**
- Nucleosome chain gives a beads on string appearance under electron microscope.
- Nucleosomes constitute the repeating unit of a structure in nucleus called **chromatin.**
- The beads on string structure in chromatin is packaged to form chromatin fibers that are further coiled and condensed at metaphase stage of cell division to form **chromosomes.**
- The packaging of chromatin at higher level requires additional set of proteins (acidic) that collectively are referred to as **non-histone chromosomal (NHC) proteins.**



Chromatin fibers are two types :

Euchromatin:- In a typical nucleus,some regions of chromatin are loosely packed ,less stained, genetically more active and are called **euchromatin.**

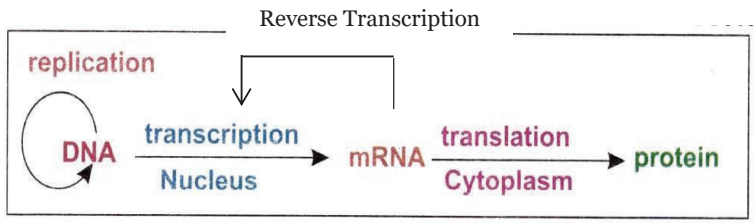
Heterochromatin:- The chromatin that is more densely packed,more stained and genitically inacticregions are called as **Heterochromatin.**

Differentiate between euchromatin and Heterochromatin

Euchromatin	Heterochromatin
1.Regions of chromatin,which are loosely packed	1.Regions of chromatin, which is densely packed
2.less stained chromatin	2.Darky stained chromatin
3.Transcriptionally active	3.Transcriptionally inactive

Central dogma in molecular biology:

- The flow of information from DNA to mRNA and mRNA to proteins is called central dogma in molecular biology. It involves two steps namely transcription and translation.
- It was proposed by **Francis Crick**.
- Biosynthesis of mRNA from DNA is called **transcription.**
- In some viruses the flow of information is in reverse direction (Reverse transcription)



Reverse transcription –

✕ The formation of DNA from RNA is known as Reverse - transcription.

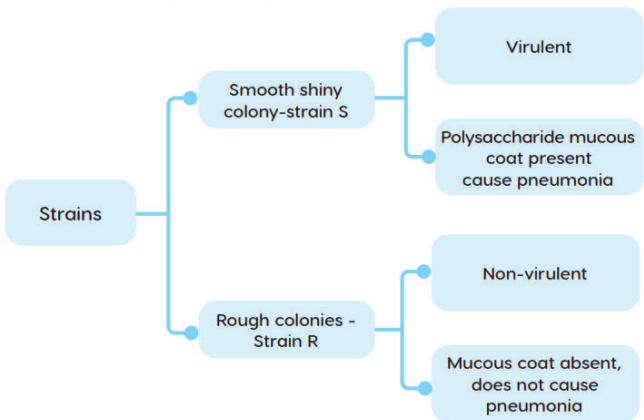
5.2. The Search For Genetic Material

1. TRANSFORMATION EXPERIMENT

✕ **Fredrick Griffith (1928)** discovered the transformation process in Streptococcus pneumoniae. This bacterium causes pneumonia in man. He worked on 2 strain of this bacteria.

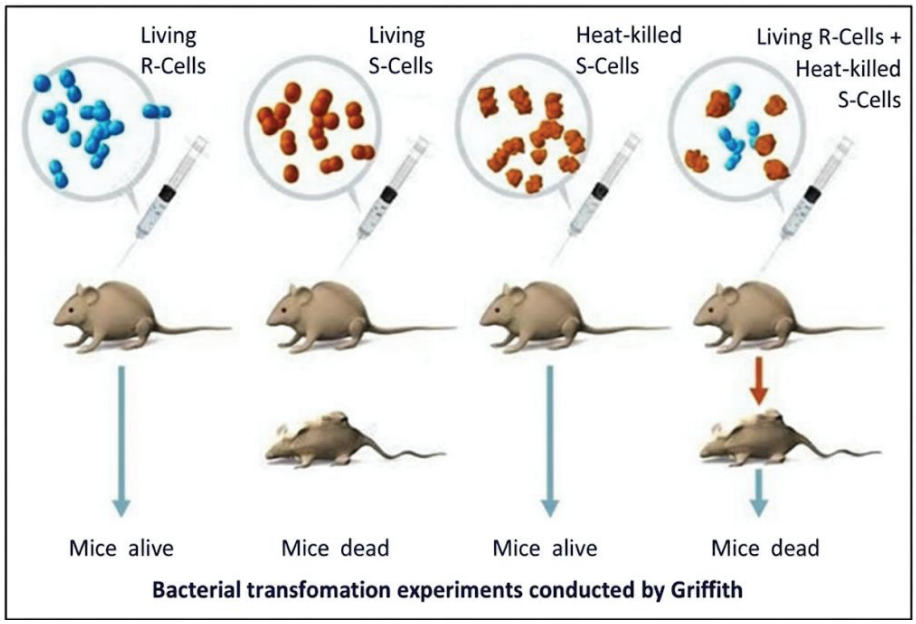
✕ **S-Strain (Smooth strain) :** These produce smooth colonies and are virulent i.e. it causes pneumonia.

✕ **R-Strain (Rough strain) :** These produce rough colonies and are nonvirulent i.e., it doesn't causes pneumonia.



- Heat killed bacteria is inactivated bacteria, it is similar to dead bacteria but inside it contains DNA Which is in normal condition.
- **The experiment can be described in following four steps :**

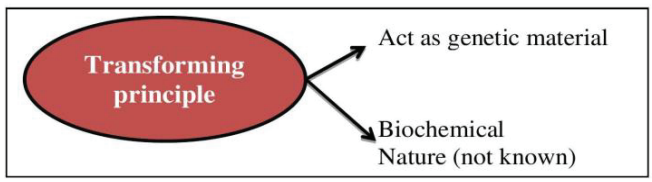
Step 1 :- When S-strain injected to mice, mice undergo death.
S-strain ⟶ Inject into mice ⟶ Mice dies
Step 2 :- When R-strain injected to mice, mice do not undergo death.
R-strain ⟶ Inject into mice ⟶ Mice lives
Step 3 :- When heat killed S-strain injected to mice, mice do not undergo death.
S-strain(Heat killed) ⟶ Inject into mice ⟶ Mice lives
Step 4 :- When heat killed S -strain mixed with live R strain, injected to mice, mice undergo death.
S-strain(Heat killed) + R-strain ⟶ Inject into mice ⟶ Mice dies



Bacterial transfomation experiments conducted by Griffith

CONCLUSION

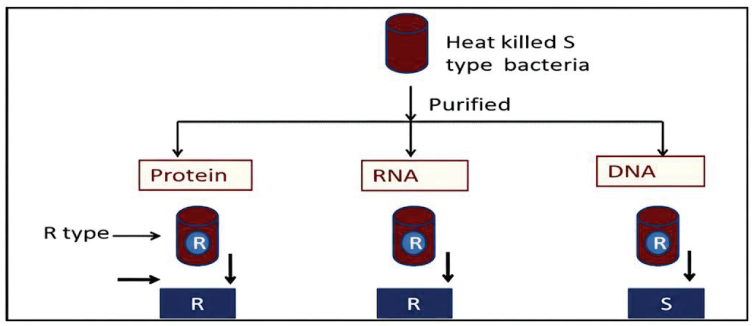
- He concluded that R-strain bacteria had somehow been transformed by the heat killed S-strain.
- Some 'transforming principle', transferred from the heat killed S strain, had enabled the R-strain to synthesise a smooth polysaccharide coat and become virulent.



Biochemical characterization of Transforming Principle :

- Later, **Avery, Macleod and McCarty (1933-1944)** repeated the experiment in vitro to identify the biochemical nature of transforming substance. They proved that this substance is DNA.
- Prior to the work, the genetic material was thought to be a protein.
- Their experimental steps are follows:-
- **Step -1 :** Protein from heat killed S-strain mixed with R-strain show is no transformation.
- **Step -2 :** RNA from heat killed S-strain mixed with R-strain shows is no transformation.

- **Step -3 :** DNA from heat killed S-strain mixed with R-strain shows is transformation.
- **Step -4 :** DNA from heat killed S-strain mixed with R-strain and protease,shows transformation.
- **Step -5 :** DNA from heat killed S-strain mixed with R-strain and RNase ,shows transformation
- **Step -6 :** DNA from heat killed S-strain mixed with R-strain and DNase ,shows no transformation



Conclusion:-

1. **Protease -** Did not affect transformation.
2. **RNase -** Did not affect transformation.
3. **DNase -** Did inhibit transformation.

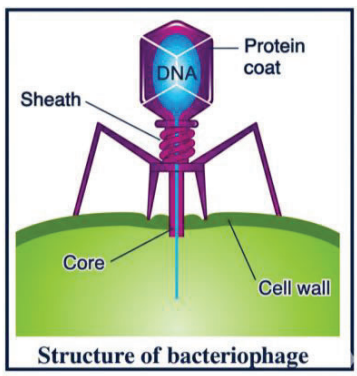
   (This proves that DNA is genetic material). But all biologists are not convinced.

Difference between DNAs and DNase

DNA's	DNase
A nucleic acid	An enzyme
Monomers are DNA nucleotides	Monomers are amino acids
Act as genetic material in most of the organisms.	Cleaves the DNA

2. HERSHEY AND CHASE EXPERIMENT(1952)

- This experiment gave unequivocal (leaving no doubt) proof that DNA is the genetic material.
- They worked with viruses that infects bacteria called **bacteriophages**.
- The bacteriophage attaches to the bacteria and its genetic material then enters the bacterial cell.



Structure of bacteriophage

- **Hershey** and **Chase** worked to discover whether it was protein or DNA from the viruses that entered the bacteria.
- They use radioactive isotope of S(^{35}S) and P(^{35}P).
- They grew some viruses on a medium that contained **radioactive phosphorus** and some others on medium that contained **radioactive sulfur.** This experiment consist of three steps.

1. **Infection :** Both type of labelled phages were allowed to infect normally cultured bacteria in separate experiments.
2. **Blending :** After infection, the bacteria cells were gently agitated in a blender to remove the virus particles from the bacteria.
3. **Centrifugation:** Later ,the culture was centrifuged to separate lighter virus particles from heavier bacterial cells. Finally ,it was observed that bacteria infected with viruses having radioactive DNA were radioactive, i.e., DNA passed from virus to bacteria.
4. **Bacteria infected with viruses having radio active** proteins were not radioactive, i.e., proteins had not entered the bacteria from the viruses. Through this experiment. It was clear that DNA The virus particles were separated from the bacterium by spinning them in a centrifuge.

Conclusion

1. After the centrifugation the bacterial cells showed the presence of radioactive DNA labelled with P^{32} while radioactive protein labelled with S^{35} appeared on the outside of bacteria cells (i.e., in the medium).

2. Labelled DNA was also found in the next generation of phage. This clearly showed that only DNA enters the bacterial host and not the protein.

3. DNA, therefore, is the infective part of virus and also carries all the genetic information.

This provided the unequivocal proof that DNA is the genetic material.

Properties of Genetic Material(DNA V/S RNA)

A molecule that can act as a genetic material must fulfill the following criteria:

a. **Replication:-** It should be able to generate its replica (**Replication**).

b. **Stability:-** It should be stable chemically and structurally. It means it should not change its structure easily with changed stages of life ,age ,climat etc.

c. **Mutations:-** It should provide the scope for slow changes (**mutation**) that are required for evolution.

d. **Genetic expression:-** It should be able to express itself in the form of **'Mendelian Characters'.**

Difference between DNA & RNA

	DNA	RNA
1.	Genetic material in most of the organism	Act as a genetic material in some viruses . Eg .TMV, QB-bacteriophage
2.	Deoxyribose sugar is present	Ribose sugar is present
3.	Thymine is present (it provide additional stability)	Uracil is present
4.	It is generally double stranded Exception:- Φ × 174 bacteriophage	It is generally single stranded Exception:- reovirus.
5.	More stable & less reactive.	Less stable & more reactive.
6.	DNA being more stable is preferred for storage for information.	For the transmission of genetic information RNA is better genetic material.
7.	Can't code for the protein directly	Can directly code for the synthesis of protein.
8.	Can't play catalytic role	Can act as catalyst (ribozyme activity)
9.	Slow mutations	Faster mutations

5.3. Replication

- Synthesis of two identical molecules of DNA from a single DNA molecule is called **DNA replication**.
- In eukaryotes, the replication occurs during in **S-phase of interphase during cell cycle.**
- The replication of DNA and Cell division cycle should be highly coordinated. A failure of in cell division after DNA replication results into polyploidy.

The machinery and the Enzymes

❖ In molecular biology, the term "**machinery**" often refers to the **cellular components** involved in processes like **DNA replication.**

Enzymes of DNA replication

- ✓ **Helicase / Unwindase** - Separates the two strands of DNA by breaking hydrogen bonds.
- ✓ **Topoisomerase II (Gyrases)** - To relieve torsional stress during unwinding of strands.
- ✓ **Primase (RNA polymerase)** - Synthesizes RNA primer.
- ✓ **DNA polymerase-I (Kornberg enzyme)** - Gap filling enzyme.
- ✓ **DNA polymerase-III** - It adds nucleotides.
- ✓ **DNA ligase** - Joins okazaki enzymes.

Semi-conservative mechanism of DNA replication:

- The replication where two identical molecules of DNA are formed from a single DNA molecule, each one having one parental and one new strand is called **semi conservative replication.**
- Semi-conservative method of replication was proposed by Watson and Crick

The following steps are included in DNA replication :-

1. **INITIATION AND UNWINDING**

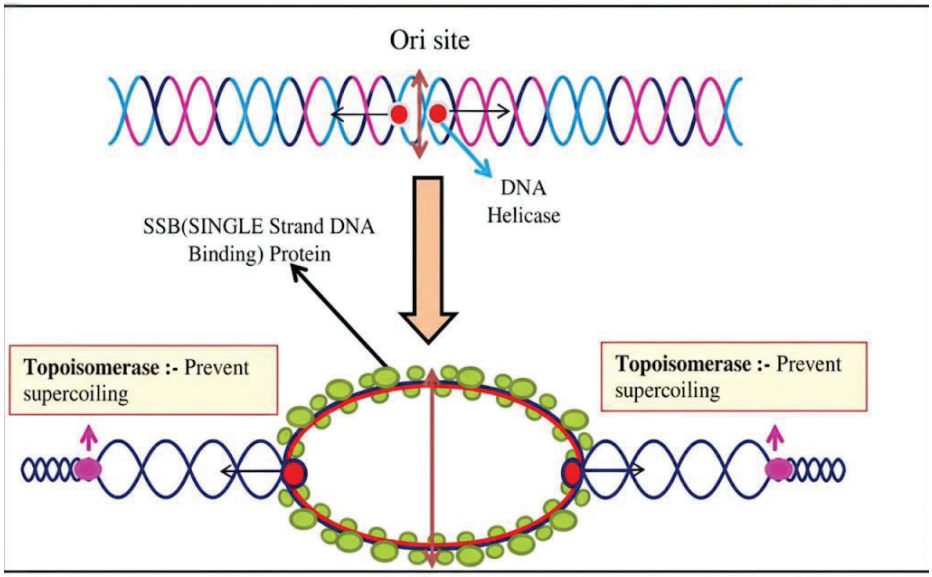
a.Origin of Replication (Ori):- Replication begins at specific locations known as the **"origin of replication"** (ori in prokaryotes).

b.Unzipping (Unwinding) : The enzyme **Helicase unwinds** the DNA double helix by breaking the hydrogen bonds between the base pairs, forming a Y-shaped structure called **the replication fork.**

c.Stabilixzation (SSBs) : Single-strand binding proteins (SSBs) bind to the separated strands to prevent them from **re-annealing (rejoining).**

d. Relieving Strain (Topoisomerase): The enzyme topoisomerase binds ahead of the replication fork to relieve the supercoiling/torsional stress caused by unwinding.

Note : The process of DNA replication takes a few minutes in prokaryotes and a few hours in Eukaryotes.



2. **PRIMER BINDING**

Primase Action: Because DNA Polymerase cannot initiate synthesis directly, an enzyme called Primase synthesizes a short RNA primer (a short nucleotide sequence) on each template strand to provide a starting point.

3. **ELONGATION (NEW STRAND SYNTHESIS)**

- ✕ To start the synthesis of new chain, special type of RNA is required which is termed as RNA Primer.
- ✕ The formation of RNA primer is catalysed by an enzyme - RNA Polymerase (primase).
- ✕ Synthesis of RNA primer takes place in $5' \rightarrow 3'$ direction.
- ✕ The formation of new chains is catalysed by an enzyme DNA Polymerase. In prokaryotes it is of 3 types :

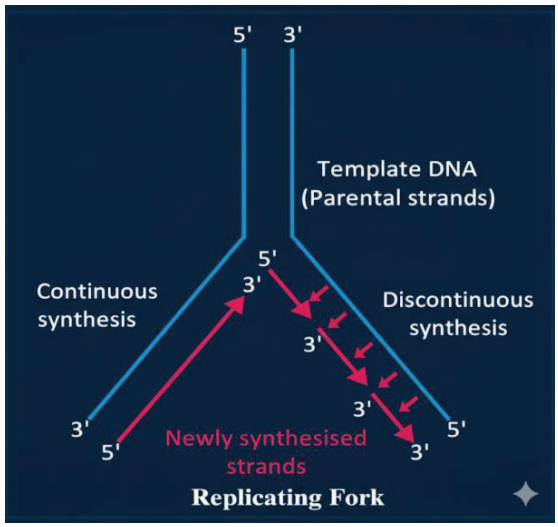
1. **DNA - Polymerase I :-** This was discovered by ARTHUR KORNBERG (1957). So it is also called as 'Kornberg's enzyme'. It separates RNA - primer from DNA and also fills the gap. It is also known as DNA-repair enzyme.
2. **DNA - Polymerase II :-** It is least reactive in replication process.
3. **DNA - Polymerase III :-** This is the main enzyme in DNA Replication. It is most important. This is also known as **Replicase.**

- All DNA polymerase I, II and III enzymes have $5' \rightarrow 3''$ polymerisation activity and $3' \rightarrow 5''$ exonuclease activity.
- The average rate of polymerisation has to be approximately **2000 bp per second.**
- For the formation of new chain nucleotides are obtained from **Nucleoplasm.**
- In the nucleoplasm, Nucleotides are present in the form of triphosphates like dATP, dGTP, dCTP, dTTP etc.
- **Deoxyribonucleoside triphosphate** serve dual purposes :-

1. Acting as substrates for enzyme.
2. They provide energy for polymerisation.

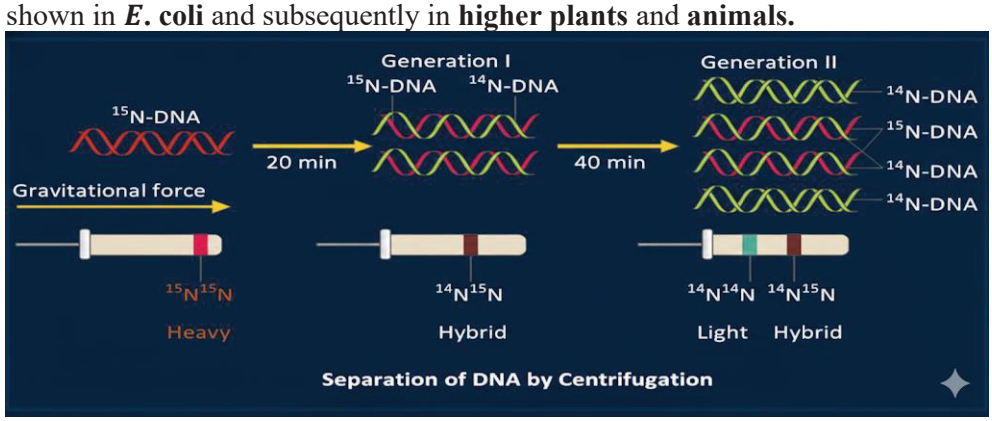
- ✕ The formation of new chain always takes place in $5' \rightarrow 3'$ direction.
- ✕ As a result of this, one chain of DNA is continuously formed and it is termed as **Leading strand.**

- The formation of second chain begins from the centre and not from the terminal points, so this chain is discontinuous and is made up of small segments called **Okazaki Fragments.**
- This discontinuous chain is termed as **Lagging strand.**
- The Okazaki fragments are joined together by an enzyme **DNA Ligase** and formed a complete new chain.



EXPERIMENTAL PROOF OF SEMI CONSERVATIVE MODE OF DNA REPLICATION

- **Meselson & Stahl** (1958) experimentally proved that DNA replication is semiconservative.
- It was first shown in ***E.* coli** and subsequently in **higher plants** and **animals.**



Steps of the Experiment :

- They grew E. coli in $^{15}NH_4Cl$ medium for many generations. (^{15} N is heavy nitrogen not radioactive element).
- The result was that ^{15} N was incorporated into newly synthesized DNA and other nitrogen containing compound as well.
- This heavy DNA molecule could be distinguished from normal DNA by centrifugation in a cesium chloride (CsCl) density gradient.
- E. coli are transferred into a medium with normal $^{14}NH_4Cl$ & let them grow. (E. coli divides in 20 minutes).
- They took samples at definite time intervals as the cells multiplied, and extracted the DNA that remained as double-stranded helices. Various samples were separated independently on **CsCl gradients** to measure the densities of DNA.
- The DNA extracted from the culture one generation after the transfer from ^{15} N to ^{14} N medium had a **hybrid or intermediate density.**

- DNA extracted from the culture after another generation (after 40 min) was composed of equal amount of this **hybrid DNA** and of **'light 'DNA.**
- Heavy isotope DNA ^{15} N Settled at lower level and light DNA at higher level.
- Further it shows that 3rd generation onwards the percentage of heavy DNA decrease and light DNA increases.
- This could happen due to conservation of one parental strand in each daughter DNA.
- Very similar experiments involving use of **radioactive thymidine** to detect distribution of newly synthesized DNA in the Chromosomes was performed on **vinca faba** (faba beans) by **Taylor** and his **colleagues** in 1958.The experiments proved that the DNA in Chromosomes also replicate semi-conservativrly.

5.4. Transcription

- The process of copying genetic information from one strand of the DNA into RNA is termed as transcription.
- Out of two strand of DNA only one strand participates in transcription and is called " Antisense strand" or "Template strand".
- Here also, the principle of complementarity governs the process of transcription, except the adenosine complements now forms base pair with uracil instead of thymine.
- However, unlike in the process of replication, which once set in, the total DNA of an organism gets duplicated but in transcription only a segment of DNA and only one of the strands is copied into RNA.

Q. Why both the strands of DNA are not copying during transcription?

Ans. ***(1)*** *If both strands act as a template during transcription they would code for RNA molecule with different sequences and If they code for proteins the sequence of amino acids in the protein would be different.*

(2) *If the two RNA molecules produced simultaneously they would be complementary to each other hence would form a dsRNA which prevent translation of RNA.*

GENE AND CISTRON

A gene is defined as the functional unit of inheritance.

- Segment of DNA which can be transcribed is known as gene.
- The segment of DNA which coding for a polypeptide is known as Cistron.
- Every cistron is a gene but every gene is not a Cistron.

TRANSCRIPTION UNIT

- A transcription unit in DNA is defined primarily by the three regions in the DNA:

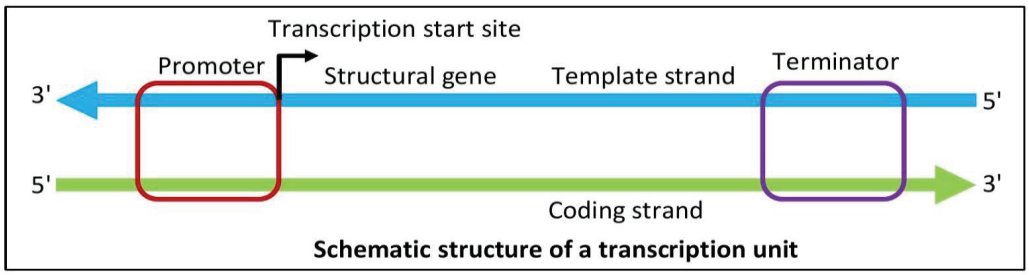
  I. A Promoter

  II. The Structural gene

  III. A Terminator

- The strand that has the polarity $3' \rightarrow 5'$ acts as a template, and is also referred to as template strand.

- The other strand which has the polarity (5′ → 3′) and the sequence same as RNA (except thymine at the place of Uracil) is known as coding strand (which does not code for anything)
- All the reference point while defining a transcription unit is made with coding strand.



Schematic structure of a transcription unit

- It provides binding site for RNA polymerase, and it is the presence of a promoter in a transcription unit that also defines the template and coding strands.
- The terminator is located towards 3′-end (downstream) of the coding strand and it usually defines the end of the process of transcription.

	Prokaryotes	Eukaryotes
1.	Transcription and translation take place in the same compartment.	In eukaryotes transcription occur in nucleus and translation occur in cytoplasm.
2.	Single type of RNA polymerase is present.	In eukaryotes there are three types of RNA polymerases that synthesised different RNA.
3.	It can form all the three types of RNA.	RNA polymerase-I for 28s rRNA, 18*s* rRNA, 5.8s rRNA synthesis.
4.	No formation of pre cursor of mRNA.	RNA polymerase-II for hnRNA synthesis (Precursor of m-RNA)
5.	The structural gene in prokaryotes is mostly polycistronic.	RNA polymerase-III for tRNA, 5s rRNA, snRNA synthesis. is mostly Monocistronic.
6.	The genes in prokaryotes are not splited.	The gene is splited and have exons and introns.

PROCESS OF TRANSCRIPTION

- There is single DNA dependent RNA polymerase that catalyses transcription of all types of RNA in bacteria.

  Following steps are present in transcription.

(1) INITIATION:

- D DNA has a Promoter site where RNA polymerase binds and a terminator site where transcription stops.
- Sigma factor recognises the promoter site of DNA.
- With the help of sigma factor RNA polymerase enzyme is attached to a specific site of DNA called **Promoter site.**

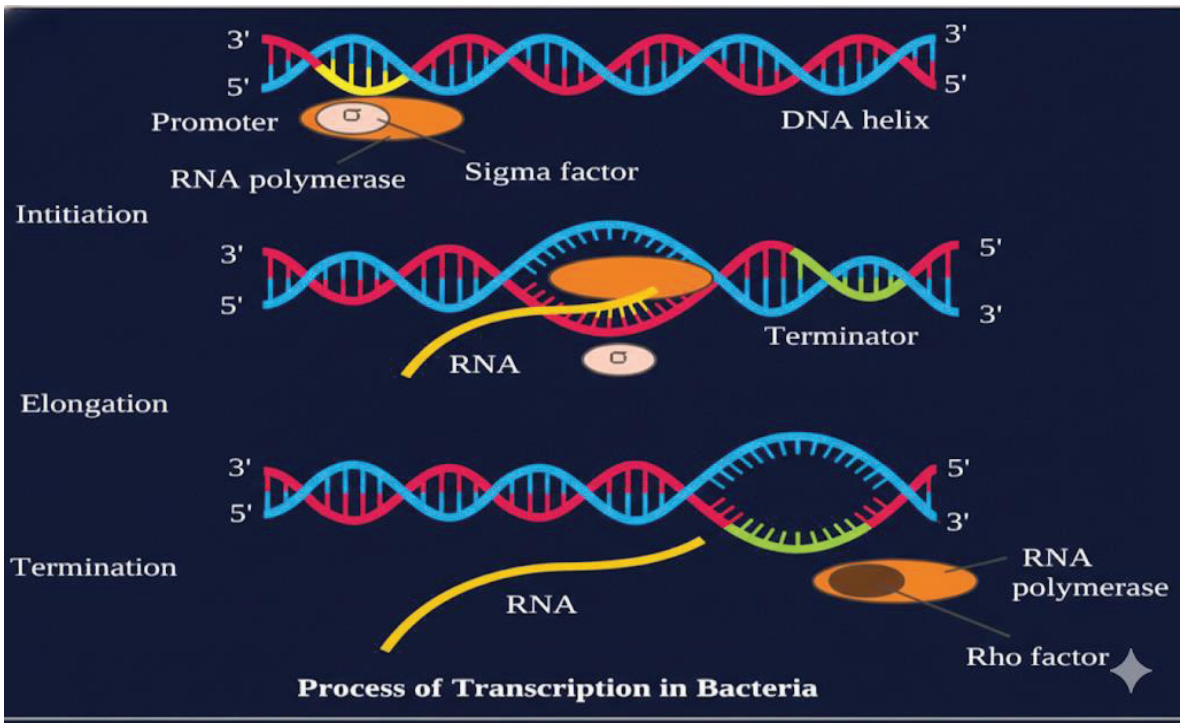
(2) ELONGATION :

- After initiation, sigma factor separates.
- At start point RNA polymerase enzyme breaks hydrogen bonds between two DNA strands and separates them.

- One of them strand takes part in transcription.
- Transcription proceeds in 5‘ to 3' direction.
- Ribonucleotide triphosphate come to lie opposite complementary nitrogen bases of anti sense strand.
- These Ribonucleotides are present in the form of triphosphate ATP, GTP, UTP and CTP (perform dual role).
- RNA polymerase enzyme establishes phosphodiester bond between adjacent ribonucleotides.

(3) TERMINATION:

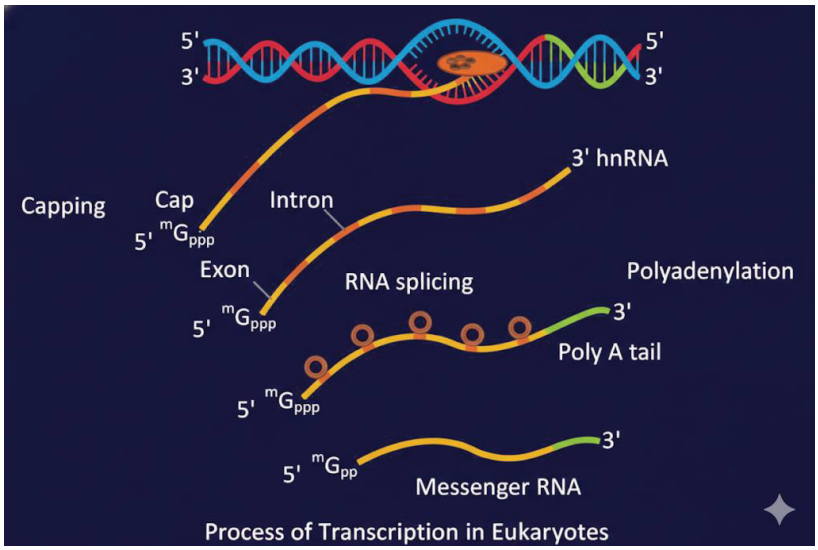
- When RNA polymerase enzyme reaches at terminator site, it separates from DNA template.
- In most cases RNA polymerase enzyme can recognise the 'Terminator site' and stop the synthesis of RNA chain, but in prokaryotes, it recognizes the terminator site with the help of Rho factor (factor).
- Rho (ρ) factor is a specific protein which helps RNA polymerase enzyme to recognize the terminator site.



SPLIT GENE

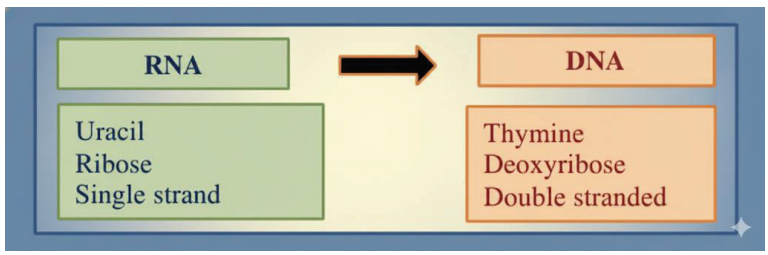
The process of splicing occur in nucleus of eukaryotic cell.

- Mostly eukaryotic genes are example of split gene.
- Mostly prokaryotic genes are example of non split gene.
- Exception: - Archaebacteria.
- The split gene represent an ancient (primitive) feature of gene.
- The presence of introns is probaly reminiscent of antiquity (remember of past).
- The splicing process represents the dominance of RNA world.



5.5. RNA World

- RNA was the first **genetic material.**
- There is now enough evidence to suggest that essential life processes (such as metabolism, translation, splicing, etc.), evolved around RNA.
- RNA used to act as a genetic material as well as a catalyst (there are some important biochemical reactions in living systems that are catalysed by RNA catalysts and not by protein enzymes).
- RNA being a catalyst was reactive and hence unstable. Therefore, DNA has evolved from RNA with chemical modifications that make it more stable.



- DNA being double stranded and having complementary strand further resists changes by evolving a process of repair.

Chemical nature of RNA/ Nitrogen bases of RNA:

Nitrogen bases	N_2 base + pentose sugar = nucleoside	Nucleoside $+PO_4$ group = Nucleotide
Adenine	Adenine + Ribose sugar = Adenosine	Adenosine $+PO_4$ group = Adenosine Monophosphate [AMP] OR Adenylic acid
Guanine	Guanine + Ribose sugar = Guanosine	Guanosine $+PO_4$ group = Guanosine Monophosphate [GMP] of Guanylic acid
Cytosine	Cytosine + Ribose sugar= Cytidine	Cytidine $+PO_4$ group = Cytidine Monophosphate [CMP] OR Cytidylic acid

Uracil	Uracil + Ribose sugar = Uridine	Uridine $+PO_4$ group = Uridine Monophosphate [CMP] OR Uridylic acid

Types of RNA:

(A) Genetic RNA or Genomic RNA - In some viruses RNA works as genetic material **eg**.,TMV, QB bacteriophage.

(B) Non-genetic RNA - mainly of 3 types -

(1) rRNA (2) tRNA (3) mRNA

RNA functions as adapter, structural and in some cases as a catalyst **(Ribozyme)**

(1) Ribosomal RNA (r-RNA):-

- This RNA is 80% of the cell's total RNA.
- It is found in ribosomes and it is produced in nucleolus. (Except 5s)
- It is the most stable form of RNA.
- rRNAs play structural and catalytic role during translation.
- At the time of protein synthesis, r-RNA provides attachment site to t-RNA and m-RNA and attaches them on the ribosome.

(2) Messenger RNA (mRNA) :

- The m – RNA is 1 – 5% of the cell's total RNA.
- The name m-RNA was given by Jacob and Monod.
- The mRNA is produced by genetic DNA in the nucleus.
- It is least stable RNA.
- The mRNA provides the template for protein synthesis.

(3) Transfer RNA (tRNA) :

- It is 10 – 15% of total RNA.
- It is synthesized in the nucleus by DNA.
- It is also known as soluble RNA (sRNA)
- It is also known as Adapter RNA.
- It is the smallest RNA (4s).

Function : At the time of protein synthesis it acts as a carrier of amino-acids.

STRUCTURE OF tRNA

- The structure of tRNA is most complicated.
- It looks like a clover leaf but in actual structure the tRNA is a compact molecule which looks like inverted 'L'.
- There are present three nucleotides are present in a particular sequence at 3′ end of tRNA and that sequence is CCA.
- 3 ' end is known as Acceptor end.

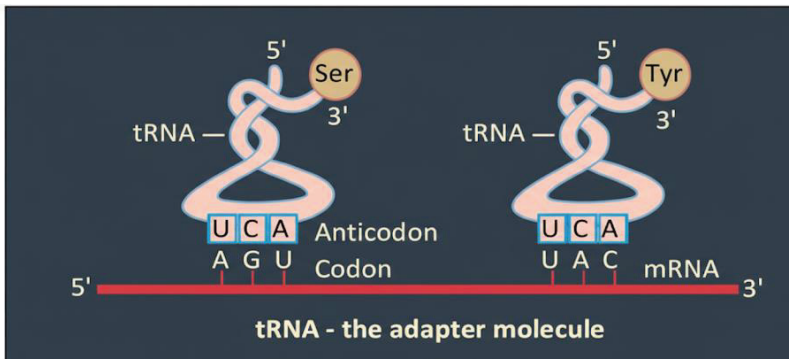
- There are some abnormal nitrogenous bases in the loops, that is why hydrogen bonds are not formed.

e.g.

(i) Inosine (I)

(ii) Pseudo uracil (ψ)

(iii) Dihydrouridine (DHU)



t-RNA have following loops :-

(A) TψC Loop or Attachment loop :-

This loop connects tRNA to the larger subunit of ribosome.

(B) Recognition Loop (Anticodon loop) :-

- tRNA recognizes its place on mRNA with the help of Anticodon.
- The anticodon of tRNA recognises its complementary sequence on mRNA.
- This complementary sequence is known as codon (mRNA)

(C) DHU Loop :

- It is also known as Aminoacyl synthetase recognition loop

5.6. Genetic Code

- Term Given by **George Gamow.**
- Discovered by **Nirenberg, Matthaei and Khorana**.
- **Codon :-** Is the nucleotide sequence on mRNA which codes for particular amino acid.
- **Genetic code:-** It is the sequence of nucleotides on mRNA which codes for whole polypeptide chain.

TRIPLET NATURE OF CODON

- Gamow (1954) pointed out the possibility of three letters code (Triplet code).
- The main problem of genetic code was to determine the exact number of nucleotide in a codon which codes for one amino acid.
- There are four types of Nitrogen bases in mRNA (A, U, G, C) for 20 types of amino acids.

Possible Number of Nitrogen Bases in a Codon	Total codon	Coded amino acids	Remaining amino acids
Singlet (one N base code one amino acid)	$4^1 = 4$	4	16
Doublet (two N bases code	$4^2 = 16$	16	4

one amino acid)			
Triplet (three N bases code one amino acid)	$4^3 = 64$	20	0

Deciphering of genetic code:-

- Severo Ochoa enzyme (polynucleotide phosphorylase) was also helpful in polymerising RNA with defined sequences in a template independent manner (enzymatic synthesis of RNA).
- Marshall Nirenberg's developed cell-free system for protein synthesis finally helped the code to be deciphered.
- The chemical method developed by Har Gobind Khorana.
- He was instrumental synthesising RNA molecules with defined combinations of bases (homopolymers and copolymers).
- Finally, a checker-board for genetic code was prepared.

SECOND LETTER

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

Characteristics of Genetic Code :

(i) Triplet in Nature :

- A codon is composed of three adjacent nitrogen bases which code on specifies one amino acid in polypeptide chain.

  For e.g.: In mRNA if there are total 90 Nitrogen bases.

  Then this mRNA determines **30** amino acids in polypeptide chain.

  In above example, number of nitrogen bases are **90** so codons are **30** and **30** codons decide **30** amino acids in polypeptide chain.

(ii) Universality :

- The genetic code is nearly universally. The same genetic code is present in all kinds of living organism including viruses, bacteria, unicellular and multicellular organisms.

- For e.g. in Bacteria:- UUU code Phenylalanine
  Plants: - UUU code Phenylalanine
  Animals:- UUU code Phenylalanine
- Exception:- Mitochondrial codon and some Protozoan codon.

(iii) Unambigous:

- Genetic code is unambiguous i.e. one codon specifies only one amino acid and not any other.
- In this case one codon never code for two different amino acids.
- Exception GUG codon which codes both Valine and Methionine amino acids.

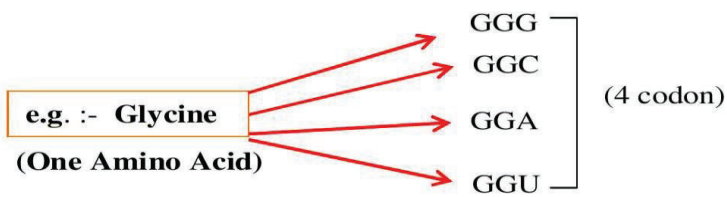
(iv) Non-Overlapping :

A nitrogen base is a constituent of only one codon.

(v) Commaless :

- There is no punctuation (comma) between the adjacent codon i.e. each codon is immediately followed by the next codon.
- If a nucleotide is deleted or added, then whole genetic code read differently from the point of insertion or deletion.
- A polypeptide chain having 50 amino acids shall be specified by a linear sequence of 150 nucleotides.
- If a nucleotide is added in the middle of this sequence, the first 25 amino acids of polypeptide will be same but next 25 amino acids will be different.

(vi) Degeneracy of genetic code :- Single amino acid coded by more than one codon.



Leucine:- 6 codon
Serine:- 6 codon
Arginine:- 6 codon

Exception: Methionine :- 1 codon
Tryptophan:- 1 codon

(vii) Chain Initiation and Chain Termination Codon :-

- AUG has dual functions. It codes for Methionine (met), and it also act as initiator codon..
- AUG codes methionine amino acid in eukaryotes and in prokaryotes AUG codes N formyl methionine.
- Out of 64 codons 3 codons are stop or nonsense or termination Codon .
- Nonsense codons do not specify any amino acid.
  UAA (Ochre)
  UAG (Amber)
  UGA (Opal)
- So only 61 codons are sense codons which specify 20 amino acid.

5.7. 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.

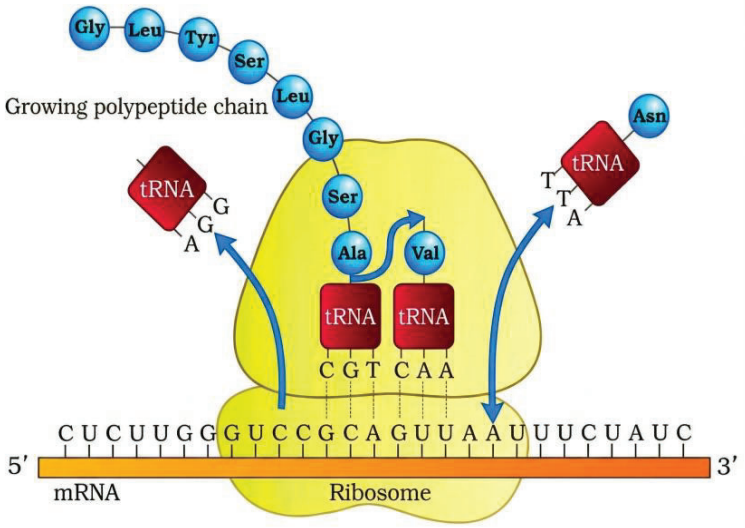


Fig :- Translation

Translation

1. **Activation of amino acid :-**

$$\text{Amino acid} + \text{ATP} \xrightarrow{\text{enzyme}} \text{Amino acyl AMP enzyme complex} + \text{PPi(Pyrophosphate)}$$

2. **Charging of t-RNA**

Amino acyl AMP enzyme complex + t-RNA → Amino acyl t-RNA complex + Amp + enzyme

3. **Translation :- 3 steps**

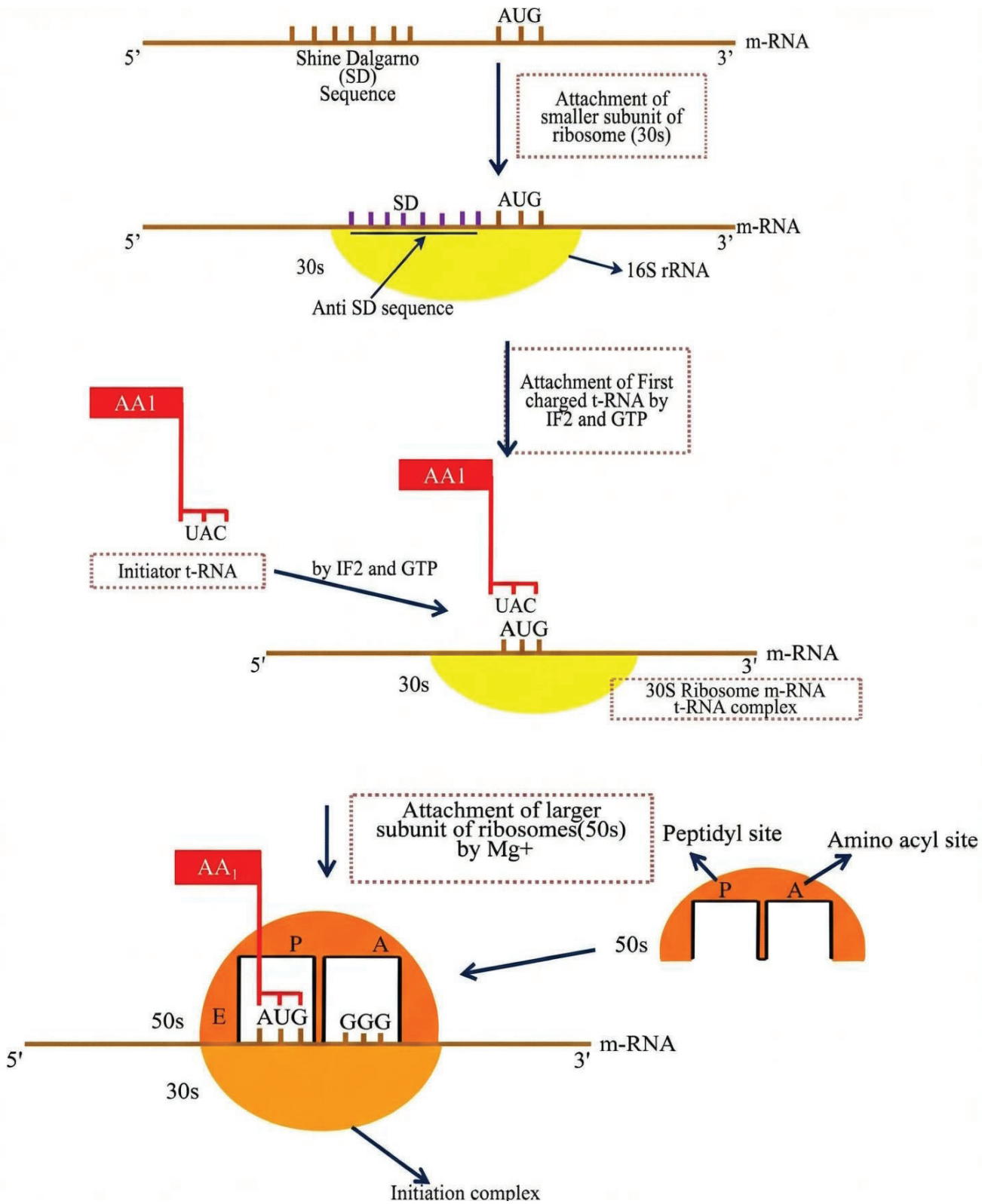
(A) Initiation **(B) Elongation** **(C) Termination**

(A) Initiation :-

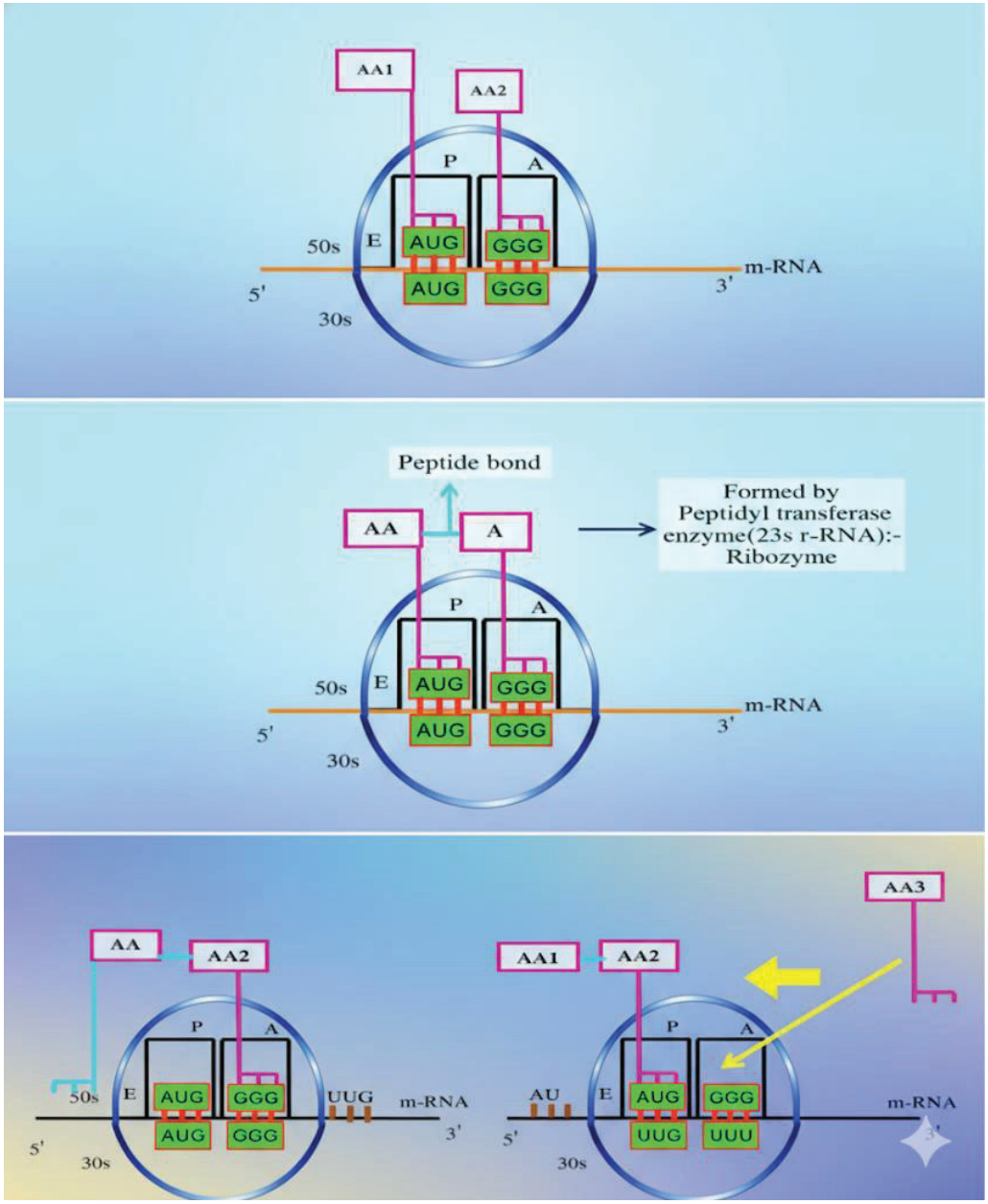
Requirment :-

1. m-RNA
2. Charged t-RNA,
3. 30s and 50s sub units of ribosome
4. GTP
5. Mg^{+2}
6. Initiation factors - In prokaryotes 3 factors:- IF1, IF2, IF3

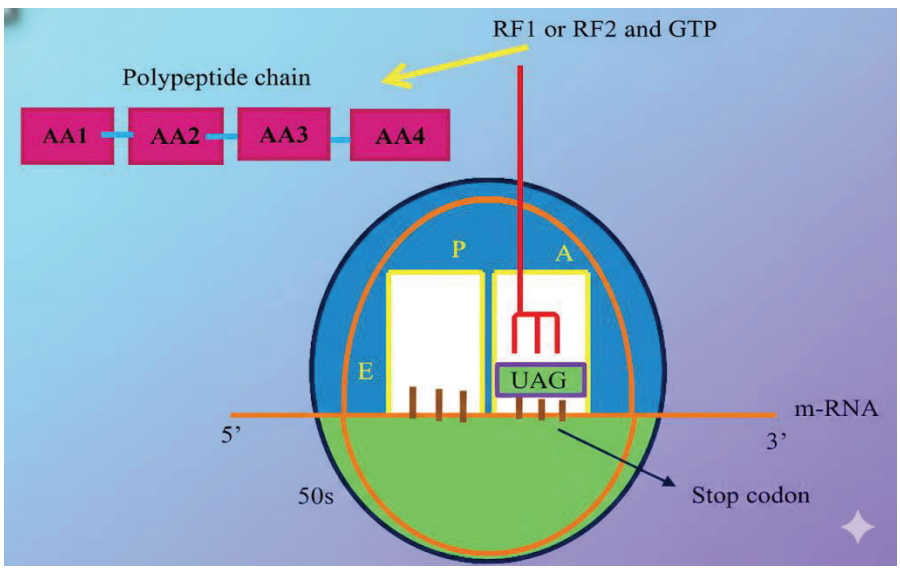
(A) Initiation



(B) Elongation:- By elongation factors (prokaryotes) :- 3 factors EF-Tu, EF-Ts, EF-G)



(C) Termination :- by releasing factors (in prokaryotes RF1, RF2, RF3)

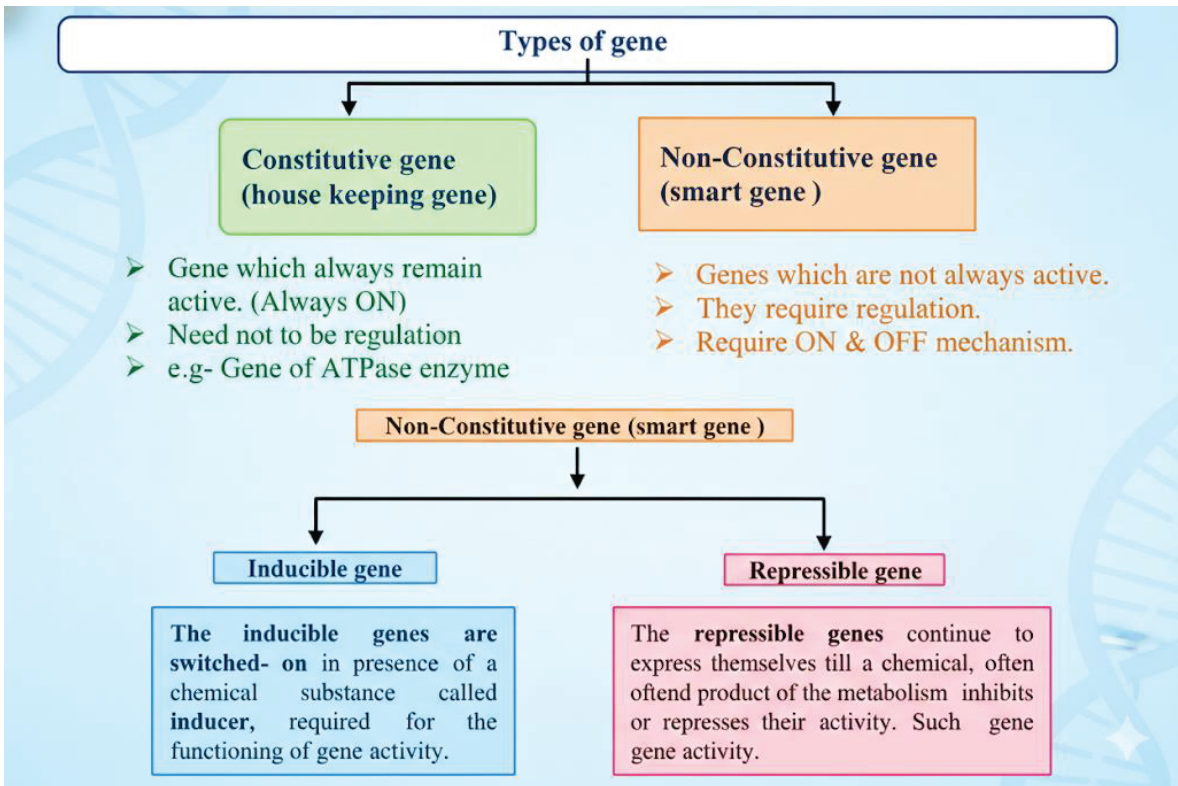


Untranslated regions :-

- An mRNA also have some additional sequences that are not translated and are referred as untranslated regions (UTR).
- The UTRs are present at both 5'end (before start codon) and at 3'end (after stop codon).
- The UTR (untranslated regions) present on mRNA are required for efficient translation process (by recognising the smaller subunit of ribosome by mRNA)

5.8. Regulation Of Gene Expression

- It is the molecular mechanism by which expression of any gene is regulated as per requirement of cell/organism.



Gene regulation in eukaryotes:-

In eukaryotes, it can be regulated at several levels

i. Transcriptional level (formation of primary transcript),

ii. Processing level (regulation of splicing),

iii. Transport of mRNA from nucleus to the cytoplasm,

iv. Translational level.

Gene regulation in prokaryotes :-

- In prokaryotes, control of the rate of transcriptional initiation is the predominant site for control of gene expression.
- In a transcription unit, the activity of RNA polymerase at a given promoter is in turn regulated by interaction with accessory proteins, which affect its ability to recognise start sites.

- These regulatory proteins can act both positively (activators) and negatively (repressors).
- In 1961, two French microbiologist Francois Jacob and Jacque Monod at the Pasteur Institute in Paris, proposed a mechanism called operon model for the regulation of gene action in E. coli.
- An operon is a segment of DNA, which acts as a single regulated unit having :-
  - **One or more structural genes**
  - **An operator gene,**
  - **A promoter gene,**
  - **A regulator gene.**

Operon are of two types :-

(1) Inducible:- An inducible operon system normally remains in switched off condition and begins to work only when the substance to be metabolised by it is present in the cell. Inducible operon system generally occurs in catabolic pathways. e.g. Lac operon of ***E***. coli.

(2) Repressible:- A repressible operon system is normally in it's switch on state and continue to synthesise a metabolise till the latter is produced in amount more than required, or else it becomes available to the cell from outside. Repressible operon system is commonly found in anabolic pathway. e.g. Tryptophan operon of E. coli.

THE LAC OPERON

- Lac means lactose, a disaccharide which is made up of glucose and galactose.
- In lac operon, a Polycistronic structural gene is regulated by a common promoter and regulatory genes.

GENES OF LAC OPERON :-

Structural genes –

- There are three genese.

i. The **z** gene codes for beta-galactosidase.
Responsible for the hydrolysis of the disaccharide, lactose into its monomeric units, galactose and glucose.

ii. The **y** gene codes for permease, which increases permeability of the cell to β-galactosides (Lactose).

iii. The ' **a** ' gene encodes a transacetylase (transfers an acetyl group from acetyl Co A to beta-galactosidase).

- Hence, all the three gene products in lac operon are required for metabolism of lactose.

Operator gene - It lies adjacent to the structural genes and directly controls the synthesis of mRNA over the structural genes.

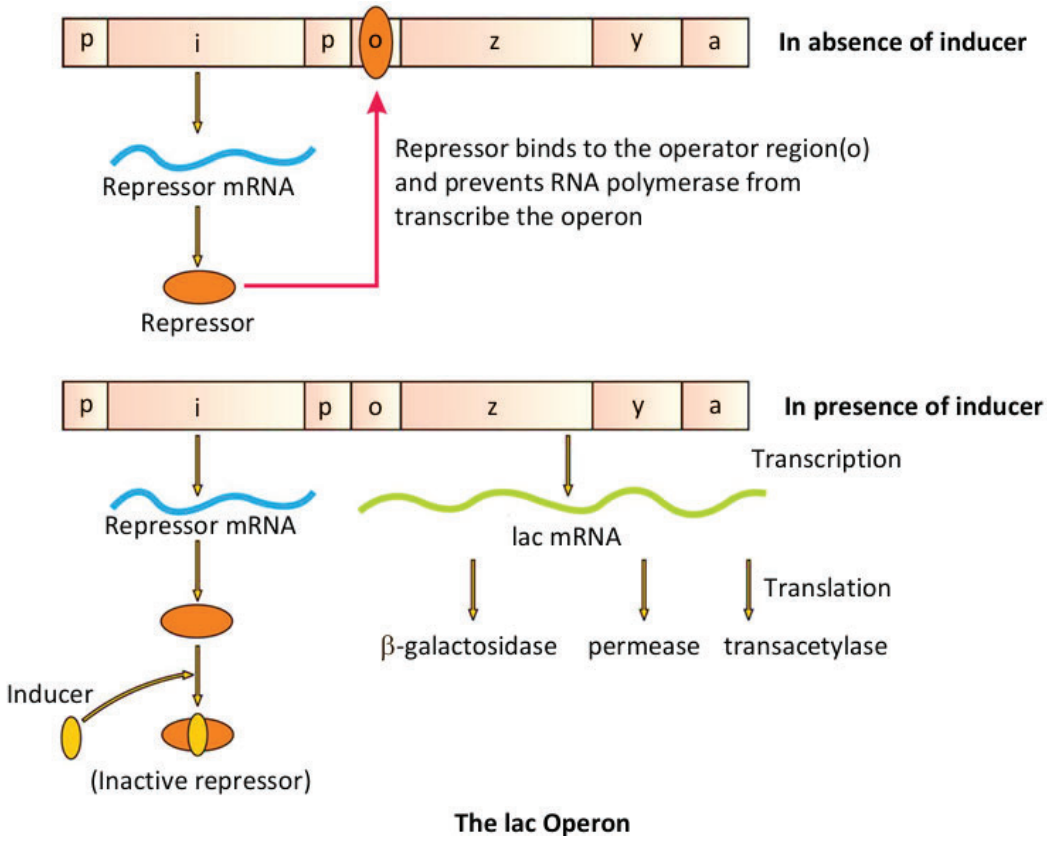
Promoter gene - This gene is the site for initial binding of RNA polymerase.

Regulator gene(i) - It produces a repressor that binds to operator gene and stops the working of the this gene.

- Repressor has two binding site (1) operator gene (2) effective molecule (inducer)
- **Inducer -** It is a chemical (substrate, hormone or some other metabolite) which after coming in contact with the repressor, forms an inducer repressor complex.

- This complex cannot bind with the operator gene, which is thus switched on.
- The inducer for lac operon of Escherichia coli is lactose.
- Allolactose is real inducer of lac operon.

Working of Lac operon :- Off conditions



The lac Operon

5.9. DNA Fingerprinting

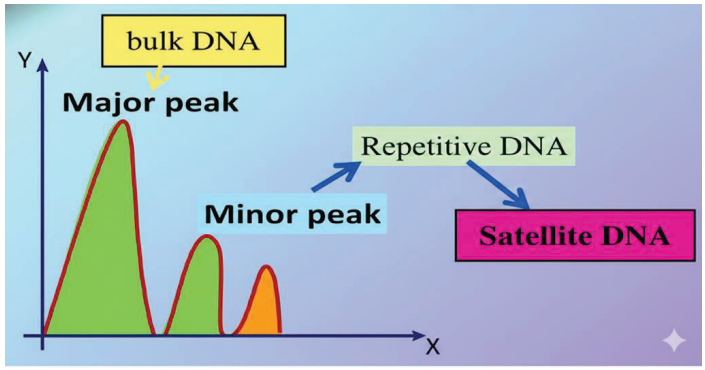
- **Also known as DNA profiling/DNA typing/DNA test.**
- It is technique to identify a person on the basis of his/her DNA specificity.
- This technique was invented by sir Alec Jeffreys (1984).
- In India DNA Finger printing has been started by Dr. V.K. Kashyap & Dr. Lal Ji Singh at (CCMB Hydrabad).

Gel electrophoresis:-

- The cutting of DNA by restriction endonucleases results in the fragments of DNA. These fragments can be separated by a technique known as gel electrophoresis.
- Since DNA fragments are negatively charged molecules they can be separated by forcing them to move towards the anode under an electric field through a medium/matrix.
- The DNA fragments separate (resolve) according to their size through sieving effect provided by the agarose gel. Hence, the smaller the fragment size, the farther it moves.
- In DNA fingerprinting gel - electrophoresis used for separation of DNA fragments.

PRINCIPLE :-

- DNA of human is almost (99.9%) same but very small amount (0.1%) that differs from person to person.
- Human genome has 3.3×10^9bp
- These differences are mainly due to - Repetitive DNA sequences.
- These repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation.



- These sequences normally do not code for any proteins,
- These sequence show high degree of polymorphism and form the basis of DNA fingerprinting.

Polymorphism:- (variation at genetic level)

- Differences in DNA sequences.
- Arises due to mutations.
- Allelic sequence variation has traditionally been described as a DNA polymorphism if more than one variant (allele) at a locus occurs in human population with a frequency greater than **0.01**.
- In simple terms, if an inheritable mutation is observed in a population at high frequency, it is referred to as DNA polymorphism.
- Depending on base composition (A : T rich or G:C rich), length of segment, and number of repetitive units, the satellite DNA is classified into many categories,

(1) Minisatellites **(2) Microsatellites**

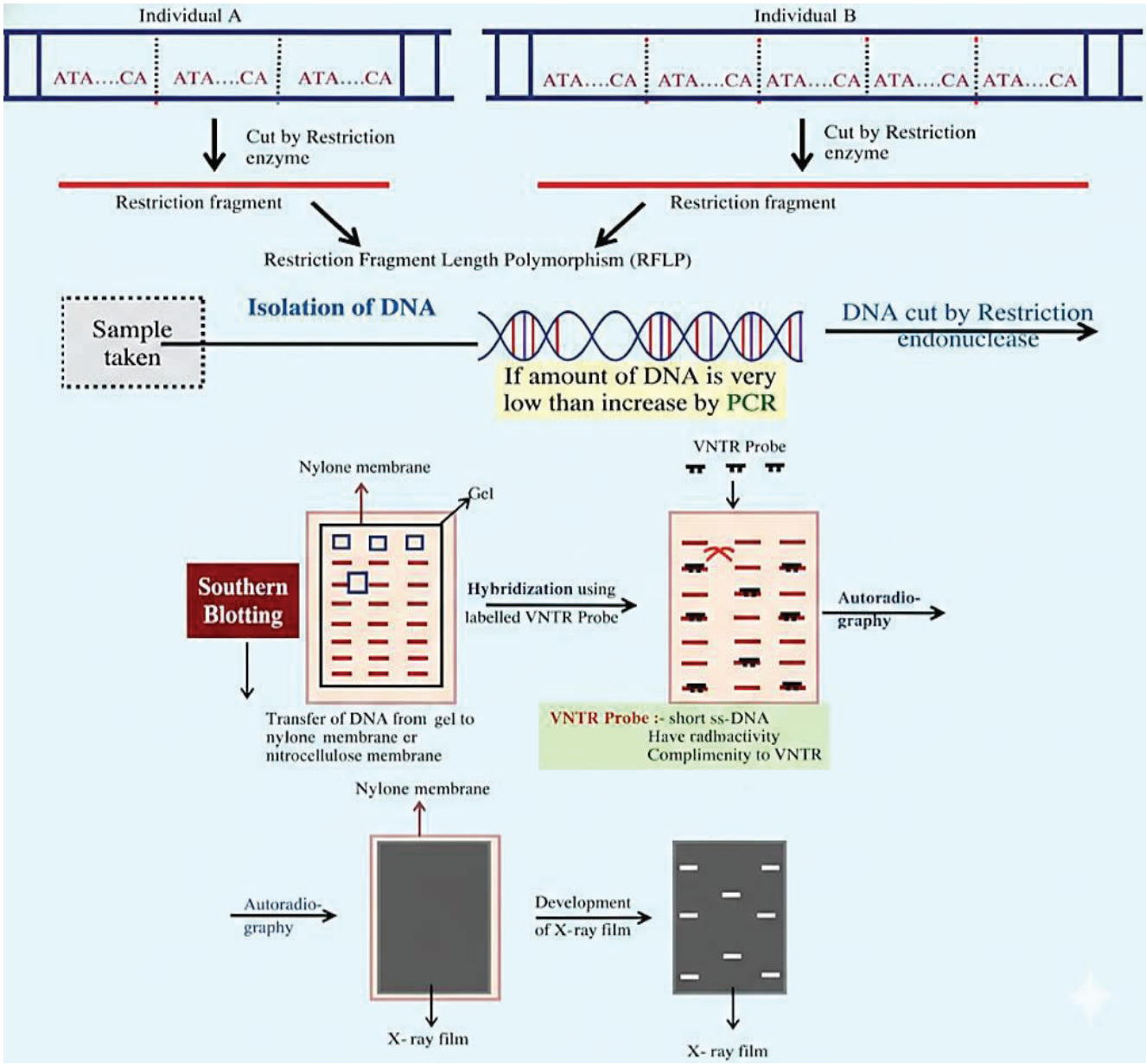
Micro-satellites:-

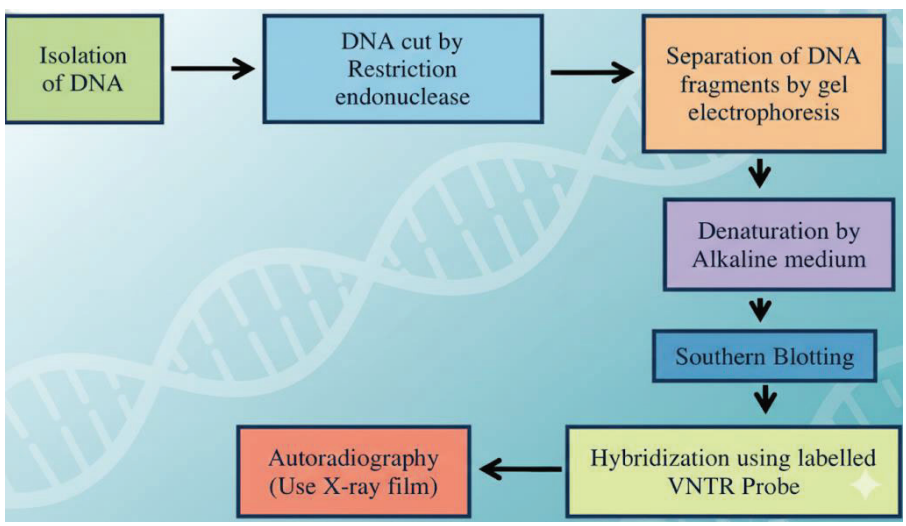
1. This satellites has 1 to 6 bp repetition.
2. Also called SSR (Simple Sequence Repeat).

Mini-satellites :-

1. This satellites has 11 to 60 bp repetition.
2. Also called VNTR (Variable Number of Tandem Repeats).
3. Size of VNTR varies in size from 0.1 to 20 kb .
4. Repeat number vary in different human even though their repeat number also vary from chromosome to chromosome in an individual. Except: monozygotic twins

5. On both sides of VNTR pallindromic sequences are present(restriction site).



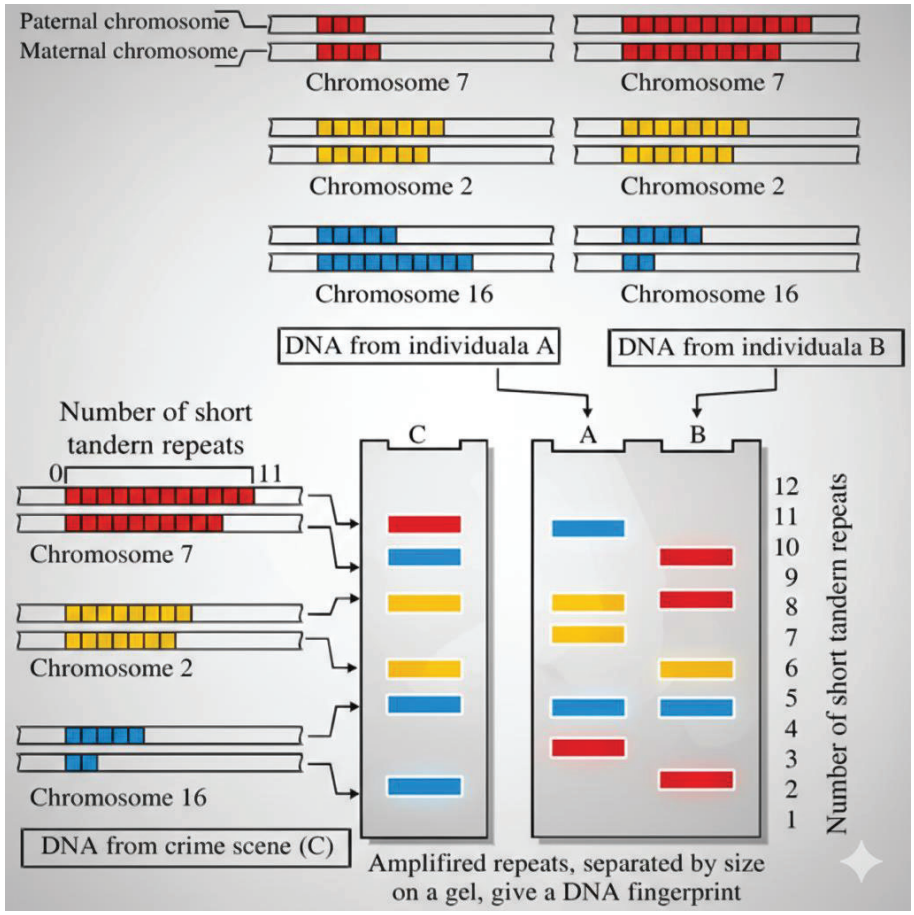


Application of DNA fingerprinting :-

(1) Identification of the criminal (forensic science)

(2) In determining population and genetic diversities

(3) Paternity Tests :- The RFLP pattern of child 50% match with father and 50% with mother



Schematic representation of DNA fingerprinting

5.10. Human Genome Project (Hgp)

- ✕ Started in 1990.
- ✕ Completed in 2003.
- ✕ Chromosome 1st completed in MAY 2006.
- ✕ Studied 24 chromosomes = 22 Autosomes +2 sex chromosome

Mega project :-

In human genome 3×10^9bp present

Cost of sequencing required per bp is :- 3$ US dollars

Estimated cost of the project would be approximately:- 9 billion US dollars

- ✕ If obtained sequences were to be stored in typed form in books, and if each page of the book contained 1000 letters and each book contained 1000 pages, then 3300 such books would be required to store the information of DNA sequence from a single human cell.
- ✕ HGP was closely associated with the rapid development of a new area in biology called as Bioinformatics.

- The Human Genome Project was a 13-year project coordinated by the U.S. Department of Energy and the National Institute of Health.
- During the early years of the HGP, the Wellcome Trust (U.K.) became a major partner.
- Aditional contributions came from Japan, France, Germany, China and others.

Goals of HGP

i. Identify all the approximately 20,000-25,000 genes in human DNA.
ii. Determine the sequences of the 3 billion chemical base pairs that make up human DNA;
iii. Store this information in databases;
iv. Improve tools for data analysis;
v. Transfer related technologies to other sectors, such as industries;
vi. Address the ethical, legal, and social issues (ELSI) that may arise from the pro

Method :-

1) **ESTs (Expressed Sequence Tag):-** Identifying all the genes that are expressed as RNA.
2) **Sequence Annotation:-** Sequencing the whole set of genome that contained all the coding and non - coding sequence.

Instrument:- Automated DNA sequencer based on SANGER principle

Vector:- BAC (bacterial artificial chromosomes)

YAC (yeast artificial chromosomes)

Features :-

1. Human genome contain :- 3164.7 million bp.
2. Average gene consists of :- 3000 bases.
3. Largest gene :- Dystrophin at 2.4 million bases
4. Estimated genes :- 30000 .
5. Function unknown :- Over 50% genes.
6. Coding part :- Less than 2%.
7. Most genes :- Chromosome 1 (2968).
8. Fewest genes :- Chromosome Y (231).
9. SNPs- (single nucleotide polymorphism) :- 1.4 million locations.
10. Repetitive sequence:- Large portion of human genome

Applications and Future Challenges:-

- One of the greatest impacts of having the Human genome sequence may well be enabling a radically new approach to biological research.
- In the past, researchers studied one or a few genes at a time.
- With whole-genome sequences and new high-throughput technologies, we can approach questions systematically and on a much broader scale.

EXERCISE

PART-A

I. Select the correct alternative from the choices given: 1 Mark Each

1. **The two nucleotides of DNA are linked through 3 and 5 carbon of pentose sugar by**
   a) N- Glycosidic bond b) Phosphodiester bond
   c) H bond d) Phosphoester bond

2. **In biochemical characterization of transforming principle, which of the following enzymes affect transformation**
   a) Protease b) DNase c) Amylase d) Lipase

3. **The experiment that proves the semiconservative principle of DNA replication**
   a) Griffith experiment
   b) Hershey and Chase experiment
   c) O. Avery, MacLeod & M. McCarty experiment
   d) Meselson & F. Stahl experiment

4. **Average rate of polymerization during DNA replication is**
   a) 200bp/sec b) 200bp/min c) 2000bp/sec d) 2000bp/min

5. **RNA polymerase I Transcribes**
   a) rRNA b) mRNA c) tRNA d) hnRNA

6. **GGU, GGC, GGA and GGG all code for glycine. Which salient feature of the genetic code does it prove?**
   a) Unambiguous b) Degenerate codons c) Universal code d) Initiator code

7. **Aminoacylation of tRNA occurs during**
   a) Transcription b) Translation c) Regulation of operon d) DNA fingerprinting

8. **In a single stranded DNA, if the ratio of A: G is 60:40 then the ratio of T: C is**
   a) 60: 40 b) 40: 60 c) 20: 80 d) None of the above

9. **The components of deoxyguanosine are**
   a) Guanine + Ribose b) Guanine + Deoxyribose
   c) Guanine + Deoxyribose + Phosphate d) Guanine + Ribose + Phosphate

10. **The coding sequences present in processed RNA is called**
    a) Genes b) Exons c) Introns d) Cistron

11. If a processed mRNA contains 636 nucleotides, including one stop codon, and codes for a polypeptide chain, how many amino acids are encoded?

a) 212 b) 211 c) 210 d) 636

12. If the mRNA sequence 5'-AUG UUU UUU UUU UAA-3' is translated, how many types of amino acids occur?

a) 4 types b) 3 types c) 2 types d) 1 type

13. Statement 1: Deoxyribonucleotide triphosphate (dNTPs) acts as substrate during DNA replication
Statement II: Deoxyribonucleotide triphosphate (dNTPs) also acts as the source of energy in the process of DNA replication.

Choose the correct statement

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

14. In pea plants, each character is governed by a gene which is

a) Monocistron b) Polycistron c) Operon d) Intron

15. Which of these are correct:

I. UTR (Untranslated regions are located on DNA)

II.UTR is present both at 5′ before the start codon and also at 3′ after the stop codon

III.UTR provides stability to mRNA

17A. If template DNA is 3'-ATGCAATCT-5', its complementary DNA strand is:

a) 3'-TACGTTAGA-5' b) 3'-TACGTTAGA-5'
c) 5'-TACGTTAGA-3' d) 5'-ATGCAATCT-3'

17. Methyl Guanosine Triphosphate is added at the 5′ of hnRNA in a process of

a) Splicing b) Capping c) Tailing d) Codin

17A. If the template DNA strand is 3?-ATGCAATCT-5?, its complementary DNA strand would be

a) 3'TACGTTAGA 5' b) 3'ATGCAATCT5'

c) 5'TACGTTAGA 3' d) 5'ATGCAATCT3'

18. Expand YAC

a) Yeast artificial centromere b) Yeast artificial chromosome

c) Yeast automated chromosome d) Yeast annotated chromosome

19. Expand BAC

a) Bacterial artificial centromere

b) Bacterial artificial chromosome

c) Bacterial automated chromosome

d) Bacterial annotated chromosome

20. Match the following:

A. Alec Jeffreys	i. Lac operon
B. F. Sanger	ii. Transforming principle
C. Jacob & Monod	iii. Chain-termination DNA sequencing
D. Griffith	iv. DNA finger print

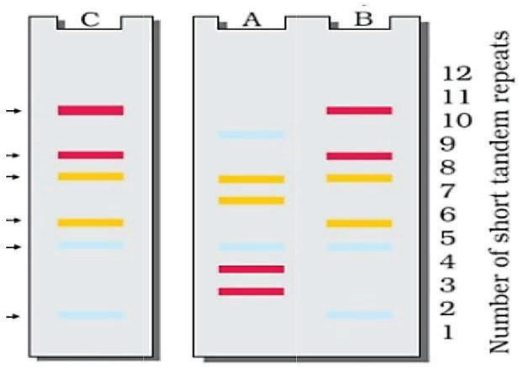
a) A-iv, B-ii, C-i, D-iii

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

c) A-iii, B-iv, C-ii, D-I

d) A-iii, B-i, C-ii, D-iii

21. If A & B are the DNA of two mothers and C is DNA of child. On observation of the banding pattern of the DNA finger printing, it can be concluded that



Amplified repeats,separated by size on a gel, give a DNA fingerprint

a) Child C belongs to mother A

b) Child C belongs to mother B

c) A & B are sisters

d) No conclusions can be drawn.

22. Statement I: In Bio-chemical analysis of the transforming principle only DNAase could not transform R strain to S strain.

Statement II: This experiment proved that proteins and RNAase not the transforming principle.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

23. During transcription, the site of DNA at which RNA polymerase binds is called

a) Promoter b) Regulator c) Enhancer d) Inducer

24. In a double-stranded DNA molecule with 100 total nucleotides, 30 are adenine. The numbers of thymine, guanine, and cytosine respectively are:

a) 30, 20, 20 b) 30, 20, 30 c) 20, 30, 20 d) 20, 20, 30

25. The Chemical method developed by Har Gobind Khorana was

a) Synthesizing RNA molecules with defined combinations of bases

b) Synthesizing RNA without a template.

c) Categorization of RNA

d) Cell-free Protein synthesis

26. In a structural gene consisting of 300 base pairs, if 4 nucleotides are added and 2 are deleted in the same region, it leads to:

a) Point mutation b) Frame shift mutation.

c) Unaltered change. d) 101 amino acids.

27. Human insulin is produced in E. coli cells by rDNA technology. This proves that genetic code is/a

a) Universal. b) Triplet codon c) Degenerate d) Initiator codon

28. Statement I: In the Avery-MacLeod-McCarty experiment, DNase treatment prevented transformation of R strain to *S* strain.

Statement II: Protease and RNase treatments did not prevent transformation.

a) Both statements I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

Answer Key					
1. B	2. B	3. D	4. C	5. A	6. B
7. B	8. D	9. B	10. B	11. B	12. C
13. A	14. A	15. D	16. A	17. B	17A. C
18. B	19. B	20. B	21. B	22. B	23. A
24. A	25. A	26. B	27. A	28. A	

(Gene, Lysine, Automated DNA sequences, DNA, Glycosidic, RNA polymerase I, 5'→3', Severo Ochoa, Bioinformatics, Inducer)

1. A nitrogenous base is linked to the OH of carbon of pentose sugar by ___ bond
2. Histones are rich in basic amino acid residues like ___ .
3. The polarity of the coding strand of a transcription unit is ___ .
4. Template-independent enzymatic synthesis of RNA was demonstrated using the enzyme ___
5. A ___ is defined as a structural unit of inheritance.
6. DNA sequencing is done by using ___ developed by Frederick Sanger.

7. Lactose regulates switching on and off of the lac operon hence it is termed as ___
8. is branch of Biology that deals with store of DNA sequences in data bases and data analysis tools.
9. 28 S, 18 S and 5.8 S are all transcribed by the enzyme ___
10. The radioactive P was used to label ___ of the viral particle in Hershey and Chase experiment.

Answer Key		
1. Glycosidic	2. Lysine	3. 5′ → 3
4. Severo Ochoa	5. Gene	6. Automated DNA sequencer
7. Inducer	8. Bioinformatics	9. RNA polymerase I
10. DNA		

PART - B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each

Q1. What is the structural unit of a nucleic acid called? Name the chemical components of the unit.
Ans: The structural units of nucleic acids are nucleotides. The chemical components are pentose sugar, a phosphate group and a nitrogenous base.

Q2. Mention the four nitrogenous bases present in DNA.
Ans: The four nitrogenous bases present in DNA are Adenine (A), Guanine (G), Cytosine (C) and Thymine (T).

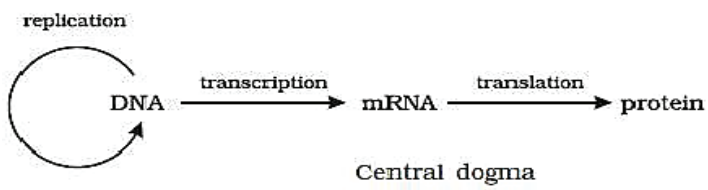
Q3. Mention the four nitrogenous bases present in RNA.
Ans: The four nitrogenous bases found in RNA are Adenine (A), Guanine (G), Cytosine (C) and Uracil (U).

Q4. List the nucleosides of DNA.
Ans: The four nucleosides that make up DNA are deoxyadenosine, deoxyguanosine, deoxycytidine and thymidine.

Q6. If a double-stranded DNA has 20% cytosine, calculate the percentage of adenine.
Ans: C = 20%, therefore G = 20%. Hence G + C = 40%, leaving A + T = 60%. Because A = T, adenine = 30% (and thymine = 30%).

of guanine is always equal to that of cytosine. i.e, A=T and G=C. Also, the purines and pyrimidines are

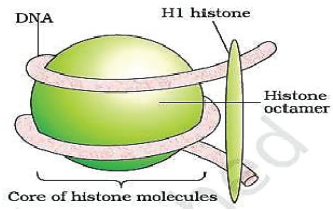
Q7. Explain the central dogma of molecular biology with a schematic representation.
Ans: Francis Crick proposed the central dogma which states that genetic information flows from DNA → RNA → Protein.



Central dogma

Q8. Draw a labelled diagram of nucleosome.

Ans: Diagram to be drawn.



Q9. Define the terms transcription and translation.

Ans: Transcription is the process of copying genetic information from DNA into RNA. Translation refers to the process of polymerization of amino acids to form a polypeptide.

Q10. How many base pairs of DNA are present in a typical nucleosome? Mention the types of proteins present in a nucleosome.

Ans: About 200 base pairs of DNA are present. A nucleosome contains an octamer of histone proteins: two molecules each of H2A, H2B, H3 and H4; H1 is associated with linker DNA.

Q11. Write the conclusion that can be drawn from Griffith's experiment.

Ans: Griffith concluded that some transforming principle from heat-killed S strain converted live R strain into virulent form.

Q12. Mention any two criteria that a molecule must fulfill to act as genetic material.

Ans: It should be able to replicate and should be chemically and structurally stable.

Q13. DNA is a better genetic material than RNA. Justify with two reasons.

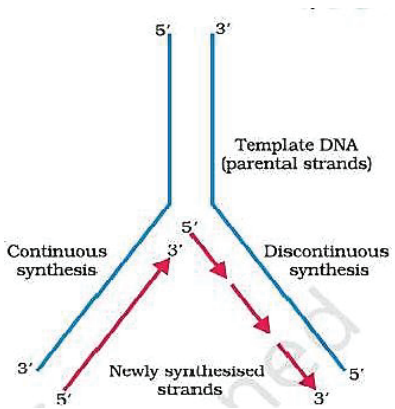
Ans: DNA is more stable because even if the two complementary strands are separated by factors like heat they can come together again. But RNA is more labile and easier degradable because of additional –OH group in the 2 positions of ribose in every nucleotide. DNA is chemically less reactive and structurally more stable when compared to RNA. DNA has thymine which gives additional stability. RNA molecules donot have thymine. Both RNA and DNA can mutate. But RNA mutates at a faster rate as it is less stable.

Q14. Mention the functions of DNA polymerase and DNA ligase during replication.

Ans: During DNA replication. DNA polymerase synthesizes new DNA strands by adding nucleotides to a growing chain, while DNA ligase joins together fragments of DNA, joins together fragments of DNA, particularly on the lagging strand, to create a continuous double helix.

Q15. Draw a labelled diagram of replication fork.

Ans :



Q16. "Both the strands of DNA molecule do not act as templates during transcription". Justify with two reasons.

Ans: During transcription, only one strand of DNA acts as a template. If both strands were used, it would lead to the production of two different RNA molecules with complementary sequences. This would result in the formation of a double-stranded RNA molecule, which is not the intended outcome of transcription and would interfere with protein synthesis. Additionally, it would also lead to the production of two different proteins with potentially conflicting functions

Q17. Identify the following: (a) Pentose sugar present in DNA (b) Pyrimidine present only in DNA.

Ans: (a) Deoxyribose (b) Thymine.

Q18. If 5'-ATGC-3' is a template DNA strand, write its complementary strand with polarity.

Ans: 3'-TACG-5'.

Q19. If the total length of DNA in an egg is 2.1×10^6 bp, what is the length of DNA in zygote?

Ans: if the total length of DNA in a egg is 2.1X106bp, then length of DNA in the zygote will be 4.2X106bp. This is because a zygote is formed by the fusion of an egg and a sperm, each contributing an equal amount of DNA.

Q20. In a dsDNA of 400 bp, if there are 150 adenines, find the number of other bases.

Ans: 400 bp = 800 nucleotides. By Chargaff's rule, A = T and G = C. Therefore, T = 150. The remaining 500 nucleotides are G + C, so G = 250 and C = 250.

Q21. If a DNA molecule 34 nm long has 30 guanine nucleotides, calculate the number of other nucleotides.

Ans: In B-DNA, the axial rise is 0.34 nm per base pair. Thus, 34 nm corresponds to 100 bp = 200 nucleotides. If G = 30, then C = 30. The remaining 140 nucleotides are A + T; hence A = 70 and T = 70.

Q22. In a dsDNA sample, 100 cytosine nucleotides constitute 20% of the total nucleotides. Calculate its lengtl

Ans: Total nucleotides = 100 / 0.20 = 500. Therefore, the DNA contains 250 base pairs. Length = 250 x 0.34 nm = 85 nm.

Q23. Differentiate between euchromatin and heterochromatin.

Ans:

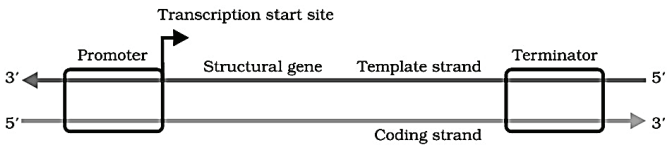
Euchromatin	Heterochromatin
- Loosely packed chromatin. - Stains lightly. - Generally transcriptionally active.	- Densely packed chromatin. - Stains darkly. - Generally transcriptionally inactive.

Q24. In Meselson and Stahl experiment, what would be the proportion of bands after 60 minutes?

Ans: The Meselson, and Stahl experiment demonstrated the semi-conservative mechanism of DNA replication. In this experiment, E. coli was grown in a medium containing heavy nitrogen (15 N) and then switched to a medium containing light nitrogen (14 N). After one generation (20 minutes), the DNA was hybrid (one strand heavy and one strand light). After two generations (40 minutes), there were equal amounts of hybrid and light DNA. After three generations (60 minutes), the proportion of light DNA increases while the proportion of hybrid DNA decreases.

Q25. Draw a schematic representation of transcription unit.

Ans:



Q26. Write the sequence of mRNA from the given template strand.

Ans: Template: 3'-TACTGTGAGCTACTCATT-5' mRNA: 5'-AUGACACUCGAUGAGUAA-3'

Q27. Write any two differences between prokaryotic and eukaryotic transcription units.

Ans:

Prokaryotic transcription unit	Eukaryotic transcription unit
1. Transcription and translation can occur simultaneously in the cytoplasm. 2. Transcription units are often polycistronic.	1. Transcription occurs in the nucleus; translation occurs in the cytoplasm. 2. Transcription units are generally monocistronic.

Q28. Differentiate monocistronic and polycistronic transcription units.

Ans: A monocistronic transcription unit codes for one polypeptide, whereas a polycistronic transcription unit codes for more than one polypeptide.

Q29. Differentiate between introns and exons.

Ans:

- Exons: expressed/coding sequences that are retained in mature RNA.
- Introns: intervening sequences removed during RNA splicing and absent from mature RNA.

Q30. Differentiate the template strand from the coding strand.

Ans: Template strand: read by RNA polymerase in the 3'->5' direction; the RNA formed is complementary to it.
Coding strand: not used as the template; runs 5'->3' and has the same base sequence as RNA except that DNA contains T in place of U.

Q31. Write the coding strand and mRNA sequence for the given template strand.

Ans: Template strand: 3'-ATGCATAGCAT-5'

Coding strand: 5'-TACGTATCGTA-3' mRNA: 5'-UACGUAUCGUA-3'

Q32. Write a note on sigma factor and rho factor.

Ans: Sigma (σ) factor helps RNA polymerase recognise and bind the promoter during initiation.
Rho (ρ) factor participates in termination at rho-dependent terminators in prokaryotes.

Q33. What is heterogeneous nuclear RNA (hnRNA)? How is it converted into functional mRNA?
Ans: Heterogeneous nuclear RNA (hnRNA) is a precursor to messenger RNA (mRNA) in Eukaryotic cells. It is a large, immature RNA molecule containing both coding (exons) and non-coding (introns) sequences. Heterogeneous nuclear RNA (hnRNA) is converted into mRNA by splicing, capping and tailing.

Q34. Name the two amino acids richly present in histones.
Ans: Lysine and Arginine are the two amino acids richly present in histones that impart positive charge.

Q35. If 60% DNA is heterochromatins, what percent is genetically active?
Ans: If 60% is heterochromatin, the remaining 40% is euchromatin and is generally more transcriptionally active.

Q36. Label X and Y with respect to central dogma.
Ans: X – Transcription; Y – Translation.

Q37. According to Griffith experiment why did the mice die when heat killed s strain and live r strain was injected into mice.
Ans: Griffith inferred that a "transforming principle" from heat-killed S bacteria converted live R bacteria into virulent S-type bacteria. His experiment did not identify the chemical nature of the transforming principle.

Q38. Mention any four properties of genetic material.
Ans: Replication, stability, mutation, inheritance.

Q39. Calculate time required for DNA replication.
Whose 2n = 6.6x109 bp takes place at the rate of polymerization, 2000 bp/sec. How long it would

Q39. Calculate the time required for DNA replication.

If the DNA content is 6.6 x 10^9 bp and the polymerisation rate is 2000 bp/s, then:
Time = (6.6 x 10^9) / (2.0 x 10^3) = 3.3 x 10^6 s = about 916.7 h (about 38.2 days).
This is an idealised single-rate calculation.

Q40. DNA is more stable than RNA. Substantiate.

Ans: DNA is more stable because deoxyribose lacks the 2'-OH group present in RNA, making DNA less prone to hydrolysis. Thymine in DNA also helps cellular repair systems distinguish normal bases from some products of cytosine deamination.

Ans: A–1, B–2, C–3, D–4.

A. DNA ligase	1. Joining of Okazaki fragments

B. DNA polymerase	2. Synthesis of DNA strand
C. RNA polymerase I	3. Synthesis of rRNA
D. RNA polymerase III	4. Synthesis of tRNA

Q42. In the context of DNA replication, what is the polarity of leading strand and lagging strands?

Ans: The leading strand has a polarity of 5' to 3', while the lagging strand is synthesized in the same 5' to 3' direction but runs opposite to the leading strand.

Q43 5′→3′ strands of DNA are not copied during transcription. Give reason.

Ans: - During transcription, only one strand of DNA is copied to produce RNA. This is because transcribing both DNA strands would result in two complementary RNA molecules, which would then bind to each other, forming a double-stranded RNA (dsRNA). This dsRNA would prevent the RNA from being translated into proteins, essentially rendering the transcription process ineffective. Additionally, transcribing both strands would lead to the production of two different RNA molecules, potentially coding for different proteins, which would complicate the genetic information transfer machinery.

Q44. List the essential roles of ribosome during translation.

Ans: Ribosomes play two essential roles during translation: they act as the site where protein synthesis occurs and they catalyze the formation of peptide bonds between amino acids. Specifically, the ribosome binds to mRNA and facilitates the interaction with tRNA, which carries specific amino acids, to assemble a polypeptide chain according to the mRNA's instructions.

45. Genetic code is said to triplet and universal. Why?

Ans: - The genetic code is said to be triplet because it is read in groups of three nucleotides (codons) to specify an amino acid. It's considered universal because, with a few minor exceptions, all known living organisms use the same set of codons to direct protein synthesis.

Q46. AUG has dual function. Justify.

Ans: AUG has dual function

1. Its codes for methionine (met)
2. It also acts as initiator codon.

Q47. There are no tRNA for stop codons. Substantiate.

Ans: There are no tRNA molecules with anticodons that correspond to the stop codons (UAG, UGA, and UAA). Instead, proteins called release factors recognize these codons and trigger the termination of protein synthesis.

Q48. tRNA is regarded as adapter molecule. Substantiate.

Ans: - tRNA is called an adaptor molecule because it acts as a bridge between the mRNA and the amino acid sequence during protein synthesis. It binds to a specific codon on the mRNA via its anticodon loop and carries the corresponding amino acid to the ribosome, where the protein is assembled.

Q49. Mention the initiator and terminator codons.

Ans: - In the process of protein synthesis, the initiator codon is AUG, which codes for methionine and signals the start of translation. The termination codons, also known as stop codons, are UAA, UAG, and UGA, and they signal the end of translation, causing the release of the newly formed polypeptide chain.

Q50. Name the initiator codon and the amino acid coded by it.

Ans: - The initiator codon is AUG, and it codes for the amino acid methionine in eukaryotes and formyl methionine in prokaryotes.

Q51. If AUG codes for methionine and UAC codes for Tryptophan, write its anticodon on tRNA.
Ans: - If AUG codes for methionine and UAC codes for tryptophan, the anticodon on the tRNA for methionine would be 5'-CAU-3', and the anticodon for tryptophan would be 5'-GUA-3'. Remember that codons and anticodons are complementary and antiparallel.

Q52. Differentiate point mutation and frame-shift mutation.
Ans: - Point mutations and frameshift mutations are both types of genetic mutations, but they differ in their impact on the DNA sequence. Point mutations involve a change in a single nucleotide base, while frameshift mutations involve the insertion or deletion of nucleotides, which alters the reading frame of the genetic code.

Q53. Mention the four levels in regulation of gene expression in eukaryotes.
Ans: - In eukaryotes, gene expression is regulated at four main levels: transcriptional, post-transcriptional, translational, and post-translational. These levels allow for precise control of which genes are expressed, when they are expressed, and to what extent.

Q54. Mention the role of repressor and inducer in regulation of gene expression.
Ans: - In the regulation of gene expression, repressors and inducers play opposing roles. Repressors are proteins that bind to DNA and block the transcription of a gene, while inducers are molecules that can bind to repressors, preventing them from binding to DNA, thus allowing transcription. In essence, repressors inhibit gene expression, and inducers can relieve this inhibition.

Q55. Mention the functions of β-galactosidase and permease in lactose metabolism in E. coli.
Ans: - In E. coli, beta-galactosidase and permease play crucial roles in lactose metabolism, working together to utilize lactose as an energy source. Beta-galactosidase breaks down lactose into glucose and galactose, while permease facilitates the transport of lactose into the cell.

Q56. How does the Lac-operon function in the presence of inducer (lactose) in the medium?
Ans: - In the presence of lactose, the lac operon is activated, leading to the production of enzymes that break down lactose. Lactose acts as an inducer, binding to the lac repressor protein and preventing it from binding to the operator site on the DNA. This allows RNA polymerase to bind to the promoter and transcribe the genes necessary for lactose metabolism.

Q57. How does the Lac-operon function in the absence of inducer (lactose) in the medium?
Ans: - When lactose is absent the lac operon is switched off. This is becasue a repressor protein is produced which binds to the operator region. This prevents RNA polymerase from binding to the operon and therefore prevents transcription of the structual genes.

Q58. Mention any two goals of Human Genome Project (HGP).
Ans: -:

(i) Identify all the approximately 20,000-25,000 genes in human DNA;
(ii) Determine the sequences of the 3 billion chemical base pairs that make up human DNA;
(iiii) Store this information in databases;
(iv) Improve tools for data analysis;
(v) Transfer related technologies to other sectors, such as industries;
(vi) Address the ethical, legal, and social issues (ELSI) that may arise from the pro

Q59. Mention two applications of Human Genome Pro etc.
Ans: The knowledge from the DNA sequences helps to understand our biological system Human genome provides a new approach to biological research.

Q60. Mention two salient features of human genome.

Ans: -

1. The human genome contains 3164.7 million bp.
2. Less than 2% of the genome codes for proteins.

Q61. Which chromosome in human genome has

a) Highest number of genes b) Least number of genes

Ans: - Chromosome 1 has most genes (2968) and the Y has the fewest (231).

Q62. Mention the two approaches with respect to the methodology of sequencing DNA in Human Genome Pro etc.

Ans: - The methods involved two major approaches. One approach focused on identifying all the genes that are expressed as RNA (referred to as Expressed Sequence Tags (ESTs). The other took the blind approach of simply sequencing the whole set of genomes that contained all the coding and non-coding sequence, and later assigning different regions in the sequence with functions (a term referred to as Sequence Annotation).

Q63. Mention two common vectors used for the amplification of DNA fragments during the sequencing of human genome.

Ans: - YAC- yeast artificial chromosome, BAC- Bacterial artificial chromosome

Q64. Name the two commonly used host cell and the vectors in HGP.

Ans: - In the Human Genome Project (HGP), the two most commonly used host cells were bacteria and yeast. The corresponding vectors were Bacterial Artificial Chromosomes (BACs) and Yeast Artificial Chromosomes (YACs). These vectors were crucial for cloning and amplifying DNA fragments during the sequencing process.

Q65. Which is the largest known human gene? Mention the number of genes in it.

Ans: - The largest known human gene is dystrophin, which has around 2.4 million base pairs. It is responsible for providing instructions for making a protein called dystrophin, primarily found in muscles used for movement.

Q66. Mention any two differences with reference to transcription in prokaryotes and eukaryotes.

Ans: - Two key differences in transcription between prokaryotes and eukaryotes are the location of the process and the presence of post-transcriptional modifications. In prokaryotes, transcription occurs in the cytoplasm, while in eukaryotes, it takes place in the nucleus. Additionally, eukaryotic mRNA undergoes processing.

PART- C

V. Answer the following questions as directed: 5 Marks Each:

Q1. What are the components of Thymine monophosphate (TMP)?

Ans: - It is an ester of phosphoric acid with the nucleoside thymidine. dTMP consists of a phosphate group, the pentose sugar deoxyribose, and the nucleobase thymine.

Q2. What are the components of Uridine monophosphate (UMP)?

Ans: - Uridine monophosphate (UMP) is composed of three components: a phosphate group, the sugar ribose, and the nitrogenous base uracil. It is a nucleotide, the building block of RNA. UMP is sometimes referred to as uridylic acid.

Q3. Mention the location of N- glycosidic bond, Hydrogen bond & phosphoester bond present in DNA?

Ans: - In DNA, N-glycosidic bonds link nitrogenous bases to the deoxyribose sugar, forming the nucleosides (base + sugar). Phosphodiester bonds connect the phosphate group of one nucleotide to the 3' carbon of the sugar in the adjacent nucleotide, forming the sugar-phosphate backbone of DNA. Hydrogen bonds pair complementary nitrogenous bases (A with T, and G with C) on opposite strands, holding the two DNA strands together.

Q4. Identify the following:

a) Pyrimidine present both in DNA and RNA
b) Purines present in DNA and RNA
c) Chemical bond present between 2 nucleotides.

Ans: -

a) The pyrimidine base present in both DNA and RNA is cytosine. While thymine is unique to DNA and Uracil is unique to RNA cytosine is present in both the nucleic acids.
b) The purines found in both DNA and RNA are adenine and guanine.
c) The chemical bond present between two nucleotides in a polynucleotide (like DNA or RNA) is called a phosphodiester bond. This bond forms between the phosphate group of one nucleotide and the sugar molecule of the adjacent nucleotide.

Q5. Mention the three codons that do not code for any amino acid.

Ans: - The three codon's that do not code for amino acid is UAA, UAG, UGA.

Q6. Lac operon is a Polycistronic gene. Give reason

Ans: The lac operon is considered Polycistronic because it contains multiple structural genes (lacZ, lacY, and lacA) that are transcribed together into a single mRNA molecule, which then gets translated into multiple proteins. This coordinated expression of multiple genes from a single mRNA is the defining characteristic of a Polycistronic gene.

Q7. Mention the three structural genes and the proteins they code for in E. coli.

Ans: In the E. coli lac operon, there are three structural genes: lacZ, lacY, and lacA. These genes code for the following proteins: β-galactosidase (LacZ), lactose permease (LacY), and transacetylase (LacA), respectively.

Q8. RNA polymerase exhibit division of labour. Substantiate.

Ans: - There are at least three RNA polymerases in the nucleus apart from RNA polymerase found in the organelles. There is a clear-cut division of labour.

1. **RNA polymerase I:** Transcribes rRNA (28S, 18S and 5.8S)
2. **RNA polymerase II:** Transcribes precursor of mRNA, the heterogeneous nuclear RNA (hnRNA).
3. **RNA polymerase III:** Catalyses transcription of tRNA, 5srRNA (small ribosomal RNAs) and snRNA (small nuclear RNAs).

Q9. How is hnRNA processed to form mature mRNA? List the processes involved.

Ans: hnRNA is processed by: (1) splicing - introns are removed and exons joined; (2) 5' capping - a methyl-guanosine cap is added; and (3) 3' tailing - adenylate residues are added. The mature mRNA is then exported for translation.

Q10. Mention one function of each mRNA, rRNA and tRNA.

Ans: - mRNA carries genetic information from DNA to ribosomes, tRNA decodes mRNA and brings amino acids to the ribosome, and rRNA forms the core structure of ribosomes and catalyzes peptide bond formation.

Q11. Mention the functions of RNA polymerase I, RNA polymerase II and RNA polymerase II in eukaryotes.

Ans: RNA polymerase I: Transcribes rRNA (28S, 18S and 5.8S)

1. **RNA polymerase II:** Transcribes precursor of mRNA, the heterogeneous nuclear RNA (hnRNA).
2. **RNA polymerase III:** Catalyses transcription of tRNA, 5srRNA (small ribosomal RNAs) and snRNA (small nuclear RNAs).

Q12. With reference to transcription, define:

a) Splicing
b) Capping
c) Tailing

Ans: In eukaryotic transcription, splicing, capping, and tailing are crucial RNA processing steps.

a. **Splicing** :- The process of removal of introns and Exons are join in a defined order.
b. **Capping :-** In this process an unusual Nucleotides (methyl guanosine triphosphate) is added to the 5-end of hnRNA.
c. **Tailing :-** In this process adenylate residues (200-300) are added at 3'-end in a template independent manner**.**

PART-D

VI. Answer the following questions in 200-250 words each, wherever applicable:

Q1. What are the functions of the following?

a) i gene b) lacZ gene c) lacY gene d) lacA gene e) inducer

Ans: a) i gene: codes the repressor protein of the lac operon.
b) lacZ: codes beta-galactosidase, which hydrolyses lactose.
c) lacY: codes permease, which increases uptake/permeability to lactose.
d) lacA: codes transacetylase.
e) Inducer: allolactose binds the repressor and inactivates it, allowing transcription.

Q2. a) Mention the three steps involved in transcription in prokaryotes.

b) State the roles of sigma factor and rho factor.

Ans: The three steps are initiation, elongation and termination. Sigma factor helps RNA polymerase recognise and bind the promoter during initiation. Rho factor participates in rho-dependent termination.

Q3. Describe the double helix model of DNA proposed by Watson & Crick

Ans:

1. DNA is made up of **two polynucleotide chain** where backbone is constituted by sugar phosphate and the nitrogen bases project inside.
2. ii. The two chains have antiparallel polarity. It means one chain has the polarity**5'→3'** and the other has **3'→5'.**
3. The bases in two strands are paired through hydrogen bond (H-bonds) forming base pairs (bp). **Adenine** forms two hydrogen bonds with Thymine from opposite strand and Guanine is bonded with **Cytosine** with three H-bonds. As a result, always a purine comes opposite to a pyrimidine.

4. The two chains are coiled in a **right-handed fashion**. The pitch of the helix is 3.4 nm [a nanometer is 1 billionth of a meter i.e. 10^{-9} m] and there are roughly 10 bp in each turn.
   The distance between a bp in a helix is approximately equal to 0.34 nm and the diameter of DNA molecule is **2 nm or 20 A°.**
5. The plane of one base pair stack over the other in the DNA helix. This in addition to H – bonds confirm stability of helical structure. The double helix has two grooves namely minor and major groove in every turn.

Q4. Explain Griffith's experiment to explain the 'transforming principle'.

Ans: Transforming principle: In 1928, Frederick Griffith showed that a heritable "transforming principle" could convert non-virulent bacteria into virulent bacteria. He did not identify that principle as DNA; this was established later.

1. **Smooth shiny strain (S):-** Capsulated, virulent (pathogenic) and produces Pneumonia (which produces smooth colonies on a culture plate). This is because S-Strain has a mucous (polysaccharide) coat.
2. **Rough strain (R):-**Non-capsulated, non-virulent and unable to cause pneumonia (R-strain does not contain mucous coat).

Experiment:

1. S strain injects into mice → mice die
2. R strain → inject into mice → mice live
   — Mice injected with S – strain die from pneumonia infection. But mice injected with R – strain did not develop pneumonia.
   — Griffith was able to kill bacteria by heating them.
3. Heat killed S strain → inject into mice → mice live
4. Heat killed S strain + R strain (live) → inject into mice → mice die.

- He observed that heat killed S – strain injected to mice and did not kill them. When he injected a mixture of heat killed S – strain and living R – strain bacteria, the mice died.
- The body of the dead mouse showed the presence of S – strains.
- So, he concluded that R – strain had somehow been transformed by the heat-killed S strain
- bacteria. Some 'transforming principle', transferred from the heat-killed S strain, had enabled the R strain to synthesize a smooth polysaccharide coat and become virulent. This must be due to the transfer of the genetic material.
- However, the biochemical nature of the genetic material was not defined from his experiments.

Q5. Explain the steps involved in DNA replication.

Ans: -Mechanism of DNA Replication:

- Replication is a process in which DNA make its identical copies called replica.
- DNA replication takes place during S phase of interphase, prior to cell division

The Machinery and the Enzymes:

- In living cells, such as E. coli, the process of replication requires a set of catalysts (enzymes).
- The main enzyme is referred to as DNA-dependent DNA polymerase, since it uses a DNA template to catalyze the Polymerization of deoxynucleotides.
- DNA polymerases are highly efficient enzymes as they have to catalyze polymerization of a large number of nucleotides in a very short time.
- **For example:** E. coli that has only 4.6 ×106 bp and completes the process of replication within 18 minutes; therefore, the average rate of polymerisation is approximately 2000 bp per second.
-

- DNA polymerases catalyze the reaction with high degree of accuracy. Any mistake during replication would result into mutations.
- Energetically replication is a very expensive process. Deoxyribonucleoside triphosphates serve dual purposes. In addition to acting as substrates, they also provide energy for polymerization reaction.
- The two terminal phosphates in deoxyribonucleoside triphosphates are high energy phosphates like ATP.
- In addition to DNA-dependent DNA polymerase are other enzymes required for replication are helicases (unwindase), Primase, Topoisomerases, ligases etc.
- For long DNA molecules, the two strands of DNA cannot be separated to its entire length due to very high energy requirement. Hence the replication occurs within a small opening of the DNA helix, referred to as replication fork.
- The DNA-dependent DNA polymerases catalyze polymerization only in one direction that is 5 3'.
- As a result, on one strand (the template with polarity 3' 5'), the replication is continuous, while on the other (the template with polarity 5 3'), it is discontinuous (Okazaki fragments).
- The discontinuously synthesized fragments are later joined by the enzyme DNA ligase.
- The DNA polymerases on their own cannot initiate the process of replication and also the replication does not initiate randomly at any place
- There is a definite region in E. coli DNA where the replication originates. Such regions are termed as Origin of replication.
- In eukaryotes, the replication of DNA takes place at S-phase of the cell-cycle. The replication of DNA and cell division cycle should be highly coordinated. Any failure in cell division after DNA replication results into polyploidy (a chromosomal anomaly).

6. Explain the experiment that gave the final proof for DNA as the genetic material.

Ans: - The Genetic Material is DNA [Hershey and Chase experiment]:

✓ The unequivocal proof that DNA is the genetic material came from the experiments of Alfred Hershey and Martha Chase (1952).
✓ They worked with viruses that infect bacteria called bacteriophages.
✓ The bacteriophage attaches to the bacteria and its genetic material then enters the bacterial cell.
✓ The bacterial cell treats the viral genetic material as if it was its own and subsequently manufactures more virus particles.
✓ Hershey and Chase worked to discover whether it was protein or DNA from the viruses that entered the bacteria.

Experiment:

✓ Hershey and chase grew some viruses on a medium that contain radioactive phosphorus and some others on medium that contain radioactive sulfur.
✓ Radioactive phosphorus to label DNA and radioactive sulfur to label proteins.
✓ Viruses grown in the presence of radioactive phosphorus contained radioactive DNA but not radioactive protein because DNA contains phosphorus but protein does not.
✓ Similarly, viruses grown on radioactive sulfur contained radioactive protein but not radioactive DNA because DNA does not contain sulfur.
✓ Radioactive phages were allowed to attach to E. coli bacteria.
✓ As the infection proceeded, the viral coats were removed from the bacteria by agitating them in a blender.
✓ The virus particles were separated from the bacteria by spinning them in a centrifuge.

Results:

✓ Bacteria which were infected with viruses that had radioactive DNA were radioactive, indicating that DNA was the material that passed from the virus to the bacteria.

- ✓ Bacteria that were infected with viruses that had radioactive proteins were not radioactive. This indicates that proteins did not enter the bacteria from the viruses.
- ✓ Hershey and chase experiment proved that DNA is genetic material that is passed from virus to bacteria. Subsequently it becomes clear that in some viruses RNA is the genetic material.

7. Explain the experiment to prove that DNA replicates semi conservatively.

Ans: - The Experimental Proof: It is now proven that DNA replicates semi conservatively. Replication was shown first in Escherichia coli and subsequently in higher organisms, such as plants and human cells.

- ➢ Matthew Meselson and Frank in Stahl performed the experiment in 1958.

1. **Meselson** and **Stahl** grew E. coli in a medium containing 15NH4Cl (15N is the heavy isotope of nitrogen) as the only nitrogen source for many generations. The result was that 15N was incorporated into newly synthesized DNA (as well as other nitrogen containing compounds).
   This heavy DNA molecule could be distinguished from the normal DNA by centrifugation in a cesium chloride (CsCl) density gradient (15N is not a radioactive isotope, and it can be separated from 14N only based on densities).
2. Then they transferred the cells into a medium with normal 14NH4Cl and took samples at various definite time intervals as the cells multiplied, and extracted the DNA that remained as double-stranded helices. The various samples were separated independently on CsCl gradients to measure the densities of DNA
3. **Meselson** and **Stahl** founded that DNA of the first generation was hybrid and had uniform homogenous density between 15N and 14N (First generation means after 20 min E. coli divides in 20min).
   The second generation after 40 min show two density bands indicated that 50% DNA are normal (containing only 14N) and 50% DNA turned hybrid (containing 14N and 15N).
   Similar experiments involving u e of radioactive thymidine to detect the distribution of newly synthesized DNA in the chromosomes was performed on **Vicia faba** (faba beans) by Taylor in 1958. The experiment proved that the DNA in chromosomes also replicate semi conservatively

8. Enumerate the characteristics of Genetic code.

Ans: -

1. The codon is Triplet. 61 codons code for amino acids and 3 codons do not code for any amino acids, hence they function as stop codons.
2. Some amino acids are coded by more than one codon, hence the code is degenerate.
3. The codon is read in mRNA in a contiguous fashion. There are no punctuations.
4. Genetic code is nearly universal. A particular codon codes for the same amino acid in all organisms from bacteria to higher plants and animals. For example, from bacteria to human UUU would code for Phenylalanine (Phe). [Some exceptions to this rule have been found in mitochondrial codons and in some Protozoans].
5. AUG has dual functions. It codes for Methionine (met), and it also act as initiator codon.
6. UAA, UAG UGA are stop terminator codons.

9. Explain the process of Transcription in prokaryotes.

Ans: - In bacteria, there are three major types of RNAs: mRNA (messenger RNA), tRNA (transfer RNA), and rRNA (ribosomal RNA). All three RNAs are needed to synthesize a protein in a cell.

1. The mRNA provides the template, tRNA brings amino acids and reads the genetic code, and rRNAs play structural and catalytic role during translation.
2. All three types of RNA's in bacteria are synthesized by single DNA-dependent RNA polymerase.
3. Transcription occurs in three steps, which are **initiation**, **elongation** and **termination**

4. **Initiation:** RNA polymerase binds to promoter along with Initiation-factor (σ) (sigma factors) to initiate the transcription. It uses nucleoside triphosphates as substrate and polymerizes following the rule complementarity.
5. **Elongation:** The RNA polymerase alone is only capable of catalyzing the process of elongation.
6. **Termination:** RNA polymerase associates with Termination-factor (ρ) transcription. (Rho factors) terminate the
7. Once the RNA polymerases reach the terminator region, the nascent RNA fall off, so also the RNA polymerase. This results in termination of transcription.
8. In bacteria, mRNA does not require any processing to become active, and also since transcription and translation take place in the same compartment (there is no separation of cytosol and nucleus in bacteria).
9. Many times, the translation can begin much before the mRNA is fully transcribed.
10. Consequently, the transcription and translation can be coupled in bacteria.

10. Explain the operon that is involved in utilization of lactose in E. coli.

Ans: -

The Lac Operon:

- ✓ Francois Jacob (geneticist) and Jacque Monod (biochemist) proposed Lac operon concept in 1961 to explain the gene regulation in **E. coli bacteria.**
- ✓ In lac operon lac refers to lactose and operon stands for a group of closely related genes which are required for lactose metabolism. The lac operon consists of one regulatory gene i (inhibitor) and three structural genes (z, y, a). A polycistronic structural gene is regulated by a common promoter and regulatory genes.
- ✓ **Examples for operons are:** lac operon, trp operon, ara operon, his operon, val operon,

Structural genes:

- ✓ The i gene codes for the repressor of the lac operon.
- ✓ The z gene codes for beta-galactosidase (β-gal), which is primarily responsible for the hydrolysis of the disaccharide, lactose into its monomeric units, galactose and glucose.
- ✓ The y gene codes for permease, which increases permeability of the cell to β –galactosides.
- ✓ A gene encodes a transacetylase.
- Hence, all the three gene products in lac operon are required for metabolism of lactose. Lactose is a substrate for the enzyme β galactosidase and it regulates switching on and off of the operon. Hence it is termed as inducer.
- Lactose is the substrate for the enzyme beta-galactosidase and it regulates switching on and off of the operons.
- Lactose is also termed as Inducer.

In the absence of Inducer (switched off) :

- ✓ When the lactose is absent in the medium, the regulator gene (i) produces the repressor proteins which binds to the operator gene.
- ✓ The binding of repressor protein to the operator prevents the binding of RNA polymerase.
- ✓ So that the transcription and translation is stopped and no enzymes for lactose metabolism are produced.
- ✓ Now the structural genes are said to be switched off.

In the presence of Inducer (switched on) :

- ✓ If lactose is provided in the growth medium of the bacteria, it acts as inducer and inactivates repressor protein.
- ✓ Hence repressor protein unable to bind to the operator gene.
- ✓ So the operator gene is free and can bind to RNA polymerase and signals the structural genes to produce polycistronic mRNA which in turn produces three enzymes necessary for lactose metabolism.
- ✓ So that lac operon is said to be switched on.
- ✓ Regulation of lac operon by repressor is referred as negative regulation [lac operon under control of positive regulation as well].

11. Mention the goals of HGP.

Ans: - Goals of HGP :

- Identify all the approximately 20,000-25,000 genes in human DNA.
- Determine the sequences of the 3 billion chemical base pairs that make up human DNA
- Store this information in data bases.
- Improve tools for data analysis
- Transfer related technologies to other sectors such as industries.
- Address the ethical, legal and social issues (ELSI) that may arise from the project

12. Explain the steps involved in translation process.

Ans: - TRANSLATION

Translation refers to the process of polymerization of amino acids to form a polypeptide (protein).

- The order and sequence of amino acids are defined by the sequence of bases in the mRNA.
- The amino acids are joined by a bond which is known as a peptide bond. Formation of a peptide bond requires energy.
- The cellular factory responsible for synthesizing proteins is the ribosome.
- The ribosome consists of structural RNAs and about 80 different proteins.
- Ribosome in its inactive state, it exists as two subunits; a large subunit and a small subunit.
- The small subunit encounters an mRNA; the process of translation of the mRNA to protein begins.
- The large subunit has two sites: p-site (peptidal site) and A-site (amino acyl site) for subsequent amino acids to bind close enough to each other for the formation of a peptide bond.
- The ribosome also acts as a catalyst (23S rRNA in bacteria is the enzyme- ribozyme) for the formation of peptide bond.
- A translational unit in mRNA is the sequence of RNA that is flanked by the start codon (AUG) and the stop codon and codes for a polypeptide.
- An mRNA also has some additional sequences that are not translated and are referred as untranslated regions (UTR).
- The UTRs are present at both 5' -end (before start codon) and at 3' -end (after stop codon). They are required for efficient translation process.
- Translation occurs in four steps. They are
  1. Charging of tRNA or aminoacylation of tRNA.
  2. Binding of smaller subunit of ribosome to mRNA
  3. Chain initiation
  4. Chain elongation
  5. Chain termination

1. Charging of tRNA:

- ✓ Amino acids are activated in the presence of ATP (and also Mg2+) and get linked to a specific tRNA molecule to form amino acyl – tRNA.

- ✓ Activation of amino acid and its subsequent linkage to tRNA are catalyzed by a specific enzyme amino acyl tRNA synthetase.
- ✓ When two charged tRNAs are brought closer, the formation of peptide bond between them would be favored energetically.

2. Binding of smaller sub unit of ribosome to mRNA:

- ✓ mRNA binds to smaller subunit of ribosome so that AUG is a first codon.

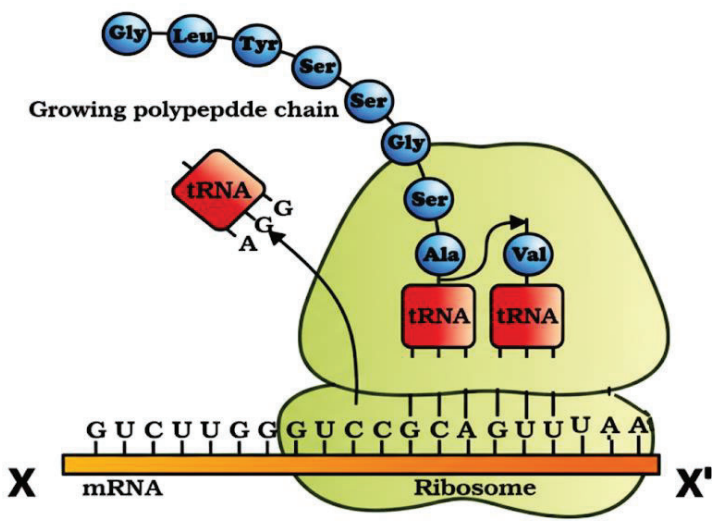
3. Chain initiation:

- ✓ tRNA with the anticodon UAC carrying the amino acid Methionine in eukaryotes (formyl methionine in prokaryotes) joints the smaller subunit of mRNA complex.
- ✓ Finally larger subunit of ribosome also joins resulting in initiation complex. They are p-site (peptidal site) and A-site (amino acyl site).
- ✓ Initiation complex consists of two subunits of ribosomes, mRNA and methionine tRNA in the p-site.

4. Chain elongation:

- ✓ During this process, the ribosomes move from codon to codon along mRNA.
- ✓ Amino acids are added one by one to form growing polypeptide.
- ✓ Elongation of polypeptide chain continued as the ribosomes moves along the mRNA in the 5' – 3' direction.

5. Chain termination:



- ✓ When the ribosome reaches terminator (Stop) codon on mRNA at the A site (UAA, UAG, and UGA) prevents elongation of the peptide chain.
- ✓ At this stage mRNA, tRNA, 2 subunits of ribosome and polypeptide chain gets separated.
- ✓ At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome into the cytoplasm

13. Mention the salient features of human genome.

Ans: - Salient features of HGP:

- ▪ The Human genome contains 3164.7 million nucleotide bases.

- The average gene consists of 3000 bases, but sizes vary greatly, with the largest known human gene being dystrophin at 2.4 million bases.
- The total number of genes is estimated as 30000 much lower than previous estimates of 80,000 to 1, 40, 000 genes. Almost all (99.9 per cent) nucleotide bases are exactly the same in all people.
- The functions of 50% of the discovered genes are unknown
- Less than 2% of the genome codes for protein.
- Repeated sequences make up very large portion of the human genome.
- Repetitive sequences are stretches of DNA sequences that are repeated many times, sometimes hundred to thousand times. They are thought to have no direct coding functions, but they shed light on chromosome structure, dynamics and evolution.
- Chromosome one has most genes (2968) and Y has the least (231).
- Scientists have identified about 1.4 million locations where single base DNA differences (SNPs – single nucleotide polymorphism, pronounced as 'snips') occur in humans. SNPs help in finding chromosomal locations for disease associated sequences and tracing human history.

14. Mention the steps involved in DNA finger printing technique developed by Alec Jeffreys

Ans: - Steps involved in DNA fingerprinting:

1. Isolation of DNA,

2. Digestion of DNA by restriction endonucleases

3. Separation of DNA fragments by Electrophoresis.

4. Transferring (blotting) of separated DNA fragments to synthetic membranes, such as nitrocellulose or nylon (Southern Blotting).

5. Hybridization using labelled VNTR probe and

6. Detection of hybridized DNA fragments by Autoradiography.

VI. Answer the following questions in 200-250 words each, wherever applicable: 5 Marks Each:

Q1. The following sequence of nucleotides 3' AUG UAC UUU AGG GAG UAA 5' in mRNA codes for a sequence of 5 amino acids. Generate the salient features of genetic code.

Ans: The genetic code is a set of rules that defines how the sequence of nucleotides in mRNA is translated into a sequence of amino acids in proteins. Here are the salient features of the genetic code:

1. **Triplet Code:** Each amino acid is encoded by a sequence of three nucleotides, known as a codon. For example, in the given sequence, 'AUG' is the start codon that codes for Methionine.
2. **Universality:** The genetic code is nearly universal, meaning that it is the same in almost all organisms, from bacteria to humans.
3. **Degeneracy:** Multiple codons can code for the same amino acid. For instance, both 'UUC' and 'UUA' code for the amino acid Leucine.
   Start and Stop Codons: The genetic code includes specific codons that signal the start (AUG) and stop (UAA, UAG, UGA) of protein synthesis.
4. **Non-overlapping:** The genetic code is read in a continuous manner, with each nucleotide belonging to only one codon.
5. **Directionality:** The mRNA is read in the 5' to 3' direction during translation, and the corresponding amino acids are added to the growing polypeptide chain in the same direction.

Q2. In text to lac operon, when Jacob & Monad cultured E.coli cell in a media devoid of lactose, E.coli cells formed colonies and when lactose was added, the E.coli cells metabolized lactose by synthesizing enzymes. Explain how lac operon switches off & switches on.

Ans: -

- **In the absence of Inducer (switched off):**
  - ✓ When the lactose is absent in the medium, the regulator gene (i) produces the repressor proteins which binds to the operator gene.
  - ✓ The binding of repressor protein to the operator prevents the binding of RNA polymerase.
  - ✓ So that the transcription and translation is stopped and no enzymes for lactose metabolism are produced.Now the structural genes are said to be switched off.
- **In the presence of Inducer (switched on):**
  - ✓ If lactose is provided in the growth medium of the bacteria, it acts as inducer and inactivates repressor protein.
  - ✓ Hence repressor protein unable to bind to the operator gene.So the operator gene is free and can bind to RNA polymerase and signals the structural genes to produce polycistronic mRNA which in turn produces three enzymes necessary for lactose metabolism that lac operon is said to be **switched on.**
  - ✓ Regulation of lac operon by repressor is referred as negative regulation [lac operon under control of positive regulation as well].

Q3. Regarding Hershey and Chase experiment

a) Mention the three steps involved.

b) Radioactive Sulphur & radioactive Phosphorus get incorporated in which parts of viral particle.

Ans: - a)

1. Infection
2. Blending
3. Cantrifugation

b) In the Harshay- Chase experiment, radioactive sulphur (32 S) was incorporated into the protein coat (capsid) of the bacteriophage. While radioactive phosphorous (32 P) was incorporated into the viral DNA. This distinction was crucial for identifying the genetic material of the virus.

Q4. Name the process involved in the following:

a) One parental DNA strand is conserved by daughter cell.

b) Separation of DNA fragment.

c) Removal of introns in hnRNA.

d) Attachment of Rho factor to RNA polymerase during transcription.

e) Polymerization of amino acids to form a polypeptide on mRNA.

Ans: -

a) Replication

b) Gel electrophoresis

c) Splicing

d) Termination

e) Translation

Q5. A policeman from the crime department approached the forensic science department to help identify the culprit DNA samples were collected from the crime site and of the two suspects.

a) Explain the process involved.

b) If the culprit had monozygotic twin, can this method give results

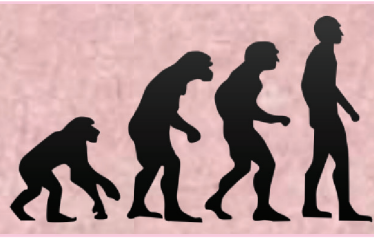
Ans: -The process of identifying a culprit using DNA samples involves several key steps. First, DNA is extracted from the samples collected from the crime scene and the suspects. This is typically done using

chemical methods that break down the cell membranes and release the DNA into a solution. Next, the extracted DNA is amplified using a technique called Polymerase Chain Reaction (PCR), which allows for the creation of millions of copies of specific DNA segments. After amplification, the DNA profiles are created using techniques such as gel electrophoresis or capillary electrophoresis, which separate the DNA fragments based on their size. The resulting DNA profiles are then compared to determine if there is a match between the samples from the crime scene and the suspects. If a match is found, it provides strong evidence that the suspect was present at the crime scene.

Regarding the second part of the question, if the culprit had a monozygotic twin, the DNA analysis may not be able to definitively identify the culprit. Monozygotic twins share nearly identical DNA, which means that if one twin is implicated, the DNA profile may not distinguish between the two. Therefore, while DNA analysis can provide strong evidence, it may not be conclusive in cases involving identical twins.

Chapter 6

Evolution



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6.7. HARDY - WEINBERG PRINCIPLE
6.8. A BRIEF ACCOUNT OF EVOLUTION
6.9. ORIGIN AND EVOLUTION OF MAN

THEORY

INTRODUCTION:

Evolution is an orderly change from one form to another. It is change in the heritable characteristics of biological populations over successive generation. It occur when evolutionary processes such as **natural selection** and **genetic drift** act on the variation.

EVOLUTIONARY BIOLOGY:-

- It is the study of history of life forms **i.e.** the changes in flora and fauna that have occurred over millions of years on earth.

6.1. ORIGIN OF LIFE

Origin of the Universe -

- The Universe is came into existence around **13.8 billion** years old.
- **Big-Bang theory** explains the origin of universe. It was proposed by **Abbe Lemaitre.**
- As per this theory the universe originated about **13.8 bya** by a single huge **thermal explosion.**
- The universe expanded and hence, the temperature came down.
- In the universe, **Hydrogen** and **Helium** formed sometime later.
- These gases condensed under its own gravitation and formed the **galaxies** of the present day universe.
- **The origin of universe :-**13.8 by a explosion of hot substance → universe expanded→ temperature came down →H and He formed → gases condensed under gravitation →formation of galaxies.

Origin and formation of the Solar system -

- Our galaxy, the **Milky Way(**Akash Ganga**)** , is one among billions of galaxies, and the solar system

formed about **4.6 billion years ago** from a rotating **cloud of gas** and **dust (nebula).**

- **Sun** is one of the millions of stars of our galaxy The sun along with its orbiting planets and asteroids constitute to form **our solar system.**
- **Solar nebula** was one of them, which was formed **our solar system.**
- The very hot **central part** of solar nebula became even hotter due to pressure and converted into the **sun**.
- The remaining **dust** and **gases** collided and stuck together and gradually became into **planets.**

Origin of Earth -

- Later, due to condensation of **atoms** and **dust particles** moving around the sun, planets were formed. Earth is also one of the planets in them.
- Earth was formed about **4.5 billion years ago** in the solar system.

Conditions of primitive (early) earth :-

- Initially, it was a hot ball of gases and vapour of various elements. There was no atmosphere on early earth.
- With the passage of years, the gases condensed into molten mass. Water **vapour, Methane, Carbon dioxide** and **Ammonia** released from the molten mass which was covered the earth surface of earth.
- The UV rays from the sun broke up water into **hydrogen** and **oxygen** and the **lighter H_2** escaped.
- oxygen combined with ammonia and methane to form water, CO_2 and others. The ozone layer was formed.
- As it cooled, the water vapour fell as rain, to fill all the depressions and form oceans.

Origin of life (Biopoiesis) :-

- Origin of life on primitive earth is called **Biopoiesis.**
- Life appeared 500 million years after the formation earth, i.e., almost four billion years back.

THEORIES FOR ORIGIN OF LIFE

- There are different theories regarding the origin of life on earth-

1. Theory of special creation
2. Theory of panspermia/Cosmozoic theory
3. Theory of spontaneous generation (Abiogenesis theory)
4. Theory of Biogenesis
5. Theory of chemical evolution/Oparin-Haldane theory

1. Theory of special creation :-

- It is oldest of all theories According to this theory, "all living beings on this earth were originally created by **God** or **super natural Power**".
- It is supported by most of the world's **religions** and **civilizations**.

2. Theory of Cosmic panspermia :-

- It is also called **Cosmozoic theory**
- It was proposed by **Richter.**
- According to this theory the units of life called **spores (Cosmozoa)** were transferred to earth from other planets. These **spores** gave rise to living organisms.

3. Theory of spontaneous generation (Abiogenesis/Autogenesis) –

- Origin of life from non-living things **spontaneously** and **continuously** is called **Abiogenesis.**
- According to this theory life came out of **decaying** and rotting matter like **straw** and **mud**.
- It was proposed by **Aristotle** and supported by **Van Helmont.**

4. Theory of Biogenesis –

- Origin of life gradually from pre-existing life is called **Biogenesis.**
- It was proposed by **Louis Pasteur, Francisco Redi, Sphallanzani.**
- Louis Pasteur experimentally proved that life arises only from pre-existing life. Spontaneous theory of origin of life is dismissed after that.

Experiment of Louis Pasteur –

- His experiment is also known as **'Swan neck flask experiment'.**
- He prepared sterilized syrup of sugar and killed yeast by boiling them in flasks.
- He took two flasks one of broken neck and another of curved neck (swan neck flask/ "S" shaped neck flask).
- He showed that in pre-sterilized swan neck flasks, life did not come from killed yeast because germ laden dust particles in the air were trapped by the curved neck which serves as filter while in another flask open to air (broken neck), new living organisms arose from “killed yeast”.
- However biogenesis theory did not answer how the first life form comes on earth.

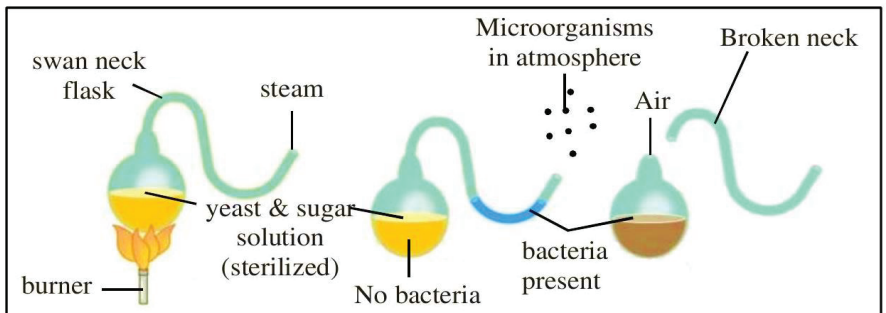


Fig : Louis Pasteur's swan neck flask experiment

5. Oparin - Haldane theory (Modern theory) –

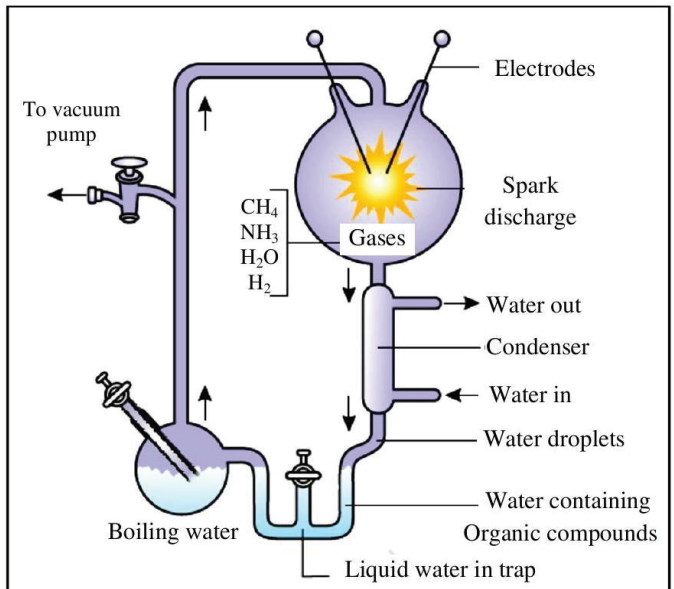
- It was proposed by **Oparin** of **Russia** and **Haldane** of **England.**
- It states that ‘the first form of life could have come from pre-existing non-living organic molecules (e.g. RNA, protein, etc.) and that formation of life was preceded by **chemical evolution,** i.e., formation of diverse organic molecules from inorganic constituents.
- Oparin's theory was published in his book **'ORIGIN OF LIFE'.**
- First life originated in **sea water**, so **water is essential for origin of life.**
- Oparin-Haldane theory is studied in two parts – **Chemogeny & Biogeny.**
- **Chemical Evolution(Chemogeny) -** formation of diverse organic molecules from inorganic constituents.
- **The condition on primitive earth that leads to the origin of life –** High temperature, volcanic eruption, reducing atmosphere containing CH_4 and NH etc.

1. **Biogeny :** Formation of self-replicating biomolecules in **broth** (primordial hot soup or warm little pond).

EVIDENCES IN FAVOUR OF CHEMICAL EVOLUTION(CHEMOGENY)

(1) Harold Urey and Stanley Miller Experiment:

- In 1953, **Stanley Miller** and **Harold Urey** conducted an experiment to give evidence in favour of **chemical evolution.**
- To prove this, they designed a glass apparatus as shown below.



Diagrammatic representation of Miller's experiment

Experimental set-up:-

- They created conditions similar to primitive earth in a laboratory scale.
- They made arrangements for insertion of **two electrodes** to provide **electrical energy** (simulation of lightning) to the spark chamber, which contained **CH4, NH3, H2** were in **2 : 1 : 2** ratio and **water vapour at 800ºC temperature.** Electric spark of **75,000 volts** were provided to the mixture.
- The spark chamber was connected to another flask with an arrangement for boiling water (provision for evaporation).The other end of the spark chamber was connected to a **trap** by a tube that passed through a condenser (an arrangement for condensation and collection of aqueous solution, equivalent to rain and Haldane's soup).
- The trap, in turn, was connected with the flask for boiling water (arrangement for circulation).

Observations :-

- After a week, they observed presence of amino acids like **glycine, alanine** and **aspartic acid.**
- In similar experiments other scientists observed, formation of **sugars, nitrogen bases, pigments** and **fats**.

(2) Evidences from meteorite –

- Analysis of meteorite contents also revealed similar compounds indicating that similar processes are occurring elsewhere in space.
- With these limited evidences, first part of the **conjectured story** i.e., chemical evolution was more or less accepted.
- This version of **abiogenesis** i.e., the first form of life arose slowly through evolutionary forces from non-living molecules is accepted by majority.

However, one formed how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed in organic evolution.

Key Note:

- The first non-cellular forms of life could have originated **3 billion** years ago.They have been originated from giant molecules like **RNA**, **Proteins** and **polysaccharides** etc.
- The **first cellular form of life** did not originate till about **200 million** years ago.

6.2. Evolution Of Life Forms - A Theory

- Charles Darwin,the famous English naturalist at the age of 22 in 1831 went for a voyage in the sail ship called **H.M.S. Beagle.**
- During his voyage he collected a large number of animals and plants and also prepared an extensive note and scientifically documented data on them.
- On the basis of this detailed study , Darwin put forward his theory known as theory of **natural selection or Darwinism.**
- In 1859 , Darwin published this work in his famous book entitled **The Origin of Species by Natural Selection.**
- According to Darwin, the existing living forms share similarities among themselves and with the life forms that existed millions of years ago.
- He said that there has been gradual evolution of life forms. Any population has built in Variation in characteristics and those characteristics enable some animals to survive better natural conditions and others perish.
- Darwin used another word fitness for individual or population. Animals with reproductive fitness produce more progeny than others.
- Nature promote animals with fitness to survive better (**Survival of the fittest**). Darwin called it **natural selection** and implied it as a mechanism of evolution.
- **Alfred Wallace**, a naturalist who worked in **Malay Archipelago** had also come 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 (epochs, periods and eras).
- The geological history of earth closely correlates with the biological history of earth.

6.3. What are the evidences for evolution?

- Evolution is the development of organisms through time.
- The evolutionary process cannot be seen by man during his short life span.
- Hence evolution can be understood only by a comparative study between living and the extinct animals and also evidences from different resources.

- The most important evidences are,

1. Evidences from embryology
2. Evidence from embryology
3. Paleontological evidences
4. Morphological and Anatomical comparative evidence
5. Biochemical evidence
6. Biogeographical evidence

1. Evidences from embryology -

- Proposed by **Ernst Haeckel.**
- He observed that all vertebrate embryos have some common features that are absent in adult.
- **E.g.** all vertebrate embryos (including human) develop vestigial gill slits just behind the head. But it is functional only in fish and not found in other adult vertebrates.
- **Ernst Haeckel** proposed the **Biogenetic Law** (or Theory of Recapitulation) in **1866.**
- He coined the phrase **"Ontogeny recapitulates phylogeny",** which means an organism's development (ontogeny) repeats its evolutionary history (phylogeny).
- Haeckel argued that embryos of different vertebrates (fish, salamander, tortoise, chicken, human) look similar in early stages because they pass through the adult stages of their ancestors
- However, **Karl Ernst von Baer** rejected this proposal.
- He noted that embryos never pass through the adult stages of other animals.

Note :-

Ernst Haeckel – Father of Embryology.

karl Van Baer – Father of Modern Embryology

1. **Point Accepted by Von Baer (Shared Principle)**

   Similarity in Early Embryos: Von Baer agreed with the observation that embryos of different vertebrates show significant structural resemblances (similarities) in their early stages of development.

   Common Ancestry: Both acknowledged that these similarities are evidence of common ancestry.

2. **Points Rejected by Von Baer**

   Von Baer rejected the core of Haeckel's theory, specifically:

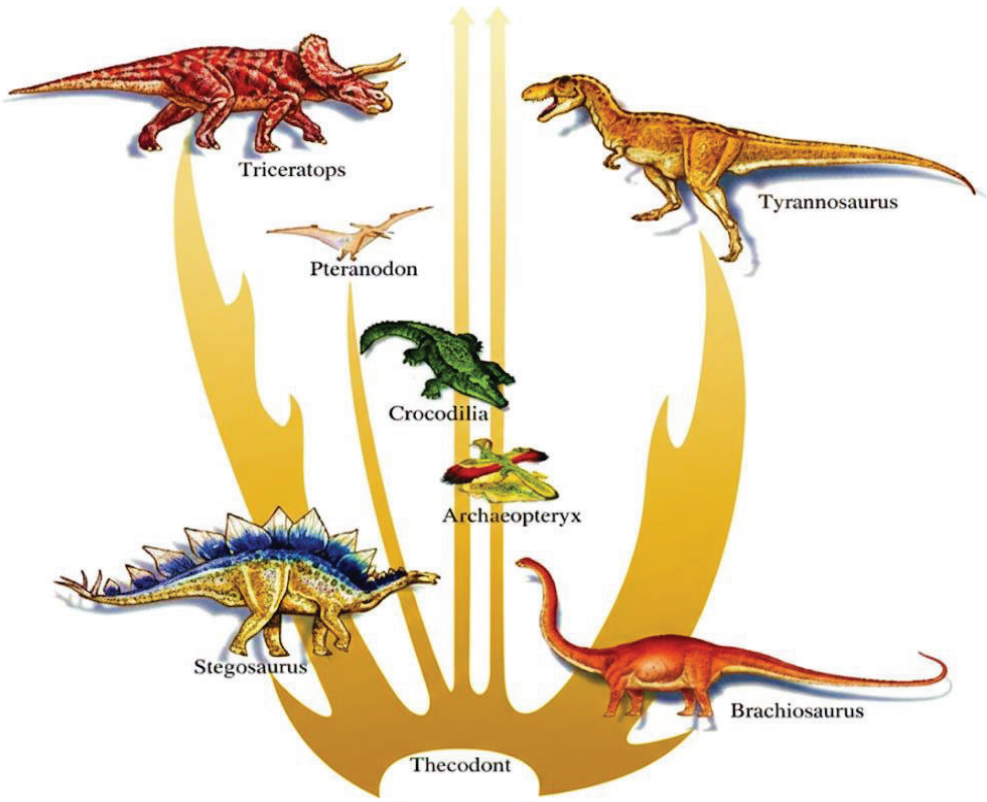
   Rejection of "Adult Stage" Recapitulation: Haeckel claimed that an embryo passes through the adult stages of its evolutionary ancestors (e.g., human embryos becoming adult fish, then adult reptiles). Von Baer argued that embryos never pass through the adult stages of other animals.

2. Paleontological evidences -

- The study of fossil is called **paleontology.**
- Fossils are **remains of hard parts of life forms** found in sedimentary rocks or stratified rocks(earth crust).They are ***written document of evolution.***
- Age of the fossils can be studied by **radiocarbon dating.**

Significance of fossils:-

- To study phylogeny (evolutionary history).**Eg**:- Horse evolution
- To study the connecting link between two groups of organisms.**Eg**,: Archaeopteryx
- To Study about extinct animals.**Eg**:- Dinosaurs
- To study about geological period by analysing fossils in different sedimentary rock layers.The study showed that life forms varied over time and certain life forms are restricted to certain geological time span.



A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds

Note :-

1. **Archaeopteryx -** It is a **fossil bird**. It shows the characters of both reptiles and birds. It has teeth, digits with claws like reptiles and beak and wings like birds This shows that the present-day birds have been evolved from reptilian ancestors by gradual changes.
2. **Fossils of horse –** The present horse is **Equs equs (**5 feet height and foot with 1 toe).The study of these fossil shows that the ancestor of the present-day horse was **2 feet height** and foot with **five toes.**

3. Morphological and anatomical comparative evidences –

The phylogenetic history can be revealed by comparative study of external and internal structures.

A. Homologous Organs -

a. The organs which have common origin, embryonic development and same fundamental structure but perform different functions are called as **homologous organs** and this phenomenon is called **homology.** Homology indicates common ancestry. **E.g :-** Fore limbs of Man and bat, Fore limbs of Man and whale ,Fore limbs of bird and horse.

1. **Homology in animals:**

   Ex-1: Human hand, Whale's flippers, Bat's wing & Cheetah's foot. These forelimbs look different and perform different functions. Though these fore limbs perform different functions in these animals, they have similar anatomical structures i.e. All of them have **humerus** (support upper arm),**Radius** and **ulna** (support fore arm), **Carpels** (Support wrist), **Metacarpals** (Support palm),**Phalanges** (Support fingers).

   Ex-2 : The brain vertebrates structure having similar anatomy, embryonic origin, and common ancestry, but they may perform different functions due to divergent evolution. **For example**, the **olfactory lobes** are more developed in **fish** (used for sensing, smelling), while the **cerebral hemispheres are much larger** and more **complex** in **mammals.**

   Ex-3 : The **heart** of vertebrates Sharing a common developmental origin and basic anatomical structure (chambers, muscles) despite having different functional complexities (2 vs 3 vs 4 chambers) across fishes, amphibians, reptiles, birds, and mammals.

2. **Homology in plants**:

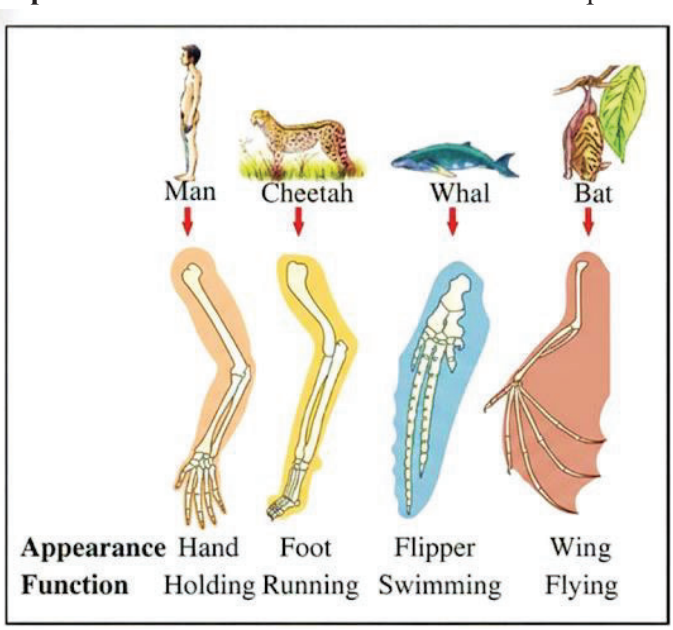
   Ex-1 : Thorns of *Bougainvillea* and tendrils of *Cucurbita* ,both are modified axillary buds that arise in the axil of leaves. Thorns are adapted for protection, while tendrils are adapted for climbing.

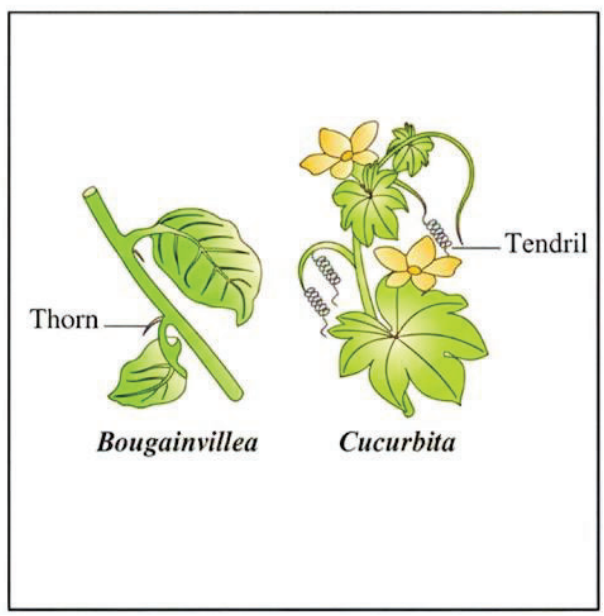
   Ex-2 : Thorns of **Punica granatum** (pomegranate) and **Tendrils of Passiflora** (passion flower): Similar to the example above, these represent modified axillary buds.

   Ex-3: Leaves of a cactus (modified into thorns for protection/water conservation) and **leaves of a pitcher plant** (modified to capture insects) are homologous as they share a common ancestor but perform different functions.

   Ex-4 : Potato tubers (underground storage stem) and **runner grass** (surface stem) are homologous, as both are derived from stem tissue.

b. The origin of homologous organs is due to ***Divergent evolution***. It is the evolution by which **related species** become **less similar** to survive and adapt in different environmental condition.





B. Analogous Organs

a. The organs which are **anatomically different** but **functionally similar** are called **analogous organs.**

1. **Analogy in Animals :-**

   Ex-1 : Wings of insects (formed of a thin flap of chitin) and **wings of birds** (modified forelimbs).

   Ex-2 : Eyes of Octopus (retina from skin) and **mammals** (retina from embryonic brain).

   Ex-3 : Flippers of penguins and **dolphins** are not anatomically similar structures though they perform similar functions.

   Ex-4 : Trachea of insects (from ectoderm) and **lungs of vertebrates** (from endoderm).

2. **Analogy in plants :-**

   Ex-1 : Sweet potato (root modification) and potato (stem modification) ,but both are adopted for **storage food** and **vegetative propagation.**

b. Due to same function, different structures evolve similarly. This is called **convergent evolution.** Similar habitat resulted in selection of similar adaptive features in different groups of organs but towards the same functions.

Differences between Divergent and Convergent evolution

Divergent evolution	Convergent evolution
It results in homologous organs	It results in analogous organs
Similar structures evolved to perform different functions	Different structures evolved to perform same function
When a species diverges over time into two different species, resulting in a Species becoming less like the original one.	When unrelated organisms evolve to similarities when adapting to similar environment.
Live in different ways than common ancestors	Live in the relatively same way as each other
Darwin Finches , Australian marsupials, Homologous Organs (Forelimbs of Vertebrates),Thorns of Bougainvillea and Tendrils of Cucurbita and Vertebrate Hearts and Brains:	Wings of insects, birds, and bats; flippers of penguins and dolphins; and Australian marsupials alongside placental mammals

4. Biochemical evidences:-

- ✕ The similarities in **proteins** and **genes** performing a common given function among diverse organisms give clues to common ancestry.
- ✕ **Organisms with similar DNA sequences are more closely related to each other.**
- ✕ **Similarities in Biochemical pathway**
- ✕ The **metabolic processes** (like **Krebs's cycle**) in organisms are also similar.
- ✕ Formation of proteins universally occurs by **polymerization of Amino acids.**

5. Biogeographical evidence:-

- ✕ Species restricted to a region develop unique features. Also, species present in widely separated regions show similarity of ancestry.

6.4. Adaptive radiation(Biogeographical evidence)

Adaptive Radiation:-

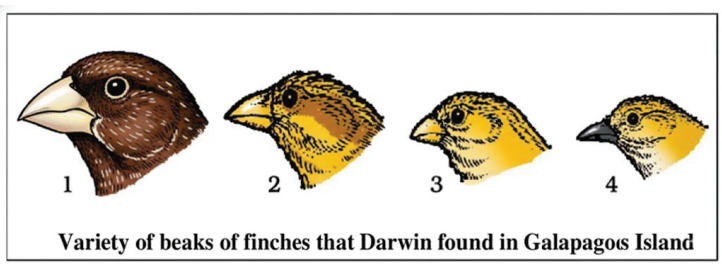
✕ It is the process of evolution of different species in a given geographical area starting from a common point and literally to other geographical areas (habitats) is called adaptive radiation.

Examples:

1. **Darwin's finches**
2. **Australian Marsupials**
3. **Placental mammals in Australia**

Example-1 Darwin's finches of Galapagos island

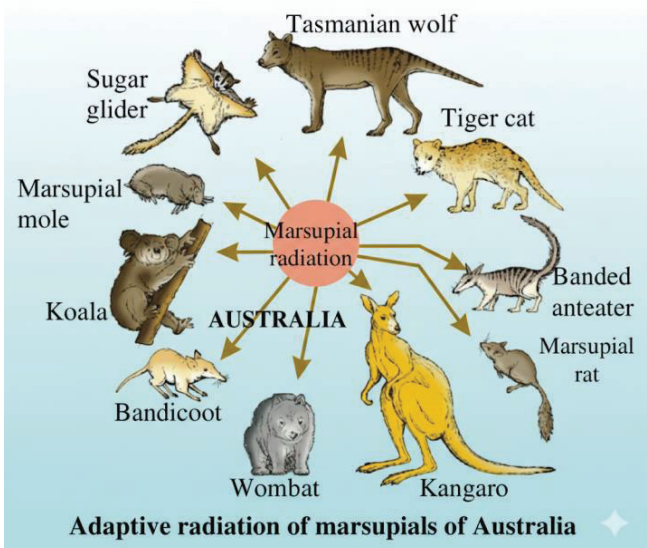
- ✕ Darwin's Finches refers to **small black birds** of **Galapagos Islands.**
- ✕ Galapagos island is situated near south America which is a group of **22 smaller islands.**
- ✕ Darwin observed many varieties of finches in the same island.
- ✕ He conjectured, all the varieties were evolved on the island itself.
- ✕ Originally the finches were **seed-eating animals.**
- ✕ From the seed eating finches many other forms with **altered beaks arose.** They may become **insectivorous** and **vegetarian finches.** Thus, the Darwin's finches showed adaptive radiation.



Variety of beaks of finches that Darwin found in Galapagos Island

Example:-2 Australian Marsupials

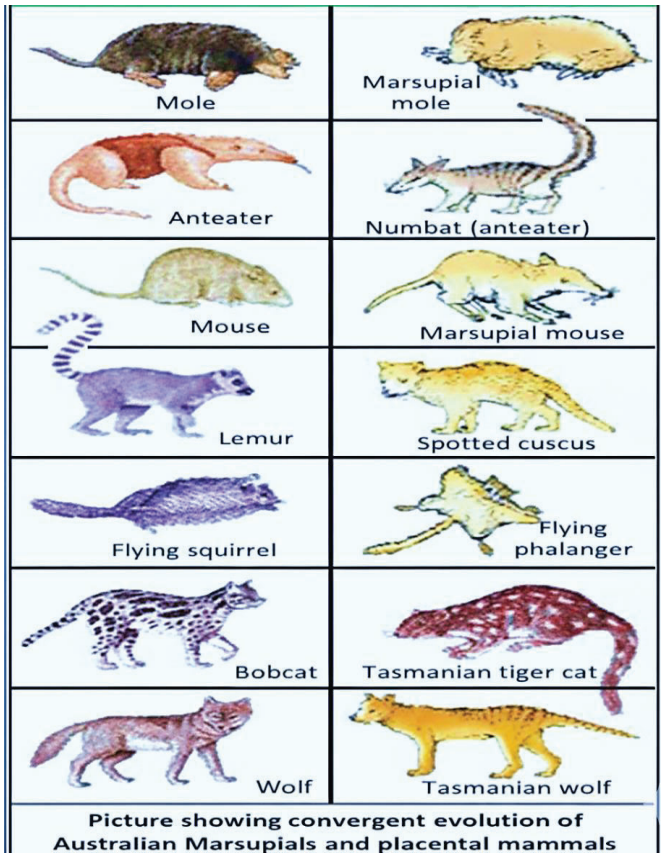
A number of marsupials, each different from the other evolved from an ancestral stock, but all within the **Australian island continent.** Eg:- Tasmanian wolf ,Tasmanian tiger cat, Flying phalanger, spotted cuscus , Marsupials mouse ,Wombat(anteater), Marsupials mole.



Adaptive radiation of marsupials of Australia

Example:-3 Placental animals in Australia

- Placental mammals in Australia also exhibit **adaptive radiation.**
- They appear to be similar to corresponding marsupials (Eg: placental wolf and Tasmanian wolf-marsupial).
- In this example more than one adaptive radiation appeared to have occurred in different habitats or isolated geographical area. So it is called **convergent evolution.**



Picture showing convergent evolution of Australian Marsupials and placental mammals

6. Natural selection by Anthropogenic Action

Natural selection is the process in which organisms with better favourable & heritable variation are survived and reproduced. Some evidences are given below:

1. **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*).After industrialization (1920), more dark-winged moths and less white winged moths were developed.

Reason:

a. **Before industrialization:** There was white lichens covered the trees. In that background, white winged moths survived but dark winged moths were picked out by predators.

b. **After industrialization:** The tree trunks became dark due to industrial smoke and soot. No growth of lichens. So white winged moths did not survive because the predators identified them easily. Dark winged moth survived because of suitable dark background.

(a) (b)

2. **Drug resistance :-** **Development of resistant varieties** in organisms against ***herbicides, pesticides, antibiotics*** or ***drugs*** etc. These are the examples for natural selection by **anthropogenic action** (evolution due to human activities).

Note:- The evolution is not a directed process in the sense of determinism. It is a stochastic process based on chance events in nature and chance mutations in the organisms.

6.5. Theories of Biological Evolution

A. Lamarckism (Theory of Inheritance of Acquired characters)

- It is proposed by **Lamarck**. It states that evolution of life forms occurred by the inheritance of acquired characters.
- Acquired characters are developed by **use** and **disuse** of organs.

a. **Evolution by use of organs**

Example :-Lamarck gave the example of Giraffes who in an attempt to forage leaves on tall trees had to adapt by elongation of their necks. As they passed on this acquired character of elongated neck to succeeding generations, Giraffes, slowly over the years came to acquire long necks.

b. **Evolution by disuse**

Example:- Disappearance of limbs in snakes.

- This theory was eliminated out because it is proved that the characters are inherited only through genes.

B. Darwinism (Theory of Natural selection)

- It was proposed by **Charles Darwin (1859)** in his book on by means of natural selection.
- It was based on observations during a sea voyage in a sail ship called **H.M.S. Beagle.**
- **Alfred wallace** (a naturalist worked in Malay Archipelago) had also come to similar conclusions.
- Work of **Thomas Malthus** on Populations influenced **Darwin**
- Darwinism is based on two key concepts namely,
  (a) Branching descent (b) Natural selection

(a) Branching Descent

- It explains that all organisms are modified descendants of previous life forms.
- Adaptive ability is inherited. If has a genetic basis.
- Fitness is the end result of the ability to adapt and get selected by nature.

(b) Natural Selection –

- The work of **Thomas Malthus** on principle of populations (1794) was influenced by **Darwin.**
- **Natural selection is based on the following facts:-**

1. **Heritable minor variations:** It is either beneficial or harmful to the organisms.
2. **Overproduction:** Population size grows exponentially due to maximum reproduction (E.g. bacterial population).
3. **Limited natural resources:** Resources are not increased in accordance with the population size.

4. **Struggle for existence:** It is the competition among organisms for resources so that population size is limited.
5. **Survival of the fittest:** In struggle for existence, organisms with beneficial variations can utilize resources better. Hence, they survive and reproduce. This is called **Survival of the fittest**. It leads to a change in population characteristics and new forms appear.

✕ Darwin ignored about **origin of variation** and **mechanism of evolution or speciation.**

Examples of natural selection :-

(i) Industrial melanism **Before Industrialization (1850s)**

(ii) Drug resistance

6.6. Mechanism Of Evolution

✕ **Hugo de Vries (1901)** proposed **Mutation Theory** of evolution .

✕ He conducted some experiments on ***Oenothera laarckiana*** (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 sudden / spontaneous process. He believed mutation caused speciation and hence called it **saltation** (single step large mutation).

Differences between Darwinism and Mutations of Hugo de-Vries

Darwinism	**Hugo de-Vries mutation theory**
Variations are small	Mutations are large and random
Variations are directional	Mutations are directionless
Evolution is slow and gradual	Evolution is occurs in single step

6.7. Hardy - Weinberg Principle

✕ This principle state that **allelic frequencies** in a population are **stable** and **constant** from generation to generation,**i.e**, The **Gene pool (**The total genes and their alleles in a population) is remains constant. This phenomenon is called **genetic equilibrium or Hardy-Weinberg equilibrium** Sum total of all the allelic frequencies is 1.

✕ The population which follows **Hardy-Weinberg equilibrium** is the stable population has only two alleles (A and a) that represents a character, the frequency of allele A=p, the frequency of allele a=q, then

$$\mathbf{p + q = 1}$$

Where:
p - Frequency of dominant allele (A)
q-Frequency of recessive allele (a)

The binomial expansion of this equation is :

$$(p+q)2 = 1$$

$$\mathbf{i.e.\ p^2 + 2pq + q^2 = 1}$$

Where: p^2 - Frequency of individuals with genotype (AA)

q^2 - Frequency of individuals with genotype (aa)

2pq-Frequency of individuals with genotype (Aa)

The conditions required for Hardy-Weinberg equilibrium are ;

a. Large population size
b. Random mating
c. No migrations or mutations
d. No genetic drift
e. No natural selection

Note :-

1. **Gene frequency** – The frequency of an alleles of a particular gene in a population is called **allele frequency** or **gene frequency.**
2. **Gene pool :-** The total genes and their alleles in a population is called gene pool.
3. **Genetic equilibrium:-** The constancy of gene pool in a population is called **genetic equilibrium.**

Factors Affecting Hardy-Weinberg Equilibrium

There are five factors affecting Hardy-Weinberg equilibrium

1. **Gene migration or Gene flow :-** When individuals migrate to another place or population, new genes or alleles are added to new population and are lost from old population, in turn changing the frequencies.When gene migration occurs many times, it is called **gene flow.**
2. **Genetic drift :-** Changes occurring in frequencies by chance is called **genetic drift**. Sometimes, due to changes in allele frequency in new population, some form a different species. This effect is called **founder effect** and the original drifted population is called **founder.**
3. **Mutation :-** It is the spontaneous and permanent change in the genetic makeup an individual.It results in formation of new phenotypes. Over few generations, this leads to **speciation.**
4. **Genetic recombination :-** Reshuffling of gene combinations during crossing over resulting in genetic variation.
5. **Natural selection :-** Heritable variations that enable survival of the fittest will leave greater number of progeny.

Natural selection can have following three effects:

a. Stabilisation:-

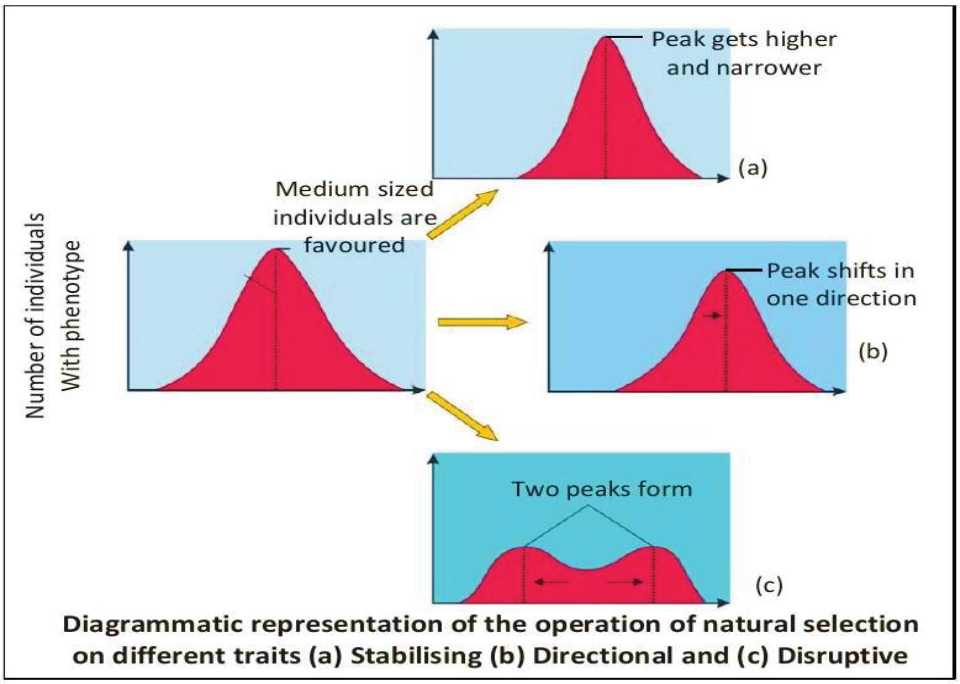
- In this,the frequency of average sized individuals increases further but the frequency of smaller and larger individuals is reduced and finally become negligible.
- The bell shaped curve gets higher and narrower due to the elimination of extreme variants.
- **Example:** Sickle celled anaemia

b. Directional change:-

- In this,the longest or shortest individuals are selected by nature and increase in frequency in the forth coming generations.
- The directional selection always the extreme (end one) is favoured.
- The bell shaped curve shifts in one direction.

c. Large number of individuals acquire value other than mean character value so peak shifts in one direction.

d. Disruption:- In this,large number of individuals acquire peripheral character values at both ends of the distribution curve and hence 2 peaks are formed.



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

6.8. A Brief Account Of Evolution

1. **Proterozoic era: 2500 - 541 million yrs ago (mya)**
   - **2000 mya:** First cellular forms of life appeared.
   - Some of the cells had the ability to release O_2 as the light reaction in photosynthesis.
   - Single celled organisms became multicellular organisms.
2. **Paleozoic era (540 - 252 mya)**
   - It has 6 periods: Cambrian (540 - 490 mya), Ordovician (490 - 443 mya), Silurian (425 mya), Devonian (405 mya), Carboniferous (360 mya) & Permian (285 mya).
   - **500 mya:** Invertebrates were formed.
   - **450 mya:** First land organisms (plants) appeared.
   - **400 mya:** Arthropods invaded the land.
   - **350 mya:** Jawless fishes were evolved.
   - **Lobefins** (stout & strong finned fishes) could move on land and go back to water. They evolved to first amphibians (ancestors of modern-day frogs & salamanders).
   - In 1938, a lobe-fin called **coelacanth** fish was caught in South Africa which was thought to be extinct.
   - **320 mya:** Sea weeds and few plants were existed.
   - Amphibians evolved to reptiles. They lay thick-shelled eggs (do not dry up in sun).
   - **Giant ferns (Pteridophytes)** were present but they all fell to form coal deposits slowly.
3. **Mesozoic era (252 - 66 mya)**

- Age of reptiles and gymnosperms.
- **It has 3 periods: Triassic (230 mya), Jurassic (208 mya) & Cretaceous (144 mya).**
- **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 (*Tyrannosaurus rex, Triceratops, Stegosaurus, Brachiosaurus*** etc.)
- ***Tyrannosaurs rex*** was the largest dinosaur (20 feet in height, huge fearsome dagger-like teeth).
- Toothed birds were emerged.

4. **Cenozoic era (66 - 0 mya)**
   - Age of Mammals & Angiosperms.
   - **It has 2 periods: Tertiary (66 mya)** & **Quaternary (2 mya** - Age of man).
   - **65 mya:** Dinosaurs suddenly disappeared. Some say climatic changes killed them. Some say most of them evolved into birds.
   - First mammals were 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 overridden by North American fauna.
   - Due to continental drift, Australian marsupials survived because of lack of competition from any other mammals.

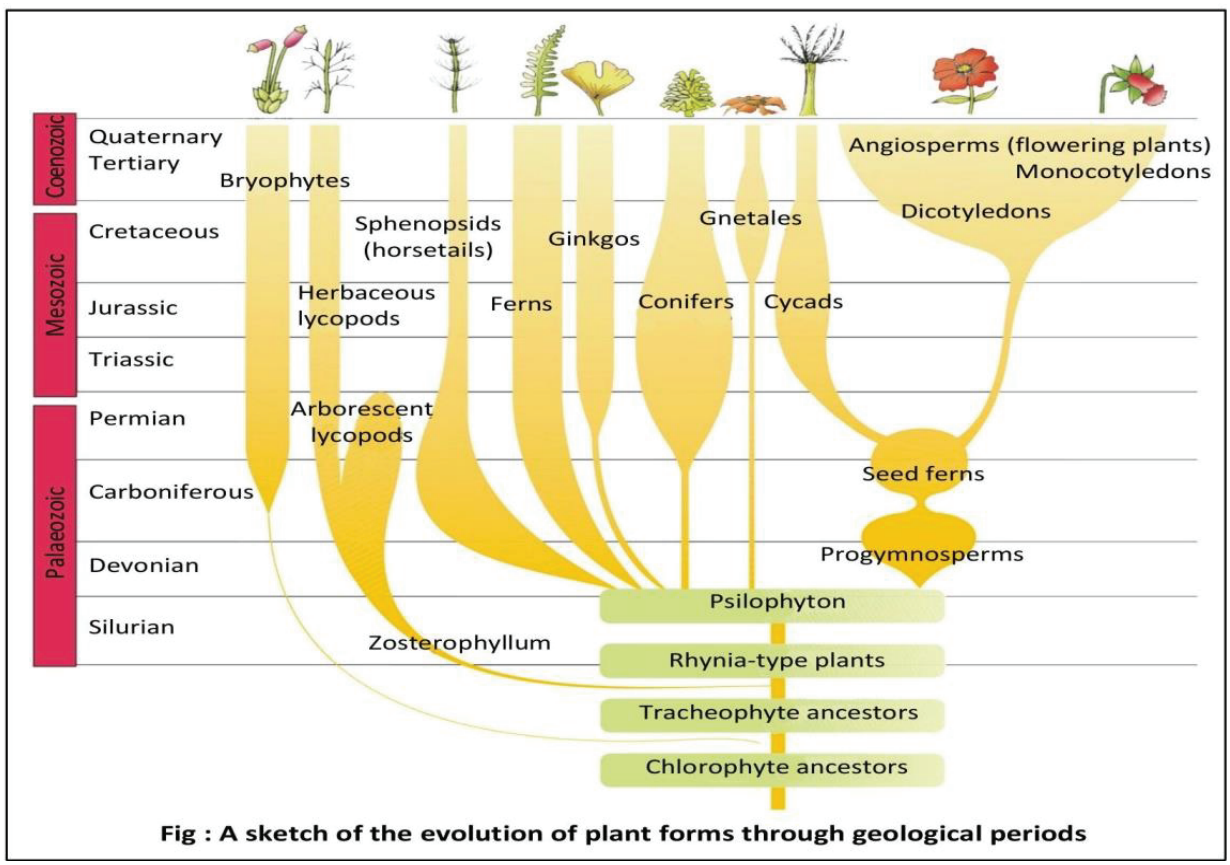
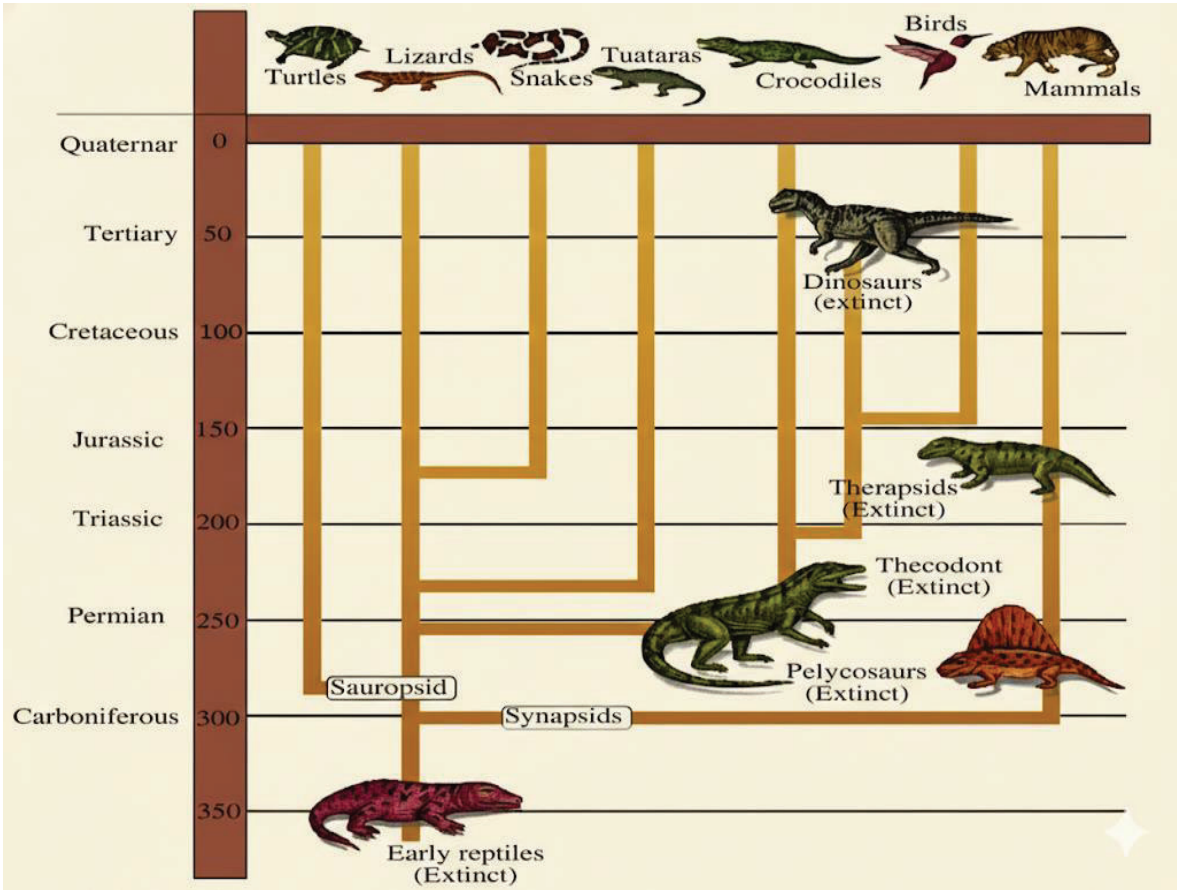


Fig : A sketch of the evolution of plant forms through geological periods



Representative evolutionary history of vertebrates through geological periods

6.9. Origin And Evolution Of Man

- The evolution of man can be understood only by the fossil evidences.
- Human evolution has started 15 mya but man appeared only 3 million years ago.
- Human beings have originated first in **East Africa.**
- The important stages of human evolution are as follows

1. Dryopithecus and Ramapithecus (15 mya)

- About 15mya, primates called **Dryopithecus** and **Ramapithecus** were existing.
- They were hairy and walked like gorilla and chimpanzees
- **Ramapithecus** was more **man-like** while **Dryopithecus** was more **ape-like.**
- Few fossils of man-like bones have been discovered in **Ethiopia** and **Tanzania**.
- These revealed hominid features leading to the belief that about **3-4 mya**, man-like primates walked in eastern Africa.

2. Australopithecines (2 mya)

- Probably lived in **East African** grasslands **2mya**.
- They hunted with stone weapons.
- Essentially ate fruit.
- Brain capacity was **500-600 cc.**
- They were intermediate between apes and man.

3. Homo habilis (Handy Man)

- Lived before **1.6 - 2 mya.**
- First human like-being

- They did not eat meat.
- Brain capacity was **650 – 800 cc**.

4. Homo erectus (1.5 mya)

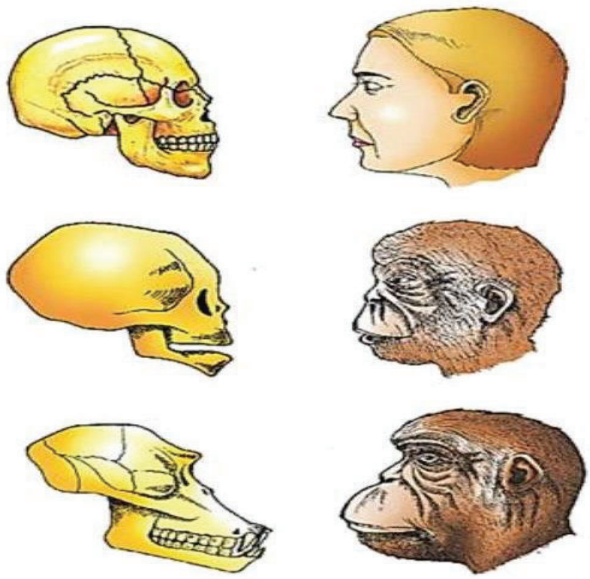
- Fossils discovered in Java in 1891.
- Lived before **1.5 mya.**
- Probably ate meat.
- Had large brain around 900 cc.

5. Neanderthal man : 1 lakh - 4000 yrs ago :

- Lived in east and central Asia between **100,000-40,000 years** back.
- Used hides to protect their body.
- Buried their dead.
- Brain capacity wad **1400 cc**

6. Homo sapiens (Modern man) :

- Arose in Africa and moved across continents and developed distinct races.
- During ice age between **75,000-10,000** years ago modern Homo sapiens arose.
- Pre historic cave art developed about **18,000 years ago.**
- Agriculture came around **10,000 years** back and human settlement started
- Brain capacity was **1450-1600 cc**



A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee. The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull.

EXERCISE

PART - A

I. Select the correct alternative from the choices given: 1 Marks Each

1. **Theory of spontaneous generation was disproved by experiments conducted by**

   a) Louis Pasteur b) Haldane & Oparin c) S.L. Miller d) Charles Darwin

2. **The thorns of Bougainvillea and Tendrils of Cucurbita represent**

   i. Homology

   ii. Convergent evolution

   iii. Divergent evolution

   iv. Analogy

   a) i & ii are cor b) i & iii are correct

   c) ii & iv are cor d) ii & iii are correct

3. **Statement 1: Man has domesticated dogs & has created different breeds by artificial breeding**

   Statement 2: Intensive breeding of dogs signifies divergent evolution.

   a) Both statements 1 & 2 are cor

   b) Statement 1 is correct & 2 is incor

   c) Statement 1 is incorrect & 2 is cor

   d) Both the statements are incor

4. **Statement 1: Antibiotic or drug resistance is due to evolution by anthropogenic action.**

   Statement 2: Many antibiotic or drugs resistant organisms arise due to over usage of antibiotics.

   a) Both statements 1 & 2 are cor

   b) Statement 1 is correct & 2 is incor

   c) Statement 1 is incorrect & 2 is cor

   d) Both the statements are incor

5. **Charles Darwin in Galapagos Island found that finches had different forms of beaks. This process of evolution is called**

   a) Natural selection b) Adaptive radiation

   c) Darwinian Fitness d) Struggle for existence

6. **A brown billed duck is newly added to a farm of white billed ducks. This indicates**

   a) Gene flow b) Genetic drift c) Mutation d) Natural selection

7. **Change in frequency of genes and alleles is due to**

   a) Mutation b) Gene flow c) Both a & b d) Neither *a* or *b*

8. The first amphibians that lived both on land and water evolved from

a) Fishes b) Turtles c) Lobefins d) Frog

9. Arrange in correct sequence of their occurrence on geological time scale.

i. Amphibians ii. Fishes iii. Reptiles iv. Mammals

a) i ii iii iv b) ii iii i iv c) ii i iii iv d) iii ii iv I

10. The biggest land reptiles that existed during Mesozoic era was

a) Ichthyosaurs b) Tyrannosaurs c) Sea cow d) Crocodiles

11. Arrange the following in the order of evolution.

a. Neanderthal man b. Australopithecus c. Ramapithecus d. Homo habilis

e. Homo erectus

a) a → b → c → d → e b) e → d → c → b → a

b) b → c → d → e → a d) c → b → d → e → a

12. Koala, Tasmanian wolf, Kangaroo & Marsupial rat, all of these represent

a) Darwin's finches b) Australian Marsupials

c) Placental mammals d) Non placental mammals

13. Statement 1: Hugo De Vries believed mutation leads to spontaneous evolution.

a) Both statements 1 & 2 are cor

b) Statement 1 is correct & 2 is incor

c) Statement 1 is incorrect & 2 is cor

d) Both the statements are incor

14. Elongation of neck in giraffes, due to inheritance of acquired characters was given by

a) Lamarck b) Thomas Malthus c) Charles Darwin d) Hardy-Weinberg

15. According to Oparin, which one of the following was not present in the primitive atmosphere of the earth?

a) Water vapour b) Oxygen c) Methane d) Hydrogen

16. Single step large mutation leading to speciation is also called

a) Natural selection b) Branching descent

c) Founder's effect d) Saltation

17. Which of the following theories attempts to explain origin of universe?

a) Panspermia theory b) Big Bang theory

c) Chemical evolution theory d) Darwin's theory

18. In Miller's experiment, the environment of primitive earth was created & temperature was

a) 400°C b) 450°C c) 800°C d) 850°C

19. Which organic compound was definitely formed in Miller's experiment?

a) Amino acids b) Proteins c) Polysaccharides d) Nucleic acids

20. The paleontological evidence for evolution is obtained from

a) Fossils b) Embryos c) Homologous organs d) Analogous organs

21. Fossils are hard remains of life forms and are found in

a) Igneous rocks b) Metamorphic rocks

c) Sedimentary rocks d) Any type of rocks

22. Statement 1: The study of fossils in various sedimentary layers indicates the geological period in which they exit.

Statement 2: The ages of fossils can be estimated using radiometric dating methods.

a) Both statements 1 & 2 are cor

b) Statement 1 is correct & 2 is incor

c) Statement 1 is incorrect & 2 is cor

d) Both the statements are incor

23. Embryological evidence for evolution was disapproved by

a) Ernst Heckel b) Karl Ernst Von Baer

c) Charles Darwin d) Alferd Wallace

24. Epochs, periods and eras depict

a) Geological history b) Biological history

c) Physiological history d) Embryological history

25. Arrange the following plants as appeared on different geological periods

a) Conifers, Gnetales, Dicotyledons, Monocotyledons

b) Gnetales, Dicotyledons, Monocotyledons, Conifers

c) Conifers, Monocotyledons, Dicotyledons, Gnetales

d) Conifers, Gnetales, Monocotyledons, Dicotyledons

26. Potato is respectively homologous & analogous to

a) Sweet potato & tendrils of Cucurbita

b) Tendrils of Cucurbita & sweet potato

c) Thorns of Bougainvillea & tendrils of Cucurbita

d) Sweet potato & wings of butterfly

27. Statement 1: Pouched mammals of Australia survived because of lack of competition

Statement 2: Continental drift has both positive & negative effect on population.

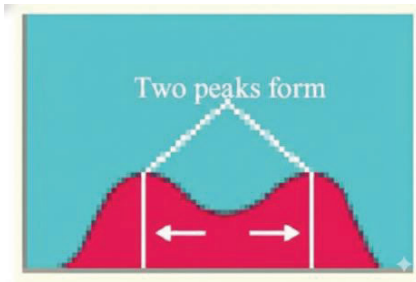
a) Both statement 1 & 2 are cor

b) Statement 1 is correct & 2 is incor

c) Statement 1 is incorrect & 2 is cor

d) Both the statements are incor

28. Observe the following diagrammatic representation of operation of natural selection on different traits. Here, Natural selection depicts



a) Stabilisation b) Directional c) Disruptive d) Cannot be depicted

Answer Key					
1. A.	**2.** B.	**3.** A.	**4.** A.	**5.** B.	**6.** A.
7. C.	**8.** C.	**9.** C.	**10.** B.	**11.** D.	**12.** B.
13. A.	**14.** A.	**15.** B.	**16.** D.	**17.** B.	**18. C.**
19. A.	**20.** A.	**21.** C.	**22.** A.	**23.** B.	**24.** A.
25. D.	**26. B.**	**27.** A.	**28.B.**		

II. Fill in the blanks: 1 Mark Each

(Conifers, Panspermia, Homo habilis, Divergent evolution, Chemical, Ichthyosaurs, Founder effect, Analogy, Embryological, Neanderthal)

1. Convergent evolution is indicated by ___
2. Adaptive radiation of marsupials of Australia indicates ___
3. If the allele frequency is very different in the new sample of population they become different species. This is called ___
4. ___ were group of plants that pre-dominated earth during Mesozoic era.
5. ___ was a land reptile that went back into water to evolve into fish-like reptiles.
6. ___ was believed to come from outer space that created life on earth.
7. Inorganic chemicals formed organic molecules which lead to first form of life. This was supported by ___ evolution.
8. Karl Ernst Von Baer disapproved ___ evidence for evolution.
9. ___ stage in human evolution used hides to protect their body and buried their dead.
10. The first Human - like being was ___ .

Answer Key		
1. Analogy	**2.** Divergent evolution	**3.** Founder effect
4. Conifers	**5.** Ichthyosaurs	**6.** Panspermia
7. Chemical	**8.** Embryological	**9.** Neanderthal
10. Homo habilis		

PART - B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each

Q1. Name any two theories that explain the origin of life.

Ans:

a. Panspermia theory: Suggests life came from outer space.

b. Chemical evolution theory: Life originated from inorganic molecules under primitive earth conditions.

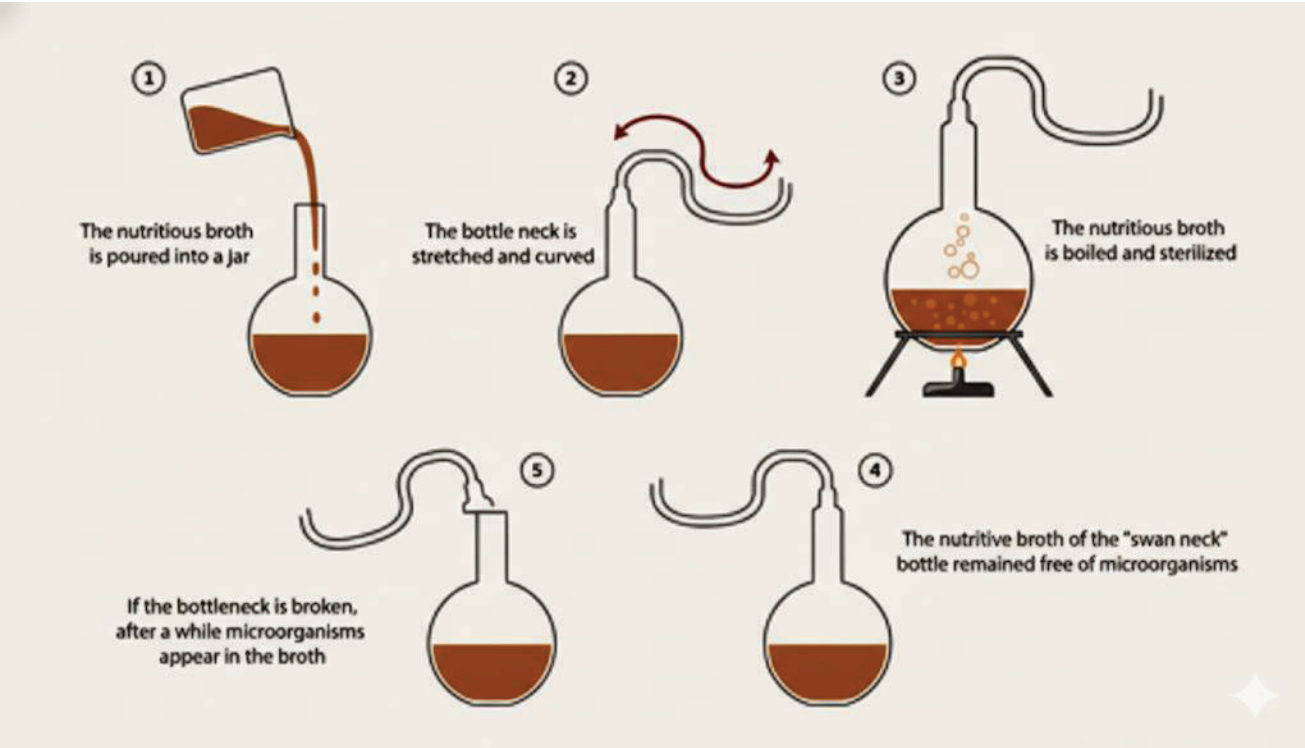
Q2. Write a shortnote on Big Bang theory.

Ans:

- The universe originated about 13.8 billion years ago.
-
- The universe expanded and cooled. · Water vapour, methane, carbon dioxide, and ammonia formed.

Q3. How could the experiment of Louis Pasteur dismiss theory of spontaneous generation of life?

Ans:



- Louis Pasteur showed life comes only from pre-existing life.
- Boiled nutrient broth in swan-neck flasks remained free of microbes.

c. When neck was broken, microbes appeared. · This disproved spontaneous generation theory.

Q4. How does Miller's experiment support the theory of chemical evolution?

Ans:

- Miller recreated primitive earth conditions in a closed flask.
- Used gases like methane, ammonia, hydrogen, water vapour.
- Electric discharge simulated lightning.
- After a week, found amino acids and organic molecules.
- Supported that life originated chemically.

Q5. List any four areas which provide evidences for evolution.

Ans:

- Palaeontology
- Comparative anatomy and morphology
- Embryology
- Molecular biology

Q6. What are fossils? How do they support evolution?

Ans:

- Fossils are impressions or remains of organisms from the past.
- Study of fossils shows gradual evolutionary changes.
- Carbon dating gives fossil age.
- Fossils of horses, man, elephants show evolutionary trends.

Q7. What are homologous organs? Give an example.

Ans:

- Organs with same structure but different functions.
- Indicate common ancestry.
- Example: Forelimbs of whale and human. [Image comparing homologous structures in forelimbs of human, whale, and bat]

Q8. What are analogousorgans? Give an example.

Ans:

- Organs with similar function but different origin.
- Show convergent evolution.
- Example: Wings of bat and butterfly.

Q9. What is convergent evolution? Give an example.

Ans:

- Evolution where different organisms develop similar traits.
- Due to similar environmental pressures.
- Example: Wings of bat and birds.

Q10. What is divergent evolution? Give an example.

Ans:

- Evolution where same structures evolve differently.
- Seen in homologous organs.
- Example: Forelimbs of human and cheetah.

Q11. Comment on the similarity between the thorn of Bougainvillea and tendril of Cucurbita with reference to evolution.

Ans:

- Both are homologous structures.
- Modified from stem, perform different functions.
- Indicate divergent evolution.

Q12. Analyze the evolutionary relationship between forelimbs of whales and human.

Ans:

- Both have same bones arranged similarly.
- Perform different functions (swimming vs. grasping).
- Indicate common ancestry (homologous organs).

Q13. Differentiate between homology and analogy.

Ans:

- Homology: Same origin, different function (e.g., bat's wing and human arm).
- Analogy: Different origin, same function (e.g., wings of bat and insect).

Q14. What is convergent evolution? Give an example of convergent evolution in plants and animals.

Ans:

- Convergent evolution: Similar traits evolve in unrelated groups.
- Animal example: Wings of birds and bats.
- Plant example: Spines of cactus and euphorbia.

Q15. Explain with the help of an example the type of evolution which is based on analogy.

Ans:

- Convergent evolution is shown by analogy.
- Example: Flippers of penguin and dolphin.
- Same function, different origin.

Q16. State the evolutionary relationship giving reasons between sweet potato and potato.

Ans:

- Both are analogous organs.
- Sweet potato is a root; potato is a stem.
- Same function of storage, different origin.

Q17. Mention the two key concepts of Darwinian theory of evolution.

Ans:

- Branching descent.
- Natural selection.

Q18. Genetic drift is a chance while gene flow is constant. Substantiate.

Ans:

- Genetic drift: Random changes in allele frequency.
- More effective in small populations.
-
-

Q19. Define the terms: a) Genetic drift b) Founder effect

Ans:

- Genetic drift: Change in allele frequency due to chance.
- Founder effect: New population formed by a few individuals leading to different allele frequency.

Q20. What is adaptive radiation? Give an example.

Ans:

- Adaptive radiation is the evolution of different species from a common ancestor in a given geographical area, with each species becoming adapted to a different ecological niche.
- Example: Darwin's finches in Galapagos Islands.

Q21. When more than one adaptive radiation occurs in an isolated geographical area it leads to convergent evolution. Give two examples.

Ans:

- Placental mammals of Australia.

- Australian marsupials show convergent evolution.

Q22. Give any two examples of natural selection by anthropogenic action.

Ans:

- Drug-resistant microbes.
- Pesticide-resistant insects.

PART - C

IV. Answer the following questions in 40-80 words each: 3 Marks Each:

Q1. What are homologous organs? Mention one example of homologous organs in plants and one in animals.

Ans: Homologous organs have same structure and origin but different functions. They indicate divergent evolution and common ancestry.

- Plant example: Thorns of Bougainvillea and tendrils of Cucurbita.
- Animal example: Forelimbs of whale and human.

Q2. What are analogous organs? Give one example of analogous organs in plants and one in animals.

Ans: Analogous organs have different origin but perform similar function. They indicate convergent evolution.

- Plant example: Potato (stem) and sweet potato (root).
- Animal example: Wings of bird and butterfly.

Q3. Differentiate between homologous and analogous structures. Give one plant and one animal example for each.

Ans:

- **Homologous:** Same origin, different function. Examples: Bougainvillea thorn and Cucurbita tendril (plant); human arm and whale flipper (animal).

- **Analogous:** Different origin, same function. Examples: Sweet potato and potato (plant); wings of bat and butterfly (animal).

Q4. Differentiate between divergent evolution and convergent evolution. Give one plant and one animal example for each.

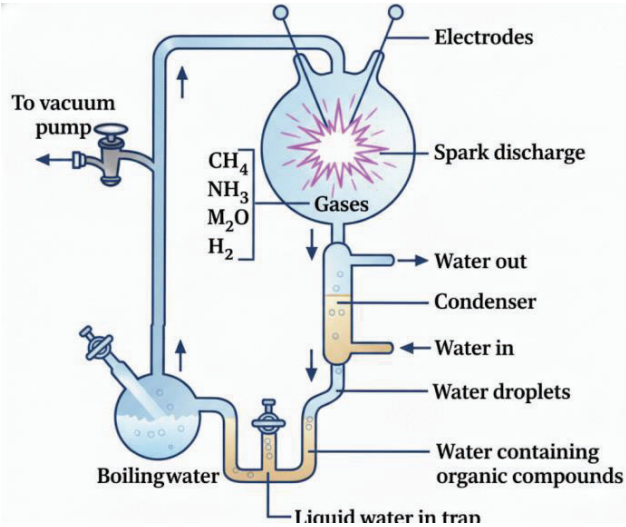
Ans:

- **Divergent evolution:** Same structure, different function. Examples: Bougainvillea thorn and Cucurbita tendril (plant); whale and cheetah forelimbs (animal).

- **Convergent evolution:** Different structure, same function. Examples: Cactus and euphorbia spines (plant); bat and bird wings (animal).

Q5. Draw a labelled diagram of Miller's experimental set-up.

Ans:



Q6. a) What were the different gases used by S.L.Miller in his experimental setup?
Ans: Methane, ammonia, hydrogen, and water vapour.

b) What conditions of primitive earth were recreated in the flask?
Ans: Electric discharge, high temperature, reducing atmosphere.

c) Write the conclusion drawn from this experiment.
Ans: Amino acids and organic molecules formed, supporting chemical evolution.

Q7. After industrialization in England, it was observed that white winged moth did not survive.
Ans:

a) Tree trunks became dark due to soot.
b) White moths were picked off by predators. Dark moths survived.
c) Lichens are indicators of air pollution.

Q8. "Darwin finches of Galapagos Islands represent one of the best examples for adaptive radiation." Substantiate.
Ans: Ancestral seed-eating finch evolved into multiple species, each with different beak adapted to type of food. This is the best example of adaptive radiation.

Q9. "Australian marsupials and Australian placental mammals explain convergent evolution and adaptive radiation." Justify the statement.
Ans: Marsupials evolved into different habitats. Placental mammals show similar body forms in similar niches. This shows both adaptive radiation and convergent evolution.

Q10. How is Darwin's concept of evolution different from that of Hugo de Vries' concept of mutation?
Ans: Darwin: Gradual evolution through natural selection.
Hugo de Vries: Sudden evolution via mutations (saltation).

Q11. State Hardy-Weinberg law. List four factors which disturb genetic equilibrium.
Ans: Allele frequency remains constant in absence of disturbances.
Disturbances: Mutation, gene flow, genetic drift, natural selection.

Q12.
a) State Hardy-Weinberg principle.
Ans: Gene frequency remains constant over generations in large, random mating population.

b) Define:

Ans:

i) Gene pool – Total genes in population.

ii) Genetic equilibrium – Stable allele frequency.

Q13. Define the terms

Ans:

a) Saltation: Large mutation causing sudden evolution.

b) Gene flow: Migration changes gene frequency.

c) Natural selection: Favourable traits increase in population.

Q14. Arrange the following ancestral forms of man in the order of their evolution:

Ans: Dryopithecus → Ramapithecus → Australopithecines → Homo habilis → Homo erectus → Neanderthal man

Q15. A gene locus has two alleles A & a. If the frequency of dominant allele A is 0.4, then what will be the frequency of homozygous dominant, heterozygous and recessive individuals in the population?

Ans:

- $p = 0.4, q = 0.6$
- Homozygous dominant (AA): $p^2 = 0.16$
- Heterozygous (Aa): $2pq = 0.48$
- Homozygous recessive (aa): $q^2 = 0.36$

PART- D

V. Answer the following questions in 200–300 words each: 5 Marks

Q1. Represent Miller's experiment with the help of a neat labelled diagram. Write the conclusion that can be drawn from the experiment.

Ans: Miller created a closed glass flask system simulating early Earth.

- Gases: Methane (CH_4), Ammonia (NH_3), Hydrogen (H_2), Water vapour (H_2O).
- Electrodes provided electric discharge to mimic lightning.
- Condenser cooled gases, and a trap collected products.
- After a week, found amino acids and organic molecules.

Conclusion: Life's building blocks can form from inorganic compounds. Supports chemical evolution.

Q2. Explain evolution by natural selection by taking an example of white-winged moths and dark-winged moths of England in pre- and post-industrialization period.

Ans:

- **Pre-industrialization:** White moths survived as tree trunks were light.
- **Post-industrialization:** Soot blackened trees; white moths visible and eaten. Dark moths camouflaged, survived better.
- Natural selection favoured dark moths.
- Evolution occurred through survival advantage of certain variants.

Q3. How does comparative anatomy and morphology act as an evidence for evolution? Explain with the help of suitable examples.

Ans:

- **Homologous organs:** Same structure, different function. Example: Human arm and whale flipper.
- **Analogous organs:** Different structure, same function. Example: Wings of butterfly and bird.
- Comparative anatomy shows common ancestry and adaptive features.

- Supports Darwin's concept of descent with modification.

Q4.

a) State Hardy-Weinberg principle.

Ans: Allele frequencies remain constant if population is large, random mating, no mutation/migration/selection.

b) Explain any four factors that affect Hardy-Weinberg equilibrium.

Ans:

1. Gene migration – Adds or removes alleles.
2. Genetic drift – Random changes in small populations.
3. Mutation – Introduces variation.
4. Natural selection – Favors advantageous traits.

Q5. Mention the various stages of human evolution with brain capacity.

Ans:

- Dryopithecus and Ramapithecus: Ape-like, man-like respectively.
- Australopithecines: Upright posture, human-like skull.
- Homo habilis: Brain capacity 650–800 cc, tool user.
- Homo erectus: 900 cc, used fire.
- Neanderthal: 1400 cc, buried dead.
- Homo sapiens: 1450 cc, originated in Africa, spread globally.

Chapter 7

Human Health & Disease

TABLE OF CONTENTS

7.1. COMMON DISEASES IN HUMANS

7.2. IMMUNITY

7.3. AIDS

7.4. CANCER

7.5. DRUGS AND ALCOHOL ABUSE

THEORY

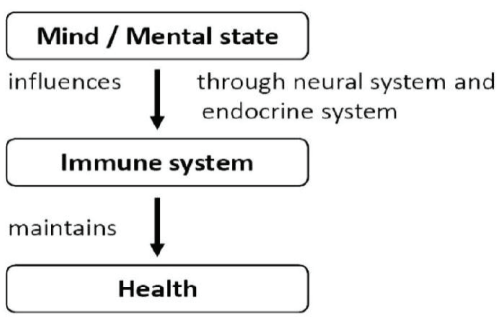
INTRODUCTION :

Good humor hypothesis of health :

- **Given by:** Early Greeks like **Hippocrates** as well as **Indian Ayurveda system of medicine.**
- **Health:** state of body and mind, where there was a balance of certain 'humors'.
- Persons with **'blackbile'** belonged to hot personality and would have fevers.
- **Disproved by:** The discovery of blood circulation by **William Harvey** using experimental method and the demonstration of normal body temperature in persons with 'blackbile' using thermometer.

Modern view about health :

- Health does not simply mean "absence of disease" or "Physical fitness."
- **Health :** state of complete physical, mental and social well-being.



Benefits of being healthy:

- Efficiency at work ↑→ Productivity ↑→ Economic prosperity
- Longevity ↑
- Infant and maternal mortality ↓

Very important to maintain good health :

- Balanced diet

- Personal hygiene
- Regular exercise (Yoga etc)

Necessary for achieving good health :

- Awareness about diseases and their effect on different body functions.
- Vaccination (immunisation) against infectious diseases.
- Proper disposal of wastes.
- Control of vectors.
- Maintenance of hygiene in food and water resources.

Health is affected by :

1. **Genetic disorders:** Deficiencies with which a child is born and deficiencies/defects which the child inherits from parents from birth
2. **Infections**
3. **Life style:**
   - Food and water we take
   - Rest and exercise we give to our bodies
   - Habits that we have or lack.**e.g.** Drug and alcohol abuse also affect our health adversely.

DISEASE

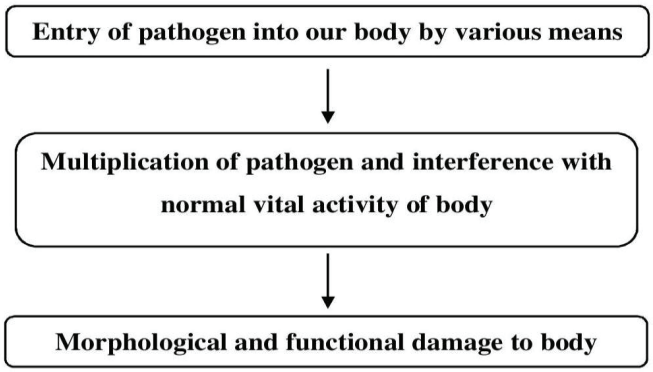
- Functioning of one or more organs or systems of the body is adversely affected,leads to various signs and symptoms is called **disease.**
- Characterised by appearance of various signs and symptoms.

Diseases can be broadly grouped into infectious and non infectious :

Infectious disease	Non-infectious diseases
The diseases which are easily transmitted from infected person to another are called infectious diseases.	The diseases which are not transmitted infected person to another are called non-infectious diseases.
These diseases are not confined to a person, they spread	These diseases are confined to a person, they don't spread

Pathogens

- Pathogens are disease causing organisms (belonging to bacteria, viruses, fungi, protozoans, helminths, etc.).
- Most parasites are therefore pathogens as they cause harm to the host by living in (or on) them.
- Pathogens have to adapt to life within the environment of the host.
- **e.g.** The pathogens that enter the gut must know a way of surviving in the stomach at low pH and resisting the various digestive enzymes.



7.1. Common Diseases In Humans

Type of disease	Examples
Bacterial	Typhoid, Pneumonia, etc
Viral	Common cold, etc
Protozoan	Malaria, Amoebiasis (Amoebic dysentery), etc
Helminthic	Ascariasis, Elephantiasis (Filariasis), etc
Fungal	Ringworms, etc

1. Typhoid(Enteric fever)

- **Pathogen :** Salmonella typhi (a bacterium)
- **Mode of transmission:-** Pathogens generally enter the small intestine through **contaminated food** and **water** and migrate to other organs through blood.
- **Infected organ :-** small intestine
- **Common symptoms :**
  - **a)** Sustained high fever (39° to 40°C)
  - **b)** Loss of appetite and weakness
  - **c)** stomach pain, constipation, headache
  - **d)** Intestinal perforation and death may occur in severe cases.
- Typhoid fever could be confirmed by **Widal test.**
- **A classical case of medicine –**

  Mary Mallon nicknamed **Typhoid Mary** was a cook by profession and was a typhoid carrier who continued to spread typhoid for several years through the food she prepared.

2. Pneumonia

- **Pathogen :** Streptococcus pneumoniae and Haemophilus influenzae (bacteria).
- Pathogens infects the alveoli (air filled sacs) of the lungs. → the alveoli get filled with fluid leading to severe problems in respiration.
- **Mode of transmission:-** A healthy person acquires the infection by inhaling the droplets/aerosol released by an infected person or even by sharing glasses and utensils with an infected person.

- **Infected organ:-** Pathogens infects the alveoli (air filled sacs) of the lungs, the alveoli get filled with fluid leading to severe problems in respiration.
- **Common symptoms :**
- Fever with chills, cough and headache, etc.
- In severe cases, the lips and finger nails may turn gray to bluish in colour.

1. Common Cold

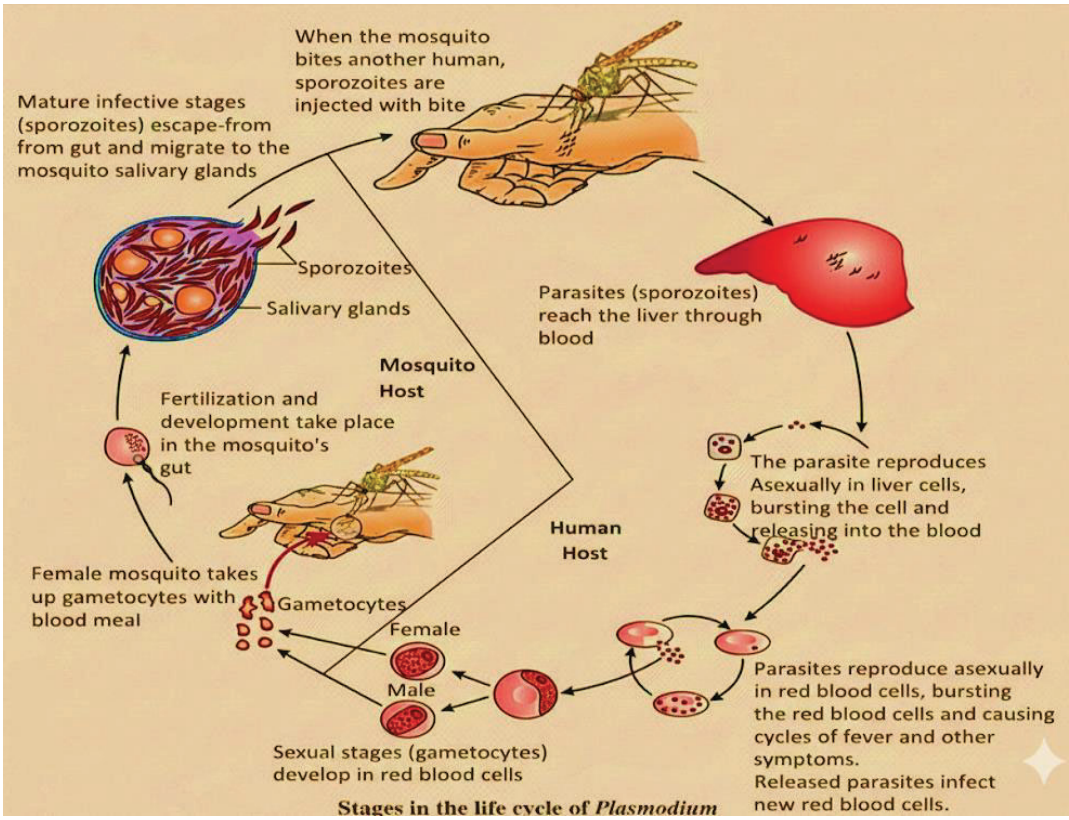
- **Pathogen :** Rhino viruses
- **Mode of transmission:-** Droplets resulting from cough or sneezes of an infected person are either inhaled directly or transmitted through contaminated objects such as pens, books, cups, doorknobs, computer keyboard or mouse, etc., and cause infection in a healthy person.
- **Infected organ :-** The They infect the nose and respiratory passage but not the lungs.
- **Common symptoms :**
- Nasal congestion and discharge, sore throat, hoarseness, cough, headache, tiredness, etc.
- Usually last for 3-7 days.

2. Malaria

- **Pathogen :** Different species of Plasmodium (*P*. vivax, *P*. malaria and *P*. falciparum) are responsible for different types of malaria.
- Of these, malignant malaria caused by Plasmodium falciparum is the most serious one and can even be fatal.
- **It requires two hosts (Digenetic)** – human(secondary host) and mosquitoes(primary host) - to complete its life cycle.
- The female Anopheles mosquito is the vector (transmitting agent) too.

Life cycle of Plasmodium:

- *Plasmodium* enters the human body as sporozoites (infectious form) through the bite of infected **female *Anopheles* mosquito.**
- Initially the parasite multiply in liver cells asexually (**Exo-erythrocycle)**. Then attack RBC resulting in rupturing of RBC (**Erythrocytic cycle).**
- The ruptured RBCs release a toxic substance called **haemozoin**. The haemozoin is responsible for chill and high fever that persists for three to four days.
- When a female Anopheles mosquito bites an infected person, these parasites enter the mosquito's body as **gametocytes** and undergo further development.
- The parasites multiply sexually within mosquito to form **sporozoites** that are stored in their salivary glands.
- When the carrier mosquitoes bite a human the sporozoites are introduced into human body and repeat the cycle once again.



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3. Amoebiasis (Amoebic Dysentery)

- **Pathogen :** Entamoeba histolytica (a protozoan)
- **Mode of transmission:-**

1. Houseflies act as mechanical carriers and serve to transmit the parasite from faeces of infected person to food and food products, thereby contaminating them.
2. Drinking water and food contaminated by the faecal matter are the main source of infection.

- **Infected organ:-** large intestine
- **Common symptoms :**
- Constipation, abdominal pain and cramps, stools with excess mucous and blood clots, etc

4. Ascariasis

- **Pathogen :** Ascaris (an intestinal parasite)
- **Mode of transmission:-**

1. The eggs of the parasite are excreted along with the faeces of infected persons which contaminate soil, water, plants, etc.
2. A healthy person acquires this infection through contaminated water, vegetables, fruits, etc.

- **Infected organ :-** Small intestine
- **Common symptoms:**
- To Internal bleeding, muscular pain, fever, anaemia and blockage of the intestinal passage, etc.

5. Elephantiasis(Filariasis)

- **Pathogens :- Wuchereria bancrofti** and **Wuchereria malayi** (filarial worms).

- **Mode of transmission:-** The pathogens are transmitted to a healthy person through the bite by the female culex mosquito.
- **Infected organ:-** lymphatic vessels of the lower limbs , genital organs.

Common symptoms :

- Filarial worms live in lymphatic vessels (usually of lower limbs).It causes chronic inflammation of the organs in which they live for may years.
- Limbs and genital organs may be deformed.

6. Ringworms

- **Pathogens:** Many fungi belonging to the genera **Microsporum**, **Trichophyton** and **Epidermophyton**.
- **Mode of transmission:-** From soil or by using towels,cloths ,com etc. eat and moisture help fungi to grow which makes them thrive in skin folds such as those in the groin or between the toes.
- **Infected organ:-** Skin,nails,folds of skin,groin, scalp

Diagram showing inflammation in one of the lower limbs due to elephantiasis

Diagram showing ringworm affected area of the skin

Common symptoms:

1. Appearance of dry, scaly lesions on various parts of the body such as skin, nails and scalp
2. These lesions are accompanied by intense itching.

Prevention and Control of Infectious Diseases

1. Maintenance of personal and public hygiene:

A. Measures for Personal Hygiene –

- Keeping the body clean.
- Consumption of clean drinking water, food, vegetables, fruits, etc.
- Good exercise
- Adequate rest ect

B. Measures for Public Hygiene –

- Proper disposal of waste and excreta.
- Periodic cleaning and disinfection of water reservoirs, pools, cesspools(septic tanks) and tanks.
- Standard practices of hygiene in public catering.

Note : These measures are particularly essential where the infectious agents are transmitted through food and water such as typhoid, amoebiasis and ascariasis.

- In cases of air-borne diseases such as pneumonia and common cold, in addition to the above measures, close contact with the infected persons or their belongings should be avoided.

C. For vector borne diseases

- Eliminating the vectors and their breeding places.
- Avoiding stagnation of water in and around residential areas.
- Regular cleaning of household coolers.
- Use of mosquito nets.
- Introducing fishes like **Gambusia** in ponds that feed on mosquito larvae.
- Spraying of insecticides in ditches, drainage areas and swamps, etc
- Providing doors and windows with wire mesh to prevent the entry of mosquitoes.
- These precautions are useful for vector borne diseases like dengue,Chikungunya, malaria and filariasi etc.

Note: Such precautions have become more important especially in the light of recent widespread incidences of the vector-borne (Aedes mosquitoes) diseases like dengue and chikungunya in many parts of India.

2. **Compulsory isolation** from infected person with infectious diseases.
3. **Immunization/Vaccination**
   - **a.** By massive immunization there is complete eradication of disease like **smallpox.**
   - b. Diseases like **polio, diphtheria, pneumonia** and **tetanus** have been controlled in large extent.
4. **Antibiotics** and other drugs are used to treat infectious diseases
5. **Awareness** should be made about infectious diseases ,their mode of transmission and preventive measures through media ,banners

7.2. Immunity

- The overall ability of the host to fight the disease-causing organisms.
- Study of immunity is called **immunology.**
- **Immunity is of two types:** 1.Innate immunity 2.Aquired immunity

INNATE IMMUNITY

- The non-specific immunity present at the time of birth is called **innate immunity.**
- It is also called as **natural immunity.**
- The innate immunity remains throughout life.
- Innate immunity is accomplished by providing different types of barriers to the entry of the foreign agents into our body.

Innate immunity consists of four types of barriers :

(1) Physical/Anatomical Barrier (2) Physiological Barrier

(3) Cellular Barrier (4) Cytokine Barrier

1. **Physical/Anatomical Barrier :-**

- These are the structural and mechanical barriers present on the surface of the body.
- It is made up of two parts :
  a. **Skin :** Main barrier which prevents entry of the micro organisms into our body
  b. **Mucosa** : Mucus coating of epithelium lining of the respiratory, gastrointestinal and urogenital tracts also

  help in trapping microbes entering our body.

2. **Physiological Barrier**

- Some **physiological secretions** of body create adverse environment for growth of microorganisms.
- Some of them are ;
  a. Acid in the stomach,
  b. Saliva in the mouth,
  c. Tears from eyes all prevent microbial growth.

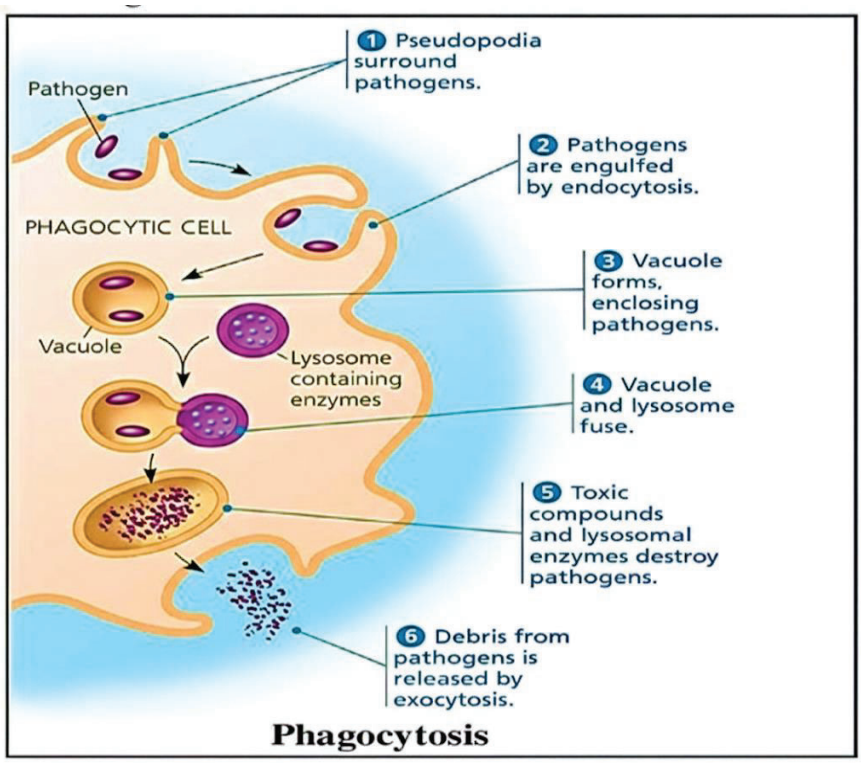
3. **Cellular Barrier**

- These are non-specific internal defence barriers present in the body.They form the **second line of defence.**
- Involvement of two types of cells :

(A) Phagocytic Cells : e.g.

- **In blood :** Polymorpho-nuclear leukocytes (PMNL- neutrophils), Monocytes
- **In tissues :** Macrophages

(B) Non-Phagocytic Cells : e.g. Natural Killer cells



4. **Cytokine Barrier**

- Cytokines are a type of proteins which form a special line of defence.e.g. Interferons, etc.
- These forms **second line defence**

- **Interferons:-** These are **antiviral Proteins** secreted by virus-infected cells
- They Protect non-infected cells from further viral infection

ACQUIRED IMMUNITY

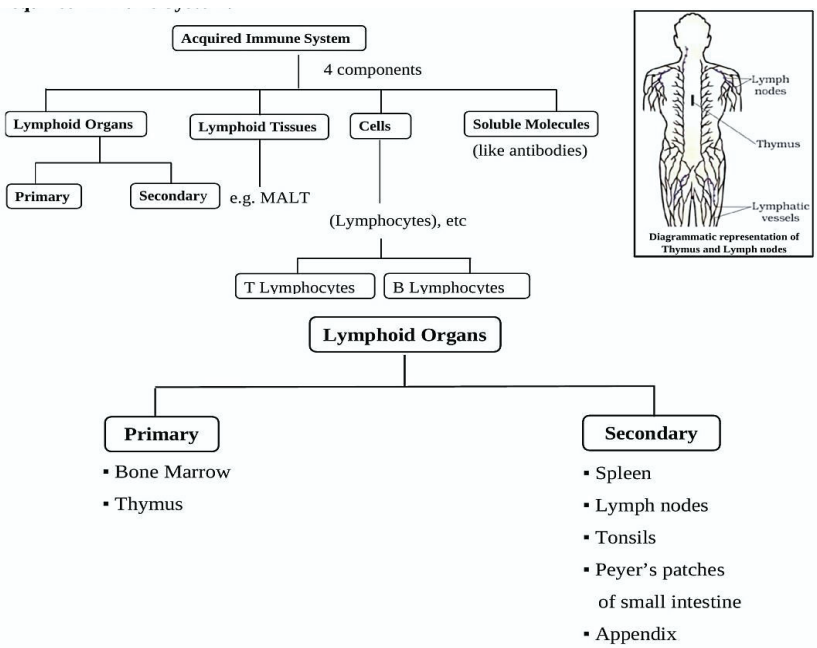
- They Protect non-infected cells from further viral infection
- It is the immunity acquired by individual after birth during in life time to get protection against harmful **microbes.**
- It is also called **adaptive immunity or specific immunity.**
- Acquired immunity was **evolved in higher vertebrates.**
- It is effective against specific pathogen and does not have a generalized ef
- It forms **third line of defence**
- **Characteristic features of acquired immunity:-**
- **Specificity:** Pathogen specific type of defence
- **Diversity:** Recognition of vast variety of pathogens (antigens)
- **Discrimination between self cells & foreign organisms (e.g. pathogens/foreign molecules):** Present
- **Memory:** Present

3R's **Recognition** ⟶ **Response** ⟶ **Remember**

Role of memory:

Encounter of body with a pathogen (antigen)	Immune response by body	Intensity of immune response
First	Primary	Low
Subsequent	Secondary/Anamnestic	High (due to memory of first encounter of body with same pathogen)

Acquired immunity is carried out by following components



1. **Lymphoid organs :-**

- These are the special type of organs present in the body, where origin, maturation and proliferation of lymphocytes occurs .
- There are two types of lymphoid organs namely; 1.Primary lymphoid organs 2.Secondary lymphoid organs.

A. **Primary lymphoid organs:-**

- The primary lymphoid organs are **bone marrow** and **thymus.**
- Here immature lymphocytes originate, mature, Proliferate and differentiate into antigen-sensitive lymphocytes.
- Mature lymphocytes migrate to secondary lymphoid organs.

a. Bone Marrow

- Main lymphoid organ where all blood cells including lymphocytes are produced

b. **Thymus**

- A lobed organ located near the heart and beneath the breastbone
- It is quite large at the time of birth but keeps reducing in size with age and by the time puberty is attained it reduces to a very small size. Both bone-marrow and thymus provide micro-enviroments for the development and **maturation of T-lymphocytes.**

B. Secondary lymphoid organs:-

- Secondary lymphoid organs include the spleen, lymph nodes, tonsils, Peyer's patches of the small intestine and appendix.
- The secondary lymphoid organs are provide the sites for interaction of lymphocytes with the antigen, which then Proliferate to become effector cells.

a. **Spleen**

- It is a large bean shaped organ
- It Mainly contains **lymphocytes** and **phagocytes**
- It acts as a filter of the blood by trapping **blood-borne microorganisms**
- It also has a large reservoir of **erythrocytes or blood bank.**

b. **Lymph nodes**

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

c. **MALT: (Mucosa Associated Lymphoid Tissue)**

- Lymphoid tissue located within the lining of the major tracts (respiratory, digestive and urogenital tracts)
- Constitutes about **50 per cent** of the lymphoid tissue in human body.

2. **Lymphocytes**

- These are the WBC cells originate from the bone marrow.
- About 50% of lymphocytes reach the thymus gland and differentiate into **T-lymphocytes.**
- Remaining 50% of lymphocytes do not reach thymus gland but differentiate into **B-lymphocytes.**

Mention any four differences between B-lymphocytes and T-lymphocytes.

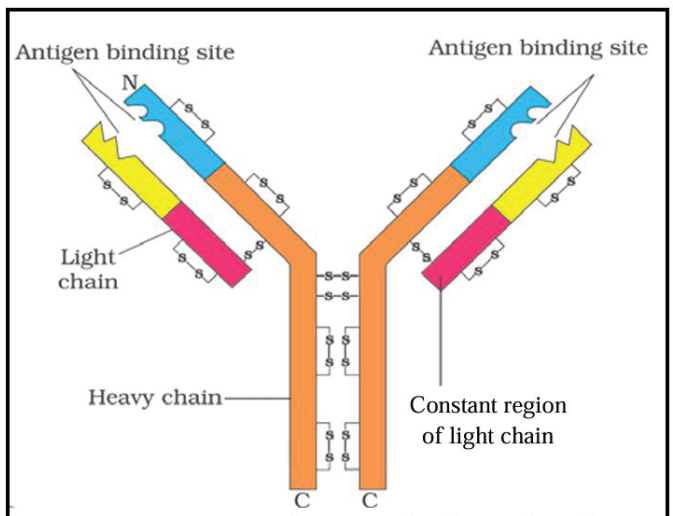
B-lymphocytes	T-lymphocytes
1.Produced and matured in Bone-marrow	1.Produced in bone-marrow,but matured in thymus
2.These cells are responsible for Humoral immunity	2.These cells are responsible for Cell mediated immunity
3.They produce antibodies	3.They do not produce antibodies
4.plasma cells produce antibodies that migrate to site of Infection and destroy the pathogen.	4.killer-T cells move to the site of Infection and kill the pathogen by secreting perforin or cytolysin.
7.Life span is short	5.Life span is long

3. **Antibody :-**It is a 'Y' shaped protein molecule which is produced in response to antigenic stimulation.

- It is belongs to the group of **'immunoglobulin '**

Structure of antibody

- Each antibody molecule has four peptide chains, two small called **light chains** and two longer called heavy **chains.**Hence an antibody is represented as $\mathbf{H_2L_2}$**.**
- The long chains have high molecular weight and short chains have low molecular weight.
- Each **'H'chain** has 400 amino acids and **'L' chain** has 200 amino acids.
- The four chains are held together by disulphide (-S-S-) bonds.
- Each chain has two regions called **V** (Variable) region and **C** (Constant) region.
- The amino acid sequence in the variable region vary in different antibodies where as it remains the same in the constant regions in the different antibodies.
- Each antibody has two antigen binding sites
- Different types (classes) of antibodies are produced in our body : IgG, IgA, IgM, IgD, and IgE.



Structure of an antibody molecule

4. **Antigen :-**It is a protein or polysaccharide which can stimulate the body cells to produce specific antibody.These are also called immunogens.

These antigens are located on the outer membranes of microbes or cells.

The membrane molecules that help in recognising the normal cells of the body by the immune system are called self antigens. These cells are not attacked by the defence system.

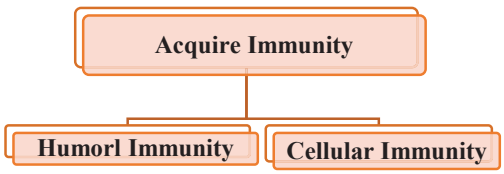
The region of antigen that reacts with antibody to produce immune response is called **epitope.**

Differences between antigen and antibody

	Antigen	Antibody
1	It is a foreign substance that enters the body and induce the formation of antibodies.	It is the specific protein substances formed in the body in response to a particular antigen.
2	It is a protein/polysaccharide/complex lipid	It is always a protein molecule.
3	It is Present on cell surface (RBC)	It is Present in the plasma
4	It is also called Immunogens.	It also called Immunoglobulin.

Types of Acquired Immunity

1. On the basis of involvement of type of lymphocytes:



1. Humoral immunity:

- The immune response by the B-cells by production of antibody in the body fluids is called humoral immunity. It is also called antibody mediated immunity.
- The antibodies produced by **B-lymphocytes** are responsible for **humoral immunity.**
- When B-cells are exposed to an antigen, some of them differentiate into plasma cells.
- The plasma cells produce antibodies. These antibodies destroy the antigen. This is called **primary immune response**.
- The undifferentiated B-cells become **memory cells.**
- The memory cells show **secondary immune response.**
- The memory cells retain the immune response throughout the life time.

2. Cell-mediated immunity (CMI):

- The immunity in which the body fights against the antigens by activated T-cells (cytotoxic T cells) is called cell mediated immunity.
- **T-lymphocytes** are responsible for cell mediated immunity.
- When an antigen enters the body the activated T-cell produce Tc-cells, T_H-cells, Ts-cells and memory T-cells.
- The **Killer T-cells** (Cytotoxic T-cells) migrates to the site of infection. They get attached to the antigen directly and destroy them by producing chemicals like perforin.
- T_H-cells activates T_C cells. They also activate B -cells to produce antibodies.
- Ts-cells suppress the activity of Tc-cells and T_H cells and also B-cells after the destruction of pathogens.
- The memory T-cells show **secondary immune response.**

Note:-Transplantation/Grafting

★very often ,when some human organs like heart ,eye ,liver ,kidney ,eye ,liver,kidney fail to function satisfactorily, transplantation is the only remedy to enable the patient to live a normal life.

★ **Why is that the organs cannot to be taken from just anybody?**

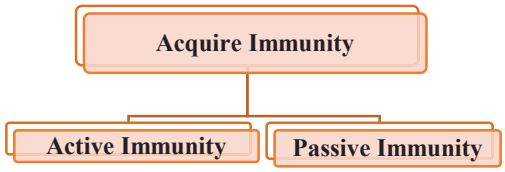
★The body is able to differentiate 'self' and 'nonself'.Grafts from just any source and animal,another primate, or any human beings cannot be made since the grafts would be rejected sooner or later.

★ The cell-mediated immune response is responsible for the graft rejection.

★ Tissue matching, blood group matching are essential before undertaking any graft or transplant.

★Even after grafting/transplantation the patient has to take immuno-suppressant (eg., Cyclosporin- A) throughout the life.

2. On the basis of participation of immune system of host:



a. Active immunity:

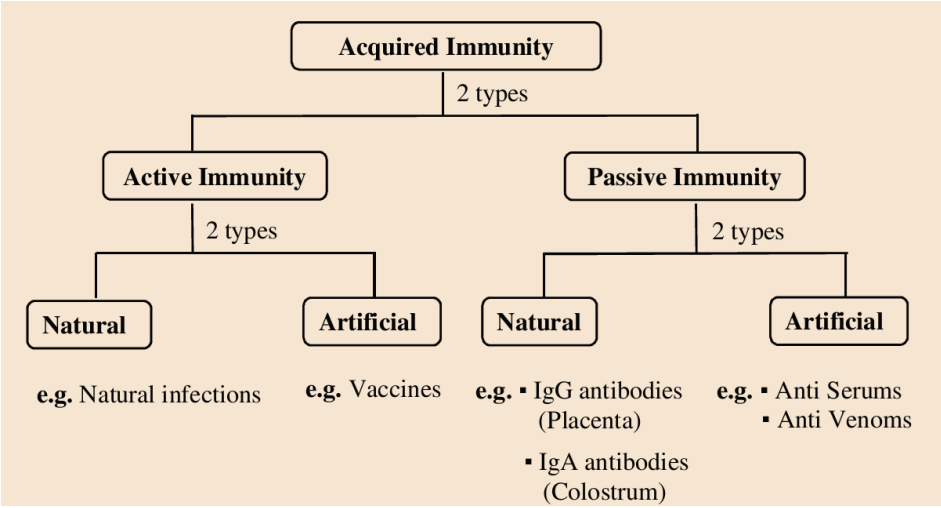
- The immunity developed by the host body when exposed to antigens in the form of **living or dead microbes or other proteins,** is called **natural active immunity.**
- Active immunity is **slow** and **takes time** to give its full effective response.
- The immunity obtained artificially through **vaccination** is called **artificial active immunity.**
- Injecting the microbes during immunization or infectious organisms gaining access into body during **natural infection** induce active immunity.

b. Passive immunity:

- Transfer of **ready-made antibodies** directly to the **host body** to protect against foreign agents, is called natural passive immunity.
- **E.g.** Transfer of antibodies through placenta and breast milk from mother to child
- **Colostrum:** The yellowish fluid secreted by mother during the initial days of lactation is called Colostrum. It has abundant **antibodies-IgA** to protect the infant.
- So mother's milk is very **essential** for the newborn infant.
- The foetus receives **antibodies**- IgG from their mother, through the **placenta** during pregnancy. When an individual is artificially injected with antibodies from animal or humans is called **artificial passive immunity.**

Differences between Active Immunity and Passive Immunity:

Active immunity	Passive immunity
It is the immunity developed in host organism on exposure to living or dead microbes or antigenic proteins.	The immunity developed in host organism due to transfer of readymade antibodies.
It is slow.	It is fast
It remains for a long period.	It is very short lived.
It forms memory cells.	It does not form memory cells.
Ex: Injecting microbes during immunization or natural infections induce active immunity	**Ex:** Transfer of antibodies from mother to child during breast feeding or though placenta.



Differences between T lymphocytes and B lymphocytes

Innate immunity	Acquired immunity
It is present from birth and is inherited from parents.	It is not present from the birth.
It is non-specific.	It is pathogen specific.
The various physical, physiological, cellular, cytokine barriers are the basis of innate immunity.	The memory cells formed by B and T-cells are the basis of acquired immunity.
The innate immunity remains throughout life.	The acquired immunity can be short-lived or life long.

VACCINATION AND IMMUNISATION

a. **Active immunization (Vaccination):-**The process of introducing a small amount of **antigen** or **inactivated/weakened pathogen** (vaccine) is called **vaccination**.

Principle of vaccination:

- The principle of immunization or vaccination is based on the property of 'memory' of the immune system.
- The antibodies produced by the body against these antigens would neutralize the pathogenic agents (bacteria, viruses)during actual infection.
- The vaccines also **generate memory - B and T-cells** that recognize the pathogen quickly on subsequent exposure and decrease the invaders with a massive production of antibodies.

b. **Passive Immunization :** Introduction of pre-formed antibodies or antitoxin directly to the body to get quick immune response is called **immunisation.**

- **Eg;** In tetanus and snakebites, the injection given to the patients, contain preformed antibodies against the tetani and snake venom.

- Recombinant DNA technology has allowed the production of antigenic polypeptides of pathogen in bacteria or yeast.
- Vaccines produced using this approach allows large scale production and hence greater availability for immunization, **e.g.,** hepatitis B vaccine produced from yeast.

VACCINE

- A preparation of antigenic proteins of pathogen or inactivated/ weakened pathogen.
- Hepatitis B vaccine has been produced from yeast with the help of recombinant DNA technology.

ALLERGIES

- Exaggerated response of the imzmune system to certain antigens present in environment.
- **Examples of allergies:-** Bronchial asthma, hay fever, anaphylactic shock, etc.
- **Allergens :-** The substances to which such an immune response is produced are called **allergens.**
- **Ex:-** mites in dust, pollens, animal dander,fur etc.
- **For determining the cause of allergy**, the patient is exposed to or injected with very small doses of possible allergens, and the reactions studied.
- **Symptoms of allergic reactions:-** Sneezing, watery eyes, running nose and difficulty in breathing, etc.
- The 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.
- **Treatment:-** The use of drugs like **anti-histamine**, **adrenalin** and **steroids** quickly reduce the symptoms of allergy.

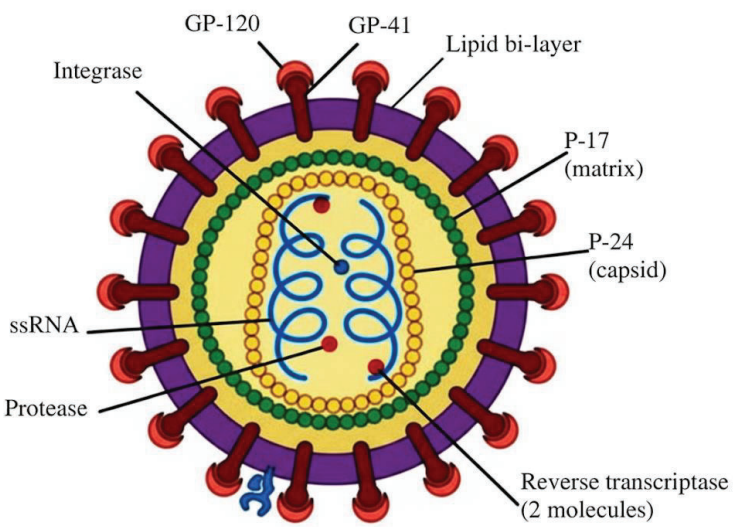
  Key Note :-Modern day life style and protected environment provided early in life result in low immunity and more sensitive to allergens. So, many children in metro cites suffer from allergies and asthma.

Autoimmunity

- In higher vertebrates, memory-based acquired immunity evolved based on ability to differentiate foreign organisms from self-cells.
- Sometimes, due to genetic and other unknown reasons, the body attacks self-cells. This results in damage to the body and is called **auto-immune disease.**
- **Example:-** Rheumatoid arthritis which affects many people in our society is an auto-immune disease.

7.3. AIDS(Acquired Immuno Deficiency Syndrome)

- It is the deficiency of immune system is acquired during the lifetime of an individual: AIDS is not a congenital disease.
- **'Syndrome'** means a **group of symptoms.**
- It is caused by the **Human Immuno deficiency Virus (HIV)**, a member of a group of viruses called **retrovirus**, which have an envelope enclosing the **RNA genome.**
- AIDS was first reported in **1981** and in the last **25 years**, it killed more than **25 million** persons.



Structure of HIV

Transmission of HIV-infection generally occurs :

- By sexual contact with infected person.
- By transfusion of contaminated blood and blood products.
- By sharing infected needles as in the case of intravenous drug abusers.
- From infected mother to her child through placenta.

People who are at high risk of getting this infection includes :

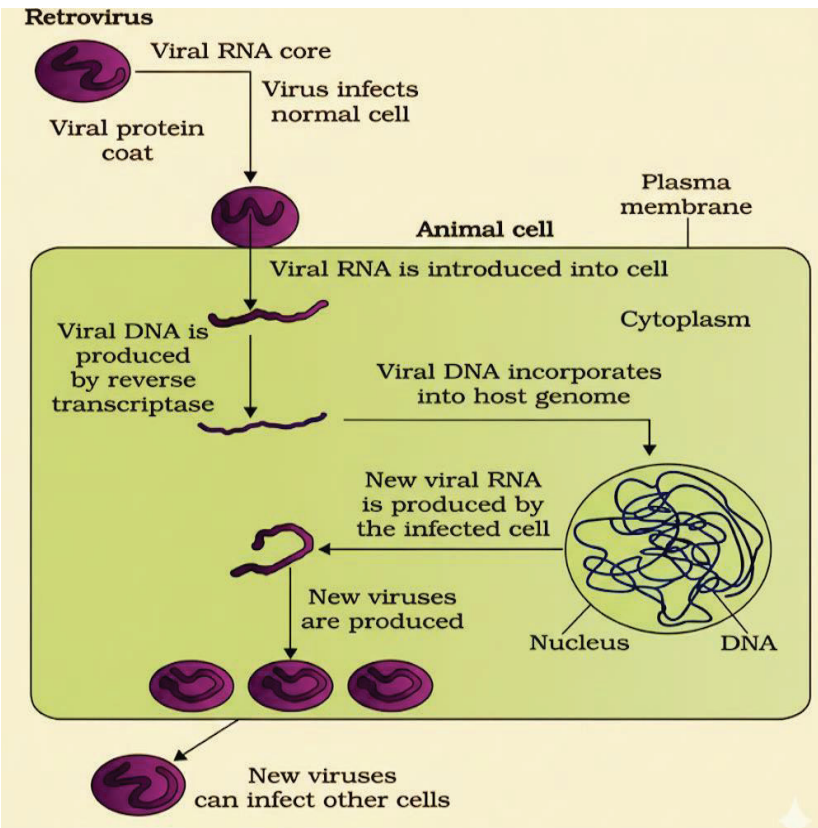
- Individuals who have multiple sexual partners.
- Individuals who required repeated blood transfusions.
- Drug addicts who take drugs intravenously.
- Children born to an HIV infected mother.

HIV cannot be transmitted by the following

- By shaking hands with AIDS patients.
- By hugging with each other.
- By sharing plates, tumblers or other utensils.
- By using public bath rooms, toilets and swimming pools.
- By mosquitoes bite.

Note :- HIV/AIDS is not spread by mere touch or physical contact; it spreads only through body fluids. It is, hence, imperative, for the physical and psychological well-being, that the HIV/AIDS infected persons are not isolated from family and society.

Replication of HIV:



Replication of retrovirus

- After getting into the body of the person, the virus enters into **macrophages** ,where viral RNA gets converted into **viral DNA with the help of the enzyme reverse transcriptase.**
- The viral DNA gets incorporated into host cell's DNA and directs the infected cells to produce **virus particles.**
- The macrophages continue to produce virus and in this way **acts like a HIV factory.**
- Simultaneously, HIV enters into **helper T-lymphocytes** ($\mathbf{T_H}$), replicates and produce **progeny viruses**.
- The progeny viruses released in the **blood attack other helper T-lymphocytes.** This is repeated leading to a progressive **decrease** in the number of **helper T lymphocytes** in the body of the infected person.

HIV enters 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 lymphocytes) → Replicates & produce progeny viruses → Attack other T_H cells → T_H cells decrease → Weaken immunity.

- Due to decrease in the number of T-lymphocytes the person starts suffering from other infections caused by **bacteria, viruses ,fungi** and even parasites like **Toxoplasma.**
- The patient becomes so immuno-deficient that he/she is unable to protect himself/herself against these infections.
- There is always a time-lag between the infection and appearance of AIDS symptoms. This period may vary from a **few months** to many years (**usually 5-10 years**).

Symptoms :-

- Bouts of Fever
- Diarrhoea
- Weight loss

Diagnostic test for AIDS :-

- A widely used diagnostic test for AIDS is **enzyme linked Immuno-Sorbent Assay (ELISA).**

Prevention of AIDS: AIDS has no medicines to cure hence prevention is the best option. Some of the preventive measure of AIDS are ;

- Avoiding sex with unknown / multiple partners.
- By using condoms.
- Use of sterilized needles and syringes in the hospitals.
- Avoiding the use of razors and blades used by others.
- Avoiding blood transfusion from HIV positive persons.
- Use of sterilized needles for tattooing and punching of ear and nose.
- Avoiding pregnancy if one is HIV positive.
- By educating people and creating awareness among the community.

Treatment of AIDS :- Some of the drugs used for the treatment of AIDS such as Anti-retroviral drugs like **Zudovidine, Azidothymidone (AZT), Dideoxyinosine (DDT** etc.

Organizations concerned with the control of AIDS

- **NACO** (National AIDS Control Organization) and Non-governmental organization **(NGOs)** are doing a lot to educate people about AIDS.
- Infection with HIV or having AIDS is something that should not be hidden – since then, the infection may spread to many more people.
- WHO has started a number of programmes to prevent the spreading of HIV infection.
- **WHO** has started a number of programmes to prevent spreading of HIV infection. They are
  1. Making blood (from blood banks) safe from HIV
  2. Ensuring the use of only disposable needles and syringes in the hospitals and clinics.
  3. Free distribution of condoms
  4. Controlling drug abuse
  5. Advocating safe sex
  6. Promoting regular check-ups for HIV in susceptible populations.
- HIV / AIDS infected people need help and sympathy instead of being shunned by society.
- It can only be tackled by the society & medical fraternity to prevent the spread of the disease.

7.4. Cancer

- The uncontrolled cell division leads to the formation of undifferentiated mass of cells or tumor is called **cancer.**
- Study of cancer is called **Oncology.**
- In our body, cell growth and differentiation is highly controlled and regulated. In cancer cells, there is breakdown of these regulatory mechanisms.
- Normal cells show a property called **contact inhibition** by virtue of which contact with other cells inhibits their uncontrolled growth. Cancer cells appears to have lost this property. As a result of this, cancerous cells just continue to divide giving rise to masses of cells called **tumors.**

Types of Tumors :-

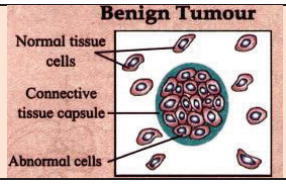
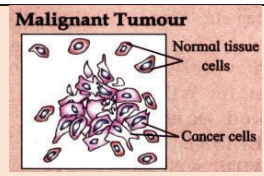
- Tumors are classified into two types namely ; **Benign** and **Malignant.**

a. **Benign tumour:** The tumours which do not spread from one part to another of the body but confined to the original location are called **benign tumours.** These are less harmful and can be surgically removed.

b. **Malignant tumour:** The tumours which spreads from the defected organs or primary tumours to other parts of the body are called **malignant tumours.**

- These cells grow very rapidly, invading and damaging the surrounding normal tissues.
- As these cells actively divide and grow, they also starve the normal cells by competing for vital nutrients.
- Cells sloughed from such tumors reach distant sites through blood, and wherever they get lodged in the body, they start a new tumor there. This property called metastasis is the most feared property of
- malignant tumors.

Differences between Benign Tumour and Malignant Tumour

Benign Tumour	Malignant Tumour
	
(1) It remains confined to the affected organ.	(1) It also spreads to other organs of the body.
(2) Rate of growth is usually slow.	(2) Rate of growth is usually rapid.
(3) There is no metastasis.	(3) There is metastasis.
(4) It causes limited damage to the body.	(4) The cancer cells migrate to other sites of the body.
(5) Benign tumors cause little damage	(5) Malignant tumors cause much damage

Characteristics of cancer cells:

- Cancer cells have lost control of cell division giving rise to tumour.
- Cancer cells have no **contact inhibition,**(Normal cells by contact with neighboring cells **inhibit** or **control** their growth process is called **contact inhibition**)
- Cancer cells grow very rapidly, invading and damaging the surrounding normal tissues.
- No differentiation of cells.
- There is no gene regulation
- Cells grow, starve the normal cells by competing for vital nutrients.

Cancer cell	Normal cell
1. Exhibit immortality	1. Do not exhibit immortality
2. Undifferentiated cells	2. Cells undergo differentiation
3. lead parasitic life on other normal cells	3. They are not parasitic cells
4. Divide without control	4. Division is controlled phenomenon
5. Lost the property of contact inhibition due to absence of surface glycoprotein-Fibronectin.	5. Exhibit contact inhibition due to presence of fibronectin

Types of cancer

Extra Edge :-

a. Cacinoma :- These are characterized by solid tumors. They are usually associated with the cells of **epithelial** or **endothelial origin.**

Ex:- Brain cancer , Breast cancer, Skin Cancer, lung cance etc.

b. **Sarcoma :-** It is mesoderm origin and therefore associated with **connective tissues.** They are also solid tumors.

Ex:- Bone cancer, Tumors of cartilage ect

c. Lymphoma :- Cancer originated from the lymph glands or in the Lymphocytes. **Ex**: Hodkin's Lymphocytes(Neck ,Throat).

d. **Leukemia** (Blood cancer):- Cancers originated in the bone marrow and other blood forming tissues. Ex: Monocytic leukemia, Lymphocytic leukemia.

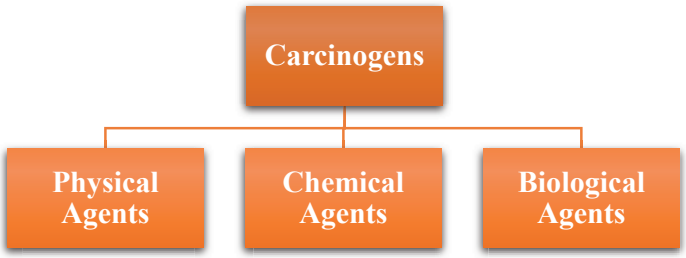
Causes of cancer :

Transformation induced by

Carcinogens

Normal Cells ⟶ **Cancerous neoplastic Cells**

- The agents which will cause the cancer are called **Carcinogens**. They may be



1. Physical Agents:- These includes. **e.g. :** Ionising radiations like X-rays and gamma rays and non-ionizing radiations like UV rays cause DNA damage leading to neoplastic transformation.

2. Chemical Agents:- These includes. **e.g. :** The chemical carcinogens present in tobacco smoke have been identified as a major cause of lung cancer.

3. Biological Agents:- These includes. **e.g. :** Cancer causing viruses called **oncogenic viruses** have genes called **viral oncogenes,** induce transformation of the normal cells.

- **Cellular oncogenes (c-onc)** or **proto oncogenes** have been identified in normal cells which, when activated under certain conditions, could lead to oncogenic transformation of the cells.

Cancer detection and diagnosis :

- Cancer can be cured if detected in early stages. It is detected by

1. **Biopsy** and histopathological studies of the tissue and blood.(In biopsy, a piece of the suspected tissue cut into thin sections is stained and examined under microscope (histopathological studies) by a pathologist).
2. **Radiography** – Techniques like radiography (use X-rays),CT(Computed Tomography), MRI(Magnetic Resonance Imaging) are very useful to detect cancers of the internal organs.
3. **Antibodies** against cancer-specific antigens.
4. **Bone marrow tests** for leukemia.

Treatment of cancer :

- The cancer can be treated by the following methods

1. **Radiotherapy** – In radiotherapy, tumor cells are irradiated lethally, taking proper care of the normal tissue surrounding the tumor mass.
2. **Chemotherapy** -It involves the use drugs like antibiotics and alkaloids. Alkaloids like **Vincristine** and **Vinblastine** are used as **anticancer drugs for leukemia.** Majority of drugs have side effects like hair loss ,anemia ect
3. **Surgery** – It involves cut and removal of cancerous tumours surgically by operation.

4. **Immunotherapy** – Tumor cells have been shown to avoid detection and destruction by immune system. Therefore, the patients are given substances called biological response modifiers such as **α-interferon** which activates their immune system and helps in destroying the tumor.

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

Note:

- Computed tomography uses X-rays to generate a three-dimensional images of the internal organs.
- MRI uses strong magnetic fields and non-ionising radiations to accurately detect pathological and physiological changes in the living tissue.

7.5. Drugs And Alcohol Abuse

Drugs are the substances which alter the physiology of the body. These are good medicines and used internally or externally for the purpose of diagnosis, prevention, **relief from depression**, pain or cure of disease. But when these used in over dosage or abuse ,they produce **harmful effects.**

Drugs Abuse : Drugs are taken other than medicinal use in large amounts that impairs one's **physical, physiological or psychological** functions of the body is called **drug abuse.**

Narcotic drugs are broadly classified into **4 types** namely, **Stimulants**, **Depressants**, **Analgesics** and **Hallucinogens**.

1. **Stimulants :-** These drugs stimulate the nervous system, provide excitement and reduce Sleep and hunger**. Ex:- Caffeine, Cocaine, Nicotine, Amphetamine ect**
2. **Depressants:- (Sedative and Tranquilizers) :-** These drugs reduce the body activities. In case of overdose it causes drowsiness, respiratory failure and coma. **Ex:- Valium, Barbiturates (sleeping pills), Alcoho etc.**
3. **Analgesics (Opiates) :-** These drugs suppress the brain activity and also reduce pain. **Ex:- Heroin (brown sugar),Morphine, Codeine, Methadone**
4. **Hallucinogens:-** These are mind expanding drugs ,they can alter thoughts, feelings and perception. Ex:- **LSD (Lysergic acid diethylamine), ganja, Marijuana, Hashish etc.**

- The drugs, which are commonly abused are **opioids**, **cannabinoids** and **coca alkaloids.** Majority of these are obtained from **flowering plants.** Some drugs are obtained from **fungi** like LSD.
- Drugs like **barbiturates, amphetamines, benzodiazepines,** and **other similar drugs,** that are normally used as medicines to help patients cope with mental illnesses like **depression** and **insomnia**, are often abused.
- **Several plants, fruits** and **seeds** having hallucinogenic properties have been **used for hundreds of years in folk-medicine, religious ceremonies and rituals** all over the globe.
- Well-known plants with hallucinogenic properties are **Atropa- belladona** and **Datura**.
- Some of the important narcotic drugs are discussed below.

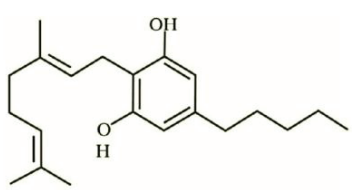
Opioids

Features	
Examples	**Natural :** • Morphine **Synthetic:** • Heroin (Diacetyl morphine)
Source	**Morphine :** Extracted from the latex of poppy plant ***Papaver somniferum*** **Heroin :** Obtained by acetylation of morphine. Commonly called smack. Characteristic features :-White, odourless, bitter, crystalline ompound.
Mode of intake	Generally by **snorting** and **injection**
Mechanism of action	Binding with specific opioid receptors present in central **nervous system** and **gastrointestinal tract(GIT)**
Effects on body	**Morphine :** Very effective **sedative** and **painkiller**, and is very useful in patients who have undergone surgery. **Heroin :** A depressant and slows down body functions.

Cannabinoids:-

Features	
Examples	■ Bhang ■ Marijuana, Hashish, Charas and Ganja
Source	**Natural :** Inflorescences of the cannabis plant Cannabis sativa **Marijuana, Hashish, Charas and Ganja :** Flower tops, leaves and the resin of cannabis plant are used in various combinations for production
Mode of intake	Generally by inhalation and oral ingestion
Mechanism of action	Interacting with cannabinoid receptors present principally in the brain
Effects on body	· Effects on cardiovascular system of the body · Also being abused by some sports persons these days

Leaves of *Cannabis sativa*



Skeletal structure of cannabinoid molecule

Coca Alkaloids

Features	
Examples	Cocaine, commonly called coke or crack
Source	Coca plant Erythroxylum coca, native to South America
Mode of intake	Usually by snorting
Mechanism of action	Interference with the transport of the neuro-transmitter dopamine
Effects on body	Potent stimulating action on central nervous system, producing a sense of euphoria and increased energy. - Excessive dosage causes hallucinations

Tobacco Use

- Tobacco has been used by human beings for more than **400 years.**
- Tobacco is **smoked**, **chewed** or **used as a snuff.**
- Tobacco contains a large number of chemical substances including **nicotine**, an alkaloid.
- **Nicotine stimulates adrenal gland** to release **adrenaline** and **nor-adrenaline** into blood circulation.
- Nicotine acts as a **Carcinogen.**

Effects of Tobacco smoking :-

1. Smoking leads to increase BP and heart rate.
2. Smoking is associated with increased incidence of **cancers of lung, urinary bladder and throat.**
3. Smoking increases **carbon monoxide (CO)** content in blood and which can reduces the oxygen carrying capacity of haemoglobin. This causes oxygen deficiency in the body.
4. Smoking is associated with **bronchitis, emphysema, coronary heart disease, gastric ulcer, etc.**
5. Tobacco chewing is associated with increased risk of cancer of the oral cavity.

ADOLESCENCE AND DRUG/ALCOHOL ABUSE

Adolescence :

- Both 'a **period'** and 'a **process'** during which a child becomes mature in terms of his/her attitude and beliefs for effective participation in society.
- The Period between 12-18 years of age is Said to be adolescence period.
- In other words, Adolescence is a bridge linking childhood and adulthood.
- It is associated with several **biological** and **behavioural changes.**
- Thus, It is a very vulnerable phase of mental and psychological development of an individual.

Causes for motivation among adolescents/ youngsters towards tobacco, alcohol and drugs use :

Causes for motivation among adolescents towards tobacco, Alcohol and drugs use :

Initially :-

- Natural curiosity
- Need for adventure and excitement

- Experimentation
- Perception that it is 'cool' or progressive to smoke, use drugs or alcohol (television, movies, newspapers, internet also help to promote this perception).

Later :

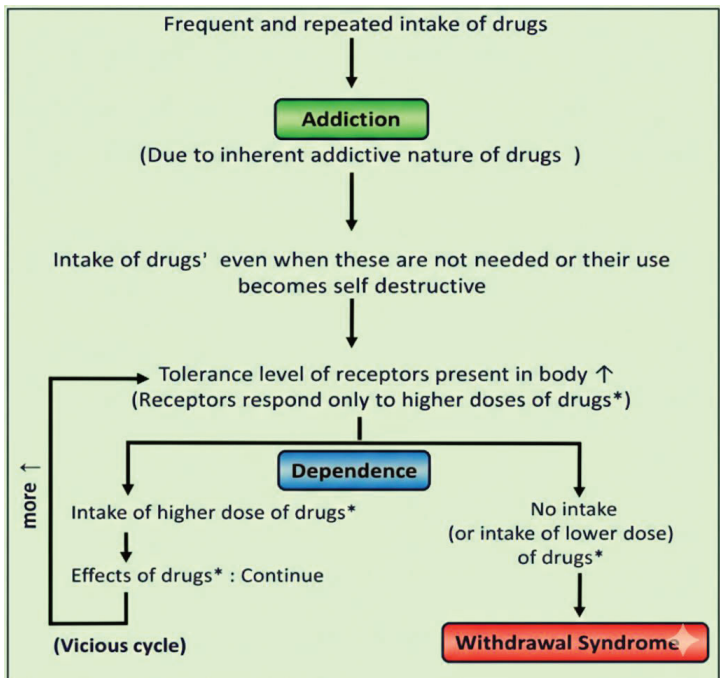
- To escape facing problems (like stress, from pressures to excel in academics or examinations)
- Unstable or unsupportive family structures and peer pressure.

Addiction and Dependence

- The most important thing, which one fails to realise, is the inherent addictive nature of tobacco, alcohol and drugs.
- **Addiction:** "Psychological attachment to certain effects- such as **euphoria** and a **temporary feeling of well being-** associated with drugs and alcohol".
- With repeated use of drugs the tolerance level of the receptors present in our body increases. Consequently the receptors respond only to higher doses of drugs or alcohol 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 is abruptly discontinued".

Withdrawal Syndrome:

- Characterised by **anxiety**, **shakiness**, **nausea** and **sweating**, etc. which may be relieved when use of drugs is resumed again.
- In some cases, withdrawal symptoms can be severe and even life threatening and the person may need medical supervision.



EFFECTS OF DRUG/ALCOHOL ABUSE

- Reckless behaviour
- Vandalism

- Violence
- Coma
- Death due to respiratory failure, heart failure or cerebral haemorrhage.
- A combination of drugs or their intake along with alcohol generally results in overdosing and even deaths.
- The chronic use of drugs and alcohol damages nervous system and liver (cirrhosis).
- Mental and financial distress to entire family and friends of abuser etc
- Social problems like stealing and spread of Infectious diseases (Ex: AIDS, Hepatitis-B).
- The use of drugs and alcohol during pregnancy is also known to adversely affect the foetus (Foetal alcohol syndrome or FAS).
- Loss of sexual drive and necrospermia

The most common warning signs of drug and alcohol abuse among youth include :

- Drop in academic performance
- Unexplained absence from school/college
- Lack of interest in personal hygiene
- Withdrawal and Isolation
- Depression, Fatigue, Aggressive and rebellious behaviour
- Deteriorating relationships with family and friends
- Loss of interest in hobbies
- Change in sleeping and eating habits
- Fluctuation in weight, appetite, etc.

CERTAIN SPORTPERSONS MISUSE

- Narcotic analgesics
- Anabolic steroids
- Diuretics and certain hormones in sports to increase muscle strength and bulk and to promote aggressiveness and as a result increase athletic performance.

THE SIDE-EFFECTS OF THE USE OF ANABOLIC STEROIDS IN MALES INCLUDE

- Acne
- Increased aggressiveness
- Mood swings
- Depression
- Reduction of size of the testicles
- Decreased sperm production
- Potential for kidney and liver dysfunction
- Breast enlargement
- Premature baldness
- Enlargement of the prostate gland

THE SIDE-EFFECTS OF THE USE OF ANABOLIC STEROIDS IN FEMALES INCLUDE

- Masculinisation (features like males)
- Increased aggressiveness
- Mood swings
- Depression
- Abnormal menstrual cycles
- Excessive hair growth on the face and body
- Enlargement of clitoris
- Deepening of voice
- These side effects in males or females may be permanent with prolonged use.
- In the adolescent male or female, severe facial and body acne, and premature closure of the growth centres of the long bones may result in stunted growth.

PREVENTION AND CONTROL OF DRUG/ALCOHOL ABUSE

- The age-old adage of 'prevention is better than cure' holds true here also.
- Measures particularly useful for prevention and control of alcohol and drugs abuse among adolescents
- Avoid undue peer pressure
- Education and counselling
- Seeking help from parents and peers
- Looking for danger signs
- Seeking professional and medical help.

EXERCISE

PART - A

I. Select the correct alternative from the choices given: 1 Mark Each

1. Which of the following pairs contains an infectious and a non-infectious disease respectively?

a) Typhoid and AIDS b) AIDS and cancer

c) Pneumonia and malaria d) Cancer and malaria

2. Which of the following is not a bacterial disease in humans?

a) Pneumonia b) Malaria c) Plague d) Diphtheria

3. One of the following is not the causal organism for ringworm.

a) Microsporum b) Trichophyton c) Epidermophyton d) Macrosporum

4. An intestinal parasite which causes blockage of the intestinal passage and whose eggs are excreted along with the faeces of infected person is ___ .

a) Wuchereria bancrofti b) Ascaris

c) Epidermophyton d) Microsporum

5. Elephantiasis, a chronic inflammation that results in gross deformities is caused by

a) Ascaris b) E. coli c) Wuchereria d) Trichophytonb

6. Which of the following is affected by the infection of Wuchereriabancrofti?

a) Lymphatic vessels b) Respiratory system

c) Nervous system d) Blood circulation

7. Which of the following diseases is transmitted by the bite of the female mosquito vector?

a) Filariasis b) Amoebiasis c) Typhoid d) Pneumonia

8. Which of the following pairs correctly matches a disease and a pathogen causing it?

a) Typhoid - Salmonella typhi

b) Pneumonia - Haemophilus influenzae

c) Malaria - Ascaris lumbricoides

d) Ringworm - Entamoeba histolytica

9. Appearance of dry, scaly lesions with itching on various parts of the body are the symptoms of

a) Elephantiasis b) Ringworm c) Ascariasis d) Amoebiasis

10. Haemozoin is a

a) Precursor of haemoglobin

b) Toxin released from Streptococcus infected cells

c) Toxin released from Plasmodium infected cells

d) Toxin released from Haemophilus infected cells.

11. A toxic substance, responsible for the chills and high fever recurring every three to four

a) Interferon b) Haemozoin c) Hirudin d) Colostrum

12. During the life cycle of Plasmodium, gametocytes develop in

a) Human RBC b) Human liver

c) Salivary glands of mosquito d) Gut of mosquito

13. Which of the following is a viral disease?

a) Pneumonia b) Typhoid c) Common cold d) Malaria

14. The human immunodeficiency virus (HIV) primarily attacks and destroys:

a) Red blood cells b) T lymphocytes c) Platelets d) Neurons

15. Which of the following is an autoimmune disease?

a) Rheumatoid arthritis b) Tuberculosis c) Malaria d) AIDS

16. The substance produced by a cell in viral infection that can protect other cells from further infection is

a) Serotonin b) Colostrum c) Interferon d) Histamine

17. Antibodies present in colostrum which protect the new born from certain diseases is

a) Ig G b) IgA c) Ig D d) Ig E

18. Which of the following is not a lymphoid tissue?

a) Spleen b) Tonsils c) Pancreas d) Thymus

19. The site where lymphocytes interact with antigens and proliferate to become effector cells are

a) Thymus and lymph nodes b) Bone marrow and thymus

c) Peyer's patches and tonsils d) Bone marrow and spleen

20. Antivenom against snake poison contains

a) Antigens b) Antigen-antibody complexes

c) Antibodies d) Enzymes

21. Vaccines work by

a) Stimulating the production of antibodies

b) Killing the pathogen directly

c) Reducing inflammation

d) Blocking the entry of pathogens into the body

22. Which form of pathogen is used in vaccination?

a) Activated and strong pathogenic antigens b) Preformed antigens

c) Inactivated and weakened pathogen d) Hyperactive and strong pathogen

23. Injection of antitoxin in tetanus confers which type of immunisation?

a) Active immunization b) Passive immunisation

c) Auto-immunisation d) Humoral immunization

24. Hepatitis B vaccine is produced from

a) Inactivated viruses b) Yeast

c) Haemophilus influenza d) Salmonella typhimurium.

25. The most abundant antibody produced against allergens is

a) IgE b) IgA c) IgG d) IgM

26. Which of the following cells actively participate during allergy?

a) B-lymphocytes b) Liver cells

c) Mast cells d) Red blood cells

27. A chemical carcinogen present in tobacco smoke is responsible for

a) Skin cancer b) Pancreatic cancer

c) Stomach cancer d) Lung cancer

28. Which of the following approaches is not used for the treatment of cancer?

a) Immunotherapy b) Surgery

c) Radiotherapy d) Anti-Retroviral therapy

29. Smack' is a drug obtained from the

a) Latex of Papaver somniferum b) Leaves of Cannabis sativa

c) Flowers of Datura d) Fruits of Erythroxylum cocao.

30. Tobacco consumption is known to stimulate secretion of adrenaline and nor-adrenaline. The component causing this could be

a) Nicotine b) Tannic acid c) Curcumin d) Catechin

31. Heroin formed by acetylation of morphine is commonly called as

a) Coke b) Crack c) Smack d) Chara's.

32. Marijuana is extracted from.

a) Resin, leaves and flowers of Cannabis plant b) Ergot fungus

c) Roots of hemp plant d) Cocoa plant.

33. Charas and ganja are the drugs which affect

a) Respiratory system b) Cardiovascular system

c) Digestive system d) Nervous system

34. Cocaine is obtained from

a) Erythroxylum coca b) Papaver somniferum

c) Atropa belladonna d) Datura stramonium

35. Cocaine is commonly called as

a) Smack b) Coke c) Heroin d) Cola

36. Cocaine is a CNS stimulant as it interferes with the transport of the neuro-transmitter ___

a) acetylcholine b) Glutamate c) Dopamine d) Glycine

37. Which of the following plants does not possess hallucinogenic properties?

a) Erythroxylum coca b) Atropa belladonna

c) Datura d) Papaver somniferum

38. Which class of substances may be misused in sports to unfairly enhance performance?

38. Which substance is sometimes misused to increase muscle mass and athletic performance?

a) Anabolic steroids b) Barbiturates c) Cannabinoids d) LSD

39. Amphetamines belong primarily to which class of psychoactive drugs?

a) Stimulants b) Opioids c) Cannabinoids d) Hallucinogens

Answer Key					
1. B	2. B	3. D	4. B	5. C	6. A
7. A	8. A	9. B	10. C	11. B	12. A
13. C	14. B	15. A	16. C	17. B	18. C
19. C	20. C	21. A	22. C	23. B	24. B
25. A	26. C	27. D	28. D	29. A	30. A
31. C	32. A	33. B	34. A	35. B	36. C
37. D	38. A	39. A	40. C		

II. Fill in the blanks. 1 Mark Each

(Aedes, Typhoid, Masculination, Smack, Yeast, Metastasis, Lymph nodes, Crack, Memory, Host, Allergens, MALT, Morphine, Houseflies, Pathogens)

1. Disease causing organisms are called ___
2. Pathogens adapt to life within the environment of the ___
3. Mary Mallon is associated with ___
4. ___ act as mechanical carriers and serve to transmit Entamoeba histolytica from faeces of infected person to food and food products.
5. Dengue and chikungunya are spread through ___
6. The principle of immunisation is based on the property of ___ of the immune system.
7. Hepatitis B vaccine is produced from ___
8. Mites in dust, pollens, animal dander are common examples of ___
9. The ___ are small solid structures located at different points along the lymphatic system.
10. ___ constitutes about 50 percent of the lymphoid tissue in human body.

11. ___ is the most feared property of malignant tumors.

12. ___ is a very effective sedative and painkiller.

13. when snorted produces a sense of euphoria and increased energy.

14. The side effects of the use of anabolic steroids in females include ___

15. ___ is a white, odourless, bitter crystalline compound which acts as a depressant.

Answer Key		
1. Pathogens	2. Host	3. Typhoid
4. Houseflies	5. Aedes	6. Memory
7. Yeast	8. Allergens	9. Lymph nodes
10. MALT	11. Metastasis	12. Morphine
13. Crack	14. Masculinisation	15. Smack

PART - C

IV. Answer the following questions in 40 – 80 words each, wherever applicable:

Q1. What are infectious diseases? Give an example.

Ans:

- Infectious diseases are those which are easily transmitted from one person to another.
- Example: Typhoid

Q2. What are non-infectious diseases? Give an example.

Ans:

- Non-infectious diseases are not transmitted from person to person.
- Example: Cancer

Q3. Differentiate infectious diseases from non-infectious diseases.

Ans:

- Infectious diseases are caused by pathogens and are transmitted from one person to another.
- Non-infectious diseases are not caused by pathogens and are not communicable

Q4. Mention any four means by which good health can be achieved.

Ans:

- Balanced diet
- Personal hygiene
- Regular exercise
- Awareness about diseases and their prevention

Q5. Write the scientific name of the pathogen and any two symptoms of typhoid.

Ans:

- Pathogen: Salmonella typhi
- Symptoms: Sustained high fever (39°–40°C), weakness

Q6. Write the scientific name of the pathogen and any two symptoms of pneumonia.

Ans:

- Pathogen: Streptococcus pneumoniae or Haemophilus influenzae
- Symptoms: Fever, cough

Q7. Write the scientific name of the pathogen and any two symptoms of common cold.

Ans:

- Pathogen: Rhinoviruses
- Symptoms: Nasal congestion, sore throat

Q8. Write the scientific name of the pathogen and any two symptoms of amoebiasis.

Ans:

- Pathogen: Entamoeba histolytica
- Symptoms: Abdominal pain, stools with blood clots

Q9. Write the scientific name of the pathogen and any two symptoms of ascariasis.

Ans:

- Pathogen: Ascaris
- Symptoms: Fever, blockage of intestinal passage

Q10. Write the scientific name of the pathogen and any two symptoms of elephantiasis.

Ans:

- Pathogen: Wuchereria bancrofti
- Symptoms: Chronic inflammation of lymphatic vessels, gross deformities of limbs

Q11. Write the scientific name of the pathogen and any two symptoms of ringworm disease.

Ans:

- Pathogen: Microsporum, Trichophyton, or Epidermophyton
- Symptoms: Dry, scaly lesions on skin, intense itching

Q12. Name the host and the site where the following occur in the life cycle of a malarial parasite:
(a) Formation of gametocytes
(b) Fusion of gametes

Ans:

(a) Host: Human; Site: RBCs
(b) Host: Female Anopheles mosquito; Site: Gut

Q13. What is immunity? Mention its types.

Ans:

- Immunity is the overall ability of the host to fight the disease-causing organisms.
- Types: Innate immunity and Acquired immunity

Q14. Mention the types of innate barriers of innate immunity.

Ans:

- Physical barriers – Skin, mucous membranes
- Physiological barriers – Acid in stomach, saliva, tears
- Cellular barriers – PMNL, monocytes, natural killer cells
- Cytokine barriers – Interferons

Q15. Differentiate between innate and acquired immunity.

Ans:

- Innate immunity is non-specific and present from birth.
- Acquired immunity is pathogen-specific and develops during life

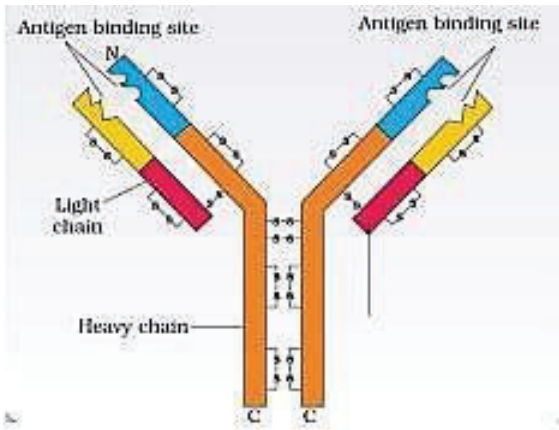
Q16. Mention the roles of B and T lymphocytes.

Ans:

- B-lymphocytes: Produce antibodies in response to antigens
- T-lymphocytes: Help B cells produce antibodies and mediate cellular immunity

Q17. Draw a labelled diagram of an antibody molecule.

Ans:



Q18. Differentiate between active immunity and passive immunity.

Ans:

- Active immunity: Antibodies are produced by host in response to antigens
- Passive immunity: Pre-formed antibodies are given to the host

Q19. Differentiate between primary and secondary immune responses.

Ans:

- Primary response: Occurs on first exposure to antigen; low intensity
- Secondary response: Occurs on subsequent exposure; stronger and quicker

Q20. What are primary lymphoid organs? Give two examples.

Ans:

- Organs where lymphocytes differentiate and mature
- Examples: Bone marrow and Thymus

Q21. What are secondary lymphoid organs? Give two examples.

Ans:

- Organs where lymphocytes interact with antigens and proliferate
- Examples: Spleen and Lymph nodes

Q22. Differentiate between primary and secondary lymphoid organs.

Ans:

- Primary: Sites of lymphocyte maturation (e.g., bone marrow, thymus)
- Secondary: Sites of lymphocyte activation (e.g., spleen, tonsils)

Q23. State the functions of primary and secondary lymphoid organs in humans.

Ans:

- Primary: Production and maturation of lymphocytes
- Secondary: Antigen interaction and proliferation of effector cells

Q24. Name the two special types of lymphocytes present in our blood which are responsible for primary and secondary responses.

Ans:

- B-lymphocytes
- T-lymphocytes

Q25. What is colostrum? Mention its significance.

Ans:

- Colostrum is yellowish fluid secreted by mother in initial lactation days
- It contains IgA antibodies that protect newborn from infections

Q26. What is passive immunisation? Give an example.

Ans:

- Passive immunisation is the direct administration of pre-formed antibodies
- Example: Anti-tetanus serum

Q27. What is allergy? Mention its symptoms.

Ans:

- Allergy is exaggerated immune response to certain environmental antigens
- Symptoms: Sneezing, watery eyes, running nose, difficulty in breathing

Q28. Name two chemicals released by the mast cells during an allergic reaction.

Ans:

- Histamine
- Serotonin

Q29. What is auto-immune disease? Give an example.

Ans:

- Disease in which the body's immune system attacks its own cells
- Example: Rheumatoid arthritis

Q30. Distinguish between benign and malignant tumors.

Ans:

- Benign: Confined to original location, do not spread
- Malignant: Invade other tissues and spread to distant sites

Q31. Metastasis is the most feared property of malignant tumors. Justify.

Ans:

- Metastasis involves spread of cancer cells to distant organs
- It causes development of secondary tumors, making treatment difficult

Q32. Mention any two characteristics of cancer cell.

Ans:

- Do not exhibit contact inhibition
- Have the property of uncontrolled cell division

Q33. What are carcinogens? Give an example.

Ans:

- Agents that cause cancer
- Example: Tobacco smoke contains chemical carcinogens

Q34. Write a note on oncogenic viruses.

Ans:

- Oncogenic viruses have genes that can cause cancer
- Example: Hepatitis B virus and Human papilloma virus (HPV)

Q35. Cancer is one of the most dreaded diseases. Explain 'Contact inhibition' and 'Metastasis' with respect to the disease.

Ans:

- Contact inhibition: Normal cells stop dividing when in contact; lost in cancer
- Metastasis: Spread of cancer cells to distant organs, forming new tumors

Q36. List the modes of transmission of HIV in humans.

Ans:

- Sexual contact with infected person
- Transfusion of contaminated blood
- Sharing infected needles
- From infected mother to child

Q37. What is drug abuse? Name any three drugs that are commonly abused.

Ans:

- Drug abuse is excessive intake of drugs without medical purpose
- Common drugs: Heroin, Cocaine, Marijuana

Q38. List any four common warning signs of drug and alcohol abuse in youth.

Ans:

- Drop in academic performance
- Isolation and secretive behaviour
- Aggression or mood swings
- Change in appearance or habits

Q39. Name an opioid drug and its source plant (scientific name). How does it affect human body?

Ans:

- Drug: Morphine
- Source: Papaver somniferum
- Effect: Depressant; relieves pain

Q40. Name the plant (scientific name) from which cocaine is obtained. What is the effect of cocaine in humans?

Ans:

- Plant: Erythroxylum coca
- Effect: Stimulant; increases energy and euphoria

Q41. Name the plant (scientific name) from which cannabinoid is obtained. What is the effect of cannabinoids in humans?

Ans:

- Plant: Cannabis sativa
- Effect: Alter mood, memory, perception

Q42. Name any two drugs which are commonly abused and write the binomial name of the plants from which these drugs are extracted.

Ans:

- Heroin – Papaver somniferum
- Marijuana – Cannabis sativa

Q43. Write the source and effect of the following drugs on the human body:

Ans:

- Morphine – From Papaver somniferum; painkiller
- Marijuana – From Cannabis sativa; hallucinogenic
- Cocaine – From Erythroxylum coca; CNS stimulant

Q44. Name a drug used:

Ans:

- As an effective sedative and pain killer – Morphine
- For helping patients cope with mental illness like depression but often misuse – Amphetamines

Q45. List any four effects of smoking.

Ans:

- Rise in blood pressure
- Increased heart rate
- Emphysema (oxygen deficiency)
- Cancer of lungs and throat

Q46. Differentiate between addiction and dependence with reference to alcohol and drugs.

Ans:

- Addiction: Compulsive drug use despite harm
- Dependence: Body shows withdrawal symptoms if drug is stopped

Q47. List any four withdrawal symptoms exhibited by an alcohol or drug addict.

Ans:

- Anxiety
- Shakiness
- Nausea
- Sweating

Q48. List the most common warning signs of drug and alcohol abuse among youth.

Ans:

- Sudden drop in academic performance
- Mood swings
- Loss of interest in activities
- Social withdrawal

Q49. List any four adverse effects of drug and alcohol abuse.

Ans:

- Liver damage
- Brain dysfunction
- Aggression and criminal behavior
- Loss of appetite and sleep

Q50. Mention four side effects of the use of anabolic steroids in males.

Ans:

- Decreased sperm count
- Liver damage
- Baldness
- Breast enlargement

Q51. Mention four side effects of the use of anabolic steroids in females.

Ans:

- Facial hair growth
- Deepening of voice
- Menstrual irregularities
- Masculinisation

V. Answer the following questions in 60 – 90 words each, wherever applicable

Q1. Define the term 'health'. Mention any four means by which good health can be achieved.

Ans: Health is a state of complete physical, mental, and social well-being. It does not merely mean the absence of disease or physical fitness.

- Balanced diet
- Personal hygiene
- Regular exercise
- Awareness about diseases and vaccination

Q2. Write the scientific name of the pathogen, mode of transmission and any two symptoms of typhoid.

Ans:

- Pathogen: Salmonella typhi
- Mode of transmission: Contaminated food and water
- Symptoms:
    1. Sustained high fever (39° to 40°C)
    2. Stomach pain and constipation

Q3. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of pneumonia.

Ans:

- Pathogen: Streptococcus pneumoniae or Haemophilus influenzae
- Mode of transmission: Inhalation of droplets from an infected person
- Symptoms:
    1. Fever and chills
    2. Cough and headache

Q4. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of common cold.

Ans:

- Pathogen: Rhinoviruses
- Mode of transmission: Inhalation or hand-to-hand contact
- Symptoms:

1. Nasal congestion and discharge
2. Sore throat and cough

Q5. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of amoebiasis.

Ans:

- Pathogen: Entamoeba histolytica
- Mode of transmission: Contaminated food and water
- Symptoms:
    1. Constipation, abdominal pain
    2. Stools with mucous and blood clots

Q6. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of ascariasis.

Ans:

- Pathogen: Ascaris
- Mode of transmission: Contaminated water, fruits, and vegetables
- Symptoms:
    1. Fever and muscular pain
    2. Blockage of intestinal passage

Q7. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of elephantiasis.

Ans:

- Pathogen: Wuchereria bancrofti and W. malayi
- Mode of transmission: Bite of female mosquito
- Symptoms:
    1. Chronic inflammation of lower limbs
    2. Gross deformities in genital organs

Q8. Write the scientific name of the pathogen that causes, mention its mode of transmission and any two symptoms of ringworm disease.

Ans:

- Pathogen: Microsporum, Trichophyton, Epidermophyton
- Mode of transmission: From soil or contact with infected towels, clothes, combs
- Symptoms:
    1. Dry, scaly lesions on skin
    2. Intense itching

Q9.

a) Name the infective stages of *Plasmodium* which *Anopheles* mosquito takes in along the blood meal from an infected person.

Ans: Gametocytes

b) Why does the infection cause chill and fever in humans?

Ans: Due to rupture of RBCs and release of haemozoin toxin

c) At what stage does *Plasmodium* enter into human body?

Ans: Sporozoite stage

Q10. Differentiate between active immunity and passive immunity. Give an example for each.

Ans:

• Active immunity: Antibodies are produced by the host body (e.g., vaccination)
• Passive immunity: Pre-formed antibodies are given (e.g., anti-tetanus serum)

Q11. Differentiate between primary and secondary lymphoid organs. Give an example for each.

Ans:

- Primary lymphoid organs are the sites where immature lymphocytes differentiate into antigen-sensitive lymphocytes.
  Example: Bone marrow, Thymus
- Secondary lymphoid organs are the sites where lymphocytes interact with antigens and proliferate to become effector cells.
  Example: Lymph nodes, Spleen, Tonsils

Q12. What are allergens? Give examples. Name the type of antibody produced to the allergens.

Ans:

• Allergens are substances that cause an overreaction of the immune system in some individuals.
• Examples: Pollen grains, dust mites, animal dander
• Antibody produced: IgE

Q13. Mention any three characteristics of cancer cells.

Ans:

• Cancer cells divide continuously to form tumors
• They do not show contact inhibition
• They metastasize and spread to distant sites

Q14. What are carcinogens? Mention any two groups of carcinogens with an example for each.

Ans:

• Carcinogens are agents that cause cancer
• Physical carcinogens: X-rays, UV rays
• Chemical carcinogens: Nicotine, tobacco smoke

Q15. When the ELISA test was conducted on an immune-suppressed person, he tested positive for a pathogen.

Ans:

a) Disease: AIDS
b) Causative entity: HIV (Human Immunodeficiency Virus)
c) Cells attacked: Helper T-lymphocytes ($CD4^+$ T-cells)

16. Mention the names of three drugs which are commonly abused and write the binomial name of the plants from which these drugs are extracted.

Ans:

• Heroin – Papaver somniferum
• Marijuana – Cannabis sativa
• Cocaine – Erythroxylum coca

Q17. Tobacco smoking is associated with rise in blood pressure and emphysema. Substantiate.

Ans:

- Nicotine stimulates adrenal glands, increasing adrenaline and noradrenaline secretion
- This raises blood pressure and heart rate
- Smoking damages alveoli, causing emphysema and oxygen deficiency

Q18. Briefly explain any three prevention and control measures of drug and alcohol abuse.

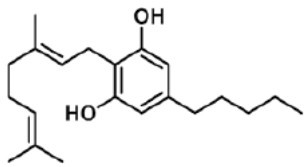
Ans:

- Avoid undue peer pressure
- Education and awareness
- Seeking help from parents, counselors, and rehabilitation centers

Q19. The skeletal structure of a drug is shown below. Answer the questions given below.

Ans:

a) Drug: Heroin (Smack)
b) Source plant: Papaver somniferum
c) Mode of intake: Snorting or injecting



PART- D

V. Answer the following questions in 200-250 words each, wherever applicable: 5 Marks Each

Q1. What is innate immunity? Explain the four types of barriers of innate immunity with suitable examples.

Ans: Innate immunity is a non-specific type of defense that is present at the time of birth. It provides barriers to the entry of foreign agents into our body and does not depend on prior exposure to pathogens.

The four types of barriers are:

1. **Physical barriers:**
   - The skin acts as a physical barrier that prevents the entry of microorganisms.
   - Mucus coating on the epithelium lining of the respiratory, gastrointestinal, and urogenital tracts traps microbes entering the body.
2. **Physiological barriers:**
   - Acid in the stomach, saliva in the mouth, and tears from eyes prevent microbial growth.
3. **Cellular barriers:**
   - White blood cells like polymorpho-nuclear leukocytes (neutrophils), monocytes, and natural killer cells in the blood and macrophages in tissues can engulf and destroy microbes.
4. **Cytokine barriers:**
   - Virus-infected cells secrete proteins called interferons that protect non-infected cells from further viral infection.

These barriers act together to prevent the entry and establishment of pathogens in the body.

Q2. Define immunity. Explain active immunity and passive immunity with examples.

Ans: Immunity is the ability of the host to fight the disease-causing organisms, conferred by the immune system. It is of two types: innate and acquired immunity.

Active immunity:

When a host is exposed to antigens (living or dead microbes or proteins), antibodies are produced in the host body. This is called active immunity.

- It is slow and takes time to give its full response.
- Example: Antibodies produced in the body after vaccination or natural infection.

Passive immunity:

When ready-made antibodies are directly given to protect the body against foreign agents, it is called passive immunity.

- It gives immediate protection.
- Examples:
  - o Colostrum from the mother contains IgA antibodies which protect the infant.
  - o Injection of antitoxin or antisera in tetanus or snake bite cases.

Thus, both active and passive immunity are crucial in protecting the body from diseases.

Q3. What are lymphoid organs? List different lymphoid organs and tissues and explain their role in immunity.

Ans: Lymphoid organs are organs where the origin, maturation, and proliferation of lymphocytes occur.

Primary lymphoid organs:

- Bone marrow – Main lymphoid organ where all blood cells including lymphocytes are produced. It also provides the environment for the development of B-lymphocytes.
- Thymus – Located near the heart and beneath the breastbone. It is the site where T-lymphocytes mature. The thymus is large at birth but shrinks with age.

Secondary lymphoid organs:

- Spleen – A large, bean-shaped organ containing lymphocytes and phagocytes. It filters blood and traps blood-borne microorganisms. It also stores erythrocytes.
- Lymph nodes – Small solid structures located along the lymphatic system. They trap microorganisms and antigens, causing the activation of lymphocytes and initiating immune response.
- Tonsils, Peyer's patches of small intestine, and appendix – Sites where lymphocytes encounter antigens.

MALT (Mucosa-Associated Lymphoid Tissue):

- Found in the lining of respiratory, digestive, and urogenital tracts.
- It constitutes about 50% of lymphoid tissue in the body.

These organs play a key role in the functioning of the immune system.

Q4. Explain the life cycle of *Plasmodium*.

Ans: Plasmodium, a malaria parasite, completes its life cycle in two hosts:

- Human (intermediate host)
- Female *Anopheles* mosquito (definitive host)

Life cycle in humans:

- Infective stage is sporozoite, injected during mosquito bite.
- Sporozoites reach liver cells, multiply and form merozoites.
- Merozoites enter RBCs, reproduce and cause their rupture.
- This leads to fever and chills.
- Some merozoites develop into gametocytes in RBCs.

Life cycle in mosquito:

- Mosquito ingests gametocytes with human blood.
- Gametes fuse in mosquito gut, forming zygote.
- Zygote develops into sporozoites, which migrate to salivary glands.
- Cycle continues with next bite.

Q5. Schematically represent the life cycle of HIV (retrovirus) in human body.

Ans: Steps in HIV life cycle:

1. HIV attaches to CD4 receptors on helper T-lymphocytes.
2. Viral RNA enters host cell.
3. Reverse transcriptase converts RNA into DNA.
4. Viral DNA integrates with host DNA via integrase enzyme.
5. Transcription and translation produce viral proteins.
6. New viruses are assembled and released to infect other cells.

Gradual destruction of T-cells leads to immunodeficiency.

Q6. Mention any five methods and techniques of cancer detection and diagnosis.

Ans:

- Biopsy and histopathological studies
- Blood and bone marrow tests
- CT (computed tomography) scans
- MRI (magnetic resonance imaging)
- Antigen/antibody detection tests

Q7. Mention any five common approaches of treatment of cancer.

Ans:

- Surgical removal of tumor
- Radiotherapy using ionizing radiation
- Chemotherapy with anticancer drugs
- Immunotherapy to boost immune response
- Use of interferons to activate immune cells

Q8. What is addiction? List four warning signals and four harmful effects caused by drug abuse.

Ans:

Addiction:

- A psychological attachment to drugs/alcohol resulting in loss of control over its intake

Four warning signals:

1. Loss of interest in studies
2. Aggressive behavior
3. Drop in academic performance
4. Isolation and depression

Four harmful effects:

1. Liver and brain damage
2. Risk of HIV, hepatitis by shared needles
3. Violent or suicidal behavior
4. Anxiety, insomnia, hallucinations

Q9. Explain prevention and control measures of alcohol and drug abuse.

Ans:

- Avoid undue peer pressure: Stay away from people who encourage drug use
- Education and awareness: Inform students about effects of drugs
- Seeking help: Approach parents, teachers, counsellors
- Rehabilitation: Professional support and therapy
- Healthy lifestyle: Engage in sports, hobbies, and social activities

PART- II

Q1. A person has been diagnosed as HIV positive.

a) Name the diagnostic test which the person underwent.

Ans: ELISA (Enzyme Linked Immuno-Sorbent Assay)

b) Write full name of pathogen involved.

Ans: Human Immunodeficiency Virus

c) Name the genome of the pathogen.

Ans: Single-stranded RNA

d) Which particular cells of this person are likely to get destroyed?

Ans: Helper T-lymphocytes ($CD4^+$ T-cells)

e) Suggest the partially effective treatment to him.

Ans: Anti-retroviral therapy

(This helps to delay the progression of the disease but does not cure it.)

Q2. a) Name the group of genes that have been identified in normal cells that could lead to cancer.

Ans: Cellular oncogenes (c-onc) or proto-oncogenes

b) Name the techniques that are useful in detecting cancers of internal organs.

Ans:

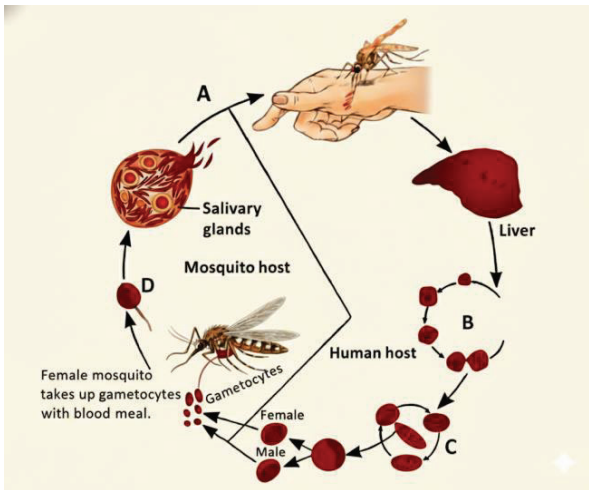
- Computed Tomography (CT)
- Magnetic Resonance Imaging (MRI)

c) Why are cancer patients often given α-interferon as part of the treatment?

Ans:

α-interferon activates immune system and helps in destroying tumor cells.

Q3. a) Stages in the life cycle of *Plasmodium* is given below. Identify A, B, C, D.



Ans:

A) When the mosquito bites another human, sporozoites are injected with bite

B) Parasites reproduce asexually in the liver cells of man and releasing into the blood

C) Parasites reproduced asexually in RBC, bursting and causing fever cycle

D) Fertilization and development take place in the mosquito's gut

b) Name the toxic responsible for the appearance of symptoms of malaria in humans.

Ans: Haemozoin

Q4. Fill the missing data in the table depicting the diseases, their causatives and symptoms.

Ans:

Name of the disease		Causative organism	Symptoms organism
a)	Ascariasis	*Ascaris*	Abdominal
b)	Ringworm (Tinea)	*Trichophyton*	Apdoaranal pain nausa, vomting diarrea, mallunution
c)	Typhoid	*Salmonella tyhi*	High fever , weakness, headache, stomach pain , constipation
d)	Pneumonia	*Streptococcus pneumoniae*	Fever, chills, cough, shortess shortess of breath, chest pain
e)	Common Cold	Rhino virus	Nasal congestion and discharge, sore throat, cough headache

a) Internal bleeding, Muscular Pain, fever, Anaemia & Blockage of intestinal passage

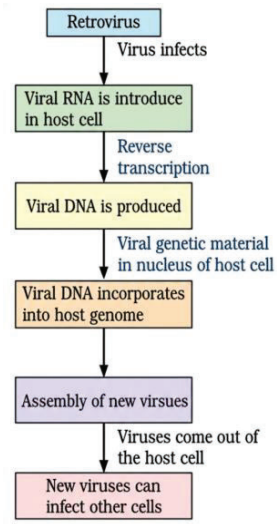
b) Ringworm

c) Salmonella typhi

d) Fever, Chills, Cough & Head ache, in severe cases lips & finger nails turn gray to bluish in colour

e) Common Cold

Q5. The flowchart shows the replication of the retro virus in the host. Answer the questions given below.



a) Fill in the missing data in boxes labelled 1 & 2.

Ans:

1) Viral DNA is produced by Reverse transcriptase

2) New viral RNA is produced by the infected cell

b) Give an example for retrovirus.

Ans: HIV

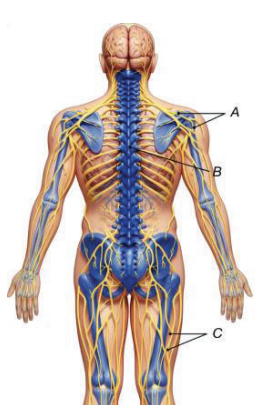
c) Name the disease caused by this retrovirus.

Ans: AIDS

d) Name the diagnostic test for this disease.

Ans: ELISA

Q6. Observe the diagram and answer the given below.



a) Identify A and write its function.

Ans: Lymph node

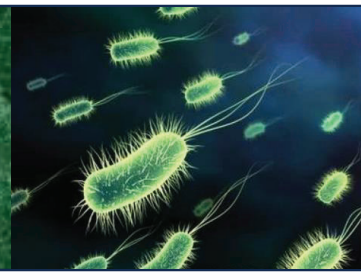
b) Identify B and write its function.

Ans: Thymus

c) Identify C.

Ans: Lymphatic vessels

Chapter 8
Microbes in Human Welfare



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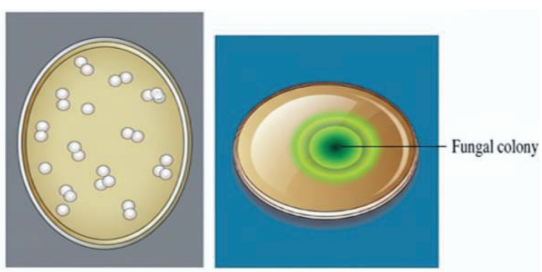
8.5. MICROBES AS BIOCONTROL AGENTS
8.6. MICROBES AS BIOFERTILISERS

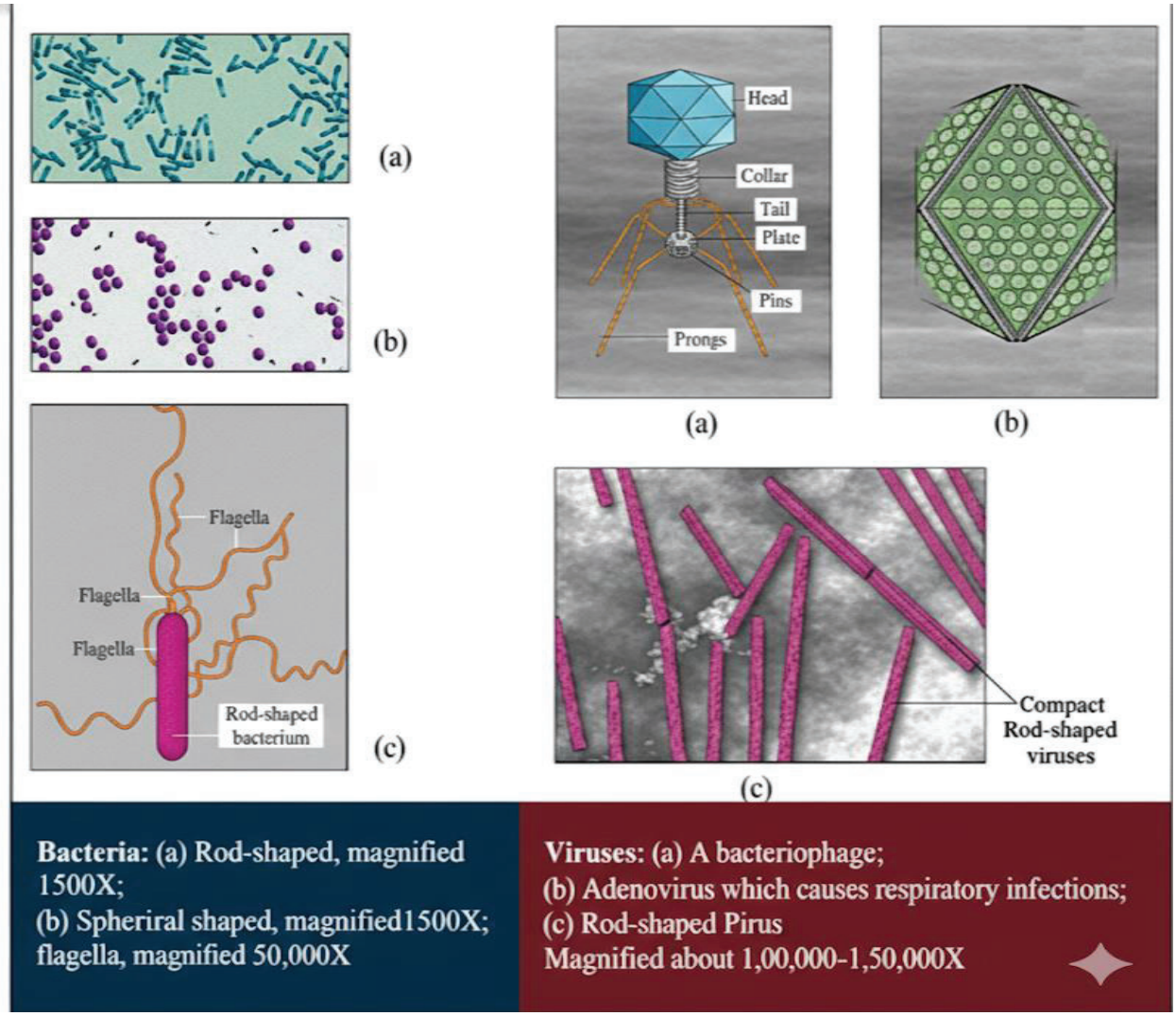
THEORY

INTRODUCTION:

- The applied branch of biology that deals with the study of microorganisms is known as **microbiology.**
- Microbes are present everywhere **i.e.** Soil, water, air, inside our bodies and that of other animals and plants.
- They are present even at sites where no other life-form could possibly exist, such few sites are-
  - Deep inside the **geysers** (thermal vents) where the temperature may be as high as **100 C .**
  - Deep in the soil.
  - Under the layers of snow several metres thick.
  - In highly acidic environments.
- Microbes include bacteria, fungi, protozoa, microscopic algae, viruses and viroids, as well as prions, which are infectious protein particles.
- 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.
- Some microbes cause diseases in both plants and animals and some other microbes are useful to mankind to obtain beneficial products to mankind.



(a) Colonies of bacteria growing in a petri dish;
(b) Fungal colony growing in a petri dish



Bacteria: (a) Rod-shaped, magnified 1500X;
(b) Spheriral shaped, magnified1500X; flagella, magnified 50,000X

Viruses: (a) A bacteriophage;
(b) Adenovirus which causes respiratory infections;
(c) Rod-shaped Pirus
Magnified about 1,00,000-1,50,000X

Uses of microbes to Man :-

The important uses of microbes to mankind are ;

1. Used in the production of household products
2. Production of fermented beverages
3. Production of antibiotics
4. Production of chemicals, enzymes and other bioactive molecules
5. Used in sewage treatment
6. Used in the production of biogas
7. Used as Bio-control agent
8. Used as Bio-fertilizer

8.1. Microbes In Household Products

1. Microbes are used in 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 into curd.

During growth, the LAB produce acids that coagulate and partially digest the milk proteins.

- A small amount of curd added to the fresh milk as **inoculum or starter** contain millions of LAB, which at suitable temperatures multiply, thus converting milk to curd.

Significances of LAB –

- It improves its nutritional quality by **increasing vitamin B_{12}.**
- In our stomach too, the LAB play very beneficial role in checking disease causing microbes.

2. Microbes are used in the production of food like Dosa and Idli :-

- The dough, which is used for making foods such as **dosa** and **idli** is also fermented by bacteria.
- The puffed-up appearance of dough is due to the production of CO_2 gas.

Note:- Fermentation is a microbial mediated process where dough rises, developing volume and flavour. Can you tell which metabolic pathway is taking place resulting in the formation of CO_2?

The metabolic pathway with CO_2 as one of the byproduct of glucose breakdown is anaerobic respiration or **alcoholic fermentation**. It involves breakdown of glucose into pyruvic acid through **glycolysis** and then breakdown of pyruvic acid into carbon dioxide and alcohol in alcoholic fermentation, eg. Yeast.

Where do you think the bacteria for these fermentations come from?

The bacteria or yeasts are inoculated artificially or simply left overnight to begin fermenting with yeast and bacteria present naturally in air.

3. Bread:-

- The dough, which is used for making bread, is fermented using **baker's yeast** (Saccharomyces cerevisiae).

4. Toddy :-

- A traditional drink of some parts of southern India is made by fermenting sap from palms.

5.Some other fermented foods :-

- Microbes are also used to ferment fish, soyabean and bamboo shoots to make foods.

6. Cheese:-

- It is a dairy product.
- Cheese, is one of the oldest food items in which microbes were used.It is a nutritive product produced by curdling and ripening of milk.
- Changes in characteristics like texture, flavour and taste, the specificity results in variety of cheeses and is due to type of microbes used.
- **Examples:-**

Microbes	Product	Significances
1. Propionibacterium sharmanii (bacteria)	Swiss cheese	The large holes are due to production of a large amount of CO_2 by bacteria.
2. Penicillium roqueforti (Fungi)	Roquefort cheese	Ripened by growing a specific fungi on them, which gives them a particular flavour.

8.2. Microbes In Industrial Products

- Even in industry, microbes are used to synthesize a number of products valuable to human beings.
- **Beverages**, **antibiotics**, **enzymes** and **chemicals** are some examples.
- Production on an industrial scale, requires growing microbes in very large vessels called **fermentors.**

1. Fermented Beverages:-

- Beverages like **wine, beer, whisky, brandy** or **rum etc.** re produced with the help of microbes especially **yeast.**
- ***Saccharomyces cerevisiae,*** is commonly called **'brewer's yeast'**. It is used for fermenting malted cereals and fruit juices to produce **ethanol(**the process is known as alcoholic fermentation**).**
- Yeast contains an enzyme called **zymase** that brings about **alcoholic fermentation.**
- Depending on the type of the raw material used for fermentation and the type of processing (with or without distillation) different types of alcoholic drinks are obtained.

Microbes	Product	Examples
Saccharomyces cerevisiae	Alcoholic beverages	**Wine** and **beer** are produced without distillation. **Whisky**, **brandy** and **rum** are produced by distillation of the fermented broth.

2. Antibiotics :-

- Antibiotics produced by microbes are regarded as one of the most significant discoveries of the twentieth century and have greatly contributed towards the welfare of the human society.
- **Anti** is a Greek word that means **'against'**, and bio means **'life'**, together they mean **'against life' (in the context of disease causing organisms);**
- Whereas with reference to **human beings,** they are **'pro life'** and **not against.**
- Antibiotics are chemical substances, which are produced by some microbes and can kill or retard the growth of other (disease-causing) microbes.
- They are used to treat **plague, whooping cough, diphtheria, leprosy**

Penicillin was the first antibiotic discovered.

- **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 Penicillin after the mould Penicillium notatum.
- Full potential of Penicillin as an effective antibiotic was established much later by **Ernest Chain and Howard Florey.**
- This antibiotic was extensively used to treat American soldiers wounded in **World War II.** Fleming, Chain and Florey were awarded the **Nobel Prize in 1945,** for this discovery.
- Antibiotics have greatly improved our capacity to treat deadly diseases such as **plague, whooping cough (kali khansi), diphtheria (gal ghotu) and leprosy (kusht rog),**

- Today, we cannot imagine a world without antibiotics.
- After Penicillin, other antibiotics were also purified from other microbes.

3. Organic acids:- Produced by microbes:-

S.No.	Microbes	Type of microbes	Organic acids	Its Uses
1.	Aspergillus niger	Fungus	Citric acid	In food, drinks, pharmaceuticals
2.	Acetobacter aceti	Bacteria	Acetic acid	As Condiment
3.	Clostridium butylicum	Bacteria	Butyric acid	Food and perfume additives
4.	Lactobacillus sp.	Bacteria	Lactic acid	Food and cosmetics

4. Enzymes:- Produced by microbes:-

S.No.	Microbes	Enzymes	Its Uses
1.	Aspergillus	Pectinase Protease	Clarifying bottled juices in Industries
2.	Some bacteria (Bacillus, Pseudomonas) Some fungi and yeasts	Lipase	helpful in removing oily stains from the laundry.
3.	Streptococcus (modified by genetic engineering)	Streptokinase	As a 'clot buster' for removing clots from the blood vessels of patients who have undergone myocardial infraction leading to heart attack.

5. Bioactive molecules Produced by microbes:-

These molecules have some biological activity.

S.No.	Microbes	Type of microbes	Product	Its Uses
1.	Trichoderma polysporum	Fungus	Cyclosporin A	As an immunosuppressive agent in organ-transplant patients
2.	Monascus purpureus	Yeast	Statins	As blood-cholesterol lowering agents. It acts by competitively inhibiting the enzyme responsible for synthesis of cholesterol.

8.3. Microbes In Sewage Treatment

- The waste-water having large amounts of organic matter including human excreta and microbes is called sewage or the municipal waste water is called **sewage.**
- The sewage should not be discharged into natural water bodies like rivers and streams directly because it contains dangerous **pathogens**.
- Before disposal, sewage is treated in Sewage Treatment Plants (STPs) to make it less polluting.
- Treatment of waste water is done by the **heterotrophic microbes** naturally present in the sewage.

This treatment is carried out in two stages:

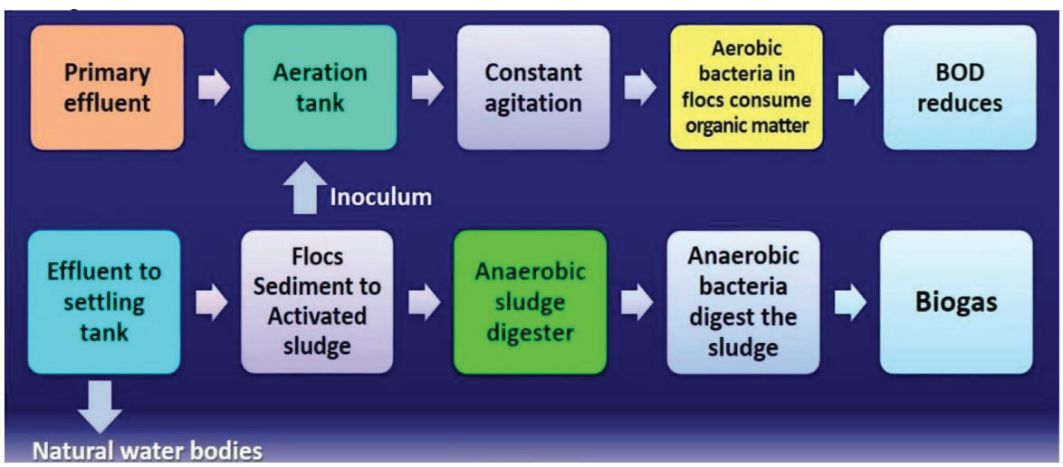
1. **Primary treatment:** It is the physical removal of particles.It involves the following steps:
   a. Initially, both large and small floating debris are physically removed through sequential **filtration.**

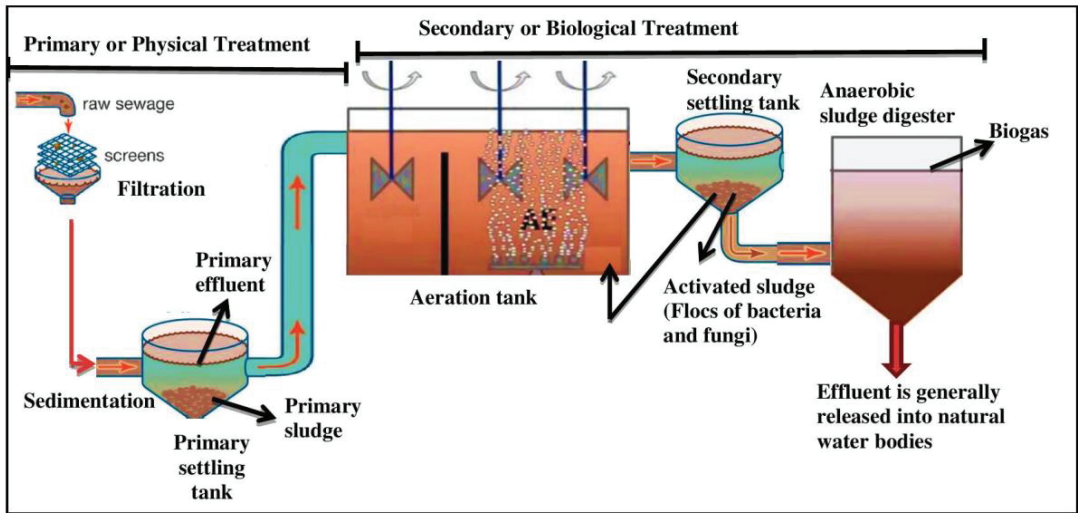
b. Then the grit (soil and small pebbles) are removed by **sedimentation**.

- All solids that settled at the bottom during sedimentation process is called **primary sludge** and Then supernatant forms the primary effluent.
- The effluent from the primary settling tank is taken for secondary treatment.

2. Secondary treatment or Biological treatment:

- The primary effluent is passed into large **aeration tanks.**
- In these tanks **air is pumped** and the effluent is mechanically agitated.This allows vigorous growth of useful aerobic microbes into **flocs (Flocs** means a mesh like structure formed by the association of masses of bacteria and fungal filaments).
- These microbes consume the major part of the **organic matter** in the effluent and reduce the **BOD (biochemical oxygen demand)** of the effluent.
- BOD refers to the amount of the oxygen required to oxidize or decompose organic matter in one liter of water by bacteria.
- BOD test denotes the amount of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential.
- When BOD of sewage water is reduced, the effluent is then passed into a settling tank where the bacterial 'flocs' are 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.**
- In anaerobic sludge digesters, anaerobic bacteria digest the bacteria and the fungi in the sludge.
- Bacterial digestion produces a mixture of gases such as **methane, hydrogen sulphide** and **carbon dioxide.** These gases form **biogas** and can be used as source of energy as it is **inflammable**.
- The purified effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams.So, Microbes play a major role in treating millions of gallons of waste water everyday across the globe.
- If the untreated sewage is often discharged directly into rivers leading to their pollution and increase in water-borne diseases.





This methodology has been practiced for more than a century now, in almost all parts of the world.

- Till date, no man-made technology has been able to rival the microbial treatment of sewage.
- **The Ministry of Environment and Forests** has initiated **Ganga Action Plan** and **Yamuna Action Plan** to save these major rivers of our country from pollution.

Primary treatment	Secondary treatment
It is the physical treatment of sewage	It is the biological treatment of sewage
It involves the removal of floating debris and grit by sequential filtration and sedimentation	It involves the oxidation of organic matter by flocs (aerobic bacteria and fungal filaments)
It can be used for land filling and composting	It is digested anaerobically to produce biogas and fertilizers

8.4. Microbes In Production Of Biogas

- Biogas is a mixture of gases (containing Methane,Carbon dioxide and Hydrogen sulphide) produced by the microbial activity which can be used as **fuel** (used for cooking and lightening).
- Methanogens grow anaerobically on cellulosic material and produce large amount of methane along with carbon dioxide and Hydrogen sulphide. **Example**:- The common methanogen is ***Methanobacterium***.
- These bacteria are commonly found in :-
  - **a.** The anaerobic sludge during sewage treatment.
  - **b.** The rumen (a part of stomach) of cattle (for cellulose digestion)

Do you think we, human beings, are able to digest the cellulose present in our foods?

No, Humans don't have cellulase enzyme.

- 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.**
- It consists of **methane $(50-70\%)$, $CO_2(30-40\%)$ and traces of hydrogen, nitrogen and hydrogen sulphide.**

Biogas plant

- The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a 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.
- Biogas plants are more often built in rural areas. The biogas thus produced is used for **cooking** and **lighting**.
- 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).**

Biogas production occurs in three stages :-

1. **In First stage:** the facultative anaerobic microbes degrade the complex polymers to simple monomers by enzymatic action.The Polymers like **cellulose**, **hemicellulose**, **proteins** and **lipids** get degraded into monomers.
2. **In second stage:** monomers are converted into **organic acids** by microbial action which are finally converted into **acetic acid.**
3. **In third stage:** acetic acid is oxidised into **methane** by the activity of anaerobic **methanogenic bacteria.**

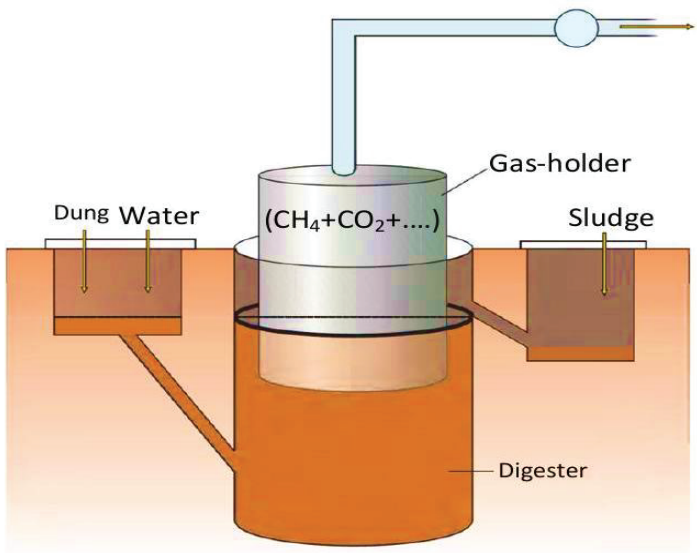


Fig : A typical biogas plant

8.5. Microbes As Biocontrol Agents

- **Biocontrol** refers to the use of biological methods for controlling plant diseases and pests. **Example:- Lady bird (beetle) controls aphids, Dragon flies control mosquito** etc.

Effects of chemicals on life forms:

- The chemicals such as weedicides, insecticides and pesticides,used to kill pathogens are toxic and extremely harmful, to human beings and animals.
- They also polluting our environment (soil, ground water), fruits, vegetables and crop plants.
- The soil is also polluted through the use of weedicides to remove weeds.
- In the 'conventional' farming practices which often use chemical methods to kill harmful life forms but also will kill useful life forms.
- The eradication of only pests is **not possible** for without them the beneficial predatory and parasitic insects which depend upon them as food or hosts would not be able to survive.
- The food web will be disturbed and it leads imbalance in the Nature.
- Thus,the use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.

Biological control of pests and diseases

- The use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.

1.	**Beetle with red and black markings - the Ladybird**	**Useful to get rid of aphids.**
2.	Dragonflies	Useful to get rid of **mosquitoes**.

S.No.	Microbes as Biocontrol agents	Significance
1.	Bacillus thuringiensis (Bt) (Bacteria)	• Bt toxin produced by this bacterium kills many insects those attack plants. • Control **butterfly caterpillars**.
2.	Trichoderma (free-living fungi that are very common in the root ecosystems).	• Use in the treatment of plant diseases. • Effective biocontrol Agents of several **plant pathogens**.
3.	Baculoviruses (Virus) (In the genus Nucleopolyhedrovirus)	• Attack **insects** and **other arthropods**

BACTERIA BACILLUS THURINGIENSIS (OFTEN WRITTEN AS Bt)

- These are available in sachets as dried spores which are mixed with water and sprayed onto 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 bacterial disease will kill the caterpillars, but leave other insects unharmed.
- Because of the development of methods of genetic engineering in the last decade or so, the scientists have introduced Bt- toxin genes into plants. Such plants are resistant to attack by insect pests.
- Bt-cotton is one such example, which is being cultivated in some states of our country.

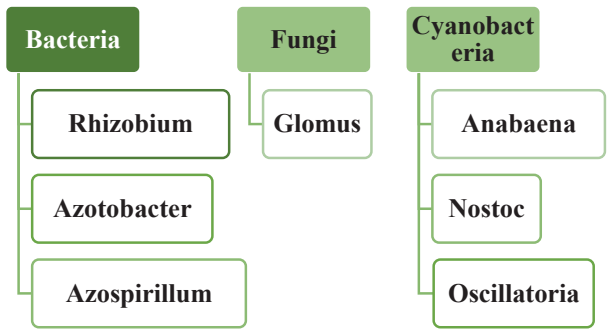
BACULOVIRUSES

Baculoviruses are pathogens that attack insects and other arthropods.

- The majority of baculoviruses used as biological control agents are in the genus ***Nucleopolyhedrovirus.***
- These viruses are excellent candidates for species-specific, narrow spectrum insecticidal applications.
- They have been shown to have no negative impacts on plants, mammals, birds, fish or even on non-target insects.
- This is especially desirable when beneficial insects are being conserved to aid in an overall **integrated pest management (IPM) programme,** or when an ecologically sensitive area is being treated.

8.6. Microbes As Biofertilizers

- **Bio-fertilisers** are the organisms that enrich the nutrient quality of the soil.
- The main sources of biofertilizers are **bacteria**, **fungi** and **cyanobacteria**.



S.No.	Microbes	Significance
1.	*Rhizobium*	• Symbiotic Nitrogen fixation • Enrich Nitrogen content in soil
2.	*Azotobacter*	• Free living bacteria • Nitrogen fixation • Enrich Nitrogen content in soil
3.	*Azospirillum*	
4.	*Glomus fungi*	• Forms Mycorrhiza • It absorbs Phosphorous from soil
5.	*Anabaena*	• Cyanobacteria, Nitrogen fixation • Add organic matter in soil and increases fertility. • Use in paddy fields as biofertilizers.
6.	*Nostoc*	
7.	*Oscillatoria*	

1. **Nitrogen fixing bacteria as Biofertilisers soil**

- **Examples** :- Rhizobium(Symbiotic),**Azospirillum** and **Azotobacter**(Free-living) thus enriching the nitrogen content of the soil.

a. Rhizobium :- It is a symbiotic nitrogen fixing bacteria present in the root nodules of legumes. It fixes the atmospheric nitrogen into organic form that can be used by the plants as a nutrient.

b. **Azospirillum** and **Azotobacter** :- These are Free-living soil bacteria.These bacteria can fix atmospheric nitrogen and increase the nitrogen content of the soil.

2. **Fungi as Biofertilisers:-**

a. Mycorrhiza:- It is a Symbiotic association between the fungus and roots of higher plants.

Example Many members of the genus **Glomus** form mycorrhiza.

The fungal symbiont in these associations:-

- Absorbs phosphorus from soil and passes it to the plant.
- Plants having such associations show other benefits also, such as resistance to root-borne pathogens.
- Tolerance to salinity and drought.
- An overall increase in plant growth and development.

3. **Cyanobacteria as Biofertilisers:-**

- **Cyanobacteria** are autotrophic microbes widely distributed in aquatic and terrestrial environments many of which can fix atmospheric nitrogen.**Examples :-**Anabaena, Nostoc, Oscillatoria, etc.
- **In paddy fields,** cyanobacteria serve as an important biofertiliser.
- Blue green algae also add organic matter to the soil and increase its fertility.

EXERCISE

PART-A

I. Select the correct alternative from the choices below: 1 Mark Each

1. **Propionibacterium shermanii is used in the production of**
   a) Roquefort cheese b) Swiss cheese
   c) Bamboo shoots d) Ferment fish
2. **Penicillium notatum is a**
   a) Bacteria b) Virus
   c) Blue green algae d) Mould
3. **Alexander Fleming discovered penicillin while working on**
   a) Staphylococci b) Streptococcus
   c) E. coli d) Salmonella
4. **Which one of the following alcoholic drinks is produced without distillation?**
   a) Wine b) Whisky
   c) Rum d) Brandy
5. **Because of the presence of which of the following vitamin, curd is considered as nutritionally rich than milk?**
   a) Vitamin B1 b) Vitamin B2
   c) Vitamin B9 d) Vitamin B12
6. **Bioactive molecules Cyclosporin-A is produced by**
   a) Fungus b) Bacteria
   c) Virus d) Protozoa
7. **Which micro-organism is useful in production of citric acid?**
   a) Acetobacter aceti
   b) Penicillium notatum
   c) Aspergillus niger
   d) Clostridium butylicum
8. **Activated sludge is the sediment deposited in**
   a) Settling tank b) Sedimentation tank
   c) Aerobic tank d) Anaerobic sludge digester
9. **Yeast is used in the production of**
   a) Bread and beer
   b) Cheese and butter
   c) Citric acid and lactic acid
   d) Lipase and pectinase

10. Biogas is the mixture of

a) CH4, CO2, H2 b) CH4, SO2, CO2

c) CH4, NO2, H2 d) CH4, SO2, H2

11. Mesh like structure consisting of bacteria associated with fungal filaments is

a) Primary sludge

b) Activated sludge

c) Floc

d) Anaerobic sludge

12. Match column I with column II and select the correct option:

a) a-(iii), b-(i), c-(ii), d-(iv)

b) a-(iii), b-(i), c-(iv), d-(ii)

c) a-(i), b-(iv), c-(ii), d-(iii)

d) a-(iii), b-(iv), c-(i), d-(ii)

13. Which of the following in sewage treatment removes suspend solids?

a) Secondary treatment b) Primary treatment

c) Sludge treatment d) Tertiary treatment

14. The primary treatment of sewage water involves

a) Anaerobic bacterial activity

b) Sludge digestion

c) Filtration and sedimentation

d) Aerobic bacterial activity

15. During sewage treatment, the gas produced in anaerobic sludge digester includes

a) Hydrogen sulphide, nitrogen, methane

b) Methane, oxygen, hydrogen sulphide

c) Methane, hydrogen sulphide, carbon dioxide

d) Hydrogen sulphide, methane, sulphur oxide

16. Mycorrhiza is involved in absorption of _____ from soil and passes it to the plant.

a) Nitrogen b) Phosphorus

c) Potassium d) Magnesium

17. Which of the following is not an advantage provided by mycorrhiza to plants?

a) Resistance to root-borne pathogens

b) Increase in yield quality

c) Tolerance to salinity and drought

d) Overall increase in plant growth and development

18. The microbial biocontrol agent for butterfly caterpillar is

a) Bacillus thuringiensis b) Saccharomyces

c) Cyanobacteria d) Staphylococcus

19. Which of the following is a bacterial biofertilizer?

a) Anabaena b) Nostoc

c) Rhizobium d) Oscillatoria

20. Which of the following is not a biofertilizer?

a) Agrobacterium b) Rhizobium

c) Nostoc d) Mycorrhiza

21. Which of the following statements regarding flocs is incorrect?

a) They are the masses of bacteria associated with fungal filaments.

b) Produced in aeration tank.

c) They consume major part of organic matter.

d) Formed by useful anaerobic microbes.

22. Compare the statements I and II:

Statement I: Mycorrhiza is the symbiotic association of algae and fungi.

Statement II: They absorb nitrogen from soil and pass it to the plant.a) Statement I is true, statement II is false.

b) Statement I is false, statement II is true.

c) Both the statements I and II are true.

d) Both the statements I and II are false.

23. Select the correct statement from the following.

a) Biogas is produced by the activity of aerobic bacteria on animal waste.

b) Methanobacterium is an aerobic bacterium found in rumen of cattle.

c) Biogas, commonly called gobar gas, is pure methane.

d) Activated sludge in settlement tanks of STPs is a rich source of aerobic bacteria

Answer Key					
1. B.	5. D.	9. A.	13. B.	17. B.	21. D.
2. D.	6. A.	10. A.	14. C	18. A.	22. D.
3. A.	7. C.	11. C.	15. C.	19. C.	23. D.
4. A.	8. A.	12. A.	16. B.	20. A.	

II. Fill in the blanks : 1 Mark Each

(Saccharomyces cerevisiae, Immunosuppressive agent, Clostridium butylicum, CO_2, Nucleopolyhedrovirus, methanogens, fermentors, Toddy, municipal waste water, clot buster, antibiotics, Rhizobium, mycorrhiza, activated sludge, effluent, Glomus)

1. Large vessels used in industry for growing microbes are called _____。
2. Sediments of flocs in the settling tank are called _____。
3. ___ are chemical substances, produced by some microbes and can kill or retard the growth of other microbes

4. Baculoviruses used as biocontrol agents are belongs to the genus _____.
5. The symbiotic association of fungi in roots of plants are known as _____.
6. Many members of the genus _____ form mycorrhiza.
7. Root nodules in leguminous plants are formed by symbiotic association of ___
8. _____ are the bacteria found in rumen of cattle.
9. Cyclosporin- A used as _____ are produced by Trichoderma polysporum.
10. _____ is a traditional drink of some parts of southern India is made by fermenting sap from palms.
11. The puffed appearance of dough is due to the production of _____.
12. Baker's yeast _____ is used for making bread.
13. Streptokinase is used as _____ for patients with myocardial infarction.
14. _____ is also called sewage.
15. _____ is a producer of butyric acid.

Answer Key

1. Fermenters
2. Activated sludge
3. Antibiotics
4. Nucleopolyhedrovirus
5. Mycorrhiza
6. Glomus
7. Rhizobium
8. Methanogens
9. Immunosuppressive agent
10. Toddy
11. CO_2
12. Saccharomyces cerevisiae
13. Clot buster
14. Municipal waste water
15. Clostridium butylicum

PART - B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each

Q1. Presence of microbes in water is an indication of pollution in water. At the same time, microbes also reduce pollution in water. Justify the statement.

Ans:

- Pollution Indicator: Presence of coliform bacteria in water indicates contamination and fecal pollution.
- Pollution Reduction: Useful microbes in sewage treatment plants degrade organic matter, thereby reducing water pollution.

Q2. Discuss the importance of aeration tank and anaerobic sludge digester in sewage treatment.

Ans:

- Aeration Tank: Aerobic microbes form 'flocs' and consume organic matter, which significantly reduces the BOD of effluent.

- Anaerobic Sludge Digester: Anaerobic microbes break down the sludge to release a mixture of gases called biogas (CH_4, CO_2, H_2S).

Q3. Discuss the role of fungi as biofertilizers.

Ans:

- Mycorrhizal fungi (e.g., *Glomus*) form a symbiotic association with plant roots.
- They help in phosphorus absorption and protect the plant from root-borne pathogens and environmental stress.

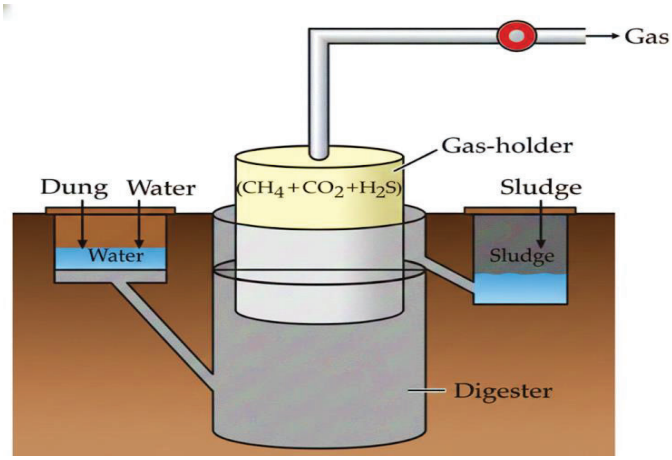
Q4. Define BOD. Mention its significance.

Ans:

- Definition: BOD (Biochemical Oxygen Demand) is the amount of oxygen required by microbes to decompose organic matter in one litre of water.
- Significance: It is a measure of the organic matter present in water. Higher BOD indicates higher water pollution.

Q5. Draw a neat labelled diagram of Biogas plant.

Ans:



Q6. Name the microbes responsible for the production of:

Ans:

- a) large holes in Swiss cheese: Propionibacterium shermanii
- b) Acetic acid: *Acetobacter aceti*

Q7. Mention any two significant roles of LAB (Lactic Acid Bacteria).

Ans:

- It converts milk into curd and improves its nutritional quality by increasing Vitamin B12.
- It plays a beneficial role in checking disease-causing microbes in our stomach.

Q8. List any two bioactive molecules of fungal origin and explain how those molecules help in restoring good health in humans.

Ans:

- Cyclosporin A: Used as an immunosuppressive agent in organ-transplant patients.
- Statins: Used as blood-cholesterol lowering agents.

Q9. Name any two bacteria used in the production of organic acids.

Ans:

- Acetobacter aceti (Acetic acid)
- Clostridium butylicum (Butyric acid)

Q10. Mention the scientific names of the organisms used in the production of cyclosporine A and statins.

Ans:

- Cyclosporin A: Produced by the fungus *Trichoderma polysporum*.
- Statins: Produced by the yeast *Monascus purpureus*.

Q11. Give any two examples for cyanobacteria which can fix atmospheric nitrogen.

Ans:

- Anabaena, Nostoc

Q12. How do cyanobacteria act as biofertilizers?

Ans:

- They fix atmospheric nitrogen and enrich the nitrogen content of the soil.
- They also add organic matter to the soil, increasing its fertility (e.g., in paddy fields).

Q13. What are flocs? Write their significance in sewage treatment.

Ans:

- Flocs: These are masses of bacteria associated with fungal filaments to form mesh-like structures.
- Significance: They consume the major part of the organic matter in the effluent, reducing its BOD during secondary treatment.

Q14. What is BOD? Write its significance.

Ans:

- BOD is the measure of oxygen required for microbial decomposition of organic matter.
- It indicates the level of pollution in water.

Q15. Name any two gases produced during sludge digestion in sewage treatment.

Ans:

- Methane (CH_4), Hydrogen Sulphide (H_2S)

Q16. Name the processes that help in physical removal of particles during sewage treatment.

Ans:

- Sequential Filtration & Sedimentation

Q17. Mention any two benefits offered by mycorrhiza other than as biofertilizer.

Ans:

- Provide resistance against pathogens.
- Increase tolerance to salinity and drought.

Q18. Biocontrol of insects and pests is desirable and beneficial compared to the use of insecticides and pesticides. Justify this with two reasons.

Ans:

- Biocontrol agents are eco-friendly and species-specific.
- They do not cause pollution or harm to non-target organisms.

Q19. Mention the source and use of penicillin.

Ans:

- Source: The fungus *Penicillium notatum*.

- Use: First antibiotic discovered, kills/stops growth of bacteria.

Q20. Name any two distilled and non-distilled alcoholic beverages.

Ans:

- Distilled: Whisky, Brandy, or Rum.
- Non-distilled: Wine and Beer.

PART - C

IV. Answer the following questions in 40 – 80 words each: 3 Marks Each

Q1. Mention the product and its use for the following:

Ans:

- **a) Acid produced by *Aspergillus niger*** – Citric acid, used in food and beverage industry.
- **b) Enzyme produced by *Streptococcus*** – Streptokinase, used as a clot-buster for myocardial infarction.
- **c) Bioactive molecule produced by *Trichoderma polysporum*** – Cyclosporin A, an immunosuppressive agent used in organ transplantation.

Q2. a) The use of biofertilizers is encouraged in agriculture to reduce the use of chemical fertilizers. Why?

Ans:

- Because chemical fertilizers pollute soil and water, whereas biofertilizers are eco-friendly and sustainable.

b) Write the role of mycorrhiza as biofertilizer.

Ans:

- Mycorrhiza increases phosphorus absorption, provides resistance to pathogens, and enhances plant growth.

Q3. Name the microbes that help in the production of the following products commercially:

Ans:

- **a) Cyclosporin A** – Trichoderma polysporum
- **b) Citric acid** – Aspergillus niger
- **c) Statins** – Monascus purpureus

Q4. List any three benefits of mycorrhiza as biofertilizer.

Ans:

- Increases phosphorus uptake.
- Provides resistance to root-borne pathogens.
- Enhances tolerance to salinity and drought, promoting overall plant growth.

Q5. Mention one use each for the following enzymes:

Ans:

- **a) Lipase** – Used in detergents and food processing.
- **b) Pectinase** – Used in fruit juice clarification.
- **c) Streptokinase** – Used as clot-buster in treatment of heart attack patients.

Q6. Briefly explain the contribution of Alexander Fleming.

Ans:

- Alexander Fleming discovered penicillin in 1928 while working on *Staphylococcus*.
- He noticed that *Penicillium notatum* inhibited bacterial growth.
- Penicillin became the first antibiotic and saved millions of lives, especially during World War II.

Q7. Mention any three cyanobacteria that are used as biofertilizers.

Ans:

- Anabaena, Nostoc, Oscillatoria.

Q8. Substantiate the following:

Ans:

- **a) Methanogens are found in the rumen of cattle.**
  - They digest cellulose in rumen and produce methane (biogas).
- **b) Nucleopolyhedrovirus (NPV) are species-specific.**
  - They attack only specific insects, thus safe for non-target organisms.
- **c) BOD is an index of water pollution.**
  - Higher BOD indicates more organic pollution, while lower BOD means cleaner water.

PART-D

V. Answer the following questions **5 Marks each**

Q1. Discuss the role of microbes in household products.

Ans:

- Microbes play a vital role in household food products. Lactic acid bacteria (LAB) convert milk into curd, enriching it with vitamin B12 and improving digestibility.
- LAB also inhibit harmful microbes in the gut. Saccharomyces cerevisiae (baker's yeast) is used for making bread, where CO_2 makes the dough puff and soft.
- Yeast is also used in fermenting rice, idli, dosa batter, giving them their spongy texture.
- Alcoholic beverages like wine and beer are produced by yeast fermentation of sugar without distillation.
- Traditional drinks like toddy are made by fermenting sap from palms.
- Thus, microbes contribute to food processing, flavor, nutrition, and preservation in households.

Q2. Explain the role of microbes in industrial products.

Ans:

- Microbes produce a variety of commercial products.
- Aspergillus niger produces citric acid, used in food and beverage industries.
- Acetobacter aceti is used for acetic acid production. Clostridium butylicum produces butyric acid, and Lactobacillus species produce lactic acid.
- Enzymes like pectinase, lipase, and streptokinase are industrially important.
- Antibiotics like penicillin from Penicillium notatum revolutionized medicine.

- Bioactive molecules include **Cyclosporin-A** (immunosuppressive agent from Trichoderma) and statins (cholesterol-lowering from Monascus).

- These products are widely used in food, pharmaceuticals, and healthcare, proving microbes as industrial workhorses.

Q3. Explain the process of sewage treatment.

Ans:

- Sewage treatment is done in two main stages.
    - **Primary treatment:** Physical removal of particles through filtration and sedimentation. Suspended solids settle as primary sludge, and the supernatant forms effluent.
    - **Secondary treatment:** Effluent is passed to an aeration tank, where aerobic microbes form flocs and consume organic matter, reducing BOD. This water is then sent to a settling tank, where microbes settle as activated sludge. Part of the sludge is recycled; the rest goes to anaerobic sludge digesters, producing biogas (CH_4, CO_2, H_2S). The treated water is discharged into natural water bodies.

Q4. Describe the role of microbes as (a) Biocontrol agents (b) Biofertilizers.

Ans:

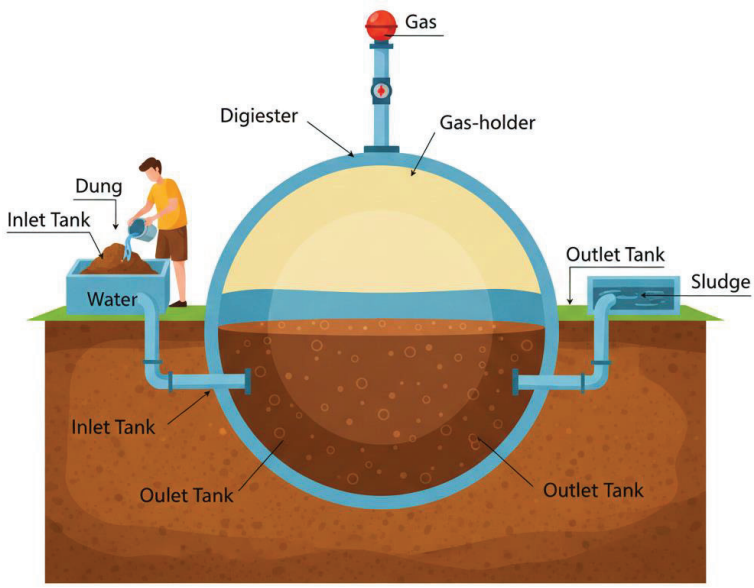
- **(a) Biocontrol agents:** Microbes naturally control pests. Bacillus thuringiensis produces toxin proteins killing insect larvae. Nucleopolyhedrovirus is specific to certain insects, safe for non-target species. Trichoderma fungi protect roots against pathogens.
- **(b) Biofertilizers:** Microbes enrich soil nutrients. Rhizobium fixes nitrogen in legume root nodules. Cyanobacteria (Anabaena, Nostoc) fix atmospheric nitrogen in paddy fields. Mycorrhizal fungi (Glomus) enhance phosphorus uptake and improve plant resistance.

Q5. a) Describe the role of microbes in sewage treatment. (3 Marks)

Ans:

- Microbes form flocs in aeration tanks, degrading organic matter and reducing BOD. In anaerobic sludge digesters, methanogens produce biogas from sludge. Thus, microbes purify water and generate renewable energy.

b) Draw a neat labelled diagram of typical Biogas plant. (2 Marks)



Q6. a) Explain the role of three organisms as biocontrol agents. (3 Marks)

Ans:

- Bacillus thuringiensis: Kills caterpillars by producing insecticidal proteins.
- Trichoderma: Protects plants from root-borne pathogens.
- Nucleopolyhedrovirus: Highly species-specific virus used against insect pests.

b) What is the significance of BOD? (1 Mark)

Ans: BOD indicates the level of organic pollution in water.

c) Give an example for a fungus found in Mycorrhiza. (1 Mark)

Ans Glomus.

Q7. a) Name the bioactive molecule for the following: (3 Marks)

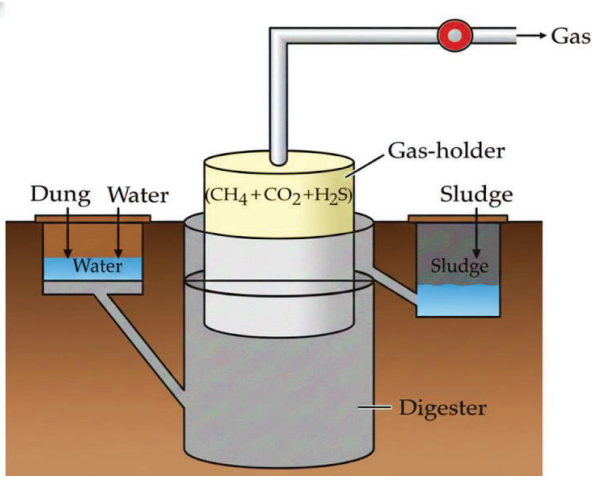
Ans:

i) A clot buster agent – Streptokinase
ii) An immunosuppressive agent – Cyclosporin A
iii) A blood cholesterol lowering agent – Statins

b) What are biofertilizers? Give one example. (2 Marks)

Ans: Biofertilizers are microorganisms that increase nutrient availability to plants. Example: Rhizobium.

Q8. a) Draw a neat labelled diagram of biogas plant. (3 Marks)



b) What are flocs? Write their significance in sewage treatment. (2 Marks)

Ans: Flocs are masses of bacteria with fungal filaments. They degrade organic matter, reducing BOD in sewage treatment.

PART – E

VI. Answer the following questions **5 Marks**

Q1. Complete the below given tabular column with appropriate answers.

Ans:

Microbe	Product	Uses
Propionibacterium shermanii	Swiss cheese	Large holes in cheese due to CO_2 release
Penicillium notatum	Penicillin	Antibiotic

Monascus purpureus	Statins	Blood cholesterol–lowering agent
Aspergillus niger	Citric acid	Food preservative, soft drink industry
Clostridium butylicum	Butyric acid	Used in pharmaceuticals & plastics

Q2. The biological method used for controlling plant diseases and pests is also a process of natural predation. Justify.

Ans:

- Biocontrol agents exploit natural relationships between microbes and pests, acting like natural predators.
- **Example:** *Bacillus thuringiensis* produces toxin proteins ingested by caterpillars, killing them without affecting other organisms.
- *Nucleopolyhedrovirus* (NPV) infects only specific insect species, making it eco-friendly and safe for non-target animals.
- *Trichoderma* fungi protect root systems by competing with and killing pathogens.
- Unlike chemical pesticides, these methods reduce pollution, maintain biodiversity, and provide long-term pest resistance.

Q3. The chemical composition of agricultural land can be improved by two methods… Discuss.

Ans:

- Chemical fertilizers supply nutrients quickly but lead to soil degradation, water pollution, and eutrophication.
- Microbial biofertilizers like *Rhizobium*, *Anabaena*, and *Nostoc* naturally fix nitrogen.
- Mycorrhizal fungi (*Glomus*) enhance phosphorus uptake and water absorption.
- These microbes are renewable, eco-friendly, and improve soil fertility long-term.
- Thus, biofertilizers are sustainable compared to chemical fertilizers, which harm the environment.

Q4. Complete the passage with appropriate answers.

Ans: While working on **Staphylococcus** (bacteria), **Alexander Fleming** (scientist) observed the growth of a mould **Penicillium notatum** (fungus) which did not allow the bacteria to grow. He found out that it was due to a chemical **penicillin** (antibiotic) produced by the mould.
of **Britain** (country) wounded in World War II. **Fleming**, **Chain** and **Florey** (Scientists) were awarded **Nobel** prize in **1945** (year) for this discovery.

Q5. A person planned to start a biotechnology-based industry… Suggest him names of microorganisms.

Ans:

- **Lactobacillus –** for production of curd and lactic acid.
- **Saccharomyces cerevisiae –** baker's yeast, used in bread, beer, and wine production.
- **Penicillium notatum –** source of antibiotic penicillin.
- **Aspergillus niger –** production of citric acid.
- **Acetobacter aceti –** acetic acid (vinegar).
- **Trichoderma polysporum –** produces cyclosporin A (immunosuppressive agent).
- **Monascus purpureus –** produces statins to lower blood cholesterol.

- These microbes are commercially useful in food, pharmaceuticals, and beverages.

Q6. Assign the role of the following microbes:

Ans:

a) Lactobacillus in milk – Converts milk to curd, enriches vitamin B12, improves gut health.

b) Methanogens in rumen of cattle – Digest cellulose, release methane (biogas).

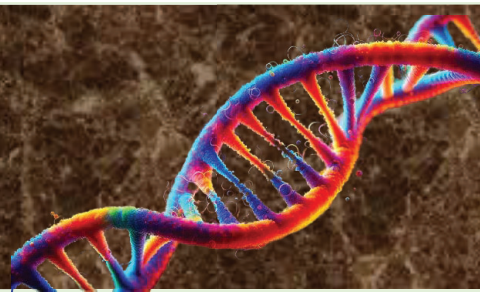
c) *Rhizobium* in nodules of legumes – Fix atmospheric nitrogen into ammonia for plants.

d) *Glomus* in mycorrhiza – Enhances phosphorus uptake and tolerance to stress.

e) *Trichoderma* in root ecosystems – Acts as a biocontrol agent against fungal pathogens.

Chapter 9

BIOTECHNOLOGY PRINCIPLES AND PROCESSES



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Theory

INTRODUCTION:

BIOTECHNOLOGY - It deals with techniques of using live **organisms** or **enzymes** from organisms to produce **products** and **processes** useful to humans.

- The term biotechnology was coined by **Karl Ereky**
- In this sense, making curd, bread or wine, which are **all microbe-mediated processes, could also be thought as a form of biotechnology.**
- Today, biotechnology in a restricted sense, refers to such of those processes which use **genetically modified organisms** to achieve the same on a larger scale.

Biotechnology

- Making curd, bread, wine are all microbe-mediated process or products.
- Synthesising a gene and using it.
- Developing a DNA vaccine.
- Correcting a defective gene.
- In vitro fertilisation leading to a 'test-tube' baby.
- Use of Genetically modified Organisms for manufacture products at larger scale.

The European Federation of Biotechnology (EFB) has given a definition of biotechnology that encompasses both traditional view and modern molecular biotechnology.

The definition given by EFB is as follows :-

'The integration of natural science and organisms, cells, parts there of, and molecular analogues for products and services'.

It refers to the art of using natural processes that takes place in a cell or living organism through the knowledge of science or biotechnological processes for human benefits and usages.

ERAS OF BIOTECHNOLOGY

OLD/TRADITIONAL

Use of natural capabilities of micro organisms.
For e.g.
1. Wine, Bread production by ***S. cerevisiae***
2. Curd making by ***Lactobacillus sp.***
3. Citric acid production by ***Aspergillus niger***

NEW/MODERN

Use of genetic engineering / Recombinant DNA technology

GMO (Genetically Modified Organisms) are produced.
For e.g. Human insulin gene transferred in ***E.coli***

9.1. Principles Of Biotechnology

Among many, the two core techniques that enabled birth of modern biotechnology.

Principles of Biotechnology

GENETIC ENGINEERING

Techniques to alter the chemistry of genetic material (DNA and RNA), to introduce these into host organisms.

It will change their phenotype.

BIOPROCESS ENGINEERING

Maintenance of sterile (microbial contamination free) ambience.

Growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc.

Conceptual development of the principle of genetic engineering

- Asexual reproduction preserves parental characters along with undesirable character.
- Sexual reproduction creates variations which may be **desirable** or **undesirable**.so it is not possible to get only desirable traits.
- Traditional **hybridisation** often led to inclusion of **undesired genes** along with **desired genes.**
- The technique of genetic engineering include the creation of recombinant DNA ,use of **gene Cloning and gene transfer.**This helps to isolate and introduce only **desirable genes without introducing undesirable genes** in target organism.

Fate of Alien DNA

What happens when a Alien DNA molecule is somehow introduced into a host cell?

The piece of DNA transferred to host cell would not be able to multiply itself. It is because of the absence of 'ori' site in the alien DNA.

How can you make the foreign DNA multiply or make copies of itself within the host cell?

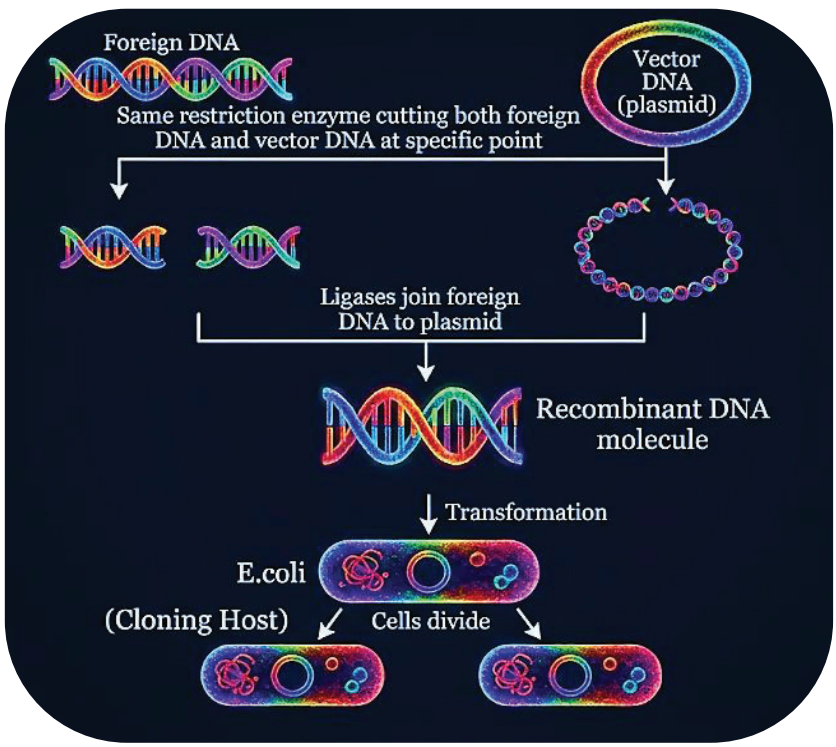
When the alien DNA gets integrated into the genome of host ,it multiplies and inherited. This is because in a Chromosomes there is a specific DNA sequence called **origin of replication,** which is responsible for initiating replication.

9.2.Construction of artificial rDNA

- The technique of genetic engineering which includes the creation of **Recombinant DNA** (two
- DNA molecules from different sources/genomes are linked is called as **rDNA**).
- The first recombinant DNA was constructed by **Stanley Cohen** and **Herbert Boyer** in **1972.**
- They cut antibiotic resistance gene from a plasmid of ***salmonella typhimurium*** with the help of restriction enzyme.
- They cut piece of DNA was then linked with another plasmid DNA.
- This plasmid DNA act as vector to transfer the piece of DNA attached to it.
- The antibiotic resistance gene made to join with plasmid vector by enzyme **DNA ligase.**
- This results in new combination of circular autonomously replicating DNA created in vitro and is known as **Recombinant DNA.**
- When this DNA is transferred into E.coli ,it could replicate using the new host DNA **polymerase enzyme and make multiple copies.**
- The ability to multiply copies of antibiotic resistance gene in E.coli is called Cloning of antibiotic resistance gene in E.coli.
- Genetic modification of an organism by the use of **gene cloning** and **gene transfer.**

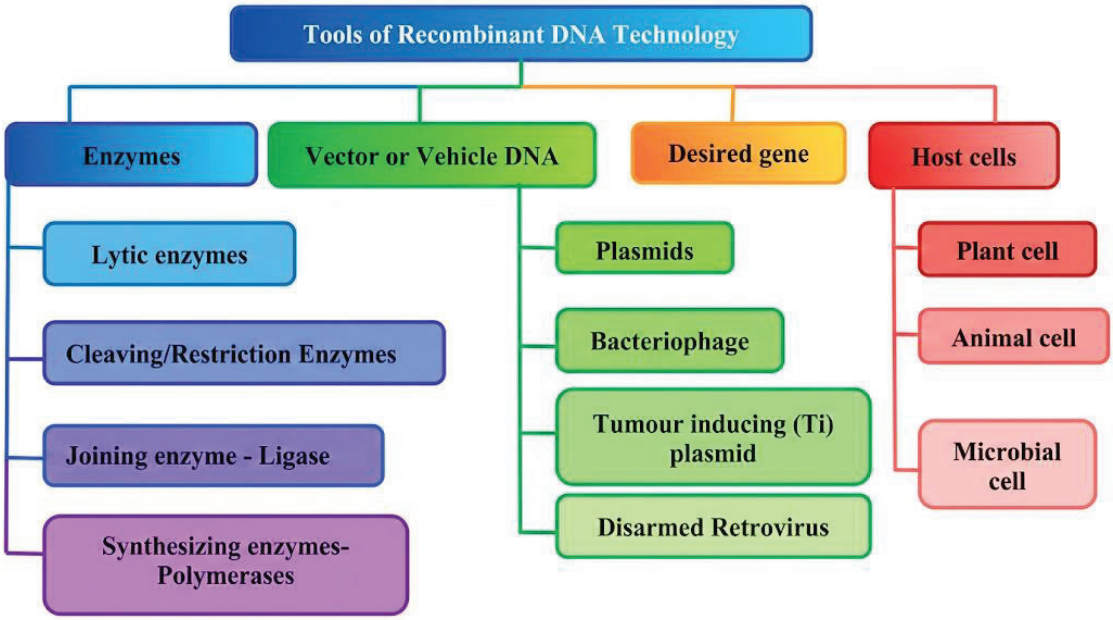
Three basic steps in genetically modifying an organism -

1. **Identification** of DNA with desirable genes.
2. **Introduction** of the identified DNA into the host.
3. **Maintenance** of introduced DNA in the host and transfer of the DNA to its progeny.



Diagrammatic Representation of rDNA Technology

9.3. Tools Of Recombinant DNA Technology



ENZYME

1. **Lysing enzymes :-** They are **cell wall degrading enzymes** which are used to open the cell for isolating DNA.

   (a) Lysozyme :- Digests bacterial cell wall.

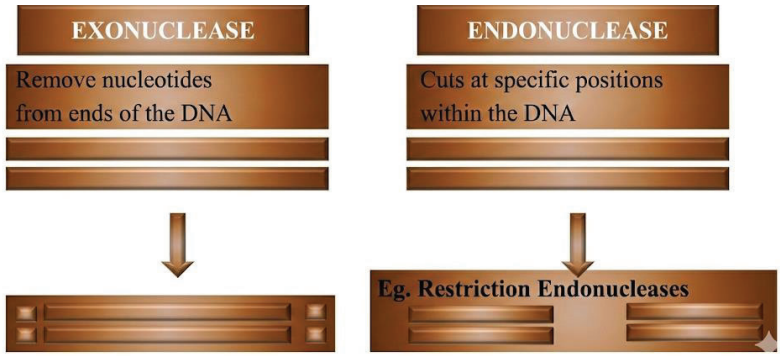
   (b) Cellulase :- Digests plant cell wall.

   (c) Pectinase :- Digests plant cell wall.

   (d) Chitinase :- Digests fungal cell wall.

2. **Cleaving Enzymes/Restriction Enzymes:-**

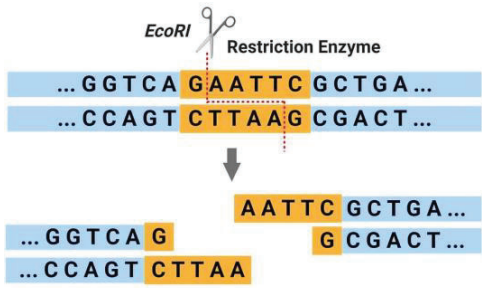
- The nuclear enzymes that break DNA at specific sites are called **restriction endonucleases(REN).**
- The RENs are popularly known as **molecular scissors or molecular knives.**
- These are first discovered by **Hamilton smith.**
- In the year 1963, the two enzymes responsible for restricting the growth of bacteriophage in Escherichia coli were isolated.
  1. One enzyme **added methyl groups** to DNA to mask the restriction site,
  2. The other enzyme **cut DNA of bacteriophage.** The later was called **restriction endonuclease.**
- The first restriction endonuclease discovered was **Hind II.**
- It was found that Hind II always cut DNA molecules at a particular point by recognizing a specific sequence of **six base pairs.** This specific **six base pairs sequence** recognized by REN is known as the **recognition sequence for Hind II.**
- Restriction enzymes belong to a larger class of enzymes called **nucleases.**
- These are of two types namely **exonucleases** and **endonucleases.**



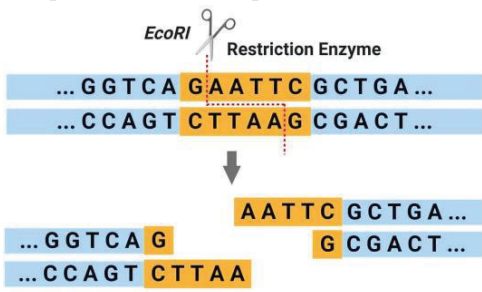
- Today more than **900** restriction enzymes have been isolated from over **230** strains of bacteria each of which recognize different recognition sequences.

Mode of functioning of REN enzyme:

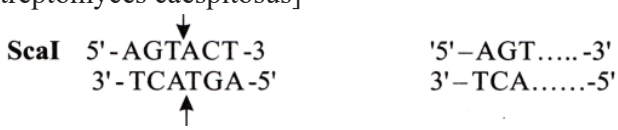
- Each restriction endonuclease recognizes a specific **palindromic nucleotide sequences** in the DNA and binds to it.
- This enzyme cut each of the two strands of the double helix at specific points in their sugar -phosphate backbones
- **Palindromes** are groups of letters that form the same words when read both forward and backward.**Ex :-** "MALAYALAM",'MADAM' ect
- The palindromic DNA is a **sequence of base pairs that reads same forward or backward on the two** strands of DNA. **For example,** the following sequences read the same on the two strands in 5′ to 3′ direction. This is also true if read in the 3 ' to 5 ' direction.



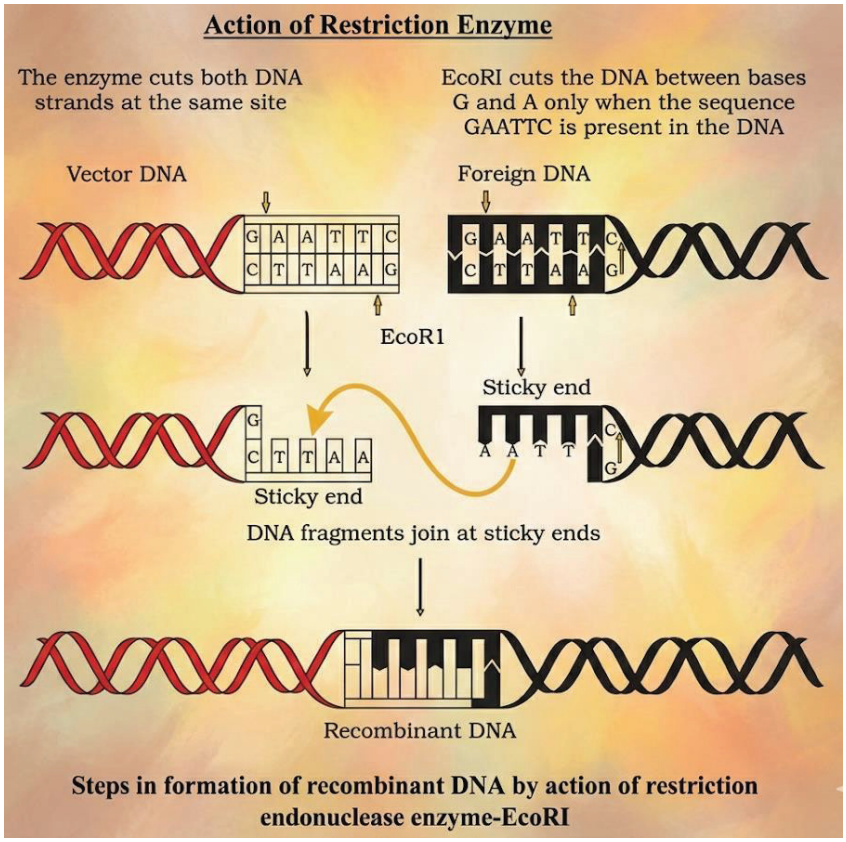
- One group of endonucleases cut the strand of DNA a little away from the centre of the palindrome sites and produces short single-stranded ends. Such single-stranded ends are called **sticky ends** and these can be joined together by using **DNA ligases.**
- **Example** for this category is EcoRI [Escherichia coli]



- Another group of endonucleases cut both the strands of DNA at the same place of palindromic sequence so that single stranded pieces are not left at the ends.
- These ends without single stranded sequences are called **blunt ends**
- **Examples:-** ScaI [Streptomyces caespitosus]



- **Fragments** with blunt ends may be used as such or also made sticky by addition of poly A and Poly T sequences with the help of terminal transferase.



Steps in formation of recombinant DNA by action of restriction endonuclease enzyme-EcoRI

NOMENCLATURE OF RESTRICTION ENDONUCLEASE –

The first letter : Indicates genus of bacteria.

Second and third letter : Indicates species of bacteria.

Fourth letter : Indicates strain of bacteria (optional).

Roman numerical : Order in which the enzymes were isolated from bacteria.

Examples:-

Enzymes Name	Genus name of source organism	Species name of source organism	Strain	Order of isolation from the bacteria strain
EcoRI	Escherichia	coli	**RY13**	I
Hind II	Haemophilus	influenzae	d	II
Hind III	Haemophilus	Influenzae	d	III
Bam HI	Bacillus	amyoliquefaciens	H	I

DNA ligase :-

JOINING ENZYME - DNA LIGASE (Molecular Glue)

- It makes phosphodiester bond in DNA.
- Sticky ends in DNA facilitates the action of enzyme Ligase.

SYNTHESIZING ENZYMES:-

1. **DNA POLYMERASE -** Synthesizes DNA.

2. **RNA POLYMERASE -** Synthesizes RNA.
3. **REVERSE TRANSCRIPTASE -** Synthesizes DNA from RNA.

(II) VECTOR DNA / VEHICLE DNA)

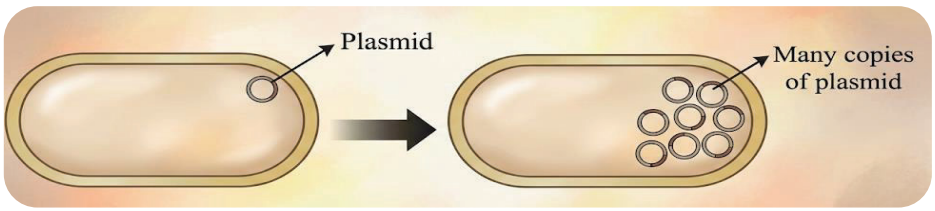
Vectors are the DNA **carriers** or **vehicles** that help to carry the desired gene from choice of organism to an **host cell** or **organisms** of interest.

Features required into a **CLONING VECTOR –**

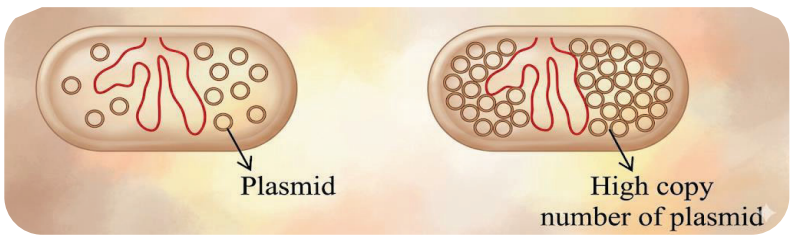
1. Origin of replication
2. Selectable marker
3. Cloning/Restriction sites

1. Origin of replication (ori) :-

- This is a specific DNA sequence from where **replication starts.**
- The alien DNA can be linked with the **plasmid vector** which has **ori** so that, this alien piece of DNA can **replicate** and **multiply** itself in the host organism. This is called as **Cloning** or making multiple identical copies of any template DNA.



- Ori responsible for controlling the **copy number of the linked DNA**. So, if one wants to recover many copies of the target DNA it should be cloned in a vector whose **origin support high copy number.**
- Some plasmids may have only **one** or **two copies per cell** whereas others may have **15-100 copies per cell.** Their numbers can go even higher.

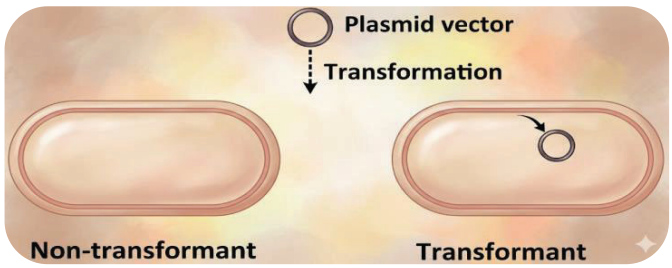


2. Selectable marker :-

- The **antibiotic resistance gene** present in the vector for **identifying** and **eliminating** the **non-transformants** and **selectively** permitting the growth of **transformants** are called **selectable markers.**
- **Transformation** is a process by which a piece of DNA is introduced into a host bacterium.

Examples:-(a) Antibiotic resistance genes – Ampicillin, Tetracycline, kanamycin etc.

(b) Genes encoding enzymes – β-galactosidase coding gene.



- The normal E.coli cells do not having resistance against any of these antibiotics.

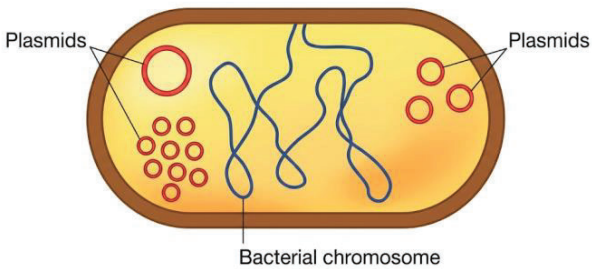
3. **Cloning sites / Restriction sites-** Site in vector where desired gene is inserted.

- The sites of plasmid where the desirable DNA can be inserted are called **Cloning sites.**
- These sites are recognized by specific RENs hence these are also called **recognition sites.**
- Single recognition site is preferred in each plasmid
- Presence of more than one recognition sites within the vector will generate several fragments, which will complicate the gene cloning.

Some examples of vectors:-

1) Plasmids as a vector-

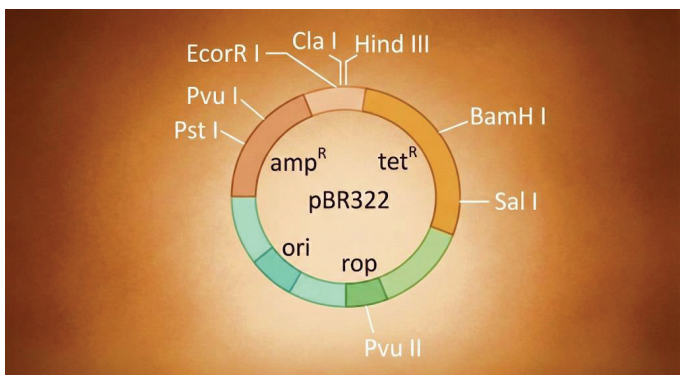
- Plasmids are **small, circular**, **extra-chromosomal** and **self replicating** ,double stranded DNA molecule present in bacteria.
- The have the ability to replicate within bacterial cells independent of the control of chromosomal DNA.
- They contain some genes like antibiotic resistance genes.
- They can cut at specific site by using restriction enzyme and desired gene can be inserted into these plasmids.



Examples:- F-plasmid ,R-Plasmid ect in addition to these plasmids there are some artificial plasmid like pBR-322(plasmid of Boliver and Rodriguez) and pUC-18 (plasmid of University of California)

Structure of pBR-322

- The Plasmid of **Boliver** and **Rodriguez** [pBR-322] is one of the earliest plasmid vectors to be constructed
- It measures about 4.3 kb in size. It has
- It has **thirteen** unique sites in different regions out of which **seven are important.**



Note :-

- It has restriction sites Hind III,EcoR I,Bam HI, Sal 1, Pvu-I, Pvu-II, Pst I, Cla I, etc
- EcoR I - Escherichia coli (GAATTC)
- Cla I - Caryophanon latum (ATCGAT)
- Hind III - Haemophilus influenzae (AAGCTT)
- BamH I - Bacillus amyoliquefaciens (GGATTC)
- Sal I - Streptomyces albus (GTCGAC)

- Pvu II - Proteus vulgaris (CAGCTG)
- Pst -I -Providencia stuarti (CTGCAG)
- Pvu I - Proteus vulgaris (CGATCG)

The following are the features that are required to facilitate cloning of genes into a **vector** or **plasmid**:-

1. Origin of replication (ori site)
2. Cloning sites
3. Selectable marker

1. Origin of replication (ori)

- This is a DNA sequence from where replication starts.
- Any piece of DNA when linked to this sequence can be made to replicate within the host cells. This sequence is also responsible for controlling the number of copies of the linked DNA.
- If many copies of the target DNA are required it should be cloned in a vector whose origin supports high number of copies.
- Normally each plasmid replicate to produce 20-30 copies per cell

2. Cloning sites:

- The sites of plasmid where the desired DNA can be inserted are called **cloning sites.**
- These sites are recognized by specific RENs hence are also called **recognition sites.**
- Single recognition site is preferred in each plasmid.
- Presence of more than one recognition sites will cause DNA fragmentation and disturb gene cloning.

3. Selectable marker:

- The antibiotic resistant genes inserted in the plasmids for **identification** and **elimination** of **non-transformants** and **selectively** permitting the growth of the transformants are called Selectable markers. **Eg**; Tetracycline resistant gene
- **Transformation** is a procedure through which a piece of DNA is introduced in a host bacterium. Normally, the genes encoding resistance to antibiotics such as **ampicillin, tetracycline or kanamycin**, etc., are considered useful selectable markers for E. coli.
- The normal E. coli cells **do not** have resistance against any of these antibiotics.

2) Bacteriophages as a Vector- Use to transfer the desired gene in bacterial cells.

For eg. λ -bacteriophage

NOTE- Plasmids and Bacteriophages have the ability to replicate within bacterial cells independent of the control of chromosomal DNA.

3) Vectors for cloning genes in plants and animals :

- **Ti plasmid of Agrobacterium tumefaciens** is used to deliver the desirable gene into plant cells.
- **Retroviruses are made non-pathogenic** and are used to deliver desirable genes into animal cells.

(III) Host cells - The cells of an organism in which we want to introduce the desired gene is known as host cells. It may be- **Plant cell, Animal cell** and **Bacterial cell.**

Host organisms in which foreign gene is inserted, such genetically modified organisms are also called as **Transgenic organisms.**

9. 4. Processes Of Recombinant DNA Technology

Steps involved in rDNA technology

1) Isolation of DNA.
2) Fragmentation of DNA by Restriction Endonuclease.
3) Agarose gel electrophoresis for isolating desired gene.
4) Amplification of gene of interest by PCR.
5) Ligation of DNA fragment into vector and thus forms rDNA.
6) Insertion of rDNA into host cells.
7) Selection of cells having rDNA (Recombinants).
8) Obtaining foreign gene product at large scale in Bioreactors.

(1) Isolation of DNA

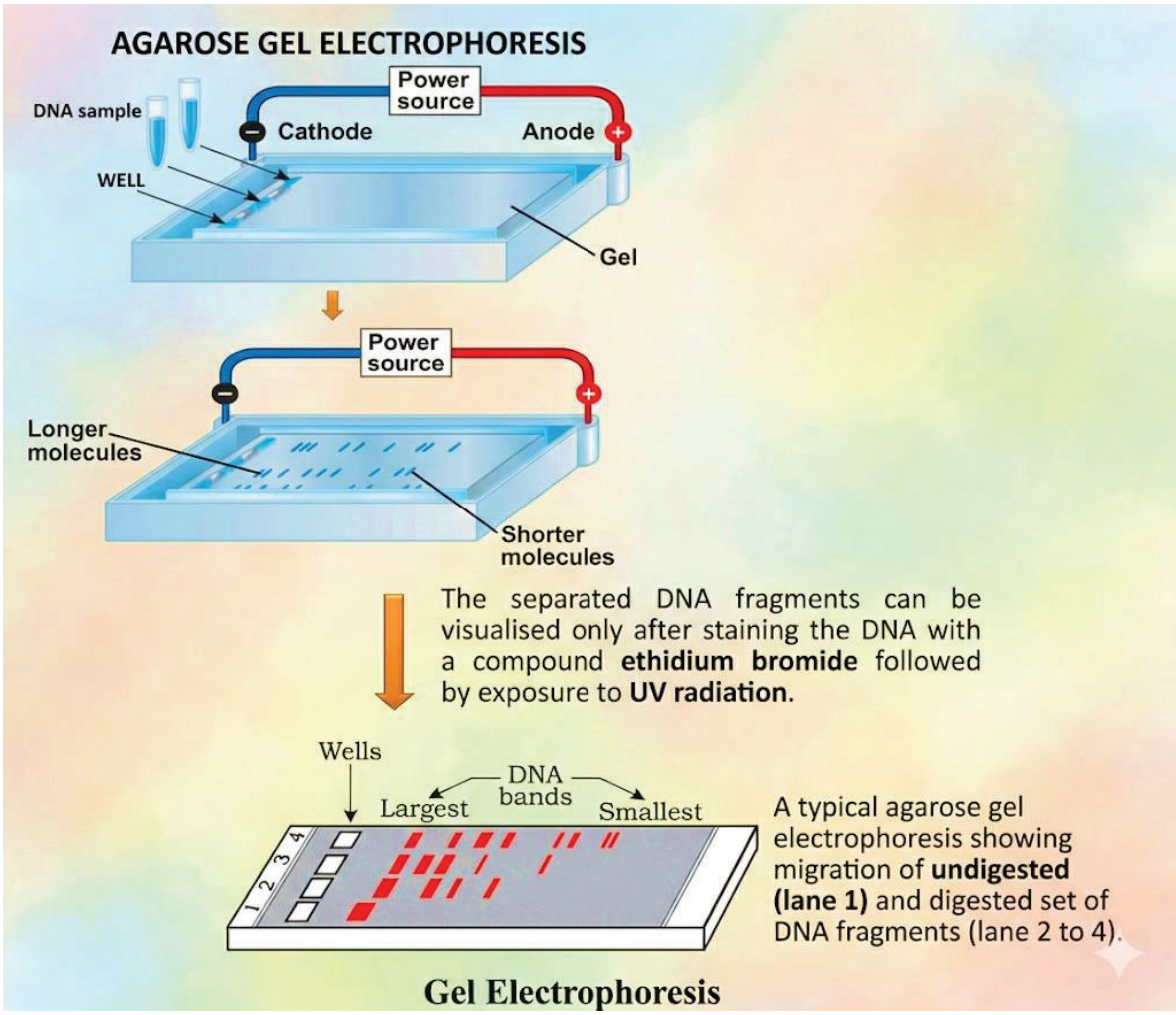
- Since the DNA is enclosed within the membranes, we have to break the cell open to release DNA along with other macro molecules(like RNA, proteins, polysaccharides and Lipids).
- In majority of organisms DNA is the genetic material. In order to cut the DNA with restriction enzymes, it needs to be in pure form, free from other macro-molecules.
- This can be achieved by treating the bacterial cells/plant or animal tissue with specific enzymes.
  - For bacterial cell -**Lysozyme**
  - For Fungal cell – **Chitinase**
  - For plant cell -**Cellulase**
  - For animal cell -**Protease, Lipase**
- The RNA can be removed by treatment with RNA digesting enzyme-**Ribonuclease.**
- Proteins can be removed by treatment with digesting Enzymes- **protease**
- Other biomolecules are removed by **appropriate treatments.**
- Thus pure DNA gets separated from proteins and other macro molecules.
- Finally, the purified DNA can be made precipitated by treating with **child ethanol.**
- After that ,the DNA seen **collection of fine threads** in the suspension.
- This threads of DNA can be removed by **spooling.**

(2) Fragmentation of DNA by Restriction Endonuclease

- The **purified DNA molecules are treated with REN** and **incubated at optimal conditions.**
- REN cuts the DNA into small fragments with sticky complementary single stranded DNA.

(3) Agarose gel electrophoresis for isolating desired gene-

- The cutting of DNA by **Restriction endonucleases** results in the fragments of DNA. These fragments can be separated by a technique known as **gel electrophoresis.** This was developed by Tiselius (1937).
- **Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion.**
- Since DNA fragments are **negatively** charged molecules they can be separated by forcing them to move towards the **positive electrode(anode)** under an electric field through a **agarose medium.**
- Nowadays the most commonly used **matrix is agarose** which is a natural polymer **extracted from sea weeds.**
- **The DNA fragments separate (resolve) according to their size** through sieving effect provided by the agarose. **Hence, the smaller the fragment size, the further it moves.**



- The separated DNA fragments cannot be seen in the visible light without staining.
- So, the plate is stained with ethidium bromide followed by exposure to **UV radiation.**
- **The DNA fragments are appear Bright orange after exposure to UV light.**
- The separated bands of desired DNA are cut out from the agarose gel and desired gene can be extracted from the gel piece. This step is known as **elution.**
- The DNA fragments purified in this way are used in constructing recombinant DNA by joining them with Cloning vectors.

(4) Amplification of gene of interest by PCR-

PCR stands for **Polymerase Chain Reaction.**

- The process of production of multiple copies of gene (or DNA) of interest in-vitro in presence of DNA polymerase is called **polymerase Chain Reaction.**
- Technique was invented by **Kary Mullis** in 1985.
- Principle - in vitro DNA replication.
- **Use -** Amplification of gene/DNA.
- **Instrument**- Thermal cycler. It is an automated cycler which can heat and cool the contents in a short time.

Requirements in PCR process- There are following requirement for PCR process -

(1) Desired gene in genomic DNA is used as a template.

(2) Deoxynucleotides (dNTPs) are used to make new strands.

(3) Two sets of **DNA primers** (small chemically synthesised oligonucleotides that are complementary to the regions of DNA) are used.

(4) Thermostable DNA polymerase (isolated from a bacterium, **Thermus aquaticus**), which remain active during the high temperature induced denaturation of ds DNA. It is known as **Taq DNA Polymerase.**

The steps in PCR process-

1) **Denaturation** (94°C) –
- In this ,the reaction mixtures is subjected to a temperature 94°C.
- It results the separation of two strands of DNA due to the breaking of hydrogen bonds. This is called **Denaturation.**
- The duration of the step is 2 minutes at 94°c.

2) **Annealing** (54°C) –
- During this step, the mixture is cooled to **54°c** to allow the primers to anneal their complementary sequences in single stranded template DNA.
- The duration of the step is **1 minute.**

3) **Extension** (72°C) –
- During this step, the mixture is heated again to 72°c for 2 minutes.
- At this optimum temperature **Taq DNA polymerase (**isolated from Thermus aquaticus) enzyme extends the primers using the **deoxynucleotides** provided in the reaction using provided DNA as template.

Applications of PCR :

- Diagnosis of pathogen and mutation
- Used in DNA fingerprinting

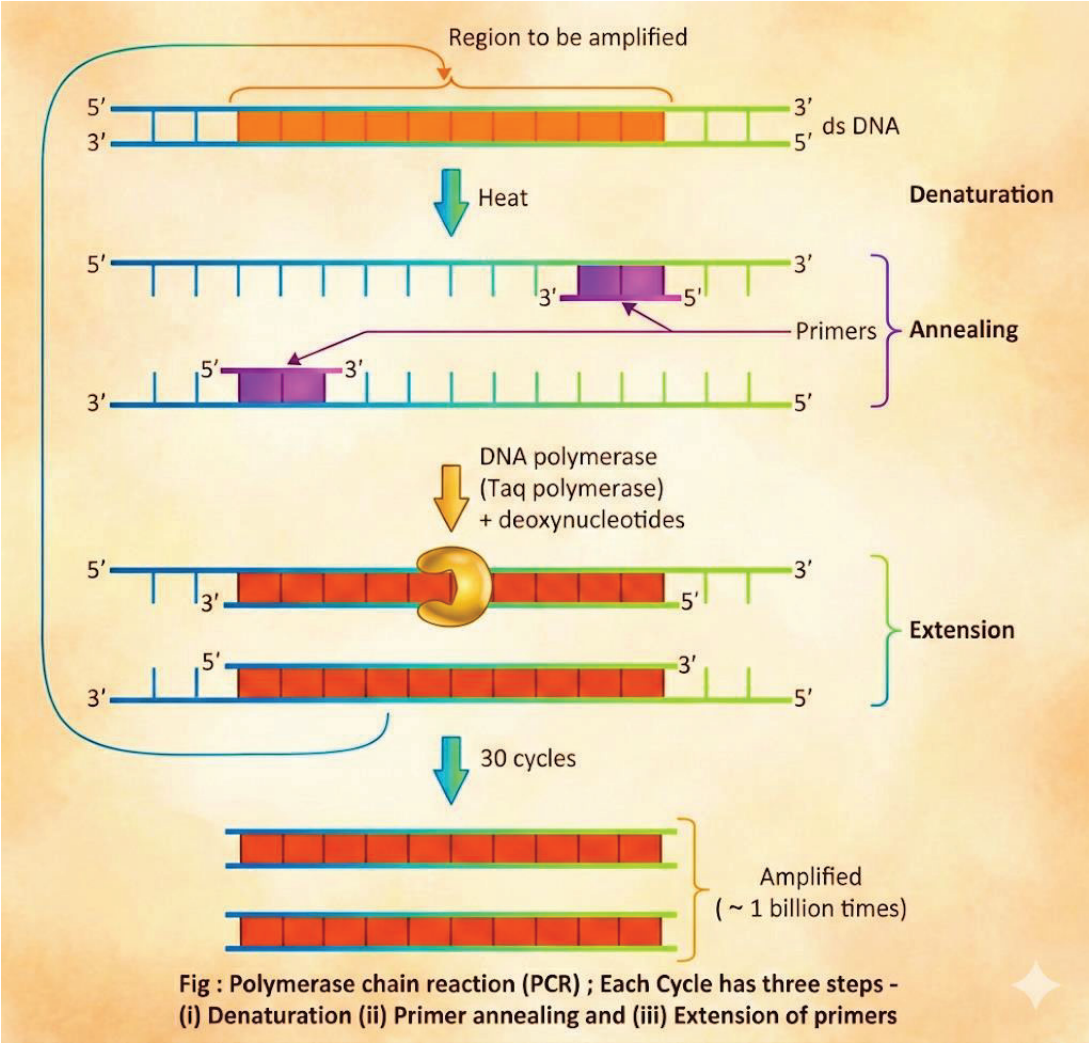


Fig : Polymerase chain reaction (PCR) ; Each Cycle has three steps - (i) Denaturation (ii) Primer annealing and (iii) Extension of primers

(5) Ligation of DNA fragment into vector and thus forms rDNA -

- The **hybrid DNA** formed by the fusion of **desired DNA** and **Plasmid or Vector DNA** is called **recombinant DNA.**
- The vector is an vehicle which is used to transfer DNA into host cell. **Ex :** plasmid , bacteriophage ect
- The vector having Ampicillin resistance gene is cut with same restriction endonuclease as that was used to generate the chromosomal DNA fragments.
- The chromosomal fragments and linearized vector are incubated with DNA ligase which covalently joins the DNA molecules.
- The hybrid plasmids which contains an inserted fragments are called **Recombinant plasmid.**

Note: - Recombinant DNA –If desired gene is ligated with vector. Non-recombinant DNA – If vector is self ligated.

(6) Insertion of alien DNA into host cells - Transfer of desired gene from one organism into another is an important aspect of genetic engineering.

(i) Bacterial Transformation

(ii) Gene transfer in plant cells by Ti plasmid.

(iii) Gene transfer in animal cells by Retrovirus.

(i) Bacterial transformation by Heat shock treatment:

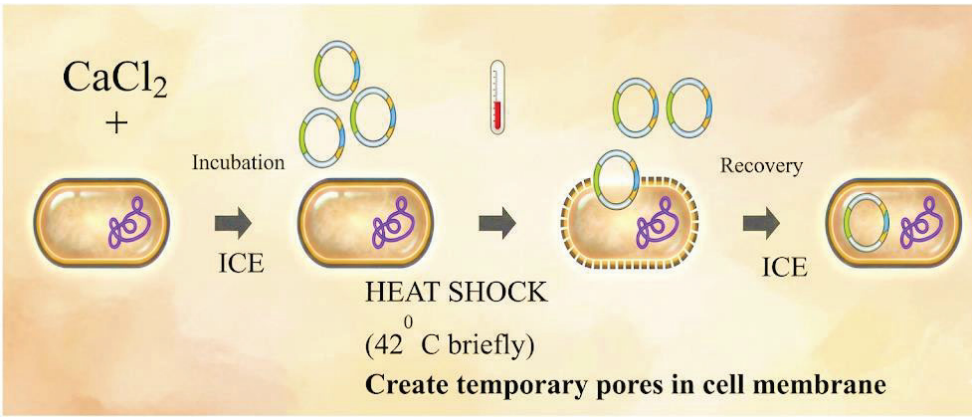
- **Bacterial transformation:-**The process of uptake of DNA by bacteria.

Competent cells :-

- As DNA is a hydrophilic molecule, it **cannot** pass through cell membranes.
- In order to force bacteria to take up the plasmid, the bacterial cells must first be made **'competent'** to take up DNA.
- This is done by treating bacteria with a specific concentration of a divalent cation, such as **calcium**, so that the cell wall becomes positively charged.
- Thus negatively charged DNA fragments of rDNA are attached to the receptor sites of cells wall.

Process of Transformation (Heat shock treatment)

- The competent cells are incubated along with alien DNA (rDNA/target DNS) in an ice-cold conditions.
- It is followed by heating them briefly to **42°c** (**heat shock**),and then putting them back on ice.
- Heat shock destabilizes cell wall/membranes resulting in the formation of small pores in that.
- This enables the bacteria to take up the recombinant DNA.
- After that Immediately the cells containing medium should be cooled by placing it on the ice. This allows the competent cells to take up the foreign DNA.



Note : The bacteria to be used as hosts should be without plasmids.

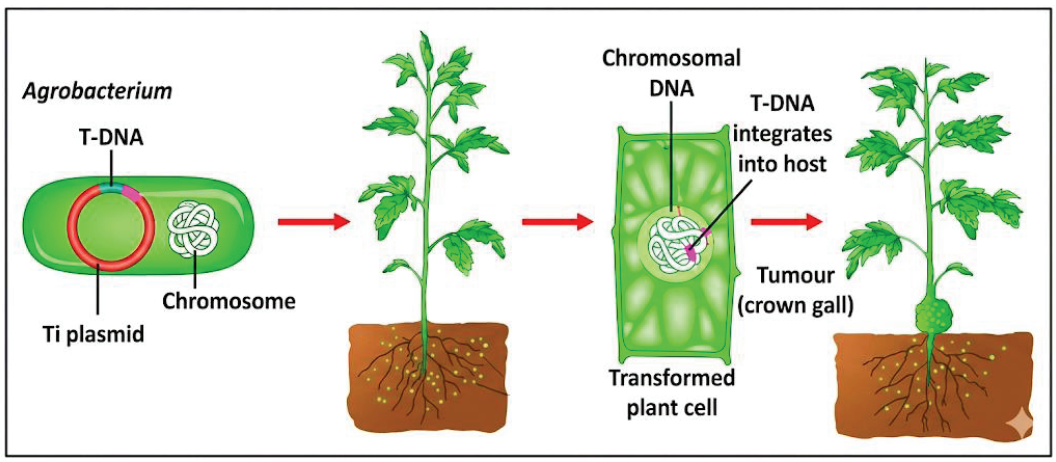
Transformants : E.coli with plasmid

Non-transformants : E.coli without plasmid

(ii) Gene transfer in plant cells- By Ti plasmid :

A. By Ti plasmid :-

- A plant pathogenic bacterium **Agrobacterium tumefaciens** produces **crown galls** or **plant tumours** in **almost all dicotyledonous plants.**
- Tumour formation is induced by it's plasmid which is therefore called **Ti plasmid (Ti = Tumour inducing).**
- **Agrobacterium tumefaciens** naturally transfers some part of Ti-plasmid in to host plant DNA without any human effort so it is called **natural genetic engineer of plant.** Agrobacterium is the only bacterium known for gene transfer ability.
- In the transformation process two essential component in Ti-plasmid –
  1. T-DNA - (Transfer DNA)
  2. Vir-region - (Virulence region)
- Inside the host plant cell T-DNA is separated from Ti-plasmid, and integrated into host plant DNA that causes **crown gall tumour.**



- The **tumor inducing (Ti) plasmid** of Agrobacterium tumefaciens is removed and modified into a cloning vector to deliver **gene of our interest** to the target plants.
- When we use Ti plasmid as a vector, first we remove the tumour causing gene from T-DNA region. Then desired gene in inserted in place of it. Now, this plasmid is called **Disarmed plasmid.**

B. **By Biolistics or Gene gun method:-** Biolistic is a mean of introducing DNA into cells that involves bombardment with high- velocity micro projectile coated with DNA.

- In biolistic method tungsten or gold particles coated with foreign DNA are bombarded into target cells at a very high velocity.
- Although this method is suitable for plants yet this technique is also used to insert DNA into animal cells.

(iii) Gene transfer in Animal cells :

A. By Disarmed pathogen vectors (Retrovirus)

- Similarly as the Ti plasmid, retroviruses in animals have ability to transform normal cells into cancerous cells. So, retrovirus have also been disarmed and are now used to deliver desirable genes into animal cells.
- Such genetically modified animals having foreign gene are called as **Transgenic animals.**

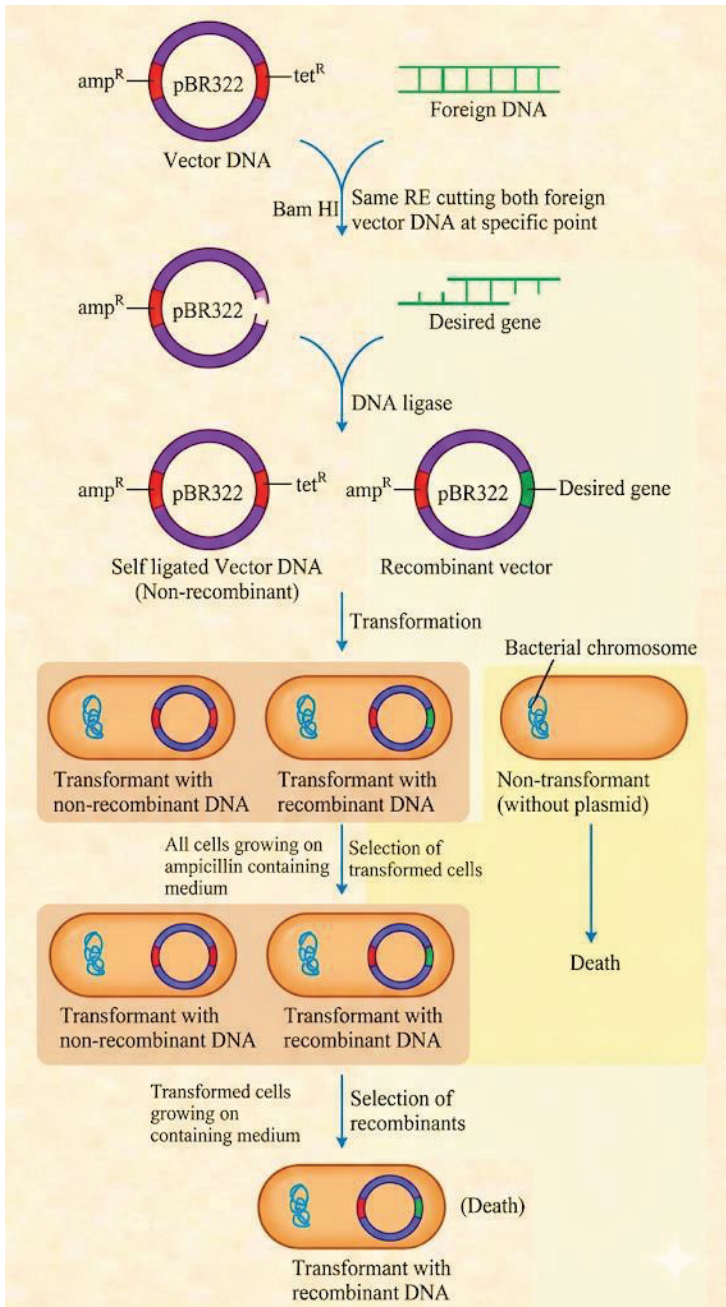
B. **Microinjection-** In this method, the **foreign DNA is directly injected** into the **nucleus of an animal cell** by using **micropipettes** or **glass needles**.

(7) Selection of Transformants with recombinant DNA (Recombinants)

- We need to select those transformants who have recombinant DNA, such cells are called as **Recombinants.**
- There are two methods for selection of transformants with recombinant DNA-

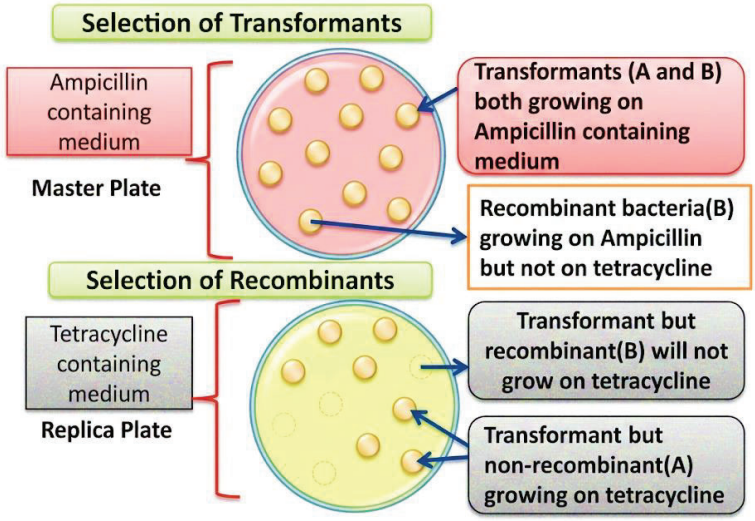
(a) Selection by two antibiotic resistant genes.

(b) Selection by Lac Z gene (β-galactosidase coding gene)



(a) Selection by two antibiotic resistant genes - A modified plasmid vector (pBR322) is suitable for selection by two antibiotic resistant genes .

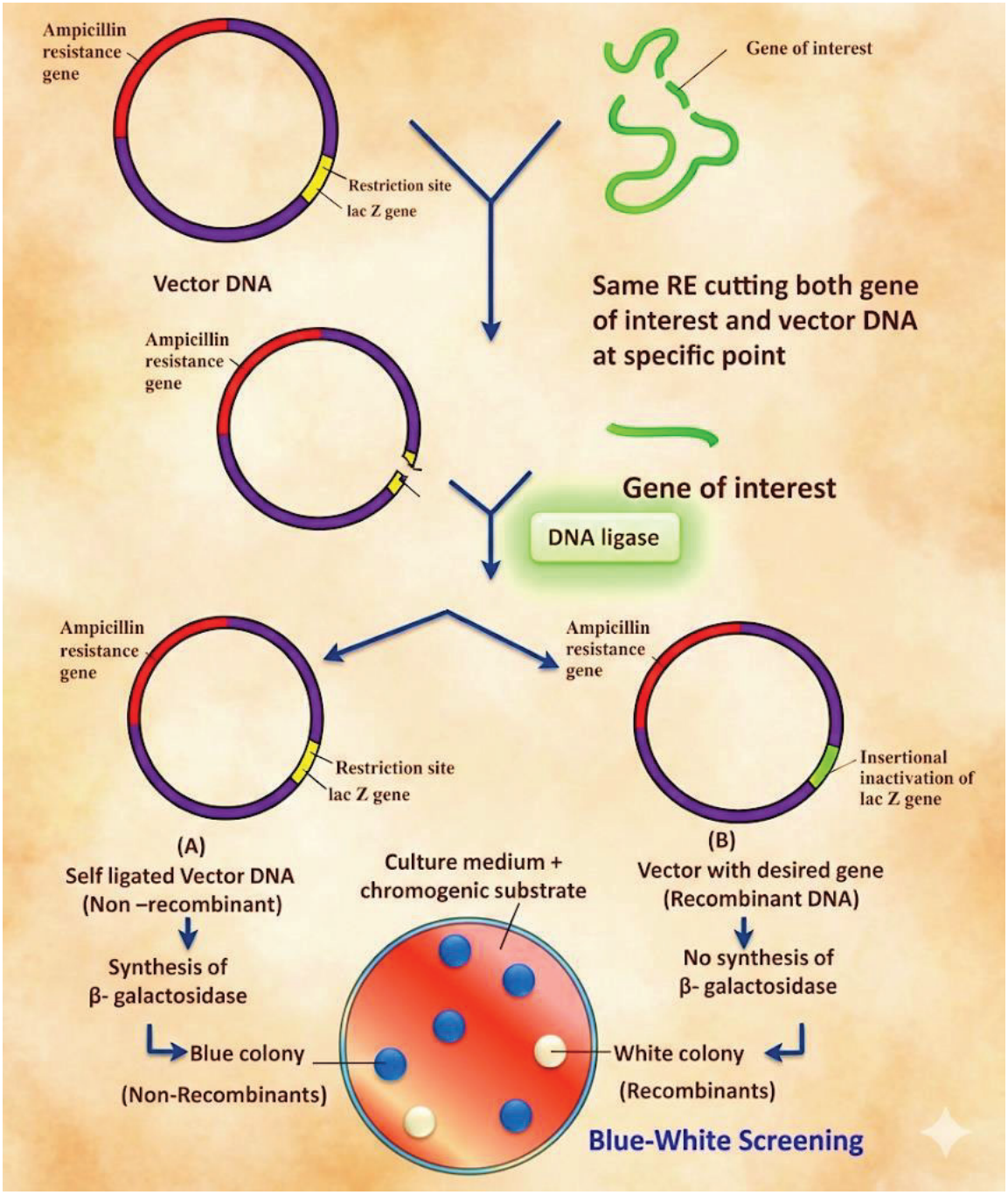
- Plasmid vector(pBR322) has two antibiotic resistant genes ampicillin and tetracycline along with different restriction sites for different restriction enzymes.
- The ligation of alien DNA at the **BaH I site of tetracycline resistance gene** in the vector PBR322.
- The recombinant plasmids will lose tetracycline resistance due to **insertion of foreign DNA (Insertional inactivation)** which helps in selection of recombinants.



- **In this experiment**, recombinants can be selected out from non-recombinant ones by **plating the transformants on ampicillin containing medium.**
- The transformants (plasmid transferred) growing on ampicillin containing medium are then **transferred on a medium containing tetracycline.**
- The **recombinants** will grow in ampicillin containing medium but not on that containing tetracycline. But, **non-recombinants** will grow on the medium containing both the antibiotics.
- In this case, **one antibiotic resistance(Amp^R) gene helps in selecting the transformants.** While, the other antibiotic **resistant gene(Tet^R) gets 'inactivated due to insertion'** of alien DNA, and helps in selection of **recombinants.**
- Selection of recombinants due to inactivation of antibiotic genes is a cumbersome (troublesome) procedure because it requires simultaneous plating on two plates having different antibiotics.

(b) Selection by Lac Z gene (β-galactosidase enzyme coding gene)

- Alternative selectable markers have been developed which differentiate **recombinants from non-recombinants** on the basis of their ability to produce colour in the presence of a chromogenic substrate.
- Insertion of foreign gene leads to the inactivation of selectable marker gene, such phenomenon is called as **Insertional inactivation**. It is responsible in **selecting the recombinants**.
- In this, a recombinant DNA is inserted within the coding sequence of an enzyme, which is referred to as insertional inactivation.
- The presence of a chromogenic substrate X–gal gives blue coloured colonies if the plasmid in the bacteria does not have an insert.
- Presence of insert results into insertional inactivation of the **β- galactosidase (reporter enzyme)** and the **colonies do not produce any colour,** these are identified as **recombinant colonies.**



(8) Obtaining the Foreign Gene Product -

- When we insert a piece of alien DNA into a **cloning vector** and **transfer it into a bacterial, plant or animal cell, the alien DNA gets multiplied.**
- In almost all recombinant technologies, the ultimate aim is to produce a **desirable protein.**
- Hence, there is a need for the **recombinant DNA to be expressed.** The foreign gene gets expressed under appropriate conditions.
- If any protein encoding gene is expressed in a heterologous host, is called a **recombinant protein.**
- The cells harbouring cloned genes of interest may be grown on a small scale in the laboratory.
- The cultures may be used for extracting the desired protein and then purifying it by using different separation techniques.

- After having cloned the gene of interest and having optimised the conditions to induce the expression of the target protein, one has to consider producing it on a large scale.
- **Continuous culture system-** In this culture, the used medium is drained out from one side while fresh medium is added from the other side to maintain the cells in their physiologically most active log/exponential phase.
- This type of culturing method produces a larger biomass leading to higher yields of desired protein. Small volume cultures cannot yield appreciable quantities of products.

(9) Bioreactor -

- To produce in large quantities, the bioreactors are developed.
- In this, large volumes (100-1000 litres) of culture can be processed.
- Thus, bioreactors can be thought of as vessels in which raw materials are biologically converted into specific products, individual enzymes, etc., using microbial ,plant, animal or human cells.
- A bioreactor provides the optimal conditions for achieving the desired product by providing optimum growth conditions (temperature, pH, substrate, salts, vitamins, oxygen).
- The most commonly used bioreactors are of stirring type.
- A stirred-tank reactor is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents.
- The stirrer facilitates even mixing and oxygen availability throughout the bioreactor. Alternatively air can be bubbled through the reactor.

A bioreactor has the following components.

(a) An agitator system /stirrer

(b) An oxygen delivery system

(c) A Foam control system

(d) A Temperature control system

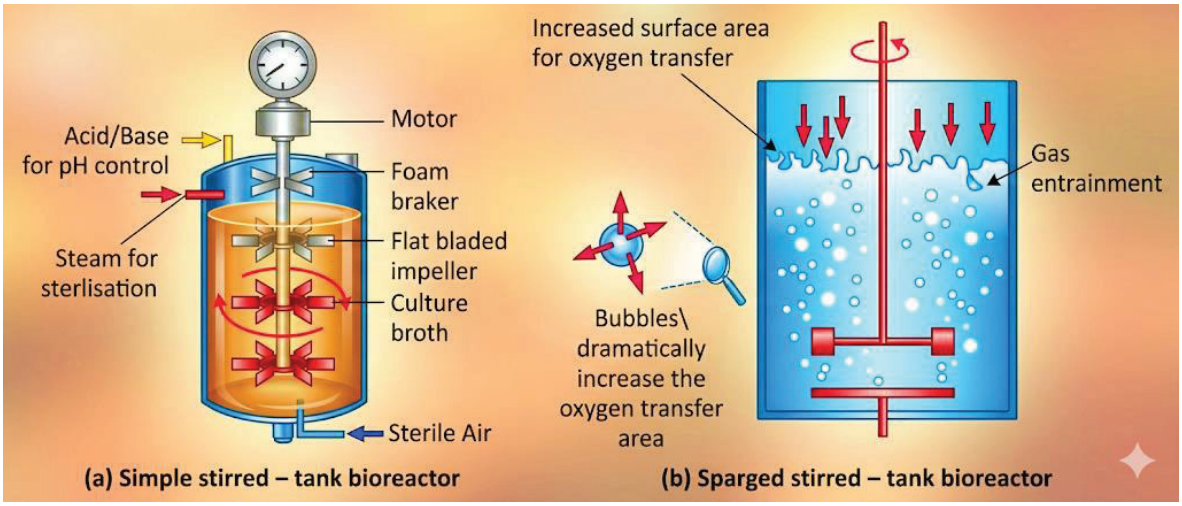
(e) pH control system

(f) Sampling ports to withdraw small volumes of cultures periodically

There are two type of bioreactors-

(a) Simple stirred-tank bioreactor

(b) Sparged stirred-tank bioreactor - through which sterile air bubbles are sparged.



(10) Downstream Processing-

- The series of processes involved in the separation and purification of a gene product at the end of biosynthetic phase in r-DNA technology are collectively called **downstream processing.**
- The various steps in downstream processing are as follows

1. The processes include separation and purification of the product.
2. The product has to be formulated with suitable preservatives
3. clinical trials
4. Strict quality control testing for each product is also required.

PU BOARD QUESTION BANK QUESTIONS

PART – A

I. Multiple Choice Questions: 1 Mark Each:

1. Which of the following is NOT a feature of plasmids?

a) Extra-chromosomal b) Circular structure

c) Single-stranded d) Independent replication

2. The procedure through which a piece of DNA is introduced into a host bacterium is:

a) Amplification b) Cloning

c) Transformation d) Restriction

3. Autonomously replicating circular extra-chromosomal DNA is called:

a) Vector b) Restriction enzyme

c) Marker d) Plasmid

4. Plant cells are bombarded with high-velocity micro particles of gold or tungsten coated with DNA in a method known as:

a) Microinjection b) Biolistics

c) Heat shock d) Vector-mediated

5. The commonly used vector for cloning genes in animals is:

a) Rhino viruses b) Disarmed retrovirus

c) Disarmed Ti plasmid d) Agrobacterium tumefaciens

6. Enzymes which remove nucleotides from the ends of the DNA are:

a) Endonucleases b) Exonucleases

c) DNA Ligase d) DNA polymerase

7. The restriction site of the EcoRI enzyme is:

a) 5'-GAATTC-3' b) 3'-GAATTC-5'

c) GAATTC d) 5'-CTTAAG-3'

8. The technique used to separate DNA fragments in recombinant DNA technology is:

a) Gel electrophoresis b) PCR

c) Autoradiography d) Downstream processing

9. Which of the following is the stain used to visualize DNA fragments in gel electrophoresis?

a) Cotton blue b) Ethidium bromide

c) Acetocarmine d) Saffranine

10. The extraction of separated bands of DNA by cutting them out from the agarose gel is:

a) Denaturation b) Fragmentation c) Elution d) Separation

11. The thermostable enzyme DNA polymerase (Taq polymerase) is obtained from:

a) Agrobacterium tumefaciens b) Thermus aquaticus

c) Escherichia coli d) Meloidogyne incognita

12. In the naming of restriction enzymes, the first letter of the name is derived from:

a) Species b) Genus c) Strain d) Family

13. Restriction enzymes belong to the larger class of enzymes called:

a) Oxidoreductases b) Ligases c) Isomerases d) Nucleases

14. Agrobacterium tumefaciens transforms normal plant cells into a tumor by delivering a piece of DNA known as:

a) Z-DNA b) C-DNA c) T-DNA d) R-DNA

15. Recombinant DNA is directly injected into the nucleus of an animal cell by:

a) Microinjection b) Gene gun c) Insertion d) Biolistics

16. Agrobacterium tumefaciens is used as a vector for cloning genes in:

a) Plants b) Animals c) Bacteria d) Viruses

17. Any protein-encoding gene expressed in a heterologous host is called a:

a) Recombinant DNA b) Recombinant RNA

c) Recombinant polysaccharide d) Recombinant protein

18. Hind II cuts DNA molecules at a specific point by recognizing a specific sequence of:

a) 4 base pairs b) 6 base pairs c) 5 base pairs d) 8 base pairs

17. A protein produced by expression of a cloned/recombinant gene in a heterologous host is called a:

a) Recombinant DNA b) Recombinant RNA c) Recombinant polysaccharide d) Recombinant protein

c) Denaturation → Annealing → Extension

d) Extension → Annealing → Denaturation

20. In the diagram of the pBR322 vector, identify the restriction sites/features A, B, C, and D: (Note: Referring to standard pBR322 mapping)

a) A – ampR, B – tetR, C – Ori, D – HindIII

b) A – Ori, B – HindIII, C – ampR, D – tetR

c) A – HindIII, B – tetR, C – ampR, D – Ori

d) A – tetR, B – HindIII, C – Ori, D – ampR

21. Statement I: Sticky ends result from the action of restriction enzymes. Statement II: Stickiness facilitates the action of DNA polymerase.

a) Statement I is true, statement II is false

b) Statement I is false, statement II is true

c) Both statements are true

d) Both statements are false

22. The purpose of a stirred-tank bioreactor is:

a) Providing anaerobic conditions in the culture vessel

b) Purification of the product

c) Addition and mixing of preservative

d) Availability of oxygen throughout the process

23. Which statement about cloning vectors is correct?

a) Hind II cuts DNA at a specific sequence of 6 base pairs

b) Micro-injection introduces rDNA into plant cells

c) Biolistics introduces rDNA into animal cells

d) Retroviruses are commonly used cloning vectors in animals

24. Statement I: Plasmid DNA acts as a vector to transfer the piece of DNA attached to it. Statement

23. Which statement about a cloning vector is correct?

a) It must contain an origin of replication (ori).

b) It must lack selectable markers.

c) It cannot contain a cloning site.

d) It must be unable to replicate in a host.

25. A single strand of nucleic acid tagged with a radioactive molecule is called a:

a) Vector b) Marker c) Plasmid d) Probe

Answer Key

Answer Key				
1. C	2. C	3. D	4. B	5. B
6. B	7. A	8. A	9. B	10. C
11. B	12. B	13. D	14. C	15. A
16. A	17. D	18. B	19. C	20. C
21. A	22. D	23. A	24. A	25. D

(Agrobacterium, Cancerous cells, Sticky ends, DNA, DNA Ligase, Heat shock, Cellulase, Vector, Restriction endonuclease, Primers, Ethidium bromide, EcoRI, Transformation, Polymerase Chain Reaction, Palindrome)

3. The plasmid DNA act as _____ to transfer the piece of DNA attached to it.

4. _____ functions by inspecting the length of a DNA sequence.

5. Small chemically synthesized oligonucleotides that are complementary to the regions of DNA are

4. A _____ recognises a specific nucleotide sequence and cleaves DNA at or near that site.

7. The technique that serves the purpose of early diagnosis is _____

8. _____ the enzyme used to break cells to release DNA along with other macromolecules in plants.

9. Retroviruses in animals have the ability to transform normal cells into _____.

10. Stickiness of the cut ends of DNA facilitates the action of the enzyme _____ .

11. _____ is the sequence of base pairs of DNA that reads same on the two strands when orientation of reading is kept same.

12. _____ is a procedure through which a piece of DNA is introduced in a host bacterium.

13. _____ is a method of making a competent host by placing cells in alternate temperature.

14. _____ is negatively charged, hence moves towards anode.

15. GAATTC is the restriction site of _____ .

Answer Key				
1. Agrobacterium	2. Sticky ends	3. Vector	4. Restriction endonuclease	5. Primers
6. Elution	7. Polymerase Chain Reaction	8. Cellulase	9. Cancerous Cells	10. DNA Ligase
11. Palindrome	12. Transformation	13. Heat Shock	14. DNA	15. EcoRI

PART – B

III. Answer the following questions 2 Marks Each:

Q1. What is biotechnology? Mention any two uses of it to mankind.

Ans: Biotechnology involves using living organisms or their components to create products and processes useful for humans. Two uses of biotechnology include producing recombinant DNA technology to create vaccines or therapeutic proteins, and creating genetically modified organisms for agricultural improvements, like pest-resistant crops.

Q2. Mention two core techniques that enabled the birth of modern biotechnology.

Ans: The two core techniques that enabled the birth of modern biotechnology are genetic engineering and the maintenance of a sterile environment in chemical engineering processes.

Q3. Name two bacteria that were used for developing recombinant DNA by Stanley Cohen and Herbert Boyer.

Ans: Stanley Cohen and Herbert Boyer used two bacteria for developing recombinant DNA: Salmonella typhimurium and Escherichia coli.

Q4. Mention any four tools used in recombinant DNA technology.

Ans: Four tools used in recombinant DNA technology are restriction enzymes, DNA ligase, vectors, and competent host organisms.

Q5. What are restriction enzymes? Mention their types.

Ans: Restriction enzymes are molecular scissors that cut DNA at specific sequences. They are a class of nucleases and are categorized into two main types: exonucleases, which remove nucleotides from the ends of the DNA, and endonucleases, which cut the DNA at specific sites within the molecule.

Q6. Differentiate between exonuclease and endonuclease.

Ans: Exonucleases remove nucleotides from the ends of a DNA molecule. In contrast, endonucleases make cuts at specific positions within the DNA.

Q7. Explain the convention for naming restriction endonucleases scientifically.

Ans: The convention for naming restriction enzymes uses a specific system. The first letter of the name comes from the genus of the organism, and the next two letters come from the species. The fourth letter (if present) indicates the strain, and the Roman numeral denotes the order of discovery. For example, EcoRI is named after Escherichia coli strain RY13, and it was the first enzyme discovered from this strain.

Q8. Mention the roles of restriction endonucleases and DNA ligase in genetic engineering.

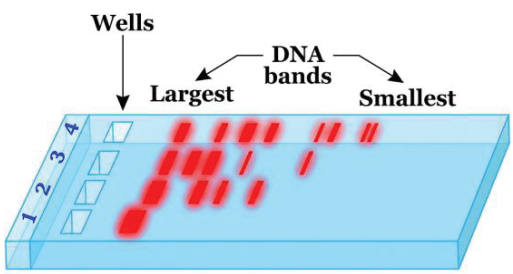
Ans: Restriction endonucleases act as molecular scissors, cutting the DNA at specific recognition sites to create fragments with "sticky ends". DNA ligase then acts as a molecular glue, joining these DNA fragments together to form a new recombinant DNA molecule.

Q9. Name the technique involved in the separation and isolation of DNA fragments. Which dye is used to stain the gel to make the DNA visible under UV light?

Ans: The technique used for the separation and isolation of DNA fragments is gel electrophoresis. The dye used to stain the gel and visualize the DNA fragments under UV light is ethidium bromide.

Q10. Draw a neat labeled diagram of a typical agarose gel electrophoresis.

Ans:



Q11. With reference to rDNA technology, what do you mean by 'insertional inactivation' and write the significance of it.

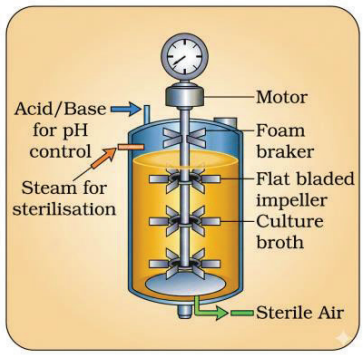
Ans: Insertional inactivation is a method for selecting recombinants in which the insertion of a foreign DNA fragment into a cloning vector's coding sequence for a selectable marker gene inactivates that gene. This is significant because it allows for the differentiation of recombinant cells (those with the inserted DNA) from non-recombinant cells (those without).

Q12. What are selectable markers? Mention their significance in genetic engineering?

Ans: Selectable markers are genes within a vector that help identify transformed cells and selectively allow their growth while killing non-transformed cells. Their significance in genetic engineering is that they help in the identification and selection of transformants from non-transformants by conferring resistance to certain antibiotics, such as ampicillin or tetracycline.

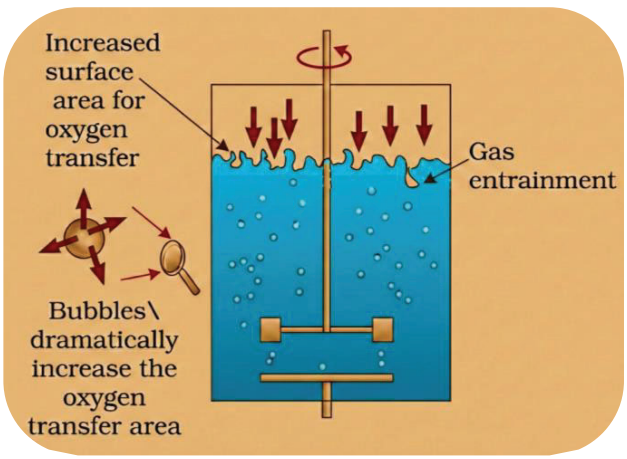
Q13. Draw a neat labeled diagram of a stirred tank bioreactor.

Ans:



Q14. Draw a neat labeled diagram of a sparged stirred tank bioreactor.

Ans:



Q15. How are bacteria like Escherichia coli made competent to take up recombinant DNA?

Ans: Escherichia coli and other bacteria are made competent to take up recombinant DNA by treating them with a specific concentration of a divalent cation like calcium chloride. This makes the cell membrane permeable to DNA. The cells are then subjected to a short-term heat shock (alternating between cold and hot temperatures) to force the DNA into the cell.

Q16. Define polymerase chain reaction. Name the enzyme used in it.

Ans: Polymerase Chain Reaction (PCR) is a technique used to amplify a specific segment of DNA to produce millions of copies. The enzyme used in PCR is a thermostable DNA polymerase.

Q17. Mention any four techniques available for the introduction of Alien DNA into host cells.

Ans: Four techniques for introducing foreign DNA into host cells are microinjection, biolistics (or gene

gun), heat shock, and vector-mediated transfer using organisms like disarmed retroviruses or tumifaciens.

Q18. What are palindromic nucleotide sequences? Write the restriction site for EcoRI enzyme.

Ans: Palindromic nucleotide sequences are sequences of base pairs that read the same on the two DNA strands when the orientation of reading is kept the same. The restriction site for the EcoRI enzyme is 5'-GAATTC-3' on one strand and 3'-CTTAAG-5' on the complementary strand.

Q19. Explain the method of preparing a competent host by heat shock method.

Ans: To prepare a competent host using the heat shock method, bacterial cells are first treated with a divalent cation such as calcium. This makes the cell wall and membrane permeable. The cells are then incubated with the recombinant DNA on ice. Following this, they are briefly placed in a hot water bath (e.g., at 42°C) before being immediately returned to ice. This sudden change in temperature allows the DNA to enter the bacterial cell.

Q20. Define the terms: a) Microinjection b) Biolistics

Ans: a) Microinjection is a technique where recombinant DNA is directly injected into the nucleus of an animal cell using a fine needle. b) Biolistics, also known as the gene gun method, is a process where plant cells are bombarded with high-velocity micro-particles of gold or tungsten coated with DNA.

Q21. Name the bacterium from which Taq polymerase is obtained. What is the unique feature of Taq polymerase?

Ans: The thermostable enzyme Taq polymerase is obtained from the bacterium Thermus aquaticus. Its unique feature is that it remains active at high temperatures, which is required for the denaturation step of the Polymerase Chain Reaction (PCR).

Q22. Name the vectors for cloning genes in plants and animal cells respectively.

Ans: For cloning genes in plants, a disarmed Ti plasmid from Agrobacterium tumefaciens is used. For animal cells, disarmed retroviruses are commonly used as vectors.

Part C

IV. Answer the following questions 3 Marks Each:

Q1. What is biotechnology? Mention two core techniques that enabled the birth of modern biotechnology.

Ans: Biotechnology is the use of living organisms or their components to produce products and processes beneficial to mankind. Modern biotechnology was born from two core techniques: genetic engineering, which allows the creation of recombinant DNA by altering the chemistry of genetic material, and the maintenance of a sterile environment in large-scale culture systems to enable the growth of only the desired microbe or cell.

Q2. Explain three basic steps of gene cloning.

Ans: The three basic steps of gene cloning are:

1. Isolation of the desired DNA fragment: The specific gene of interest is isolated from its source.
2. Ligation of the DNA fragment into a vector: The isolated gene is then inserted and joined with a cloning vector, such as a plasmid, using a DNA ligase enzyme to create a recombinant DNA molecule.
3. Transferring the recombinant DNA into a host cell: The newly formed recombinant DNA is introduced into a suitable host organism, like a bacterium, which can then be cultured to produce multiple copies of the gene and its product.

Q3. Mention the three basic steps in genetically modifying an organism.

Ans: The three basic steps in genetically modifying an organism are:

1. Identification of DNA with desirable genes: The specific gene of interest must first be identified and located in the donor organism's genome.
2. Introduction of the identified DNA into the host: The isolated DNA fragment containing the desired gene is then transferred into the host organism's genome using a vector.
3. Maintenance of the introduced DNA in the host and transfer of the DNA to its progeny: The new recombinant DNA must be replicated and stably maintained within the host cell and passed on to its offspring.

Q4. Discuss the mechanism of action of restriction enzymes with a schematic representation.

Ans: Restriction enzymes act by recognizing specific palindromic nucleotide sequences on the DNA. They then cut the sugar-phosphate backbone of the DNA at or near these sites. For example, the enzyme EcoRI recognizes the sequence 5'-GAATTC-3'. It cuts between the G and A bases on both strands, creating an overhang. These overhanging stretches are known as sticky ends, which can form hydrogen bonds with complementary sequences from other DNA fragments cut with the same enzyme. The enzyme DNA ligase is then used to permanently join these fragments together.

Q5. Schematically represent the steps in recombinant DNA technology.

Ans: The sequential steps involved in recombinant DNA technology are:

1. Isolation of the genetic material (DNA).
2. Fragmentation of DNA by restriction endonucleases.
3. Isolation of the desired DNA fragment.
4. Ligation of the DNA fragment into a vector.
5. Transferring the recombinant DNA into the host cell.
6. Culturing the host cells in a medium at a large scale.
7. Extraction of the desired product.

Q6. What is plasmid? Describe any two features of an ideal plasmid.

Ans: A plasmid is a small, circular, extra-chromosomal DNA molecule found in some bacteria that can replicate independently of the host's chromosomal DNA. Two features of an ideal plasmid for use as a cloning vector are:

1. Origin of replication (ori): This is a specific sequence on the DNA that initiates replication. It ensures that the inserted DNA fragment is also replicated along with the plasmid.

2. Selectable markers: These are genes, such as those for antibiotic resistance (e.g., ampicillin resistance), which help in selecting for transformed host cells and eliminating non-transformants.

Q7. Mention the significance of the following in plasmid: a) Ori site b) Selectable markers c) Cloning sites

Ans:

a) **Ori site (Origin of replication):** This is a specific DNA sequence that controls the number of copies of the linked DNA that can be maintained in the host cell. It is essential for cloning because it ensures that the inserted gene is replicated and passed on to daughter cells.

b) **Selectable markers:** These are genes that allow the identification and selection of transformed host cells from non-transformed ones. They typically confer resistance to antibiotics like ampicillin or tetracycline.

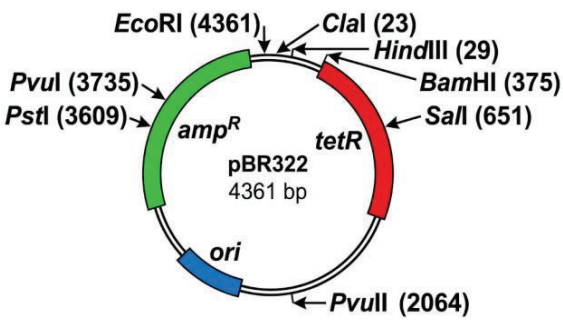
c) **Cloning sites:** These are recognition sites for restriction enzymes where foreign DNA can be inserted. A good cloning vector should have very few, preferably single, recognition sites to ensure that the vector is cut only once, allowing for successful ligation of the foreign DNA.

Q8. Explain the procedure of making bacterial cells competent to take up recombinant DNA.

Ans: Bacterial cells are made competent, or capable of taking up foreign DNA, by treating them with a specific concentration of a divalent cation, such as calcium, which increases the permeability of the cell membrane. This is followed by a heat shock treatment. The cells, along with the recombinant DNA, are first incubated on ice. Then, they are quickly transferred to a hot water bath (around 42°C) for a short period and immediately placed back on ice. This sudden temperature change creates pores in the cell membrane, allowing the DNA to enter the cell.

Q9. Draw a labeled diagram of plasmid pBR322.

Ans:



Q10. Sketch and label three steps of PCR.

Ans: The three steps of PCR are:

1. **Denaturation:** The double-stranded DNA is heated to a high temperature (around 94-96°C) to separate the strands.

2. **Annealing:** The temperature is lowered (typically to 50-65°C) to allow the primers to bind to their complementary sequences on the single DNA strands.

3. **Extension (or Elongation):** The temperature is raised (around 72°C) to allow a thermostable DNA polymerase to synthesize a new DNA strand by adding nucleotides to the primers.

Q11. What is polymerase chain reaction? List three steps of PCR technique. Mention the polymerase enzyme used in PCR.

Ans: Polymerase Chain Reaction (PCR) is a molecular biology technique used to amplify a specific DNA segment to produce millions of identical copies in a short time. The three main steps of the PCR technique are denaturation, annealing, and extension. The polymerase enzyme used in PCR is a thermostable DNA polymerase, most commonly Taq polymerase, which is obtained from the bacterium Thermus aquaticus.

Q12. Briefly explain the separation and isolation of DNA fragments.

Ans: The separation and isolation of DNA fragments are primarily done using gel electrophoresis. The DNA, which is negatively charged, is placed in wells on a gel matrix, and an electric current is applied. DNA fragments move towards the positive electrode (anode), with smaller fragments traveling faster and farther than larger ones. This separates the fragments by size. The DNA is then stained with ethidium bromide and viewed under UV light, where the bands of DNA fluoresce. The separated bands of DNA are then cut out from the agarose gel, and the DNA is extracted from the gel piece in a process called elution.

Q13. Write the importance of the following in r-DNA technology: a) PCR b) Ethidium bromide c) Bioreactor

Ans:

a) PCR (Polymerase Chain Reaction): PCR is a crucial tool in recombinant DNA technology as it allows for the amplification of a specific gene or DNA fragment to obtain millions of copies. This is essential for various downstream applications, such as sequencing, cloning, and diagnostic purposes.

b) Ethidium bromide: This is a dye used to stain DNA fragments after they have been separated by gel electrophoresis. When exposed to UV light, the DNA stained with ethidium bromide fluoresces, making the otherwise invisible bands of DNA visible for analysis and isolation.

c) Bioreactor: A bioreactor is a large vessel (100-1000 liters) that provides the optimal conditions for the large-scale production of a recombinant protein. It maintains conditions such as temperature, pH, and oxygen levels, ensuring the growth of the host cells and the efficient production of the desired product.

Q14. Explain the feature of cloning vectors.

Ans: An ideal cloning vector has several key features:

1. **Origin of replication (ori)**: A sequence that allows the vector to replicate inside the host cell and controls the copy number of the DNA.
2. **Selectable marker:** A gene, typically for antibiotic resistance, which helps identify and select transformants.
3. **Cloning sites:** Specific recognition sites for restriction enzymes where foreign DNA can be ligated. These sites should be present in a minimal number to avoid multiple cuts in the vector.
4. **Small size:** A small vector is easier to manipulate and can accommodate larger fragments of foreign DNA.

Q15. Define the following with reference to recombinant DNA technology: a) Cloning b) Elution c) Transformation

Ans:

a) Cloning: In recombinant DNA technology, cloning is the process of producing a population of

genetically identical individuals or cells that all contain a specific recombinant DNA molecule.

b) Elution: Elution is the process of extracting the separated DNA fragments from the agarose gel after they have been cut out.

c) Transformation: Transformation is the procedure through which a piece of DNA (the recombinant DNA) is introduced into a host bacterium.

Q16. Mention the importance of the following with respect to genetic engineering: a) tumifaciens b) Salmonella typhimurium c) Thermus aquaticus

Ans:

a) Agrobacterium tumefaciens This bacterium naturally transfers a piece of DNA (T-DNA) to plant cells, causing tumors. In genetic engineering, its tumor-inducing Ti plasmid has been disarmed and modified into a cloning vector to deliver foreign genes into plant cells.

b) Salmonella typhimurium: This was one of the first bacteria used by Stanley Cohen and Herbert Boyer in their pioneering work to construct the first recombinant DNA molecule.

c) Thermus aquaticus: This is a thermophilic bacterium from which the heat-stable Taq polymerase enzyme is obtained. This enzyme is essential for the Polymerase Chain Reaction (PCR) because it can withstand the high temperatures required for DNA denaturation.

Q17. Briefly explain the process of isolation of DNA from a plant cell.

Ans: To isolate DNA from a plant cell, the cells must first be broken open to release the DNA, along with other macromolecules. This is typically done by treating the cells with enzymes that break down the cell wall, such as cellulase. The DNA can then be purified by treating the cell lysate with enzymes like ribonuclease (to remove RNA) and proteases (to remove proteins). Finally, the pure DNA is precipitated by adding chilled ethanol. The DNA forms a white fibrous mass that can be spooled out of the solution.

Q18. Mention six optimum conditions which are maintained in a bioreactor.

Ans: Six optimum conditions maintained in a bioreactor are:

1. Temperature.
2. pH.
3. Substrate (nutrient) levels.
4. Oxygen availability.
5. Salt and vitamin concentrations.
6. Proper mixing to ensure a homogenous mixture throughout the vessel.

Q19. Mention sequential steps involved in rDNA technology.

Ans: The sequential steps involved in recombinant DNA technology are:

1. Isolation of the genetic material (DNA).
2. Fragmentation of DNA by restriction endonucleases.
3. Isolation of the desired DNA fragment.
4. Ligation of the DNA fragment into a vector.
5. Transferring the recombinant DNA into the host cell.
6. Culturing the host cells in a medium at a large scale.
7. Extraction of the desired product.

Q20. What is downstream processing? Write a note on downstream processing.

Ans: Downstream processing is the series of processes that a bioproduct undergoes after it has been synthesized in a bioreactor. It involves the separation and purification of the bioproduct. This process can be quite complex, as each product, such as a drug or a protein, requires different purification steps. The products must also be formulated with appropriate preservatives and undergo clinical trials and quality control testing before they can be released for use.

Q21. a) What is recombinant protein? b) Name the thermostable enzyme used in polymerase chain reaction. c) Name the bacterium from which thermostable Taq polymerase is obtained.

Ans:

a) A recombinant protein is a protein produced by expressing a cloned or recombinant gene in a heterologous host. organism.

b) The thermostable enzyme used in Polymerase Chain Reaction (PCR) is Taq polymerase.

c) The bacterium from which thermostable Taq polymerase is obtained is Thermus aquaticus.

Part D

V. Answer the following questions 5 Marks Each:

Q1. a) Write any four tools used in recombinant DNA technology. b) Mention any two methods of introducing alien DNA into host cells. c) Name the stains used to visualize DNA fragments in Gel electrophoresis.

Ans:

a) Four tools used in recombinant DNA technology are restriction enzymes, DNA ligase, vectors, and competent host organisms.

b) Two methods of introducing foreign DNA into host cells are microinjection and biolistics (gene gun).

c) The stain used to visualize DNA fragments in gel electrophoresis is ethidium bromide.

Q2. Write the convention for naming the restriction enzymes with a suitable example.

Ans: The convention for naming restriction enzymes uses a specific system derived from the organism from which they are isolated:

- The first letter of the name comes from the genus of the bacterium.
- The second and third letters come from the species.
- The fourth letter (if it exists) indicates the particular strain of the organism.
- A Roman numeral at the end indicates the order in which the enzyme was discovered in that strain.

Example: EcoRI is named after Escherichia coli strain RY13.

- 'E' is from the genus Escherichia.
- 'co' is from the species coli.
- 'R' is from the strain RY13.
- 'I' is the Roman numeral for the first enzyme isolated from this strain.

Q3. a) Write a note on downstream processing.

Ans:

Downstream processing: This is the final stage of the bioprocess, which involves the purification and formulation of the finished product after the recombinant protein has been synthesized. The downstream process includes multiple steps like separation, purification, and quality control. Since each bioproduct (e.g., a vaccine, a drug, or an enzyme) has different properties, the purification process is specific to each product. The product must be formulated with appropriate preservatives and undergo clinical trials and strict quality control testing before it can be sold.

Q4. Describe the characteristics that a plasmid should possess to be used as a cloning vector in genetic engineering.

Ans: An ideal plasmid for use as a cloning vector must have several key characteristics:

1. **Origin of replication (ori):** This is a specific DNA sequence that initiates replication and controls the number of copies of the vector within the host cell. It is essential for the inserted gene to be replicated and passed on to daughter cells.
2. **Selectable marker:** These are genes that help in identifying and selecting transformed cells from non-transformed ones. Examples include genes for resistance to antibiotics like ampicillin or tetracycline. The selectable marker also helps in identifying recombinants by using a process called insertional inactivation.
3. **Cloning sites:** These are recognition sites for restriction enzymes where foreign DNA can be inserted. A vector should have a minimal number of these sites (preferably single).
4. **Small size:** A small-sized plasmid is easier to isolate and manipulate in the lab and can accommodate larger DNA inserts.

Q5. Briefly explain the steps involved in recombinant DNA technology.

Ans: The process of recombinant DNA technology involves several sequential steps:

1. **Isolation of the genetic material:** DNA is first isolated from the donor organism. For plant cells, the cell wall is broken down using enzymes like cellulase.
2. **Fragmentation of DNA:** The isolated DNA is cut into fragments using restriction endonucleases at specific sites.
3. **Isolation of the desired DNA fragment:** The desired gene or DNA fragment is then separated from the other fragments using gel electrophoresis.
4. **Ligation of the DNA fragment into a vector:** The isolated DNA fragment is then joined with a cloning vector using the enzyme DNA ligase to create a recombinant DNA molecule.
5. **Transferring the recombinant DNA into the host:** The recombinant DNA is introduced into a suitable host organism using techniques like heat shock, microinjection, or biolistics.
6. **Culturing the host cells:** The transformed host cells are grown in a large-scale culture, such as a bioreactor, to produce the desired product.
7. **Extraction of the desired product:** The final product is separated and purified from the culture medium in a process called downstream processing.

Q6. Explain the process of amplification of a gene using PCR.

Ans: Polymerase Chain Reaction (PCR) is a method for amplifying a specific DNA fragment to create millions of copies. The process involves three main steps:

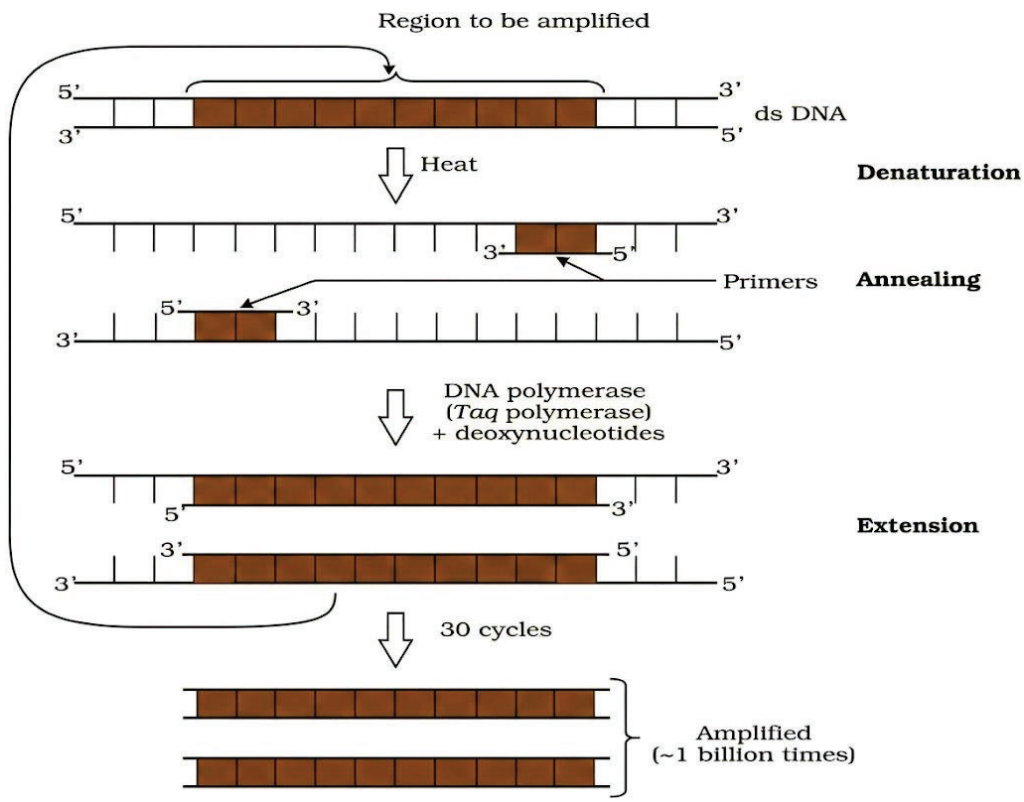
1. **Denaturation:** The reaction mixture is heated (around 94-96°C) to break the hydrogen bonds between the two DNA strands, separating them.
2. **Annealing:** The temperature is then lowered to allow the primers to bind to their complementary sequences on the single DNA strands.
3. **Extension:** The temperature is raised (around 72°C) for Taq polymerase to synthesize new DNA strands by adding nucleotides.
   Each cycle doubles the amount of DNA, allowing a small amount to be amplified into a large quantity.

Q7. What is polymerase chain reaction? Name the bacterium from which the polymerase enzyme used in this technique is obtained. Write the schematic representation of this technique.

Ans: Polymerase Chain Reaction (PCR) is a technique used to amplify a specific segment of DNA in a test tube, creating millions of copies.

- The polymerase enzyme used in this technique is called **Taq polymerase**, which is a thermostable DNA polymerase.
- This enzyme is obtained from the thermophilic bacterium **Thermus aquaticus**.

Schematic Representation of PCR:



Q8. Describe the process of separation of DNA fragments using gel electrophoresis.

Ans: Gel electrophoresis is a technique used to separate DNA fragments based on their size:

1. **Gel Preparation and Loading:** An agarose gel is prepared and the DNA fragments are loaded into wells at one end of the gel.

2. **Electric Field Application:** An electric current is applied. Since DNA is negatively charged, the fragments migrate towards the positive electrode (anode).

3. **Separation:** The agarose gel acts as a sieve, allowing smaller DNA fragments to move faster and farther through the pores, while larger fragments move more slowly.

4. **Visualization:** The gel is stained with ethidium bromide. The DNA bands are then visualized as bright orange bands under UV light.

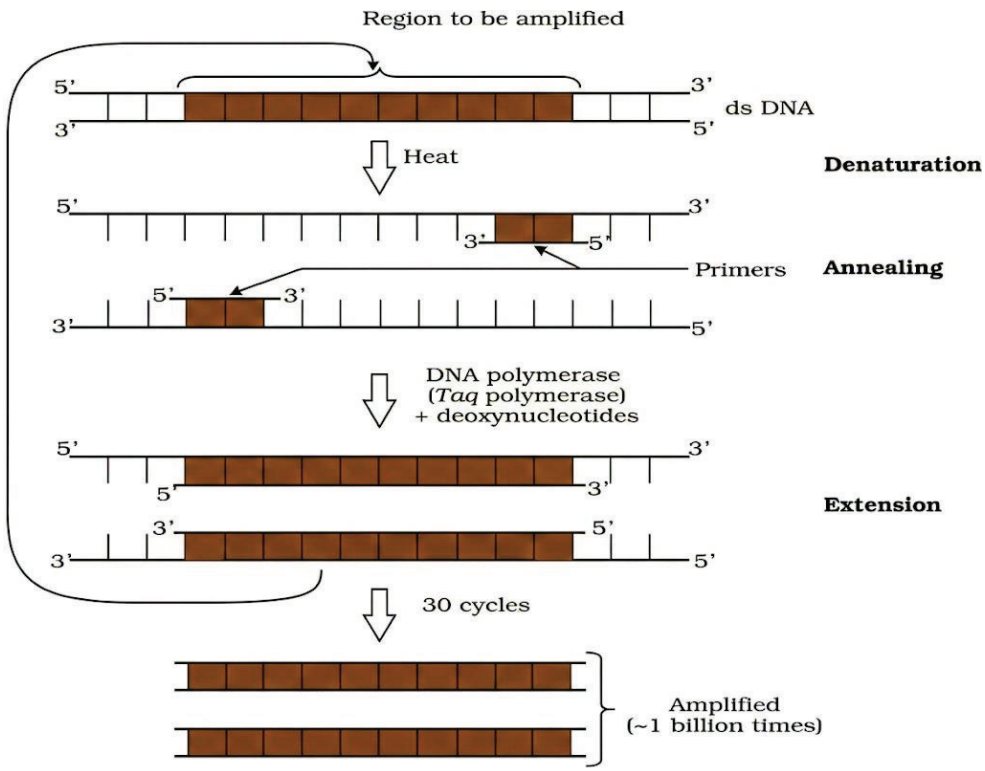
5. **Elution:** The desired DNA band is cut out from the gel, and the DNA is extracted from the gel piece in a process called elution.

Q9. a) Define polymerase chain reaction. Mention its significance in genetic engineering. b) Write the diagrammatic representation of steps involved in PCR.

Ans:

a) Polymerase Chain Reaction (PCR) is a technique used to amplify a specific DNA segment, creating millions of copies in a short time. Its significance is that it allows for the in-vitro synthesis of multiple copies of a gene of interest, which is essential for cloning, gene expression studies, and diagnostics.

b) **Diagrammatic representation of steps involved in PCR:**



Q10. What are bioreactors? Mention the control systems of a stirred tank bioreactor and write their functions.

Ans: Bioreactors are large-volume vessels (typically 100-1000 liters) designed to culture living cells or

organisms under controlled conditions for the production of commercially valuable products. A stirred-tank bioreactor is one of the most common types and has several control systems to ensure optimal conditions:

a) Agitator system: A stirrer is used for proper mixing of the culture broth, ensuring a homogenous environment for the cells and an even distribution of nutrients and oxygen.

b) Oxygen delivery system: A sparger bubbles sterile air into the reactor, providing a constant supply of oxygen for aerobic processes.

c) Temperature control system: A jacketed vessel with a heating and cooling system maintains the optimal temperature for cell growth and product synthesis.

d) pH control system: A sensor and pump system adds acid or base to maintain the desired pH level, which is crucial for enzyme activity and cell viability.

e) Foam control system: Bioreactors often have a system to add anti-foaming agents to prevent foam formation, which can hinder proper mixing and oxygen transfer.

f) Sampling ports: These are a system for taking small, sterile samples from the reactor to monitor the progress of the fermentation process.

Q11. What is insertional inactivation? Explain with respect to β-galactosidase enzyme? How are recombinants and non-recombinants identified?

Ans: Insertional inactivation is a method for selecting recombinants (cells with the foreign DNA insert) by inserting the foreign DNA into a selectable marker gene on the vector, which inactivates the gene's function. This can be explained using the β-galactosidase enzyme and a vector containing the lacZ gene. The lacZ gene codes for β-galactosidase, an enzyme that can break down a chromogenic substrate (e.g., X-gal) to produce a blue color. The vector is designed with a restriction site within the lacZ gene.

- **Non-recombinants**: If a foreign gene is not inserted into the vector, the lacZ gene remains intact and produces functional β-galactosidase. When these cells are grown on a medium containing X-gal, they will produce a blue color, indicating they are non-recombinants.
- **Recombinants:** If the foreign DNA is successfully ligated into the vector at the restriction site within the lacZ gene, it disrupts the gene's sequence, leading to the production of an inactive β-galactosidase enzyme. When these cells are grown on the same medium, they will not produce the blue color, indicating they are recombinants with the foreign DNA insert.

VI. Answer the following questions 5 Marks Each:

Q1. Give reason for the following:

a) Why is an origin of replication (ori) essential in a cloning vector?

b) Restriction enzymes are called 'molecular scissors'.

c) DNA ligase is used in genetic engineering.

d) Gel electrophoresis is considered as a very important technique in recombinant DNA technology.

e) DNA fragments move towards anode under electric field through a medium in gel electrophoresis.

Ans:

a) The origin of replication (ori):

The ori is the sequence from which replication starts. It allows the vector and inserted foreign DNA to replicate in the host and helps determine copy number. Foreign DNA is inserted at a suitable cloning site, not necessarily within ori.

recognition sequences. This allows for the precise cutting of both the foreign DNA and the vector to create compatible fragments that can be joined together.

c) DNA ligase is used in genetic engineering to join the cut DNA fragments together. It acts as a molecular glue, forming a stable phosphodiester bond between the sugar-phosphate backbones of the foreign DNA and the vector, creating a stable recombinant DNA molecule.

d) Gel electrophoresis is a very important technique because it allows for the separation and isolation of DNA fragments of different sizes, which is a crucial step in recombinant DNA technology. It is used to separate the desired gene fragment from other DNA fragments after they have been cut by restriction enzymes.

e) DNA fragments move towards the anode because DNA is a negatively charged molecule due to the phosphate groups in its backbone. When an electric field is applied across the gel, the negatively charged DNA is attracted to and moves towards the positive electrode, or anode.

Q2. Give reasons for the following:

a) Origin of replication in vector is an essential site required for gene cloning.
b) Selectable marker in a vector is essential site without which identifying recombinant DNA becomes difficult.
c) Vectors in rDNA technique needs to have very few, preferably single recognition site.
d) Selection of recombinants due to inactivation of antibiotics is a cumbersome procedure.
e) Chilled ethanol is used in DNA isolation.

Ans:

a) The origin of replication (ori) is an essential site in a vector because it is the sequence from which replication starts. It controls the copy number of the vector and the inserted gene within the host cell, ensuring that the gene is amplified and maintained.

b) A selectable marker is essential because it allows for the identification of transformed cells and the elimination of non-transformed cells. Without it, it would be impossible to tell which bacterial cells have successfully taken up the recombinant DNA.

c) Vectors need to have very few, preferably single, recognition sites to ensure that the restriction enzyme cuts the vector at only one location. This allows the foreign DNA to be inserted at a single, specific site, which is crucial for a successful ligation and prevents the fragmentation of the vector itself.

d) The selection of recombinants using the inactivation of antibiotics is considered a cumbersome procedure because it requires plating the transformants on two different plates with different antibiotics, which is a time-consuming and labor-intensive process.

e) Chilled ethanol is used in DNA isolation because DNA is insoluble in alcohol. When cold ethanol is added to the purified DNA solution, the DNA precipitates, forming visible white fibrous threads that can be spooled out.

Q3. Given below are the steps involved in recombinant DNA technology. These steps have to be conducted in a definite order. Arrange them in a correct order.

Ans: The correct order of the steps involved in recombinant DNA technology is:

v) Isolation of DNA

vi) Fragmentation of DNA by restriction endonucleases

vii) Isolation of desired DNA fragment

iv) Ligation of the DNA fragment into a vector

i) Transferring the recombinant DNA into the host

ii) Culturing the host cells in a medium at large scale

iii) Extraction of the desired product

Q4. What are selectable markers? Give any two examples. Mention the significance of selectable markers in genetic engineering.

Ans: Selectable markers are genes present in a vector that help in selecting transformed cells and eliminating non-transformed cells in a cloning experiment. Two examples of selectable markers are genes for ampicillin resistance and tetracycline resistance.

Their significance in genetic engineering is twofold:

1. They provide a way to differentiate between cells that have taken up the vector (transformants) and those that have not. Only the transformants will be able to grow on a medium containing the specific antibiotic.
2. They can also be used to distinguish between recombinants (cells with the foreign DNA insert) and non-recombinants using a process called insertional inactivation, where the insertion of the foreign gene inactivates the marker gene, changing the cell's phenotype.

Q5. a) Define plasmid. Give an example. b) Insertion of rDNA into the host is an important step in genetic engineering. An ampicillin resistant gene transferred to E. coli acts as a selectable marker. Explain.

Ans:

a) A plasmid is a small, circular, extra-chromosomal DNA molecule that exists independently of the host's chromosomal DNA and can replicate on its own. An example is the plasmid pBR322.

b) When an ampicillin-resistant gene is used as a selectable marker, it allows for the identification of successful transformants. In a typical experiment, a vector containing this gene is used to transfer a foreign gene into E. coli cells. The cells are then grown on a medium containing ampicillin. Only the cells that have successfully taken up the vector with the ampicillin resistance gene will survive and grow. This effectively selects the transformed cells from the millions of non-transformed cells, which will die in the presence of the antibiotic.

Chapter 10
BIOTECHNOLOGY AND ITS APPLICATIONS

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Theory

Introduction:

In the previous chapter, we were discussed about principles and processes of biotechnology which essentially deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals.

The applications of biotechnology

❖ Biotechnology plays an important role in

1. Genetically modified crops for agriculture
2. Energy production(To produce energy to meet its increasing demand)
3. Bioremediation and waste treatment (To removal of pollutants from the environment)
4. Diagnostics(To detect diseases like cancer ect)
5. Therapeutics(To treat diseases)
6. Processed food

Major research areas of Biotechnology:- Three critical research areas of biotechnology are as follows;

1) **Providing the best catalyst** in the form of improved organism usually a microbe or pure enzyme.
2) **Creating optimal conditions** through engineering for a catalyst to act.
3) **Downstream processing technologies** to purify the protein/organic compound.

10.1. Biotechnological Application In Agriculture

Biotechnological applications in agriculture

- There are three options that can be thought for increasing food production. They are

a) Agro-chemical based agriculture:-

- Food crops can be improved by using agro-chemicals such as fertilizers and pesticides. But every farmer cannot afford them because they are expensive.
- It increase **productivity** and **decrease quality.**

b) Organic agriculture :-

- It is farming practice in which use of **farm yard manure, bio-fertilisers, bio pesticides** and **biochemicals** for enhancing crop production instead of using artificial fertilizers and pesticides.
- It **increase quality** and **decrease productivity.**

c) Genetically engineered crop-based agriculture:- Genetic modification to create **Tailor made plants.**

- The **Green Revolution** succeeded in **tripling the food supply** but yet it was not enough to feed the growing human population.
- 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 (fertilizers and pesticides).
- However, for farmers in the developing world agrochemicals are often too expensive, and further increases in yield with existing varieties are not possible using conventional breeding.

Is there any alternative path that our understanding of genetics can show so that farmers may obtain maximum yield from their fields?
Is there a way to minimize the use of fertilizers and chemicals so that their harmful effects on the environment are reduced?

- **Use of genetically modified crops is a possible solution.**

Genetically Modified Organisms

- The **bacteria, fungi ,plants** and **animals** whose genes have been altered by manipulation are called **Genetically Modified Organisms.**

Significance of Genetically Modified plants -

1. **To produce herbicide resistant plant.**

   Eg. First transgenic plant was tobacco. It contains resistant gene against weedicide **(Glyphosate).**

2. **Made crops more tolerant to abiotic stresses** (cold, drought, salt, heat).
3. **Enhanced nutritional value of food.**

   Eg., Vitamin 'A' enriched rice - GOLDEN RICE(In this rice gene of **β-carotene** is transferred from daffodil to rice).

4. **Helped to reduce post harvest losses.**

   Eg. **Flavor Savr Tomato**, a transgenic variety of tomato

Due to the inhibition of **polygalacturonase** enzyme which degrades pectin. So that tomato variety remains fresh and retain flavour much longer.

5. **Increased efficiency of mineral usage** by plants (this prevents early exhaustion of fertility of soil).
6. **Tailor - made plants :-** In addition of these uses, GM has been used to create tailor - made plants to supply alternative resources to industries in the form of starches, fuels and pharmaceuticals.

   Eg. **Production of Hirudin** - It is a protein that prevents **blood clotting.** The gene encoding hirudin was chemically synthesized and transferred into Brassica napus, where hirudin accumulates in seeds. The hirudin is purified and used as medicine.

7. **Production of pest resistant crop plants**
   A. Insect resistant plant
   B. Nematode resistant plant

A. **Insect resistant plant –**

- The insects resistant plants could decease the amount of usage of Insecticides .
- A bacterium called **Bacillus thuringiensis (Bt)** produces insecticidal toxin.
- Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect created a **bio-pesticides**. **EX** : Bt-Cotton ,rice , tomato, potato and Soya bea etc.

Bt-Cotton

- It is an insect resistant, genetically modified plant produced against bollworm in
- Some strains of ***Bacillus thuringiensis*** produce **proteins crystals** (Cry proteins).The cry proteins kill certain insects such as -
  a) Lepidopterans - Tobacco budworm, Armyworm, Cotton bollworm.
  b) Coleopterans - Beetles
  c) Dipterans - Flies, Mosquitoes.
- ***Bacillus thuringiensis*** forms protein crystals during a **particular phase of their growth.** These crystals contain a toxic **insecticidal protein.**

Que. Why does this toxin not kill the Bacillus?

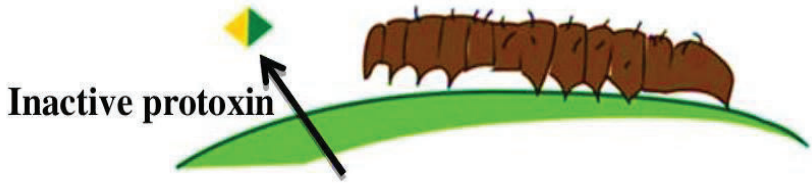
Ans : The Bt toxin protein exist as inactive protoxins in bacteria.

- **Bacillus thuringiensis**, produces **crystal [Cry] protein**.
- The gene encoding cry protein is called **"cry gene".** Means, Bt toxin is coded by a **gene named cry.**

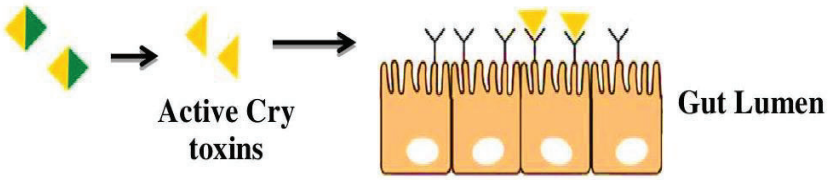
Note:- Specific Bt toxin genes were isolated from Bacillus thuringiensis and incorporated into the several crop plants such as cotton.

Mechanism of Action of Bt toxin on insect

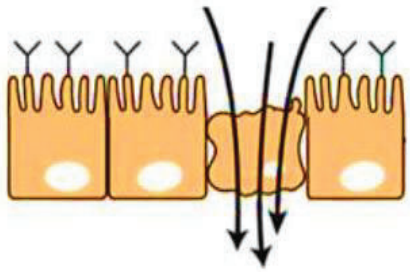
A. The Bt toxin protein exist as inactive protoxins synthesized by Bt-Cotton and once an insect Larvae ingest **Cry proteins**(Inactive protoxins).



B. In larval midgut, it is converted into an active form form of toxin due alkaline of gut which solubilise the crystals. The activated toxin bind to epithelial receptors.



C. The toxin binding causes cell swelling and lysis and eventually causes death of the in



- Specific **Bt toxin genes** were isolated from Bacillus thuringiensis and incorporated in to the several crop plants such as **cotton plant.**
- The choice of genes depends upon

  (i) the crop (ii) the targeted pest
- Bt toxins are **insect-group specific.**

Types of Bt genes

- The proteins encoded by the genes **cryIAc** and **cryIab** control the **cotton bollworms,**
- The **cryIAb** controls **corn borer**.

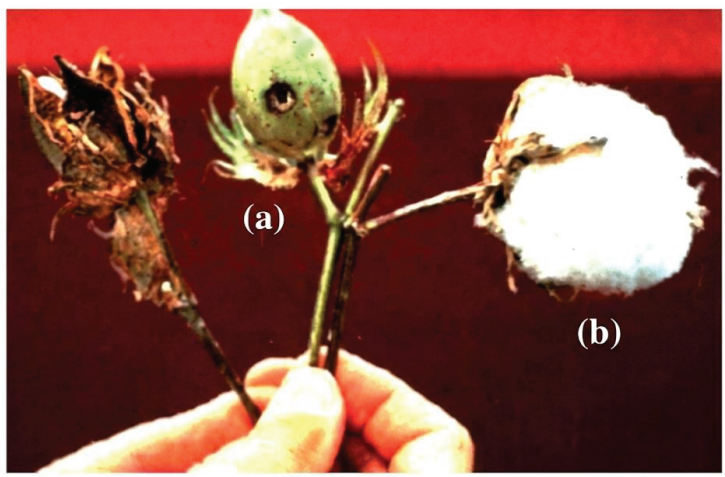
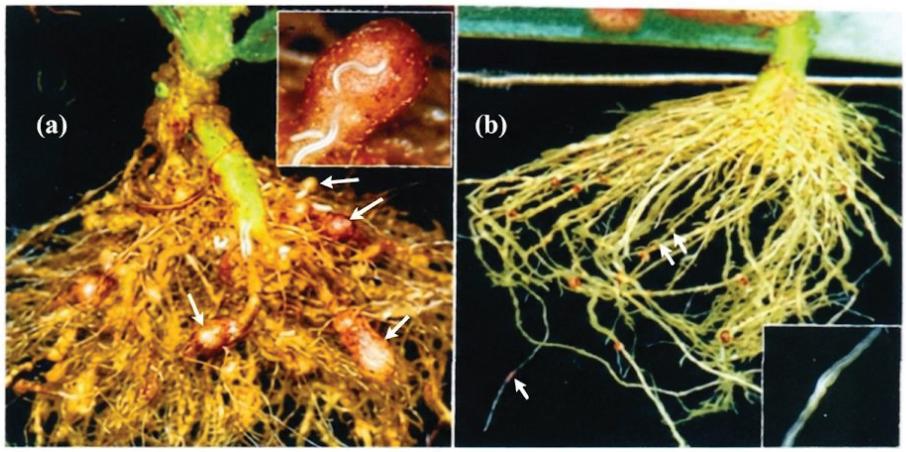


Fig. : Cotton boll : (a) destroyed by bollworms; (b) a fully mature cotton boll

B. **Nematode resistant plant - Transgenic Tobacco.**



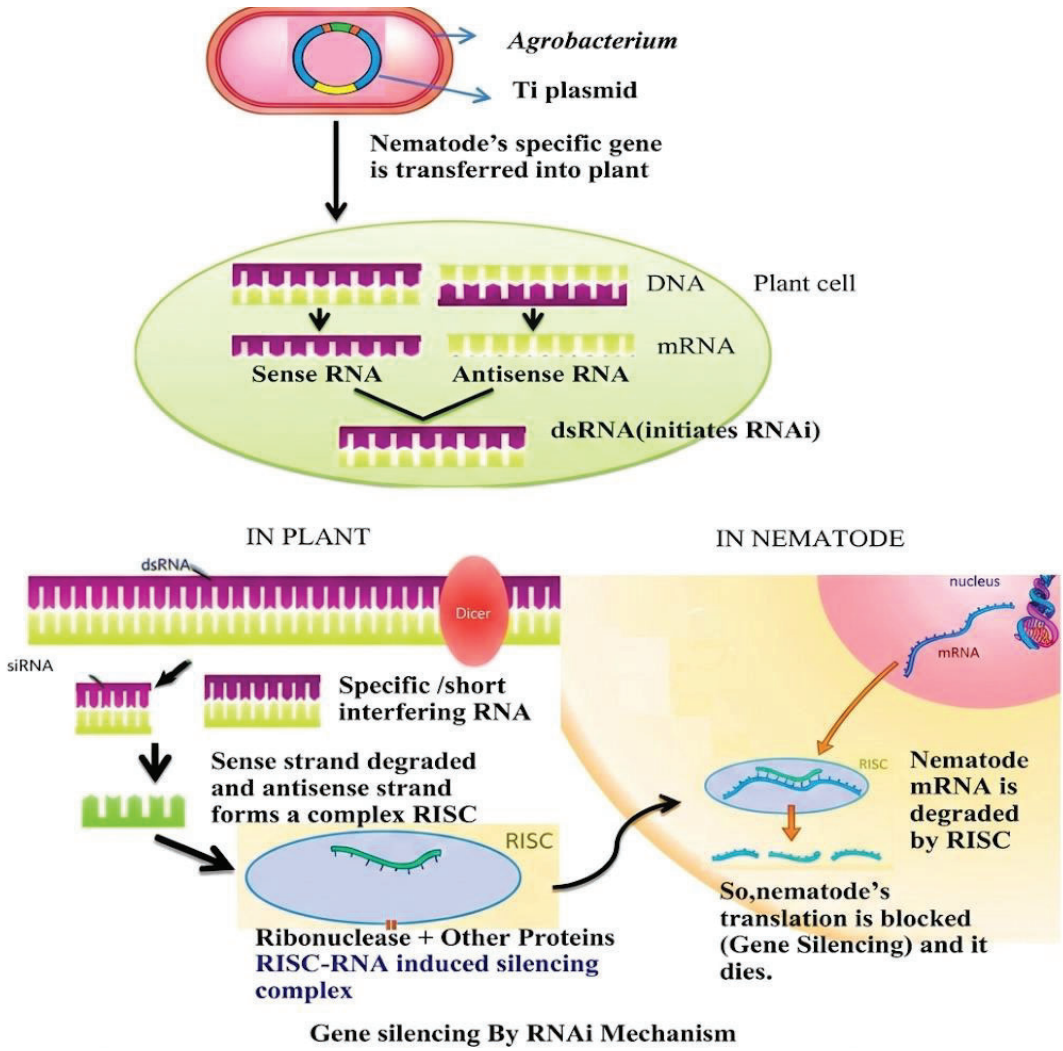
Host plant-generated dsRNA triggers protection against nematode infestation: (a) Roots of a typical control plants; (b) transgenic plant roots 5 days after deliberate infection of nematode but protected through novel mechanism.

- A nematode ***Meloidegyne incognita*** cause **root-knot disease** in **tobacco, tomat etc.** It invades the plant roots and causes the roots to grow large and form galls.
- As a result roots crack and invite secondary infection. Due to this water and mineral absorption is blocked resulting in the **great reduction in yield.**
- A novel strategy was adopted to prevent this infestation which was based on the process of **RNA interference (RNAi).**
- RNAi takes place in all eukaryotic organisms as a method of **cellular defense.**

RNA interference method/Mechanism of RNA interference

- This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the mRNA (silencing).
- A specific gene for Meloidogyne incognita is isolated and made to produce both sense and anti-sense RNA in the host cell.
- This gene is introduced into the host plant (tobacco) by using **Agrobacterium vector.**
- It produces both **sense** and a**nti-sense RNA** in the transgenic host plant cell.These two RNAs forms a double stranded RNA.
- The dsRNA breakup to form 20 to 23 short interference RNA fragments [siRNA] in presence of dicer enzyme.
- These siRNAs develops a silencing complex called RNA induced silencing complex [RISC].
- The RISC enters into the nematode when it consumes the transgenic plant cells.
- This RISC cleaves mRNA having complementary base sequence and makes the mRNA of nematode silent i.e. stop the production of proteins.
- The consequence was that the parasite could not survive in a transgenic host expressing specific interfering RNA. The transgenic plant therefore got itself protected from the parasite.
- This is a common method of cellular defence in eukaryotic organisms.

❖ The source of this complementary RNA could be from an infection by ribo-viruses or mobile genetic elements or transposons that replicate via an RNA intermediate.



Gene silencing By RNAi Mechanism

10.2. Biotechnological Applications In Medicine

❖ The recombinant DNA technological processes are employed in the mass production of safe and more effective therapeutic drugs.

❖ These do not induce unwanted immunological responses as in products isolated from non-human sources.

❖ About **30 recombinant therapeutics** have been approved for human-use in the world.

❖ In India, **12 recombinant therapeutics** are presently being marketed.

(I) Genitically engineered insulin

❖ Insulin is a protein hormone used to treat patients suffering from **Diabetes mellitus.**

❖ Management of adult-onset diabetes is possible by taking insulin at regular time intervals.

1. **What would a diabetic patient do if enough human-insulin was not available?**
2. **Ans :**One would have to isolate and use insulin from other animals.

3. **Can insulin be orally administered to diabetic people or not. Why?**

   Ans : No, because it is proteinaceous and will be digested in digestive system.

4. **Would the insulin isolated from other animals be just as effective as that secreted by the human body itself and would it not elicit an immune response in the human body?**

   Ans : Insulin used for diabetes was extracted from pancreas of slaughtered cattle and pigs.Insulin from an animal source, though caused some patients to develop allergy or other types of reactions to the foreign protein.

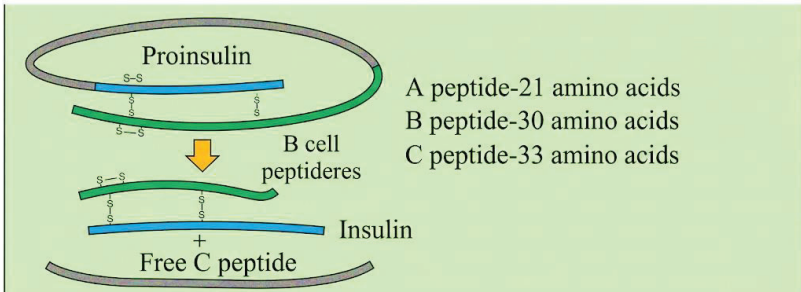
❖ By rDNA technology, if bacteria is available that could make human insulin. Suddenly the whole process becomes so simple. We can easily grow a large quantity of the bacteria and make as much insulin as we need.

Structure of Insulin -

❖ Insulin is a proteinaceous hormone consists of **two polypeptide chains A and B** that are linked together by **disulphide bridges.**

❖ In mammals, including humans, insulin is synthesised as a **prohormone** (like a pro-enzyme, the pro-hormone also needs to be processed before it becomes a fully mature and functional hormone) which contains an extra stretch called the **C-peptide.**

❖ The **C- peptide** is not present in the **mature insulin** and is removed during maturation into insulin.



Maturation of pro-insulin into insulin after removal of C-peptide

Formation of Genetically Engineered Insulin (Humulin) -

❖ The first genetically engineered insulin obtained by recombinant DNA technique with the help of E.Coli was produced by the American Company, **Eli-Lilly** on July 5, 1983.

❖ It has been given the trade name **Humulin** and has been approved for clinical use.

❖ **The main challenge for production of insulin** using rDNA techniques was getting insulin assembled into a mature form.

❖ In 1983, Eli Lilly an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of ***E***. coli to produce insulin chains.

❖ Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

(II) GENE THERAPY

❖ A new system of medicine gene therapy, may used to treat some hereditary diseases such as SCID, haemophilia etc.

- Gene therapy is a collection of methods that allows correction of a gene defect that has been diagnosed in a child/embryo. Here genes are inserted into a person's cells and tissues to treat a disease.
- Correction of a genetic defect involves delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.
- The first clinical gene therapy was given in 1990 to a 4-year old girl with adenosine deaminase (ADA) deficiency. This enzyme is crucial for the immune system to function.
- The disorder is caused due to the deletion of the gene for adenosine deaminase.

ADA deficiency can be cured by-

(1) Enzyme replacement therapy, in which functional ADA is given to the patient by injection.

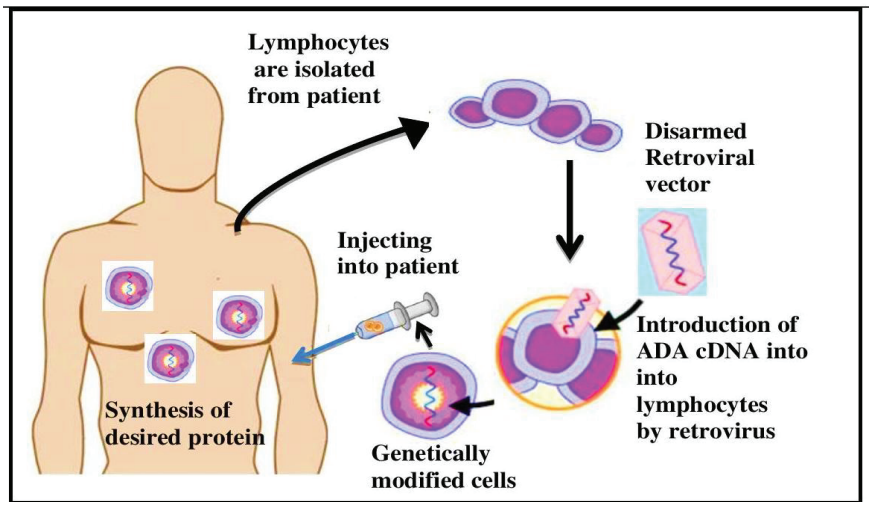
(2) Bone marrow transplantation

- But the problem with both of these approaches that they are not completely curative.

(3) Gene therapy

- As a first step towards gene therapy, lymphocytes from the blood of the patient are grown in a culture outside the body.
- **A functional ADA cDNA** (using a retroviral vector) is then introduced into these lymphocytes, which are subsequently returned to the patient.

Note:- cDNA stands for Complementary DNA, which is formed by mRNA by reverse transcription. cDNA molecules don't have introns.



- However, as these cells are not immortal, the patient requires periodic infusion of such genetically engineered lymphocytes, so they should be preserved for future use.
- **If the gene isolate from marrow cells producing ADA is introduced into cells at early embryonic stages, it could be a permanent cure.**

Medical Diagnosis Of Disease (Molecular Diagnosis)

We know that for effective treatment of a disease, early diagnosis and understanding its pathophysiology is very important.

- **Conventional methods of diagnosis (Serum and Urine analysis etc**.)- Early detection is not possible.
- **There are some of the techniques that serve the purpose of early diagnosis.**
  - **Polymerase Chain Reaction (PCR)**
  - **Enzyme Linked Immuno Sorbent Assay (ELISA)**
  - **Recombinant DNA technology**

1. POLYMERASE CHAIN REACTION (PCR)

- Presence of a pathogen (bacteria, viruses, etc.) is normally suspected only when the pathogen has produced a disease symptom.
- By this time the concentration of pathogen is already very high in the body.
- However, very low concentration of a bacteria or virus (at a time when the symptoms of the disease are not yet visible) can be detected by amplification of their nucleic acid by PCR.

PCR is now routinely used to-

(i) Detect HIV in suspected AIDS patients.

(ii) Detect mutations in genes in suspected cancer patients too.

- It is a powerful technique to identify many other genetic disorders.
- ***Can you explain how PCR can detect very low amounts of DNA?***
  - PCR can amplify small amount of genetic material into its many identical copies.
  - If person is infected and has viral genetic material then by using primers according to virus, viral genetic material will be amplified and can be detected easily.

2. ELISA (ENZYME LINKED IMMUNO SORBENT ASSAY)

- ELISA technique is based on the principle of Antigen - Antibody interaction.
- Infection by pathogen can be detected -
  (i) By the presence of antigens (proteins, glycoproteins, etc.) or
  (ii) By detecting the antibodies synthesized against the pathogen.

3. PROBES -

- **A single stranded DNA or RNA, tagged with a radioactive molecule (probe)** is allowed to hybridize 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.

10.3. Transgenic Animals

- **Transgenic Animals -** Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as **transgenic animals. Ex :**Transgenic rats, rabbits, pigs, sheep, cows and fish have been produced, although **over 95 percent of all existing transgenic animals are mice.**

Why are these animals being produced? How can man benefit from such modifications?

There are following applications of transgenic animals are ;

a) **Normal physiology and development :** Transgenic animals can be specifically designed to-

- Allow the study of how genes are regulated,
- How gene affect the normal functions of the body and its development.
  E.g.- Study of complex factors involved in growth such as insulin-like growth factor.
- By introducing genes from other species that alter the formation of this factor and studying the biological effects that result, information is obtained about the biological role of the factor in the body.

b) **Study of disease :** Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease.

- These are specially made to serve as models for human diseases so that investigation of new treatments for diseases is made possible.
- Today transgenic models exist for many human diseases such as –
  - ✓ Cancer
  - ✓ Cystic fibrosis
  - ✓ Rheumatoid arthritis
  - ✓ Alzheimer's disease.

c) **Biological products :** Medicines required to treat certain human diseases can contain biological products, but such products are often expensive to make.

- Transgenic animals that produce useful biological products can be created by the introduction of the portion of DNA (or genes) which codes for a particular product such as-
  - ✓ Human protein **(α-1-antitrypsin) used to treat emphysema.** Similar attempts are being made for treatment of **Phenylketonuria (PKU) and Cystic fibrosis.**
  - ✓ In 1997, the **first transgenic cow, Rosie**, produced human **protein-enriched milk (2.4 grams per liter).**The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow-milk.

d) **Vaccine safety :** Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans.

- Transgenic mice are being used to test the safety of the polio vaccine.
- If successful and found to be reliable, they could replace the use of monkeys to test the safety of batches of the vaccine.

e) **Chemical safety testing :** This is known as toxicity/safety testing. The procedure is the same as that used for testing toxicity of drugs.

- Transgenic animals are made that carry genes which make them more sensitive to toxic substances than non-transgenic animals
- They are then exposed to the toxic substances and the effects studied.
- Toxicity testing in such animals will allow us to obtain results in less time.

10.4. Ethical Issues

Ethical Issues - The manipulation of living organisms by the human race cannot go on any further, without regulation.

- Some ethical standards are required to evaluate the morality of all human activities that might help or harm living organisms.
- Genetic modification of organisms can have unpredictable results when such organisms are introduced into the ecosystem.
- Therefore, the Indian Government has set up organisations such as **GEAC(Genetic Engineering Approval Committee),** GEAC will make decisions regarding -
  (i) The validity of GM research and
  (ii) The safety of introducing GM-organisms for public services.
- The modification/usage of living organisms for public services (as food and medicine sources, for example) has also created problems with patents granted for the same.
- **GM crops** are already in cultivation **in U.S.A., Europe** and several other countries.
- **In India,** some insect **resistant cotton varieties** expressing **cry genes** have reached the farmers fields.
- It has been argued that transgenic crops may be harmful to the environment.
- The two points.
  (i) Firstly, the transgene may be transferred through pollen from these crops to their wild relatives.
  (ii) Secondly GM crops may pollute the environment.

BIO-PATENT

- A patent is a right granted by a government to an inventor to prevent others from commercial use of his invention.
- There is growing public anger that certain companies are being granted patents for products and technologies that make use of the genetic materials, plants and other biological resources that have long been identified, developed and used by farmers and indigenous people of a specific region/country.

For example:

- **Rice** is an important food grain, the presence of which goes back thousands of years in Asia's agricultural history.
- There are an estimated **200,000 varieties of rice in India alone. The diversity of rice in India is one of the richest in the world.**
- **Basmati rice** is distinct for its unique **aroma** and **flavour** and 27 documented varieties of Basmati are grown in India. There is reference to Basmati in ancient texts, folklore and poetry, as it has been grown for centuries.

- **In 1997**, an **American company** got patent rights on Basmati rice through the **US Patent** and **Trademark Office**. This allowed the company to sell a **'new' variety of Basmati,** in the US and abroad.
- This 'new' variety of Basmati had actually been derived from **Indian farmer's varieties.** Indian Basmati was crossed with **semi-dwarf varieties** and claimed as an invention or a novelty. The patent extends to functional equivalents, implying that other people selling Basmati rice could be restricted by the patent.
- Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines, e.g., turmeric, neem.
- If we are not vigilant and we do not immediately counter these patent applications, other countries/individuals may encash on our rich legacy and we may not be able to do anything about it.

BIOPIRACY

- The use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment is called **biopiracy.**
- Most of the industrialized nations are rich financially but poor in biodiversity and traditional knowledge.
- While, the developing and underdeveloped countries are rich in biodiversity and traditional knowledge related to bio-resources. This traditional knowledge can be exploited to develop modern applications and can also be used to save time, effort and expenditure during their commercialization.
- There has been growing realization of the injustice, inadequate compensation and benefit sharing between developed and developing countries. Therefore, some nations are developing laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge.
- The **Indian Parliament** has recently cleared the **second amendment of the Indian Patents Bill**, that takes such issues into consideration, including patent terms emergency provisions and research and development initiative.

EXERCISE

PART – A

I. Multiple Choice Questions — 1 Mark Each:

1. In human insulin, the two polypeptide chains are linked together by

a) Covalent bonds
b) Glycosidic bonds
c) Phosphodiester bonds
d) Disulphide bonds

2. ADA deficiency in humans could be permanently cured by

a) Bone marrow transplantation
b) Introduction of functional ADA through injection
c) Introduction of gene isolated from marrow cells producing ADA into embryonic cells
d) Enzyme replacement therapy

3. A novel strategy adapted to prevent the infection of Meloidogyne incognita is based on

a) Molecular diagnosis
b) RNA interference
c) Electrophoresis
d) Micro-injection

4. The plants developed by the fusion of protoplasts of two different plants are called

a) Somaclones
b) Somatic hybrids
c) Transgenic plants
d) GM plants

5. Which of the following statement is correct with respect to synthesis of insulin?

a) Synthesized as pro-enzyme and needs to be processed to become functional enzyme.
b) Synthesized as pro-hormone and needs to be processed to become functional hormone
c) Synthesized as pro-enzyme and needs to be processed to become functional pro-hormone.
d) Synthesized as pro-hormone and needs to be processed to become functional proenzyme.

6. Bt-toxin is produced by the bacterium

a) Bacillus subtilis
b) Bacillus thuringiensis
c) Escherichia coli
d) Salmonella typhi

7. Corn borers are controlled by the protein encoded by the gene

a) cryIAc
b) cryIIAb
c) cryIVAb
d) cryIAb

8. The silencing of mRNA has been used in producing transgenic plants resistant to

a) White rusts
b) Bacterial blights
c) Bollworms
d) Nematodes

9. Meloidogyne incognita is a

a) Protozoa
b) Nematode
c) Fungi
d) Algae

10. The name given to the first transgenic cow is

a) Dolly
b) Rosie
c) Marie
d) Lilly

11. Crystals of BT toxin produced by some bacteria do not kill the bacteria themselves because

a) Bacteria are resistant to the toxin
b) Toxin is immature
c) Toxin is inactive
d) Bacteria encloses toxin in a special sac

12. Crystalline protein synthesized by Bacillus thuringiensis is activated by

a) Acidic pH in insect fore-gut
b) Acidic pH in insect mid-gut
c) Alkaline pH in insect fore-gut
d) Alkaline pH in insect mid-gut

13. The use of bio resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment is called

a) Bioethics b) Bio war c) Biopiracy d) Bio remedy

14. The mobile genetic elements are called

a) Transcripts b) Transposons c) Transforms D) Transgenes

15. Identify the incorrect statement.

a) The transgenic cow Rosie produced milk enriched with α-lactalbumin.
b) Bt toxin genes cryIAc controls corn borer.
c) Human protein α-1-antitrypsin is used to treat emphysema.
d) The commercial production of human insulin was made possible using genetically engineered E. coli.

16. Insect tolerant gene from Bacillus thuringiensis is introduced using Ti plasmid of

a) Agrobacterium tumefaciens
b) Escherichia coli
c) Meloidogyne incognita
d) Salmonella typhi

17. Statement I: The plants genetically identical to the original plants are called somaclones.
Statement II: Somaclones can be obtained through micro-propagation.

a) Statement I is true, statement II is false
b) Statement I is false, statement II is true.
c) Both the statements I and II are true
d) Both the statements I and II are false.

18. Pollen grains of a plant whose $2n = 48$ are cultured to get callus by tissue culture method. What would be the number of chromosomes in the cells of the callus?

a) 48 b) 24 c) 36 d) 12

19. In tissue culture, to get virus free plants from a diseased one, which part has to be choosen.

a) Intercalary meristem b) Apical meristem c) Lateral meristem d) Anther

20. Identify the correct statement

a) Bacillus thuringiensis produces an insecticidal protein that can kill Meloidogyne incognita
b) The gene cryIAc can control corn borer.
c) Using Agrobacterium vectors, nematode-specific gene sequences were introduced into the host plant.
d) Bt protoxin is converted into inactive protein in the insect gut.

21. Maximum number of existing transgenic animals are

a) Mice b) Rats c) Rabbits d) Cows

22. The therapy given to cure adenosine deaminase deficiency comes under the category of

a) Chemotherapy b)Gene therapy c) Radiation therapy d) Immunotherapy

23. Which among the following is commonly used in transfer of foreign DNA into plants ?

a) Bacillus thuringiensis
b) Agrobacterium tumefaciens
c) Meloidogyne incognita
d) Escherichia coli

24. Statement I : Bacillus thuringiensis produces insecticidal protein crystals called Bt toxin

Statement II : These toxins exist as pro-hormones before entering into insect gut.

a) Statement I is true, statement II is false.

b) Statement I is false, statement II is true.

c) Both the statements I and II are true.

d) Both the statements I and II are false.

Answer Key				
1. D.	**2.** C.	**3.** B.	**4.** B.	**5.** B.
6. B.	**7.** D.	**8.** D.	**9.** B.	**10.** B.
11. C.	**12.** D.	**13.** C.	**14.** B.	**15.** B.
16. A.	**17.** C.	**18.** B.	**19.** B.	**20.** C.
21. A.	**22.** B.	**23.** B.	**24.** A.	

II. FILL IN THE BLANKS 1 Mark Each:

(Transposons, Corn borer, ELISA, Polypeptide, Meristem, Pro-hormone, Agrobacterium, Adenosine deaminase, Cotton bollworm, Somaclones, Totipotency, Eli Lilly, Alpha-lactalbumin, Emphysema)

1. The capacity to generate a whole plant from any cell or explants is called _____.

2. Although the plant is infected with a virus, _____ is free of virus.

3. The first clinical gene therapy was given to a girl with _____ deficiency.

4. _____ is based on the principle of antigen–antibody interaction.

5. In mammals' insulin is synthesized as a _____.

6. The protein encoded by the genes cryIAb controls _____.

7. The proteins encoded by the genes cryIAc and cryIIAb controls the _____.

8. Using _____vectors nematode specific genes were introduced into host plants.

9. The artificial human protein $\alpha - 1$–antitrypsin is used to treat _____.

10. The transgenic cow Rosie produces milk rich in _____ protein.

11. _____is an American company responsible for commercial production of human insulin.

12. Human insulin consists of two _____chains.

13. _____ are the mobile genetic elements.

14. The plants genetically identical to the original plants from which they were grownare known as _____.

Answer Key				
1. Totipotency	**2.** Meristem	**3.** Adenosine deaminase	**4.** ELISA	**5.** Pro-hormone
6. Corn borer	**7.** Cotton bollworm	**8.** Agrobacterium	**9.** Emphysema	**10.** Alpha-lactalbumin
11. Eli Lilly	**12.** Polypeptide	**13.** Transposons	**14.** Somaclones	

PART – B

III. Answer the following questions in 3-5 sentences each: 2 Marks Each:

1. What are genetically modified organisms? Give any two examples.

Ans:

• Genetically modified organisms are the organisms in which the DNA is manipulated to possess and express a foreign gene.

• Examples: Bt cotton, transgenic cow Rosie.

2. Mention any two benefits of genetically modified plants.

Ans:

• They have increased yields and better tolerance to abiotic stresses.

• They reduce reliance on chemical pesticides.

3. What are cry genes? Give two examples.

Ans:

• Cry genes are insecticidal protein genes from Bacillus thuringiensis.

• Examples: cryIAc and cryIIAb.

4. Mention two genes that are responsible for producing cry protein to control cotton bollworms.

Ans:

• cryIAc

• cryIIAb

5. Mention any two problems associated with conventional breeding that were solved through GM crops. Mention one problem associated with its use.

Ans:

• Time-consuming process and limited success.

• GM crops solved resistance to pests and higher yield.

• Problem: Fear of unintended effects on health and environment.

6. Mention the genes of Bacillus thuringiensis that give resistance against a) Cotton bollworms b) Corn borer

Ans:

• a) cryIAc and cryIIAb

• b) cryIAb

7. Differentiate between somatic hybrids and somaclones.

Ans:

• Somatic hybrids are formed by fusion of protoplasts of different plants.

• Somaclones are genetically identical plants produced through micropropagation.

8. What is meristem culture? Mention its significance.

Ans:

• Meristem culture is the in vitro culture of meristematic tissue.

• It is used to produce virus-free plants.

9. Differentiate between pro-insulin and a mature insulin.

Ans: Pro-insulin has an extra C-peptide connecting A and B chains.

Mature insulin lacks C-peptide, having only A and B chains connected by disulfide bonds.

10. Mention any two biological products produced by transgenic animals with their applications.

Ans: α-1-antitrypsin: Used to treat emphysema.

Human protein (e.g., antithrombin): Used in medical therapy.

11. What is gene therapy? Mention a disease which has been treated using this technique.

Ans: Gene therapy is a collection of methods to correct a gene de

ADA deficiency has been treated using gene therapy.

12. Transgenic animals can be used to produce biological products. Justify with two examples.

Ans: Transgenic animals produce α-1-antitrypsin for emphysema treatment.

Transgenic sheep produce human proteins in milk.

13. Mention any two biological products obtained from transgenic animals.

Ans:

- α-1-antitrypsin
- Antithrombin protein

14. Mention any two roles of Genetic Engineering Approval Committee.

Ans:

- They evaluate the safety of genetically modified organisms.
- They approve large-scale use of GM crops and recombinant products.

15. Name any two modern diagnosis tools which help in early detection of disease.

Ans:

- PCR
- ELISA

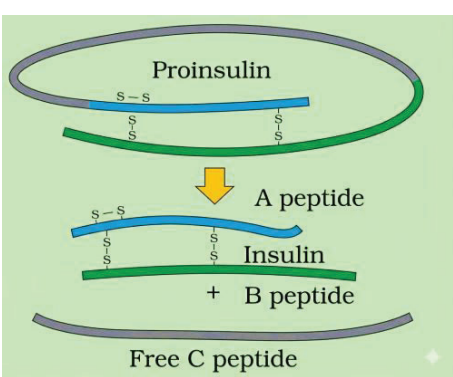
16. Write any two applications of PCR as a molecular diagnostic tool.

Ans:

- Detection of genetic disorders.
- Early diagnosis of cancer.

17. Give the diagrammatic representation of maturation of pro-insulin into insulin.

Ans:



18. PCR and ELISA are the tools for early detection of diseases. Justify the statement by giving the principles behind the techniques.

Ans:

• PCR detects mutations at the gene level using DNA amplification.

• ELISA is based on antigen-antibody interaction.

19. How insulin was produced before its production through genetically modified E. coli?

Ans:

• Insulin was extracted from pancreas of slaughtered cattle and pigs.

• This sometimes caused allergic reactions in humans.

IV. Answer the following questions in 40-80 words each: 3 Marks Each:

1. Mention the three critical areas of biotechnology.

Ans:

• Providing best catalyst in the form of improved organism.

• Creating optimal conditions through engineering.

• Downstream processing technologies for product purification.

2. Name any three options that can be thought for increasing food production in agriculture.

Ans:

• Agro-chemical based agriculture.

• Organic agriculture.

• Genetically engineered crop-based agriculture.

3. In which way genetically modified plants are useful?

Ans:

• They reduce use of chemical pesticides.

• Help in pest resistance and enhanced nutritional value.

• Increase tolerance to environmental stress.

4. What is Bt toxin? How does it kill cotton boll worms?

Ans:

• Bt toxin is an insecticidal protein produced by *Bacillus thuringiensis*.

• It is activated in the insect's alkaline midgut.

• It creates pores in the gut lining causing cell lysis and death.

5. Mention the three groups of insects that are susceptible to Bt toxins.

Ans:

• Lepidopterans (e.g., bollworms)

• Coleopterans (e.g., beetles)

• Dipterans (e.g., mosquitoes)

6. Explain how the development of Bt cotton has reduced the use of insecticides.

Ans:

• Bt cotton contains cry genes that kill bollworms.

• It reduces need for external pesticide sprays.
• Leads to environmental safety and reduced input cost.

7. Write a note on production of human insulin by genetic engineering.

Ans:

• Two DNA sequences for A and B chains of insulin were inserted into plasmids.
• Plasmids introduced into *E. coli* for expression.
• Chains extracted, purified and joined by disulphide bonds.

8. What is RNA interference? Explain the procedure of developing nematode resistant tobacco plant by RNA interference.

Ans:

• RNA interference is a gene silencing method.
• Nematode-specific genes introduced into tobacco produce sense and anti-sense RNA.
• These form dsRNA which silences nematode mRNA, preventing infection.

9. Briefly explain the steps involved in PCR-based molecular diagnosis of mutations in cancer patients.

Ans:

• DNA is isolated from patient cells.
• Specific primers amplify mutated gene regions using PCR.
• The mutations are detected by analyzing the amplified DNA.

10. What is gene therapy? Explain the steps involved in curing ADA deficiency by gene therapy.

Ans:

• Functional ADA gene is inserted into lymphocytes using viral vectors.
• Modified cells are returned to the patient.
• These cells produce functional ADA enzyme.

11. What is gene therapy? Give an example.

Ans:

• Gene therapy is introducing functional genes to correct defective ones.
• Example: ADA deficiency cured by inserting ADA gene into lymphocytes.

12. Write a note on gene therapy.

Ans:

• It involves correction of a defective gene using normal gene.
• First clinical success was treating ADA deficiency.
• Modified cells restored ADA enzyme function.

13. Mention three applications of PCR as a tool of molecular diagnosis.

Ans:

• Detect mutations in genetic disorders.
• Early detection of cancers.
• Detection of viral and bacterial infections.

14. What is biopiracy? Explain it with reference to Basmati Rice.

Ans:

- Biopiracy is unauthorized use of bio-resources without compensation.
- US company patented Basmati rice varieties developed in India.
- India challenged and won the patent reversal.

15. Briefly explain the process of somatic hybridization with an example.

Ans:

- Fusion of protoplasts of different plants.
- Hybrid cell regenerated into plant.
- Example: Tomato and potato to produce pomato.

16. Mention significances of the following in early diagnosis. a) PCR b) ELISA

Ans:

- a) Detects mutations in genes before disease symptoms.
- b) Detects infection using antigen-antibody interaction.

V. Answer the following questions as directed: 5 Marks Each:

1. "One of the applications of biotechnology is the production of insect-resistant crop plant". Justify the statement with reference to Bt cotton.

Ans:

- Bacillus thuringiensis (Bt) produces a protein toxic to specific insects, including cotton bollworms.
- The Bt gene (cryIAc or cryIIAb) has been cloned and transferred into cotton plants.
- This gene produces Bt toxin in the cotton plant, which remains inactive (protoxin) until ingested by the in
- In the insect's alkaline midgut, the protoxin is converted into an active toxin.
- This toxin binds to midgut epithelial cells, creating pores and causing cell lysis and death.
- Thus, Bt cotton becomes resistant to bollworms and eliminates the need for chemical insecticides.

2. a) What are genetically modified crops? Give example. b) What is Biopiracy? Comment on the Biopiracy of Basmati rice.

Ans:

- a) Genetically modified crops are plants with altered DNA to express a foreign gene for desired traits.

Example: Bt cotton.

- b) Biopiracy is the exploitation of bioresources by multinational companies without authorization or compensation.

Example: A US company patented Basmati rice lines developed in India.

This patent was challenged and revoked as it violated the intellectual property rights of Indian farmers.

3. What is Bt cotton? The development of Bt cotton has greatly reduced the reliance on chemical pesticides. Justify.

Ans:

- Bt cotton is a transgenic plant containing cry genes from Bacillus thuringiensis.
- It produces Bt toxin that kills specific insect larvae, especially bollworms.
- The toxin binds to midgut cells of the insect, forms pores, and causes cell lysis.

• This reduces the need for external insecticides.
• It results in reduced cost, safer environment, and higher yield.

4. Briefly explain the uses of transgenic animals.

Ans:

• Transgenic animals are used to study gene regulation and their effects on development.
• They help in understanding diseases like cancer.
• Used to produce useful biological products such as α-1-antitrypsin and antithrombin.
• Serve as models to test drug safety and toxicity.
• Help in xenotransplantation and development of vaccines.

5. What is RNA interference? How does RNA interference help to develop resistance in tobacco plant against Nematode infection?

Ans:

• RNA interference (RNAi) is a gene-silencing method.
• Double-stranded RNA is formed from sense and antisense strands.
• This dsRNA silences specific mRNA of nematodes.
• Nematode-specific genes are introduced into host plants.
• Result: tobacco plants become resistant to Meloidogyne incognita infection.

6. With reference to tissue culture, define the following terms: a) Explants b) Micropropagation c) Totipotency d) Somatic hybridization e) Somaclones

Ans:

• a) Explants: Part of a plant taken for tissue culture.
• b) Micropropagation: Rapid multiplication of plants using tissue culture.
• c) Totipotency: Ability of a cell to regenerate into a whole plant.
• d) Somatic hybridization: Fusion of protoplasts from different plants.
• e) Somaclones: Plants genetically identical to the parent plant.

7. What is tissue culture? Explain any four applications.

Ans:

- Tissue culture is the technique of growing plant cells/tissues in an artificial medium.
  Applications:
- Production of virus-free plants using meristem culture.
- Clonal propagation of elite varieties.
- Development of somatic hybrids.
- Germplasm conservation.

8. Explain the applications of biotechnology in the field of medicine.

Ans:

• Genetically engineered insulin: Produced using E. coli carrying human insulin genes.
• Gene therapy: Used to correct genetic defects like ADA deficiency.
• Molecular diagnostics: Techniques like PCR and ELISA help in early disease detection.
• Transgenic animals: Produce human proteins like α-1-antitrypsin.
• Vaccines and monoclonal antibodies: Engineered using biotechnological techniques.

9. In agriculture, use of genetically modified crops is more advantageous over conventional method. Justify the statement giving five reasons.

Ans:

- GM crops provide resistance to pests and diseases.
- Enhance tolerance to abiotic stress like drought and cold.
- Improve nutritional quality of food crops.

10. In tissue culture, the technique of somatic hybridization is one of the superior thinking of scientists. Substantiate the statement with appropriate example.

Ans:

- Somatic hybridization fuses protoplasts of different species, overcoming sexual incompatibility.
- It combines desirable traits from both parents.
- Example: Pomato (fusion of tomato and potato protoplasts).
- Helps in creating hybrids that are otherwise not possible.
- Enhances crop improvement programs.

VI. Answer the following questions as directed: 5 Marks Each:

Q1. Biotechnology has its own applications in many ways as it comprises number of techniques. Given below are the few applications created by biotechnology. Name the technique behind the applications.

a) Detection of pathogen using antigen-antibody interaction.
b) Identification of mutation in a gene.
c) Detection of the pathogen before the development of disease symptoms.
d) Control of Meloidogyne infection in tobacco plants.
e) Production of thousands of plants in short duration using tissue culture.

Ans:

a) ELISA
b) PCR
c) PCR
d) RNA interference
e) Micropropagation

Q2. Genetic engineering is a technique of altering the chemistry of genetic material to introduce into host organism to create change in phenotype of the host. In light of this, answer the following:

a) Which is the source organism of cry gene? (1)
b) Name the host plant to which cry gene was inserted? (1)
c) Give any two examples for the cry gene. (1)
d) Explain the mode of action of the protein produced by the cry gene. (2)

Ans:

a) *Bacillus thuringiensis*
b) Cotton
c) $cryIAc$ and $cryIIAb$
d) Cry protein is ingested by insect larvae. In alkaline midgut, it is activated to toxin. It binds to epithelial cells and forms pores, leading to cell lysis and death.

Q3. RNA interference is a novel strategy to control *Meloidogyne incognita* infection in tobacco plants. Given below are the steps involved in this technique. Arrange them in a definite sequence.

Ans: Correct sequence:

a) Nematode specific genes were introduced into the host plants.
b) DNA produces both sense and anti-sense RNA.
c) Being complementary, the two RNAs forms double stranded RNA.
d) Initiates RNAi.
e) Silences the specific mRNA in the nematode.

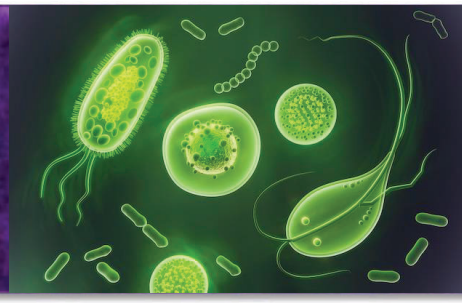
Q4. Give reasons for the following:

a) Even though Bt toxin can kill many insects, it will not kill the bacteria that produces it.
b) Even though Bt toxin is inactive, it kills the insect when enters its midgut.
c) The gene encoding 'cry' protein inserted into a crop plant.

Ans:

a) Bt toxin exists as inactive protoxin in bacteria.
b) In alkaline pH of insect gut, protoxin is activated into toxin.
c) To make the plant insect-resistant by producing Bt toxin.

Chapter 11
ORGANISMS AND POPULATIONS



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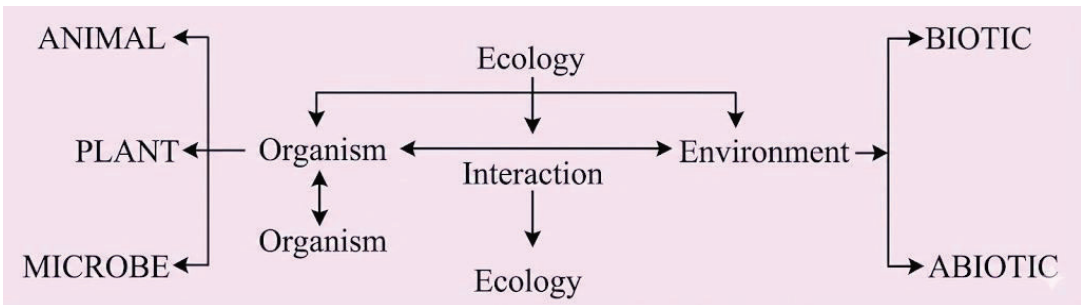
11.2. POPULATION ATTRIBUTES
11.3 POPULATION GROWTH
11.4. POPULATION INTERACTIONS

Theory

INTRODUCTION:

Ecology -

- It is derive from Greek Word :- **Oikos –** Home , **Logos –** Study
- Ecology is a subject which studies the interactions among organisms and between the organism and its physical (abiotic) environment.

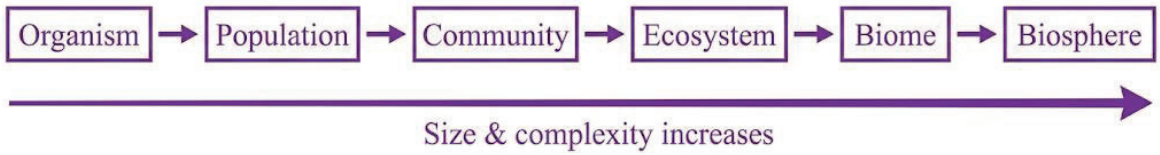


Ecologist: Those who study Ecology.

- The term ecology was coined and described by **- E. Haeckel**
- Father of Ecology **– Reiter**
- Father of Indian Ecology **- Prof. Ram Deo Misra**
- First of all term ecology was employed for study of plant **by – Warming**

ECOLOGICAL HIERARCHY

The hierarchy in the level of organization connected with ecological grouping of organism is called ecological hierarchy.



Organism :

- It is smallest unit of ecological hierarchy and basic unit of ecological study.
- Ecology at the organismic level is essentially **physiological ecology.**
- It tries to understand how different organisms are adapted to surrounding environment in terms of survival and reproduction. **Example :** Individual Deer.

Population :

- A group of Individuals (members) of same species living at one place (specific geographical area) in a given time is known as population. **e.g. Group of Deer**

Community :

- Groups of organisms of different species that live together in a common area, at a given time is called Community. **E.g.,** Different population of plants and animals in a forest.

Ecosystem :

- An ecosystem can be visualised as a functional unit of nature, where living organisms (biotic) interact among themselves and also with the surrounding physical environment (abiotic) **e.g.,** Pond ecosystem.

Biome :

- A large unit of environment consisting of a major vegetation type and associated found in a specific climate zone is called a biome. e.g., tropical rain forest

Biosphere :

- All the ecosystem of the world are collectively called **biosphere.**

11.1. Populations

- In nature, we rarely find isolated, single individuals of any species.
- Majority of them live in groups.
- A group of individuals belonging to the same species living together in a common area at a given time is called **population.**

Examples of populations

- All the cormorants in a wetland.
- Rats in an abandoned dwelling.
- Teakwood trees in a forest tract.

- Bacteria in a culture plate.
- Lotus plants in a pond.
  - Individual organism is the one that has to cope with a changed environment, it is at the population level that natural selection operates to evolve the desired traits.
  - Population ecology is, therefore, an important area of ecology because it links ecology to population genetics and evolution.

11.2. Population Attributes

- It is the characteristics of a population that an individual organism do not possess.

Individual	Population
Birth	Birth Rate
Death	Death Rate
Sex	Sex ratio
Specific Age	Age distribution

I. Birth Rate or Natality :

- Birth rate is defined as total number of births in a population with respect to total number of individual of the population in a year.
- Birth rate is represented as per capita birth rate

$$b = \frac{\text{Total number of birth}}{\text{Initial population}}$$

Example : If in a pond there are 20 lotus plant last year and through reproduction 8 new plant are added, then the birth rate during the year is calculated as :

Solution : $b = \frac{\text{Total birth}}{\text{Initial population}} = \frac{8}{20}$, $b = 0.4$ offspring per lotus per year.

II. Death Rate or Mortality:

- Death rate is defined as total number of deaths in a population with respect to total number of individual of the population in a year.
- Death rate is represented as per capita death rate

$$d = \frac{\text{Total number of death}}{\text{Initial population}}$$

Example : If 4 individuals in a laboratory population of 40 fruit flies died during week. The death rate is calculated as :

Solution : $d = \frac{\text{Total number of death}}{\text{Initial population}} = \frac{4}{40}$, $d = 0.1$ individual per fruitfly per week

III. Sex Ratio :

- Another attribute characteristic of a population is sex ratio.
- An individual is either a male or a female but a population has a sex ratio (e.g. 60% of the population are females and 40% males).

IV. Age and Sex Structures :

- A population at any given time is composed of individuals of different ages.
- Population has 3 age groups.

  Pre-Reproductive individuals - < 15yr.

  Reproductive individuals - 15 – 44yr.

  Post-Reproductive individuals - > 45yr.
- If the age distribution (per cent individuals of a given age or age group) is plotted for the population, the resulting structure is called an **age pyramid.**
- For human population, the age pyramids generally show age distribution of males and females in a co combined diagram.
- The shape of the pyramids reflects the growth status of the population -

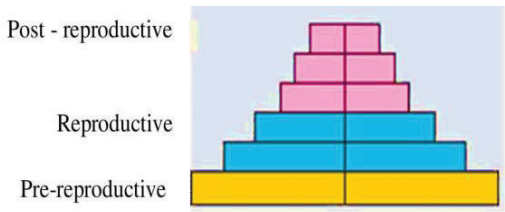
  1. Expanding

  2. Stable

  3. Declining

1. **Expanding (Triangular shape pyramid)**

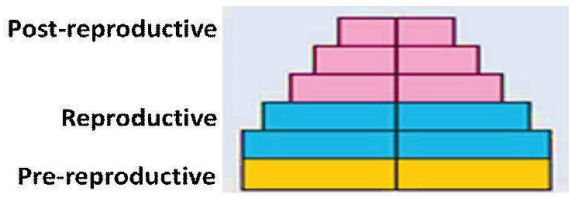
- A number of pre-reproductive individuals, moderate number of reproductive individuals and fewer post-reproductive individuals will form young population it shows rapid growth.
- It indicates **expanding population** with high growth rate.



Expanding

2. **Stable (Bell-shaped age pyramid)**

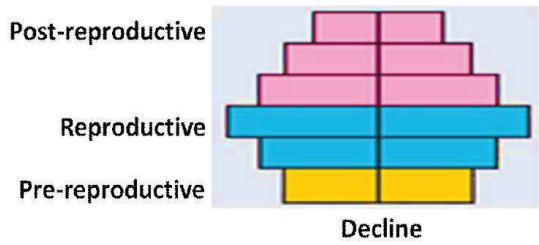
- An equal number of pre-reproductive and reproductive individuals will constitute a mature population or stable population.
- It indicates the **stable population** with zero growth rate.
- Developed countries have a steeper pyramid which represent nearly a stable population.



Stable

3. **Decline (Urn shaped pyramid)**

- Fewer number of pre reproductive individuals as compared to reproductive ones will make population aged.
- It indicates declining population with growth rate in minus.



V. Population density (Population size)

- It is measured as total number of individual present in **unit area** or **unit volume.**
- The size of a population for any species is not a static parameter. It keeps changing in time depending on various factor including **food availability, predation pressure** and **adverse weather.**

Population density measurement by various methods -

1. **Direct Count :-** The entire population is counted, used for small populations or sessile organisms.This method is not possible for large populations.
2. **Percent cover or Biomass:-** In some cases ,the per cent cover or biomass is a more meaningful measure of the population size. **E g.,:-** In an area, if there are 200 carrot grass (Parthenium hysterophorus) plants but only a single huge banyan tree with a large canopy, stating that the population density of banyan is low relative to that of carrot grass amounts to underestimating the enormous role of the Banyan in that community.
3. **Relative density:-** Sometimes, determining actual/absolute population density is difficult at that time we will use relative density method .**E.g., :-** Let's say we need to count rough number of fishes in a pond ;here can count fishes in small area and use this number to analyse the total like ,if 10% of pond has 5000 fishes the complete pond will roughly has 50000 fishes.
4. **Indirect method :- E.g., :-** In national parks and tiger reserves ,the tiger census or counting is actually done by counting the number of pug marks and fecal pellets of tigers when they come near water body to drink water.

11.3. Population Growth

- **Population growth** is actual increase in the density in a given habitat over a period of time.
- The size of a population for any species is not a static parameter. It keeps changing with time, depending on various factors including food **availability, predation, pressure** and **adverse weather.**
- The density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes –

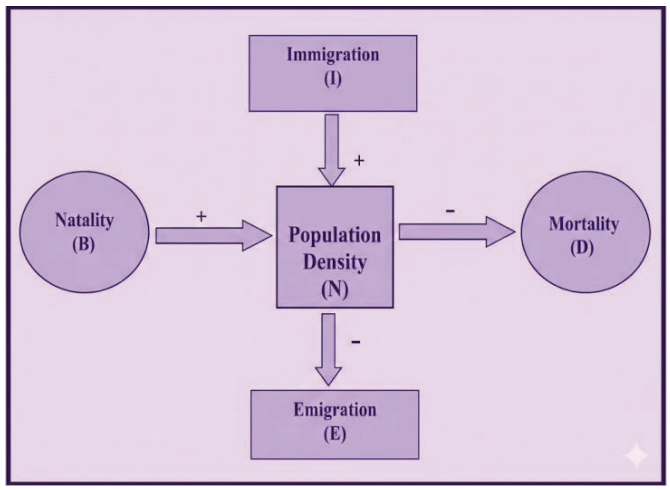
a. **Natality** (B) :- It refers to the number of births during a given period in the population that are added to the initial density.

b. **Mortality(D) :-** It is the number of deaths in the population during a given period.

c. **Immigration (I) :**It is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.

d. **Emigration (M) :-** It is the number of individuals of the population who left the habitat and gone elsewhere during the time period under consideration.

- **So, if N is the population density at time t, then its density at time $t+1$ is $N_{t+1} = N_t + [(B+I) - (D+E)]$**



- Population density will increases if the number of birth plus the number of immigration $(B+I)$ s more than the number of death plus the number of emigrants $(D+E)$.
- Under normal conditions, births and deaths are the most important factors influencing population density.
- The other two factors assuming importance only under special conditions. For instance, if a new habitat is just being colonized, immigration may contribute more significantly to population growth than birth rates.

Population Growth Models/Curves

1. **Exponential growth [Geometric growth Curve or J-shaped curve]**

- Population that exhibits rapid increase in growth when resources are unlimited,is called **exponential growth.**
- When resources in the habitat are unlimited, each species has the ability to realise fully its innate potential to grow in numbers. Then the population grown in an **exponential** or **geometric fashion.**
- If in a population of size " N ", the birth rates are represented as b and death rates as d , then the increase or decrease in N during a unit time period $t\left(\frac{dN}{dt}\right)$ will be

$$\frac{dN}{dt} = (b-d) \times N$$

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

$$\frac{dN}{dt} = rN$$

Here $\mathbf{r}$ = intrinsic rate of Natural increase or Biotic potential or growth rate.

The above equation describes the **exponential** or **geometric growth** pattern of a population and result in J-shaped curve. When we plot N in relation to time.

The integral form of the exponential growth equation as :-

$$N_t = N_0 e^{rt}$$

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

- **Few example of magnitude of *r*-values**

Norway rat is 0.015

F Flour beetle it is 0.12 .

In 1981, the r- value for human population in India was 0.0205.

2. **Logistic growth curve (Sigmoid curve / S-shaped) :**

- Decrease in the rate of growth as the population reaches carrying capacity or maximum number of individuals is called **Logistic growth.**
- This growth is more realistic.
- **Carrying Capacity (K) -** Maximum number of individuals of a particular species in a habitat that is allowed by nature as resources (food and space) is limiting.
- A population growing in a habitat with limited resources show initially a lag phase, followed by phases of **acceleration** and **deceleration** and finally an **asymptote**, when the population density reaches the carrying capacity (K).
- A plot of N in relation to time (t) result in a sigmoid curve. This type of population growth is called Verhulst - Pear logistic growth.
- It is described by the following equation :

$$\frac{dN}{dt} = rN\left[\frac{K-N}{N}\right]$$

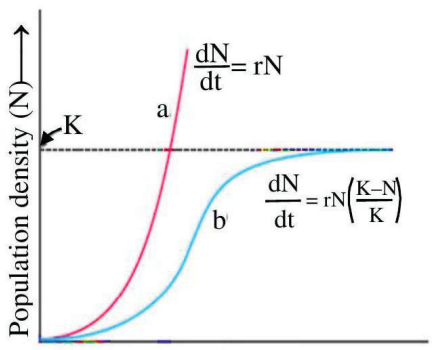
Where,

N = Population density at time t

r = Intrinsic rate of natural increase

K = Carrying capacity

Since resources for growth for most animal populations are finite and become limiting sooner or later, The logistic growth model is considered a more realistic one.



Population growth curve

(a) when responses are not limiting the growth, plot is exponential,

(b) when responses are limiting the growth, plot is logistic

Life History Variation

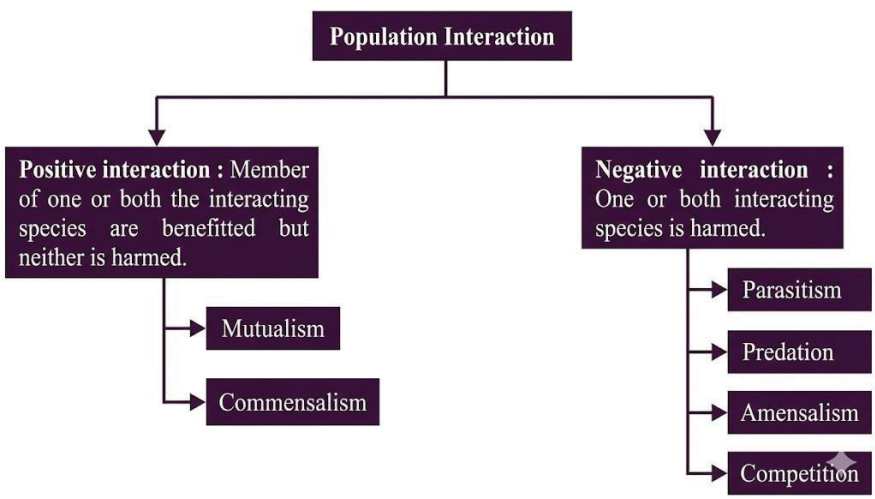
- Populations evolve to maximise their reproductive fitness, also called **Darwinian fitness** (high **r** value), in the habitat in which they live.
- Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy some of these are as follows –
  - **Breeding Nature :**-Some organisms breed only once in their lifetime (Pacific salmon fish, bamboo) while others breed many times during their lifetime (most birds and mammals).
  - **Number and size of Offsprings :-** Some produce a large number of small-sized offspring (Oysters, pelagic fishes) while others produce a small number of large-sized offspring (birds, mammals).
  - Ecologists suggest that life history traits of organisms have evolved in relation to the constraints imposed by the **abiotic** and **biotic components** of the habitat in which they live.

11.4. Population Interactions

- In nature, animals, plants and microbes do not and cannot live in isolation but interact in various ways to form a biological community in nature,is called **population interaction.**
- These interactions may be **intraspecific** (which occur within the same species)and **interspecific** (between two different species).
- They could be **beneficial, detrimental or neutral** (neither harm nor benefit) to one of the species or both.
- Assigning a ' + ' sign for beneficial interaction, ' - ' sign for detrimental and ' **0** ' for neutral interaction.

Table : Population Interactions

Species A	Species B	Name of Interaction
+	+	Mutualism
-	-	Competition
+	-	Predation
+	-	Parasitism
+	0	Commensalism
-	0	Amensalism



A. Positive interactions:- 1.Mutualism 2.Commensalism

1. **Mutualism (,++) or Obligate mutualism (co-evolution, co-existence and co-extinction)** :- It is a Positive inter specific interaction in which members of two different species completely depend on each other for growth and survival in which both interacting species are benefited. It is obligatory relationship.

Examples:-

1. **Lichens** - Lichen shows a close relationship between a fungus and an alga or cyanobacteria. Alga provides food materials to the fungus and fungi in turn provide shelter to the algae.
2. **Mycorrhiza** - It is a symbiotic association between the fungus and roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil where as the plant provides carbohydrates to the fungi.
3. **Plant-pollinator interactions** - Plants need the help of animals for pollination and dispersal of seeds. The insects in turn get nectar and pollen as food from the plants.
4. **Root nodules** of leguminous plants and **nitrogen fixing bacteria** - ***Rhizobium*** bacteria helps in nitrogen fixation and in turn the leguminous plants provide shelter to the bacteria.
5. **Fig tree and wasps** - Fig tree is pollinated by a species of wasp only. The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites. The female wasp lays eggs inside the fruit of fig tree. The fig provides seeds as food for developing larvae.
6. **Mutualism between Fig tree and wasp species** -The fig species can be pollinated only by its partner wasp species and no other species.

Flower is pollinated by wasp

- The female wasp uses the fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing its larvae.
- The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites.
- In return for the favour of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

Fig. : Wasp laying eggs in a fig fruit

7. **Mutualism between Bees and Orchid flower -**
   - Orchids show diversity of floral patterns, which have evolved to attract the right pollinator insect (bees and bumblebees) and ensure guaranteed pollination by it.

Fig: Showing bee a pollinator on orchid flower

   - The Mediterranean orchid Ophrys employs **"sexual deceit"** to get pollination done by a species of bee, one petal of its flower bears resemblance to the female of the bee in size, colour and markings.
   - The male bee is attracted to what it perceives(thinking) as a female, **'Pseudo-copulates'** with the flower and during that process is dusted with pollen from the flower. when this same bee 'pseudo-copulates' with another **flower**, it transfer pollen to it and thus pollinates the flower.
   - Here we can see how **co-evolution**. If the female bee's colour patterns changes even slightly for any reason during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

2. **Commensalism (,+ 0) -**It is the type of interspecific interaction in which one is benefitted while other is almost unaffected or neither harmed nor benefited.

Ex:

1. **Orchids growing as an epiphyte on a mango plant**- Here orchids are commensals which get the benefit of support but the mango plant is not harmed.

2. **Barnacles on the back of a whale** - Barnacle (Balanus) is a commensal which get the benefit of space. This helps the barnacle in search of food along with the movement of whales. Thus Barnacle is benefited and whales are not harmed.
3. **The cattle Egret and grazing cattle** - As the cattle move during grazing they stir up and flush out the insects from the vegetation. Otherwise it is difficult for egret to find insects and catch them. Then the egrets find the insects and catch them. The cattle not harmed.
4. **Sea anemone and clown fish** - Clown fish lives among tentacles of sea anemone. The fish gets protection from predators. Sea anemone is neither benefitted nor harmed.
5. **Sucker fish and Shark** - Sucker fish (Echeneis) attaches to the ventral side of a shark by its sucker. It rides along fixed to the shark. But occasionally detaches itself from the fish. It is to capture the fragments falling off from the shark's prey.

B. **Negative interaction (antagonism)/detrimental :- 1. Parasitism 2. Predation 3. Amensalism 4. Competition**

1. Parasitism (+ / -)

- Parasitism is an interaction between two organisms where smaller one (parasite) is benefitted and larger is one (predator) is harmed.
- Smaller organism benefitted is called **parasite** & the larger organism suffered is called host.
- Parasitic mode of life ensures **free lodging and meals.**
- The parasite gets nutrition and shelter from the host.
- Many parasites have evolved to be host-specific in such a way that host and the parasites tend to co-evolve ; that is ,if the host evolves special mechanisms for rejecting the parasites,the parasite has to evolve mechanisms to counteract and neutralize them.

Types of Parasites:

A. **Ectoparasites** -Parasites that feed on the external surface of host organism
1. **Lice** on humans
2. **Ticks** on dogs
3. Marine fishes infested with copepods
4. ***Cuscuta*** (parasitic plant) growing on hedge plants.
5. **Leech** on cattle

Note:- The female mosquito is not considered a particular although it needs our blood for reproduction.

B. **Endoparasites** - parasites that live inside at various sites.
1. **Plasmodium** - living in RBC of humans.
2. **Ascaris** (Round worm) - living in small intestine of man.
3. **Entamoeba histolytica**-living in large intestine of man.
4. **Tape worm** (Taenia solium) - in intestine.
5. **Liver fluke** (Fasciola hepatica) - complete life cycle in two hosts (snail and fish).
6. **Filarial worm** is a parasite of lymph tissue.

Special adaptations of Parasite

1. Loss of unnecessary sense organs
2. Presence of **adhesive organs** or **suckers** to cling on to the host.
3. Loss of digestive system
4. High reproductive capacity.
5. Complex life cycle involving one or two intermediate hosts.
6. Liver fluke has two intermediate hosts to complete its life cycle.

Harmful Effects of parasitism

- Parasites always harm the host.
- Reduce the survival, growth and reproduction of host.
- Reduces the population density of host.
- Make the host more vulnerable to predators by making it physically week.

Brood parasitism.

- It is a special type of parasitism found in birds.
- The parasitic birds lay its eggs in the nest of its host and let the host incubate them.
- **Koel** (cuckoo) lays its eggs in the nest of crow (host).
- The crow incubates the eggs of koel until the formation of young ones.
- The egg of parasitic bird is similar with the egg of the host in size, shape and colour.
- It is to reduce the chances of the host bird detecting foreign eggs & ejecting them from the nest.

2. Predation (+/−):

- Predation is an interaction in which one organism is benefited and the other is harmed or killed OR The organism of higher trophic level (**predator**) feeds on organism of lower trophic level (prey) is called the predation.
- The organism that catches and kills the other organism is called **predator** and the organism killed by predator is called **prey.**

The role of predators :-

- Predation acting as **'conduits'(channel).**Which helps in the transfer of energy from plants to higher trophic levels.
- Predators keep the prey populations under control.
- Biological control (bio-control) of pests is based on prey-predator relationship.

Control of invasive species -

- Exotic species have no natural predator hence they grow very rapidly.
  Ex: Cactus (prickly pear) is introduced into Australia as hedge created problem. Further it was controlled by introducing **cactus feeding the moth predator.**

Predators also help in maintaining species diversity

- In a community, by reducing the intensity of competition among competing prey species.
- **Ex**: When ***Pisaster*** (starfish) a predator, was removed from American Pacific coast about **10 species** of invertebrates became extinct within a year because of interspecific competition.
- If a predator over-exploits its prey, the prey might become extinct and following it, the predator will also become extinct due to lack of food.

Why Predators in nature are prudent ?

- If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct for lack of food. This is the reason why predators in nature are **'prudent'.**

The prey defense mechanism -

a. **Prey species have evolved various defenses to lessen the impact of predation.**

   Ex., Some species of **insects and frogs** are cryptically-coloured (camouflaged) to avoid being detected easily by the predator.

b. **Some are poisonous and therefore avoided by the predators.**

Ex., The **Monarch butterfly** is highly distasteful to its predator (bird) because of a special chemical present in its body.Interestingly, the butterfly acquires this chemical during its caterpillar stage by feeding on a poisonous weed.

Defense mechanism of plants from predator herbivores :

- Nearly **25%** of all insects are known to be phytophagous (feeding on plant sap and other parts of plants).
- The problem is particularly severe for plants because, unlike animals, they cannot run away from their predators. Plants therefore have evolved an **astonishing**(amazing) variety of **morphological** and **chemical** defenses against herbivores.

Example :-

Ex-1 :- Defense mechanism of plants from predator herbivores Thorns (Acacia, Cactus) are the most common morphological means of defense.

Ex-2:- Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.

Ex-3:- The weed **Calotropis** growing in abandoned fields. The plant produces highly **poisonous cardiac glycosides** and that is why you never see any cattle or goats browsing on this plant.

Ex-4:-A wide variety of chemical substances that we extract from plants on a commercial scale **(nicotine, caffeine, quinine, strychnine, opium, etc.,)** are produced by them actually as defenses against grazers and browsers.

3. **Amensalism (-/0) :**

In amensalism on the other hand one species is harmed whereas the other is unaffected. e.g. The mould Penicillium secretes penicillin which kills bacteria but the mould is unaffected.

4. **Competition (- /−) :**

- Competition is an interaction where two organisms compete for the same resources like food and space etc.

Types of competition:-

1. **Interspecific competition :-** It is the competition occurs between two different species.
2. **Intraspecific competition:-** It is generally believed that competition occurs when closely related species compete for the same resources that are limiting, but this is not entirely true :

a) **Resources are limited:-**Totally unrelated species could also compete for the same resources.
Ex: American lakes visiting flamingoes and resident fishes have their common food, Zooplanktons.

b) **Resources are limited:-** Resources need not be limiting for competition to occur, in interference competition **(indirect competition).**
Ex:**Abingdon tortoise** in **Galapagos Islands** became extinct within a decade after **goats** were introduced on the island, due to greater browsing ability.

- **Competitive release** -A species, whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed. **Ex:** Superior barnacle ***Balanus*** dominates the intertidal area and excludes the smaller barnacle ***Chthamalus*** from that zone (**Connell's** elegant field experiment).

- **Gause's *'Competitive Exclusion Principle'*** - Two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior will be eliminated eventually.
- **Resource partitioning-** If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different foraging pattern.
  Ex: MacArthur showed five closely related species of warblers (Perching birds) living on the same tree were able to avoid competition and co-exist due to behavioral differences in their foraging activities.

EXERCISE

PART – A

I. Multiple Choice Questions: 1 Mark Each:

1. The correct order of various levels of biological organization in an eco-system is:

a) Organism → Population → Community → Ecosystem → Biome.

b) Organism → Population → Biome → Ecosystem → Community

c) Biome → Ecosystem → Population → Organism → Community.

d) Biome → Community → Ecosystem → Population → Organism.

2. In a pond if there were 20 lotus plants last year and through reproduction 16 are added. Calculate the birth rate:

a) 0.8 offspring per lotus per year.

b) 0.4 offspring per lotus per year.

c) 0.8 offspring per year.

d) 1.25 offspring per year.

3. In an aquarium if there are 8 fishes and in a week 2 fishes die. Calculate the death rate:

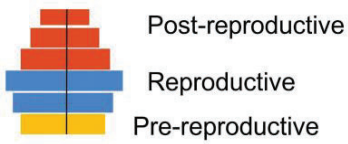
a) 0.25 individual per fish per week.

b) 3.0 individual per fish per week.

c) 0.25 individual fish per week.

d) 3.0 individual fish per week.

4. The shape of the age pyramid reflects the population's growth status. In this context, the given age pyramid indicates that the population is



a) Expanding b) Stable c) Declining d) Cannot be depicted

5. Statement 1: Population size is determined by population density.

Statement 2: Population density is not the meaningful measure of the population

a) Both statements 1 & 2 are correct

b) Statement 1 is correct & 2 is incor

c) Statement 1 is incorrect & 2 is correct

d) Both the statements are incor

6. In a population with a large number of older individuals than younger ones it can be predicted to:

a) Decline b) Standard. c) Grow d) Does not effect

7. The change in population size can be used to evaluate :

a) Impact of predator

b) Effect of pesticide.

c) Introduction of exotic species

d) All the above.[Easy]

8. Statement 1: If the predator is too efficient and over exploits its prey then the predator itself becomes extinct.

Statement 2: Prey species have evolved various defense s to lessen the impact of the predation.

a) Both statements 1 & 2 are correct

b) Statement 1 is correct & 2 is incor

c) Statement 1 is incorrect & 2 is correct

d) Both the statements are incor

Answer Key				
1. A.	**2.** A.	**3.** A.	**4.** A.	**5.** B.
6. A.	**7.** D.	**8.** A.		

II. Fill in the blanks 1 Mark Each:

(Exponential, Resource partitioning, 0.0205, Commensalism, Logistic growth)

1. The r value for human population in India in 1981 was _____ .
2. The population growth is called _____when it finally reaches an asymptote.
3. The population interaction where one species is benefitted and the other is neither benefitted nor harmed is called _____.
4. Closely related species of Warblers living on the same tree avoid competition by the mechanism called _____
5. When resource availability in a habitat is unlimited it leads to _____growth.

Answer Key				
1. **0.0205**.	**2.** Logistic growth.	**3.** Commensalism.	**4.** Resource partitioning.	**5.** Exponential growth.

PART – B

III. Answer the following questions in 3-5 sentences each: 2Marks Each:

Q1. Mention the four basic levels of biological organization that ecology is concerned with?

Ans: Ecology is basically concerned with four levels of biological organization – organisms, populations, communities and biomes.

Q2. Mention any two population attributes.

Ans: Birth rates, death rates, sex ratio and age group.

Q3. Name the four basic processes that fluctuates population density.

Ans: Natality, mortality, immigration and emigration.

Q4. Mention the two patterns of population growth in organisms.

Ans: Exponential growth and Logistic growth.

Q5. Differentiate between exponential growth and logistic growth.

Ans:

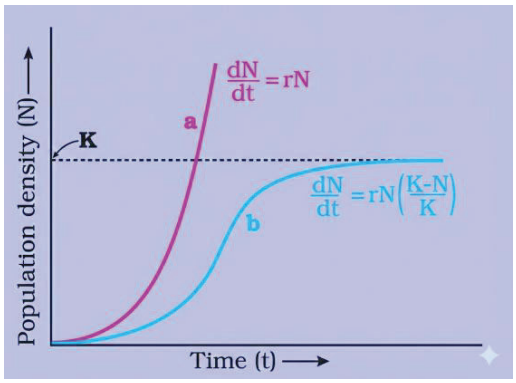
Exponential growth	Logistic growth
When resources in the habitat are unlimited, each species has the ability to realise fully its innate potential to grow in number.	When resources are limited in the habitat leads to competition between individuals, eventually, the 'fittest' individual will survive and reproduce.
Then the population grows in an exponential or geometric fashion.	In nature, a given habitat has enough resources to support a maximum possible number, beyond which no further growth is possible (carrying capacity).

Q6. Give two examples or organisms that breed only once in their life time.

Ans: Pacific salmon fish and bamboo.

Q7. Show diagrammatic representation of exponential and logistic growth curves of population growth in a combined diagram.

Ans:



Q8. Mention any four types of interspecific interactions in organisms.

Ans: Mutualism (+ +), Competition (– –), Predation (+ –), Parasitism (+ –), Commensalism (+ 0), Amensalism (– 0).

Q9. Mention two examples for defense of prey against predators in plants.

Ans:

- Thorns in Acacia and Cactus are the most common morphological means of defense.
- Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.

Q10. Define predation. Give any two examples.

Ans: Interspecific interactions arise from the interaction of one species benefits (predator) and the interaction is detrimental to the other species (prey).

Examples:

- Tiger and the deer
- Sparrow eating any seed

Q11. Mention two adaptations in plants to escape from grazers and browsers.

Ans:

- Thorns in Acacia and Cactus are the most common morphological means of defense.
- Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.

Q12. Give an example each for

Ans:

a) **Morphological defense:** Thorns in Acacia and Cactus

b) **Chemical defense in plants against grazing animals:** Calotropis plant produces highly poisonous cardiac glycosides

Q13. Give an example for following defense mechanism.

Ans:

a) **Camouflage:** Some species of insects and frogs are cryptically-coloured (camouflaged) to avoid being

detected easily by the predator
b) **Distasteful for the predator:** The Monarch butterfly is highly distasteful to its predator

Q14. Explain interference competition with an example.
Ans: The feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant.
E.g. The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats.

Q15. Explain competitive release with an example.
Ans: A species whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed.
Example: Connell's elegant field experiments showed that on the rocky sea coasts of Scotland, the larger and competitively superior barnacle *Balanus* dominates the intertidal area, and excludes the smaller barnacle *Chthamalus* from that zone.

Q16. Write short note on resource partitioning with a suitable example.
Ans: If two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging patterns are called resource partitioning.
Example: MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

Q17. Mention two adaptations in organisms for parasitic mode of life.
Ans: Parasites evolved special adaptations such as:

- The loss of unnecessary sense organs
- Presence of adhesive organs or suckers to cling on to the host
- Loss of digestive system
- High reproductive capacity

Q18. What are Ectoparasites? Give example.
Ans: Parasites that feed on the external surface of the host organism are called Ectoparasites.
Examples: lice on humans and ticks on dogs.

Q19. What are endoparasites? Give an example.
Ans: The parasitic organisms live inside the host body at different sites (liver, kidney, lungs, red blood cells, etc.).
Example: The human liver fluke.

Q20. Define commensalism. Give examples.
Ans: The interaction in which one species benefits and the other is neither harmed nor benefited is called commensalism.
Examples: An orchid growing as an epiphyte on a mango branch, and barnacles growing on the back of a whale.

Q21. Define mutualism. Give an example.
Ans: The interaction in which confers benefits on both the interacting species called mutualism.

Examples: Lichens represent an intimate mutualistic relationship between a fungus and photosynthesizing algae or cyanobacteria. Mycorrhizae are associations between fungi and the roots of higher plants.

Q22. What is brood parasitism? Give an example.

Ans: In brood parasitism the parasitic bird lays its eggs in the nest of its host and lets the host incubate them. E.g. Brood parasitism between cuckoo and crow.

Q23. State Gause's competitive exclusion principle.

Ans: Gause's Competitive Exclusion Principle states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually.

Q24. Female mosquito is not considered as parasite although it feeds on human blood. Why?

Ans: The female mosquito is not considered a parasite, although it needs our blood for reproduction and mosquitos' main food source is plant sap.

Q25. Differentiate between Ectoparasite and endoparasite with examples.

Ans:

Ectoparasite	Endoparasite
Parasites that feed on the external surface of the host organism are called Ectoparasites.	The parasitic organisms live inside the host body at different sites (liver, kidney, lungs, red blood cells, etc.).
Examples: lice on humans and ticks on dogs.	Example: The human liver fluke

Q26. Cattle egret and grazing cattle is a classical example of commensalism. Comment.

Ans: The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and flush out insects from the vegetation that otherwise might be difficult for the egrets to find and catch.

Q27. Fig species and pollinator wasp is an example of evolution of mutualists. Justify.

Ans: The fig species can be pollinated only by its 'partner' wasp species and no other species. The female wasp uses the fruit not only as an oviposition (egg-laying) site but uses the developing seeds within the fruit for nourishing its larvae.

IV. Answer the following questions in 40-80 words: 3 Marks Each:

Q1. If N is population density at time t, B is natality, D is mortality, I is immigration, E is emigration.

a) Give the equation to determine density at time t + 1.

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

b) Which of the above determinants contribute to an increase in population density?

Ans: Natality and immigration

c) Which of the above determinants contribute to a decrease in population density?

Ans: Mortality and emigration

Q2. List out the three attributes of a population.

Ans: The important attributes are birth rate, death rate, sex ratio, age distribution and population density.

Q3. Write a note on brood parasitism.

Ans: The parasitic bird lays its eggs in the nest of its host and lets the host incubate them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to

reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest.
E.g. Brood parasitism between cuckoo and crow.

Q4. If a plot of N in relation to time (t) results in a sigmoid curve and dN/dt = rN((K − N)/K).
a) Name the type of population growth.
Ans: Logistic growth

b) What does K represent in the equation?
Ans: K represents carrying capacity.

c) On what condition does the curve become stationary?
Ans: When the population density reaches the carrying capacity the curve become stationary.

Q5. What is resource partitioning? Describe with an example.
Ans: If two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging patterns are called resource partitioning.
Example: MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

Q6. What is parasitism? Mention the types of parasites with an example for each.

Ans: Is a type of negative type of interaction in this interaction one species is depends on another group of species for food and shelter is called parasitism.

Types of parasites

1. **Endoparasites:** Parasites that live inside the host body at different sites (liver, kidney, lungs, RBC etc).
   E.g. liver fluke, tape worm, round worm.
2. **Ectoparasites:** Parasites that feed on the external surface of host.
   E.g. lice on humans, ticks on dogs.
3. **Brood parasitism:** The parasitic birds lay eggs in the nest of its host and lets the host incubate them.
   E.g. Brood parasitism between cuckoo and crow.

Q7. What is parasitism? Write a note on brood parasitism.
Ans: Is a type of negative type of interaction in this interaction one species is depends on another group of species for food and shelter is called parasitism.
The parasitic bird lays its eggs in the nest of its host and lets the host incubate them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest.
E.g. Brood parasitism between cuckoo and crow.

Q8. What is parasitism? Mention two adaptations in organisms for parasitic mode of life.
Ans: Is a type of negative type of interaction in this interaction one species is depends on another group of species for food and shelter is called parasitism.
Parasites evolved special adaptations such as:
¬ The loss of unnecessary sense organs
¬ Presence of adhesive organs or suckers to cling on to the host
¬ Loss of digestive system
¬ High reproductive capacity

Q9. What is mutualism? Why plant–animal interaction often involves co-evolution of mutualists?
Ans: The interaction in which confers benefits on both the interacting species called mutualism.

Plant–animal interactions often involve co-evolution of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another. In many species of fig trees, there is a tight one-to-one relationship with the pollinator species of wasp.

Q10. Explain how Mediterranean orchid Ophrys employs sexual deceit to ensure pollination?

So male bee 'pseudocopulates' with the flower and is dusted with pollen. When this bee 'pseudocopulates' with another flower, it transfers pollen to it.

Q11. Name the type of interactions seen in each of the following examples:

a) A sparrow eating on a seed.

Ans: Predation

b) Abingdon tortoise and goats in Galapagos Island.

Ans: Competition

c) A Cascuta growing on a hedge plant.

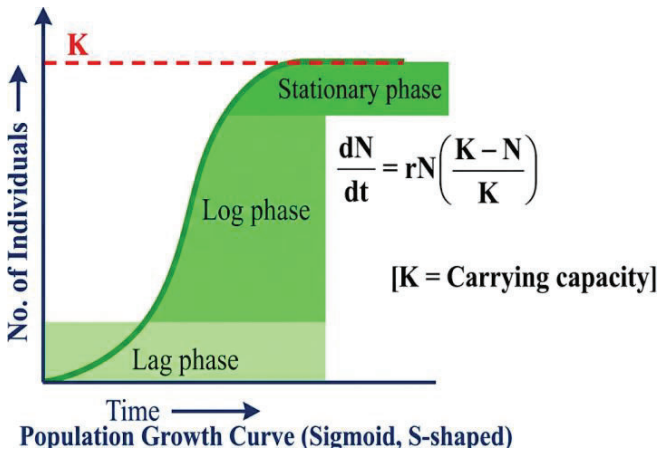
Ans: Parasitism

PART- D

V. Answer the following questions in 200-250 words: 5 Marks Each:

Q1. Explain Verhulst-Pearl logistic growth with a diagram and write its mathematical expression.

Ans: A population growing in a habitat with limited resources show initially a lag phase followed by accelerated growth and finally stationary phase. When the population of a species has limited resources, it leads to competition between individuals for resources and under this condition the fittest individual will survive and reproduce. The logistic growth model is considered a more realistic one.



Population Growth Curve (Sigmoid, S-shaped)

This type of population growth is called Verhulst-Pearl Logistic Growth. It can be described by following equation:

$dN/dt = rN (K - N / K)$

Where,

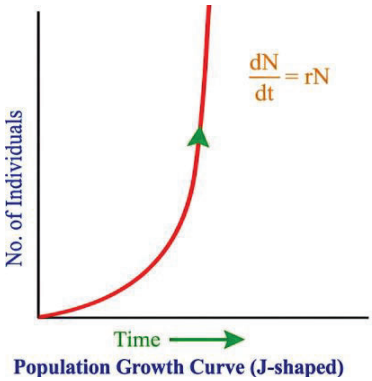
N = Population density after time t

r = Intrinsic rate of natural increase

K = Carrying capacity

Q2. Graphically represent exponential growth and give its mathematical equation.

Ans:



Population Growth Curve (J-shaped)

N- population of size
b - birth rate
d - death rate
r – intrinsic rate of natural increase
$\frac{dN}{dt}$-increase or decrease in N

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

Let $(b - d) = r$,

$dN/dt = rN$

Exponential growth equation can be expressed as

$Nt = N0\ e^{rt}$

Where,

Nt = Population density after time t

N0 = Population density at time zero

r = Intrinsic rate of natural increase

e = the base of natural logarithms (2.71828)

Q3. Mention any five population interactions with an example for each.

Ans:

1. **Mutualism:** e.g. Mycorrhizae are associations between fungi and the roots of higher plants.
2. **Competition:** e.g. visiting flamingoes and resident fishes compete for their common food, the zooplankton in the lake.
3. **Predation:** e.g. Tiger and the deer
4. **Parasitism:** e.g. Lice on humans and ticks on dogs
5. **Commensalism:** e.g. An orchid growing as an epiphyte on a mango branch

Q4. Define competition. Explain interference competition and competitive release with suitable examples.

Ans: The two groups of species compete for the same limited resources and both the species are harmful is called competition.

The feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant. E.g. The Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats.

A species whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed.

Example: Connell's elegant field experiments showed that on the rocky sea coasts of Scotland, the larger

and competitively superior barnacle *Balanus* dominates the intertidal area, and excludes the smaller barnacle *Chthamalus* from that zone.

Q5. Explain the role of predation in an ecosystem with suitable examples. Add a note on morphological and chemical defensive adaptations in plant and animal preys against their predators.

Ans: Predators act as 'conduits' for energy transfer across trophic levels.

They keep prey populations under control. E.g. The invasive cactus was brought under control only after a cactus-feeding predator (a moth) from its natural habitat.

Predators also help in maintaining species diversity in a community by reducing the intensity of competition among competing prey species. E.g. In the rocky intertidal communities of the American Pacific Coast the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year because of interspecific competition.

If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct for lack of food.

Defensive adaptations in plant and animal preys against their predators:

Thorns (Acacia, Cactus etc.) are the most common morphological means of defense of plants. Many plants produce chemicals that make the herbivore sick, inhibit feeding or digestion, disrupt its reproduction or kill it. E.g. *Calotropis* produces highly poisonous cardiac glycosides, therefore cattle or goats do not eat it.

Nicotine, caffeine, quinine, strychnine, opium etc. are defenses against grazers and browsers.

Some species of insects and frogs are cryptically-coloured (camouflaged) to avoid being detected easily by the predator.

Some are poisonous and therefore avoided by predators. The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body.

Q6. What is mutualism? Explain any four examples of mutualism.

Ans: The interaction in which confers benefits on both the interacting species called mutualism.

Examples:

Lichens – Fungus and alga or cyanobacteria are mutually benefited where fungi give shelter and reproduce by producing spores and algae provide food.

Mycorrhizae – Association between fungi and the roots of higher plants. The fungi help the plant in absorption of essential nutrients from the soil while the plant provides carbohydrates to fungi.

Fig trees and wasps – The fig species is pollinated only by its partner wasp species. The female wasp pollinates the fig inflorescence while searching for egg-laying sites. The fig provides developing seeds as food for wasp larvae.

Orchids – One petal of the flower resembles the female bee in size, colour and markings and attracts male bees to ensure pollination.

Q7. What is mutualism? Why does plant–animal interaction often involves co-evolution of mutualists? Justify your answer with an example.

Ans: The interaction in which confers benefits on both the interacting species called mutualism.

Plant–animal interactions often involve co-evolution of the mutualists. The fig species can be pollinated only by its partner wasp species. The female wasp uses the fruit as an oviposition site and the developing seeds for nourishing larvae. The wasp pollinates the fig inflorescence while searching for egg-laying sites, and in return the fig provides food for wasp larvae.

Q8. 'Parasitic mode of life ensures free lodging and free meals'. Justify the statement by listing the special adaptations developed by parasites.

Ans: Many parasites have evolved to be host-specific and both host and parasite tend to co-evolve. If the host evolves defense mechanisms, the parasite evolves counter mechanisms.
Parasites evolved special adaptations such as loss of unnecessary sense organs, presence of adhesive organs or suckers to cling on to the host, loss of digestive system and high reproductive capacity.

Q9. Name the type of interactions seen in each of the following examples:

a) Clown fish living among the tentacles of sea anemone

Ans: Commensalism

b) Cuckoo/koel and a suitable host bird during the breeding season

Ans: Brood parasitism

c) Barnacles growing on back of a whale

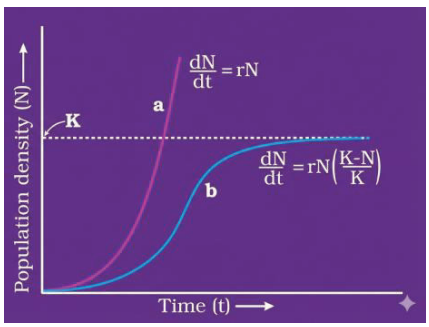
Ans: Commensalism

e) Sexual deceit in the Mediterranean orchid Ophrys

Ans: This is deceptive pollination/specialised plant-pollinator interaction. The orchid benefits from pollination, while the pollinator receives no usual floral reward; it is not a simple mutualism.

VI. Answer the following questions in 200-250 words: 5 Marks Each:

Q1. Refer to the graphs given below regarding growth patterns in organisms and answer the questions that follow.



a) Curve 'a' represents which type of growth?

Ans: Exponential growth curve

b) Curve 'b' represents which type of growth?

Ans: Logistic growth curve

c) Which growth model is considered more realistic one in nature?

Ans: Logistic growth curve

d) When bacteria are cultured under controlled optimum environmental conditions. Which curve is obtained?

Ans: Exponential growth curve

e) Can predation, competition and parasitism themselves be represented by a logistic growth curve? Explain.

Ans: No. The logistic curve describes population growth under limited resources and carrying capacity. These interactions can influence population size or growth rate, but they are not themselves represented by the logistic curve.

Ans: Predation, competition and parasitism can influence population growth, but the logistic model specifically describes because in all the above interaction one group will under the control of another group.

Q2. Fill out the tabular column with the appropriate terms describing biological interactions among species.

Species A	Species B	Name of interaction
Phytophagous insects	Plants	Predation
Balanus	Chthamalus	Competitive
Marine fish	Copepods	Parasitism
Mango tree	Orchid	Commensalism
Fig	Wasp	Mutualism

Chapter 12

ECOSYSTEM

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12.1. CLASSIFICATION OF ECOSYSTEM

12.2. COMPONENTS OF ECOSYSTEM

12.3. ECOSYSTEM - STRUCTURE AND FUNCTION

12.4. ECOLOGICAL PYRAMIDS

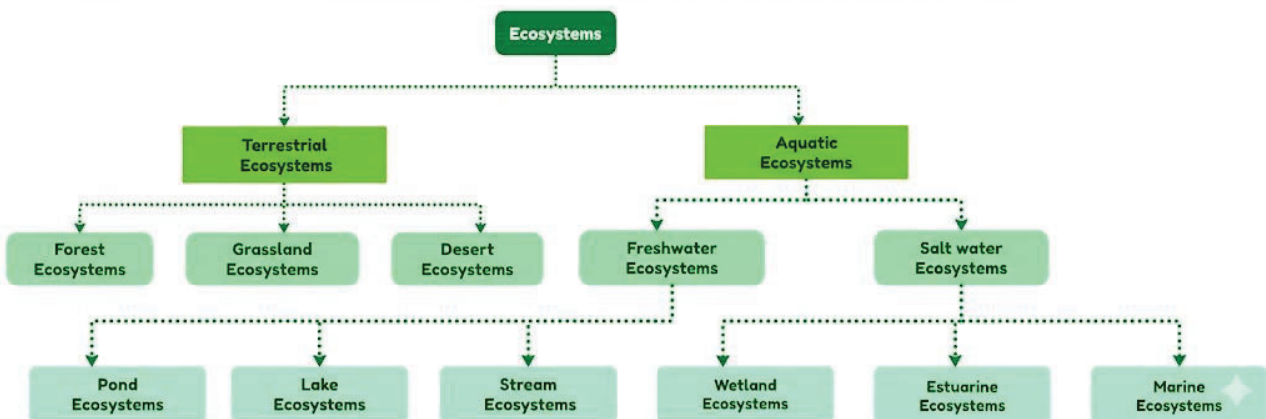
Theory

INTRODUCTION:

Ecology -

- The term "ecosystem" first coined by **Sir A.G Tansley (1935).**
- **According to Tansley –** Ecosystem is **symbol of structure and function of nature.**
- Father of Ecosystem ecology - **E.P Odum.**
- **According to E.P Odum -** Ecosystem is the smallest structural and functional unit of nature.
- **Definition :-** "Ecosystem is the **functional unit of nature**, where **living organisms (**biotic components**) interact among** themselves and also with the surrounding **physical environment(**abiotic components**)**".
- Ecosystem varies greatly in size from a **small pond** to a **large forest** or **a sea**.
- Many ecologists regard the **entire biosphere** as a **global ecosystem**, as a composite of all **local ecosystems on Earth**.

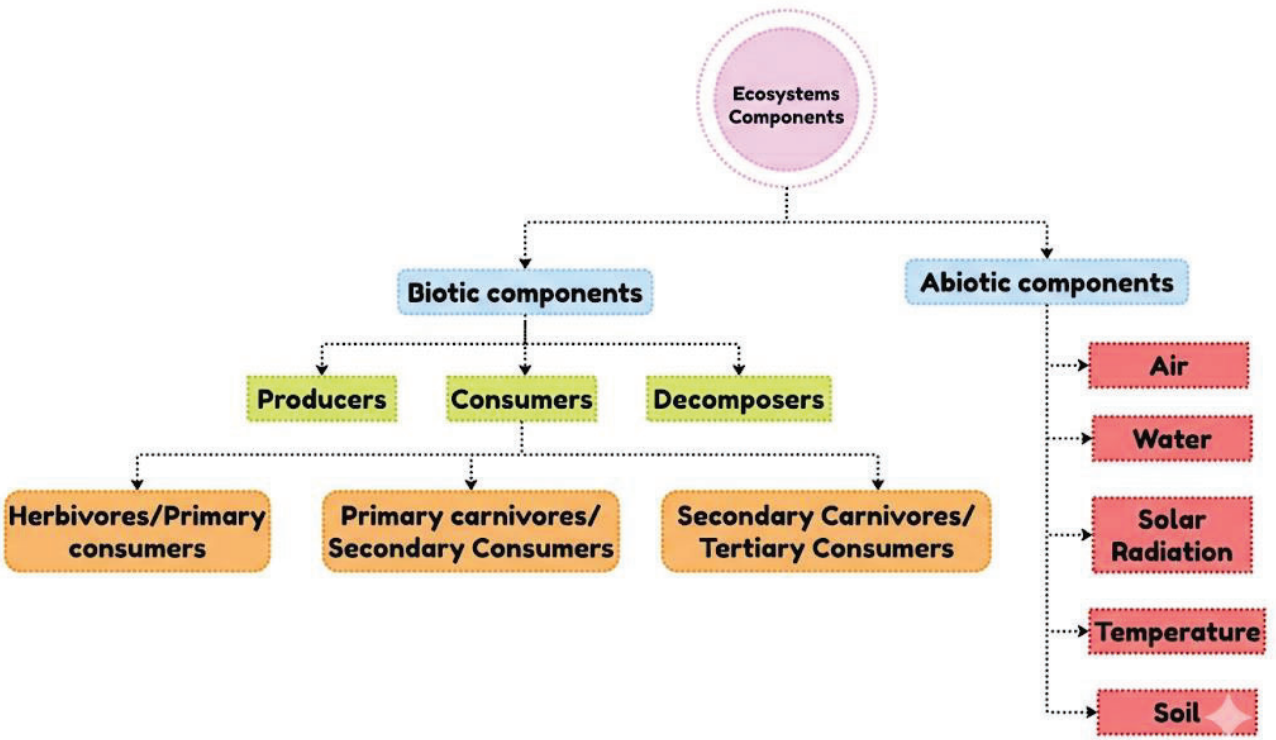
12.1 Classification Of Ecosystem



1. **Natural Ecosystem:** A natural ecosystem is a biological environment that is found in nature (e.g. a forest) rather than created or altered by man. Natural Ecosystem may be terrestrial (like desert, forest, etc.) or aquatic like pond, river, lake, etc.
   a. **Aquatic ecosystem -** The ecosystems of water bodies. **Ex:** Pond, lake, wetland, river and estuary.
   b. **Terrestrial ecosystem -** The ecosystems of land surface. **Ex**: Forest, grassland and desert.
2. **Artificial Ecosystem:** Humans have modified some ecosystems for their own benefits and these are Artificial Ecosystem. They can be terrestrial (crop field, garden etc.) or aquatic (aquarium, dam, manmade pond etc.).

12.2. Components Of Ecosystem

- The ecosystem consists of **biotic** and **abiotic components** and their interaction with each other resulting in a **physical structure.**
- All the functions like **productivity, decomposition, flow of energy** and **nutrient cycles** are takes place within these components of the ecosystem.
- An ecosystem maintains a **functional balance** amongst its various components. The phenomenon is called **homeostasis or balance of nature.**



- There are two main components in the ecosystem:-

1. **Biotic Components (Living Community)**

- These are categorized based on their nutritional role:-

A. **Producers (Autotrophs):** Green plants, algae, and phytoplankton that produce food via photosynthesis.

B. **Consumers (Heterotrophs):** Consumers are those that depend on producers, **directly** or **indirectly**. Hence they are called Heterotrophs

- There are two main components in the ecosystem:-

1. **Primary Consumers (Herbivores):-** Organisms that feed on producers (green plants) are called primary consumers. They are also called as '**herbivores'** or plant eating organisms. **Examples** of terrestrial herbivore are grasshopper, sheep, goats, cow, rabbit, deer, elephant etc. **Examples** of aquatic herbivores are **zoo plankton** etc.
2. **Secondary consumer (1° Carnivore) :-**Animals that kill and eat the herbivores or plant eating animals are called secondary consumers. They are also called as '**carnivores'**, **Example**; lion, tiger, foxes, frogs, snakes, crocodiles, etc.
3. **Tertiary Consumers (2° Carnivores):-**They are carnivores at the topmost level in a food chain that feed on other carnivores or secondary consumers. **Example**: an owl eats a snake but an owl is eaten by a hawk, therefore a hawk is a tertiary consumer. Tertiary consumers that occupy the top trophic level, and are not predated by any other animals are called **'apex predators'.**
4. **Omnivores:-** The organisms eat both plants and animals. These animals are called as '**omnivores**. **Example;** cockroach, foxes, seagull and human.

C. **Decomposers (Saprotrophs):** Decomposers are organisms that help decompose dead or decaying organisms. Hence they are called **Saprotrophs.** e.g., **Bacteria, fungi ect**

2. Abiotic Components (Physical and Chemical Factors):- These non-living factors influence the survival and distribution of organisms.

   a. **Climatic Factors:** Sunlight, temperature, wind, and rainfall.
   b. **Edaphic Factors:** Soil structure, texture, and pH.
   c. **Chemical Factors:** Inorganic and organic compounds, nutrients (nitrogen, phosphorus), and oxygen.

12.3. Ecosystem - Structure And Function

- The ecosystem consists of biotic and abiotic factor.
- The flow of energy takes place within these component of the ecosystem.
- The interaction of biotic and abiotic components results in a **physical structure** characteristic of each type of ecosystem.
- The two important structural features of an ecosystem are:

  1. Species composition

  2. Stratification

1. **Species composition:-** The identification and enumeration of plant and animal species in an ecosystem gives it species composition.
2. **Stratification :-** Vertical distribution of different species occupying different levels is called stratification.

- **For example :-**Trees occupy top vertical strata or layer of a forest, shrubs the second and herbs and grasses occupy the bottom layers.

Pond Ecosystem :-

- It is a self-sustainable unit and rather simple and explain even the complex interactions that exist in an aquatic ecosystem.
- **A pond** is a shallow water body with all the **biotic and abiotic components.**

1. **Abiotic components** - These are **non-living components**. Abiotic components of a pond are water (with inorganic & organic substances), soil with minerals, sunlight, temperature and other climatic conditions. These regulate the function of entire pond.
2. **Biotic Components –** These are living components. The biotic Components of a pond are
   a. **Producers:-**
      These are **autotrophic plants.** They prepare their own food materials through photosynthesis
      Ex: Phytoplankton, Algae , floating, Submerged and marginal plants found at the edges.
   b. **Consumer:-**
      These are **heterotrophic animals.** These are of three types namely primary consumers(**Herbivores**), Secondary consumers (**primary carnivores**) and Tertiary consumers (**Secondary carnivores**).
      Ex: Zooplankton, free swimming and bottom dwelling animals.
   c. **Decomposers -** These are **Saprotrophs**. They help in the conversion of dead plants and animals into simple inorganic forms that are added into the soil.

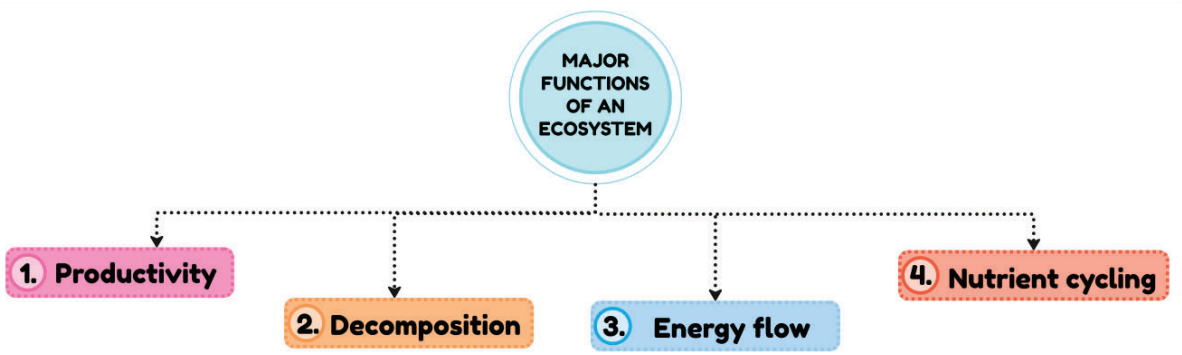
- **Pond performs all the functions** of any ecosystem . **Example-**

1. Conversion of **inorganic into organic** material with the help of the **radiant energy** of the **sun** by the **autotrophs.**
2. Consumption of the **autotrophs by heterotrophs.**
3. **Decomposition** of dead matter.
4. **Mineralisation** of the dead to release them back for reuse by the **autotrophs**.
5. There is **unidirectional movement of energy** towards the higher trophic levels and its dissipation and **loss as heat to the environment.**

Four basic Function of pond Ecosystem :-

1. Productivity
2. Decomposition
3. Energy flow
4. Nutrient cycling

1. **PRODUCTIVITY** : The rate of **biomass production** is called **productivity**. It is expressed in term of $\mathbf{gm^{-2}y^{-1}}$ **or** $\mathbf{(Kcalm^{-2})yr^{-1}}$. There are two types of productivity.



A. Primary Productivity

B. Secondary Productivity

A. Primary productivity

- The amount of biomass or **organic matter produced per unit area** over a time period by plants during photosynthesis is called **primary production.**
- It is expressed in terms of **weight** ($\mathbf{gm^{-2}}$) or **energy** ($\mathbf{kcal\ m^{-2}}$).
- It is expressed in terms of $\mathbf{gm^{-2}yr^{-1}}$ or $\mathbf{kcalm^{-2}yr^{-1}}$ to compare the productivity of different ecosystems.
- Primary productivity depends on the **plant species inhabiting** a particular area.

The primary productivity can be divided into to two category:-

a. Gross primary productivity (GPP)

b. Net primary productivity(NPP)

a. Gross primary productivity (GPP) –

- Gross primary productivity of an ecosystem is the rate of production of organic matter during photosynthesis.
- Some amount of GPP is utilized by plants in respiration and remaining part passed to next trophic level.

b. Net primary productivity (NPP) –

- The amount of energy left in the producers after utilization of some energy for respiration,Gross primary productivity Minus respiration losses (R).

GPP – R = NPP OR **NPP = GPP – R**

R= Respiration / Metabolic activities

- NPP is the available biomass for the consumption to heterotrophs.

B. **Secondary productivity**

- It is defined as the rate of formation of new organic matter by **consumers**.
- It is small and decrease with rise to trophic level. It simply say synthesis of organic matter from organic matter.

Factors affecting Primary productivity:-

1. Primary productivity depends on The plant species inhabiting a particular area.

2. Environmental factor.

3. Availability of nutrients.

4. Photosynthetic capacity of plants.

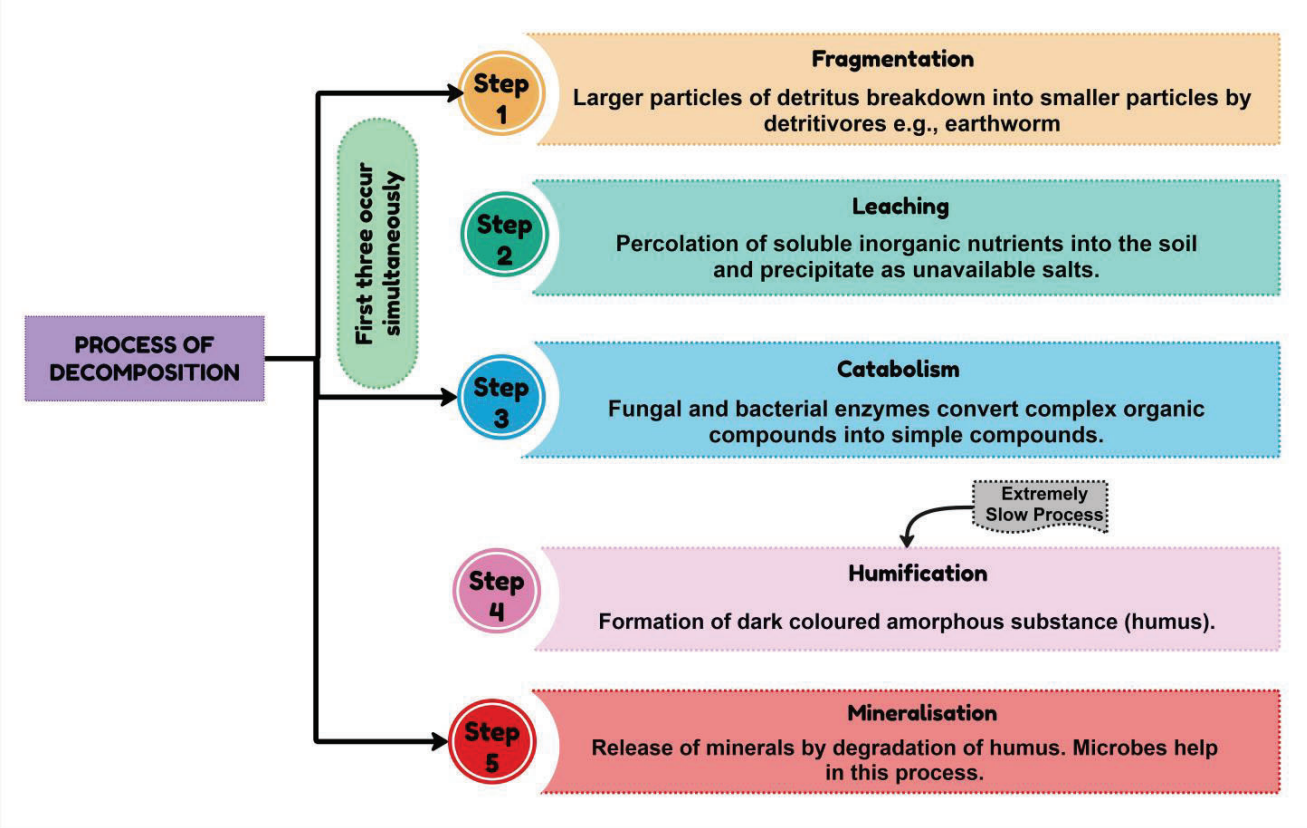
5. Therefore, it varies in different types of ecosystem.

- The **annual net primary productivity** of the whole biosphere is **approximately 170 billion tons (dry weight)** of organic matter. Of this, despite occupying **about 70%** of the surface, the productivity of the oceans are **only 55 billion tons**. Rest of course, is on land.

On land the **maximum productivity rate** is found in **tropical rain forest** followed by **tropical deciduous forests, temperate forests, savannah, temperate grasslands** and **desert.**

2. DECOMPOSITION

- The process of break down complex organic matter into inorganic substances like **carbon dioxide, water and nutrients** and the process is **called decomposition.**
- The organisms which bring about decomposition are called **decomposers.**
- **Detritus:-**Dead plant remains **such as leaves, bark, flowers and dead remains of animals, including fecal matter**, constitute **detritus.** which is the **raw material** for decomposition.
- The organisms which feed on detritus is called **Detrivore.** Ex**:** Earthworm (Friend of farmer)



Steps in the Process of Decomposition :

1. Fragmentation :-

- It is the process of breakdown of detritus into smaller particles by **detrivores**. This process is called **fragmentation.** E.g; **-Earthworm.**

2. Leaching :-

- It is the process in which **water-soluble inorganic nutrients** go down into the soil horizon and get precipitated as unavailable salts.

3. Catabolism :-

- The process of degradation of detritus into simpler inorganic substances by **bacteria** and **fungal enzymes.**
- It is important to note that all the above steps decomposition operate simultaneously on the **detritus.**

- **Humification and mineralisation** occur during decomposition in the soil.

4. Humification :-

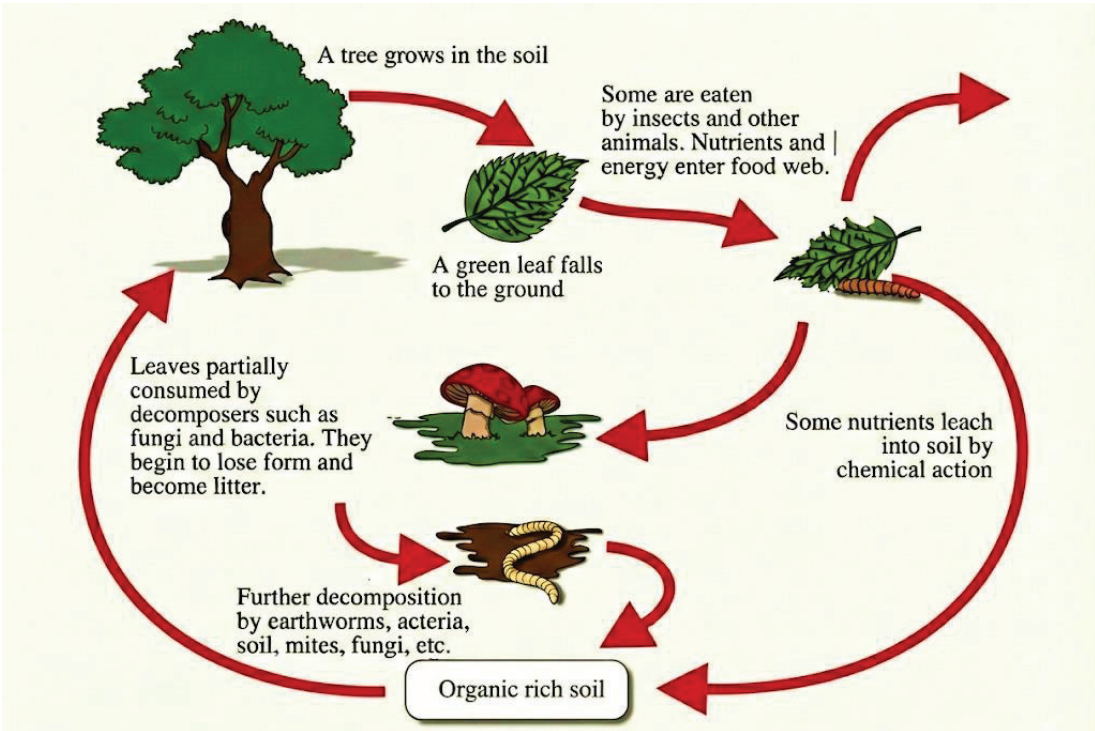
- It is the process of accumulation of a dark coloured **amorphous substance** called **humus ,**during in bacterial decomposition.

❖ **Characteristic features of Humus**

- Highly resistant to **microbial action**
- Undergoes decomposition at an extremely slow rate
- It serves as a reservoir of nutrients.
- Being colloidal in nature it serves as a reservoir of nutrients.

5. Mineralisation :-

- The process of formation of inorganic nutrients from humus by the action of microbes is called **Mineralisation.** Humification and Mineralization occurs simultaneously.
- Decomposition is largely an **oxygen-requiring process.**



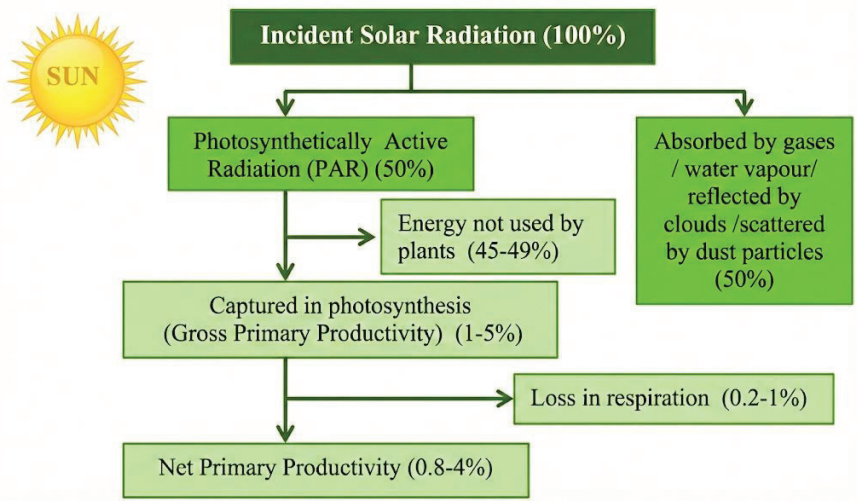
Diagrammatic representation of decomposition cycle in a terrestrial ecosystem

Factors Affecting Decomposition :-

1. Decomposition **rate is slower if detritus** is rich in **lignin and chitin.**
2. Decomposition rate is higher when detritus is rich in nitrogen and water-soluble substances like **sugars.**
3. **Temperature and soil moisture** are the most important climatic factors that regulate decomposition through their effects on the **activities of soil microbes**.
4. Warm and **moist environment favour** decomposition.
5. Low temperature and **anaerobiosis inhibit decomposition**.

3. ENERGY FLOW

- Sun is the only source of energy for all ecosystems on Earth. Except for the deep sea hydro-thermal ecosystem.
- In the incident solar radiation less than **50%** of the incident solar radiation is **photo synthetically active radiation (PAR).**
- The plants and photosynthetic bacteria **(autotrophs)**, fix Sun's radiant energy to make food from simple inorganic materials.
- Plants capture only **2-10 % of the PAR** and this small amount of energy sustains the entire living world.



- The green plant in the ecosystem which can trap solar energy to convert it into chemical energy are called **producers.** These are organisms that synthesize food. In terrestrial ecosystem, major producers are **herbivorous** and **woody plants.** Primary producers in an aquatic ecosystem are **Phytoplankton, algae and higher plants.**
- All the animals depend plants (directly or indirectly) for their food needs are called **consumers or heterotrophs.**

Consumers are divided into the following Categories :-

1. **Primary consumer :-** Animal which feed directly on plants e.g., herbivores (Insect, Zooplantons ect).
2. **Secondary consumer: -** Consumer that feed on primary consumer. e.g., 1° Carnivores(Frog, Fox ect).
3. **Tertiary consumers :-** Consumers that feed on secondary consumers. e.g., 2°Carnivores (Tiger, lion ect).

Energy in food chain is based on two laws of thermodynamics :

A. **First law of thermodynamic :** Energy is neither created nor destroyed but only transformed from one state to another state.

B. **Second law of thermodynamic :** The transfer of food energy from one organism to another organism leads to loss of energy as heat due to metabolic activity.

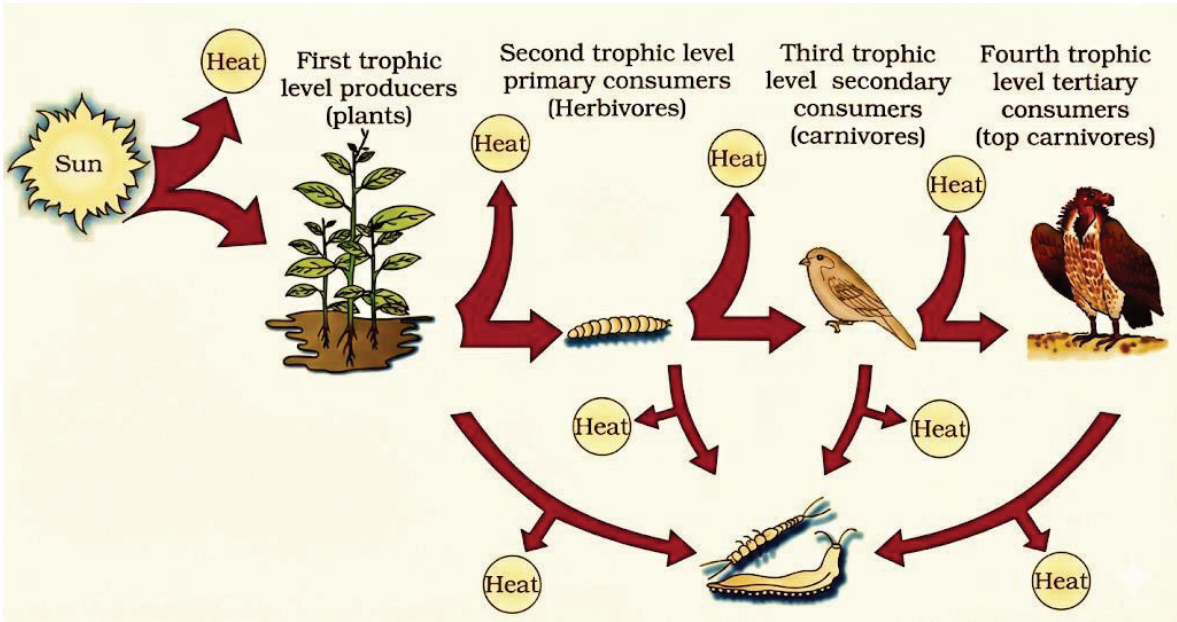
- Further, **ecosystems are not exempt** from the **Second Law of thermodynamics**.
- They need a **constant supply of energy** to synthesize the molecules they require, to counteract the **universal tendency** toward **increasing disorderliness**.

Energy flow Model :-

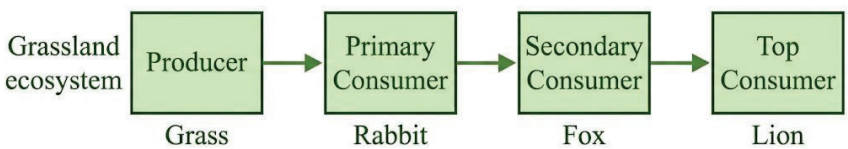
- Energy flow in an ecosystem is always **unidirectional or one way** .
- It **cannot pass** in the **reverse direction**.
- There is **decrease** in the content and **flow of energy** with the rise in trophic level.
- A part of **energy captured by producers** is used for **maintenance** and **as food to herbivores.**
- The **remaining net productivity is** either used by human or **passes into detritus chain**.

Lindeman's 10 percent law:- (Given by Lindeman's in 1942)

- At each step of food chain, when **food energy** is transferred from **one trophic level** to the **next higher trophic level**, only about **10% of energy** is passed on to the **next trophic level**. This is known as **Lindeman's 10% law.**
- The number of trophic levels in the **GFC is restricted** as the transfer of energy follows 10 per cent law.
- Nearly **90% of energy** is **lost** when it moves from **one trophic level to the next**.
- In nature, it is possible to have so many levels - producer, herbivore, primary carnivore, secondary carnivore in the GFC.



Food Chain :- The process of flow of energy from producer top consumers through a series of organism is called **food chain.**



Characteristics of food chain :-

1. **A food chain consists of series of populations** which are related by eating and beaing eaten.
2. A food chain is **generally straight** and have **3 to 6 trophic levels.**

3. There is **progressive reduction** in available biomass, energy and number of individuals with the rise in trophic level.
4. A **major part of energy** made available at each trophic level is **lost as heat** .
5. Some organism like **humans operate** at more than one trophic level.

Type of Food Chain

In the nature three types of food chains are present :-

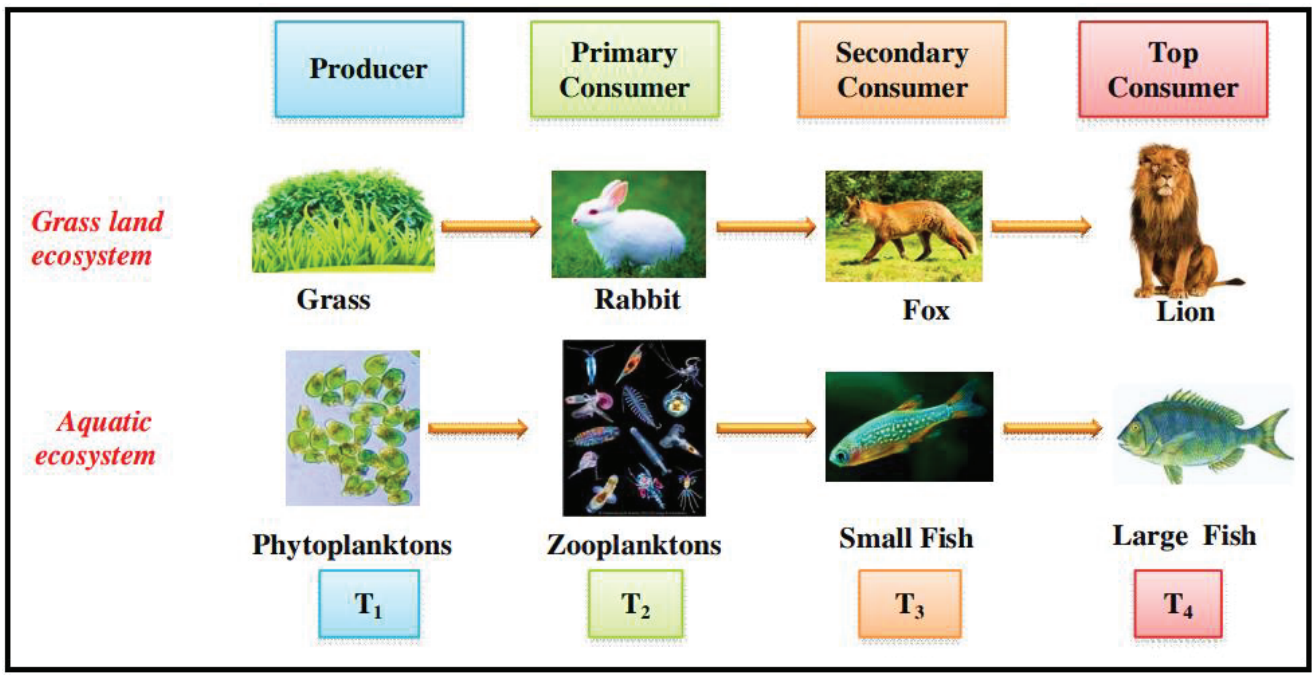
A. Grazing food chain or Predatory food chain.

B. Detritus food chain or Saprophytic food chain.

C. Parasite food chain.

A. Grazing food chain or Predatory food chain :-

- This food chain **begins with producers** (plants) and in successive order it goes from small organism to large organism.
- **Most of the food chain** in nature are of this types.
- **In aquatic** ecosystem **GFC** is the major conduit for energy flow.



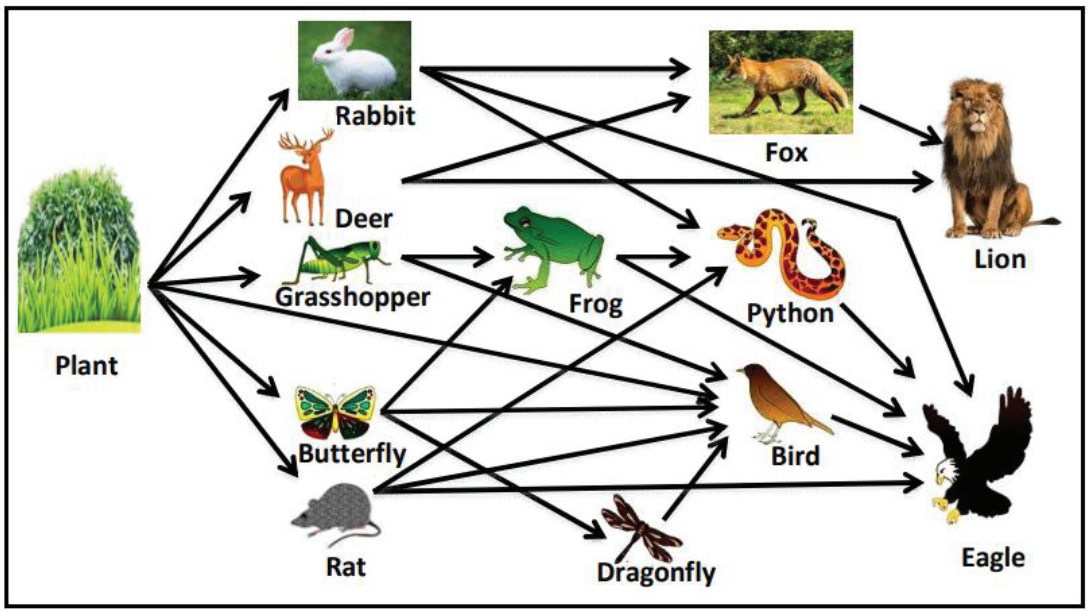
B. Detritus food chain or Saprophytic food chain

- The detritus food chain (DFC) begins with **dead organic matter.** It is made up of decomposers.
- It is made up of decomposers/Saprotrophs(heterotrophs)which are heterotrophic organisms,mainly **fungi** and **bacteria**.
- They meet their energy and **nutrient requirements** by degrading dead organic matter or **detritus**. These are also known **as Saprotrophs (sapro: to decompose).**
- Decomposers secrete **digestive enzymes** that breakdown **dead and waste materials into simple,** inorganic materials, which are subsequently absorbed by them.
- **DFC** is the major conduit(channel) for energy flow in **terrestrial ecosystem.**

S.No	Grazing food chain	Detritus food chain
1	In this food chain, energy is derived from the Sun.	In this food chain, energy comes from organic matter (or detritus) generated in trophic levels of the grazing food chain.
2	It begins with producers, present at the first trophic level. The plant biomass is then eaten by herbivores, which in turn are consumed by a variety of carnivores.	It begins with detritus such as dead bodies of animals or fallen leaves, which are then eaten by decomposers or detritivores. These detritivores are in turn consumed by their predators.
3	This food chain is usually large.	It is usually smaller as compared to the grazing food chain.

FOOD WEB :

- In big ecosystem many food chains are naturally inter-connected at a different trophic levels to form web called as **food web.**
- In food web transfer of **energy is unidirectional** but from many different alternatives pathway.
- As much as **food web is complex** that ecosystem is **more stable**.
- Those ecosystem which have simple food web are not very stable.

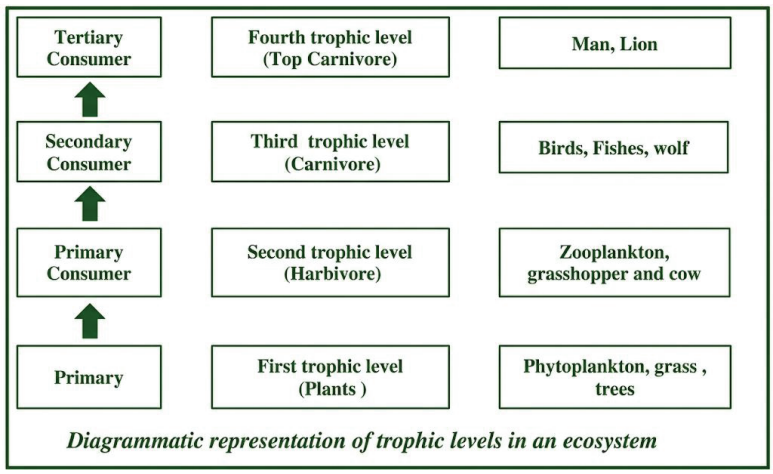


- **DFC** may be connected with the **GFC** at some levels:- some of the organisms of **DFC are prey to the GFC animals**, and in a natural ecosystem, some animals like **cockroaches, crows,** etc., are **omnivores**.
- These natural inter-connections of food chains make it a **food web.**
- Food web is **more real** than food chain.
- Food web is **not straight**.
- Food chain **do not run parallel**.
- Normally a food web operates according to **taste** and **food preferences** of the organism at each trophic level.

Trophic Level :

- Based on the source of their nutrition or food, organisms occupy a specific place in the food chain that is known as their **trophic level.**

- **Example:-**
- **Producers** belong to the **first trophic level.**
- **Primary consumer** (herbivores) belongs to **second trophic level.**
- **Secondary consumers** (Primary carnivores) form **third trophic level.**
- Tertiary consumers (Secondary carnivores) form fourth trophic level.
- Organisms occupy a place in the **natural surroundings** or in a **community** according to their **feeding relationship** with other organisms.
- The important point to note is that the amount of **energy decreases** at successive **trophic levels.**Because organisms utilizes some amount of energy for respiration.



Diagrammatic representation of trophic levels in an ecosystem

Standing crop :

- 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)** .
- Biomass of a species is expressed in terms of **fresh** or **dry weight**.
- Measurement of biomass in terms of **dry weight is more accurate.**

Standing state :-

- The amount of nutrients present in the soil at a given time.It is an abiotic component of an ecosystem.

12.4. Ecological And Function

- The Graphical representation of ecological parameters (number, biomass and energy) at different trophic levels of food chain are called **ecological pyramids.**
- Ecological pyramids were first developed by **Charles Elton** a British ecologist; hence ,they are also called as **Eltonion Pyramids.**
- **Structure -** The base of each **pyramid represents** the producers or the **first trophic level** while the apex represents **tertiary or top level consumer**.
- Any calculations of **energy content, biomass or numbers**, has to include all organisms at that trophic level.
- A given organism may occupy more than **one trophic level simultaneously**.

- In most ecosystems, all the **pyramid, of number, of energy and biomass 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.
- A Given species may occupy more than one trophic level in the same ecosystem at the same time.
  Example : Sparrow is primary consumer when it **eats seeds**, **fruits** and **peas**. It is secondary consumer when it eats **insects** and **worms**.

Type of Ecological Pyramids:

The **three types of ecological pyramids** that are usually studied are :-

(a) Pyramid of number (b) Pyramid of biomass (c) Pyramid of energy

a. **Pyramid of number :-** It is a graphical representation of the number of individuals at various trophic levels of food chain with the producers at the base and consumers at the apex.

- In most the ecosystems pyramid of number is **upright. Ex:-Pyramids of numbers in a grassland ecosystem ,Pyramid of number in aquatic ecosystem ect**
- **Pyramid of number in Tree ecosystem :-** In tree ecosystem an **inverted pyramid is obtained**.A large tree provide food to several herbaceous birds.The birds support still larger population of ectoparasites.

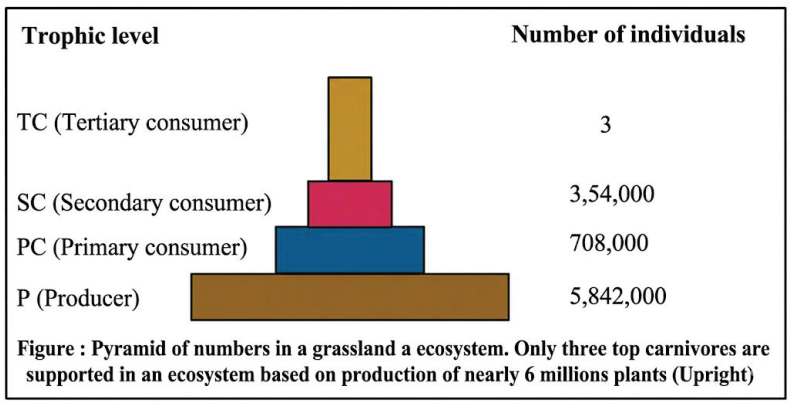


Figure : Pyramid of numbers in a grassland a ecosystem. Only three top carnivores are supported in an ecosystem based on production of nearly 6 millions plants (Upright)

Note: The Pyramid of number for big tree, it is inverted. There are exceptions to this generalization: when a large tree support, a large number of herbaceous birds. The birds are in turn ,eaten by carnivorous birds like falcon or eagle, which are smaller in number it forms a spindle shaped pyramid.

b. **Pyramid of biomass :-**

- It is the graphical representation of the amount of biomass at various trophic levels of food chain with producers at the base and top level consumer at top. Generally the pyramid of biomass is **upright.**
  Example :- pyramid of biomass in Grassland ecosystem ,In a tree ecosystem ect

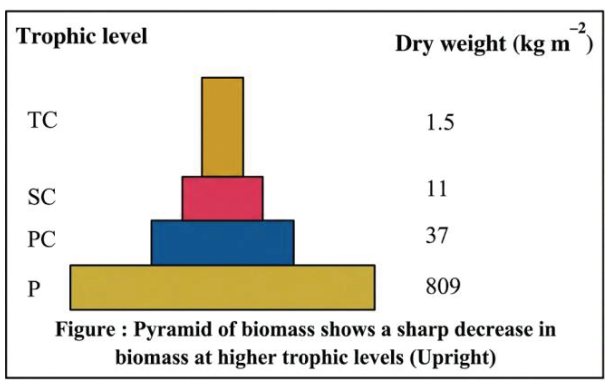


Figure : Pyramid of biomass shows a sharp decrease in biomass at higher trophic levels (Upright)

- The pyramid of biomass in aquatic ecosystem is **inverted**. Here the biomass of **Phytoplanktons** is much less than the **zooplanktons**, which is less than the **small fish** and the **big fish** having the maximum biomass.

Fig. : Inverted pyramid of biomass–small standing crop of phytoplankton supports large standing crop of zooplankton.

c. Pyramid of energy

- The relationship between producers and consumers in an ecosystem can be represented in the form of a pyramids in terms of flow of energy called **pyramids of energy.**
- Pyramid of energy is **always upright**, can **never be inverted**, because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step. It follow **10% law.**

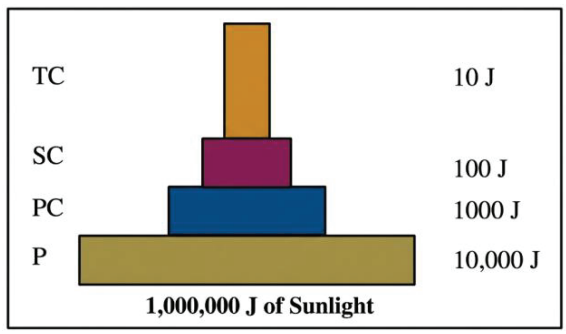


Fig. : An ideal pyramid of energy. (Upright) Observe that primary producers convert only 1% of the energy in the sunlight available to them into NPP.

Limitations of ecological pyramids:-

1. Pyramids such as it does not take into account the **same species** belonging **to two or more trophic levels.**
2. It assumes a **simple food chain**, something that almost **never exists in nature**; It does not accommodate a **food web**.
3. Saprophytes are **not given any place**.

Differentiate between Food chain and Food web

S.NO	Food chain	Food web
1	It is a single linear sequence of organisms.	It contains a number of interconnected food chains.
2	Members present at higher trophic levels feed on single types of organisms.	One organism has alternate food sources.

Differences between Litter and Detritus

S.NO	Litter	Detritus
1	Litter contains all kinds of wastes generated above the ground.	Detritus is composed of the remains of dead plants and animals.
2	Litter contains both biodegradable and non biodegradable matter.	Detritus contains only biodegradable matter.

Differences between Upright pyramid and Inverted pyramid.

S.NO	Upright pyramid	Inverted pyramid
1	The pyramid of energy is always upright.	The pyramid of biomass and the pyramid of numbers can be inverted.
2	In the upright pyramid, the number and biomass of organisms in the producer level of an ecosystem is the highest, which keeps on decreasing at each trophic level in a food chain.	In an inverted pyramid, the number and biomass of organisms in the producer level of an ecosystem is the lowest, which keeps on increasing at each tropic level.

EXERCISE

PART – A

Multiple Choice Questions **1 Mark Each**

1. **The functional unit of nature is called**
   a) Community b) Population c) Biome d) Ecosystem
2. **The rate of biomass production is called**
   a) Productivity b) Primary productivity
   c) Secondary productivity d) Gross primary productivity
3. **The amount of organic matter or biomass produced per unit area over a time period by producers during photosynthesis is**
   a) Productivity b) Primary productivity
   c) Secondary productivity d) Gross primary productivity
4. **The rate of production of organic matter during photosynthesis is**
   a) Productivity b) Primary productivity
   c) Secondary productivity d) Gross primary productivity
5. **GPP-R is**
   a) Primary productivity b) Net primary productivity
   c) Secondary productivity d) Gross primary productivity
6. **NPP is represented as**
   a) GPP-PP b) GPP-SP c) GPP-R d) GPP-P
7. **The annual net primary productivity of the whole biosphere is estimated approximately**
   a) 170 billion tons b) 55 billion tons c) 120 billion tons d) 70 billion tons
8. **The annual net primary productivity of oceans is**
   a) 170 billion tons b) 55 billion tons c) 120 billion tons d) 70 billion tons
9. **in GPP-R, the letter 'R' represents**
   a) Respiratory loss b) Intrinsic rate of natural increase
   c) Respiratory quotient d) Reproductive loss
10. **The rate of formation of new organic matter by producers is**
    a) Net primary productivity b) Primary productivity
    c) Secondary productivity d) Gross primary productivity
11. **The productivity available as biomass for the consumption of heterotrophs is**
    a) GPP b) NPP c) PP d) SP
12. **The percent of energy that flows to each trophic level in a food chain is**
    a) 5% b) 10% c) 15% d) 20%
13. **In which of the following ecosystem the pyramid of biomass is generally inverted?**
    a) Grassland b) Tree c) sea d) Forest

14. Identify the he correct sequence of steps in the process of decomposition is

a) Fragmentation → leaching → catabolism → humification → mineralization

b) Leaching → fragmentation → catabolism → humification → mineralization

c) Humification → fragmentation → leaching → catabolism → mineralization

d) Catabolism → fragmentation → leaching → humification → mineralization

15. Identify the decomposers among the following in the pond ecosystem.

A) Bacteria B) Fungi C) Flagellates D) Phytoplankton

a) A only b) A & B only c) A,B & C d) A, B, C & D

16. Which of the following statement is not true about 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 something that almost never exists in nature.

c) It does not accommodate a food web

d) Saprophytes are given a place in ecological pyramids as they play a vital role in the ecosystem.

17. A food chain with 1000 kcal of energy at the first tropic level is expected to transfer what amount of the energy at the third tropic level

a) 100 kcal b) 500 kcal c) 10 kcal d) 1 kcal

18. If the energy produced at the level of the producers is 1000 J , the energy available for the secondary consumers is

a) 1000 J b) 100 J c) 10 J d) 1 J

19. The process of breaking down of complex organic matter into inorganic substances is

a) Fragmentation b) catabolism c) decomposition d) Leaching

20. Which process releases inorganic nutrients from organic matter during decomposition?

a) Fragmentation b) Leaching c) Mineralisation d) Catabolism

a) Chitin b) Nitrogen

c) Water soluble sugars d) Water insoluble sugars

22. Each trophic level has a certain mass of living material at a particular time and is called

a) Standing state b) standing crop c) Organic matter d) Biomass

23. Statement I: Pyramid of energy maybe upright or inverted.

Statement II: Only 10% of energy goes to next trophic level.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

24. Statement I: The pyramid of biomass in sea is generally inverted.

Statement II: The biomass of fishes far exceeds that of phytoplankton.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

Answer Key				
1. D	2. A	3. B	4. D	5. B
6. C	7. A	8. B	9. A	10. B
11. B	12. B	13. C	14. A	15. C
16. D	17. C	18. C	19. C	20. C
21. A	22. B	23. D	24. A	

II. Fill in the blanks: 1 Mark Each:

(Stratification, Detritus, Fragmentation, Earthworm, Catabolism, Soil, Oxygen, Inhibit, Favour, Detritus Food Chain (DFC), Grazing Food Chain (GFC), Food web, Trophic level, Producers, Decline, Terrestrial ecosystem, 10 percent law)

1. The vertical distribution of different species occupying different levels is called _____
2. The dead plant and animal remains including faecal matter constitutes _____
3. _____ is the process of breakdown of detritus into smaller particles.
4. _____ is an example for detrivore.
5. The process of degradation of detritus into simpler inorganic substances by bacterial and fungal enzymes is _____

6. Humification and mineralisation occur during decomposition in the _____.

7. Decomposition is largely an _____-requiring process.

8. Low temperature and anaerobiosis _____ decomposition.
9. Warm temperature and moist environments _____ decomposition.
10. The food chain that begins with dead organic matter is _____
11. In aquatic ecosystems _____ is the major conduit for energy flow.
12. The natural interconnections of many food chains are called _____
13. The specific place of organisms in the food chain based on the source of their nutrition is called _____
14. The base of each ecological pyramid represents _____
15. Pyramid of biomass shows a sharp _____ in biomass at higher trophic levels
16. In _____ greater fraction of energy flows through DFC than GFC.
17. According to the _____ only 10% of energy flows to the each trophic level from the lower trophic level.

Answer Key			
1. Stratification.	2. Detritus.	3. Fragmentation.	4. Earthworm.
5. Catabolism.	6. Soil.	7. Oxygen.	8. Inhibit.

9. Favour	10. Detritus Food Chain.	11. Grazing Food Chain.	12. Food web.
13. Trophic level.	14. Producers.	15. Decline.	16. Terrestrial ecosystem..
17. 10 percent law.	18. B.	19. D.	20. A.

PART – B

III. Answer the following questions in 3-5 sentences each: 3 Marks Each:

Q1. Define ecosystem. Why is biosphere regarded as global ecosystem by ecologists?

Ans: An ecosystem is a structural and functional unit of nature where organisms interact with each other and with their environment. The biosphere is regarded as a global ecosystem because it includes all ecosystems of Earth, linked by energy flow and nutrient cycling.

Q2. List the basic or fundamental categories of ecosystems on earth with an example for each.

Ans: Two categories exist:

1. **Terrestrial ecosystems** – e.g., forests, deserts, grasslands.
2. **Aquatic ecosystems –** e.g., ponds, lakes, rivers, oceans.

Q3. List the four primary functions of an ecosystem.

Ans: (i) Productivity (ii) Decomposition (iii) Energy flow (iv) Nutrient cycling.

Q4. Define productivity and mention its types.

Ans: Productivity is the rate of biomass production per unit area and time. Types: (i) Primary productivity (GPP and NPP by producers) (ii) Secondary productivity (biomass by consumers).

Q5. Define a) Primary productivity b) Secondary productivity.

Ans:

- **Primary productivity**: Biomass production by autotrophs through photosynthesis.
- **Secondary productivity:** Biomass produced by consumers from food assimilation.

Q6. Distinguish between primary productivity and secondary productivity.

Ans:

- Primary productivity is by producers (plants, algae).
- Secondary productivity is by consumers (herbivores, carnivores).

Q7. Define a) Gross primary productivity b) Net primary productivity.

Ans:

- Gross primary productivity (GPP): Total rate of photosynthesis including respiration.
- Net primary productivity (NPP): GPP minus energy lost in respiration.

Q8. Distinguish between gross primary productivity and net primary productivity.

Ans:

- GPP is total biomass produced.
- NPP is biomass available to consumers (GPP – R).

Q9. Mention two conditions which increase the rate of decomposition in ecosystem.

Ans:

- Warm and moist climate.
- Aerobic conditions.

Q10. Mention two conditions which decrease the rate of decomposition in ecosystem.

Ans:

- Low temperature and anaerobic conditions.
- Lignin or chitin-rich detritus.

Q11. Define food chain. Mention the types of food chain.

Ans: A food chain is a sequential transfer of energy between organisms.

Types: Grazing food chain and Detritus food chain.

Q12. Distinguish between food chain and food web.

Ans:

- Food chain is linear.
- Food web is a network of interconnected chains.

Q13. Schematically represent a grazing food chain.

Ans: Producers → Primary consumers → Secondary consumers → Tertiary consumers.

Q14. 'Ecological pyramids have limitations'. Justify with two reasons.

Ans:

1. They ignore food webs.
2. They do not consider organisms occupying multiple trophic levels.

Q15. a) Why is the pyramid of biomass in sea generally inverted?

Ans: Because phytoplankton biomass is less than fish biomass.

b) Pyramid of energy is always upright and can never be inverted. Why?

Ans: Because energy decreases at each trophic level due to loss as heat.

PART – C

IV. Answer the following questions in 40 – 80 words each: 3 Marks Each:

Q1. Describe the components of an aquatic ecosystem taking pond as an example.

Ans: A pond ecosystem has abiotic factors (water, soil, light, nutrients) and biotic components.

Producers: Phytoplankton, algae, aquatic plants.

Consumers: Zooplankton, insects, fishes, frogs, birds.

Decomposers: Bacteria and fungi.

It is self-sustainable.

Q2. Define the terms a) Detritus b) Decomposition c) Detrivores.

Ans:

- Detritus: Dead plant and animal remains.
- Decomposition: Breakdown of organic matter into inorganic substances.
- Detrivores: Organisms like earthworms that feed on detritus.

Q3. Explain the factors that regulate decomposition.

Ans: Rate depends on:

(i) Climatic conditions – warm, moist, aerobic favours; low temperature/anaerobic slows.
(ii) Quality of detritus – nitrogen-rich decomposes faster than lignin-rich.
(iii) Soil organisms – microbes and earthworms accelerate decomposition.

Q4. Schematically represent pyramid of numbers with appropriate units.
Ans: Producers (many) → Herbivores (less) → Carnivores (fewer) → Top carnivores (least). Upright.

Q5. Schematically represent pyramid of biomass with appropriate units.
Ans:
Grassland: Producers 1000 g/m² → Herbivores 100 g/m² → Carnivores 10 g/m² (upright)
Aquatic: Producers 4 g/m² → Zooplankton 8 g/m² → Fishes 80 g/m² (inverted)

Q6. Schematically represent pyramid of energy with appropriate units.
Ans: Always upright: Producers 10,000 kcal → Herbivores 1000 kcal → Carnivores 100 kcal → Top carnivores 10 kcal

Q7. 'Ecological pyramids have limitations'. Justify with three reasons.
Ans:
1. Ignore role of decomposers.
2. Assume linear chains, not webs.
3. Do not consider species at multiple trophic levels.

PART – D

V. Answer the following questions in 200 – 250 words each: 5 Marks Each:

Q1. What is productivity? Mention the types of primary productivity. Compare primary productivity and secondary productivity in an ecosystem.
Ans: Productivity is the rate of biomass production per unit area and time.
Types:
(i) Gross primary productivity (GPP) – total photosynthesis including respiration.
(ii) Net primary productivity (NPP) – GPP minus respiration (R), biomass available to consumers.
Comparison: Primary productivity is biomass produced by producers through photosynthesis, forming the base of the food chain. Secondary productivity is biomass produced by consumers from assimilation and depends on primary productivity.

Q2. Define the terms: a) Food chain b) Food web c) Trophic level d) Stratification e) Standing crop.
Ans:
- Food chain: Linear transfer of energy from one trophic level to the next.
- Food web: Network of interconnected food chains.
- Trophic level: Position of an organism in the food chain based on its feeding.
- Stratification: Vertical distribution of species (trees, shrubs, herbs).
- Standing crop: Biomass present at a trophic level at a given time.

Q3. Describe the various steps involved in the process of decomposition.
Ans: Steps:
(i) Fragmentation by detritivores.
(ii) Leaching of soluble nutrients.
(iii) Catabolism by microbial enzymes.

(iv) Humification – formation of humus.
(v) Mineralisation – release of inorganic nutrients from humus.
This ensures nutrient cycling.

Q4. 'Ecological pyramids have limitations'. Justify.

Ans: They exclude decomposers, ignore food webs, do not account for species at multiple trophic levels, sometimes biomass pyramids are inverted, and oversimplify energy transfer. Thus, they are only partial models of ecosystems.

PART – E

VI. Answer the following questions in 200 – 250 words each: 5 Marks Each:

Q1. a) Fill in the blanks with suitable options that correctly identifies A, B and C in the given table.

Organism	Trophic level	Food chain
Eagle	A	Grazing
Earthworm	Primary consumer	B
Frog	C	Grazing

Ans:

- A = Tertiary consumer
- B = Detritus food chain
- C = Secondary consumer

Explanation: Eagle is a tertiary consumer in grazing food chain. Earthworm is a primary consumer in detritus food chain. Frog is a secondary consumer in grazing food chain.

Q2. b) Construct a pyramid of energy showing different trophic levels and energy content, given that 600 kcal at the second trophic level.

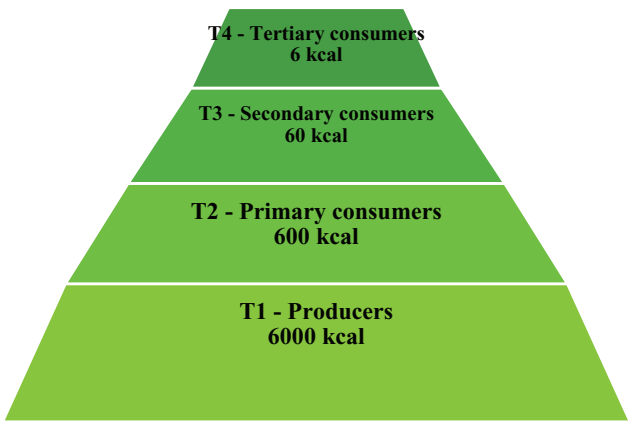
Ans: If primary consumers (2nd level) have 600 kcal:

- Producers (1st level): 6000 kcal
- Secondary consumers (3rd level): 60 kcal
- Tertiary consumers (4th level): 6 kcal

Diagram (schematic):

Producers → 6000 kcal → Primary consumers → 600 kcal → Secondary consumers → 60 kcal → Tertiary consumers → 6 kcal

Explanation: This shows the energy pyramid is always upright due to 10% law (only ~10% energy transfers to next trophic level).



Chapter 13

BIODIVERSITY AND CONSERVATION

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13.3. IMPORTANCE OF SPECIES DIVERSITY
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13.5. BIODIVERSITY CONSERVATION

THEORY

- Biodiversity refers to the variety and variability of living organisms at genetic, species and ecosystem levels.
- The term ?biodiversity? was coined by Walter G. Rosen and was popularized by E. O. Wilson.
- Biodiversity is studied at three major levels:

1. Genetic diversity
2. Species diversity
3. Ecological (ecosystem) diversity

LEVELS OF BIODIVERSITY

1. Genetic Diversity :

- It is the diversity at the level of genes and their alleles of same species.
- A single species might show high diversity at the genetic level over its distributional range.

Example:-1 The genetic variation shown by the medicinal plant ***Rauwolfia vomitoria*** growing in different Himalayan ranges might be in terms of the **potency** and **concentration** of the active chemical **(reserpine)** that the plant produces.

Example:-2 India has more than $\mathbf{50,000}$ genetically different strains of rice and $\mathbf{1,000}$ varieties of mango.

2. Species Diversity :

- The diversity at the species level(i.e., it is the variety of species and their relative abundance present within a region).

  For example: The Western Ghats have a greater amphibian species diversity than the Eastern Ghats.

3. **Ecological Diversity :**

- It is a measure of diversity at community and ecosystem levels or Occurrence of varities of ecosystem in a geographical area is called **ecological diversity.**

  For example:- At the ecosystem level, **India**, for instance, with its **deserts, rain forests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows** has a greater ecosystem diversity than a Scandinavian country like **Norway.**

13.2. Global Species Diversity

- According to the **IUCN (2004)**, the total number of **plant** and **animal** species described so far is slightly more than **1. 5 million**.
- According to **Robert May** places the global species diversity at about **7 million** species would have on earth.(He considered the species to be discovered in the tropics, i.e. only **22%** of the total species have been recorded so far).
- Many taxonomic groups, species inventories are more complete in temperate than in tropical countries.
- Some extreme estimates range from **20 to 50 million**.

EARTH'S BIODIVERSITY

Animal Species :

- More than **70%** of all the species are recorded are animals.
- Insects form **70**% of the total animal species.
- Insects are the most species-rich taxonomic group, (out of every **10** animals on this planet, **7** are insects).

Plant Species :

- More than **22**% of all the species are recorded as plants.
- Include **algae, fungi, bryophytes, gymnosperms** and **angiosperms**.
- Number of fungi species in the world is more than the combined total of the species of **fishes**, **amphibians**, **reptiles** and **mammals**.

Prokaryotes :

- Biologists are not sure about how many prokaryotic species there might be.
- The problem is that conventional taxonomic methods are not suitable for identifying microbial species and many species are simply not culturable under laboratory conditions.
- If we accept biochemical or molecular criteria for delineating species for this group, then their diversity alone might run into millions.

Representing global biodiversity :

- Proportionate number of species of major taxa of **plants, invertebrates** and **vertebrates.**

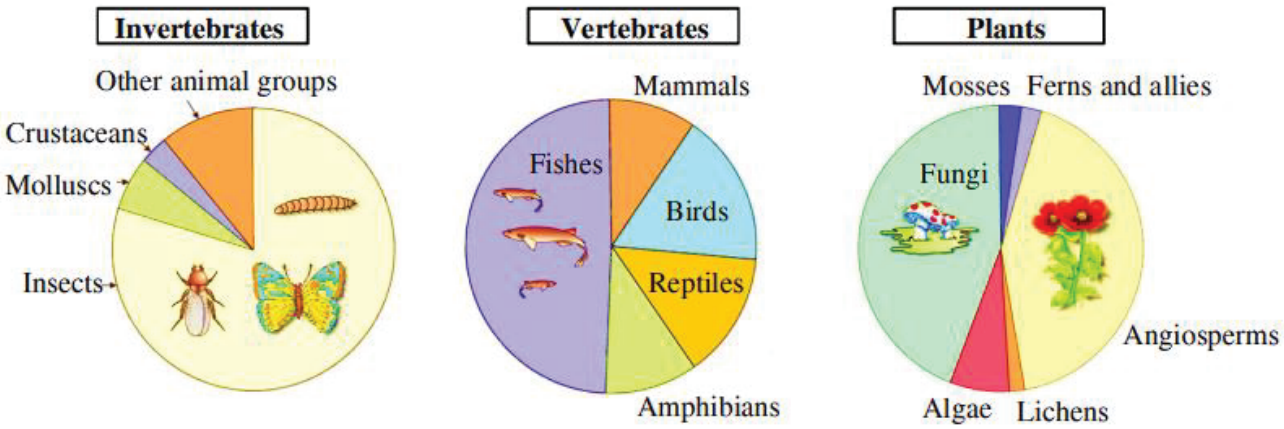
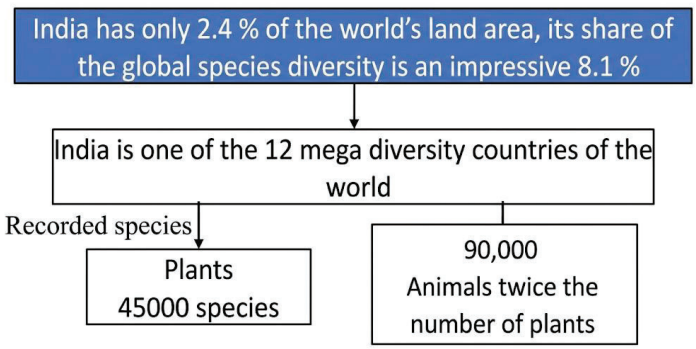


Fig. : Representing global biodiversity : Proportionate number of species of major taxa of plants, invertebrates and vertebrates

INDIA'S BIODIVERSITY



- Applying **Robert May's global estimates** ,India, would have more than **1,00,000 plant species** and more than **3, 00, 000 animal species** yet to be **discovered** and **described**.
- **Would we ever be able to complete the inventory of the biological wealth of our country?**
- **Challenges faced during the discovery of species -**
  - The immense trained manpower (taxonomists) and the time required to complete the job.
  - The situation appears more hopeless when we realise that a large fraction of these species faces the threat of becoming extinct even before we discover them.
  - Nature's biological library is burning even before we catalogued the titles of all the books stocked there.

PATTERNS OF BIODIVERSITY

1. Latitudinal Gradients :

- The diversity of plants and animals is not uniform throughout the world but shows a rather uneven distribution.
- For many group of animals or plants, there are interesting patterns in diversity, the most well- known **being** the latitudinal gradient in diversity.
- In general, species diversity decreases as we move away from the equator towards the poles.
- With very few exceptions, tropics (latitudinal range of **23. 5°N** to **23. 5°S**) harbour more species than temperate or polar areas.

Example 1 : Distribution of birds species in world

- Colombia located near the equator has nearly **1,400 species of birds.**
- New York in temperate region at 41°N has **105 species.**
- Greenland in polar region at 71°N only **56 species.**
- India, with much of its land area in the tropical latitudes, has more than **1,200** species of birds.

Example 2 : Distribution of vascular plants

A forest in a tropical region like Equador has up to **10 times** as many species of vascular plants as a forest of equal area in a temperate region like the **Midwest of the USA.**

Example 3 : Tropical Amazonian rain forest in South America has the greatest biodiversity on earth

(i) 40,000 species of plants
(ii) 3,000 species of fishes
(iii) 1,300 species of birds
(iv) 427 species of mammals
(v) 427 species of amphibians
(vi) 378 species of reptiles
(Vii) More than 1,25,000 invertebrates

- Scientists estimate that in these rain forests there might be at least **2 million insect species** waiting to be discovered and named.

What is so special about tropics that might account for their greater biological diversity?

Ecologists and evolutionary biologists have proposed various hypothesis; some important ones are –

a. Speciation :

It is generally a function of time.

Temperate regions subjected to frequent glaciations in the past, while tropical latitudes have remained relatively undisturbed for millions of years and thus, the species in tropical regions had a long evolutionary time for species diversification.

b. Niche specialization :

Tropical environments, unlike temperate ones, are less seasonal, relatively more constant and predictable. Such constant environments promote niche specialisation and lead to a greater species diversity.

c. Light availability : There is more solar energy available in the tropics, which contributes to higher productivity; this in turn might contribute indirectly to greater diversity.

2. Species - Area Relationships :

German naturalist and geographer **Alexander von Humboldt** observed that within a region species richness increased with increasing explored area, but only up to a limit.

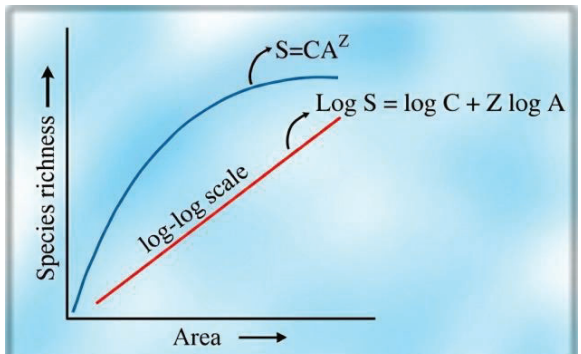
In fact, the relation between species richness and area for a wide variety of taxa (angiosperm plants, birds, bats, freshwater fishes) turns out to be a rectangular hyperbola.

On a logarithmic scale, the relationship is a straight line described by the equation

$$\log S = \log C + Z \log A$$

Where ;

$\mathbf{S} =$ Species richness
$\mathbf{A} =$ Area
$\mathbf{Z} =$ Slope of the line (regression coefficient)
$\mathbf{C} = Y -$ intercept



Showing species area relationship note that on log scale the relationship becomes linear.

Value of Z

- Ecologists have discovered that the value of Z lies in the range of **0.1** to **0.2**, regardless of the taxonomic group or the region.
- Whether it is the plants in Britain, birds in California or molluscs in New York state, the slopes of the regression line are amazingly similar.
- But,if you analyse the species-area relationships among very large areas like the entire continents, the slope of the line to be much steeper (Z values in the range of **0.6** to 1.2).

  For example for frugivorous (fruit - eating) birds and mammals in the tropical forests different continents, the slope is found to be **1.1.5.**

Que. What does steeper slopes mean in this context?
Ans. The steeper slope indicates a higher value of Z.

13.3. Importance Of Species Diversity To The Ecosystem

Species diversity is important for productivity, stability, resilience and health of ecosystem.

1. Productivity:

An ecosystem with higher biodiversity is also more productive than an ecosystem with less diversity. Using large outdoor plots, **David Tilman** confirmed that higher biodiversity leads to increase in productivity.

2. Stability:

Ecosystem with rich species remains constant i.e without much variations and show more productivity is called **stability.**

3. Resilience:

Increased biodiversity provides quick **recovery** or **resilience** to ecosystem against natural or man-made disturbance and invasion by alien species.

4. Ecosystem health:

Rich biodiversity helps for the very survival of the human race on this planet. It is because larger number of species has higher number of niches, more interactions and more inter-relationships.

Effect of reduction in Biodiversity (The rivet popper hypothesis)

- It was proposed by **Stanford ecologist Paul Ehrlich** to explain the effect of decrease in biodiversity in the ecosystem.
- He compared
  - **Airplane** - Ecosystem
  - **Rivets** - Species
  - **Rivets on wings of plane** - Key species
- In an airplane (ecosystem) all parts are joined together by thousands of rivets (species).
- If every passenger starts popping a rivet to take home (species extinct), it may not affect flight safety initially but as more and more rivets are removed the plane becomes dangerously weak.
- Further more which rivet is removed may also be critical.
- Loss of rivets on the wings (key species) is obviously a more serious threat to fight safety than loss of a few rivets on the seats or windows inside the plane.

13.4. Loss Of Biodiversity

1. The biological wealth of our planet has been declining rapidly and the accusing finger is clearly pointing to human activities.

   Example : The colonization of tropical Pacific Islands by humans is said to have led to the extinction of more than 2,000 species of native birds.
2. The **IUCN Red List (2004)** documents the extinction of **784** species (including **338** vertebrates, 359 invertebrates and **87** plants) in the last **500** years.
3. Some examples of recent extinctions include the **Dodo** (Mauritius), **Quagga** (Africa), **Thylacine** (Australia), **Steller's Sea Cow** (Russia) and **three subspecies** (Bali, Javan, Caspian) of tiger.
4. The last **20 years** alone have witnessed the disappearance of **27 species.** Careful analysis of records shows that extinctions across taxa are not random; some groups like amphibians appear to be more vulnerable to extinction. This is the fact that more than **15, 500** species world-wide are facing the threat of extinction.
5. Presently, **12**% of all bird species, **23**% of all mammal species, **32**% of all amphibian species and **31**% of all gymnosperm species in the world face the threat of extinction.
6. **In general, loss of biodiversity in a region may lead to –**

   a. Decline in plant production.

   b. Lowered resistance to environmental perturbations such as drought.

   c. Increased variability in certain ecosystem processes such as plant productivity, water use, and pest and

disease cycles.

CAUSES OF BIODIVERSITY LOSS

The accelerated rates of species extinctions that the world is facing now are largely due to human activities. There are four major causes ('The Evil Quartet' is the sobriquet used to describe them).

1. **Habitat loss and fragmentation:**

- This is the most important cause driving animals and plants to extinction.
- **Example:-** The tropical rain forest reduced to **6%** from **14%** of earth land surface.
- The Amazon rain forest (it is so huge that it is called the **'lungs of the planet"**) harbouring probably millions of species is being cut and cleared for cultivating **soya beans** or for **conversion to grasslands** for raising beef cattle.
- Degradation of many habitats by pollution is also threatens the loss of diversity.
- 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.

2. **Over-exploitation :**

- Humans have always depended on nature for food and shelter, but when 'need' turns to 'greed',it leads to over-exploitation of natural resources.
- Many species extinctions in the last 500 years (Steller's sea cow, passenger pigeon) were due to over exploitation by humans.
- Presently many marine fish populations around the world are over harvested, endangering the continued existence of some commercially important species.

3. **Alien species invasions :**

When alien species are introduced unintentionally or deliberately for whatever purpose, some of them turn invasive, and cause decline or extinction of indigenous species.

Example :

1. The **Nile perch** introduced into Lake **Victoria in east Africa** led eventually to the extinction of an ecologically unique assemblage of more than **200 species of cichlid fish** in the lake.
2. The environmental damage caused and threat posed to our native species by invasive weed Species like ,Carrot grass **(Parthenium),Lantana** and water hyacinth **(Eichhornia).**
3. The recent illegal introduction of the **African catfish Clarias gariepinus** for aquaculture purposes is posing a threat to the **indigenous catfishes** in our rivers.

4. **Co-extinctions :**

When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct.

Example:

- When a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate.
- Another example is the case of a coevolved plant-pollinator mutualism where extinction of one

invariably leads to the extinction of the other.

13.5. BIODIVERSITY CONSERVATION

Why should we conserve Biodiversity?

There are many reasons to conserve biodiversity we can group then into three categories.

1. **Narrowly Utilitarian :** Humans derive countless direct economic benefits from nature –

   Examples:-

   - Food - cereals, pulses, fruits, etc.
   - Firewood
   - Fibre
   - Construction material
   - **Industrial products -** tannins, lubricants, dyes, resins, perfumes, etc.
   - **Products of medicinal importance -** More than 25% of the drugs currently sold in the market worldwide are derived from plants. About 25,000 species of plants contribute to the traditional medicines used by native peoples around the world. Many more medicinally useful plants there are in tropical rain forests waiting to be explored.
   - **Bioprospecting** (exploring molecular, genetic and species-level diversity for products of economic
   - importance) is going on vigorously.

2. **Broadly Utilitarian :**

   The broadly utilitarian argument says that biodiversity plays a major role in many ecosystem services that nature provides.

   a. **Oxygen -** The Amazon forest is estimated to produce, through photosynthesis, **20%** of the total O_2 in the earth's atmosphere.

   b. **Pollination of plants –** Eg. Bees, bumblebees, butterflies, moths, beetles, birds and bats are engaged in pollination of plants which is essential for the formation of fruits and seeds.

   c. **Aesthetic Value -** Ecotourism is based on it. It provides a lot of pleasure and excitement to listen to bird songs, observe blooming of flowers, birds watching and wildlife watching.

   d. Flood and erosion control

   e. Nutrient cycling

   f. Biological pest control

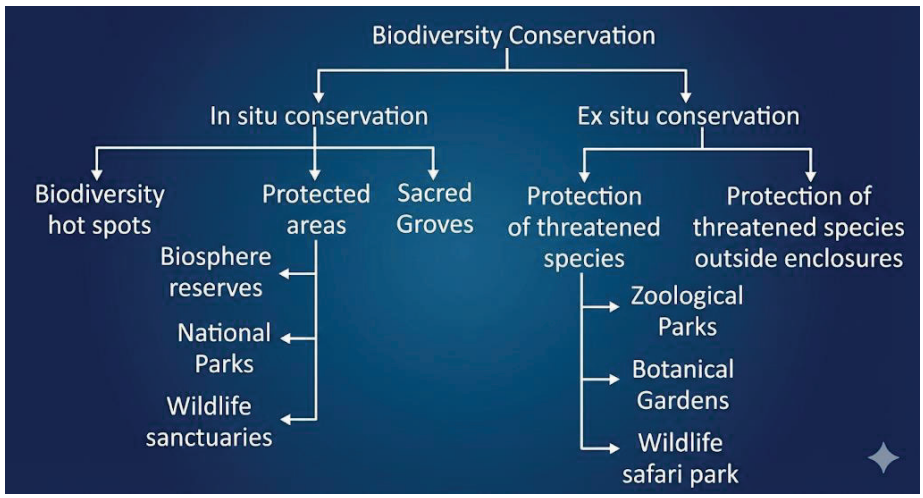
   g. Regulation of climates

3. **Ethical :**

   - The ethical argument for conserving biodiversity relates to what we owe to millions of plant, animal and microbe species with whom we share this planet.
   - Philosophically or spiritually, we need to realize that every species has an intrinsic value, even if it may not be of current or any economic value to us.
   - It is our moral duty to care for the well-being of biodiversity and pass on our biological legacy in good

order to future generations.

How do we Conserve biodiversity?



A. IN SITU CONSERVATION

- In this approach, threatened animals and plants were protected within their natural habitats.
- In situ (on site) conservation.
- Here we protect the whole ecosystem, its biodiversity at all levels is protected (We save the entire forest to save the tiger).

1. Hot Spot

- There are the region with very high species richness, high degree of endemism (species confined only to a specific region) but most threatened.
- Initially **25** biodiversity hotspots were identified in world, now number of biodiversity hot spot in the world are **34** out of these **3** hotspots are found in India.
  a) Western Ghats and Sri Lanka
  b) Indo-Burma
  c) The Himalayas

The key criteria for determining a hot spot are :

- High level of species richness.
- High degree of endemism (that is, species confined to that region and not found anywhere else).
- High degree of threat which is measured in terms of habitat loss (It means hot spots are regions of accelerated habitat loss).
- Although all the biodiversity hotspots put together cover less than **2%** of the earth's land area, the number of species they collectively harbour is extremely high and strict protection of these hotspots could reduce the ongoing mass extinctions by almost **30%.**

1. Protected Areas

In India, ecologically unique and biodiversity-rich regions are legally protected as –

- 14 Biosphere Reserves
- National parks

- Wildlife sanctuaries

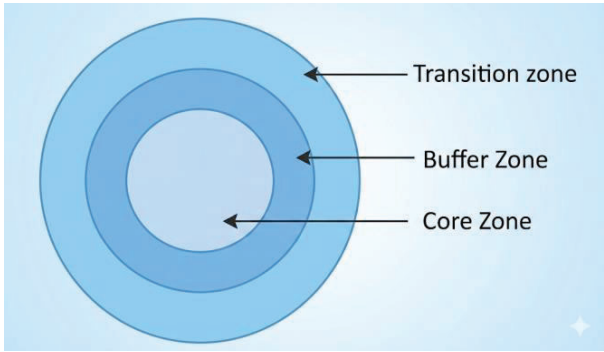
A. **Biosphere Reserves:** It is a specified protected area in which multiple use of the land is permitted.

There are 3 zones of Biosphere Reserve :

a. **Core Zone :** It lies at the centre where no human activity is allowed.

b. **The Buffer zone :** Where limited human activity is allowed.

c. **Manipulating zone or Transition zone :** Where a large number of human activities would go on.



B. **National Parks**

- These are areas strictly reserved for betterment of wildlife maintained by the **government**.
- Where cultivation, grazing, habitat manipulation and Private ownership is not permitted.
- The early national parks **e.g., Yellow Stone National Park, Royal Park near Sydney**. **Jim Corbett National Park** near Nainital (Uttarakhand) was the first national park established in India.

C. Wildlife Sanctuary :- Here, protection is given only to the animals. Collection of minor forest products, harvesting of timber ,woods and private ownership are allowed so long as they do not harm the animals. E.g. **periyar wildlife sanctuary in Kerala.**

2. Sacred Groves

- The patches or fragments of forest is protected by humans because of their religious belief are called **Sacred groves**

Examples of sacred groves in India are found in –

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

B. **EX SITU CONSERVATION**

- 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.
- It is off-site conservation

Examples:-

- Zoological parks,
- botanical gardens

- wildlife safari parks
- Cryopreservation

CONVENTIONS OF BIODIVERSITY

- International Efforts for Conserving biodiversity are ;

1. The **historic Convention on Biological Diversity ('The Earth Summit')** held in **Rio de Janeiro in 1992 .**It has 3 objectives :-

   a. Conservation of biodiversity

   b. Sustainable use of biodiversity

   c. Sharing of benefits arising from genetic resources.

2. In a follow-up, The **World Summit** on **Sustainable Development held in 2002** in **Johannesburg, South Africa :-**190 countries pledged their commitment to **achieve by 2010**, a significant reduction in the current rate of biodiversity loss at global, regional and local levels.

EXERCISE

PART – A

I. Multiple Choice Questions: 1 Mark Each:

1. The term biodiversity was popularized by

a) Edward Wilson b) Robert May

c) Alexander Von Humboldt d) Paul Ehrlich

2. Robert May places global species diversity at about

a) 2 million b) 1.5 million c) 2.5 million d) 7 million

3. As per species inventories 70% of species recorded are

a) Plants b) Fungi c) Bryophytes d) Animals

4. The most species-rich taxonomic group among invertebrates is

a) Birds b) Insects c) Mammals d) Fishes

5. The most species-rich taxonomic group among vertebrates is

a) Birds b) Insects c) Mammals d) Fishes

6. The most species-rich taxonomic group among plants is

a) Algae b) Fungi c) Angiosperms d) Ferns

7. The share of global species diversity of India is

a) 8.1% b) 8.5% c) 9% d) 2.4%

8. The species-area relationship was given by

a) Edward Wilson b) Robert May

c) Alexander Von Humboldt d) Paul Ehrlich

9. In the given species-area equation, $\log S = \log C + Z\log A$, the letter ' Z ' represents

a) Area b) Species richness

c) Regression coefficient d)Y-intercept

10. According to ecologists the value of ' Z ' lies in the range of

a) $0.1 - 0.5$ b) $0.2 - 0.6$ c) $0.6 - 1.2$ d) $0.1 - 0.2$

11. The species-area relationship among very large areas such as entire continents has ' Z ' values in the range of

a) $0.1 - 0.5$ b) $0.2 - 0.6$ c) $0.6 - 1.2$ d) $0.1 - 0.2$

12. The slope of the line (regression coefficient) for fruit-eating birds and mammals in the tropical forests of different continents is found in the range of

a) $0.1 - 2.5$ b) $1 - 1.5$ c) $0.6 - 1.2$ d) $0.1 - 0.2$

13. The rivet popper hypothesis was proposed by

a) Paul Ehrlich b) Alexander Von Humboldt

c) Edward Wilson d) Mac Arthur

14. Which species introduced for aquaculture is a serious threat to indigenous catfishes in India?

a) Clarias gariepinus b) Eichhornia c) Parthenium d) Lantana

15. The narrow utilitarian arguments for conserving biodiversity are

a) Cereals & Fruits b) Ecosystem services c) Intrinsic values d) Aesthetic pleasures

16. The following are the in-situ conservation approaches except

a) National parks b) Wildlife sanctuaries c) Biosphere reserve d) Botanical gardens

17. The following are the ex-situ conservation approaches except

a) Zoological parks b) Seed banks c) Sacred groves d) Botanical gardens

18. Which of the following is an in-situ conservation practice?

a) Botanical garden b) Sacred grove c) Seed bank d) Cryopreservation

19. The earth summit was held in Rio de Janeiro in

a) 1991 b) 1992 c) 2010 d) 2002

20. The world summit on sustainable development was held in 2002 in

a) Canada b) Johannesburg c) Brazil d) Tokyo

21. Statement I: There are 36 recognised biodiversity hotspots in the world.

Statement II: High level of species richness and high degree of endemism are criteria for selection of a biodiversity hotspot.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

22. Statement I: Tropical regions have got a long evolutionary time for species diversification as compared to temperate regions.

Statement II: Temperate regions have unde gone frequent glaciations in the past whereas tropical regions have remained relatively undisturbed for millions of years.

a) Both statement I and statement II are correct

b) Both statement I and statement II are incorrect

c) Statement I is correct but statement II is incorrect

d) Statement I is incorrect but statement II is correct

Answer Key					
1. A	2. D	3. D	4. B	5. D	6. C
7. A	8. C	9. C	10. D	11. C	12. B
13. A	14. A	15. A	16. D	17. C	18. B
19. B	20. B	21. A	22. A		

II. Fill in the blanks 1 Mark Each:

(Overexploitation, Decreases, Cryopreservation, Cichlid, 2.4%, Reserpine, Lungs, Increases, Amazon rain forest, In-situ, Ex-situ, 2%, Sacred groves, Biodiversity hotspot, Seed bank, Endemism)

1. The genetic diversity shown by Rauwolfia vomitoria growing in Himalayan produces an active chemical called _____
2. The extinction of Steller's sea cow and passenger pigeon was due to _____.
3. The introduction of Nile perch into Lake Victoria in east Africa led to the extinction of ecologically unique assemblages of _____fish in the lake
4. The land area of India is _____
5. In general species diversity _____as we move away from the equator towards the poles
6. _____in south America has the greatest biodiversity on earth
7. The Amazonian rain forest is called _____of the planet
8. The protection of endangered or threatened species away from their natural habitat is _____
9. The protection of the entire forest to save the tiger is an example for _____.conservation
10. Biodiversity hotspots account for _____of the earth's land area
11. Tracts of forests that are set aside and all the trees and wildlife within were venerated and given full protection constitute _____
12. The regions with high species richness and a high degree of endemism are called biodiversity _____
13. The phenomenon of species confined to a particular region and not found elsewhere is called _____
14. Seeds of different genetic strains of commercially important plants can be kept for long periods in _____
15. Gametes of threatened species can be preserved in viable and fertile conditions for long periods using _____

Answer Key

1.	Reserpine.	2.	Overexploitation.	3.	Cichlid.	4.	2.4%.	5.	Decreases.
6.	Amazon rain forest.	7.	Lungs.	8.	Ex-situ.	9.	In-situ.	10.	2%.
11.	Sacred groves.	12.	Biodiversity hotspot.	13.	Endemism.	14.	Seed bank.	15.	Cryopreservation.

PART-B

III. Answer the following questions in 3-5 sentences: 2 Marks Each:

Q1. Define biodiversity? Who popularized the term biodiversity

Ans: Biodiversity, or biological diversity, refers to the variety and variability among living organisms at all levels. Biodiversity is the term popularised by the **sociobiologist Edward Wilson**

Q2. Mention any two levels of Biodiversity

Ans:

- Genetic diversity
- Species diversity

Q3. What is genetic diversity? India has more than 50,000 different strains of rice. Mention the level of biodiversity it represents

Ans: Genetic diversity is diversity shown by a single species at genetic level. The existence of over 50,000 different strains of rice in **India represents genetic diversity.**

Q4. "India is rich in genetic diversity". Justify the statement by giving two examples

Ans: India shows high genetic variation in several crops and medicinal plants.
Examples:

1. India has more than 50,000 genetically different strains of rice.
2. India has 1000 varieties of mango

Q5. Give an example for genetic diversity. Name an active chemical produced by medicinal plant Rauwolfia vomitoria

Ans: An example of genetic diversity is the presence of 1000 varieties of mango in India. The medicinal plant Rauwolfia vomitoria produces an active chemical called Reserpine.

Q6. What is species diversity? Give an example

Ans: Species diversity refers to the variety of different species in a given area or ecosystem. Example: the western ghats have a greater amphibian species diversity than Eastern Ghats

Q7. What is ecological or ecosystem diversity? Give an example

Ans: Ecosystem diversity refers to the variety of habitats, biotic communities, and ecological processes in the biosphere. Example: India has diverse ecosystems such as deserts, mangroves, forests, grasslands, and wetlands.

Q8. Differentiate genetic diversity and species diversity

Genetic Diversity	Species Diversity
Variation in genes within a species	The variety of different species in a given area or ecosystem
Example: Different strains of rice	Example: Amphibian species in Western Ghats

Q9. Differentiate genetic diversity and ecological diversity

Genetic Diversity	Ecological Diversity
Variation in genes within a species	Variety of ecosystems or habitats
Example: Different varieties of mango	Example: Mountains, deserts, wetlands

Q10. Differentiate species diversity and ecological diversity

Species Diversity	Ecological Diversity
The variety of different species in a given area or ecosystem	Variety of ecosystems or habitats
Example: Amphibian species in Western Ghats	Example: Mountains, deserts, wetlands

Q11. Name any four recent extinct organisms as per IUCN Red List

Ans:

1. Dodo
2. Steller's sea cow
3. Passenger pigeon
4. Quagga

Q12. Mention any two effects of biodiversity loss

Ans:

(a) Decline in plant production

(b) Lowered resistance to environmental perturbations such as drought

Q13. Mention David Tilman's observation with respect to species richness in a community

Ans: David Tilman's long-term experiments showed that plots with more species showed less year-to-year variation in total biomass. He also observed that increased diversity contributed to higher productivity.

Q14. Mention "The Evil Quartet" of biodiversity loss in a given habitat

Ans: The four main causes (Evil Quartet) are:

1. Habitat loss and fragmentation
2. Over-exploitation
3. Alien species invasions
4. Co-extinctions

Q15. Give any two examples for species which have become extinct due to overexploitation

Ans:

1. Passenger pigeon
2. Steller's sea cow

Q16. "Alien species invasion leads to extinction of indigenous species." Justify the statement by giving two appropriate examples

Ans:

1. The Nile perch introduced into Lake Victoria in east Africa led to the extinction of more than 200 species of cichlid fish.
2. The African catfish Clarias gariepinus introduced for aquaculture is threatening indigenous catfishes in Indian rivers.

Q17. What is co-extinction? Give an example

Ans: Co-extinction is when a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct. Example: The extinction of a host fish may lead to the extinction of its parasite.

Q18. What are biodiversity hotspots? Name any two biodiversity hotspots in India

Ans: Biodiversity hotspots are regions with very high levels of species richness and high degree of endemism. Examples:

1. Western Ghats
2. Himalayas

Q19. What is in situ conservation? Mention any two examples for in situ conservation

Ans: In situ conservation is the protection of species in their natural habitats. Examples:

1. National parks
2. Wildlife sanctuaries

Q20. What is ex situ conservation? Mention any two examples for ex situ conservation

Ans: Ex situ conservation is the conservation of species outside their natural habitat. Examples:

1. Botanical gardens
2. Seed banks

Q21. Differentiate in situ and ex situ conservation

In Situ Conservation	Ex Situ Conservation
Protection of species in their natural habitats	Conservation of species outside their natural habitat
Example: National parks	Example: Zoological parks, gene banks

Q22. What are sacred groves? Give an example.

Ans: Sacred groves are forest patches protected by local communities because of cultural or religious traditions. Example: sacred groves of Meghalaya.

Q23. How are sacred groves important in conserving biodiversity?

Ans: Sacred groves are biodiversity-rich areas protected from exploitation due to cultural beliefs. They provide habitat for many rare and endemic species.

Q24. How cryopreservation helps in the conservation of biodiversity?

Ans: Cryopreservation stores genetic material (like gametes, embryos, tissues) at ultra-low temperatures (-196℃), ensuring long-term preservation and availability for future breeding or conservation.

Q25. List any two ecosystem services supported by biodiversity.

Ans: (1) Pollination of crops and wild plants. (2) Nutrient cycling, soil formation, water purification and climate regulation are important ecosystem services.

Q26. Write any two advanced techniques used in ex situ conservation

Ans:

1. Cryopreservation
2. Tissue culture (Micropropagation)

Q27. a) What are endemic species?

Ans: Endemic species are those species confined to a particular region and not found anywhere else. Example: Lion-tailed macaque in Western Ghats.

b) Who proposed the ‘rivet popper’ hypothesis?

Ans: The ‘rivet popper’ hypothesis was proposed by Paul Ehrlich, a Stanford ecologist.

Q28. a) Among vertebrates, which group of animals has the highest number in global biodiversity?

Ans: Fishes represent the group with the highest number of species among vertebrates.

b) Why is the Amazon rainforest sometimes called the 'lungs of the planet'?

Ans: The phrase is a popular metaphor for the forest's immense photosynthetic activity and role in the global carbon and water cycles; it should not be interpreted as a net source of 20% of atmospheric oxygen.

PART - C

IV. Answer the following questions in 40 – 80 words: 3 Marks Each:

Q1. Briefly explain the three levels of biodiversity with suitable examples

Ans: There are three levels of biodiversity:

a) Genetic diversity – Variation of genes within species. Example: Over 50,000 strains of rice in India.

b) Species diversity – Variety of species in a region. Example: Western Ghats has more amphibian species than the Eastern Ghats.

c) Ecosystem diversity – Variety of ecosystems in a region. Example: India has forests, deserts, mangroves, wetlands, etc.

Q2. "Tropical rainforests have greater biodiversity compared to temperate forests". Justify with three reasons

Ans:

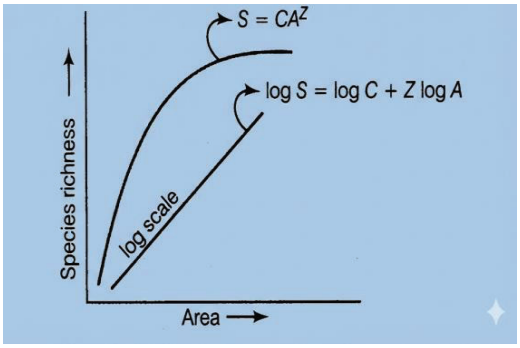
a) Tropical regions are more stable and remained undisturbed for millions of years.

b) They receive more solar energy, promoting high productivity and diversity.

c) Favourable climatic conditions support speciation and survival of species over time.

Q3. Draw a graphical representation of species-area relationship

Ans:



- X-axis: Area (log A)
- Y-axis: Number of species (log S)
- The curve is upward sloping and concave, showing that species richness increases with area.
- Equation: **log S = log C + Z log A**

Q4. Explain the species-area relationship of biodiversity as explained by Alexander von Humboldt

Ans: Humboldt observed that within a region, species richness increases with increasing area but only up to a limit. For various taxa, this relationship forms a rectangular hyperbola. On a logarithmic scale, it is a straight line:

log S = log C + Z log A

Where S = Species richness, A = Area, Z = slope, C = Y-intercept. Larger areas support more habitats and species.

Q5. In the formula log S = log C + Z log A, what do 'S', 'A', and 'Z' represent?

Ans:

- S = Species richness (number of species)
- A = Area surveyed
- Z = Slope of the line (rate of increase in species with area)

Q6. Write the salient features of stable community with reference to biodiversity

Ans:

a) Should not show large variation in productivity year-to-year
b) Must be resistant or resilient to occasional disturbances
c) Must resist invasions by alien species

Q7. Comment on David Tilman's long-term ecosystem experiments and its significance

Ans: Tilman's grassland experiments showed:

a) Communities with higher species richness have higher productivity
b) Diverse communities are more stable and resistant to invasions
c) Biodiversity is essential for ecosystem functioning and sustainability

Q8. Describe the 'rivet popper' hypothesis as explained by Paul Ehrlich. Mention its significance

Ans:

- Ecosystem stability is compared to an airplane held together by rivets (species).
- Loss of a few rivets (species) may not immediately affect safety (functioning), but cumulative loss weakens the plane.
- Loss of key rivets (key species) can critically destabilize the ecosystem.
  Significance: Even small extinctions can destabilize ecosystems, highlighting the need to conserve all species.

Q9. List out the three general effects of loss of biodiversity

Ans:

a) Decline in plant production
b) Lowered resistance to environmental perturbations (e.g., drought)
c) Increased variability in ecosystem processes like plant productivity, water use, pest cycles

Q10. "Introduction of alien species causes biodiversity loss". Justify with three examples

Ans:

a) Nile perch in Lake Victoria caused extinction of 200+ species of cichlid fish
b) Invasive weeds like Parthenium, Lantana, and water hyacinth threaten native species
c) African catfish Clarias gariepinus introduction threatens indigenous catfishes in Indian rivers

Q11. Why should we conserve biodiversity? Explain

Ans:

a) **Narrow utilitarian reasons** – Provides food, firewood, fiber, medicine, and industrial products
b) **Broad utilitarian reasons** – Oxygen, pollination, climate regulation, aesthetic pleasure
c) **Ethical reasons** – Every species has an intrinsic right to exist; moral duty to protect them

Q12. Briefly explain narrowly utilitarian reason for conserving biodiversity

Ans: Direct benefits include food (cereals, pulses, fruits), medicine (Rauwolfia, Neem), fibers, wood, fuel, and industrial products (tannins, dyes, perfumes). Preserving biodiversity ensures these resources for the future.

Q13. Briefly explain broadly utilitarian reason for conserving biodiversity

Ans: Indirect services include pollination, oxygen production, air and water purification, climate regulation, nutrient cycling, and aesthetic pleasure. These maintain ecosystem balance and human survival.

Q14. "Biodiversity plays a major role in providing many ecosystem services." Justify with three reasons.

Ans: a) Biodiversity supports nutrient cycling, soil formation and decomposition.
b) Pollination by insects, birds and bats supports reproduction of wild plants and many crops.
c) Diverse ecosystems contribute to water purification, carbon storage, climate regulation and cultural/aesthetic values.

Q15. Name the biodiversity hotspots of India

1. Western Ghats
2. Himalayas
3. Indo-Burma region
4. Sundaland

PART- D

V. Answer the following questions as directed: 5 Marks Each:

Q1. Define biodiversity. Explain the major causes of biodiversity loss

Ans: Biodiversity, or biological diversity, refers to the variety and variability among living organisms at all levels.

Major causes of biodiversity loss (Evil Quartet):

Habitat loss and fragmentation:

- Most important cause driving species to extinction.
- Example: Tropical rainforests once covered 14% of Earth's land; now only 6%.
- Amazon rainforest is being cleared for soya cultivation and cattle grazing.
- Fragmentation affects species requiring large territories or migratory animals.

Overexploitation:

- Extinctions of Steller's sea cow, passenger pigeon due to human overuse.
- Many marine fish populations are overharvested.

Alien species invasions:

- Nile perch in Lake Victoria led to extinction of 200+ cichlid fish species.
- Invasive weeds like Parthenium, Lantana, and water hyacinth threaten native species.
- African catfish Clarias gariepinus threatens indigenous catfish in rivers.

Co-extinctions:

- Extinction of one species leads to extinction of dependent species.
- Example: Extinction of a host fish causes extinction of its parasites; loss of a plant species may end a coevolved pollinator.

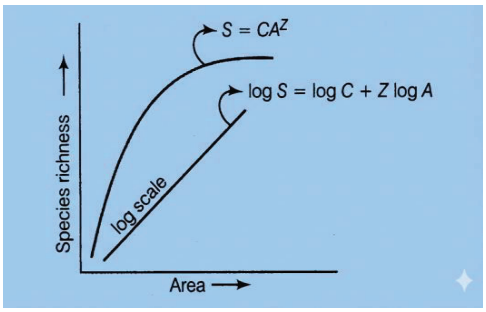
Q2. What are endemic species? Differentiate in situ conservation and ex situ conservation with suitable examples

Ans: Endemic species: Species confined to a particular region and not found anywhere else.

In Situ Conservation	Ex Situ Conservation
Protection of species in their natural habitat	Conservation of species outside their natural habitat
Maintains natural evolution and interaction	Useful for critically endangered species
Cost-effective and long-term	Expensive and requires maintenance
Examples: National parks, wildlife sanctuaries	Examples: Zoological parks, gene banks

Q3. Explain species-area relationship with graphical representation

Ans:



- Alexander von Humboldt observed species richness increases with explored area but only up to a limit.
- Relationship forms a rectangular hyperbola; on log scale, it is a straight line:
  log S = log C + Z log A
  Where: S = Species richness, A = Area, Z = slope, C = Y-intercept
- Z values:
  - Small areas: 0.1–0.2 (gradual increase, curve b)
  - Large areas/continents: 0.6–1.2 (steep increase, curve a)
- Example: Frugivorous birds and mammals in tropical forests, Z ≈ 1.15

Q4. Describe different ecosystem services provided by biodiversity

Ans:

1. **Narrow utilitarian reasons:** Provides food (cereals, pulses, fruits), firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes), and medicinal products.
2. **Broadly utilitarian reasons:**
   - o Water purification, carbon storage and climate regulation
   - Pollination by bees, birds, bats ensures fruit and seed production
   - Aesthetic and cultural benefits (forests, flowers, bird songs)
3. **Ethical reasons:** Every species has an intrinsic right to exist; moral duty to protect them

Q5. Refer to the graph showing species-area relationship and answer the questions that follow:

(a) Write the equation of the curve 'a' and 'b' .(2 Marks)

Ans: The general equation is S = C A^Z; equivalently, log S = log C + Z log A.

Where

S = Species richness

A = Area

Z= Slope of the line (regression coefficient)

C = Y- intercept

- For curve ‘b’ which is represents normal species-Area relationship for smaller regions, the Z value ranges between 0.1–0.2
- For curve ‘a’, which represents larger areas like continents, the Z value is higher , typically Z = 0.6–1.2

(b) Explain how the value of Z varies (3 marks)

Ans:

- Z reflects the rate of increase in species richness with area.
- Smaller areas (grasslands, forests): Z = 0.1–0.2 → gradual increase in species richness (curve b)
- Very large areas (continents, biomes): Z = 0.6–1.2 → sharp increase in species richness (curve a)

Example: Frugivorous birds and mammals in tropical forests show Z ≈ 1.15