1. REPRODUCTION IN ORGANISMS

- **Reproduction** is a process in which an organism produces young ones (offspring) similar to itself.
- The period from birth to the natural death of an organism is known as its **lifespan.**
- No individual is immortal, except unicellular organisms. There is no natural death in unicellular organisms.

Life spans of some organisms

Organism	Lifespan	Organism	Lifespan	Organism	Lifespan
Rose	5-7 years	Butterfly	1-2 weeks	Tortoise	100-150 yrs
Rice plant	3-7 months	Fruit fly	2 weeks	Crow	15 yrs
Banyan tree	400+ yrs	Parrot	140 yrs	Cow	22 yrs
Banana tree	2-3 yrs	Crocodile	60 yrs	Elephant	50-70 yrs
Dog	22 yrs	Horse	40-50 yrs		

- Based on the number of participants, reproduction is 2 types: **Asexual reproduction & Sexual reproduction.**

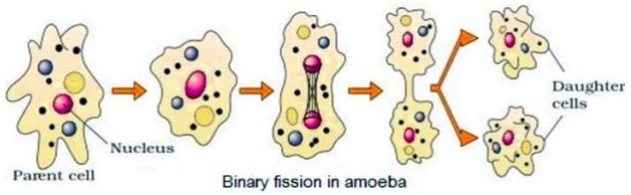
ASEXUAL REPRODUCTION

- It is the production of offspring by a single parent.
- It is seen in unicellular organisms, simple plants & animals.
- The offspring are identical to one another and to their parent. Such morphologically and genetically similar individuals are known as **clone**.

Types of asexual reproduction

a. Fission: In this, the parent cell divides **(cell division)** into two or more individuals. E.g. Protists and Monerans. Fission is 2 types:

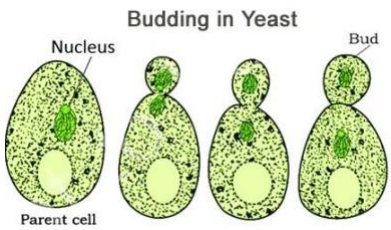
- **Binary fission:** It is the division of parent cell into two individuals. E.g., *Amoeba, Paramecium.*
- **Multiple fission:** It is the division of parent cell into many individuals. E.g. *Plasmodium, Amoeba.*

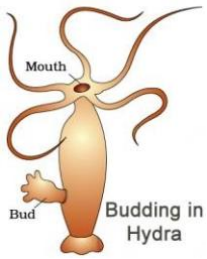


Binary fission in amoeba

Under unfavourable condition, *Amoeba* withdraws its pseudopodia and secretes a 3-layered hard covering (cyst) around itself. It is called **encystation.** Under favourable conditions, encysted *Amoeba* undergoes multiple fission to give many minute amoeba or pseudopodiospores. The cyst wall bursts out and spores are liberated to grow up into many amoebae. This is called **sporulation.**

b. Budding: In this, a bud appears and grows in the parent body. After maturation, it is detached from parent body to form new individual. E.g. *Hydra*, Sponge, Yeast etc.





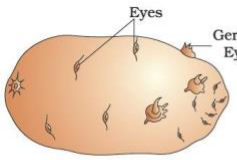
***c.* Fragmentation:** In this, the body breaks into distinct pieces (fragments) and each fragment grows into an adult capable of producing offspring. E.g. *Hydra.*

d. Vegetative propagation: It is the production of offspring from **vegetative propagules** in plants.

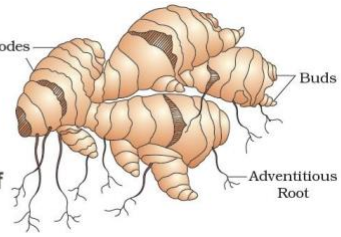
Vegetative propagules are units of vegetative propagation.

Examples for vegetative propagules:

- **Buds ('eyes')** of the potato tuber.
- **Rhizomes** of banana & ginger.
  Buds & Rhizomes arise from the **nodes** of modified stems. The nodes come in contact with damp soil or water and produce roots and new plants.
- **Adventitious buds** of *Bryophyllum.* They arise from the notches at margins of leaves.
- **Bulbil** of *Agave.*
- **Offset** of water hyacinth.
- **Runner, sucker, tuber, bulb etc.**



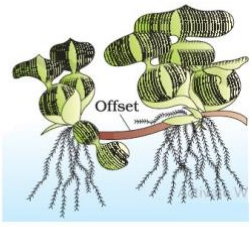
Eyes of potato



Rhizome of ginger


Bulbil of *Agave*

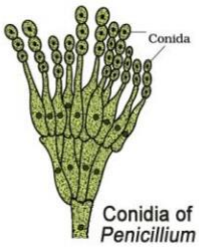
Leaf buds of *Bryophyllum*



Offset of water hyacinth

Other asexual reproductive structures: E.g. **zoospores** (microscopic motile structures in some algae and protists), **conidia** (*Penicillium*) and **gemmules** (*sponge*).


Zoospores in *Chlamydomonas*



Conidia of *Penicillium*


Gemmules in sponge

Asexual reproduction is the common method in simple organisms like algae and fungi. During adverse conditions, they can shift to sexual method.

Higher plants reproduce asexually (vegetative) & sexually. But most of the animals show only sexual reproduction.

SEXUAL REPRODUCTION

- It is the reproduction that involves formation of male and female gametes, either by the same individual or by different individuals of the opposite sex.
- It results in offspring that are not identical to the parents or amongst themselves.
- It is an elaborate, complex and slow process as compared to asexual reproduction.
- The period of growth to reach in maturity for sexual reproduction is called the **juvenile phase**. In plants, it is known as **vegetative phase.**
- In higher plants, the flowering indicates the end of vegetative phase (beginning of **reproductive phase).**
- ***Annual & biennial*** plants show clear cut **vegetative, reproductive & senescent phases.** In ***perennial*** plants, these phases are very difficult to identify.
- Some plants exhibit unusual flowering. E.g.
  - Bamboo species flower only once in their lifetime (after 50-100 years), produce large number of fruits and die.
  - *Strobilanthus kunthiana* flowers once in 12 years.
- In animals, juvenile phase is followed by morphological & physiological changes prior to reproductive behaviour.
- Birds living in nature lay eggs only seasonally. However, birds in captivity (e.g. poultry) can be made to lay eggs throughout the year.
- The females of placental mammals exhibit cyclical changes in the ovaries, accessory ducts and hormones during the reproductive phase. It is called **oestrus cycle** in **non-primates** (cows, sheep, rat, deer, dog, tiger etc.) and **menstrual cycle** in **primates** (monkeys, apes & humans).

Based on breeding season, mammals are 2 types:

a. **Seasonal breeders:** The mammals (living in natural conditions) exhibiting reproductive cycles only during favourable seasons.

b. **Continuous breeders:** They are reproductively active throughout their reproductive phase.

Senescence (old age):

- It is the last phase of lifespan and end of reproductive phase.
- During this, concomitant changes occur in the body. E.g. slowing of metabolism etc. It ultimately leads to death.

In plants & animals, **hormones** cause transition between **juvenile, reproductive & senescence phases.** Interaction between hormones and environmental factors regulate the reproductive processes and the associated behavioural expressions of organisms.

EVENTS IN SEXUAL REPRODUCTION

3 stages: Pre-fertilisation, Fertilisation & Post-fertilisation events.

1. Pre-fertilisation Events

These are the events prior to the fusion of gametes.
They include **gametogenesis** and **gamete transfer.**

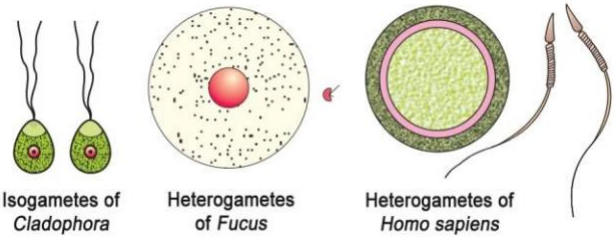
a. Gametogenesis

It is the formation of male and female gametes.

Gametes (haploid cells) are 2 types:

a. **Homogametes (isogametes):** Similar gametes. They cannot categorize into male & female gametes. E.g. Some algae like ***Cladophora***.

b. **Heterogametes:** The male and female gametes are distinct types. Male gamete is called **antherozoid (sperm)** and female gamete is called **egg** (**ovum)**. E.g. ***Fucus*** (an alga), Human beings etc.

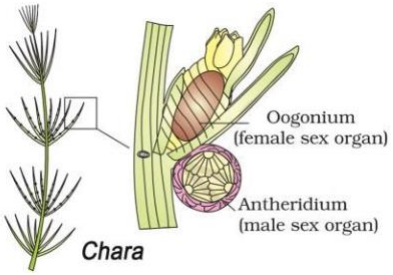


Sexuality (bisexual or unisexual) in organisms:

a. **Bisexual:** Male & female reproductive structures present in the same individual.

Bisexual plants: E.g. *Hibiscus, Pisum.*
In flowering plants, male flower is **staminate** (bears stamens) and female flower is **pistillate** (bears pistils).

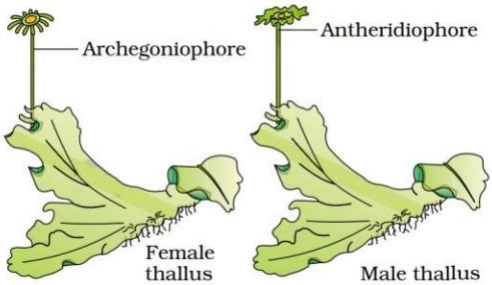
If male & female flowers are present on same plant, it is called **monoecious**. E.g. Cucurbits, coconuts, *Chara.*



Bisexual animals (hermaphrodites): E.g. Earthworms, leech, sponge, tapeworm, etc.

b. **Unisexual:** Male and female reproductive structures are present on different individuals.

If male & female flowers are present on different plants, it is called **dioecious**. E.g. papaya, date palm, *Marchantia.*



Unisexual animals: E.g. Cockroach, higher animals etc. Fungi may be **homothallic** (bisexual) or **heterothallic** (unisexual).

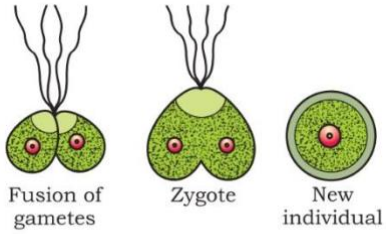
Cell division during gamete formation:

- Many monerans, fungi, algae & bryophytes have **haploid** parental body. They produce haploid gametes by **mitosis.**
- Pteridophytes, gymnosperms, angiosperms & animals have **diploid** parental body. They produce haploid gametes by **meiosis** of **meiocytes** (gamete mother cell).

Name of organism	Chromosome number	
	In meiocytes (2n)	In gametes (n)
Human being	46	23
Housefly	12	6
Rat	42	21
Dog	78	39
Cat	38	19
Fruit fly	8	4
Ophioglossum	1260	630
Apple	34	17
Rice	24	12
Maize	20	10
Potato	48	24
Butterfly	380	190
Onion	16	8

b. Gamete Transfer

- Male gametes need a medium to move towards female gametes for fertilisation.
- In most organisms, male gamete is motile and the female gamete is stationary.
  In some fungi and algae, both types of gametes are motile.
- In simple plants (algae, bryophytes & pteridophytes), gamete transfer takes place through water medium. To compensate the loss of male gametes during transport, large number of male gametes is produced.



Homogametic contact in alga

- In seed plants, **pollen grains** (in anthers) carry male gametes and **ovule** carries the egg. Pollen grains are transferred to the stigma.
- In bisexual self-fertilizing plants (e.g. peas), anthers & stigma are closely located for easy transfer of pollen grains.
- In cross pollinating plants (including dioecious plants), **pollination** helps in transfer of pollen grains. Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge male gametes near the egg.
- In dioecious animals, the fertilisation helps for successful transfer and coming together of gametes.

2. Fertilisation (syngamy)

- It is the fusion of gametes to form a diploid **zygote**.
- In rotifers, honeybees, some lizards, birds (turkey) etc., female gamete develops to new organisms without fertilisation. This is called **parthenogenesis.**

Types of fertilization:

a. External fertilisation: Syngamy occurs in the external medium (water), i.e. zygote is formed outside the body. E.g. most aquatic organisms (many algae, bony fishes etc.) and amphibians.
Such organisms show synchrony between the sexes and release large number of gametes into the surrounding medium to ensure syngamy.
Disadvantage: The offspring are extremely vulnerable to predators threatening their survival up to adulthood.

b. Internal fertilisation: Syngamy occurs inside the body of the organism. E.g. terrestrial organisms, belonging to fungi, animals (reptiles, birds, mammals) & plants (bryophytes, pteridophytes, gymnosperms & angiosperms). In this, non-motile egg is formed inside the female body to where motile male gamete reaches and fuses.
In seed plants, the non-motile male gametes are carried to female gamete by pollen tubes.
There is large number of sperms produced but the number of eggs is very low.

3. Post-fertilisation Events

These are the events after the formation of zygote.

Zygote

- Development of the zygote depends on the type of life cycle of the organism and the nature of environment.
- In fungi and algae, zygote develops a thick wall that is resistant to desiccation and damage. It undergoes a period of rest before germination.
- In organisms with **haplontic life cycle,** zygote divides by meiosis into **haploid spores** that grow into haploid individuals.
- Sexually reproducing organisms begin life as a zygote.
- Zygote is the vital link between organisms of one generation and the next.

Embryogenesis

- It is the development of **embryo** from the zygote.
- During embryogenesis, zygote undergoes **cell division** (mitosis) and **cell differentiation**.
- Cell divisions increase the number of cells in the embryo. Cell differentiation causes the modifications of groups of cells into various tissues and organs to form an organism.

Based on place of zygote development, animals are 2 types:

a. Oviparous: Here, animals lay fertilized/unfertilized eggs. E.g. Reptiles & birds lay fertilized eggs covered by hard **calcareous shell.** After incubation, young ones hatch out.

b. Viviparous: Here, zygote develops into a young one inside the female body. Later, the young ones are delivered out of the body. E.g. most of mammals.
It shows proper care and protection. So the chances of survival of young ones are greater.

Embryogenesis in flowering plants ***(see next chapter)***

MODEL QUESTIONS

1. Write technical terms for the following:

   (a) Morphologically different types of gametes.
   (b) Process of formation of male and female gametes.
   (c) Formation of new organisms without fertilization.
   (d) Cell which undergo meiosis.
   (e) Male and female sex organs in the same animal.
   (f) Development of fruits without fertilization.

2. Observe the relationship of the first two and fill in the blanks.
   (a) Sponge: gemmules Hydra: .....
   (b) Homothallic Plants: Monoecious & bisexual Heterothallic Plants: .....

3. Match the following:

A	B
A. Buds ('eyes')	1. *Bryophyllum*
B. Rhizomes	2. Water hyacinth
C. Adventitious buds	3. Banana & ginger
D. Bulbil	4. Potato tuber
E. Offset	5. *Agave*

4. Distinguish between continuous breeders and seasonal breeders with examples.
5. Differentiate between homogametes and heterogametes with examples.
6. Some plants exhibit unusual flowering. Give any 2 examples.
7. Differentiate between
   (a) Asexual reproduction & Sexual reproduction
   (b) Juvenile phase & Senescent phase
   (c) Monoecious and Dioecious
   (d) Oviparous & Viviparous
8. Classify the following organisms, according to the nature of fertilization.
   Shark, Tortoise, Tape worm, Frog, Chlamydomonas, Ficus Tree
9. Viviparity is more advantageous than oviparity. Do you agree? Justify.

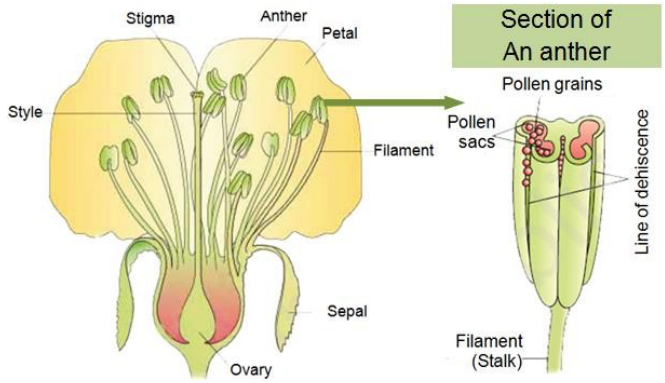
2. SEXUAL REPRODUCTION IN FLOWERING PLANTS

All flowering plants (angiosperms) show sexual reproduction. **Flowers** are the sites of sexual reproduction.

PRE-FERTILISATION: STRUCTURES & EVENTS

- Several hormonal and structural changes result in differentiation & development of the **floral primordium.**
- Inflorescences bear the floral buds and then the flowers.

STRUCTURE OF A FLOWER



A typical flower has 2 parts: **Androecium & Gynoecium.**

Androecium (male reproductive part)

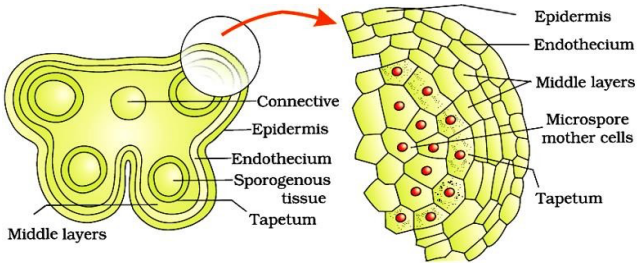
It consists of a whorl of **stamens.** Their number and length are variable in different species.

A stamen has 2 parts:

a. Filament: Long and slender stalk. Its proximal end is attached to the thalamus or the petal of the flower.

b. Anther: Terminal and typically **bilobed.** Each lobe has 2 thecae **(dithecous).** Often a longitudinal groove runs lengthwise separating the theca.

Transverse section of anther:



- The anther is a tetragonal structure consisting of four **microsporangia** located at the corners (2 in each lobe).
- The microsporangia develop to **pollen sacs.** They extend longitudinally all through the length of an anther and are packed with pollen grains.

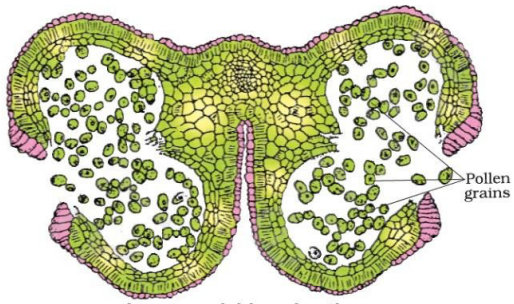
Structure of a microsporangium:

- A typical microsporangium is near circular in outline.
- It is surrounded by 4 wall layers: **epidermis, endothecium, middle layers & tapetum** (innermost layer).
- The outer 3 layers give protection and help in dehiscence of anther to release the pollen.
- The **tapetum** nourishes the developing pollen grains. Cells of the tapetum contain dense cytoplasm and generally have more than one nucleus.
- In young anther, each microsporangium has **sporogenous tissue** at centre. It consists of compactly arranged homogenous diploid cells (sporogenous cells).

Microsporogenesis:


Microspore tetrad

- As the anther develops, each sporogenous cell **(microspore mother cell or pollen mother cell)** undergoes meiotic divisions to form **microspore tetrads** (microspores arranged in a cluster of four cells).
- Formation of microspores from pollen mother cell (PMC) through meiosis is called **microsporogenesis.**
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into **pollen grains.**
- Each microsporangium contains thousands of pollen grains. They are released with the dehiscence of anther.



A mature dehisced anther

Pollen grain (male gametophyte):

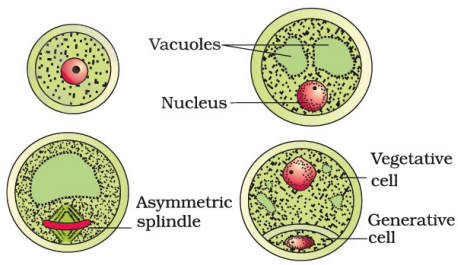
Generally spherical. 25-50 µm in diameter. Cytoplasm is surrounded by a plasma membrane.

A pollen grain has a two-layered wall: **exine** and **intine.**

- **Exine:** Hard outer layer. Made up of **sporopollenin** (highly resistant organic material). It can withstand high temperature and strong acids and alkali. Enzymes cannot degrade sporopollenin.
  Exine has apertures called **germ pores** where sporopollenin is absent.
  Pollen grains are preserved as fossils due to the presence of sporopollenin. Exine exhibits patterns and designs.
- **Intine:** Inner wall. It is a thin and continuous layer made up of **cellulose** and **pectin.**

A matured pollen grain contains 2 cells:

- **Vegetative cell:** It is bigger, has abundant food reserve and a large irregularly shaped nucleus.
- **Generative cell:** It is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and a nucleus.



Stages of a microspore maturing into a pollen grain

- Over 60% angiosperms shed their pollen grains at 2-celled stage. In others, generative cell divides mitotically to give 2 male gametes. Thus pollen grains are shed at 3-celled stage.

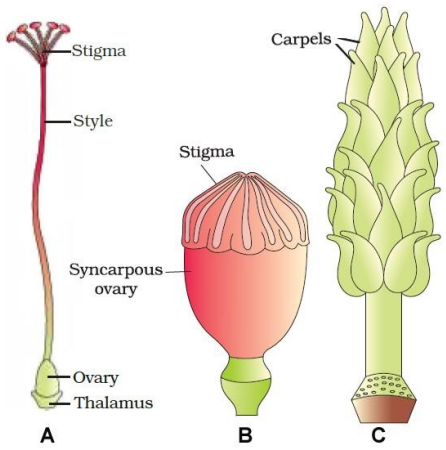
- The shed pollen grains have to land on the stigma before they lose viability. The viability period of pollen grains is variable. It depends on temperature and humidity.
- Viability of pollen grains of some cereals (rice, wheat etc.) is 30 minutes. Some members of *Leguminoseae, Rosaceae & Solanaceae* have viability for months.

Economic importance of pollen grains:

- These are **rich in nutrients.** Pollen tablets are used as food supplements. Pollen tablets & syrups increase performance of athletes and race horses.
- They are stored for years in liquid nitrogen (-196^{0}C). They can be used as **pollen banks** in crop breeding programmes.
- Pollen grains of some plants (e.g. *Parthenium* or carrot grass) are allergic for some people. It leads to chronic respiratory disorders (asthma, bronchitis, etc.).

Gynoecium (female reproductive part)

- It may have a single pistil (**monocarpellary**) or more than one pistil **(multicarpellary).**
- In **multicarpellary**, the pistils may be fused together (**syncarpous**) or free (**apocarpous**).



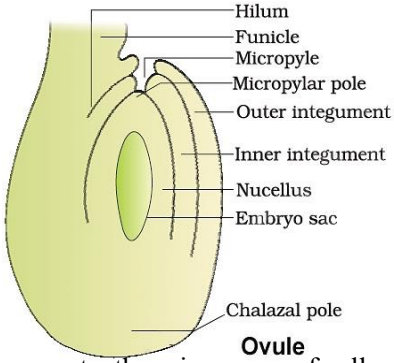
A. *Hibiscus* pistil.
B. Multicarpellary, syncarpous pistil of *Papaver*.
C. Multicarpellary, apocarpous gynoecium of *Michelia*

Each pistil has three parts:

- **Stigma:** Landing platform for pollen grains.
- **Style:** Elongated slender part beneath the stigma.
- **Ovary:** Basal bulged part. It has **ovarian cavity** (**locule)** in which **placenta** is located. Arising from the placenta are the **ovules (megasporangia).** Number of ovules in an ovary may be one (wheat, paddy, mango etc.) to many (papaya, water melon, orchids etc.).

Structure of Megasporangium (Ovule):

- Ovule is attached to the placenta by a stalk **(funicle)**.
- Junction between the body of ovule and funicle is called **hilum.**
- Each ovule has 1 or 2 protective envelopes **(integuments)** except at the tip where a small opening **(micropyle)** is present.
- Opposite the micropylar end is the **chalaza** (basal part).

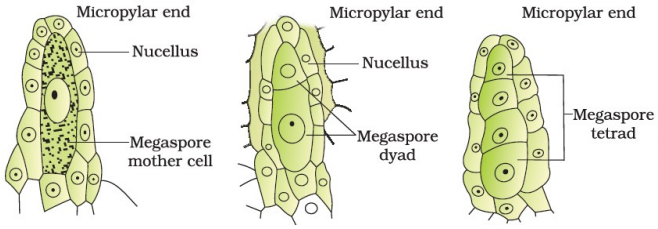


Ovule

- Enclosed within the integuments, there is a mass of cells called **nucellus**. Its cells contain reserve food materials.
- Inside the nucellus is **embryo sac (female gametophyte)**.
- An ovule generally has a single embryo sac formed from a megaspore.

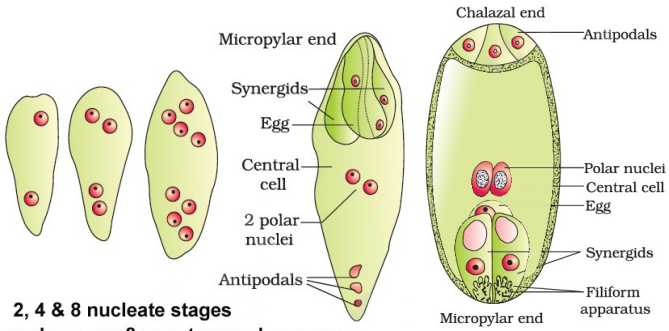
Megasporogenesis:

- It is the formation of megaspores from **megaspore mother cell (MMC).**
- Ovules generally differentiate a single MMC in micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus.
- MMC undergoes meiosis to produce 4 **megaspores**.



Formation of Female gametophyte (embryo sac):

- In majority of flowering plants, one megaspore is functional while the other three degenerates.
- The **functional megaspore** develops into the **female gametophyte.** The embryo sac formation from a single megaspore is called **monosporic** development.
- Nucleus of the functional megaspore divides mitotically to form two nuclei. They move to the opposite poles, forming **2-nucleate** embryo sac.
- The nuclei again divide two times forming **4-nucleate** and **8-nucleate** stages of the embryo sac.



2, 4 & 8 nucleate stages embryo sac & a mature embryo sac
Mature embryo sac

- These divisions are free nuclear, i.e. nuclear divisions are not followed immediately by cell wall formation.
- After the 8-nucleate stage, cell walls are laid down leading to the organization of the typical **female gametophyte.**
- 6 of the 8 nuclei are surrounded by cell walls and organized into cells. Remaining 2 nuclei (polar nuclei) are situated below the egg apparatus in the large **central cell.**

Distribution of cells within the embryo sac:

A typical mature embryo sac is **8-nucleate** and **7-celled**.

- 3 cells (2 **synergids** + one **egg cell)** are grouped at the **micropylar end** and form **egg apparatus.**
  Synergids have special cellular thickenings at the **micropylar tip** called **filiform apparatus.** It helps to guide the pollen tubes into the synergid.
- 3 cells **(antipodals)** at the **chalazal end.**
- A large **central cell** with two **polar nuclei.**

POLLINATION

It is the transfer of pollen grains from the anther to the stigma of a pistil.

Based on the source of pollen, pollination is 3 types:

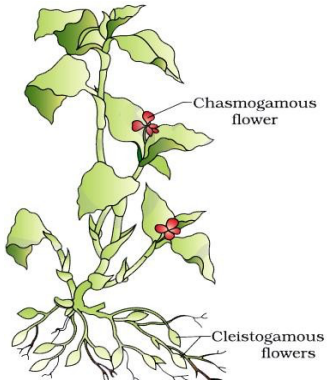
a. **Autogamy (self-pollination):** It is the transfer of pollen grains from the anther to stigma of the **same flower.**

   In flowers with exposed anthers & stigma, complete autogamy is rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity. Also, anthers & stigma should be close to each other.

   Plants like *Viola* (common pansy), *Oxalis* & *Commelina* produce 2 types of flowers:

   - **Chasmogamous flowers:** They are similar to flowers of other species with exposed anthers and stigma.
   - **Cleistogamous flowers:** They do not open at all. Anthers & stigma lie close to each other. They are autogamous. When anthers dehisce in the flower buds, pollen grains come in contact with stigma for pollination. Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

     Cleistogamy leads to inbreeding depression.



b. **Geitonogamy:** It is the transfer of pollen grains from the anther to the stigma of **another flower of the same plant.** It is functionally cross-pollination involving a pollinating agent. But it is genetically similar to autogamy since the pollen grains come from the same plant.

c. **Xenogamy:** It is the transfer of pollen grains from anther to the stigma of a **different plant.** It brings genetically different pollen grains to the stigma.

Agents of Pollination

1. Abiotic agents (wind & water)

Pollination by wind (anemophily):

- More common abiotic agent.
- Wind pollinated flowers often have a single ovule in each ovary and numerous flowers packed into an inflorescence.
- E.g. Corncob – the tassels are the stigma and style which wave in the wind to trap pollen grains. Wind-pollination is quite common in grasses.
- **Ways for effective pollination:**
  - The flowers produce enormous amount of pollen.
  - Pollen grains are light and non-sticky.
  - They often possess well-exposed stamens (for easy dispersion of pollens into wind currents).
  - Large, feathery stigma to trap air-borne pollen grains.

Pollination by water (hydrophily):

- It is quite rare. It is limited to about 30 genera, mostly monocotyledons. E.g. *Vallisneria* & *Hydrilla* (fresh water), *Zostera* (marine sea-grasses) etc.
- But in lower plants, water is a regular mode of transport for the male gametes. Distribution of some bryophytes & pteridophytes is limited because they need water for the transport of male gametes and fertilisation.
- In *Vallisneria,* the female flower reaches the surface of water by the long stalk and the male flowers or pollen grains are released on to the surface of water. They are carried by water currents and reach the female flowers.
- In sea grasses, female flowers remain submerged in water. Pollen grains are long and ribbon like. They are carried inside the water and reach the stigma.
- The pollen grains of most of the water-pollinated species have a mucilaginous covering to protect from wetting.
- Not all aquatic plants use hydrophily. In most of aquatic plants (water hyacinth, water lily etc.), the flowers emerge above the level of water for entomophily or anemophily.
- Wind and water pollinated flowers are not very colourful and do not produce nectar.

2. Biotic agents (animals)

- Majority of flowering plants use animals as pollinating agents. E.g. Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds & humming birds) bats, primates (lemurs), arboreal (tree-dwelling) rodents, reptiles (gecko lizard & garden lizard) etc.
- Pollination by insects **(Entomophily),** particularly bees is more common.
- Often flowers of animal pollinated plants are specifically adapted for a particular species of animal.
- **Features of insect-pollinated flowers:**
  - Large, colourful, fragrant and rich in nectar. Nectar & pollen grains are the floral rewards for pollination.
  - Small flowers form inflorescence to make them visible.
  - The flowers pollinated by flies and beetles secrete foul odours to attract these animals.
  - The pollen grains are generally sticky.
- When the animal comes in contact with the anthers and the stigma, its body gets pollen grains. When it comes in contact with the stigma, it results in pollination.
- Some plants provide safe places as floral reward to lay eggs. E.g. *Amorphophallus* (It has the tallest flower of 6 feet).

  A moth species and the plant *Yucca* cannot complete their life cycles without each other. The moth deposits its eggs in the locule of ovary. The flower gets pollinated by moth. The larvae come out of the eggs as seeds start developing.
- Many insects consume pollen or nectar without bringing about pollination. They are called **pollen/nectar robbers.**

Outbreeding Devices

Hermaphrodite flowers can undergo self-pollination. Continued self-pollination results in inbreeding depression. To avoid **self-pollination (autogamy)** and encourage **cross-pollination,** there are some devices in plants:

a. **Avoiding synchronization:** Here, the pollen is released before the stigma becomes receptive or stigma becomes receptive before the release of pollen.

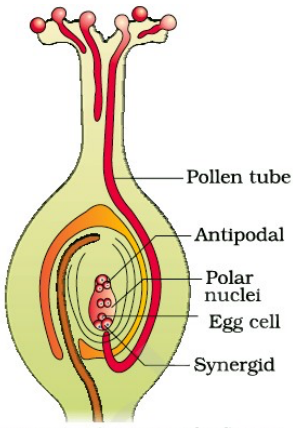
b. **Arrangement of anther & stigma at different positions.**

c. **Self-incompatibility:** It is a genetic mechanism to prevent self-pollen (from same flower or other flowers of the same plant) from fertilization by inhibiting pollen germination or pollen tube growth in the pistil.

d. **Production of unisexual flowers:** If male & female flowers are present on the same plant (i.e., monoecious, e.g. castor & maize), it prevents autogamy but not geitonogamy. In dioecious plants (e.g. papaya), male and female flowers are present on different plants **(dioecy).** This prevents both autogamy and geitonogamy.

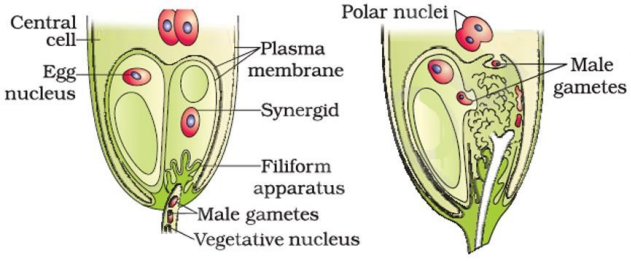
Pollen-pistil Interaction

- It is a process in which pistil recognizes compatible or incompatible pollen through the chemical components produced by them.
- Pistil accepts **compatible pollen** and promotes post-pollination events.
- It rejects **incompatible pollen** by preventing pollen germination or pollen tube growth.
- Pollen grain germinates on the stigma to produce a **pollen tube** through one of the germ pores. The contents of pollen grain move into pollen tube. Pollen tube grows through the tissues of stigma and style and reaches the ovary.



Longitudinal section of a flower showing growth of pollen tube

- In plants which shed pollen grains at **2-celled** condition (a vegetative cell & a generative cell), the generative cell divides into two male gametes during pollen tube growth.
- In plants which shed pollen in **3-celled condition,** pollen tubes carry 2 male gametes from the beginning.
- Pollen tube → **ovary** → **micropyle** → **ovule** → enters one of the **synergids** through **filiform apparatus.** Filiform apparatus guides the entry of pollen tube.



a) Entry of tube into a synergid

(b) Discharge of male gametes into a synergid, then to egg & central cell

- A plant breeder can manipulate pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

Artificial hybridisation

It is a crop improvement programme in which desired pollen grains are used for pollination.

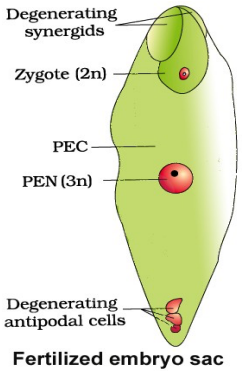
Steps:

- **Emasculation:** Removal of anthers from the bisexual flower bud of female parent before the anther dehisces.
- **Bagging:** Here, emasculated flowers are covered with a bag (butter paper) to prevent contamination of its stigma with unwanted pollen.
- **Pollination:** When stigma attains receptivity, pollen grains collected from male parent are dusted on the stigma.
- **Rebagging** the flowers. It is allowed to develop the fruits.

For unisexual flowers, there is no need for emasculation. Female flower buds are bagged before the flowers open.

DOUBLE FERTILISATION

- After entering the synergid, the pollen tube releases 2 male gametes into the cytoplasm of the synergid. One male gamete moves towards the egg cell and fuses with its nucleus **(syngamy)** to form **zygote** (diploid).
- The other male gamete moves towards the two polar nuclei located in the central cell and fuses with them to produce a triploid **primary endosperm nucleus (PEN).** As it involves fusion of 3 haploid nuclei, it is called **triple fusion.**
- Since 2 types of fusions (syngamy & triple fusion) take place in an embryo sac, it is called **double fertilisation.** It is an event unique to flowering plants.
- The central cell after triple fusion becomes the **primary endosperm cell (PEC)** and develops into the **endosperm** while the zygote develops into an **embryo.**



Fertilized embryo sac

POST- FERTILISATION: STRUCTURES & EVENTS

Post-fertilisation events: Endosperm & embryo development, maturation of ovule(s) into seed(s) & ovary into fruit.

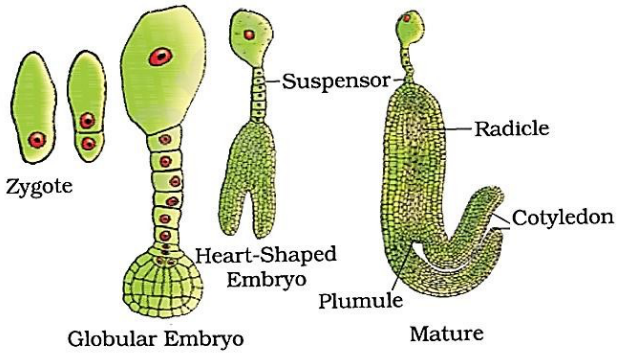
Endosperm development

- **Primary endosperm cell (PEC)** divides repeatedly to form a **triploid endosperm tissue.**
- Endosperm cells are filled with reserve food materials. They are used for **nutrition** of the developing embryo.
- In common endosperm development, PEN undergoes successive nuclear divisions to give free nuclei **(free-nuclear endosperm).** Number of free nuclei varies greatly.
- Endosperm becomes cellular due to cell wall formation.
- **Tender coconut water** is a **free-nuclear endosperm** (made up of thousands of nuclei) and the surrounding **white kernel** is the **cellular endosperm.**

Embryo development

- Embryo develops at the micropylar end of the embryo sac where the zygote is situated.
- Most zygotes divide only after the formation of some endosperm. This provides nutrition to developing embryo.

- In monocots & dicots, seeds differ greatly but **embryogeny** (early embryonic developments) is similar.
- **Zygote → Pro-embryo → Globular → Heart-shaped → Mature embryo.**



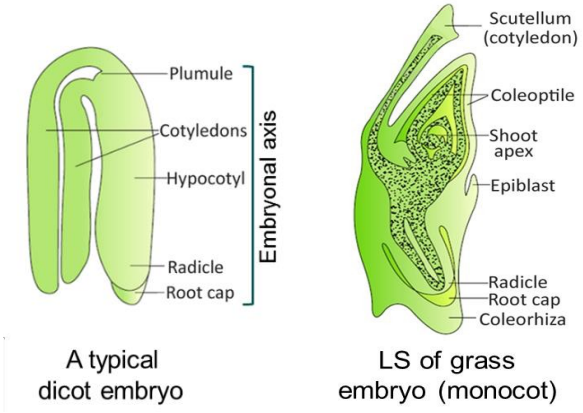
Stages in embryo development in a dicot

Dicotyledonous embryo

- It has an **embryonal axis** and 2 **cotyledons.**
- Portion of embryonal axis above the level of cotyledons is the **epicotyl,** which terminates with **plumule (stem tip).**
- The cylindrical portion below the level of cotyledons is **hypocotyl** that terminates with the **radicle (root tip).** The root tip is covered with a **root cap.**

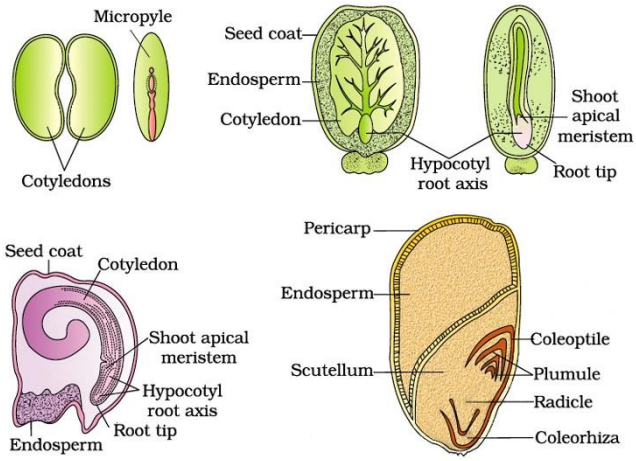
Monocotyledonous embryo

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



Seed from Ovule

- Seed is the fertilized ovule formed inside fruits. It is the final product of sexual reproduction.
- It consists of **seed coat(s), cotyledon(s) & an embryo axis.**
- The cotyledons are simple, generally thick and swollen due to storage food (as in legumes).
- Mature seeds are 2 types:
  - **Non-albuminous (Ex-albuminous) seeds:** Have no residual endosperm as it is completely consumed during embryo development. E.g. pea, groundnut, beans.
  - **Albuminous seeds:** Retain a part of endosperm. E.g. wheat, maize, barley, castor, coconut.
- Occasionally, in some seeds (black pepper, beet etc.) remnants of nucellus are also persistent. It is called **perisperm.**
- Integuments of ovules harden as tough protective seed coats. It has a small pore (micropyle) through which O_2 & water enter into the seed during germination.
- As the seed matures, it becomes dry by reducing water content (10-15 % moisture by mass). The metabolic activity of the embryo slows down. It may enter a state of inactivity **(dormancy).** Under favourable conditions (moisture, oxygen & suitable temperature), they germinate.



Structure of some seeds

Advantages of seeds:

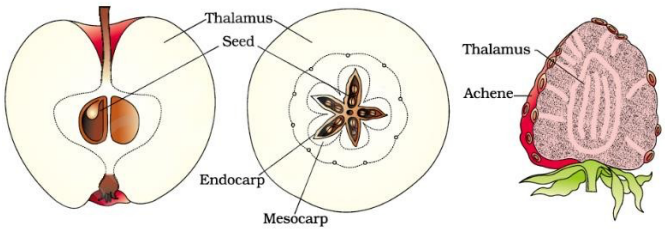
- Since pollination and fertilisation are independent of water, seed formation is more dependable.
- Better adaptive strategies for dispersal to new habitats. It helps the species to colonize in other areas.
- They have food reserves. So seedlings are nourished until they are capable of photosynthesis.
- The hard seed coat protects the young embryo.
- Being products of sexual reproduction, they generate new genetic combinations and variations.
- Dehydration & dormancy helps to store seeds. It can be used as food throughout year and to raise crop in next season.

Viability of seeds after dispersal:

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

Fruit from Ovary

- The ovary develops into a fruit. Transformation of ovules into seeds and ovary into fruit proceeds simultaneously.
- The wall of ovary develops into **pericarp** (wall of fruit).
- The fruits may be **fleshy** (e.g. guava, orange, mango, etc.) or **dry** (e.g. groundnut, mustard etc.).
- Fruits are 2 types:
  - **True fruits:** In this, fruit develops **only from the ovary.** Other floral parts degenerate & fall off. E.g. most plants.



False fruits of apple and strawberry

- **False fruits:** In this, the **thalamus** also contributes to fruit formation. E.g. apple, strawberry, cashew etc.

- In some species, fruits develop without fertilisation. Such fruits are called **parthenocarpic fruits.** E.g. Banana.
- Parthenocarpy can be induced through the application of growth hormones. Such fruits are seedless.

APOMIXIS AND POLYEMBRYONY

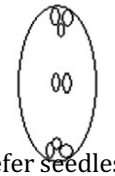
- **Apomixis** is the production of seeds without fertilisation. E.g. Some species of *Asteraceae* and grasses.
- It is a form of asexual reproduction that mimics sexual reproduction.
- In some species, diploid egg cell is formed without reduction division and develops into the embryo without fertilisation.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

Importance of apomixis in hybrid seed industry

- If the seeds collected from hybrids are sown, plants in the progeny will segregate and lose hybrid characters.
- Production of hybrid seeds is costly. So hybrid seeds are also expensive. If the hybrids are made into apomicts, there is no segregation in the hybrid progeny. So farmers can keep on using hybrid seeds to raise new crop.

MODEL QUESTIONS

1. Observe the relationship of the first two and fill in the blanks.
   (a) Radicle : coleorrhiza — Plumule : .....
   (b) m.m.c : microspore mother cell — PEN : .....
   (c) 2n : zygote — 3n : .....
   (d) Intine : Pectin — Exine : .....
   (e) Female gametophyte: Embryo sac — Male gametophyte: .....
2. In Angiosperms, the zygote is diploid while the endosperm in triploid. Discuss the events leading to the formation of diploid zygote and triploid endosperm.
3. Emasculation and bagging are two important steps in artificial hybridization. State the importance of both the processes in artificial hybridization.
4. The Petal of an angiosperm possesses 22 chromosomes. State the ploidy and chromosome number of the following structures supposed to be seen in the plant.
   (a) Coleoptile (b) Perisperm (c) Endosperm
   (d) Generative cell (e) Globular Embryo (f) Endosperm
5. Group the following parts into n, 2n, 3n
   Egg, synergids, PEN, pollen, embryo, nucellus, integuments, endosperm
6. Differentiate (a) Perisperm and Pericarp (b) Epicotyl and Hypocotyl
7. Observe the diagram



   (a) What is the structure shown here?
   (b) How many nuclei were in its younger stage?
   (c) What are the upper three nuclei together called?
8. "People prefer seedless fruits than seeded ones." Name a process concerned with development of seedless fruits.
9. Production of unisexual flowers in coconut prevents only autogamy, but in papaya it prevents both autogamy & geitonogamy. Justify.
10. Ibin says that "Apomixis is a boon to hybrid seed industry" Evaluate this statement and write your opinion.
11. Continuous self-pollination result in breeding depression in plants. List out devices by which cross pollination is encouraged in nature.
12. Apple is called a false fruit. Give reason. Which part of the flower forms the fruit?
13. Tender coconut has liquid endosperm inside it. But, when matured it has solid endosperm.
    (a) Mention the function of endosperm
    (b) Give the functional difference between liquid endosperm and solid endosperm.

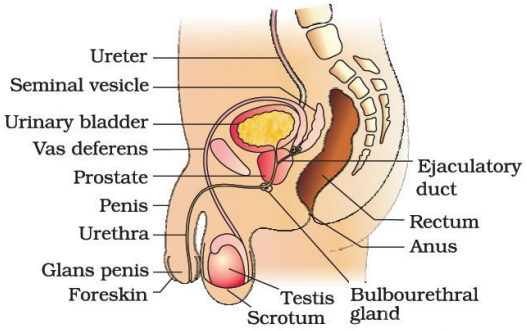
3. HUMAN REPRODUCTION

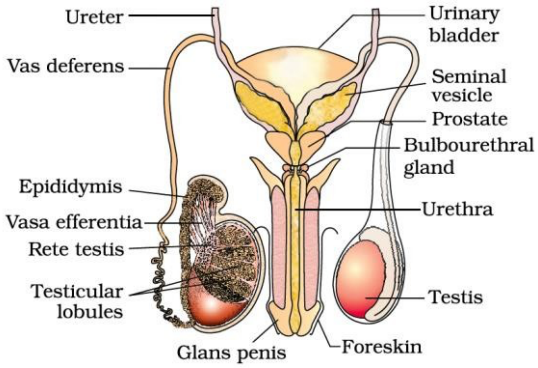
Reproduction is the production of young ones by an organism. Humans are sexually reproducing and viviparous.

HUMAN REPRODUCTIVE SYSTEM

1. Male Reproductive System

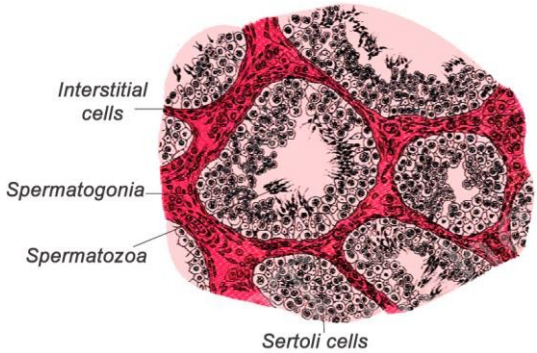
- It consists of **paired testes, Accessory ducts, Accessory glands & external genitalia (penis).**





a. Paired testes

- **Primary sex organs** that produce **sperms** & **testosterone.**
- Testes are formed within the abdomen. Soon after the birth or at the 8th month of pregnancy they descent into the **scrotal sac (scrotum)** through **inguinal canal**.
- The low temperature (2-2.5^0 C less than the body temperature) of scrotum helps for proper functioning of testes and for **spermatogenesis.**
- Each testis is oval shaped. Length 4-5 cm, width: 2-3 cm.
- Each testis has about 250 **testicular lobules**.
- Each lobule contains 1-3 coiled **seminiferous tubules.**
- Seminiferous tubule is lined internally with **spermatogonia (male germ cells) & Sertoli cells (supporting cells)**.
- Sertoli cells give shape and nourishment to developing spermatogonia.
- The regions outside the seminiferous tubules (interstitial spaces) contain small blood vessels, **interstitial cells (Leydig cells)** and immunologically competent cells.
- Leydig cells secrete testicular hormones **(androgens).**



b. Accessory ducts (Duct system)

- Include **rete testis, vasa efferentia, epididymis** & **vas deferens.** They conduct sperms from testis as follows:
- Seminiferous tubules → **rete testis** (irregular cavities) → **vasa efferentia** (series of fine tubules) → **epididymis** (stores sperms temporarily) → **vas deferens** → join with duct of **seminal vesicle** to form **ejaculatory duct** → **urethra** → **urethral meatus.**
- Urethra receives ducts of prostate and Cowper's glands.

c. Accessory glands

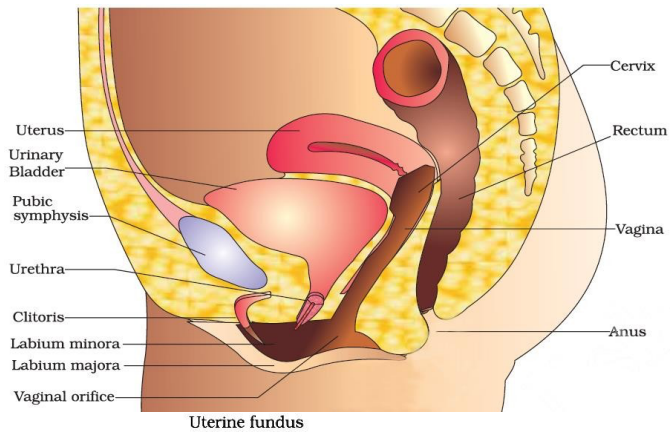
- Include a **prostate gland,** a pair of **seminal vesicles** and a pair of **Cowper's glands (bulbo-urethral glands).**
- Their collective secretion **(seminal plasma)** is rich in fructose, Ca and enzymes.
- Seminal plasma + sperms → **semen.**
- **Functions of seminal plasma:**
  - Helps for transporting sperms.
  - Supplies nutrients to sperms.
  - Provides alkalinity to counteract the acidity of uterus.
  - Secretions of Cowper's glands lubricate the penis.
- Secretions of epididymis, vas deferens, seminal vesicle & prostate help for maturation and motility of sperms.

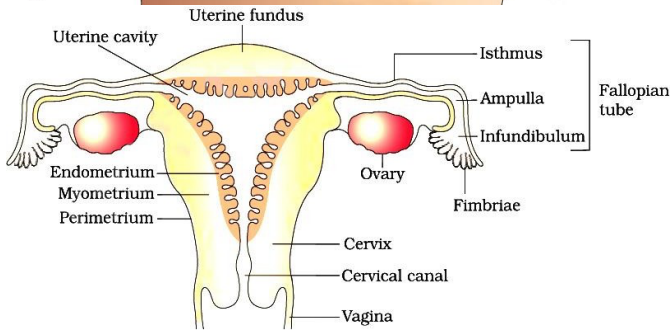
d. Penis (external genitalia)

- It is a **copulatory organ** made of erectile **spongy tissue.**
- When spongy tissue is filled with blood, the penis erects. It facilitates **insemination**.
- The cone-shaped tip of the penis is called **glans penis.** It is covered by **prepuce (foreskin).**

2. Female Reproductive System

It includes **Ovaries, Accessory ducts** & **External genitalia.**





a. Paired ovaries

- Primary sex organs which produce **ova (female gamete)** & steroid **ovarian hormones (estrogen & progesterone).**
- Each ovary is **2-4 cm** in length.
- They are located on both side of the lower abdomen and connected to the pelvic wall and uterus by ligaments.
- Each ovary is covered by a thin epithelium which encloses the **ovarian stroma.**
- The stroma has outer **cortex** and inner **medulla.**
- Ovary contains groups of cells (**Ovarian follicles).** Each follicle carries a centrally placed **ovum.**

b. Accessory ducts (Duct system)

Include 2 **oviducts (Fallopian tubes), a uterus** & **vagina.**

➢ **Oviducts:** Each oviduct (10-12 cm long) has 3 parts:
- **Infundibulum:** Funnel-shaped opening provided with many finger-like **fimbriae.** It helps to collect the ovum.
- **Ampulla:** Wider part.
- **Isthmus:** Narrow part. It joins the uterus.

The **ciliated epithelium** lined the lumen of the oviduct drives the ovum towards the uterus.

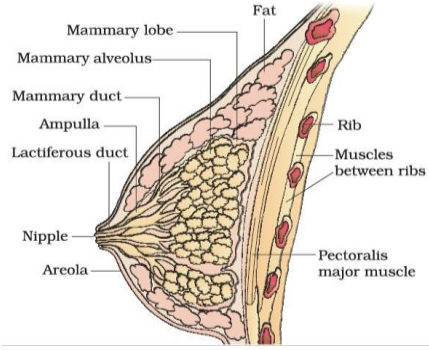
➢ **Uterus (womb)**: It is inverted pear shaped. It is supported by ligaments attached to the pelvic wall.
Uterus has 3 parts- Upper **fundus,** middle **body** and terminal **cervix.** Cervix opens to vagina.
Cervical canal and vagina forms **birth canal.**
The uterine wall has 3 layers:
- **Perimetrium**: External thin membrane.
- **Myometrium**: Middle thick layer of smooth muscle.
- **Endometrium**: Inner glandular and vascular layer.

➢ **Vagina:** It opens to the exterior between **urethra** & **anus.** The lumen of vagina is lined by a glycogen-rich mucous membrane consisting of **sensitive papillae** & **Bartholin's glands.** Bartholin's glands secrete mucus that lubricates the penis during sexual act.

c. External genitalia (vulva or pudendum)

- Consist of **Mons pubis, labia majora, labia minora, hymen & clitoris.**
- **Mons pubis:** A cushion of fatty tissue covered by pubic hair.
- **Labia majora**: Large, fleshy, fatty and hairy outer folds. Surrounds vaginal opening.
- **Labia minora**: Small, thin and hairless inner folds.
- **Hymen (Maiden head):** A membrane which partially cover the vaginal opening. It is often torn during the first coitus. It may also be broken by a sudden fall or jolt, insertion of a vaginal tampon; active participation in some sports items etc. In some women, hymen persists after coitus. So the hymen is not a reliable indicator of virginity or sexual experience.
- **Clitoris:** A highly sensitive organ lying just in front of the urethral opening.

Mammary glands (breasts)



- A pair of mammary glands contains glandular tissue & fat.
- Glandular tissue of each breast has 15-20 **mammary lobes** containing clusters of cells **(mammary alveoli).**
- Cells of alveoli secrete milk. It is stored in lumen of alveoli.
- The alveoli open into **mammary tubules.**
- The tubules of each lobe join to form a **mammary duct.**
- Several mammary ducts join to form a wider **mammary ampulla** which is connected to **lactiferous duct** through which milk is sucked out.

GAMETOGENESIS

- It is the formation of gametes in the gonads.
- It is 2 types: **Spermatogenesis** and **Oogenesis.**

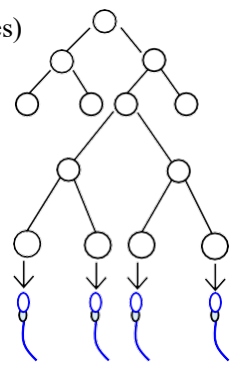
1. Spermatogenesis

It is the process of formation of sperms (spermatozoa) in seminiferous tubules of testis. It has 2 stages:

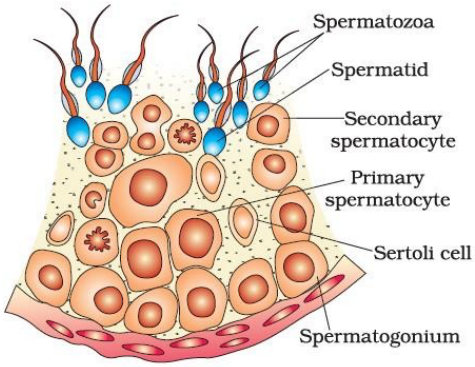
a. **Formation of spermatids:** In this, Sperm mother cells (Spermatogonia or male germ cells) produce spermatids.
b. **Spermiogenesis: Spermatids** transform into **sperm.**

Schematic representation of spermatogenesis

Spermatogonia -2n (46 chromosomes)
↓ *Mitosis differentiation*
Primary spermatocytes (2n)
↓ *1st meiotic division*
Sec. spermatocytes -n (23)
↓ *2nd meiotic division*
Spermatids (n)
↓ *Differentiation*
Spermatozoa (n)



- **4 spermatids** are formed from each primary spermatocyte.
- After spermiogenesis, sperm heads are embedded in Sertoli cells to get nourishment. Then they are released to lumen of seminiferous tubules. It is called **spermiation.**



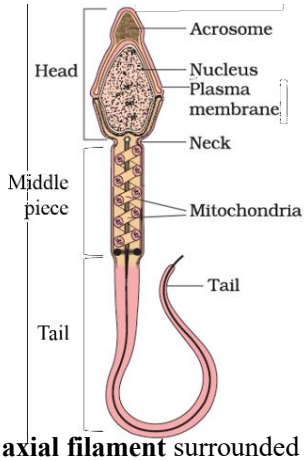
Diagrammatic sectional view of a seminiferous tubule

Role of Hormones in Spermatogenesis

- 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 acts on the **Leydig cells** and stimulates secretion of androgens. Androgens stimulate the spermatogenesis.
- FSH acts on the **Sertoli cells** and stimulates secretion of some factors for the spermiogenesis.

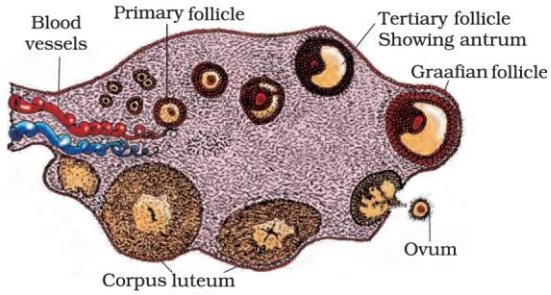
Structure of spermatozoa (Sperm)



- A mature sperm is about **60 µ (0.06 mm)** long.
- A plasma membrane envelops the whole body of sperm.
- A sperm has 3 regions:
  a. **Head:** Oval shaped. Formed of **nucleus** and **acrosome.** Acrosome is formed from **Golgi complex.** It contains **lytic enzymes.** Behind the head is a neck.
  b. **Middle piece:** Composed of **axial filament** surrounded by **mitochondria** & **cytoplasm.** Mitochondria produce energy for the sperm motility.
  c. **Tail:** Consists of a **central axial filament**. The sperm moves in fluid medium and female genital tract by the **undulating movement** of the tail.
- Man ejaculates **200-300 million sperms** during a coitus.
- For normal fertility, at least 60% sperms must have normal shape and size. 40% of them must show vigorous motility.

2. Oogenesis

- It is the process of formation and maturation of **ovum.**
- It takes place in **Graafian follicles.**



- Oogenesis is initiated in embryonic stage when 2 million of **egg mother cells (oogonia)** are formed within each ovary.
- No more oogonia are formed and added after birth.
- Oogonia multiply to form **primary oocytes.** They enter **prophase-I** of the meiosis and get temporarily arrested at that stage.
- Each primary oocyte gets surrounded by a layer of **granulosa cells** to form **primary follicle.**
- Many primary follicles degenerate during the phase from birth to puberty. Therefore, at puberty, only **60,000-80,000** primary follicles are left in each ovary.
- Primary follicles get surrounded by more layers of granulosa cells and a new **theca** to form **secondary follicles.**
- The secondary follicles transform into a **tertiary follicle.** It has a fluid filled cavity **(antrum).** The theca layer forms an inner **theca interna** and an outer **theca externa.**
- The primary oocyte in tertiary follicle grows and undergoes first unequal meiotic division to form a large **secondary oocyte (n)** & a tiny first **polar body (n).** So, secondary oocyte retains nutrient rich cytoplasm of primary oocyte.
- It is unknown that whether the first polar body divides further or degenerates.
- The tertiary follicle further changes into the **mature follicle (Graafian follicle).**
- Secondary oocyte forms a new membrane **(zona pellucida).**
- Graafian follicle now ruptures to release the **secondary oocyte (ovum)** from the ovary. This is called **ovulation.**

Schematic representation of oogenesis

Oogonia -2n (46 chromosomes)

↓ *Mitosis differentiation (at foetal stage)*

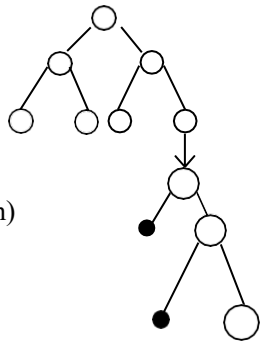
Primary oocyte- 2n (grows in size)

↓ *1st meiotic division (prior to ovulation)*

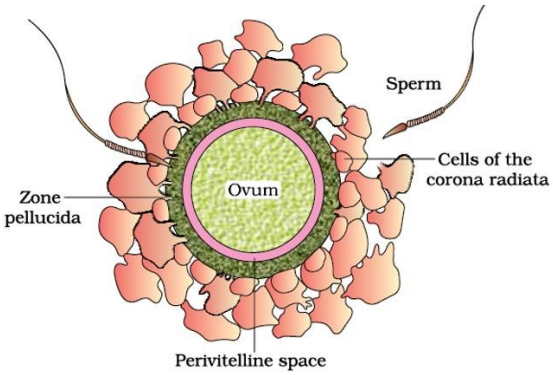
Sec. oocyte (n) & first polar body (n)

↓ *2nd meiotic division (during fertilization)*

Ovum (n) & second Polar body (n)



Structure of ovum (egg)



- Spherical and **non-motile.** About **0.2 mm** in diameter.
- Ovum has 3 membranes:
  a. **Plasma membrane:** Innermost layer.
  b. **Zona pellucida:** Outer to the plasma membrane.
  c. **Corona radiata:** Outer layer formed of follicle cells.

Spermatogenesis & Oogenesis- A comparison

Spermatogenesis	Oogenesis
Occurs in testis.	Occurs in ovary.
Limited growth phase.	Elaborated growth phase
Each primary spermatocyte gives 4 sperms.	Each primary oocyte gives one ovum.
No polar body formation.	Polar bodies are formed.
Begins at puberty and extends up to senility.	Begins at embryonic stage but suspends up to puberty. It ceases around the age of fifty.

MENSTRUAL CYCLE (REPRODUCTIVE CYCLE)

- It is the cyclic events starting from one menstruation till the next during the **reproductive period** (from puberty to menopause) of a woman's life.
- Its duration is **28 or 29 days.**
- Menstrual cycle is also seen in other primates.
- Menstrual cycle includes **Ovarian cycle** (changes in ovary) & **Uterine cycle** (changes in uterus, oviduct & vagina).
- Menstrual cycle has the following phases:

I. Menstrual phase: 1-5th day

- The cycle starts with **menstrual flow (bleeding).**
- It lasts for **3-5 days.**
- Menstruation occurs if the released ovum is not fertilized. It results in breakdown of endometrial lining and uterine blood vessels that comes out through vagina.
- Lack of menstruation indicates pregnancy. It may also be caused due to stress, poor health etc.
- **Menarche:** The first menstruation during puberty.

II. Follicular (Proliferative) phase: 5-13th day

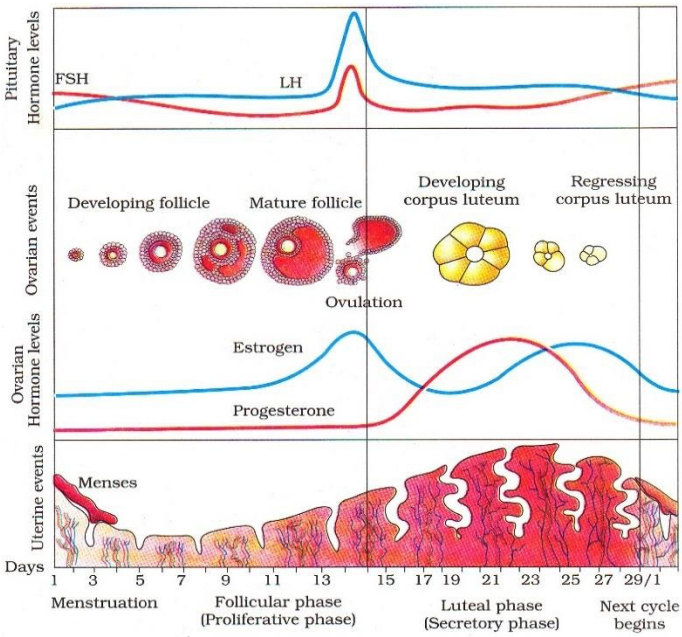
- It starts from **5th day** after menstruation and completed within **8-12 days.**
- In this phase, the action of gonadotropins **(FSH &LH)** from pituitary occurs. FSH stimulates
  - Development of primary follicles into **Graafian follicles.**
  - Secretion of **oestrogens** by **Graafian follicles.**
- Oestrogens stimulate
  - **Proliferation** of **ruptured uterine endometrium** and mucus lining of **oviduct & vagina**.
  - Development of secondary sexual characters.
  - Suppression of FSH secretion.
  - Secretion of LH (Luteinizing hormone).

III. Ovulatory phase: 14th day

- LH & FSH attain a peak level in the middle of cycle.
- Rapid secretion of LH (**LH surge**) induces rupture of Graafian follicle and thereby **ovulation** (on 14th day).

IV. Secretory (Luteal) phase: 15-28th day

- After ovulation, Graafian follicle is transformed to a yellow endocrine mass called **Corpus luteum.** It secretes **progesterone.**
- **Functions of progesterone:**
  - Makes the endometrium **maximum vascular, thick** and **soft.** Thus, the uterus gets ready for implantation.
  - Inhibits the FSH secretion to prevent development of a second ovarian follicle.
- If fertilization does not occur, corpus luteum degenerates. It causes disintegration of endometrium. It leads to next **menstruation** and new cycle.
- If a woman becomes pregnant, all events of menstrual cycle stop and there is no menstruation.
- Menstrual cycle ceases around **50 years** of age. It is called **Menopause.**



Menstrual hygiene:

- Take bath and clean body regularly.
- Use sanitary napkins or clean homemade pads.
- Change them after every 4–5 hrs as per the requirement.
- Dispose the used napkins or pads properly. Do not throw them in the drainpipe of toilets or in the open area.
- After handling the napkin, wash hands with soap.

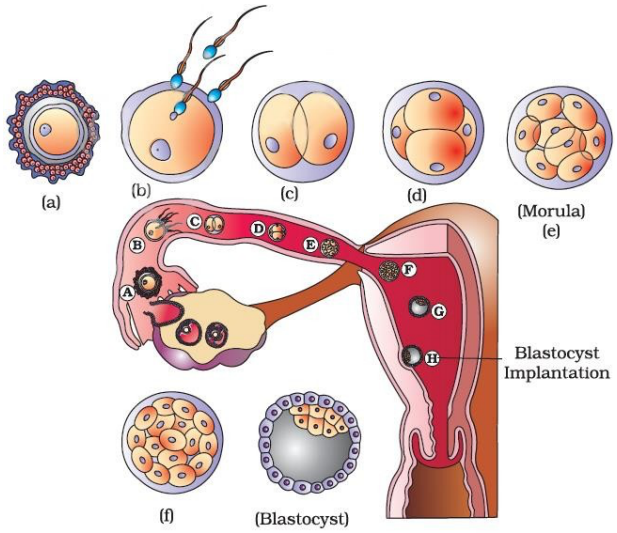
FERTILIZATION AND IMPLANTATION

- During copulation, semen is released by the penis into the vagina. It is called **insemination.**
- Fusion of a sperm with ovum is called **fertilization.** It occurs in **Ampullary region** of fallopian tube.

Sperms → vagina → cervical canal → uterus → isthmus
↓
Fertilization ← Ampullary region
↑
Ovum (from ovary) → fimbriae → infundibulum

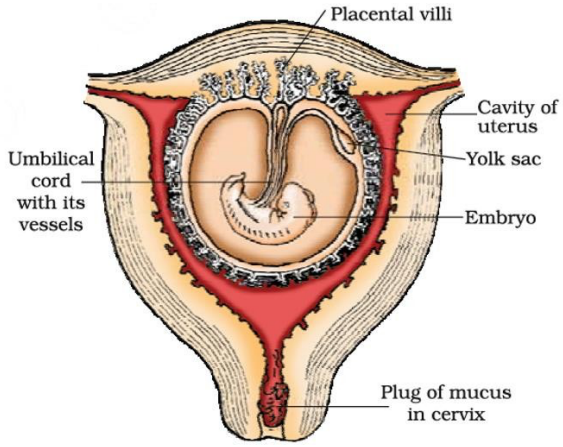
- Fertilization happens only if ovum & sperms are transported simultaneously. So all copulations do not lead to fertilization & pregnancy.
- A sperm contacts with **zona pellucida.** It induces changes in the membrane that block entry of additional sperms.
- The secretions of the **acrosome** help sperm to enter the egg cytoplasm via zona pellucida & plasma membrane. This causes second meiotic division of secondary oocyte to form an **ovum (ootid)** and a **second polar body.**
- The haploid nuclei of the sperm and ovum fuse together to form a **diploid zygote.**
- Zygote undergoes mitotic division **(cleavage)** as it moves through the isthmus towards the uterus and forms 2, 4, 8, 16 daughter cells called **blastomeres.**
- The embryo with 8-16 blastomeres is called a **morula.**
- Morula continues to divide and transforms into **blastocyst.**
- In blastocyst, blastomeres are arranged into **trophoblast** (outer layer) and an **inner cell mass** attached to trophoblast.

- The trophoblast layer gives nourishment to inner cell mass. Also, it gets attached to endometrium.
- After attachment, uterine cells divide rapidly and cover the blastocyst. Thus, the blastocyst becomes embedded in the endometrium. This is called **implantation.**
- The inner cell mass gets differentiated to **3 germ layers** (outer **ectoderm,** middle **mesoderm** & inner **endoderm).** This 3-layered structure **(gastrula)** forms the embryo.



PREGNANCY AND EMBRYONIC DEVELOPMENT

- After implantation, finger-like projections **(chorionic villi)** appear on the trophoblast.
- They are surrounded by uterine tissue and maternal blood.
- The chorionic villi & uterine tissue are interdigitated to form **placenta.** It is a structural and functional unit b/w embryo (foetus) and maternal body.
- Placenta is connected to the embryo by an **umbilical cord.** It transports substances to and from the embryo.



Functions of placenta

- Acts as **barrier** between the foetus and mother.
- Supply **O_2, nutrients** etc. from mother to foetus.
- Remove **CO_2 and excretory wastes** from foetus.
- Acts as an endocrine gland. It secretes **Human chorionic gonadotropin (hCG), human placental lactogen (hPL), oestrogens, progesterone** & **relaxin.** Relaxin is also secreted by ovary.
- During pregnancy, levels of **estrogens, progestogens, cortisol, prolactin, thyroxin** etc. are also increased in maternal blood. They support the fetal growth, metabolic changes in the mother and maintain pregnancy.
- The germ layers give rise to all tissues (organs). The **stem cells** in inner cell mass have the potency to give rise to all the tissues and organs.
- Human pregnancy **(gestation period)** lasts 9 months (for cats: 2 months, dogs: 2 months, elephants: 21 months).

Changes in embryo during pregnancy

- **After one month:** Heart is formed.
- **End of second month:** Limbs and digits are developed.
- **End of 12 weeks (first trimester):** Major organs (limbs, external genital organs etc.) are well developed.
- **During 5th month:** First movement of foetus and appearance of hair on the head.
- **End of 24 weeks (end of 2nd trimester):** Body is covered with fine hair, eyelids separate and eye lashes are formed.
- **End of 9 months:** Ready for delivery.

PARTURITION AND LACTATION

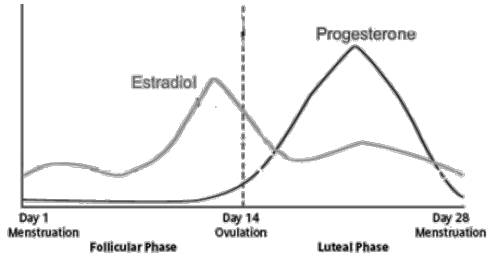
- **Parturition (labour):** Process of giving birth to young ones.
- Parturition is induced by **neuroendocrine mechanism.**
- The signals originating from the foetus and placenta induce mild uterine contractions **(fetal ejection reflex)**. This causes the release of **oxytocin** from **maternal pituitary.**
- Oxytocin causes stronger uterine muscle contractions which in turn stimulate further secretion of oxytocin. This process is continued leading to expulsion of the baby out of the uterus through the **birth canal.**
- After parturition, the **umbilical cord** is cut off.
- The placenta & remnants of umbilical cord are expelled from the maternal body after parturition. It is called **"after birth".**
- The mammary glands produce milk towards the end of pregnancy. It is called **lactation.**
- The yellowish milk produced during the initial few days of lactation is called **colostrum.** It contains several antibodies essential to develop resistance for the new born babies.

MODEL QUESTIONS

1. Odd man out. Justify your answer.
   a. Prostate, rete testis, vas deferens, hymen b. Infundibulum, clitoris, ampulla, isthmus
2. Note the relationship between the first two terms and fill the fourth place.
   a. Graafian follicles: ovum Seminiferous tubules: ……..
   b. Leydig cells: testosterone Corpus luteum: ……..
   c. First menstruation: Menarche Stopping of menstrual cycle: ……..
   d. Follicular phase: 5-13th day Ovulatory phase: ……
3. Arrange in correct sequence of sperm conduction.
   Vasa efferentia, urethral meatus, vas deferens, common ejaculatory duct, urethra, Rete testis, epididymis
4. Rearrange the following in correct sequence:
   Mammary tubules → mammary alveoli → lactiferous duct → mammary ampulla → mammary duct
5. Match the following

A	B	C
Spermatogenesis	Formation of ovum	Follicle cells
Spermiogenesis	Sperm head embedded in Sertoli cells	Starts from spermatogonia
Spermiation	Formation of sperms	Differentiation of sperms
Oogenesis	Spermatids to sperms	Release of sperms to lumen of seminiferous tubules

6. One ml of semen contains about 120 million sperms
   a. Name the functional unit of testis b) Mention the importance of scrotal sac in spermatogenesis
7. Prepare a flowchart explaining the process of spermatogenesis/ oogenesis.
8. The number of primary spermatocytes and primary oocytes are 200 and 50 respectively. What will be the number of sperms and ova formed?
9. A human ovum is released on the 14th day of menstrual cycle
   a) What happens to the ovum if it is fertilized by a sperm? b) Where does the fertilization occur?
   c) What will happen to the Graafian follicles if the ovum is fertilized?
10. Observe the given graphical representation of menstrual cycle.



   a. By considering a pregnant lady, redraw the graph.
   b. Compare the hormonal differences between a normal and pregnant lady.
11. Match the following

A	B	C
Formation of male gametes	Ovulation	Fallopian tube
Release of egg	Parturition	Seminiferous tubules
Fusion of sperm and ovum	Spermatogenesis	Uterus
Giving birth to young one	Fertilization	Ovary

12. Give reason:
    a) Ovulation does not take place during gestation period.
    b) All copulations do not lead to fertilization & pregnancy.
    c) The yellowish milk produced during the initial few days of lactation is essential for new born babies.
13. Placenta makes the intimacy between mother and foetus.
    a) What is placenta? b) In what ways it makes intimacy with foetus?
    c) Name the portions of foetal and maternal parts of placenta.
    d) It can act as an endocrine gland. Can you agree? Why?
14. Select the correct sequence:
    a) Zygote → blastocyst → morula → gastrula → foetus b) Zygote → gastrula → morula → blastocyst → foetus
    c) Zygote → morula → gastrula → blastocyst → foetus d) Zygote → morula → blastocyst → gastrula → foetus

4. REPRODUCTIVE HEALTH

According to **World Health Organisation (WHO),** ***Reproductive health*** *is a total well-being in all aspects of reproduction i.e., physical, emotional, behavioural & social.*

REPRODUCTIVE HEALTH: PROBLEMS & STRATEGIES

India initiated reproductive health programmes **(family planning)** in 1951.

Wider reproduction-related areas are in operation under the **Reproductive & Child Health Care (RCH) programmes.**

Such programmes deal the following:

- Give awareness about reproduction related aspects for creating a reproductively healthy society.
- Educate people about birth control, care of pregnant mothers, post-natal care of mother and child, importance of breast feeding, equal opportunities for male & female child etc.
- Awareness of problems due to population explosion, social evils like sex-abuse and sex-related crimes, etc.

Aims and needs of sex education in schools

- To provide right information about sex-related aspects. It helps to avoid sex-related myths and misconceptions.
- To give proper information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS etc.

POPULATION STABILIZATION & BIRTH CONTROL

- In **1900,** world population was about **2 billion**. By **2000,** it rocketed to about **6 billion** and **7.2 billion in 2011.**
- In India, population was nearly **350 million** at the time of independence. It reached **1 billion by 2000** and crossed **1.2 billion** in **May 2011.** It means every sixth person in the world is an Indian.
- According to the 2011 census report, our population growth rate was less than **2%** (i.e. 20/1000/year), a rate at which our population could increase rapidly.

Reasons for population explosion

- Increased health facilities and better living conditions.
- Rapid decline in death rate, **maternal mortality rate (MMR)** and **infant mortality rate (IMR).**
- Increase in number of people in reproducible age.

Impacts of population explosion

Scarcity of basic requirements (e.g. food, shelter & clothing).

Control measures

- Motivate smaller families by using **contraceptive methods.**
- Aware peoples about a slogan ***Hum Do Hamare Do*** **(we two, our two).** Many couples have adopted a **'one child norm'.**
- Statutory rising of marriageable age of females (18 years) and males (21 years).

Properties of an ideal contraceptive

- User-friendly, easily available, effective and reversible.
- No or least side-effects.
- It should not interfere with sexual drive, desire & sexual act.

CONTRACEPTIVE METHODS

1. Natural/Traditional methods

Avoid chances of ovum and sperms meeting. It includes

- **Periodic abstinence:** Avoid coitus from day 10 to 17 of the menstrual cycle **(fertile period)** to prevent conception.
- **Coitus interruptus (withdrawal):** Withdraw penis from the vagina just before ejaculation to avoid insemination.
- **Lactational amenorrhea:** It is the absence of menstrual cycle & ovulation due to intense lactation after parturition. Fully breastfeeding increases lactation. This method helps to prevent conception. This is effective up to 6 months following parturition.

  It has no side effect. But chances of failure are high.

2. Barriers

They prevent physical meeting of sperm & ovum. E.g.

- **Condoms (E.g. Nirodh):** Made of rubber/latex sheath.

  Condoms for male: Cover the penis.

  Condoms for female: Cover the vagina & cervix.

  Condoms are used just before coitus. They prevent the entry of semen into female reproductive tract.

  Condoms are very popular because:
  - It protects the user from STDs and AIDS.
  - Easily available and disposable.
  - It can be self-inserted and thereby give privacy to user.
- **Diaphragms, cervical caps** and **vaults:**
  - Made of rubber and are inserted into the female reproductive tract to cover the cervix during coitus.
  - They block the entry of sperms through the cervix.
  - They are reusable.
  - **Spermicidal creams, jellies & foams** are used along with these barriers to increase contraceptive efficiency.

3. Intra Uterine Devices (IUDs)

These are inserted by doctors or nurses in the uterus through vagina. They increase phagocytosis of sperms.

IUDs are ideal method to delay pregnancy or space children.

Types of IUDs:

- **Non-medicated IUDs:** They retard sperm motility. Also have spermicidal effect. E.g. Lippes loop.
- **Copper releasing IUDs:** Cu ions suppress motility and fertilising capacity of sperms. E.g. CuT, Cu7, Multiload 375.
- **Hormone releasing IUDs**: They make the uterus unsuitable for implantation and the cervix hostile to the sperms. E.g. Progestasert, LNG-20.

4. Oral contraceptives

- Oral administration of **progestogens** or **progestogen–oestrogen** combinations in the form of tablets **(pills)**.
- Pills are taken daily for 21 days starting within the first five days of menstrual cycle. After a gap of 7 days (menstruation period), it should be repeated in the same pattern till the female desires to prevent conception.
- They inhibit ovulation and implantation and thicken cervical mucus to prevent entry of sperms.
- Pills are very effective with lesser side effects.

- ***Saheli:*** New oral contraceptive for the females. It is developed by **Central Drug Research Institute (CDRI)** in **Lucknow.** It contains a non-steroidal preparation. It is a 'once a week' pill with very few side effects and high contraceptive value.

5. Injectables

- Progestogens or Progestogens-oestrogen combination are used by females as **injections** or **implants** under skin.
- Their mode of action is like that of pills and their effective periods are much longer.

Progestogens *or* ***progestogen-oestrogen*** *combinations &* ***IUDs*** *are used as* ***emergency contraceptives*** *within 72 hours of coitus. It avoids pregnancy due to rape or casual intercourse.*

6. Surgical methods (sterilization)

- It helps to block gamete transport and thereby prevents conception. It is very effective but reversibility is poor.
- **Vasectomy:** Sterilization procedure in males. In this, a small part of the vas deferens is removed or tied up through a small incision on the scrotum.
- **Tubectomy:** Sterilization procedure in females. In this, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.

Side effects of anti-natural contraceptives:

Nausea, abdominal pain, breakthrough bleeding, irregular menstrual bleeding, breast cancer etc.

MEDICAL TERMINATION OF PREGNANCY (MTP)

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

Importance of MTP

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

MTPs are safe during the **first trimester,** (up to 12 weeks of pregnancy). 2nd trimester abortions are very risky.

Problems related with MTPs

- Majority of the MTPs are performed illegally.
- Misuse of **amniocentesis** test for foetal sex determination. If the foetus is female, it is followed by MTP. Such practices are dangerous for the young mother and foetus.

Amniocentesis: In this, some amniotic fluid of the foetus is taken to analyse the foetal cells & dissolved substances. It is used to test the presence of genetic disorders, survivability of the foetus etc.

Government of India enacted **The Medical Termination of Pregnancy (Amendment) Act, 2017** to reduce illegal abortion and consequent maternal mortality and morbidity. According to this Act, a pregnancy may be terminated within the first 12 weeks on the opinion of a registered medical practitioner. If the pregnancy is between 12 - 24 weeks, two registered medical practitioners must be of the opinion.

SEXUALLY TRANSMITTED DISEASES (STDs)

- Diseases or infections transmitted through sexual intercourse are called **Sexually transmitted diseases/infections (STDs or STIs)/Venereal diseases (VD) or Reproductive tract infections (RTI).** E.g. Gonorrhoea, syphilis, genital herpes, genital warts, trichomoniasis, hepatitis-B & AIDS.
- Hepatitis-B & HIV are also transmitted
  - By sharing of injection needles, surgical instruments etc.
  - By transfusion of blood.
  - From infected mother to foetus.
- Except hepatitis-B, genital herpes & HIV, other diseases are completely curable if detected early and treated properly.
- **Early symptoms**: Itching, fluid discharge, slight pain, swellings, etc. in the genital region.
- Absence or less significant early symptoms and the social stigma deter the infected persons to consult a doctor. This leads to **pelvic inflammatory diseases (PID),** infertility, chlamydiasis, cancer of the HIV leading to reproductive tract etc.
- All persons are vulnerable to STDs. These are very high among persons in the age group of 15-24 years.
- **Prevention:**
  i. Avoid sex with unknown partners/multiple partners.
  ii. Always use condoms during coitus.
  iii. In case of doubt, go to a qualified doctor for early detection and get complete treatment.

INFERTILITY

- It is the inability to conceive or produce children even after 2 years of unprotected sexual cohabitation.
- The reasons for this may be physical, congenital, diseases, drugs, immunological or even psychological.

ASSISTED REPRODUCTIVE TECHNOLOGIES (ART)

These are the technologies used to correct the infertility problems. Some of them are given below:

1. *In vitro* fertilisation (IVF) or Test tube baby programme

In this method, ova from the wife/donor and sperms from the husband/donor are collected and are induced to form zygote under simulated conditions in the laboratory. This is followed by **Embryo transfer (ET).**

ET is 2 types:

- **Zygote Intra Fallopian Transfer (ZIFT):** Transfer of zygote or early embryo (with up to 8 blastomeres) into fallopian tube.
- **Intra Uterine Transfer (IUT):** Transfer of embryo with more than 8 blastomeres into the uterus.

Embryo formed by ***in vivo*** **fertilisation** (fertilisation within the female) is also used for such transfer to assist those females who cannot conceive.

2. Gamete Intra Fallopian Transfer (GIFT)

Transfer of an ovum from a donor into the fallopian tube of another female who cannot produce ovum, but can provide suitable environment for fertilization and development.

3. Intra cytoplasmic sperm injection (ICSI)

It is a laboratory procedure in which a single sperm (from male partner) is injected directly into an egg (from female partner). After fertilization, the embryo is implanted into the woman's uterus.

4. Artificial insemination (AI) technique

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

Problems of ART

- It requires specialized professionals and expensive instrumentation. Therefore, these facilities are available only in very few centres.
- Emotional, religious and social problems.

Legal adoption is a good method for couples looking for parenthood.

MODEL QUESTIONS

1. Is sex education necessary in school? Justify your answer.
2. Removal of gonads cannot be considered as contraceptive method. Why?
3. Match the following

A	B	C
Lactational amenorrhea	Vasectomy	'Once a week'
IUD	*Saheli*	Breastfeeding
Sterilization	Natural method	Lippes loop
Oral contraceptive	Inserts in uterus	Reversibility is poor

4. Note the relationship between the first two words and fill up the fourth place
   a. Male: vasectomy — Female: ……
   b. LNG-20: Hormone releasing IUD — Multiload 375: ……..
   c. IUD: Intra-uterine device — IUI: ……..
5. Condoms are more popular than other contraceptive devices. Give reasons (any 4)
6. Consider the following contraceptive methods.
   Lactational amenorrhea, Condoms, Oral contraceptive pills
   a) Which method, in your opinion, is more desirable? Why?
   b) Mention 2 methods of contraception like Lactational amenorrhea. What is the advantage ofthese methods?
7. Match the following

A	B	C
ZIFT	More than 8 blastomeres	Direct injection of sperm into egg
GIFT	Very low sperm count	Embryo to oviduct
IUT	Up to 8 blastomeres	Ovum to oviduct
ICSI	Transfer of egg	Uterus

8. Expand the following
   a) IVF b) ZIFT c) GIFT d) ICSI
9. "Female foeticide is very high in India. So MTP (Induced abortion) must be completely banned". Do you agree with this statement? Why?
10. Anil said that IUD, IUT and IUI are the three methods of ART.
    a. Do you agree with this statement? Justify. b. Expand the above abbreviations.
11. A person is affected with itching, fluid discharge, swelling etc. in his genital region. But he did not consult a doctor.
    a. Mention the type of disorder affected him.
    b. Can you give any advice to him about the importance of consulting the doctor?
    c. How to prevent such type of diseases?

5. PRINCIPLES OF INHERITANCE AND VARIATION

IMPORTANT TERMS

- **Genetics:** Study of inheritance, heredity and variation of characters or Study of genes and chromosomes.
- **Inheritance:** Transmission of characters from parents to progeny. It is the basis of **Heredity**.
- **Variation:** Difference between parents and offspring.
- **Character:** A heritable feature among the parents & offspring. E.g. Eye colour.
- **Trait:** Variants of a character. E.g. Brown eye, Blue eye.
- **Allele:** Alternative forms of a gene. E.g. T (tall) and t (dwarf) are two alleles of a gene for the character height.
- **Homozygous:** The condition in which chromosome pair carries similar alleles of a gene. Also known as **pure line (True breeding).** E.g. TT, tt, YY, yy etc.
- **Heterozygous:** The condition in which chromosome pair carries dissimilar alleles of a gene. E.g. Tt, Yy etc.
- **Dominant character:** The character which is expressed in heterozygous condition. It indicates with capital letter.
- **Recessive character:** The character which is suppressed in heterozygous condition. It indicates with small letter.
- **Phenotype:** Physical expression of a character.
- **Genotype:** Genetic constitution of a character.
- **Hybrid:** An individual produced by the mating of genetically unlike parents.
- **Punnett square:** A graphical representation to calculate probability of all genotypes of offspring in a genetic cross.

MENDEL'S LAWS OF INHERITANCE

Gregor Mendel is the Father of genetics.
He conducted some hybridization experiments on **garden peas (*Pisum sativum*)** for 7 years (1856-1863).

Steps in making a cross (Deliberate mating) in pea:

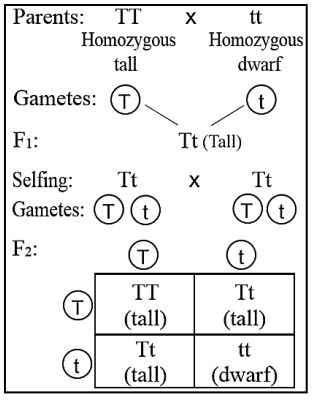
- **Selection** of 2 pea plants with contrasting characters.
- **Emasculation:** Removal of anthers of one plant to avoid self-pollination. This is female parent.
- **Pollination:** Collection of pollen grains from the male parent and transferring to female parent.
- **Collection & germination** of seeds to produce offspring.

Mendel selected 7 pairs of true breeding pea varieties:

7 Characters	Contrasting Traits	
	Dominant	Recessive
1. Stem height	Tall	Dwarf
2. Flower colour	Violet	White
3. Flower position	Axial	Terminal
4. Pod shape	Inflated	Constricted
5. Pod colour	Green	Yellow
6. Seed shape	Round	Wrinkled
7. Seed colour	Yellow	Green

INHERITANCE OF ONE GENE

Monohybrid cross: A cross involving 2 plants differing in one character pair. E.g. Mendel crossed tall and dwarf pea plants to study the inheritance of one gene.



Monohybrid phenotypic ratio:
3 Tall: 1 Dwarf = **3:1**

Monohybrid genotypic ratio:
1 Homozygous tall (TT)
2 Heterozygous tall (Tt)
1 Homozygous dwarf (tt)
= **1:2:1**

Mendel made similar observations for other pairs of traits. He proposed that some **factors** were inherited from parent to offspring. Now it is called as **genes**.

> Do not use ***T*** for tall and ***d*** for dwarf because it is difficult to remember whether ***T*** & ***d*** are alleles of same gene or not.

The F_1 (Tt) when self-pollinated, produces gametes **T** and **t** in equal proportion. During fertilization, pollen grains of **T** have **50%** chance to pollinate eggs of **T** & **t**. Also, pollen grains of **t** have **50%** chance to pollinate eggs of **T** and **t.**
$1/4^{th}$ of the random fertilization leads to TT (¼ TT).
1/2 (2/4) of the random fertilization leads to Tt (½ Tt).
$1/4^{th}$ of the random fertilization leads to tt (¼ tt).

Tt x Tt

Binomial expression = $(ax + by)^2$

Hence $(½\ T + ½\ t)^2$ = (½ T + ½ t) (½ T + ½ t)

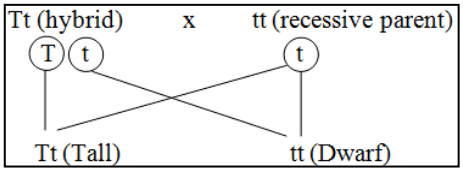
= ¼ TT + ¼ Tt + ¼ Tt + ¼ tt

= ¼ TT + ½ Tt + ¼ tt

Mendel self-pollinated the F_2 plants. He found that dwarf F_2 plants continued to generate dwarf plants in F_3 & F_4. He concluded that genotype of the dwarfs was homozygous- ***tt***.

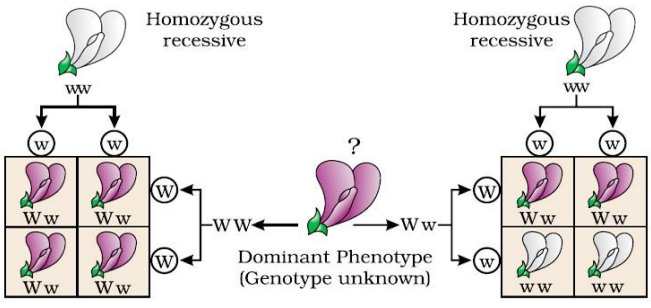
Backcross and Testcross

- **Backcross:** Cross between a hybrid and its any parent.
- **Testcross:** Crossing of an organism with dominant phenotype to a recessive individual. E.g.



Hence monohybrid test cross ratio= **1:1**

Test cross is used to find out the unknown genotype of a character. E.g.



All violet: Unknown flower is homozygous dominant

50% violet, 50% white: Unknown flower is heterozygous

Mendel conducted **test cross** to determine the F_2 genotype.

Mendel's Principles or Laws of Inheritance

1. First Law (Law of Dominance)

- *Characters are controlled by discrete units called* ***factors.***
- *Factors occur in pairs.*
- *In a dissimilar pair of factors, one member of the pair dominates* ***(dominant)*** *the other* ***(recessive).***

2. Second Law (Law of Segregation)

"During gamete formation, the factors (alleles) of a character pair present in parents segregate from each other such that a gamete receives only one of the 2 factors".

Homozygous parent produces similar gametes. Heterozygous parent produces two kinds of gametes.

INHERITANCE OF TWO GENES

Dihybrid cross: It is a cross between two parents differing in 2 pairs of contrasting characters. E.g. Cross b/w pea plant with homozygous round shaped & yellow coloured seeds (RRYY) and wrinkled shaped & green coloured seeds (rryy).

Parents: RRYY X rryy

Gametes: (RY) (ry)

F_1: RrYy (Round yellow)

Selfing: RrYy X RrYy

Gametes: (RY) (Ry) (rY) (ry) (RY) (Ry) (rY) (ry)

F_2:

	(RY)	(Ry)	(rY)	(ry)
(RY)	RRYY *Ro. Yel*	RRYy *Ro. Yel*	RrYY *Ro. Yel*	RrYy *Ro. Yel*
(Ry)	RRYy *Ro. Yel*	RRyy *Ro. Gr*	RrYy *Ro. Yel*	Rryy *Ro. Gr*
(rY)	RrYY *Ro. Yel*	RrYy *Ro. Yel*	rrYY *Wri. Yel*	rrYy *Wri. Yel*
(ry)	RrYy *Ro. Yel*	Rryy *Ro. Gr*	rrYy *Wri. Yel*	rryy *Wri. Gr*

On observing the F_2, Mendel found that yellow and green colour segregated in a 3:1 ratio.

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

Dihybrid Phenotypic ratio= 9 Round yellow: 3 Round green: 3 Wrinkled yellow: 1 Wrinkled green = **9:3:3:1**

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

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

Dihybrid genotypic ratio: 1:2:1:2:4:2:1:2:1

RRYY	=1	RRYy	=2	RrYY	=2
RrYy	=4	RRyy	=1	Rryy	=2
rrYY	=1	rrYy	=2	rryy	=1

Mendel's 3rd Law: Law of Independent Assortment

- It is based on the results of dihybrid crosses.
- It 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".*

The concept of dominance

- Every gene contains information to express a particular trait.
- In heterozygotes, there are 2 types of alleles:
  - ***Unmodified (normal or functioning) allele:*** It is generally dominant and represents original phenotype.
  - ***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
  - (i) Normal/less efficient enzyme or
  - (ii) A non-functional enzyme or
  - (iii) No enzyme at all

In the first case: The modified allele will produce the same phenotype like unmodified allele. 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.

OTHER PATTERNS OF INHERITANCE (NON-MENDELIAN INHERITANCE)

1. Incomplete Dominance

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

Parents: RR x rr (Red flowered, White flowered)

Gametes: (R) (r)

F_1: Rr (Pink)

Selfing: Rr x Rr

Gametes: (R) (r) (R) (r)

F_2:

	(R)	(r)
(R)	RR (Red)	Rr (Pink)
(r)	Rr (Pink)	rr (White)

Here, cross between homozygous **red** & **white** produces **pink** flowered plant. Thus phenotypic & genotypic ratios are same.

Phenotypic ratio=

1 Red: 2 Pink: 1 White

Genotypic ratio=

1 (RR): 2 (Rr): 1(rr)

This means that **R** was not completely dominant over **r**.

- Pea plants also show incomplete dominance in other traits.

2. Co-dominance

- It is the inheritance in which both alleles of a gene are expressed in a hybrid. E.g. ABO blood grouping in human.
- ABO blood groups are controlled by the gene **I**.
- This gene controls the production of **sugar polymers (antigens)** that protrude from plasma membrane of RBC.
- The gene **I** has three alleles I^A, I^B & **i**.
- I^A and I^B produce a slightly different form of the sugar while allele **i** doesn't produce any sugar.

Alleles from parent 1	Alleles from parent 2	Genotype of offspring	Blood types (phenotype)
I^A	I^A	$I^A I^A$	A
I^A	I^B	$I^A I^B$	AB
I^A	i	I^Ai	A
I^B	I^A	$I^A I^B$	AB
I^B	I^B	$I^B I^B$	B
I^B	i	I^Bi	B
i	i	ii	O

When I^A and I^B are present together, they both express their own types of sugars. This is due to **co-dominance.**

3. Multiple allelism

- It is the presence of **more than two alleles** of a gene to govern same character.
- E.g. ABO blood grouping (3 alleles: I^A, I^B & i).
- In an individual, only two alleles are present. Multiple alleles can be found only in a population.

4. 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 considers the influence of environment.
- In a polygenic trait, the phenotype reflects the contribution of each allele, i.e., the effect of each allele is additive.

Human skin colour:

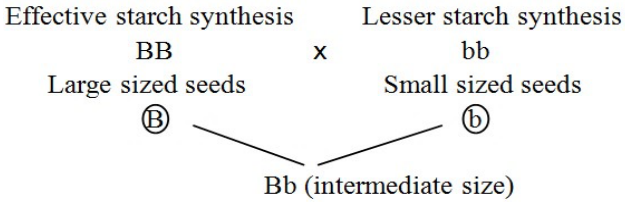
- Assume that 3 genes A, B, C control human skin colour. The dominant forms **A, B & C** responsible for **dark skin** colour and recessive forms **a, b & c** for **light skin** colour.
- Genotype with all the dominant alleles **(AABBCC)** gives **darkest skin** colour.
  Genotype with all the recessive 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.

5. Pleiotropy

- Here, a single gene exhibits multiple phenotypic expressions. Such a gene is called **pleiotropic gene.**
- In most cases, the mechanism of pleiotropy is the effect of a gene on metabolic pathways which contributes towards different phenotypes.
- E.g. Starch synthesis in pea, sickle cell anaemia, phenylketonuria etc.
- In Phenylketonuria & sickle cell anaemia, the mutant gene has many phenotypic effects. E.g. Phenylketonuria causes mental retardation, reduction in hair and skin pigmentation.

Starch synthesis in pea plant:

- Starch is synthesized effectively by **BB** gene. Therefore, large starch grains are produced. **bb** have lesser efficiency in starch synthesis and produce smaller starch grains.
- Starch grain size also shows **incomplete dominance.**



CHROMOSOMAL THEORY OF INHERITANCE

Mendel's work remained unrecognized till 1900 because,

- Communication was not easy.
- His mathematical approach was new and unacceptable.
- The concept of genes (factors) as stable and discrete units could not explain the continuous variation seen in nature.
- He could not give physical proof for the existence of factors.

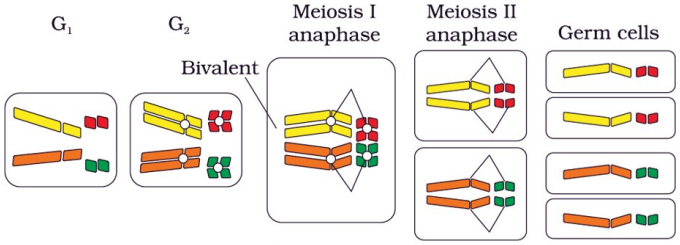
In 1900, **de Vries, Correns** & **von Tschermak** independently rediscovered Mendel's results.

Chromosomal Theory of Inheritance (1902):

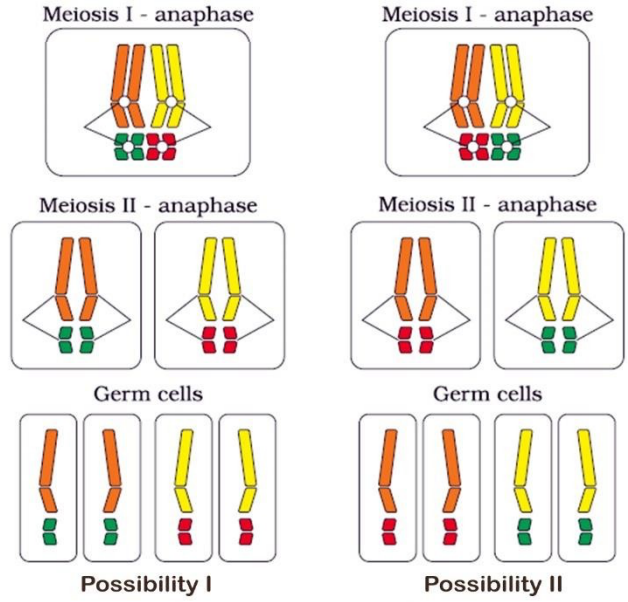
- Proposed by **Walter Sutton** & **Theodore Boveri.**
- They said that pairing & separation of a pair of chromosomes lead to segregation of a pair of factors they carried.
- **Sutton** united chromosomal segregation with Mendelian principles and called it the **chromosomal theory of inheritance**. It states that,

- Chromosomes are **vehicles of heredity.**
- Two identical chromosomes form a **homologous pair.**
- Homologous pair **segregates** during gamete formation.
- Independent pairs **segregate independently** of each other.

Genes (factors) are present on chromosomes. Hence genes and chromosomes show similar behaviours.



Segregation of chromosomes



Independent assortment of chromosomes

Thomas Hunt Morgan proved chromosomal theory of inheritance using fruit flies (***Drosophila melanogaster)***.

It is the suitable material for genetic study because,

- They can grow on simple synthetic medium.
- Short generation time (life cycle: 12-14 days).
- Breeding can be done throughout the year.
- Hundreds of progenies per mating.
- Male and female flies are easily distinguishable. E.g. Male is smaller than female.
- It has many types of hereditary variations that can be seen with low power microscopes.

LINKAGE AND RECOMBINATION

Linkage is the physical association of two or more genes on a chromosome. They do not show independent assortment.

Recombination is the generation of non-parental gene combinations. It occurs due to independent assortment or crossing over.

Morgan carried out several dihybrid crosses in ***Drosophila*** to study sex-linked genes. E.g.

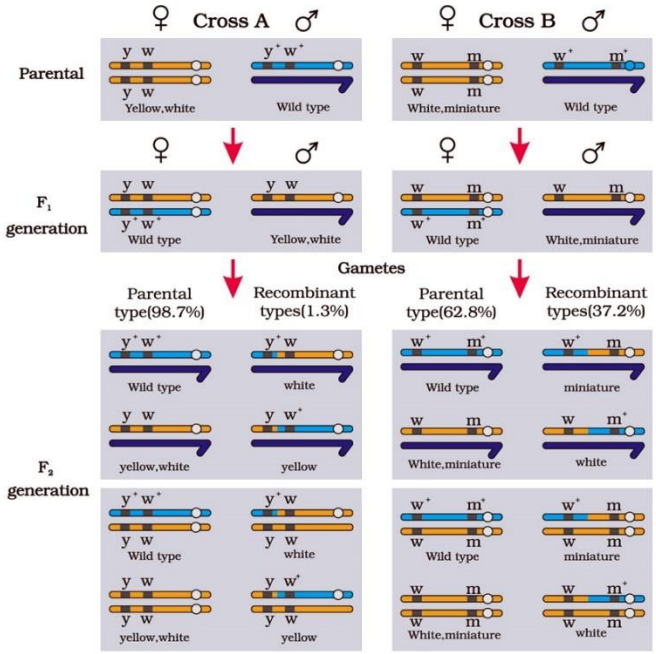
Cross 1: Yellow-bodied, white-eyed females
X
Brown-bodied, red-eyed males (wild type)

Cross 2: White-eyed, miniature winged
X
Red eyed, large winged (wild type)

Morgan intercrossed their F_1 progeny. He found that

- The two genes did not segregate independently and the F_2 ratio deviated from the 9:3:3:1 ratio.
- Genes were located on the X chromosome.
- When two genes were situated on the same chromosome, the proportion of parental gene combinations was much higher than the non-parental type. This is due to **linkage.**
- Genes of white eye & yellow body were very tightly linked and showed only **1.3%** recombination.
- Genes of white eye & miniature wing were loosely linked and showed **37.2%** recombination.

- **Tightly linked genes** show **low recombination**. **Loosely linked** genes show **high recombination.**



Alfred Sturtevant used the recombination frequency between gene pairs for measuring the distance between genes and 'mapped' their position on the chromosome.

Genetic maps are used as a starting point in the sequencing of genomes. E.g. **Human Genome Project.**

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

a. 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.

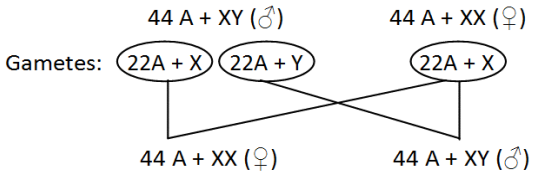
***b.* XX-XY mechanism:** Male is heterogametic (X & Y) and female is homogametic (X only). E.g. Human & *Drosophila.*

c. ZZ-ZW mechanism: Male is homogametic (ZZ) and female is heterogametic (Z & W). E.g. Birds.

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

Sex Determination in Humans (XX-XY type)

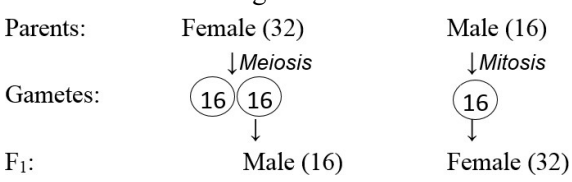
- Human has 23 pairs of chromosomes (22 pairs of autosomes and 1 pair of sex chromosomes).
- A pair of X-chromosomes (XX) is present in the female, whereas X and Y chromosomes are present in male.
- During spermatogenesis, males produce 2 types of gametes: 50 % with X-chromosome and 50 % with Y-chromosome.
- Females produce only ovum with an X-chromosome.
- There is an equal probability of fertilization of the ovum with the sperm carrying either X or Y chromosome.



The sperm determines whether the offspring male or female.

Sex determination in honeybee

- 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.



MUTATION, PEDIGREE ANALYSIS AND GENETIC DISORDERS

MUTATION

It is a sudden heritable change in DNA sequences resulting in changes in the genotype and the phenotype of an organism.
Mutation is 2 types:

- ✓ **Point mutation**: The mutation due to change (substitution) in a single base pair of DNA. E.g. sickle cell anaemia.
- ✓ **Frame-shift mutation:** It is the deletion or insertion of base pairs resulting in the shifting of DNA sequences.
- Loss (deletion) or gain (insertion/ duplication) of DNA segment cause Chromosomal abnormalities (aberrations).
- Chromosomal aberrations are seen in **cancer cells.**
- The agents which induce mutation are called **mutagens.** They include
  - **Physical mutagens:** UV radiation, α, β, γ rays, X-ray etc.
  - **Chemical mutagens:** Mustard gas, phenol, formalin etc.

PEDIGREE ANALYSIS

- In human, control crosses are not possible. So the study of family history about inheritance is used.
- Such an analysis of genetic traits in several generations of a family is called **pedigree analysis**.
- The representation or chart showing family history is called **family tree (pedigree).**
- In human genetics, pedigree study is utilized to trace the inheritance of a specific trait, abnormality or disease.

Symbols used in pedigree analysis

Male: □ Female: ○ Sex unspecified: ◇

Affected individual: ■ ● ◆ Mating: □—○

Mating b/w relatives (consanguineous mating): □═○

Parents above & children below

Parents with affected male child

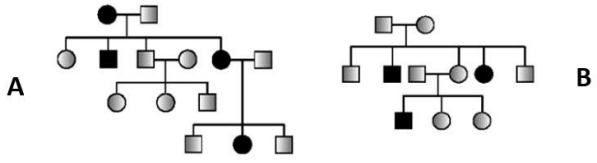
Five unaffected offspring

GENETIC DISORDERS

The disorders due to change in genes or chromosomes.
2 types: **Mendelian disorders & Chromosomal disorders.**

1. Mendelian Disorders

- It is caused by alteration or mutation in the single gene.
- E.g. **Haemophilia, Colour blindness, Sickle-cell anaemia, Phenylketonuria, Thalassemia, Cystic fibrosis etc.**
- The pattern of inheritance of Mendelian disorders can be traced in a family by the pedigree analysis.
- Mendelian disorders may be dominant or recessive.
- Pedigree analysis helps to understand whether the trait is dominant or recessive.



Pedigree analysis of
(A) Autosomal dominant trait (E.g. Myotonic dystrophy)
(B) Autosomal recessive trait (E.g. Sickle-cell anaemia)

Haemophilia (Royal disease):

- It is a sex linked (X-linked) recessive disease.
- In this, a protein involved in the blood clotting is affected.
- A simple cut results in non-stop bleeding.
- The disease is controlled by 2 alleles, **H** & **h**. **H** is normal allele and **h** is responsible for haemophilia.

X^HX^H	Normal female
X^HX^h	Heterozygous female (carrier). She may transmit the disease to sons.
X^hX^h	Hemophilic female
X^HY	Normal male
X^hY	Hemophilic male

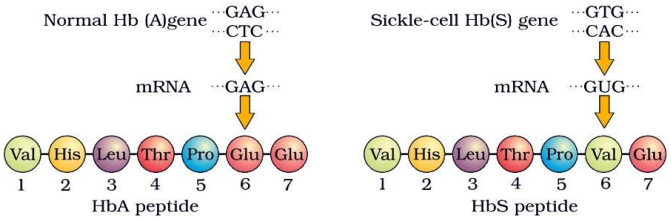
- In females, haemophilia is very rare because it happens only when mother is at least carrier and father haemophilic (unviable in the later stage of life).
- Queen Victoria was a carrier of hemophilia. So her family pedigree shows many haemophilic descendants.

Colour blindness:

- It is a sex-linked (X-linked) recessive disorder due to defect in either red or green cone of eye. It results in failure to discriminate between red and green colour.
- It is due to mutation in some genes in X chromosome.
- It occurs in 8% of males and only about 0.4% of females. This is because the genes are X-linked.
- Normal allele is dominant (C). Recessive allele (c) causes colour blindness.
- The son of a heterozygous woman (carrier, X^CX^c) has a 50% chance of being colour blind.
- A daughter will be colour blind only when her mother is at least a carrier and her father is colour blind (X^cY).

Sickle-cell anaemia:

- This is an autosome linked recessive disease.
- It can be transmitted from parents to the offspring when both the partners are carrier (heterozygous) for the gene.
- The disease is controlled by a pair of allele, Hb^A and Hb^S.
  Homozygous dominant (Hb^AHb^A): normal
  Heterozygous (Hb^AHb^S): carrier; sickle cell trait
  Homozygous recessive (Hb^SHb^S): affected
- The defect is caused by the substitution of **Glutamic acid (Glu)** by **Valine (Val)** at the **sixth position** of the **β-globin chain** of the haemoglobin (Hb).



- This is due to the single base substitution at the sixth codon of the **β-globin gene** from **GAG** to **GUG.**
- The mutant Hb molecule undergoes polymerization under low oxygen tension causing the change in shape of the RBC from biconcave disc to elongated sickle like structure.

Phenylketonuria:

- An inborn error of metabolism.

- Autosomal recessive disease.
- It is due to mutation of a gene that codes for the enzyme ***phenyl alanine hydroxylase.*** This enzyme converts an amino acid ***phenylalanine*** into ***tyrosine.***
- The affected individual lacks this enzyme. As a result, phenylalanine accumulates and converts into ***phenyl pyruvic acid*** and other derivatives.
- They accumulate in brain resulting in mental retardation. These are also excreted through urine because of poor absorption by kidney.

Thalassemia:

- An autosome-linked recessive blood disease.
- It is transmitted from unaffected carrier (heterozygous) parents to offspring.
- It is due to mutation or deletion.
- It results in reduced synthesis of α or β globin chains of haemoglobin. It forms abnormal haemoglobin and causes anaemia.
- Based on the chain affected, thalassemia is 2 types:
  - **α Thalassemia:** Here, production of **α globin** chain is affected. It is controlled by two closely linked genes **HBA1 & HBA2** on **chromosome 16** of each parent. Mutation or deletion of one or more of the four genes causes the disease. The more genes affected, the less α globin molecules produced.
  - **β Thalassemia:** Here, production of **β globin** chain is affected. It is controlled by a single gene **HBB** on **chromosome 11** of each parent. Mutation of one or both the genes causes the disease.
- Thalassemia is a **quantitative problem** (synthesise very less globin molecules). Sickle-cell anaemia is a **qualitative problem** (synthesise incorrectly functioning globin).

2. Chromosomal disorders

They are caused due to absence or excess or abnormal arrangement of one or more chromosomes. 2 types:

a. Aneuploidy: The gain or loss of chromosomes due to failure of segregation of chromatids during cell division.

b. Polyploidy (Euploidy): It is an increase in a ***whole set of chromosomes*** due to failure of cytokinesis after telophase stage of cell division. This is very rare in human but often seen in plants.

Examples for chromosomal disorders

- **Down's syndrome:** It is the presence of an additional copy of chromosome number 21 **(trisomy of 21).**

  Genetic constitution: 45 A + XX or 45 A + XY (i.e. **47** chromosomes).

  Features:
  - They are short statured with small round head.
  - Broad flat face.
  - Furrowed big tongue and partially open mouth.
  - Many "loops" on finger tips.
  - Broad palm with characteristic palm simian crease.
  - Retarded physical, psychomotor & mental development.
  - Congenital heart disease.
- **Klinefelter's Syndrome**: It is the presence of an additional copy of X-chromosome in male (trisomy).

  Genetic constitution: 44 A + XXY (i.e. **47** chromosomes).

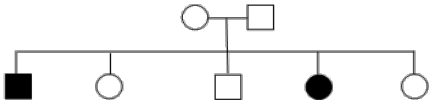
  Features:
  - Overall masculine development. However, the feminine development is also expressed. E.g. Development of breast **(Gynaecomastia).**
  - Sterile.
  - Mentally retarded.
- **Turner's syndrome**: This is the absence of one X chromosome in female (monosomy).

  Genetic constitution: 44 A + X0 (i.e. **45** chromosomes).

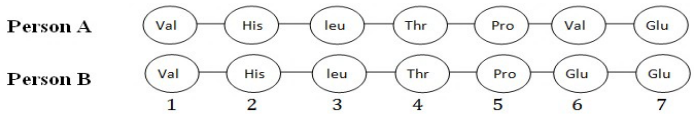
  Features:
  - Sterile, Ovaries are rudimentary.
  - Lack of other secondary sexual characters.
  - Dwarf.
  - Mentally retarded.

MODEL QUESTIONS

1. A pure yellow seeded pea plant is crossed to a pure green seeded one. Give the F_2 phenotypic ratio.
2. "All test crosses are backcrosses but all backcrosses are not test cross." Justify.
3. A Dihybrid heterozygous round yellow seeded garden pea was crossed with homozygous double recessive parent.
   a. What type of a cross is this? b. Represent the cross schematically
   c. What is the significance of this cross?
4. A diploid organism is heterozygous for 4 loci, how many types of gametes can be produced? (NCERT question)
5. Two heterozygous parents are crossed. If the two loci are linked what would be the distribution of phenotypic features in F1 generation for a dihybrid cross? (NCERT question)
6. Write down the possible genotypes and phenotypes of the young ones in the following crosses.
   a. Father and mother: AB group b. Father O group mother AB group
   c. Father homozygous A group and mother heterozygous B group.
7. *Drosophila* is an ideal material for genetic study. Why?
8. In our society, females are often blamed for producing female child. As a zoology student, evaluate this statement.
9. Analyse the diagram of pedigree analysis and answer the following questions.



   a. Mention the number of male and female offspring.
   b. How many individuals are affected? Mention the ratio of affected male and female offspring.
   c. Is this character dominant or recessive? Justify.
   d. From this chart, find out whether the parents are homozygous or heterozygous.
10. Note the relationship between first two words and fill up the fourth place.
    a. Human : X & Y Drosophila: ……
    b. Turner's syndrome : XO Klinefelter's syndrome: ……
11. Odd man out and justify your answer.
    a. 45 A+ XX, 45 A + XY, 44 A + XX, 44 A + XO
    b. Haemophilia, sickle cell anaemia, Turner syndrome, phenyl ketonuria
12. The beta globin chains of the haemoglobin molecule of two persons are given below.



    a. Which person has abnormal chain?
    b. Name the disorder affected him.
    c. Briefly explain the reason for that disorder.
13. Chromosome sets of four individuals are given below
    22AA + XXY, 22AA + XO, 45 A + XX, 45 A + XY
    a. How many autosomes and allosomes are present in normal male and females?
    b. Identify and write the names of chromosomal abnormalities in the above listed chromosome set.
    c. Down's syndrome may occur in both sexes. Comment.
14. A man suffering from hemophilia marries a carrier woman. Work out the chances of their progeny suffering from the disease. Use a flow chart.

7. EVOLUTION

Evolution is an orderly change from one form to another.
Evolutionary Biology is the study of evolutionary history of life forms.

ORIGIN OF LIFE

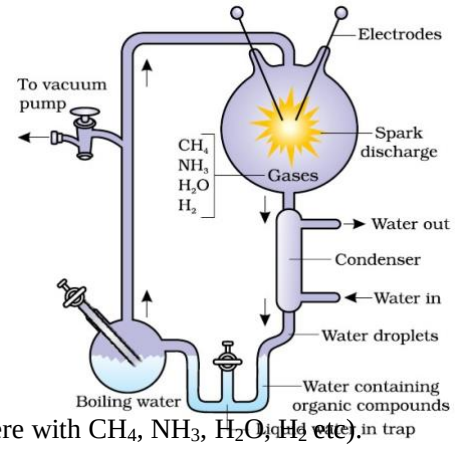
- **Big Bang Theory** states that universe originated about 20 billion years ago by a singular huge explosion.
- The earth was formed about **4.5 billion years** ago.
- There was no atmosphere on early earth. Water vapour, CH_4, CO_2 & NH_3 released from molten mass covered the surface.
- The UV rays from the sun broke up water into H_2 and O_2.
- Oxygen combined with NH_3 & CH_4 to form water, CO_2 etc.
- The ozone layer was formed. As it cooled, the water vapour fell as rain to form oceans.
- Life appeared almost **four billion years** ago.

THEORIES OF ORIGIN OF LIFE

1. **Theory of spontaneous generation (Abiogenesis):** states that, life came out of decaying and rotting matter like straw, mud etc.
   Louis Pasteur disproved this theory. He demonstrated that life comes only from pre-existing life.
   He showed that life did not come from killed yeast in a closed pre-sterilized flask. But in an opened flask, life (microbes) appeared.
2. **Biogenesis:** Proposed by **Francisco Redi, Spallanzani** & **Louis Pasteur**. It states that, life originates from pre-existing life. But it does not explain origin of first life.
3. **Cosmic theory (Theory of Panspermia):** It states that, the units of life (spores) were transferred to different planets including earth.
4. **Theory of special creation:** It states that, living things were created by some supernatural power (God).
5. **Theory of chemical evolution:** Proposed by **Oparin** & **Haldane.** It states that, the first form of life was originated from non-living inorganic & organic molecules such as CH_4, NH_3, H_2O, sugars, proteins, nucleic acids etc. i.e. *"Abiogenesis first, but biogenesis ever since".*

Urey-Miller experiment

- **Harold Urey** & **Stanley Miller** experimentally proved theory of chemical evolution. They created a condition like that of primitive earth (i.e. high temperature, volcanic storms, reducing atmosphere with CH_4, NH_3, H_2O, H_2 etc).



- They made electric discharge in a closed flask containing CH_4, NH_3, H_2 and water vapour at 800° C. As a result, some amino acids are formed.

In similar experiments, others observed formation of sugars, nitrogen bases, pigment and fats.

First **non-cellular forms** of life originated 3 billion years ago. They were **self-replicating metabolic capsule** containing RNA, proteins, Polysaccharides etc.

EVIDENCES FOR EVOLUTION

1. Paleontological evidences

Paleontology is the study of fossils.
Fossils are remnants of life forms found in rocks (earth crust). *They are written documents of evolution.*

Significance of fossils:

a. To study ***phylogeny*** (evolutionary history or race history). E.g. Horse evolution.
b. To study the ***connecting link*** between two groups of organisms. E.g. *Archaeopteryx.*
c. To study about ***extinct animals***. E.g. Dinosaurs.
d. To study about ***geological period*** by analysing fossils in different ***sedimentary rock layers.*** The study showed that life forms varied over time and certain life forms are restricted to certain geological time spans.

2. Morphological & Anatomical evidences

Comparative anatomy and morphology shows that different forms of animals have some common structural features. This can be explained as follows:

a. Homologous organs

- **Homologous organs** are the organs having fundamentally similar structure and origin but different functions. This phenomenon is called **Homology.**
- E.g. Human hand, Whale's flippers, Bat's wing & Cheetah's foot. These forelimbs have different functions but similar anatomical structures such as bones (e.g. humerus, radius, ulna, carpals, metacarpals & phalanges).
- Homology is also seen in heart, brain etc.
- **Homology in plants:** E.g. Thorns of *Bougainvillea* and tendrils of *Cucurbita*.
- 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.
- Homology indicates common ancestry.

b. Analogous organs

These are the organs having similar function but different structure & origin. This phenomenon is called **Analogy.** E.g.

- **Wings of insects** (formed of a thin flap of chitin) and **wings of birds** (modified forelimbs).
- **Eyes of Octopus** (retina from skin) and **mammals** (retina from embryonic brain).

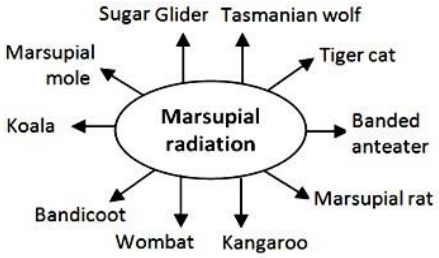
- **Flipper of Penguins** and **Dolphins**.
- **Sweet potato** (modified root) & **Potato** (modified stem).
- **Trachea of insects** (from ectoderm) and **lungs of vertebrates** (from endoderm).

Origin of analogous organs is due to ***Convergent evolution.*** It is the evolution by which **unrelated species** become more **similar** to survive and adapt in similar environmental condition.

3. Adaptive radiation (Biogeographical evidences)

Adaptive radiation (evolution by adaptation) is the evolution of different species from an ancestor in a geographical area starting from a point. It is a type of divergent evolution. E.g.

- Darwin's finches in Galapagos Islands.
- Australian marsupials (Marsupial radiation).
- Placental mammals in Australia.



When more than one adaptive radiation is appeared in an isolated geographical area, it results in ***convergent evolution.*** E.g. Australian Marsupials and Placental mammals.

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

4. Biochemical evidences

- Organisms show similarities in proteins, genes, other biomolecules & metabolism. It indicates common ancestry.

5. Embryological evidences

- 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.
- However, **Karl Ernst von Baer** rejected this proposal. He noted that embryos never pass through the adult stages of other animals.

6. Evidences for evolution by natural selection

Natural selection is the process in which organisms with better favourable & heritable variation are survived and reproduced.

Some evidences are given below:

- **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:

  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.

  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.
- 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).

THEORIES OF BIOLOGICAL EVOLUTION

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 & disuse of organs.

- **Evolution by use of organs:** E.g. Long neck of giraffe is due to continuous elongation to forage leaves on trees. This acquired character was inherited to succeeding generations.
- **Evolution by disuse:** E.g. Disappearance of limbs in snakes.

This theory was eliminated out because it is proved that the characters are inherited only through genes.

Darwinism (Theory of Natural selection)

- Proposed by **Charles Darwin.**
- 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 Archepelago)** had also come to similar conclusions.
- Work of **Thomas Malthus** on populations influenced Darwin.

Darwinism is based on 2 key concepts:

- **Branching descent:** It explains that all organisms are modified descendants of previous life forms.
- **Natural selection:** Consider a bacterial colony **A** growing on a given medium. If the medium composition is changed, only a part of the population can survive under new condition. This variant population (B) outgrows the others and appears as new species, i.e. **B is better than A under new condition.** Thus, nature selects for fitness.

Natural selection is based on the following facts:

- **Heritable minor variations:** It is either beneficial or harmful to the organisms.
- **Overproduction:** Population size grows exponentially due to maximum reproduction (E.g. bacterial population).
- **Limited natural resources:** Resources are not increased in accordance with the population size.
- **Struggle for existence:** It is the competition among organisms for resources so that population size is limited.
- **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.

MECHANISM OF EVOLUTION

- **Hugo de Vries** proposed **Mutation Theory** of evolution.
- He conducted experiments on *Oenothera lamarckiana* (evening primrose) and believed that evolution takes place through mutation and not by minor variation.
- **Darwinian variation** is minor, slow and directional. It results in **gradual evolution.**
- **Mutational variation** is sudden, random & directionless. Here, speciation is by **saltation** (single step, large mutation).
- Mutation is the origin of variation for evolution.

HARDY-WEINBERG PRINCIPLE

- It states that *allele frequencies in a population are stable and is constant from generation to generation in the absence of disturbing factors.*
- The **gene pool** (total genes and their alleles in a population) remains a constant. This is called **genetic equilibrium (Hardy-Weinberg equilibrium).**
- Sum total of all the allelic frequencies = 1
- E.g. Consider, in a diploid, **p** & **q** are the frequencies of alleles **A & a** respectively.

  Frequency of AA = p^2
  Frequency of aa = q^2
  Frequency of Aa = 2pq
  Hence $p^2 + 2pq + q^2 = 1$ [binomial expansion of $(p+q)^2$]

Change of frequency of alleles in a population disturbs Hardy-Weinberg equilibrium. This change is due to evolution.

Factors affecting Hardy-Weinberg equilibrium

a. Gene migration: Gene flow from one population to another. Here gene frequencies change in both populations. Gene flow occurs if migration happens multiple times.

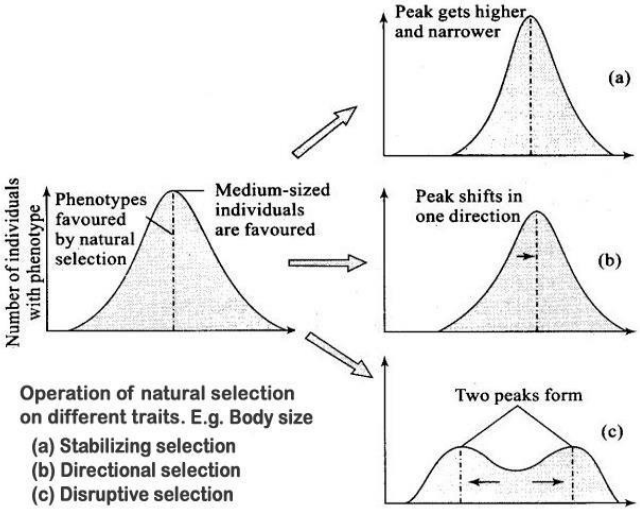
b. Genetic drift: The gene flow by chance causing change in frequency. Sometimes, the change in frequency is so different in the new sample of population that they become a different species. The original drifted population becomes founders and the effect is called **founder effect.**

c. Mutation: It results in formation of new phenotypes. Over few generations, this leads to speciation.

d. Genetic recombination: Reshuffling of genecombinations during crossing over resulting in genetic variation.

e. Natural selection: It is 3 types.

- **Stabilizing selection:** Here, more individuals acquire mean character value and variation is reduced.
- **Directional selection:** Individuals of one extreme (value other than mean character value) are more favoured.
- **Disruptive selection:** Individuals of both extremes (peripheral character value at both ends of the distribution curve) are more favoured.



A BRIEF ACCOUNT OF EVOLUTION

The geological time scale includes 4 eras: **Proterozoic, Palaeozoic, Mesozoic & Cenozoic.**

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. Palaeozoic 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.)**

  T. 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.

ORIGIN AND EVOLUTION OF MAN

- **15 mya:** ***Dryopithecus*** *&* ***Ramapithecus.***
  Hairy. Walked like gorillas & chimpanzee.
  Dryopithecus: ape-like.
  Ramapithecus: man-like.
- **3-4 mya: Man-like primates** walked up right in eastern Africa. Height up to 4 feet. This belief is based on fossils of man-like bones found in Ethiopia & Tanzania.
- **2 mya:** ***Australopithecus.*** Lived in East African grass lands. Hunted with stone weapons. Ate fruits.
  Homo habilis: First human-like being (hominid).
  Brain capacity: 650-800 cc. Did not eat meat.
- **1.5 mya:** ***Homo erectus*** **(Java man).** Large brain (900 cc). Ate meat.
- **1 lakh - 40,000 yrs ago:** ***Homo neanderthalensis*** **(Neanderthal man).**
  Brain capacity: 1400 cc. Lived in East & Central Asia. Used hides to protect their body. Buried their dead.
- **75,000 - 10,000 yrs ago (ice age)*: Homo sapiens* (Modern man).**
  Pre-historic cave art developed about 18,000 years ago. E.g. Cave paintings at Bhimbetka rock shelter in Raisen district of Madhya Pradesh.
  Agriculture & settlements: 10,000 years ago.

Sequence of Human evolution:

Dryopithecus → Ramapithecus → Australopithecus → Homo habilis → H. erectus → H. neanderthalensis → H. sapiens

MODEL QUESTIONS

1. Match the following:

A	B	C
Charles Darwin	Chemical evolution	Use and disuse of organs
Lamarck	Natural selection	Abiogenic origin of life in ocean
Hugo de Vries	Biogenesis	*Oenothera lamarckiana*
Louis Pasteur	Inheritance of acquired characters	Survival of the fittest
Oparin & Haldane	Mutation	Disproved theory of spontaneous generation

2. Analyze the relationship between first two words and fill the fourth place.
   a. Homology: Divergent evolution Analogy: ……..
   b. *Pisum sativum*: Mendel *Oenothera lamarckiana*: ……
3. Classify the following points into two categories. Give suitable titles.
   Random & directionless, Minor variation, Gradual evolution, Slow & directional, Large variation, Speciation by saltation
4. A bacterial infection was effectively controlled by using a specific antibiotic for a long time. But now- a- days this antibiotic is not found to be so effective. Give a scientific explanation for this phenomenon based on evolution.
5. Hardy- Weinberg Principle has a great contribution in population genetics.
   a. State Hardy- Weinberg Principle. b. What are the factors affecting genetic equilibrium?
   c. What is meant by Founder effect?
6. Select the correct order
   a. Paleozoic era → Proterozoic era → Mesozoic era → Coenozoic era
   b. Mesozoic era → Proterozoic era → Coenozoic era → Paleozoic era
   c. Proterozoic era → Paleozoic era → Mesozoic era → Coenozoic era
   d. Coenozoic era → Paleozoic era → Mesozoic era → Proterozoic era
7. Prepare a flowchart showing the evolution of man.

10. MICROBES IN HUMAN WELFARE

Several microbes such as bacteria, viruses, fungi etc. are useful to man in many ways. Some of them are given below:

1. MICROBES IN HOUSEHOLD PRODUCTS

- **Lactobacillus or Lactic acid bacteria (LAB):**
  - It converts milk to curd by producing acids that coagulate and partially digest the milk proteins.
  - Fresh milk can be converted to curd by adding some curd containing LAB. It also increases vitamin B_{12} in curd.
  - In stomach, LAB helps to check pathogens.
- **Bacterial fermentation (anaerobic respiration)** in dough is used to make foods such as *dosa, idli* etc. The puffed-up appearance of dough is due to the production of CO_2.
- **Baker's Yeast (*Saccharomyces cerevisiae*):** It is used to make bread by fermenting dough.
- **Toddy** is made by fermenting sap from palms.
- Microbes are used to ferment fish, soya bean & bamboo-shoots and to produce cheeses.
- **Swiss cheese** has large holes due to production of CO_2 by ***Propionibacterium sharmanii*** (a bacterium).
  Roquefort cheese is ripened by growing a fungus (*Penicillium roqueforti*) on them.

2. MICROBES IN INDUSTRIAL PRODUCTS

Production of beverages, antibiotics etc. on an industrial scale, requires growing microbes in very large vessels **(fermentors).**

Fermented beverages

- ***Saccharomyces cerevisiae (Brewer's yeast)*** is used in the production of beverages by fermenting malted cereals and fruit juices to produce ethanol.
- Wine & Beer are produced without distillation.
- Whisky, Brandy, Rum, Gin, Arrack etc. are produced by distillation of fermented broth.

Antibiotics

- Chemical substances produced by some microbes and can kill or retard the growth of pathogens.
- They are used to treat plague, whooping cough, diphtheria, leprosy etc.
- **Penicillin:** First antibiotic discovered by **Alexander Fleming**. He observed that *Staphylococci* could not grow around a mould (*Penicillium notatum*) growing in unwashed culture plates. He extracted penicillin from it.
- **Earnest Chain** and **Howard Florey** established its full potential as an effective antibiotic.
- Fleming, Chain & Florey were awarded Nobel Prize (1945).

Chemicals, enzymes & other bioactive molecules

1. Organic acids: Acid producer microbes include

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

2. Alcohol: Yeast (*S. cerevisiae*) is used to produce ethanol.

3. Enzymes:

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

4. Cyclosporine A: Produced by ***Trichoderma polysporum*** (fungus). Used as an **immunosuppressive agent** in organ transplant patients.

5. Statins: Produced by ***Monascus purpureus*** (a yeast). Used as **blood-cholesterol lowering agents**. It inhibits the enzymes responsible for synthesis of cholesterol.

3. MICROBES IN SEWAGE TREATMENT

Sewage (municipal waste-water) contains large amount of organic matter and microbes.
Sewage is treated in **Sewage Treatment Plants (STPs)** to make it less polluting. It includes 2 stages.

1. Primary treatment

It is the physical removal of particles. It includes
a. Removal of floating debris by sequential **filtration.**
b. Removal of the grit (soil & pebbles) by **sedimentation.**
The settled solids form the **primary sludge** and the supernatant form the **primary effluent.**

2. Secondary treatment (Biological treatment)

Primary effluent is passed into large aeration tanks and constantly agitated. This allows vigorous growth of useful aerobic microbes into **flocs** (bacteria associated with fungal filaments to form mesh-like structures). These microbes consume the organic matter in the effluent. This reduces the **BOD (Biochemical Oxygen Demand)** of the effluent.

> **BOD:** Amount of O_2 consumed by bacteria to oxidize all organic matter in one litre of water. It is a measure of organic matter present in the water. The greater the BOD more is its polluting potential.

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 sludge is pumped into large tanks called **anaerobic sludge digesters.** Here, some anaerobic bacteria digest the bacteria and fungi in the sludge by producing gases like CH_4, H_2S and CO_2. These gases form the biogas.
The effluent is released into natural water bodies like rivers and streams.
The Ministry of Environment & Forests initiated **Ganga Action Plan & Yamuna Action Plan** to save from water pollution.

4. MICROBES IN THE PRODUCTION OF BIOGAS

- **Biogas** is a mixture of gases (mainly CH_4) produced by the microbial activity. It is used for cooking & lighting.
- **Methanogens** grow anaerobically on cellulosic material and produce CH_4. **E.g. *Methanobacterium.***
- ***Methanobacterium*** is found in the **anaerobic sludge** and **rumen of cattle** (for cellulose digestion).
- The cattle dung **(gobar)** is rich in these bacteria. Dung can be used for generation of biogas **(Gobar gas).**
- **The Biogas plant** consists of
  - A **concrete tank** (10-15 feet deep) to collect bio-wastes and slurry of dung. A floating cover is placed over the slurry, which keeps on rising as the biogas is produced.
  - An outlet which is connected to a pipe to supply biogas.
  - An outlet to remove spent slurry (used as fertilizer).

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

5. MICROBES AS BIOCONTROL AGENTS

- **Biocontrol** is the use of biological methods for controlling plant diseases and pests. E.g. **Lady bird (beetle)** controls aphids. **Dragon flies** control mosquitoes.
- **Chemical pesticides** and **insecticides** kill both useful and harmful organisms and cause pollution. Biocontrol method has no such problems.

Microbial biocontrol agents

- ***Bacillus thuringiensis (Bt):*** To control butterfly caterpillar. The dried spores of Bt (available in sachets) are mixed with water and sprayed on to vulnerable plants such as brassicas and fruit trees. These are eaten by the caterpillar. In their gut, the toxin is released and the larvae get killed.
  The scientists have introduced *B. thuringiensis* toxin genes into plants. E.g. Bt cotton.
- ***Trichoderma sp*** (fungus): These are free livings present in the root ecosystems. They control several plant pathogens.
- ***Baculoviruses*** (Especially genus ***Nucleopolyhedro-virus):*** Attacks insects and other arthropods.
  It is suitable for *species-specific*, narrow spectrum insecticidal applications and desirable in **IPM** (Integrated Pest Management) program to conserve beneficial insects.

6. MICROBES AS BIOFERTILISERS

- **Biofertilisers** are organisms that enrich nutrient quality of the soil. E.g. Bacteria, fungi, cyanobacteria etc.
- **Rhizobium** (symbiotic bacteria in root nodules of **leguminous plants)** fix atmospheric N_2.
- Free-living bacteria in the soil (E.g. *Azospirillum* and *Azotobacter)* enrich the nitrogen content of the soil.
- **Mycorrhiza:** Symbiotic association of fungi (E.g. genus of *Glomus*) with plants. The fungus gets food from plant.
  The fungal symbiont performs the following:
  - Absorb phosphorous from soil and passes it to the plant.
  - Give resistance to root-borne pathogens and tolerance to salinity and draught.
  - Give overall increase in plant growth and development.
- **Cyanobacteria (Blue green algae):** Autotrophic microbes. They fix atmospheric nitrogen. E.g. *Anabaena, Nostoc, Oscillatoria etc*. In paddy fields, Cyanobacteria serve as an important biofertilisers. It also adds organic matter to the soil and increases its fertility.

9. STRATEGIES FOR ENHANCEMENT IN FOOD PRODUCTION

I. ANIMAL HUSBANDRY

- It is the scientific agricultural practice of breeding and raising livestock.
- It deals with the care & breeding of **livestock** (buffaloes, cows, pigs, horses, cattle, sheep, camels, goats etc.), **poultry farming** and **fisheries.**
- More than **70%** of the world livestock population is in **India** & **China.** However, the contribution to the world farm produce is only **25%,** i.e., the productivity per unit is very low. Hence new technologies should be applied to achieve improvement in quality and productivity.

Management of Farms & Farm Animals

1. Dairy Farm Management (Dairying)

- It is the management of animals for increasing yield and quality of milk and its products.
- Milk yield depends on the quality of breeds in the farm.
- It is important to select good breeds having high yielding potential and resistance to diseases.
- **Ways for the yield potential:**
  - Look after the cattle (housing well, give adequate water and maintain disease free).
  - Feeding of cattle in a scientific manner – emphasis on the quality and quantity of fodder.
  - Stringent cleanliness and hygiene of cattle & handlers while milking, storage and transport of the milk.
- Nowadays, these processes have mechanized. It reduces chance of direct contact of the produce with the handler.
- To ensure these stringent measures there should be
  - Regular inspections to identify and rectify problems.
  - Regular visits by a veterinary doctor.

2. Poultry Farm Management

- Poultry is the domesticated birds used for food or eggs. E.g. chicken, ducks, turkey and geese.
- **Components of poultry farm management:**
  - Selection of disease free and suitable breeds.
  - Proper and safe farm conditions.
  - Proper feed and water.
  - Hygiene and health care.

Animal Breeding

- A **breed** is a group of organisms related by descent and similar general appearance, features, size etc.
- **Breeding** is the modification of genotype of an organism to make that organism more useful to humans. E.g. Jersey (improved cattle breed), Leghorn (improved chicken breed).
- Animal breeding aims at increasing the yield of animals and improving the desirable qualities of the produce.
- Breeding is 2 types: **Inbreeding** and **out-breeding.**

a. Inbreeding

It is the mating of more closely related individuals within the same breed for 4-6 generations. This strategy is as follows:

- Identify and mate superior males & females of same breed.
- Evaluate the progeny obtained and identify superior males and females among them for further mating.

In cattle, a superior female produces more milk per lactation. A superior male (bull) gives rise to superior progeny.

Advantages of Inbreeding:

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

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

b. Out-breeding

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

i) Out-crossing:

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

ii) Cross-breeding:

- It is the mating of superior males of one breed with superior females of another breed.
- The desirable qualities of 2 different breeds are combined.
- The progeny hybrid animals may be used for commercial production or may be subjected to inbreeding and selection to develop new stable superior breeds.
- E.g. **Hisardale** (sheep) developed in Punjab by crossing **Bikaneri ewes** and **Merino rams.**

iii) Interspecific hybridization:

- It is the mating of male and female of two different species.
- In some cases, the progeny may combine desirable features of both the parents, and may be of considerable economic value. E.g. Mule (male ass x female horse).

Controlled breeding experiments

1. Artificial insemination

- The semen collected from male parent is injected into the reproductive tract of selected female by the breeder.
- Semen is used immediately or is frozen and used later. Frozen semen can also be transported.
- Success rate of crossing mature male & female is low even though artificial insemination is carried out.

2. Multiple Ovulation Embryo Transfer Technology (MOET)

- It is a programme for herd improvement. It improves chances of successful production of hybrids.

- In this, a cow is administered hormones such as **FSH** to induce **follicular maturation & super ovulation** (production of 6-8 eggs per cycle instead of one egg).
- The animal is either mated with an elite bull or artificially inseminated. Fertilised eggs at 8–32 cells stage are recovered non-surgically and transferred to surrogate mothers.
- MOET has been demonstrated for cattle, sheep, rabbits, buffaloes, mares, etc.
- High milk yielding breeds of females and high quality (lean meat with less lipid) meat-yielding bulls have been bred successfully to increase herd size in a short time.

Bee-keeping (apiculture)

- It is the maintenance of hives of honeybees to produce honey and beeswax.
- Most common species that can be reared is ***Apis indica.***
- Honey is a food of high nutritive and medicinal value.
- Beeswax is used in preparation of cosmetics, polishes etc.
- Apiculture can be practiced in an area having **bee pastures** of some wild shrubs, fruit orchards and cultivated crops.
- **Important points for successful bee-keeping:**
  (i) Knowledge of the nature and habits of bees.
  (ii) Selection of suitable location for keeping beehives.
  (iii) Catching and hiving of swarms (group of bees).
  (iv) Management of beehives during different seasons.
  (v) Handling and collection of honey and beeswax.
- Bees are the pollinators of crop species such as sunflower, *Brassica*, apple and pear.
- Keeping beehives in crop fields during flowering period increases pollination. It improves crop and honey yield.

Fisheries

- Fishery is an industry of catching, processing or selling of fish, shellfish or other aquatic animals (prawn, crab, lobster, edible oyster etc.).
- **Freshwater fishes:** *Catla, Rohu,* common carp etc.
  Marine fishes: *Hilsa*, Sardines, Mackerel, Pomfrets etc.
- Fisheries provide income and employment to millions of fishermen and farmers.
- **Aquaculture** (farming of aquatic organisms) & **pisciculture** (farming of fishes) are the techniques to increase the production of aquatic plants and animals.
- **Blue Revolution:** The development and flourishing of the fishery industry.

II. PLANT BREEDING

- It is the manipulation of plant species to create desired plant types suitable for better cultivation, better yields and disease resistance.
- **Green Revolution:** The development and flourishing of the agriculture. It was dependent on plant breeding.
- **Classical plant breeding** involves hybridization of pure lines and artificial selection to produce desirable traits.
- Now molecular genetic tools are used for plant breeding.

Desirable traits for plant breeding:

- Increased crop yield and quality.
- Increased tolerance to environmental stresses (salinity, extreme temperatures & drought).
- Increased resistance to insect pests and pathogens.

Steps of Plant breeding

(i) Collection of genetic variability

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

(ii) Evaluation and selection of parents

- The germplasm is evaluated for identifying plants with desirable characters.
- Selected plants are multiplied and used for hybridisation.
- Pure lines are created wherever desirable and possible.

(iii) Cross hybridisation of the selected parents

- In this, desired characters are genetically combined from 2 different parents to produce hybrid plant.
- E.g. high protein quality of one parent is combined with disease resistance from another parent.
- **Limitations:**
  - Very time-consuming and tedious process.
  - Hybrids may not combine the desirable characters. Usually only hundreds to a thousand crosses show the desirable combination.

(iv) Selection & testing of superior recombinants

- It is crucial to the success of the breeding objective and requires careful scientific evaluation of the progeny.
- It yields plants that are superior to both parents.
- These are self-pollinated for several generations till they reach a state of uniformity (homozygosity), so that the characters will not segregate in the progeny.

(v) Testing, release & commercialization

- The newly selected lines are evaluated for their yield and other agronomic traits of quality, disease resistance, etc.
- This is done by growing them in research fields and recording their performance under ideal fertiliser application irrigation and other crop management practices.
- The evaluation is followed by testing the materials in farmers' fields, for at least 3 growing seasons at several locations in the country, representing all the agro-climatic zones. The material is evaluated in comparison to the best available local crop cultivar (a check or reference cultivar).

Wheat and Rice:

- In India, food production has increased by the development of high yielding varieties of wheat and rice in the mid-1960s **(Green Revolution)**.
- During 1960-2000, wheat production increased from 11 million tons to 75 million tons. The rice production increased from 35 million tons to 89.5 million tons.

- Nobel laureate **Norman E. Borlaug** (International Centre for Wheat & Maize Improvement, Mexico) developed semi-dwarf wheat.
- In 1963, high yielding and disease resistant wheat varieties like ***Sonalika*** & ***Kalyan Sona*** were introduced in India.
- **Semi-dwarf rice varieties** were derived from **IR-8,** (developed at International Rice Research Institute (IRRI), Philippines) and **Taichung Native-1** (from Taiwan). Later better-yielding semi dwarf varieties ***Jaya*** and ***Ratna*** were developed in India.

Sugar cane: ***Saccharum barberi*** (grown in north India, but poor sugar content & yield) was crossed with ***Saccharum officinarum*** (tropical canes in south India, thicker stems and higher sugar content but do not grow well in north India) and got a hybrid sugar cane having desirable qualities like high yield, thick stems, high sugar and ability to grow in north India.

Millets: **Hybrid maize, jowar** & **bajra** developed in India. It includes high yielding varieties resistant to water stress.

Plant Breeding for Disease Resistance

- Plant diseases cause crop losses up to 20-30% or even total.
- Disease-resistant cultivars enhance food production and helps to reduce the use of fungicides and bactericides.
- Resistance of the host plant is the genetic ability to prevent the pathogens from disease.
- **Some plant diseases:**
  - **Fungal: Rusts.** E.g. brown rust of wheat, red rot of sugarcane and late blight of potato.
  - **Bacterial:** Black rot of crucifers.
  - **Viral:** Tobacco mosaic, turnip mosaic, etc.

Methods of breeding for disease resistance

1. Conventional breeding: The steps are:
- Screening germplasm for resistance sources.
- Hybridisation of selected parents.
- Selection and evaluation of the hybrids.
- Testing and release of new varieties.

Some crop varieties bred by Conventional method:

Crop	Variety	Resistance to
Wheat	Himgiri	Leaf & stripe rust, hill bunt
Brassica	Pusa swarnim (Karan rai)	White rust
Cauliflower	Pusa Shubhra, Pusa Snowball K-1	Black rot and curl blight black rot
Cowpea	Pusa Komal	Bacterial blight
Chilli	Pusa Sadabahar	Chilly mosaic virus, Tobacco mosaic virus and leaf curl.

- Conventional breeding is constrained by the availability of limited number of disease resistance genes.
- Inducing mutations in plants and screening them for resistance help to identify desirable genes. Such plants can be multiplied directly or can be used in breeding.
- Other breeding methods are selection amongst **somaclonal variants** and **genetic engineering.**

2. Mutation breeding:

Mutation (sudden genetic change) can create new desirable characters not found in the parental type.

Mutation breeding is the breeding by mutation using chemicals or radiations (e.g. gamma rays) to produce plants with desirable characters. Such plants are selected and multiplied directly or used as a source in breeding.

E.g. In **mung bean,** resistance to **yellow mosaic virus** and **powdery mildew** were induced by mutations.

- **Resistant genes** from wild species have introduced into the high-yielding cultivated varieties. E.g. In ***bhindi (Abelmoschus esculentus),*** resistance to yellow mosaic virus was transferred from a wild species. It resulted in a new variety of ***A. esculentus*** called ***Parbhani kranti.***
- Resistance genes can be transferred by **sexual hybridisation** between the **target** and the **source plant.**

Plant Breeding for Developing Resistance to Insect Pests

- Morphological, biochemical or physiological characteristics give insect resistance in host crop plants. E.g.
  - **Hairy leaves**: E.g. resistance to jassids in cotton and cereal leaf beetle in wheat.
  - **Solid stems in wheat** lead to non-preference by the stem sawfly.
  - **Smooth leaved and Nectar-less cotton varieties** do not attract bollworms.
  - **High aspartic acid, low nitrogen** and **sugar content in maize** leads to resistance to maize stem borers.
- Sources of resistance genes for breeding are cultivated varieties, germplasm collections of crop or wild relatives.

Some crop varieties bred for insect pest resistance:

Crop	Variety	Insect pests
Brassica (rapeseed mustard)	Pusa Gaurav	Aphids
Flat bean	Pusa Sem 2, Pusa Sem 3	Jassids, aphids & fruit borer
Okra (Bhindi)	Pusa Sawani, Pusa A-4	Shoot and Fruit borer

Plant Breeding for Improved Food Quality

- More than 840 million people in the world do not have adequate food. 3 billion people suffer from micronutrient, protein and vitamin deficiencies **('hidden hunger').**
- Breeding crops with higher levels of nutrients is called **Biofortification.** It helps to improve public health.

Objectives of breeding for improved nutritional quality:
- To improve Protein content and quality.
- To improve Oil content and quality.
- To improve Vitamin content.
- To improve Micronutrient and mineral content.

Examples for hybrids with improved nutritional quality:
- **Maize hybrids** having twice the amount of amino acids, **lysine & tryptophan** compared to existing maize hybrids.
- **Wheat** variety, **Atlas 66**, having high protein content.
- **Iron-fortified rice variety** containing over five times as much iron as in common varieties.
- **Vitamins & mineral rich vegetable crops:** Released by Indian Agricultural Research Institute, New Delhi.
  - Vitamin A enriched carrots, spinach, pumpkin.
  - Vitamin C enriched bitter gourd, *bathua*, mustard, tomato.
  - Iron & calcium enriched spinach & *bathua.*
  - Protein enriched beans (broad, lablab, French & garden peas).

III. SINGLE CELL PROTEIN (SCP)

- It is the protein derived from single-celled organisms.
- It is an alternate source of proteins for animal and human nutrition. E.g. ***Spirulina*** (a blue green alga), ***Methylophilus methylotrophus*** (a bacterium).
- ***Spirulina*** is rich in protein, minerals, fats, carbohydrate & vitamins. It is grown on materials like waste water from potato processing plants, straw, molasses, animal manure & sewage. This also reduces environmental pollution.
- A 250 Kg cow produces only 200 g protein/day. But 250 g ***Methylophilus methylotrophus*** produces **25 tonnes** protein. It is due to high rate of biomass production and growth.

IV. TISSUE CULTURE

- A technique of growing plant cells/tissues/organs in sterile culture medium under controlled aseptic conditions.
- The ability to generate a whole plant from any cell/explant is called **totipotency**. An **explant** is any part of a plant that is grown in a test tube under sterile nutrient media.
- The nutrient medium must provide a carbon source (such as sucrose), inorganic salts, vitamins, amino acids and growth regulators like auxins, cytokinins etc.
- The method of producing thousands of plants in very short time through tissue culture is called **micropropagation**.
- These plants will be genetically identical to original plant, i.e., they are **somaclones**.
- Tomato, banana, apple etc. are produced by this method.
- Tissue culture is also used to recover healthy plants from diseased plants. The **meristem** (it will be virus-free) from infected plant is removed and grown *in vitro* to obtain virus-free plants. Scientists have cultured meristems of banana, sugarcane, potato, etc.
- **Somatic hybridization:** It is the fusion of protoplasts from two different varieties of plants (with desirable characters) to get hybrid protoplasts. It can be grown to form a new plant called **somatic hybrids.** Protoplasts can be isolated after digesting the cell walls of plant cells.
  E.g. Protoplast of tomato + protoplast of potato → **pomato.** This hybrid plant has the characteristics of tomato & potato. But it has no all desired characteristics for its commercial utilization.

MODEL QUESTIONS

1. Find the odd one out by stating the reasons
   (a) Jaya, Ratna, Kalyan Sona, IR 8
2. One of the aims of plant breeding is to produce high yielding, disease resistant crop plants.
   (a) Describe the main steps in plant breeding.
   (b) Name the variety of bhindi which is resistant to yellow mosaic virus.
3. Some released crop varieties produced by hybridization and selection for insect pest resistant are given below. Complete the table.

Crop	Variety	Insect pests
Brassica	PUSA GAURAV	----------
----------	PUSA SEM-2, PUSA SEM-3	Jassids, aphids and fruit borer
Okra	----------	----------

4. MOET is a controlled breed experiment
   (a) Expand MOET (b) Mention any one hormone used in MOET
5. You are appointed as an Agricultural officer in the Rice breeding station. What are the criteria you will choose for producing a high yielding variety?
6. In a poultry farm, some of the chickens found to be infected with bird flu. Enumerate the measures to be taken to prevent the spread of the disease.
7. Keeping beehives in crop fields during flowering period proves economically good. Evaluate.
8. Artificial insemination is a controlled breeding. Justify
9. Your neighbour wishes to start a dairy farm. As a biology student, give some advice for a healthy dairy farm management.
10. In animal breeding programme the inbreeding techniques create pure lines in animals, but continuous usage cause inbreeding depression in animals.
    (a) What is inbreeding depression? (b) Suggest a remedial measure for inbreeding depression.
11. In a Tissue Culture lab, thousands of healthy disease-free banana plants were produced from a high yielding variety infected with virus. Name the culture method adopted here.
12. Expand the abbreviations given: a) IARI b) IRRI c) SCP d) ICWMI

8. HUMAN HEALTH AND DISEASES

- **Health** is a state of complete *physical, mental & social well-being.* It is affected by genetic disorders, infections, change in life style (food, water, rest, exercise, habits etc).
- Mind influences immune system (through neural and endocrine systems) and thereby health.
- When the functioning of organs or systems of the body is adversely affected, it is called a **disease**.
- Diseases may be **infectious** (transmits from one person to another) or **non-infectious** (do not transmit. E.g. cancer).
- Disease causing organisms are called **Pathogens.** Parasites are pathogens as they harm the host.

Good humour hypothesis (by **Hippocrates** & **Indian Ayurveda system):** It states that health is a state of body & mind where there is a balance of certain humours. Persons with 'black bile' belong to hot personality and would have fevers.

William Harvey disproved this hypothesis. He discovered blood circulation and demonstrated normal body temperature in persons with black bile using thermometer.

COMMON INFECTIOUS DISEASES IN MAN

1. BACTERIAL DISEASES

a. **Typhoid:** Pathogen is ***Salmonella typhi.***

- **Mode of transmission:** It enters small intestine through food & water and migrates to other organs via blood.
- **Symptoms:** Sustained high fever (39°-40° C), headache, weakness, stomach pain, constipation & loss of appetite. Intestinal perforation and death may occur.

Widal test is used for confirmation of the disease.

Mary Mallon **(Typhoid Mary)** was a professional cook. She was a typhoid carrier who spread typhoid for several years through the food she prepared.

b. Pneumonia: Pathogen is ***Streptococcus pneumoniae* & *Haemophilus influenzae.***

It infects lung alveoli. The alveoli get filled with fluid leading to respiratory problems.

- **Mode of transmission:** Inhaling the droplets/aerosols released by an infected person. Sharing glasses and utensils with an infected person.
- **Symptoms:** Respiratory problems, fever, chills, cough, headache. In severe cases, lips and finger nails turn grey to bluish colour.

Other bacterial diseases: Dysentery, plague, diphtheria, etc.

2. VIRAL DISEASES

a. **Common cold:** Pathogen is ***Rhinoviruses.***

It infects nose & respiratory passage but not lungs.

- **Mode of transmission:** Inhaling droplets resulting from cough or sneezes. Through contaminated objects (pens, books, cups, doorknobs, computer accessories) etc.
- **Symptoms:** Nasal congestion & discharge, fever, headache, sore throat, cough, hoarseness, tiredness etc. Common cold lasts for 3-7 days.

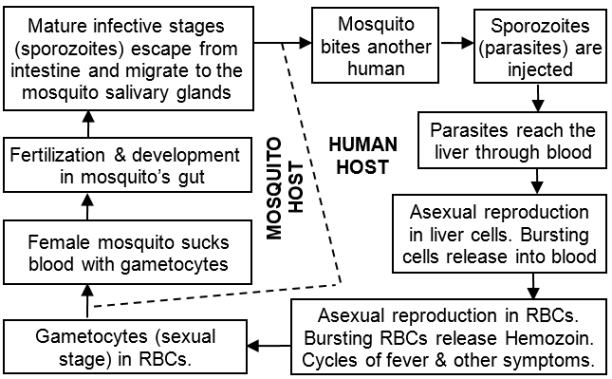
3. PROTOZOAN DISEASES

a. **Malaria:** Pathogen is ***Plasmodium sp.*** *(P. vivax, P. malariae* & *P. falciparum).*

Most serious (malignant) malaria is caused by *P. falciparum.*

- **Mode of transmission:** By female *Anopheles* mosquito.
- **Symptoms:** Haemozoin (toxin released by *Plasmodium)* causes chill and high fever recurring every 3-4 days.

Life cycle of Plasmodium



b. Amoebiasis (Amoebic dysentery): Pathogen is ***Entamoeba histolytica.***

- **Mode of transmission:** Houseflies (mechanical carriers) transmit parasites from faeces to food & water.
- **Symptoms:** Constipation, abdominal pain and cramps, stools with excess mucus and blood clots.

4. HELMINTH DISEASES

a. **Ascariasis:** Pathogen is ***Ascaris*** (Intestinal parasite).

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

b. **Filariasis (Elephantiasis):** Pathogen is **Filarial worms or *Wuchereria*** *(W. bancrofti & W. malayi).*

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

5. FUNGAL DISEASES

a. **Ring worms:** Pathogens are ***Microsporum, Trichophyton* & *Epidermophyton.*** They are seen in groin, b/w toes etc.

- **Mode of transmission:** From soil or by using towels, cloths, comb etc. Heat and moisture help fungi to grow.
- **Symptoms:** Dry, scaly lesions on skin, nails, scalp etc. Intense itching.

PREVENTION AND CONTROL OF DISEASES

Personal hygiene

Keep the body clean. Use clean drinking water, food etc.

Public hygiene

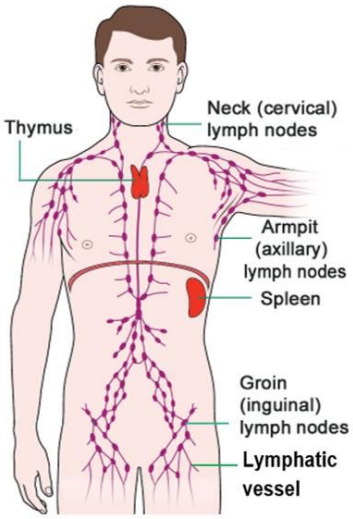
a. Proper disposal of wastes and excreta.
b. Periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks.
c. Avoid contact with infected persons or their belongings (to control air-borne diseases).
d. Standard practices of hygiene in public catering.
e. Control and eliminate the vectors (e.g. mosquitoes).
   - Avoid stagnation of water.
   - Regular cleaning of household coolers.
   - Use of mosquito nets.
   - Introduce larvivorous fishes like *Gambusia* in ponds.
   - Spraying insecticides in ditches, drainage and swamps.
   - Provide doors and windows with wire mesh.

These precautions can avoid vector-borne diseases like Malaria, Filariasis, Dengue & *Chikun gunya.*

Vaccines & **immunisation** helped to control diseases like smallpox, polio, diphtheria, pneumonia & tetanus. Drugs like **antibiotics** also helped to treat infectious diseases.

HUMAN IMMUNE SYSTEM

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



LYMPHOID ORGANS

These are the organs where origin/maturation & proliferation of lymphocytes occur. 2 types: Primary & Secondary.

a. Primary lymphoid organs

The organs where lymphocytes are matured & differentiated to antigen-sensitive lymphocytes. It is 2 types:

1. **Bone marrow:** The site of formation of all blood cells including B & T-lymphocytes.
2. **Thymus:** A bilobed organ seen near the heart and beneath the breastbone. It is large during birth but gradually reduces in size and becomes very small size in puberty. Immature T-lymphocytes from bone marrow is migrated to thymus and matured.

b. Secondary lymphoid organs

- The organs, to which matured lymphocytes migrate from primary lymphoid organs, interact with antigens and then proliferate to become **effector cells.**
  E.g. Spleen, lymph nodes, tonsils, Peyer's patches, Mucosa-associated lymphoid tissue (MALT) & appendix.
- **Spleen:** Bean-shaped organ. Contains lymphocytes and phagocytes. It removes worn-out RBCs & microorganisms from blood. It is a reservoir of erythrocytes in foetus.
- **Lymph nodes:** Found in lymphatic system. They trap microorganisms or other antigens. Trapped antigens activate lymphocytes and cause immune response.
- **MALT:** Located within the lining of respiratory, digestive & urinogenital tracts. It constitutes 50% of lymphoid tissue.

IMMUNITY

It is the ability of the immune system to fight the pathogens. It is 2 types: Innate and Acquired.

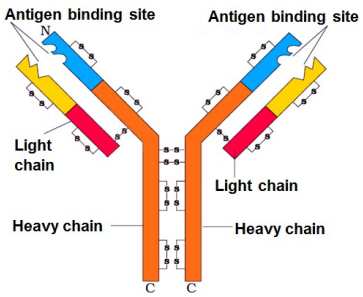
1. Innate (inborn) immunity

- It is the *non-specific* immunity present at the time of birth.
- It includes 4 types of **Barriers:**

a. **Physical barriers:** Prevents entry of microbes. E.g. ***Skin***, ***Mucus coating*** of the respiratory, gastro-intestinal and urino-genital tracts. Mucus traps microbes.
b. **Physiological barriers:** They prevent microbial growth. E.g. gastric HCl, saliva, tear etc.
c. **Cellular barriers: Phagocytes** like *WBC* [*Polymorpho-nuclear leukocytes (PMNL)* or *neutrophils, monocytes* and natural killer *lymphocytes], macrophages* etc.
d. **Cytokine barriers:** Virus infected cells secrete a cytokine protein called ***interferon.*** It protects non-infected cells from further viral infection.

2. Acquired (adaptive) immunity

- It is *pathogen specific* immunity developed during lifetime.
- It is characterized by *memory*, i.e. during first encounter of a pathogen, body produces *primary response* in low intensity. Second encounter of the same pathogen causes a *secondary (anamnestic) response* in high intensity.
- Primary and secondary immune responses are carried out with *B-lymphocytes (B-cells)* and *T-lymphocytes (T-cells)*.
  a. **B-lymphocytes:** Produce *antibodies*. These are the proteins to fight the pathogens.
  b. **T-lymphocytes:** Help B-cells to produce antibodies.



Structure of an antibody molecule

An antibody has **4 polypeptide chains:** 2 **light chains** and 2 **heavy chains (H_2L_2).**

Types of antibodies:

IgG, IgA, IgM, IgE & IgD.

Types of Acquired immune response

1. **Humoral immune response/ Antibody mediated immunity (AMI):** It is the immune response mediated by ***antibodies.*** Antibodies are found in blood plasma. So called as Humoral immune response.

2. **Cell-mediated response / cell-mediated immunity (CMI):** It is the immune response mediated by ***T-lymphocytes (T-cells).*** The body can differentiate 'self' and 'non-self' and the CMI causes Graft rejection.

   Tissue matching & blood group matching are essential before undertaking any graft/ transplant. After this, the patient should take immuno-suppressants all his life.

Types of Acquired immunity

Acquired immunity is 2 types: Active and passive.

1. **Active immunity:** It is the immunity in which antibodies are produced in a host body when the host is exposed to *antigens* (e.g. living or dead microbes or other proteins). It is a slow process. It is produced by 2 ways:
   a. **Natural Active Immunity:** It is developed during natural infection by microbes.
   b. **Artificial Active Immunity:** It is developed by injecting the microbes deliberately during immunization.
2. **Passive immunity:** Here, readymade antibodies are directly given to the body. It is 2 types:
   a. **Natural Passive Immunity:** E.g.
      - Antibodies (IgG) from mother → Placenta → Foetus
      - Antibodies (IgA) in colostrum → infants
   b. **Artificial Passive Immunity:** E.g.
      - Anti-tetanus serum (ATS)

Immunization

This is based on 'memory' of the immune system. 2 types:

1. Active Immunization (Vaccination)

- In this, a preparation of **vaccine** (antigenic proteins of pathogen or inactivated pathogen) is introduced into the body. It results in the development of antibodies.
- During actual infection, the antibodies neutralize antigens.
- The vaccines also generate memory B and T-cells. They recognize the pathogen quickly.
- E.g. Polio vaccine, Hepatitis B vaccine, DPT vaccine etc.
- Vaccines are produced using DNA recombinant technology (E.g. Hepatitis B vaccine produced from Yeast).

2. Passive Immunization

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

Allergies

- It is the exaggerated response of the immune system to certain antigens present in the environment.
- **Allergens:** Substances causing allergy. E.g. mites in dust, pollens, animal dander, fur etc.
- Antibodies produced against the **allergens** are **IgE type.**
- IgE binds on **mast cells** to release chemicals like ***histamine*** and ***serotonin*** from them. It results in allergic reactions.
- **Symptoms:** Sneezing, watery eyes, running nose, difficulty in breathing, wheezing, skin rashes etc.
- **Determination of cause of allergy:** The patient is exposed to or injected with very small doses of possible allergens, and the reactions studied.
- **Treatment:** Drugs like *anti-histamine*, *adrenaline* and *steroids* quickly reduce the symptoms of allergy.
- **Asthma** is a respiratory disease due to allergy.
- Modern-day life style and protected environment provided early in life result in low immunity and more sensitivity to allergens. So, many children in metro cities suffer from allergies and asthma.

Autoimmunity

- In higher vertebrates, memory-based acquired immunity evolved based on the ability to differentiate foreign organisms from self-cells.
- Sometimes, due to genetic and other unknown reasons, the body attacks self-cells resulting in damage to the body. It is called **auto-immune disease.** E.g. *Rheumatoid arthritis.*

AIDS (Acquired Immuno Deficiency Syndrome)

- It is the deficiency of immune system.
- Syndrome means a group of symptoms.
- It is caused by **HIV (Human Immunodeficiency Virus),** a **retrovirus** having RNA genome.
- AIDS was first reported in America (1981).
- In the last 25 years, it killed over 25 million persons.

Transmission:

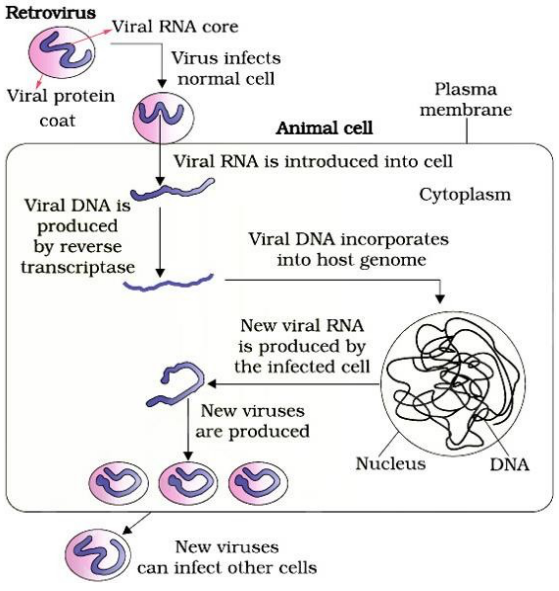
- Sexual contact with infected person.
- Transfusion of contaminated blood & blood products.
- Sharing of infected needles.
- From infected mother to her child through placenta.

High risk people of getting HIV:

- Individuals with multiple sexual partners.
- Drug addicts who take drugs intravenously.
- Individuals who require repeated blood transfusion.
- Children born to an HIV infected mother.

HIV does not spread by touch or physical contact. It spreads only through body fluids.
There is a time-lag (from few months to 5-10 years) between the infection and appearance of symptoms.

Replication of retrovirus:



Life cycle of HIV:

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.

- During this period, the person suffers from fever, diarrhoea and weight loss.
- Due to deficiency of T_H cells, he may be infected with *Mycobacterium*, viruses, fungi & parasites like *Toxoplasma.*
- **Diagnosis: ELISAtest** (Enzyme-linked immuno-sorbent Assay).
- **Treatment:** Anti-retroviral drugs are partially effective. They can only prolong the life of the patient.

Prevention of AIDS:

- Educate people about AIDS through organisations like **National AIDS Control Organisation (NACO), non-governmental organisations (NGOs), WHO** etc.
- Make blood (from blood banks) safe from HIV.
- Use disposable needles and syringes.
- Advocate safe sex and free distribution of condoms.
- Control drug abuse.
- Regular check-ups for HIV in susceptible population.

CANCER

- Cancer is an abnormal and uncontrolled multiplication of cells resulting in the formation of tumour (masses of cells).
- Normal cells show a **contact inhibition** (contact with the other cells inhibits their uncontrolled growth). Cancer cells do not have this property.

Types of Tumours

- **Benign tumours:** Confined to the place of its origin. They do not spread to other parts. Cause little damage.
- **Malignant tumours:** Mass of proliferating cells **(neoplastic or tumour cells)** that grow rapidly, invade and damage the surrounding normal tissues. Due to active division and growth, they starve normal cells by competing for nutrients. Cells sloughed from tumours reach other sites via blood where they form a new tumour. This is called **metastasis**.

Causes of cancer (Carcinogens)

- **Physical agents:** E.g. Ionizing radiations like X-rays and gamma rays and non-ionizing radiations like UV.
- **Chemical agents:** Tobacco smoke (major cause of lung cancer), vinyl chloride, caffeine, nicotine, mustard gas etc.
- **Biological agents:** E.g. **oncogenic viruses, c-onc (cellular oncogenes or proto oncogenes)** etc. When C-onc in normal cells is activated, the cells become oncogenic.

Cancer detection and diagnosis

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

  In case of leukemia: Biopsy & histopathological studies. Blood & bone marrow tests for increased cell counts.
- **Imaging techniques:**
  - **Radiography:** Use of X-rays.
  - **CT (Computerized tomography) scan:** Uses X-rays to generate a 3D image of the internals of an object.
  - **MRI (Magnetic Resonance Imaging):** Uses magnetic fields and non-ionising radiations to detect pathological and physiological changes in the living tissue.
- Use of **Antibodies** against cancer-specific antigens.
- **Molecular biology technique:** To detect cancer related genes. Such individuals should avoid carcinogens (e.g. tobacco smoke).

Treatment of cancer

- **Radiotherapy:** Tumour cells are irradiated lethally, without damaging surrounding normal tissues.
- **Chemotherapy:** Use of chemotherapeutic drugs. Many drugs have side effects like hair loss, anaemia etc.
- **Immunotherapy:** The patients are given **biological response modifiers** (e.g. α- interferon) which activates their immune system and helps in destroying the tumour.
- **Surgery.**

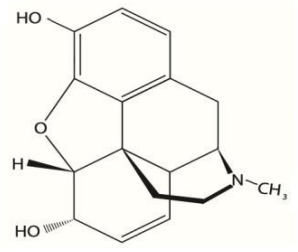
Most cancers are treated by combination of surgery, radiotherapy and chemotherapy.

DRUGS, SMOKING AND ALCOHOL ABUSE

DRUGS

1. Opioids:

- They bind to specific **opioid receptors** in CNS and gastrointestinal tract. E.g. morphine, heroin, brown sugar.



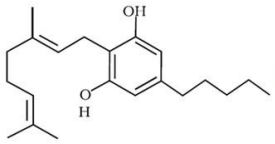
Chemical structure of Morphine


Opium poppy

- **Morphine** is extracted from latex of ***Papaver somniferum*** **(poppy plant).** It is a sedative & painkiller. Used in surgery.
- **Heroin** (*smack* or diacetylmorphine) is a white, odourless, bitter crystalline compound. It is obtained by acetylation of morphine. It is taken by snorting and injection. Heroin is a depressant and slows down body functions.

2. Cannabinoids:

- They interact with **cannabinoid receptors** in the brain.
- Generally taken by inhalation and oral ingestion.
- Natural cannabinoids are obtained from inflorescences of ***Cannabis sativa*** **(Hemp plant).** Its flower tops, leaves & resin are used to make *marijuana, hashish, charas & ganja.*
- They affect cardiovascular system.
- Cannabinoids are abused by some sportspersons.



Skeletal structure of cannabinoid molecule

Leaves of *Cannabis sativa*

Flowering branch of *Datura*

3. Coca alkaloid or cocaine (coke or crack):

- It is obtained from coca plant ***Erythroxylum coca*.**
- It interferes with transport of neurotransmitter dopamine.
- Cocaine is usually snorted.
- It stimulates CNS producing euphoria & increased energy.
- Excessive dosage of cocaine causes hallucinations.
- *Atropa belladona* & *Datura* are also hallucinogenic plants.

Drugs like barbiturates, amphetamines, benzodiazepines, etc. are used as medicines to treat mental illnesses like depression & insomnia. But their abuse causes impairment of physical, physiological or psychological functions.

SMOKING

- Tobacco has been used by human beings for over 400 years.
- It is smoked, chewed or used as a snuff.
- It contains many chemical substances like **nicotine** (an alkaloid). It stimulates adrenal gland to release adrenaline and nor-adrenaline, causing high BP and heart rate.
- Smoking causes cancers of lung, urinary bladder and throat, bronchitis, emphysema, coronary heart disease, gastric ulcer etc. Tobacco chewing causes oral cancer.
- Smoking increases CO content in blood and reduces oxyhaemoglobin. This causes O_2 deficiency in the body.

ADOLESCENCE & DRUG/ALCOHOL ABUSE

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

Causes of drug/alcohol use in Adolescence

- Curiosity and Experimentation.
- Need for adventure and excitement.
- To escape facing problems.
- Stress from pressure to excel in academics or examination.
- Television, movies, newspapers, internet etc.
- Unstable or unsupportive family structures & peer pressure.

Addiction and Dependence

- **Addiction:** It is a psychological attachment (euphoria and a temporary feeling of wellbeing) with drugs and alcohol. With repeated use of drugs, the tolerance level of the receptors increases. Thus the receptors respond only to higher doses leading to greater intake and addiction.
- **Dependence:** It is the tendency of the body to manifest a characteristic and unpleasant ***withdrawal syndrome*** if regular dose of drugs/alcohol is abruptly discontinued. This results in anxiety, shakiness, nausea and sweating. Dependence leads to social adjustment problems.

Effects of Drug/alcohol abuse

- Reckless behaviour, vandalism and violence.
- Coma and death due to respiratory failure, heart failure or cerebral haemorrhage.
- Drugs mixed with alcohol may cause death.
- Damage of nervous system and liver cirrhosis.
- Mental and social distress to family and friends.
- Social problems like stealing and spread of infectious diseases (e.g. AIDS, hepatitis B).
- Use of drugs and alcohol by pregnant woman affect the foetus (Foetal alcohol syndrome or FAS).
- Loss of sexual drive and necrospermia.
- Misuse of drugs by athletes (e.g. narcotic analgesics, anabolic steroids, diuretics & certain hormones to increase muscle strength and bulk and to promote aggressiveness).

Warning signs of drug/alcohol abuse in Adolescence period

- Drop in academic performance and absence from school.
- Lack of interest in personal hygiene.
- Withdrawal and isolation.
- Depression, fatigue, aggressive and rebellious behaviour.
- Change in sleeping and eating habits.
- Fluctuations in weight, appetite etc.
- Loss of interest in hobbies.
- Deteriorating relationships with family and friends.

Side effects of anabolic steroid abuse

In males:

- Acne.
- Mood swings & depression.
- Increased aggressiveness.
- Reduced testicles.
- Decreased sperm.
- Kidney & liver dysfunction.
- Breast enlargement.
- Premature baldness
- Enlargement of prostate gland.

In females:

- Masculinisation
- Mood swings & depression
- Increased aggressiveness
- Excessive hair growth
- Abnormal menstrual cycle
- Deepening of voice
- Enlargement of clitoris

In adolescent male & female: Severe facial and body acne, premature closure of the growth centres of the long bones resulting in stunted growth.

Prevention and control

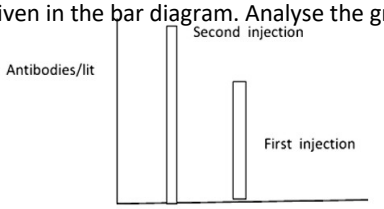
1. Avoid undue peer pressure.
2. Education and counselling.
3. Seeking help from parents and peers.
4. Looking for danger signs.
5. Seeking professional and medical help.
   a. Psychologists and psychiatrists.
   b. De-addiction and rehabilitation programs.

MODEL QUESTIONS

1. Match the following

A	B	C
Malaria	*Haemophilus influenza*	Worms
Pneumonia	*Plasmodium vivax*	Bacteria
Filariasis	*Microsporum*	Protozoan
Ringworm	*Wuchereria bancrofti*	Fungus

2. Analyze the relationship between first two words and fill the fourth place.
   a. Ascariasis: *Ascaris* Cold: ……. b. AIDS: ELISA Typhoid: …….
3. Odd man out. Justify your answer.
   a. Spleen, lymph nodes, thymus, Peyer's patches b. Gastric HCl, PMNL, saliva, tear
   c. Cocaine, Morphine, Brown sugar, Heroine
4. Expand the following abbreviations.
   a. MALT b. CMI c. AIDS d. HIV e. NACO
5. Gopal was playing with his pet dog in the courtyard. Suddenly he developed sneezing, running nose and skin rashes.
   a. With which conditions are the above symptoms related?
   b. Explain the mechanism of reaction.
6. "The soldiers of a country kill their own king". In your body, similar situation take place. Find out that process.
7. Changes occurring in the number of antibodies in an individual injected with same antigen on two separate occasions are given in the bar diagram. Analyse the graph and answer the following questions.



   a. In which injection, the number of antibodies is increased?
   b. Why the injections in two separate occasions with the same antigen cause different results?

8. Select the false statement:
   a. Peer pressure is a cause of alcoholism.
   b. Discontinuing of drug abuse causes withdrawal syndrome.
   c. Adolescence is the physical change of an individual.
   d. AIDS, Hepatitis B etc. may be spread due to drugs & alcoholism.
9. As a part of adolescence health education Programme, prepare a pamphlet showing common problems of adolescence with special regard to mental problems.
10. Prepare a table showing the adverse effects of alcoholism, drug addiction and smoking. Give suitable titles.

11. BIOTECHNOLOGY: PRINCIPLES & PROCESSES

- **Biotechnology** is the technique of using live organisms or their enzymes for products & processes useful to humans.
- The **European Federation of Biotechnology (EFB)** defines Biotechnology as *'the integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services'*.

Biotechnology deals with:
- Microbe-mediated processes (making curd, bread, wine etc).
- *In vitro* fertilization (test-tube baby programme).
- Synthesis and using of a gene.
- Preparation of DNA vaccine.
- Correcting a defective gene.

PRINCIPLES OF BIOTECHNOLOGY

Core techniques of modern biotechnology

- **Genetic engineering:** The technique in which genetic material (DNA & RNA) is chemically altered and introduced into host organisms to change the phenotype.
- **Bioprocess engineering:** Maintenance of sterile ambience in chemical engineering processes for growing desired microbe/eukaryotic cell for the manufacture of antibiotics, vaccines, enzymes etc.

Basic steps in genetically modifying an organism

a) Identification of DNA with desirable genes: Traditional hybridisation leads to inclusion and multiplication of undesirable genes along with desired genes. In genetic engineering, only desirable genes are introduced.

b) Introduction of the identified DNA into the host: A vector DNA such as plasmid is used to deliver an alien piece of DNA into the host organism.

c) Maintenance of introduced DNA in the host and transfer of the DNA to its progeny: A piece of alien DNA has no the sequence called *Origin of replication (ori)* needed for starting replication. So, it cannot multiply itself in the progeny cells of the organism. Hence alien DNA is integrated into the recipient genome (it has *ori*). It multiplies & inherits along with host DNA.

- The process of joining and inserting a foreign piece of DNA into a host organism to produce new genetic combinations is called **recombinant DNA technology.**
- First **recombinant DNA (rDNA)** was produced by **Stanley Cohen & Herbert Boyer** (1972).
- They isolated an antibiotic resistance gene (piece of DNA) from a plasmid of *Salmonella typhimurium*. It was linked with a plasmid vector and transferred into *E. coli.* As a result, the gene was expressed & multiplied in *E. coli.*

TOOLS OF RECOMBINANT DNA TECHNOLOGY

1. Restriction Enzymes ('molecular scissors')

- The enzymes that cut DNA at specific sites into fragments.
- They belong to a class of enzymes called ***nucleases***.
- In 1963, two enzymes responsible for restricting growth of bacteriophage in *E. coli* were isolated. One enzyme added methyl groups to DNA. The other ***(restriction endonuclease)*** cut DNA.
- More than **900 restriction enzymes** have been isolated from over **230 strains** of bacteria.

Naming of the restriction enzymes:

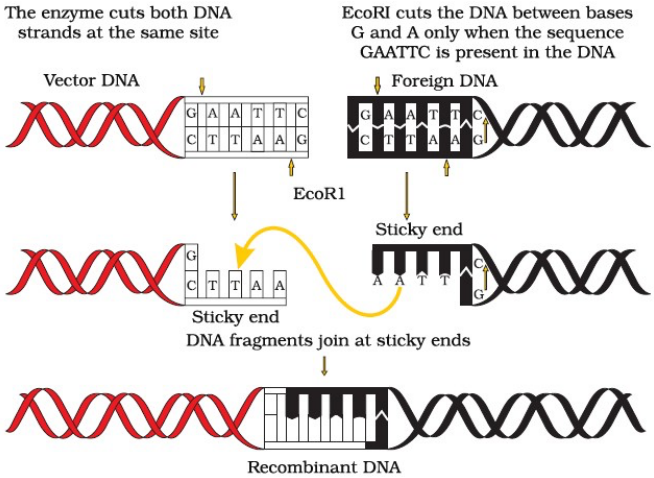
- First letter indicates genus. The second two letters indicate species of prokaryotic cell from which they were isolated. E.g. ***EcoRI*** comes from *E. coli* RY 13 (R = the strain. Roman numbers = the order in which the enzymes were isolated from that strain of bacteria).

Types of Restriction enzymes:

- **Exonucleases:** They remove nucleotides from the ends of the DNA.
- **Endonucleases:**
- They cut at specific positions within the DNA. E.g. EcoRI.
- They bind to specific recognition sequence of the DNA and cut the two strands at specific points.
- The first restriction endonuclease is **Hind II.** It cuts DNA molecules by recognizing a specific sequence of 6 base pairs. This is called the **recognition sequence** for Hind II.

- Restriction endonuclease recognizes a specific **palindromic nucleotide sequences** in the DNA. It is a sequence of base pairs that read the same on the two strands in 5′ → 3′ direction and in 3′ → 5′ direction. E.g. Palindromic nucleotide sequence for EcoRI is

5′—— GAATTC ——3′
3′—— CTTAAG ——5′

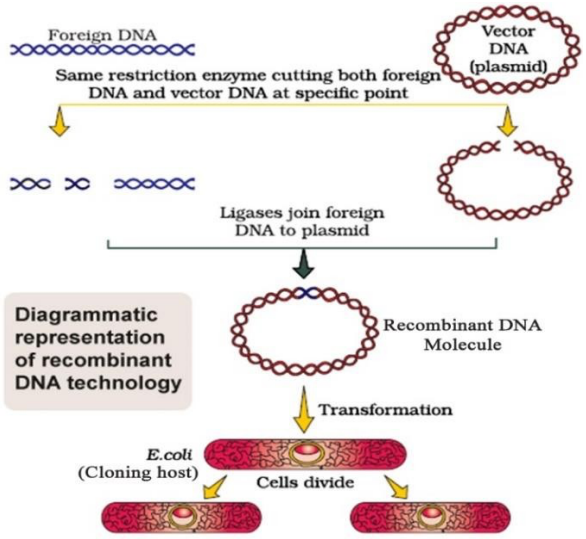


Steps in formation of recombinant DNA by EcoRI

- Restriction enzymes cut the strand a little away from the centre of the palindrome sites, but between the same two bases on the opposite strands. This leaves single stranded overhanging stretches at the ends. They are called **sticky ends**. They form H-bonds with their complementary cut

counterparts. This stickiness facilitates action of the enzyme ***DNA ligase.***

- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of sticky-ends and these are joined together by *DNA ligases.*



2. Cloning Vector

- It is a DNA molecule that can carry a foreign DNA segment and replicate inside the host cells.
  E.g. Plasmids, bacteriophages etc.
- **Plasmids** are autonomously replicating circular extra-chromosomal DNA of bacteria. Some plasmids have only 1-2 copies per cell. Others have 15-100 copies per cell.
- **Bacteriophages** (high number per cell) have very high copy numbers of their genome within the bacterial cells.
- When the cloning vectors are multiplied in the host, the linked piece of DNA is also multiplied to the numbers equal to the copy number of the vectors.

Features required for cloning into a vector

a. Origin of replication (*ori*)

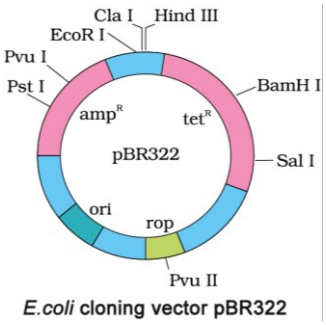
- This is a sequence where replication starts.
- A piece of DNA linked to *ori* can replicate within the host cells. This also controls the copy number of linked DNA. So, for getting many copies of the target DNA, it should be cloned in a vector whose origin support high copy number.

b. Selectable marker (marker gene)

- It is a gene that helps to select the **transformants** and eliminate the **non-transformants.**
- If a piece of DNA is introduced in a host bacterium, it is called **transformation.** Such bacterium is transformant. If transformation does not take place, it is non-transformant.
- Selectable markers of *E. coli* include the genes encoding resistance to antibiotics like *ampicillin, chloramphenicol, tetracycline, kanamycin* etc. Normal *E. coli* cells have no resistance against these antibiotics.

c. Cloning sites

- These are the **recognition sites** for restriction enzymes.
- To link the alien DNA, the vector needs a single or very few **recognition sites.**
- More than one recognition sites generate several fragments. It complicates the gene cloning.
- Ligation of alien DNA is carried out at a restriction site present in one of the two **antibiotic resistance** genes.
  E.g. In vector **pBR322,** foreign DNA is ligated at Bam H I site of tetracycline resistance gene. As a result, **recombinant plasmid** is formed. If ligation does not occur, it is called **non-recombinant plasmid.**



E.coli cloning vector pBR322

- **Restriction sites:** *Hind* III, *Eco*R I, *Bam*H I, *Sa*l I, *Pvu* II, *Pst* I, *Cla* I.
- ***ori***
- **Antibiotic resistance genes:** ampR and tetR.
- **Rop:** codes for the proteins involved in the replication of plasmid.

- When a foreign DNA is inserted within a gene of bacteria, that gene is inactivated. It is called **insertional inactivation.** Here, the recombinant plasmids lose **tetracycline resistance** due to insertion of foreign DNA.
- When the plasmids are introduced into *E. coli* cells, 3 types of cells are obtained:
  - **Non-transformants:** They have no plasmid. So they are not resistant to either tetracycline or ampicillin.
  - **Transformants with non-recombinant plasmid:** They are resistant to both tetracycline & ampicillin.
  - **Transformants with recombinant plasmid:** They are resistant only to ampicillin.
- Recombinant plasmids can be selected out from non-recombinant ones by plating transformants on **ampicillin** medium. Then the transformants are transferred on **tetracycline** medium.
- The **recombinants** grow in **ampicillin** medium but **not on tetracycline** medium. But, non-recombinants grow on the medium containing both the antibiotics.
- Thus, one antibiotic resistance gene helps to select the transformants. The inactivated antibiotic resistance gene helps to select recombinants.
- But this type of selection of recombinants is a difficult procedure because it needs simultaneous plating on 2 plates having different antibiotics. So, alternative **selectable markers** have developed based on their ability to produce colour in presence of a **chromogenic substrate.**
- In this, a recombinant DNA is inserted into the coding sequence (gene) of an enzyme, ***β-galactosidase.*** So, the gene is inactivated (insertional inactivation). Such colonies do not produce any colour. These are identified as recombinant colonies.
- If the plasmid in bacteria have no an insert, it gives **blue coloured** colonies in presence of chromogenic substrate.

d. Vectors for cloning genes in plants & animals

Genetic tools of some pathogens can be transformed into useful vectors for delivering genes to plants & animals. E.g.

- ***Agrobacterium tumefaciens*** (a pathogen of many dicot plants) can deliver a piece of DNA (T-DNA) to transform normal plant cells into a **tumor.** These tumor cells produce the chemicals required by the pathogen.

The **tumor inducing (Ti) plasmid** of *A. tumefaciens* is modified into a cloning vector which is not pathogenic but can use mechanisms to deliver genes of interest into plants.

- **Retroviruses** in animals can transform normal cells into **cancerous** cells. So, they are used to deliver desirable genes into animal cells.

3. Competent Host (For Transformation with Recombinant DNA)

- Since **DNA is a hydrophilic** molecule, it cannot pass through cell membranes. So bacterial cells are made 'competent' to take up alien DNA or plasmid as follows:
- Treat bacterial cells with a specific concentration of a divalent cation (e.g. calcium) → DNA enters the bacterium through pores in cell wall → Incubate the cells with recombinant DNA on ice → Place them briefly at **42^{0}C (heat shock)** → Put them back on ice → Bacteria take up recombinant DNA.

Other methods to introduce alien DNA into host cells

- **Micro-injection:** In this, recombinant DNA is directly injected into the nucleus of an animal cell.
- **Biolistics (gene gun):** In this, cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA. This method is suitable for plants.
- **'Disarmed pathogen' vectors:** They infect the cell and transfer the recombinant DNA into the host. E.g. *A. tumefaciens.*

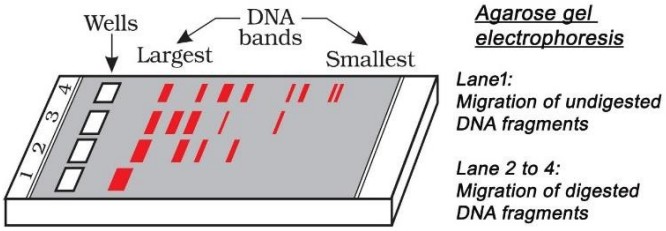
PROCESSES OF RECOMBINANT DNA TECHNOLOGY

1. Isolation of the Genetic Material (DNA)

- Treat the bacterial cells/plant or animal tissue with enzymes like ***lysozyme*** (bacteria), ***cellulase*** (plants), ***chitinase*** (fungus) etc. The cell is broken releasing DNA & other macromolecules (RNA, proteins, polysaccharides & lipids).
- RNA is removed by treating with ***ribonuclease.*** Proteins are removed by treatment with ***protease.*** Other molecules are removed by appropriate treatments.
- When chilled ethanol is added, purified DNA precipitates out as a collection of fine threads in the suspension.

2. Cutting of DNA at Specific Locations

- Purified DNA is incubated with the **restriction enzyme.** As a result, **DNA digests.** These DNA fragments are separated by a technique called **gel electrophoresis**.



- **Agarose gel electrophoresis** is employed to check the progression of a restriction enzyme digestion. DNA is negatively charged. So it moves towards the anode. DNA fragments are separated according to their size through sieving effect of the agarose gel (a polymer extracted from sea weeds). The smaller sized fragment moves farther.
- The process is repeated with the vector DNA also.
- DNA fragments can be seen as bright orange coloured bands when they are stained with **ethidium bromide** and exposed to UV radiation.
- DNA bands are cut out from agarose gel. It is called **elution.** The cut-out **gene of interest** and cut **vector** are mixed and ***ligase*** is added. It creates **recombinant DNA.**

3. Amplification of Gene of Interest using PCR

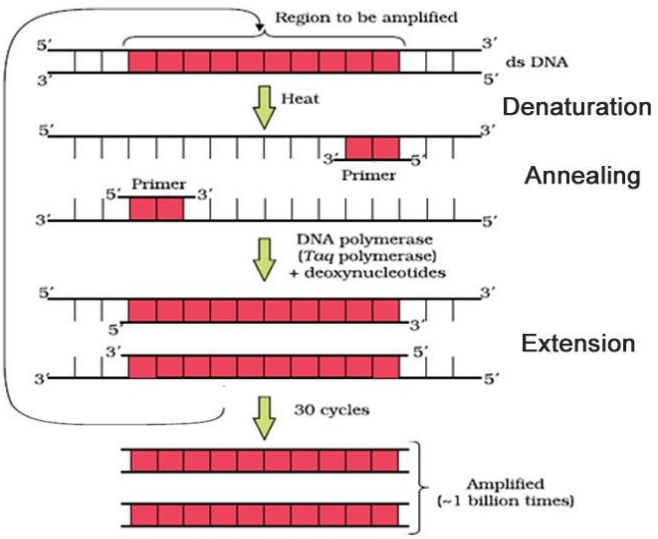
- **Polymerase Chain Reaction (PCR)** is the synthesis of multiple copies of the gene of interest *in vitro* using 2 sets of **primers** & the enzyme ***DNA polymerase.***
- Primers are small chemically synthesized oligonucleotides that are complementary to the regions of DNA.

Steps of PCR:

- **Denaturation:** It is the heating of target DNA (gene of interest) at high temperature (94^0 C) to separate the strands. Each strands act as template for DNA synthesis.
- **Annealing:** It is the joining of the two primers (at 52^0 C) at the 3' end of the DNA templates.
- **Extension:** It is the addition of nucleotides to the primer using a thermostable *DNA polymerase* called ***Taq polymerase.*** It is isolated from a bacterium, ***Thermus aquaticus.*** It remains active in high temperature during the denaturation of double stranded DNA.

  Through continuous replication, the DNA segment is amplified up to 1 billion copies.

  The amplified fragment can be used to ligate with a vector for further cloning.



4. Insertion of Recombinant DNA into Host Cell

- Using any methods, the ligated DNA is introduced into recipient (host) cell / organism. They take up DNA from its surrounding.
- If a recombinant DNA bearing **ampicillin resistant gene** is transferred into *E. coli* cells, the host cells become ampicillin-resistant cells.

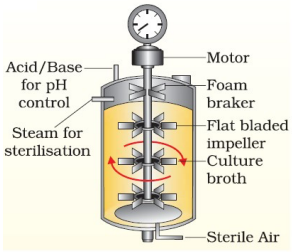
- If the transformed cells are spread on agar plates containing ampicillin, only transformants will grow. Untransformed recipient cells will die.

5. Obtaining the Foreign Gene Product

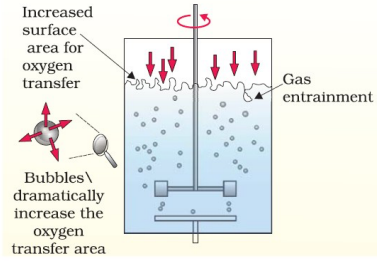
- The aim of recombinant DNA technology is to produce a desirable protein.
- If a protein encoding foreign gene is expressed in a heterologous host, it is called a **recombinant protein**.
- The cells with foreign genes can be grown in laboratory. The cultures are used to extract the desired protein and purify it by using separation techniques.
- The cells can also be multiplied in a **continuous culture system.** Here, the used medium is drained out from one side while fresh medium is added from the other. It maintains the cells more physiologically active and so produces a larger biomass. It yields more desired protein.

Bioreactors

- These are the vessels in which raw materials are biologically converted to specific products, enzymes etc., using microbial, plant, animal or human cells.
- Bioreactors are used to produce large quantities of products. They can process 100-1000 litres of culture.
- A bioreactor provides the optimal growth conditions (pH, temperature, substrate, salts, vitamins, oxygen) to get desired product.
- The most commonly used bioreactors are of stirring type **(stirred-tank bioreactor).**



Simple stirred-tank bioreactor



Sparged stirred-tank bioreactor through which sterile air bubbles are sparged

It is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents. The stirrer facilitates even mixing and oxygen availability. Alternatively, air can be bubbled through the reactor.

The bioreactor has

- An agitator system
- An oxygen delivery system
- A foam control system
- A temperature control system
- pH control system
- Sampling ports (for periodic withdrawal of the culture).

6. Downstream Processing

- It is a series of processes such as **separation and purification of products** after the biosynthetic stage.
- The product is formulated with suitable preservatives. Such formulation undergoes thorough clinical trials and strict quality control testing.

MODEL QUESTIONS

1. Identify the tools.
   a) Separation of DNA b) Amplification of DNA
   c) Large scale purification of product d) Isolation of separated DNA fragments
2. Draw & label the parts of pBR322.
3. Some processes of recombinant DNA technology are given below. Arrange them in correct order.
   a. Amplification of gene of interest using PCR b. Cutting of DNA at specific locations
   c. Obtaining the foreign gene product d. Insertion of recombinant DNA into the host cell
   e. Isolation of the genetic material (DNA) f. Downstream processing
4. Observe the following and answer to the questions.
   5'_____GAATTC_____3'
   3'_____CTTAAG_____5'
   a) Identify the above sequence.
   b) What is the significance of this kind of sequence in recombinant DNA technology?
5. Restriction enzymes & ligases opened the doorway for recombinant DNA technology. Do you agree with this? Justify.
6. Electrophoresis is the migration of charged particles in solution under the influence of an electric field.
   a) Who developed this technique? b) Name the supporting media in AGE and PAGE.
7. A plasmid is a circular double-stranded extra chromosomal DNA in a bacterial cell.
   a) Name the naturally occurring plasmids in *E. coli* and in Agrobacterium.
   b) Name an artificially reconstructed plasmid.
8. PCR is meant for making multiple copies of a gene of interest. Mention the major steps involved in PCR. Name an organism form which a thermostable DNA polymerase is isolated.

12. BIOTECHNOLOGY AND ITS APPLICATIONS

Biotechnology has many applications such as **biopharmaceuticals, therapeutics, diagnostics, genetically modified crops, processed food, bioremediation, waste treatment and energy production.**

Biotechnology has 3 critical research areas:

a. **Providing the best catalyst** in the form of improved organism usually a microbe or enzyme.
b. **Creating optimal conditions** through engineering for a catalyst to act.
c. **Downstream processing technologies** to purify the protein/organic compound.

APPLICATIONS IN AGRICULTURE

3 options for increasing food production:

a. **Agro-chemical based agriculture:** It uses fertilizers & pesticides. Expensive. Causes environmental pollution.
b. **Organic agriculture:** Expensive.
c. **Genetically engineered crop-based agriculture:** It uses genetically modified crops. **Genetically Modified Organisms** (**GMO**) are the plants, bacteria, fungi & animals whose genes are altered by manipulation.

Advantages of genetic modification in plants:

- It makes crops more tolerant to abiotic stresses (cold, drought, salt, heat etc.).
- Pest-resistant crops reduce the use of chemical pesticides.
- It reduces post-harvest losses.
- It increases efficiency of mineral usage by plants (it prevents early exhaustion of soil fertility).
- It enhances nutritional value of food. E.g. Golden rice (Vitamin A enriched rice).
- To create tailor-made plants to supply alternative resources (starches, fuels, pharmaceuticals etc.) to industries.

Pest Resistant Plants

- They act as **bio-pesticide.**
- It reduces the need for insecticides.
- E.g. Bt cotton, Bt corn, rice, tomato, potato, soyabean etc.

Bt Cotton:

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

Nematode resistance in tobacco plants:

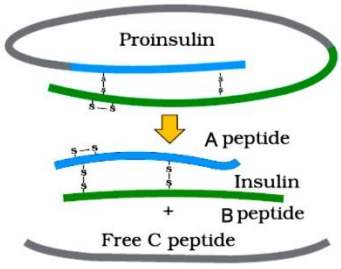
- A nematode *Meloidogyne incognita* infects the roots of tobacco plants causing a reduction in yield.
- It can be prevented by **RNA interference** (RNAi) strategy.
- **RNAi** is a method of cellular defense in all eukaryotic organisms. It prevents translation of a specific mRNA (silencing) due to a complementary dsRNA molecule.
- The source of this complementary RNA is from an infection by RNA viruses or mobile genetic elements (transposons) that replicate via an RNA intermediate.
- Isolate Nematode-specific genes (DNA). It is introduced into host plant using *Agrobacterium* vectors. It produces both sense & anti-sense RNA in host cells. These RNAs are complementary. So they form double stranded (ds) RNA. It initiates RNAi and silences the specific mRNA of nematode. Thus the parasite cannot survive in a transgenic host expressing specific interfering RNA.

APPLICATIONS IN MEDICINE

- Recombinant DNA technology helps for mass production of safe and more effective **therapeutic drugs.**
- Products from non-human sources cause unwanted immunological responses. But recombinant therapeutics does not have such problems.
- At present, about 30 recombinant therapeutics have been approved. Of these, 12 are being marketed in India.

1. Genetically Engineered Insulin

- Insulin is used to manage adult-onset diabetes.
- Insulin from the pancreas of animals (cattle & pigs) causes allergy or other types of reactions to the foreign protein.
- Now, it is possible to produce human insulin using bacteria.
- Insulin consists of two short **polypeptide chains (chain A & chain B)** that are linked by disulphide bridges.
- In mammals, insulin is synthesized as a **pro-hormone (pro-insulin).** It is processed to become mature and functional hormone.



- The pro-hormone contains an extra stretch called **C peptide**. This is removed during maturation into insulin.
- In 1983, **Eli Lilly** (an American company) prepared two DNA sequences corresponding to A & B chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains. Chains A & B were combined by creating disulfide bonds to form human insulin ***(Humulin).***

2. Gene Therapy

- It is a method to correct a gene defect in a child/embryo.
- Here, genes are inserted into a person's cells and tissues to treat a hereditary disease. It compensates for the non-functional gene.
- First clinical gene therapy (1990) was given to a 4-year old girl with **adenosine deaminase (ADA) deficiency.**
- This is caused due to the deletion of a gene of ***adenosine deaminase*** (an enzyme for the functioning of immune system). It can be cured by **bone marrow transplantation** or by **enzyme replacement therapy** (injection of ADA). But these are not completely curative.
- **Gene therapy for ADA deficiency:** Collect **lymphocytes** from the patient's blood and grow in a culture → Introduce a functional **ADA cDNA** into lymphocytes (using a retroviral vector) → They are returned to the patient.
  This should be periodically repeated as lymphocytes are not immortal.
- If the **ADA gene** from marrow cells is introduced into cells at early embryonic stages, it could be a permanent cure.

3. Molecular Diagnosis

- Conventional methods (serum & urine analysis) are not suitable for early diagnosis of diseases.
- It is possible by techniques such as **Recombinant DNA technology, PCR & ELISA.**

PCR (Polymerase Chain Reaction):

- Presence of a pathogen is normally suspected only based on symptoms. By this time, the concentration of pathogen is already very high in the body.
- However, very low concentration of a bacteria or virus can be detected by amplification of their nucleic acid by PCR.
- **Uses of PCR:**
  - To detect HIV in suspected patients.
  - To detect gene mutations in suspected cancer patients.
  - To identify many other genetic disorders.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is hybridized to its complementary DNA in a clone of cells. It is detected by autoradiography. The clone having mutated gene will not appear on photographic film, because the probe will not have complementarity with mutated gene.

ELISA (Enzyme Linked Immuno-Sorbent Assay):

- It is based on **antigen-antibody interaction.**
- Infection by pathogen can be detected by the presence of **antigens** (proteins, glycoproteins, etc.) or by detecting the **antibodies** synthesized against the pathogen.

TRANSGENIC ANIMALS

- These are the animals whose genome has been altered by introduction of a foreign gene by manipulation.
- E.g. Transgenic rats, rabbits, pigs, sheep, cows and fish.
- Over 95% of the transgenic animals are mice.

Benefits of transgenic animals

- **To study regulation of genes and their action on normal physiology & development:** E.g. Study of **insulin-like growth factor.** Genes (from other species) that alter formation of this factor are introduced and the biological effects are studied. This gives information about biological role of the factor.
- **To study the contribution of genes in the development of a disease and thereby new treatments:** E.g. transgenic models for human diseases such as cancer, cystic fibrosis, rheumatoid arthritis & Alzheimer's.
- **Biological products:** Some medicines contain expensive biological products. Transgenic animals can be used to produce biological products by introducing genes which codes for a particular product.
  They are used to treat diseases such as emphysema, phenylketonuria (PKU), cystic fibrosis etc. E.g. **human protein (α-1-antitrypsin)** used to treat emphysema.
  In 1997, **Rosie** (first transgenic cow) produced human protein-enriched milk (2.4 gm per litre). It contains **human α-lactalbumin.** It is nutritionally more balanced product for human babies than natural cow-milk.
- **Vaccine safety testing:** Transgenic mice are used to test the safety of the polio vaccine. If it is reliable, they can replace the use of monkeys to test the safety of vaccines.
- **Chemical safety testing (toxicity testing):** Some transgenic animals carry genes which make them more sensitive to toxic substances than non-transgenic animals. They are exposed to the toxic substances and the effects studied. It gives immediate results.

ETHICAL ISSUES

- **Problem of unpredictable results:** Genetic modification may cause unpredictable results.
  Indian Government has set up organizations like **GEAC** (Genetic Engineering Approval Committee) to make decisions about the validity of GM research and the safety of GM-organisms for public services.
- **Bio-piracy:** It is the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned. Certain companies have got patents for products and technologies that make use of the genetic materials, plants etc. that have been identified, developed and used by farmers and indigenous people of a country. E.g. Basmati rice, herbal medicines (turmeric, neem etc.).
  Basmati rice has unique aroma & flavour. India has 27 varieties of Basmati. In 1997, an American company got patent rights on Basmati rice through the **US Patent and Trademark Office.** This allowed the company to sell a 'new' variety of Basmati. This was actually derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as a novelty. Other people selling Basmati rice could be restricted by patent.

Generally, industrialized nations are poor in biodiversity and traditional knowledge. The developing and underdeveloped world have rich biodiversity and traditional knowledge related to bio-resources.

It has to develop laws to prevent unauthorized exploitation of bio-resources and traditional knowledge.

Indian Parliament has cleared the second amendment of the **Indian Patents Bill** that has considered patent terms emergency provisions and research and development initiative.

MODEL QUESTIONS

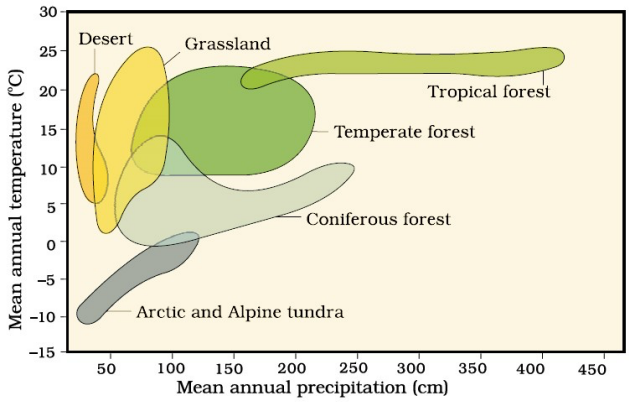
1. There are many advantages of genetic modification in plants. Mention any four advantages.
2. Now a days Bt Brinjal has been much in the news. Being a GM Food is it advantageous or disadvantageous? List out any two points each.
3. Transgenic animals are said to be beneficial to humans. Justify this statement by giving two reasons.
4. Genetically modified tomato has some significance. Comment.
5. With an example, explain how biotechnology has been applied in each of the following:
   a) In curing Diabetes mellitus b) In rising pest resistant plants
   c) In producing nutritionally balanced milk.
6. Briefly explain the terms: a) cry gene b) C peptide
7. Explain RNA interference (RNAi) strategy.
8. Biotechnology has provided some techniques for early diagnosis of diseases. Mention any 2 examples.
9. Expand the following abbreviations:
   a) GMO b) PCR c) ADA d) ELISA e) GEAC
10. Do you think it is ethical to manipulate organisms for human benefits? Justify your answer.
11. What do you understand by the term Biopiracy?

13. ORGANISMS AND POPULATIONS

Ecology is the study of interactions among organisms and between the organism and its physical (abiotic) environment.
Ecology is concerned with 4 levels of biological organization: Organisms, Populations, Communities & Biomes.

ORGANISM AND ITS ENVIRONMENT

- **Physiological ecology** (Ecology at the organismic level) is the study of adaptation of an organism to environments in terms of survival and reproduction.
- The rotation of earth and the tilt of its axis cause annual variations in temperature & seasons. Major biomes (desert, rain forest, tundra etc.) are formed due to these variations & precipitation (rain & snow).



Biome distribution with respect to annual temperature and precipitation

- Regional and local variations within a biome lead to the formation of different habitats.
- Life exists even in extreme & harsh habitats. E.g. Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, permafrost (snow laden) polar regions, high mountain tops, thermal springs & compost pits.
  Our intestine is a habitat for many microbes.
- **The physico-chemical (abiotic) components** (water, light, temperature, soil etc.) & **biotic components** (pathogens, parasites, predators, competitors etc.) lead to variation of different habitats.
- The distinct role and position of an organism in its environment is called its **niche.** By this, each organism tolerates various conditions, utilises various resources etc.

Abiotic Factors

a. Temperature

- The most ecologically relevant environmental factor.
- Temperature on land varies seasonally. It gradually decreases from equator to the poles and from plains to mountain tops. It ranges from subzero levels (in polar areas & high altitudes) to >50^{0}C (in tropical deserts).
- Average temperature in thermal springs & deep-sea hydrothermal vents is above 100^0 C.
- Mango trees cannot grow in temperate countries (Canada, Germany etc.). There is no Snow leopard in Kerala forests. Tuna fishes are rare beyond tropical latitudes in the ocean.
- Temperature affects kinetics of enzymes, basal metabolism and other physiological functions of the organism.
- Based on range of thermal tolerance, organisms are 2 types:
  - **Eurythermal:** They can tolerate a wide range of temperatures.
  - **Stenothermal:** They can tolerate only a narrow range of temperatures.

b. Water

- It is the second most important factor.
- Desert organisms have special adaptations to limited water.
- Productivity & distribution of plants is dependent on water.
- For aquatic organisms, water quality (pH, chemical composition) is important. The salt concentration (salinity in parts per thousand) is less than 5 in inland waters, 30-35 in the sea and > 100 in some hypersaline lagoons.
- Based on the tolerance to salinity, organisms are 2 types:
  - **Euryhaline:** Tolerate a wide range of salinities.
  - **Stenohaline:** Tolerate only a narrow range of salinity.

  Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems.

c. Light

- Plants need sunlight for photosynthesis.
- Small forest plants (herbs & shrubs) are adapted to photosynthesize optimally under very low light because they are overshadowed by tall, canopied trees.
- Many plants depend on sunlight for photoperiodism (e.g. flowering).
- Many animals use diurnal and seasonal variations in light intensity and photoperiod for timing their foraging, reproductive & migratory activities.
- Sun is the ultimate source for light & temperature on land. Deep (> 500m) in the oceans, the environment is dark and there is no energy available from sun.
- The spectral quality of solar radiation is also important for life. The UV spectrum is harmful to many organisms. Not all the colour components of the visible spectrum are available for marine plants.

d. Soil

- Nature & properties of soil is differed due to climate, weathering, sedimentation, method of soil development etc.
- **Soil composition, grain size & aggregation** determine the percolation and water holding capacity of the soils.
- These characteristics and parameters like **pH, mineral composition & topography** determine the vegetation and animals in an area.
- In aquatic environment, the sediment-characteristics determine the type of **benthic animals.**

Responses to Abiotic Factors

- Organisms maintain a stable internal environment ***(homeostasis)*** despite varying external environmental conditions. This is possible by following processes.

a. Regulate

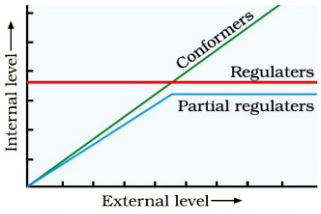
- It is the maintenance of homeostasis by physiological & behavioural means. It ensures constant body temperature

(thermoregulation), constant osmotic concentration (osmoregulation) etc. E.g. All birds & mammals, very few lower vertebrates and invertebrates.

- **Thermoregulation in mammals:** The success of mammals is mainly due to their ability to maintain a constant body temperature.
  In summer, when outside temperature is more than body temperature (37^0C), sweating occurs. This results in evaporative cooling and brings down body temperature.
  In winter, when the temperature is below 37^0C, shivering occurs. It produces heat and raises the body temperature.
- Most of the organisms are not regulators or are partial regulators because thermoregulation is **energetically expensive** especially for small animals (shrews, humming birds etc.). They have a larger surface area relative to their volume. So they lose body heat very fast when it is cold outside. Then they have to expend much energy to generate body heat. So, very small animals are rare in Polar Regions.

b. Conform

- 99% of animals and nearly all plants cannot maintain a constant internal environment. Their body temperature or osmotic concentration change with the surrounding conditions. They are called **conformers.**
- In aquatic animals, osmotic concentration of body fluids changes with that of the ambient osmotic concentration.



Diagrammatic representation of organismic response

c. Migrate

- Many animals like birds move away temporarily from stressful habitat to a more hospitable area and return when stressful period is over.
- E.g. During winter, Keolado National Park (Bhartpur, Rajasthan) hosts migratory birds coming from Siberia and other extremely cold northern regions.

d. Suspend

- In bacteria, fungi & lower plants, thick walled spores help to survive unfavourable conditions. Under suitable conditions, they germinate.
- In higher plants, seeds and some vegetative reproductive structures serve to tide over periods of stress by reducing their metabolic activity. They germinate under favourable moisture and temperature.

  In animals: Examples are
  - *Hibernation* of bears during winter.
  - *Aestivation* of some snails and fishes during summer.
  - *Diapause* (a stage of suspended development) of many zooplanktons in lakes & ponds.

Adaptations

- **Adaptation** is the morphological, physiological & behavioural attribute that enables an organism to survive and reproduce in its habitat.
- Many adaptations have evolved over a long evolutionary time and are genetically fixed.

Adaptations of kangaroo rat in North American deserts:

- Internal **fat oxidation** gives water as byproduct if there is no external source of water.
- Ability to **concentrate urine** so that minimal volume of water is used to remove excretory products.

Adaptations of desert plants:

- Presence of **thick cuticle** on leaf surfaces.
- **Sunken stomata** minimise water loss due to transpiration.
- **CAM photosynthetic pathway** enables their stomata to remain closed during day time.
- Desert plants like *Opuntia* have **no leaves** (they are reduced to spines). Photosynthesis is done by stems.

Adaptations of mammals:

- Mammals from colder climates have shorter ears and limbs to reduce heat loss. This is called **Allen's Rule.**
- Aquatic mammals like seals have a thick layer of fat (blubber) below their skin that acts as an insulator and reduces loss of body heat.

Physiological and biochemical adaptations:

- ***Archaebacteria*** are found in hot springs & deep-sea hydrothermal vents where temperature is **>100^{0}C.** Many fish thrive in Antarctic waters (temperature is below 0^0C).
- Many marine invertebrates & fishes live at great depths in the ocean where the pressure is >100 times the normal atmospheric pressure.
- At a high-altitude place (>3,500 m) we feel ***altitude sickness.*** Its symptoms are nausea, heart palpitations & fatigue. This is due to low atmospheric pressure. So the body does not get enough O_2. Gradually, we acclimatize the situation and the body compensates low O_2 availability by increasing RBC & breathing rate and decreasing the binding capacity of hemoglobin.

Behavioural adaptations:

- Desert lizards bask in the sun and absorb heat when their body temperature is low, but move into shade when the ambient temperature starts increasing.
- Some species burrow into the soil to hide and escape from the above-ground heat.

POPULATIONS

- A **population** is a group of individuals of same species that live in a given geographical area, share or compete for similar resources and potentially reproduce.
- E.g. All the cormorants in a wetland, rats in an abandoned dwelling, teakwood trees in a forest tract, bacteria in a culture plate and lotus plants in a pond etc.
- Population ecology is an important area of ecology as it links ecology to population genetics & evolution.

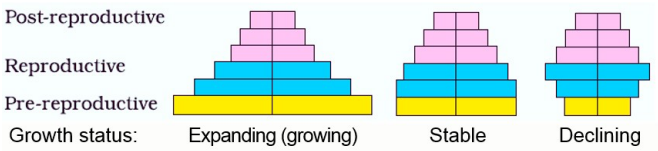
Population Attributes

- **Birth rates:** Refer to *per capita* births.
  E.g. In a pond, there are 20 lotus plants last year and through reproduction 8 new plants are added.

Hence, the current population = 28

The birth rate = 8/20 = 0.4 offspring per lotus per year.

- **Death rates:** Refer to *per capita* deaths.
  E.g. 4 individuals in a laboratory population of 40 fruit flies died during a week.
  Hence, the death rate = 4/40 = 0.1 individuals per fruit fly per week.
- **Sex ratio:** A population has a sex ratio.
  E.g. 60% of the population is females and 40% males.
- **Age pyramid:** It is the structure obtained when the age distribution (% individuals of a given age or age group) is plotted for the population.
  For human population, age pyramids generally show age distribution of males and females in a combined diagram.



Representation of age pyramids for human population

- **Population size or population density (N):** It is the number of individuals of a species per unit area or volume.
  E.g. population density of Siberian cranes at Bharatpur wetlands in any year is <10. It is millions for *Chlamydomonas* in a pond.
  Population size is also measured in **% cover or biomass.**
  E.g. In an area, 200 *Parthenium* plants and a huge banyan tree are seen. In such cases, measuring % cover or biomass is meaningful to show importance of banyan tree.

  Total number is a difficult measure for a huge population. In such cases, **relative population density** (without knowing absolute population density) is used. E.g. Number of fish caught per trap indicates its total population density in the lake.

  In some cases, indirect estimation of population sizes is performed. E.g. Tiger census in national parks & tiger reserves based on pug marks & fecal pellets.

POPULATION GROWTH

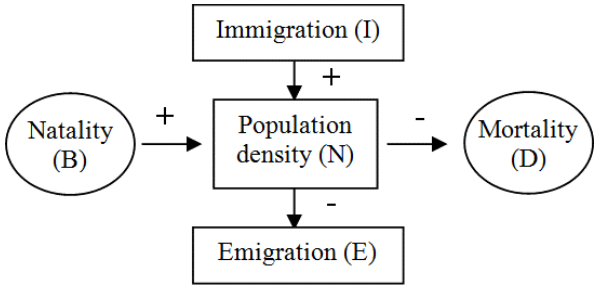
The population size changes depending on factors like food availability, predation pressure & weather.

Changes in population density give some idea about the population – whether it is flourishing or declining.

4 basic processes that fluctuate the population density:

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

Natality & immigration increase the population density and mortality & emigration decrease the population density.



- 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 increases if B+I is more than D+E. Otherwise it will decrease.
- Under normal conditions, births & deaths are important factors influencing population density. Other 2 factors have importance only under special conditions. E.g. for a new colonizing habitat, immigration may be more significant to population growth than birth rates.

Growth Models

a. Exponential growth

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

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

Let (b–d) = r, then

$$dN/dt = rN$$

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

r value for the Norway rat = 0.015

r value for the flour beetle = 0.12

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

The integral form of the exponential growth equation is

$$N_t = N_0 e^{rt}$$

Where,

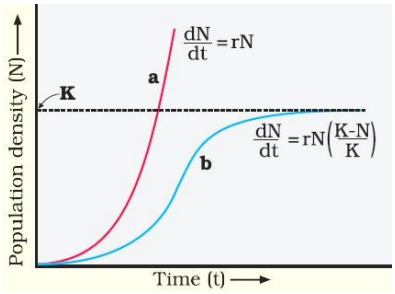
N_t = Population density after time t

N_0 = Population density at time zero

r = intrinsic rate of natural increase

e = the base of natural logarithms (2.71828)

Population growth curves



a = exponential growth (J-shaped curve)
b = logistic growth (Sigmoid curve)

b. Logistic growth

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

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

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 limited, the logistic growth model is more realistic.

Life History Variation

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

Population Interactions

- Organisms interact in various ways to form a biological community.
- Interaction between two species is called **Interspecific interactions.** They include

Name of interaction	Species A	Species B
Mutualism: Both species are benefitted (+)	+	+
Competition: Both species are harmed (-)	-	-
Predation: One (predator) is benefitted. Other (prey) is harmed	+	-
Parasitism: One (parasite) is benefitted. Other (host) is harmed	+	-
Commensalism: One is benefitted. Other is unaffected (0)	+	**0**
Amensalism: One is harmed. Other is unaffected	-	**0**

- In predation, parasitism & commensalisms, the interacting species live closely together.

a. Predation

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

Importance of predators:

- **Predators control prey populations.**
  When certain exotic species are introduced into a geographical area, they spread fast due to the absence its natural predators. E.g. Prickly pear cactus introduced into Australia (1920's) caused havoc by spreading. Later, it was controlled by introducing a cactus-feeding predator moth.
- Predators are used in **Biological control** methods.
- Predators **maintain species diversity** in a community by reducing competition among prey species.
  E.g. the predator starfish *Pisaster* in the rocky intertidal communities of American Pacific Coast. In an experiment, all these starfishes were removed from an enclosed intertidal area. It caused extinction of over 10 invertebrate species within a year, due to interspecific competition.

Defenses of prey species to lessen impact of predation:

- ***Camouflage*** (cryptic colouration) of some insects & frogs.
- Some are **poisonous** and so avoided by the predators.
- Monarch butterfly is highly distasteful to its predator bird. It is due to a special chemical in its body. It is acquired during its caterpillar stage by feeding on a poisonous weed.
- **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* produce highly poisonous **cardiac glycosides.** Therefore cattle or goats do not eat it. **Nicotine, caffeine, quinine, strychnine, opium,** etc. are defenses against grazers and browsers.

b. Competition

- It is a process in which fitness of one species ('r' value) is significantly lower in presence of another species.
- Interspecific competition is a potent force in organic evolution.
- Competition occurs when closely related species compete for the same limited resources.
- Unrelated species can also compete for the resource. E.g. Flamingoes & fishes in some shallow South American lakes compete for zooplankton.
- Competition occurs in abundant resources also. E.g. In **interference competition,** the feeding efficiency of one species is reduced due to the interfering and inhibitory presence of other species, even if resources are abundant.

Evidences for competition:

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

- **Competitive release:** It is the expansion of distributional range of a species when the competing species is removed.

  Connell's field experiments: On the rocky sea coasts of Scotland, there are 2 barnacle species: *Balanus* (larger & competitively superior) & *Chthamalus* (smaller). *Balanus* dominates intertidal area and excludes *Chthamalus.*
  When Connell experimentally removed *Balanus, Chthamalus* colonized the intertidal zone.

Gause's 'Competitive Exclusion Principle':

- It states that *two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually*. This may be true in limited resources, but not otherwise.
- Species facing competition may evolve mechanisms for co-existence rather than exclusion. E.g. resource partitioning.
- **Resource partitioning**: It is the division of limited resources by species to avoid competition. For this, they choose different feeding times or different foraging patterns. E.g. MacArthur showed that five closely related species of **warblers** living on a tree could avoid competition and co-exist due to behavioural differences in their foraging activities.

c. Parasitism

- Many parasites are **host-specific** (they can parasitize only a single host species). They tend to **co-evolve.** i.e., if the host evolves special mechanisms against the parasite, the parasite also evolves mechanisms to counteract them to remain with the same host species.
- **Adaptations of parasites:** Loss of sense organs, presence of adhesive organs or suckers to cling on to the host, loss of digestive system, high reproductive capacity etc.
- Life cycles of parasites are often complex. E.g.
  - Human liver fluke depends on 2 intermediate hosts (a snail & a fish) to complete its life cycle.
  - Malarial parasite needs mosquito to spread to other hosts.
- Parasites harm the host. They may reduce the survival, population density, growth and reproduction of the host. They may make the host physically weak and more vulnerable to predation.

Types of parasites:

1. Ectoparasites

- Parasites that feed on the external surface of host. E.g.
  - Lice on humans.
  - Ticks on dogs.
  - Ectoparasitic Copepods on many marine fishes.
  - *Cuscuta* plant on hedge plants.
- *Cuscuta* has no chlorophyll and leaves. It derives its nutrition from the host plant.
- Female mosquito is not considered a parasite, because it needs our blood only for reproduction, not as food.

2. Endoparasites

- Parasites that live inside the host body at different sites (liver, kidney, lungs, RBC etc).
- The life cycles of endoparasites are more complex.
- They have simple morphological & anatomical features and high reproductive potential.

Brood parasitism in birds:

- Here, the parasitic birds lay eggs in the nest of its host and lets the host incubate them.
- During evolution, eggs of the parasitic bird have evolved to resemble the host's egg in size and colour. So the host bird cannot detect and eject the foreign eggs easily.
- E.g. Brood parasitism between **cuckoo and crow.**

d. Commensalism

Examples:

- Orchid (+) growing as *epiphyte* on a mango branch (0).
- Barnacles (+) growing on the back of a whale (0).
- Cattle egret (+) & grazing cattle (0). The egrets forage close to where the cattle are grazing. As the cattle move, the vegetation insects come out. Otherwise it is difficult for the egrets to find and catch the insects.
- Sea anemone (0) & clown fish (+). Stinging tentacles of sea anemone gives protection to fish from predators.

e. Mutualism

Examples:

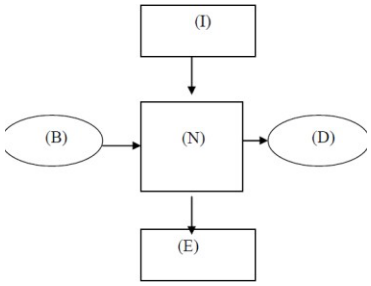
- **Lichen:** It is a mutualistic relationship between a fungus & photosynthesizing algae or cyanobacteria.
- **Mycorrhizae:** Associations between fungi & the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant provides the fungi with carbohydrates.
- **Mutualism b/w plant & animal through pollination and seed dispersion:**

  Examples:

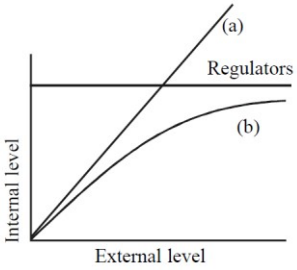
  1. **Fig trees & wasps.** The fig species is pollinated only by its 'partner' wasp species. Female wasp pollinates the fig inflorescence while searching for suitable egg-laying sites in fruits. The fig offers the wasp some developing seeds, as food for the wasp larvae.
  2. **Orchids** show diversity of floral patterns. They can attract the right pollinator insect **(bees & bumblebees)** to ensure pollination. Not all orchids offer rewards.
  3. **'Sexual deceit' of *Ophrys*** (Mediterranean orchid). One petal of its flower resembles female bee in size, colour & markings. So male bee 'pseudocopulates' with the flower and is dusted with pollen. When this bee 'pseudocopulates' with another flower, it transfers pollen to it.
     If the female bee's colour patterns change slightly during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee.

MODEL QUESTIONS

1. All freshwater animals cannot live for long in sea water or a marine organism in freshwater. Give reason.
2. Observe the figure below:



   a. Expand N, B, D, I & E
   b. When will population density increase?
   c. List two factors which influence population density under normal conditions.
3. Observe the graphical representation of organismic response and name a & b.



4. Different responses made by organism to cope with the stressful situations are given below. Arrange them in columns.

Regulate	Change of body temperature according to external environment
Conform	Hard and resistant spores /hibernation
Migrate	Sweating and shivering to maintain body temperature
Suspend	Moving to hospitable area

5. Match the following

Name of Interaction	Type of Interaction	Examples
Mutualism	+ –	*Cuscuta*
Competition	+ +	*Vanda*
Pararitism	+ 0	*Flemingoes & fisher*
Commensalism	– –	*Lichen*

6. It is common sight in villages where cattle egrets & grazing cattle are found in close association.
   a. What kind of interaction do they show?
   b. Give an example of such an interaction from plants.

14. ECOSYSTEM

An ecosystem is a functional unit of nature, where living organisms interact each other and with the physical environment.

ECOSYSTEM – STRUCTURE & FUNCTION

Types of ecosystems

- **Terrestrial ecosystem:** Forest, grassland, desert etc.
- **Aquatic ecosystem:** Pond, lake, wetland, river & estuary.
- **Man-made ecosystem:** Crop fields and aquarium.

- Entire biosphere is regarded as **global ecosystem.**
- In an ecosystem, biotic and abiotic components interact and function as a unit.
- Vertical distribution of different species occupying different levels is called **stratification**. E.g. in a forest, trees occupy top strata (layer), shrubs the second and herbs & grasses the bottom layers.

Pond (Aquatic ecosystem)

A pond is a shallow, simple, self-sustainable water body that exhibits all basic components of an ecosystem.

- **Abiotic components:** Water and soil deposit.
- **Climatic conditions:** Solar input, cycle of temperature, day-length etc.
- **Autotrophic components:** Phytoplankton, some algae and the floating, submerged and marginal plants.
- **Consumers (heterotrophs):** Zooplankton, free swimming and bottom dwelling forms.
- **Decomposers:** Fungi, bacteria and flagellates.

Pond performs all the functions of an ecosystem. E.g.

- Autotrophs convert inorganic into organic material using solar radiant energy.
- Heterotrophs consume the autotrophs.
- Decomposition and mineralization of the dead matter to release them back for reuse by the autotrophs.

4 basic components of functioning of an ecosystem:

1) Productivity
2) Decomposition
3) Energy flow
4) Nutrient cycling

1. PRODUCTIVITY

- Solar energy is the basic requirement for an ecosystem to function and sustain.
- Amount of biomass (organic matter) produced per unit area over a time period by plants during photosynthesis is called **primary production.** It is expressed in weight (g^{-2}) or energy (kcal m^{-2}).
- The rate of biomass production is called **productivity**. It is expressed in $g^{-2}\,yr^{-1}$ or (kcal m^{-2})yr^{-1}.
- It is divided into gross primary productivity (GPP) and net primary productivity (NPP).
- **Gross primary productivity (GPP):** It is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is used by plants in respiration.
- **Net primary productivity (NPP):** It is the available biomass for the consumption to heterotrophs (herbivores & decomposers). i.e., NPP is the Gross primary productivity minus respiration losses (R).

$$\textbf{NPP = GPP – R}$$

- **Secondary productivity:** It is the rate of formation of new organic matter by consumers.
- Primary productivity varies in different ecosystems because it depends on
  - The plant species inhabiting an area.
  - Environmental factors.
  - Availability of nutrients.
  - Photosynthetic capacity of plants.
- **Annual net primary productivity** of whole biosphere is about **170 billion tons** (dry weight) of organic matter. Of this, despite occupying about 70 % of the surface, the productivity of the oceans is only 55 billion tons.

2. DECOMPOSITION

- It is the breakdown of complex organic matter by decomposers into inorganic substances like CO_2, water and nutrients. It is largely an oxygen-requiring process.
- Raw material for decomposition is called **Detritus.** E.g. dead plant remains (leaves, bark, flowers etc.), dead remains of animals, fecal matter etc.

Steps of decomposition

a. **Fragmentation:** It is the breakdown of detritus into smaller particles by **detritivores** (e.g. earthworm).
b. **Leaching:** Water soluble inorganic nutrients go down into soil horizon and precipitate as unavailable salts.
c. **Catabolism:** Degradation of detritus into simpler inorganic substances by bacterial and fungal enzymes.

The above three processes occur simultaneously.

d. **Humification:** Accumulation of **humus** (dark amorphous substance) in soil. Humus is resistant to microbial action and so decomposes very slowly. Being colloidal, it serves as a reservoir of nutrients.
e. **Mineralization:** It is the release of inorganic nutrients due to the degradation of humus by some microbes.

Factors influencing decomposition

- **Chemical composition of detritus:**
  - Decomposition is slow in detritus rich in lignin & chitin.
  - It is quicker in detritus rich in nitrogen and water-soluble substances like sugars.
- **Climatic factors (temperature & soil moisture):**
  - Warm and moist environment favour decomposition.
  - Low temperature & anaerobiosis inhibit decomposition resulting in buildup of organic materials.

3. ENERGY FLOW

- Sun is the only source of energy for all ecosystems (except deep sea hydro-thermal ecosystem).
- Of the incident solar radiation, less than 50% is **photosynthetically active radiation (PAR).**
- Plants and photosynthetic bacteria (autotrophs), fix solar radiant energy to make food.
- Plants capture only **2-10%** of the PAR. This energy sustains the entire living world.
- Ecosystems obey 2nd Law of thermodynamics. They need a constant supply of energy to synthesize the molecules. It helps to counteract the entropy.

Producers (Autotrophs):

- These are organisms that synthesize food.
- In a terrestrial ecosystem, major producers are herbaceous and woody plants. Primary producers in an aquatic ecosystem are phytoplankton, algae and higher plants.
- The energy trapped by the producer is passed on to a consumer or the organism dies.

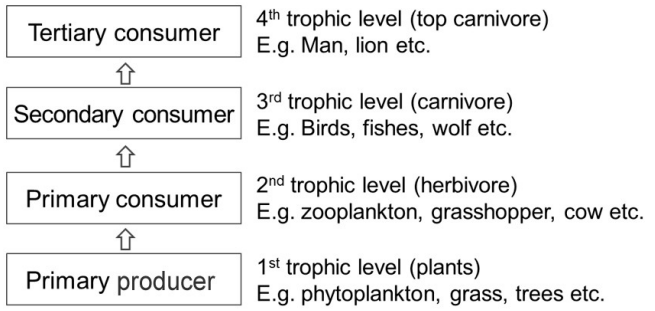
Consumers (heterotrophs):

- These are animals that directly or indirectly depend on plants for food. They include:
  - **Primary consumers (herbivores):** Feed on plants. E.g. insects, birds, mammals, molluscs etc.
  - **Secondary consumers (primary carnivores):** Feed on herbivores. E.g. frog, fox, man etc.
  - **Tertiary consumers (secondary carnivores):** Feed on primary carnivores. E.g. tiger, lion etc.
- The chain of feeding relationship between different organisms is called a **food chain.** It is 2 types:
  - **Grazing Food Chain (GFC):** Here, primary consumer feeds on living plants (producer). E.g.

Grass ⟶ Goat ⟶ Man

(Producer) (Primary Consumer) (Secondary consumer)

  - **Detritus Food Chain (DFC):** Here, primary consumer feeds on dead organic matter (detritus). Death of organism is the beginning of the DFC.
- Detritus is made up of **decomposers (saprotrophs)** such as fungi & bacteria. They secrete digestive enzymes that breakdown detritus into simple, inorganic materials, which are absorbed by them. Thus, they get energy & nutrients.
- In an aquatic ecosystem, GFC is the major conduit for energy flow.
- In a terrestrial ecosystem, a much amount of energy flows through the DFC than through the GFC.
- DFC may be connected with GFC at some levels. Some organisms of DFC are prey to the GFC animals. Some animals (cockroaches, crows, human etc.) are omnivores. Such interconnections of food chains are called **food web**.
- A specific place of organisms in the food chain is known as their **trophic level**.

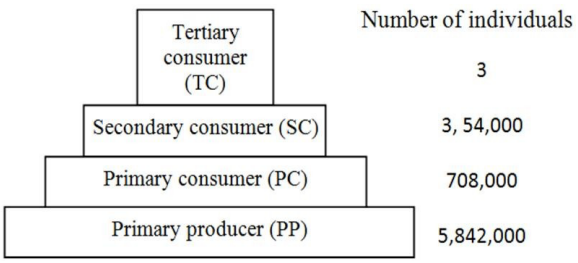


- The amount of energy decreases at successive trophic levels. When an organism dies it becomes **dead biomass (detritus).** It is an energy source for decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy.
- The amount of living material in a trophic level at a given time is called **standing crop**. It is measured as the **biomass** (mass of living organisms) or the **number in a unit area.**
- Biomass of a species is measured in terms of **fresh or dry weight.** Dry weight is more accurate because it is the exact mass of body which remains constant.
- Number of trophic levels in GFC is restricted as it follows **10% law** (only 10% of energy is transferred to each trophic level from the lower trophic level).

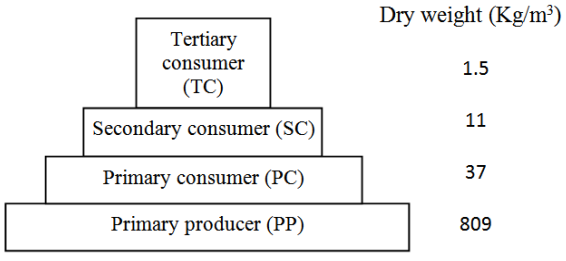
ECOLOGICAL PYRAMIDS

- The representation of a food chain in the form of a pyramid is called **ecological pyramid.**
- The base of a pyramid represents producers (first trophic level). The apex represents tertiary or top-level consumer.
- Ecological pyramids are 3 types: Pyramid of number, Pyramid of biomass and Pyramid of energy.

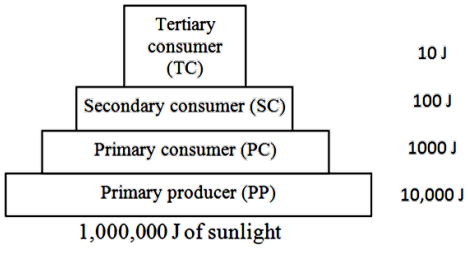
a) Pyramid of number: E.g. grassland ecosystem.



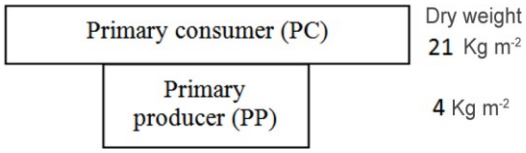
b) Pyramid of biomass: It shows a sharp decrease in biomass at higher trophic levels.



c) Pyramid of energy: Primary producers convert only 1% of the energy in the sunlight available to them into NPP.



- Any calculations of energy content, biomass, or numbers has to include all organisms at that trophic level.
- A trophic level represents a functional level, not a species as such. A species may occupy more than one trophic level in the same ecosystem at the same time. E.g. A sparrow is a primary consumer when it eats seeds, fruits, peas. It is a secondary consumer when it eats insects & worms.
- In most ecosystems, all the pyramids are upright, i.e., producers are higher in number, biomass and energy than the herbivores, and herbivores are higher in number, biomass and energy than the carnivores.
- But in some cases, inverted pyramids for number and biomass are present.
- **Inverted pyramid of number:** E.g. Insects feeding on a tree.
- **Inverted pyramid of biomass:** E.g.
  - Small standing crop of phytoplankton supports large standing crop of zooplankton.
  - Pyramid of biomass in sea is inverted because the biomass of fishes far exceeds that of phytoplankton.



- Pyramid of energy is always upright because some energy is always lost as heat at each trophic level. So energy at a lower trophic level is always more than at a higher level.

Limitations of ecological pyramids

- It does not consider the **same species** belonging to **two or more trophic levels.**
- It assumes a **simple food chain** that never exists in nature. It does not accommodate a **food web.**
- **Saprophytes** are not included.

ECOLOGICAL SUCCESSION

- It is a gradual, slow and predictable change in the species composition of an area leading to a **climax community** (community that is in equilibrium with the environment).
- In this, some species colonize an area and increase in number, whereas other species decline and disappear.
- The entire sequences of communities that successively change in an area are called **sere**. Individual transitional communities are termed **seral stages (seral communities).**
- The species invading a bare area are called **pioneer species**.
- During succession, there is a change in species diversity, increase in number of species and organisms and an increase in total biomass.
- Present-day communities are due to succession of millions of years. Succession and evolution were parallel processes.
- Succession is 2 types:
  - **Primary:** The succession taking place in areas where no living organisms ever existed. E.g. newly cooled lava, bare rock, newly created pond or reservoir.
    To establish a biotic community, fertile soil must be formed. So primary succession is a very slow process.
  - **Secondary:** The succession taking place in an area after the existed organisms are lost. E.g. abandoned farm lands, burned or cut forests, lands that are flooded.
    Since some soil or sediment is present, succession is faster than primary succession.
    The species that invade depend on the nature of the soil, availability of water etc.
- In succession, changes in vegetation affect food & shelter of animals. Thus, succession leads to change in number and types of animals & decomposers.
- Natural or human induced disturbances (deforestation, fire etc.) convert a particular seral stage to an earlier stage. They create new conditions that encourage some species and discourage or eliminate other species.

Succession of Plants

- Based on the nature of the habitat, succession of plants is 2 types: hydrarch and xerarch.
  - **Hydrarch succession:** It takes place in wetter areas. It progresses from **hydric to mesic** conditions.
  - **Xerarch succession:** It takes place in dry areas. It progresses from **xeric to mesic** conditions.
- Hence, both hydrarch & xerarch successions lead to medium water conditions **(mesic,** the climax community).
- **Primary succession on rocks (xerophytic habitat):**
  Lichens (pioneer species. They secrete acids to dissolve rock, helping in weathering & soil formation) → small plants like **bryophytes** (they need only small amount of soil) → **bigger plants** → **forest** (mesophytic).
  The **climax community (forest)** remains stable if the environment remains unchanged.
- **Primary succession in water:**
  Phytoplankton (pioneers) → rooted-submerged plants → rooted-floating angiosperms → free-floating plants → reed-swamp → marsh-meadow → scrub → trees (climax community is a forest).
  With time, the water body is converted into land.

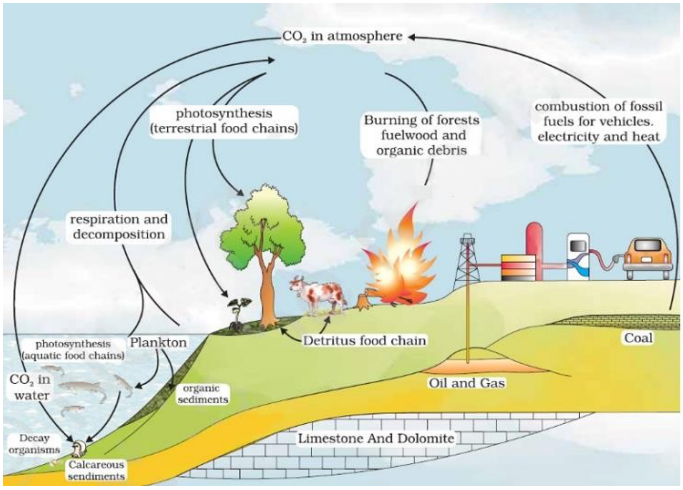
4. NUTRIENT CYCLING

- Amount of nutrients (C, N, P, Ca etc.) present in the soil in a given time is called the **standing state**. It varies in different kinds of ecosystems and also on a seasonal basis.
- Nutrients are never lost from the ecosystems. They are recycled again and again.
- The movement of nutrient elements through various components of an ecosystem is called **nutrient cycling (biogeochemical cycles).**
- Nutrient cycles are 2 types:
  a. **Gaseous cycle:** For this, the reservoir exists in the atmosphere. E.g. Nitrogen & Carbon cycles.

b. **Sedimentary cycle:** For this, the reservoir is located in Earth's crust. E.g. Sulphur & Phosphorus cycles.

- Environmental factors (soil, moisture, pH, temperature, etc.) regulate the rate of release of nutrients into the atmosphere. The reservoir meets with the deficit of nutrients due to imbalance in the rate of influx and efflux.

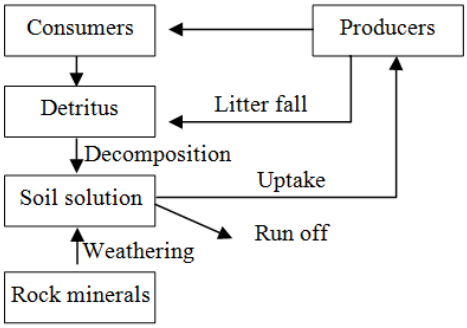
Carbon Cycle



- **Reservoir of carbon:** Atmosphere (about 1%), organisms (49% of dry weight), oceans (71% dissolved carbon. It regulates the amount of atmospheric CO_2), fossil fuel etc.
- Carbon cycling occurs through atmosphere, ocean and through living and dead organisms.
- 4×10^{13} kg of carbon is fixed in the biosphere through photosynthesis annually.
- A major amount of carbon returns to the atmosphere as CO_2 through respiration.
- Processing of wastes & dead organic matter by decomposers also release CO_2.
- Some amount of the fixed carbon is lost to sediments and removed from circulation.
- Burning of wood, forest fire and combustion of organic matter, fossil fuel and volcanic activity are other sources for releasing CO_2 in the atmosphere.
- **Role of human activities in carbon cycle:** Deforestation, burning of fossil fuel etc. has increased the rate of release of CO_2 into the atmosphere.

Phosphorus Cycle

- Phosphorus is a constituent of biological membranes, nucleic acids & cellular energy transfer systems. Many animals use phosphorus to make shells, bones and teeth.
- The natural reservoir of phosphorus is rock (in the form of phosphates).
- When rocks are weathered, minute amounts of phosphates dissolve in soil solution and are absorbed by the plants. Herbivores and other animals obtain this from plants. The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus.



Differences between carbon & phosphorous cycles

Carbon cycle	Phosphorous cycle
Atmospheric input is higher	Much smaller
There is gaseous exchange b/w organism & environment	Gaseous exchange is negligible

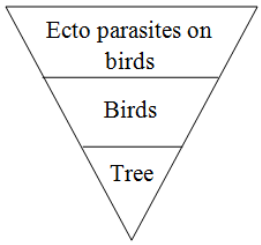
ECOSYSTEM SERVICES

- The products of ecosystem processes are called **ecosystem services.**
- E.g. forest ecosystems purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage site for carbon and provide aesthetic, cultural & spiritual values.
- **Robert Costanza** and his colleagues have tried to put price tags on nature's life-support services.
- Researchers have put an average price tag of US $ 33 trillion a year on fundamental ecosystems services. This is nearly twice the value of the global gross national product GNP (US $ 18 trillion).
- Out of this total cost, soil formation accounts for about 50%.
- Contributions of other services like recreation & nutrient cycling are less than 10% each.
- The cost of climate regulation and habitat for wildlife are about 6 % each.

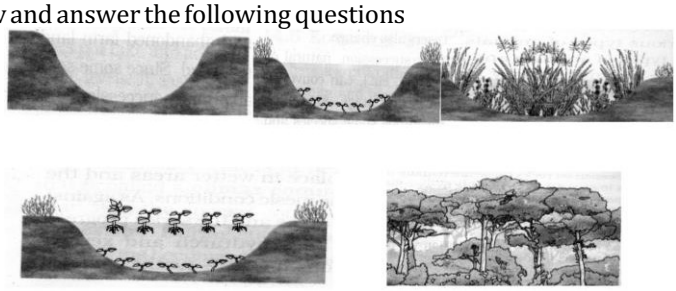
MODEL QUESTIONS

1. Fill in the blanks by noticing the relationship of the given pair
   a. Producer: plant Consumer: .....
   b. Carbon cycle: gaseous cycle Phosphorus cycle: .....
2. Analyze the following food chain.
   Partially decomposed organic matter ⟶ Earthworm ⟶ Hen ⟶ Fox
   a. Name the above mentioned food chain.
   b. How do the members in this food chain meet their energy and nutrient requirements?
3. "Pyramid of number is always upright." Comment on this statement.
4. In nature one species can occupy more than one trophic level. Is this possible? Comment.
5. Even though biological pyramids are helpful in studying food chain, they have certain limitations. Account them.
6. While visiting the forest during a study tour, a teacher told the students that once this area was a barren rocky area.
   a. Name the ecological succession on a bare rock.
   b. Which was the pioneer species in that succession?
   c. Write the changes that lead to the formation of forest from barren rocky place.
7. Different stages of an ecological succession are given below.
   - Marsh - meadow stage
   - Reed swamp stage
   - Scrub stage
   - Phytoplankton stage
   - Submerged free floating stage
   - Forest stage

   a. Arrange them in the correct sequence.
   b. Name the type of ecological succession and mention the pioneer and climax communities in this succession
8. Given below is the pyramid of number of an ecosystem.



   a. Identify the nature of pyramid.
   b. Give reason for this nature of pyramid.
9. Observe the figure given below and answer the following questions



   a. Identify the ecological concept converged through the given figures.
   b. Name the group of organisms as pioneer community and climax community in this ecological process.

15. BIODIVERSITY AND CONSERVATION

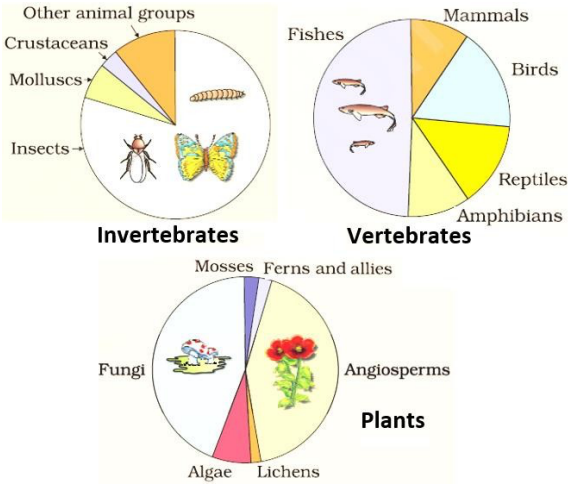
Biodiversity is the diversity of biological organisation ranging from cellular macromolecules to biomes.
Edward Wilson popularized the term 'biodiversity'.

LEVELS OF BIODIVERSITY

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

NUMBER OF SPECIES ON EARTH (GLOBAL SPECIES DIVERSITY)

- According to **IUCN (2004),** more than **1.5 million species** described so far.
- According to **Robert May's Global estimate,** 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).
- **Animals** are more diverse (**above 70%**) than **plants** including Plantae and Fungi (**22%**).
- Among animals, **insects** are most species rich group **(70%,** i.e. out of every 10 animals, 7 are insects).
- Number of fungi species is more than the combined total of the species of fishes, amphibians, reptiles & mammals.



- India has only **2.4%** of world's land area, but has **8.1%** of the species diversity. India is one of the **12 mega diversity** countries of the world. Nearly **45,000 plant species** and **twice** as many of **animals** have been recorded from India.
- Applying **May's global estimates,** India would have more than 1 lakh plant species and 3 lakh animal species.
- Biologists are not sure about total number of prokaryotic species because
  - Conventional taxonomic methods are not suitable for identifying microbial species.
  - In laboratory, many species cannot be cultured.

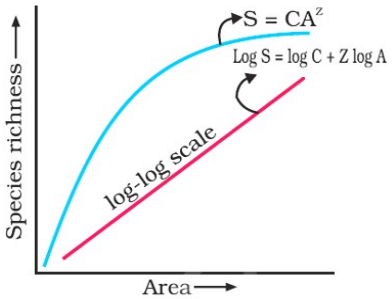
PATTERNS OF BIODIVERSITY

i. Latitudinal gradients

- Species diversity decreases from the equator to the poles.
- **Tropics** (latitudinal range of 23.5° N to 23.5° S) have more species than temperate or polar areas.
  E.g. Number of **bird species** in different latitudes:
  - **Colombia** (near equator): about **1400 species.**
  - **India** (in tropics): **> 1200 species.**
  - **New York (41° N): 105 species.**
  - **Greenland (71° N): 56 species.**
- Tropical forest region like **Equador** has up to **10 times** of vascular plant species as compared to a temperate forest region like the **Midwest of USA.**
- **Tropical Amazonian rain forest** (South America) is the greatest biodiversity on earth. It contains
  - > 40000 species of plants
  - 3000 species of fishes
  - 1300 species of birds
  - 427 species of mammals
  - 427 species of amphibians
  - 378 species of reptiles
  - > 1,25,000 species of invertebrates
- Biodiversity (species richness) is highest in tropics because
  - Tropics had more evolutionary time.
  - Relatively constant environment (less seasonal).
  - They receive more solar energy which contributes to greater productivity.

ii. Species- Area relationship

According to the study of **Alexander von Humboldt** in South American jungles, within a region, species richness increases with increasing explored area, but only up to a limit.
Relation between species richness and area gives a **rectangular hyperbola.**



$S = CA^Z$

Where,
S= Species richness
A= Area
C= Y-intercept
Z= slope of the line (regression co-efficient)

- On a logarithmic scale, the relationship is a straight line described the equation **Log S = log C + Z log A**
- Generally, for small areas, the Z value is **0.1 to 0.2.**
- But for large areas (e.g. entire continents), slope of the line is steeper **(Z value: 0.6 to 1.2).**
- E.g. for frugivorous birds and mammals in the tropical forests of different continents, the Z value is **1.15.**

IMPORTANCE OF SPECIES DIVERSITY

- According to **David Tilman,** plots with more species shows less year-to-year variation in total biomass.
- Increased diversity contributes to higher productivity. It is essential for ecosystem health and survival of human race.

- **'Rivet popper hypothesis':** It is an analogy used to understand the importance of biodiversity.
  It is proposed by Stanford ecologist **Paul Ehrlich.**
  In an airplane **(ecosystem),** all parts are joined with many rivets **(species).** If passengers pop a rivet (extinction of a species), it may not affect flight safety **(functioning of the ecosystem).** But as more and more rivets are removed, the plane becomes dangerously weak. Loss of rivets on the wings (**key species** that drive major ecosystem functions) is more dangerous than loss of a few rivets on the seats or windows.

LOSS OF BIODIVERSITY

- **IUCN Red List (2004)** says that 784 species (338 vertebrates, 359 invertebrates & 87 plants) were extinct in the last 500 years. E.g. **Dodo (Mauritius), Quagga (Africa), Thylacine (Australia), Stellar's sea cow (Russia)** and **3 subspecies (Bali, Javan, Caspian) of tiger.**
- **27 species** have been disappeared in the last 20 years.
- More than **15,500 species** are facing threat of extinction.
- **12% birds, 23% mammals, 32% amphibians, 31% gymnosperm species** face the threat of extinction.
- The current extinction rate is 100 - 1000 times faster than in the pre-human times. If this trend continues, nearly 50% species might be extinct within next 100 years.

Impacts of Loss of biodiversity

- Decline in plant production.
- Environmental perturbations such as drought.
- Increased variability in ecosystem processes such as plant productivity, water use and pest & disease cycles.

Causes of Biodiversity losses ('The Evil Quartet')

1. **Habitat loss and fragmentation:** Most important cause.
   - E.g. Tropical rain forests (loss from 14% to 6%).
   - Thousands of hectares of rain forests are being lost within hours.
   - **The Amazon rain forest** is being cut for cultivating soya beans or for conversion of grass lands for cattle.
   - Fragmentation badly affects animals requiring large territories and migratory animals.
2. **Over-exploitation: Stellar's sea cow, Passenger pigeon** etc. extinct due to over exploitation.
3. **Alien species invasions:** Alien species cause decline or extinction of **indigenous species.** E.g.
   - **Nile Perch** introduced in **Lake Victoria (East Africa)** caused extinction of more than 200 species of **cichlid fish**.
   - Invasive weed species like ***Parthenium*** **(carrot grass), Lantana** and ***Eicchornia*** **(water hyacinth)** caused damage to our native species.
   - Illegal introduction of the **African Catfish (*Clarias gariepinus*)** for aquaculture is a threat to the indigenous catfishes in our rivers.
4. **Co-extinction:** When a species becomes extinct, the species associated with it also extinct. E.g.
   - Extinction of the **parasites** when the **host** is extinct.
   - In co-evolved **plant-pollinator mutualism,** extinction of one causes the extinction of the other.

BIODIVERSITY CONSERVATION

There are 3 categories of reasons for conservation.

a. Narrowly utilitarian arguments

- Human derive economic benefits from nature such as food, firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) and medicines.
- More than 25% of the drugs are derived from plants.
- 25,000 species of plants have medicinal value.

b. Broadly utilitarian arguments

Biodiversity has many ecosystem services. E.g.

- Amazon forest *('lung of the planet')* produces 20% of total O_2 in the earth's atmosphere.
- Pollination through bees, bumblebees, birds and bats.
- Aesthetic pleasures.

c. Ethical arguments

- Every species has an **intrinsic value**. We have a moral duty to care for their well-being.

Biodiversity conservation is 2 types: ***In situ*** **(on site)** conservation and ***Ex situ*** **(off site)** conservation.

a. *In situ* conservation (on site)

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

- **National Park:** Strictly reserved for the welfare of the wildlife where private ownership, cultivation, grazing etc. are prohibited. E.g. **Eravikulam National Park in Kerala.**
- **Sanctuary:** Here, protection is given only to the animals. Collection of timbers, minor forest products and private ownership are allowed so long as they do not harm the animals. E.g. **Periyar wildlife sanctuary in Kerala.**
- **Biosphere Reserves:** Areas of land or coastal ecosystems for conservation and sustainable use.
- **Sacred forests (Sacred groves):** Forest fragments which are communally protected based on religious beliefs. E.g.
  - Sacred groves in **Khasi** & **Jaintia Hills** in Meghalaya.
  - **Aravalli Hills** of **Rajasthan.**
  - **Western Ghat** regions of Karnataka & Maharashtra.
  - **Sarguja, Chanda** & **Bastar** areas (Madhya Pradesh).

India has **14 Biosphere Reserves, 90 National Parks** and **448 wildlife sanctuaries.**

b. *Ex situ* conservation (off site)

It is the conservation of organisms outside their habitats. E.g. genetic resource centres, zoological parks, wildlife safari parks, botanical gardens, gene banks, cryopreservation etc.

Hotspots

- These are the regions with very high species richness, high degree of **endemism** (species confined only to a specific region) but most threatened.
- There are **34 hotspots** in the world.
- **3 hotspots** cover India's biodiversity regions- **Western Ghats & Sri Lanka, Indo-Burma and Himalaya.**

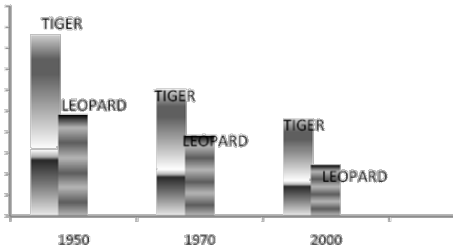
- All hotspots together cover only < 2% of the earth's land area. But the species richness is extremely high. Protection of hotspots reduced the ongoing extinctions by 30%.

International Efforts for conserving biodiversity

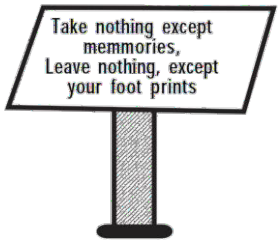
- **The Earth Summit** or **Convention on Biological Diversity (Rio de Jeneiro, 1992)** - 3 objectives:
  a. Conservation of biodiversity.
  b. Sustainable use of biodiversity.
  c. Sharing of benefits arising from genetic resources.
- **The World Summit on Sustainable Development (Johannesburg, South Africa, 2002):** 190 countries pledged to reduce the current rate of biodiversity loss.

MODEL QUESTIONS

1. There are about 20,000 species of ants 3,00,000 species of beetles and 28,000 species of fishes in the world.
   a. Which organization is dealing with the population of organisms in the world?
   b. What are the causes of bio-diversity losses?
2. Anil said: "Mosquitoes are harmful, Snakes are poisonous, and Insects damage crops. It is high time to destroy all these organisms for the welfare of human beings".
   a. Can you agree with this statement?
   b. As a biology student, how can you convince this person about the importance of each organism in the nature?
3. Amazonian rain forests have the greatest biodiversity on earth. Give 3 hypotheses to explain the reason for this.
4. "The biological wealth of our planet has been declining rapidly and the accusing finger is clearly pointing to human activities."
   a. Mention any two human activities leading to the loss of biodiversity.
   b. Mention the different ways to conserve biodiversity.
5. Introduction of exotic species is one of the major threats of biodiversity. Cite any two examples.
6. The given bar diagram shows the population of Asiatic leopard and tiger for the last 50 years in India.



   a. Analyse the figure, whether the population of tiger and leopard increasing or decreasing. Find reason.
   b. Does the decreasing population of the organisms affect the stability of the ecosystem? If yes state how?
   c. Suggest measures for protecting the population of these organisms.
7. Classify the following words into two categories and give suitable titles.
   Genetic resource centres, National parks, Botanical gardens, Sanctuaries, Biosphere reserves, Gene banks, Cultural landscapes, Zoological parks, Natural monuments, Sacred forests.
8. Distinguish between National park and Sanctuary giving one example for each.
9. This is a board seen in front of a national park.



   a. Evaluate the quotation in the board and state your opinion.
   b. Write any four reasons for extinction of animals.
   c. Name three animals extinct recently.
   d. What is the significance of IUCN red list?