CHAPTER
01

REPRODUCTION IN ORGANISM

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

• 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 isthe division of parent cell into many individuals. E.g. Plasmodium, Amoeba.

• 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.

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

Vegetative propagules are units of vegetative propagation.

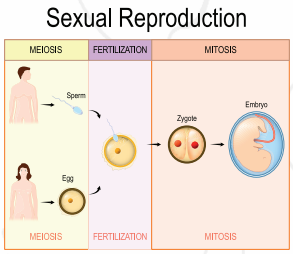
Example s for vegetative propagules:

- **Buds (eyes)** of the potatotuber.
- **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.**

Other asexual reproductive structures: E.g. zoospores (microscopic motile structures in some algae and protists), conidia (Penicillium) and **gemmules**(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 isfollowed by morphological and physiological changes prior to active reproductive behaviour.

- Birds living in nature lay eggs only seasonally. However, birds in captivity **(e.g. poultry)** can be made to lay eggs throughout the year.

- 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:

• Seasonal breeders: The mammals (living in natural conditions) exhibiting reproductive cycles only during favourable seasons.
• 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-fertilization, Fertilization & Post - fertilization events.

1. PRE-FERTILISATION EVENTS

These are the events prior to the fusion of gametes include gametogenesis andgamete transfer.

a. Gametogenesis

It is the formation of male and female gametes

Gametes (haploid cells) are 2 types:

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

◦ **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:

- Bisexual: Male & female reproductive structures present in the same individua

Bisexual plants: E.g.Hibiscus, Pisum

In flowering plants, male flower isstaminate (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.

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

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

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

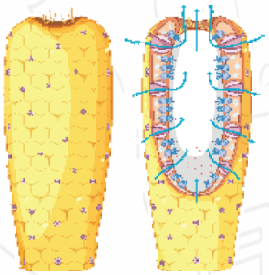
Unisexual animals: E.g. Cockroach, higher animals etc. Fungi may be **homothallic** (bisexual) or **heterothallic** (unisexual)

CELL DIVISION DURING GAMETE FORMATION:

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

Name of organism	Chromos ome number	
	n 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	32	16

b. Gamete Transfer



- Male gametes need a medium to move towards female gametes for fertilization
- 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), They gamete transfer takes place through water medium. To compensate the loss of male gametes during transport, large number of male gametes is produced

- In seed plants, pollen grains (in anthers) carry male gametes. They cannot 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. So transfer of **pollen grains** is easy.

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 o Bisexual: Male & female reproductive structures present near the egg.

In dioecious animals, the fertilization 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 leech, fertilization. This is called **parthenogenesis.**

TYPES OF FERTILIZATION

a. External fertilization: Syngamy occurs in the external lf medium (water), i.e. zygote is formed outside the body. it **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.

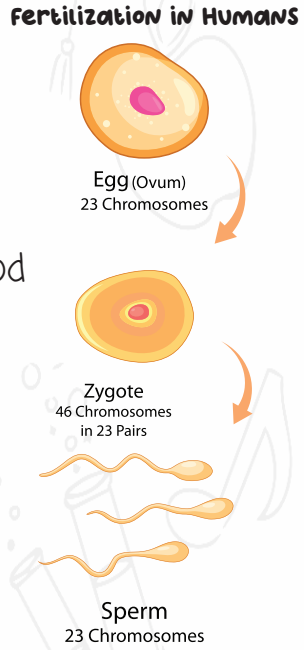
b. Internal fertilization: Syngamy occurs inside the body of the organism. E.g. terrestrial organisms, belonging to

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 ofsperms 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 thenext.

EMBRYOGENESIS

- It is the development of embryo from thezygote.
- During embryogenesis, zygote undergoes cell division (mitosis) and cell differentiation.
- Cell divisions increase the number of cells in the embryo.

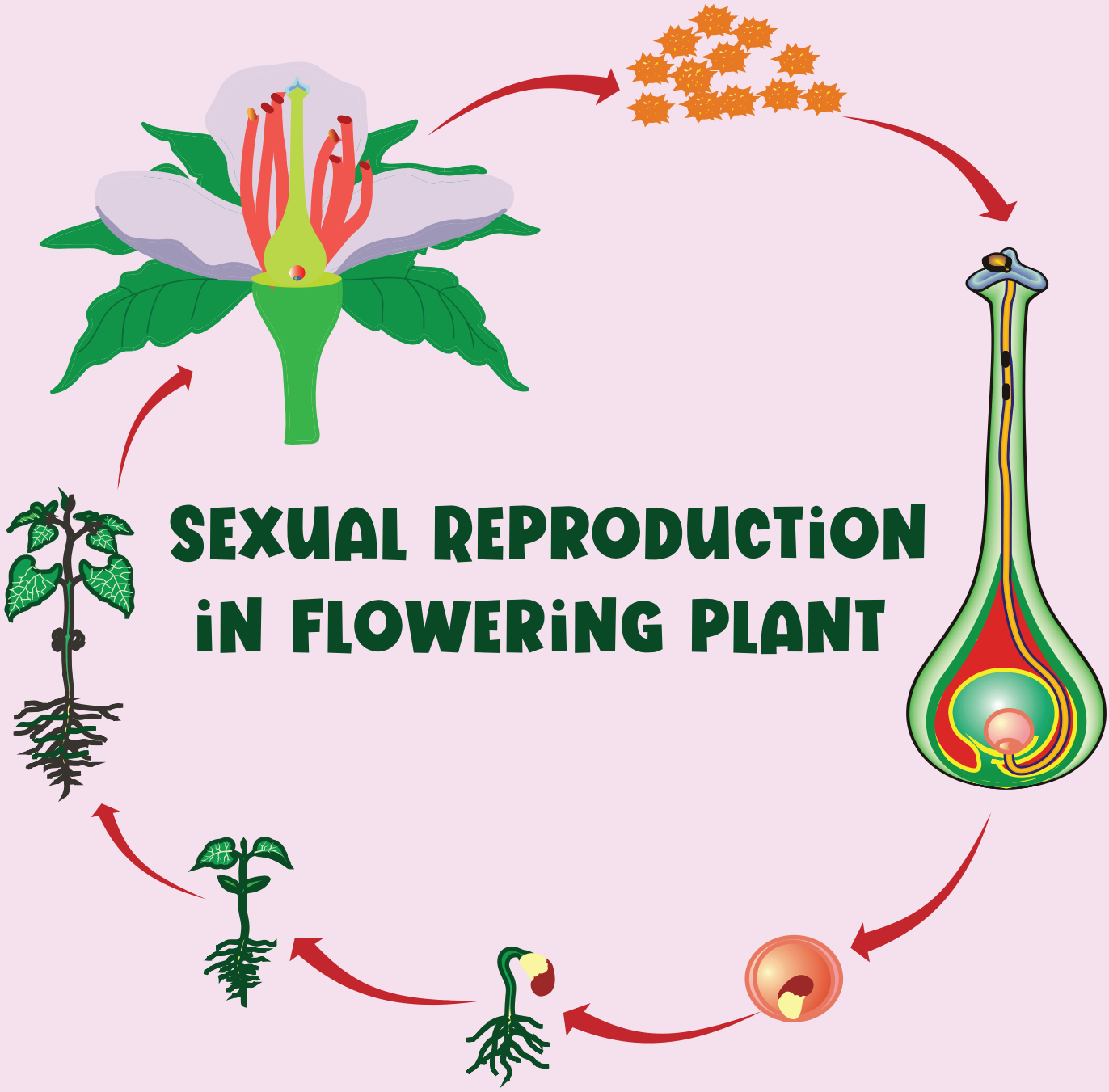
Cell differentiation causes the modifications of groups of cells into various tissues and organs to form an organism.

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

a. Oviparous: Here, animals lay fertilized/unfertilized eggs.
E.g. In reptiles & birds, the fertilized eggs covered by hard calcareous shell are laid in a safe place. After incubation, young ones hatch out.

b. Viviparous: Here, the 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. Because of proper care and protection, the chances of survivalof young ones are greater in viviparous animals.

CHAPTER
02



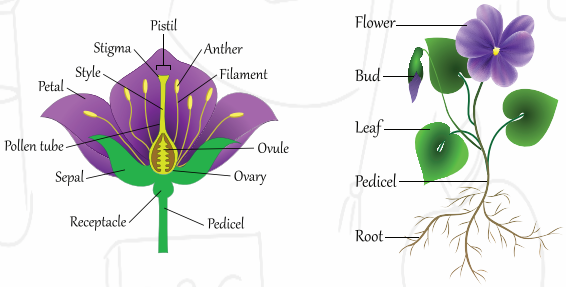
SEXUAL REPRODUCTION iN FLOWERiNG PLANT

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 and development of the floralprimordium.
- Inflorescences bear the floral buds and then the flowers.

STRUCTUREOF A FLOWER



A typical flower has 2 parts: Androecium & Gynoecium

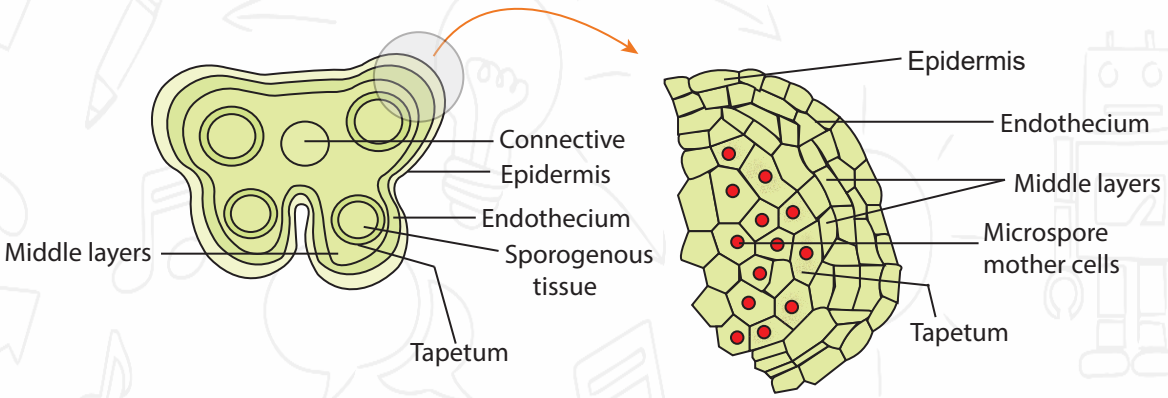
Androecium(whorlof Stamens)

It is the male reproductive part of the flower.
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 theflower.

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.
- Each lobe consists of two microsporangia.
- The microsporangia develop to pollen sacs. They extend longitudinally all through the length of an anther and are packed with **pollen grains.**

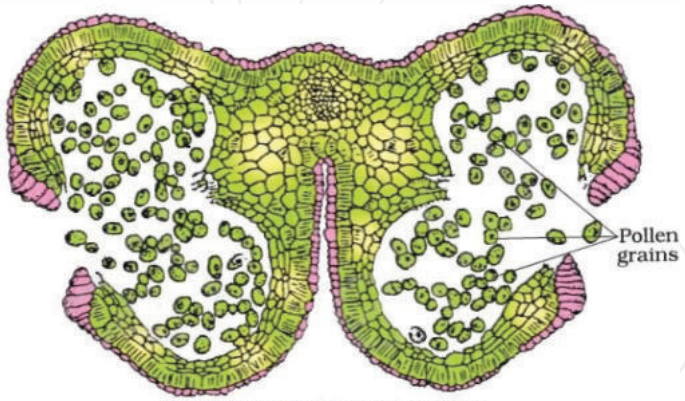
STRUCTURE OF A MICROSPORANGIUM:

- A typical microsporangium is near circular in outline.
- It is surrounded by four wall layers- the **epidermis, endothecium, middle layers & tapetum.**
- The outer 3 layers give protection and help indehiscence of anther to release the pollen.
- The **tapetum** (innermost layer) nourishes the developing pollen grains.
- Cells of thetapetum contain dense cytoplasmand generally have more than one nucleus

- When the anther is young, a group of compactly arranged homogenous cells (sporogenous tissue) occupies the centre of eachmicrosporangium.

Microsporogenesis:

- As the anther develops, each cell of sporogenous tissue undergo meiotic divisions to form microspore tetrads (microspores are arranged in a cluster of four cells). Each one is a **potential pollen (microspore mother cell).**
- The formation of microspores from a pollenmother cell **(PMC)** through meiosisis calledmicrosporogenesis.
- As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollengrains.
- 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 andintine.

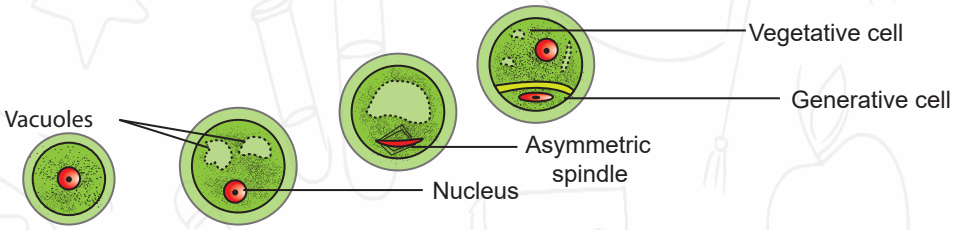
- **Exine:** The hard outer layer. Made up of sporopollenin (highly resistant organic material). It can withstand high temperature and strong acids and alkali. Enzymes cannot degrade sporopollenin.
  Exine has apertures called germ pores where sporopollenin is absent.

Pollen grains are preserved as fossils due to the presence of sporopollenin. Exine exhibits patterns and designs.

- **Intine:** The 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 irregular ly shaped nucleus.
- **Generative cell:** It is small and floats in the cytoplasm of the vegetative cell. It is spindle shaped with dense cytoplasm and anucleus.



- In over **60%** of angiosperms, pollen grains are shed at the **2-celled stage.** In others, the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed **(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 formonths

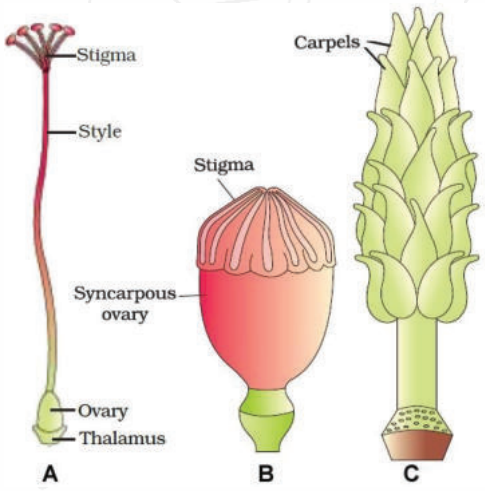
ECONOMIC IMPORTANCE OF POLLEN GRAINS:

- These are rich in nutrients. Pollen tablets are used as food supplements. Pollen tablets & syrups increase performance of athletes and race horses.
- Pollen grains can be stored for years in liquid nitrogen (-1960°C). They are used as pollen banks, similar to seed 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 (PISTIL)

- It represents the female reproductive part of the flower.
- It may consist of 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

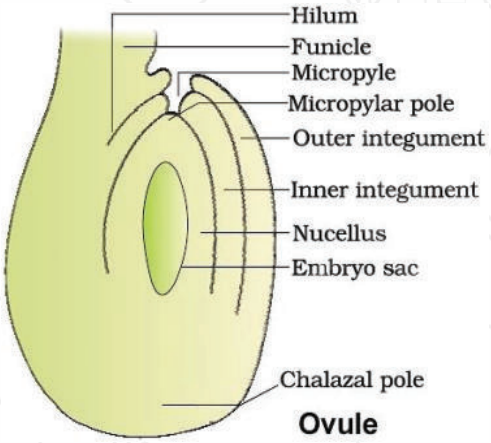


- Each pistil has three parts:

- **Stigma:** It is a landing platform for pollen grains.
- **Style:** It is an elongated slender part beneath thestigma.
- **Ovary:** It is the basal bulged part of the pistil. Inside the ovary is the ovarian cavity **(locule)** in which the placenta is located. Arising from the placenta are the **ovules (megasporangia).** The number of ovules in an ovary may be one (wheat, paddy, mango etc.) to many (papaya, water melon, orchidsetc.)

MEGASPORANGIUM (OVULE)

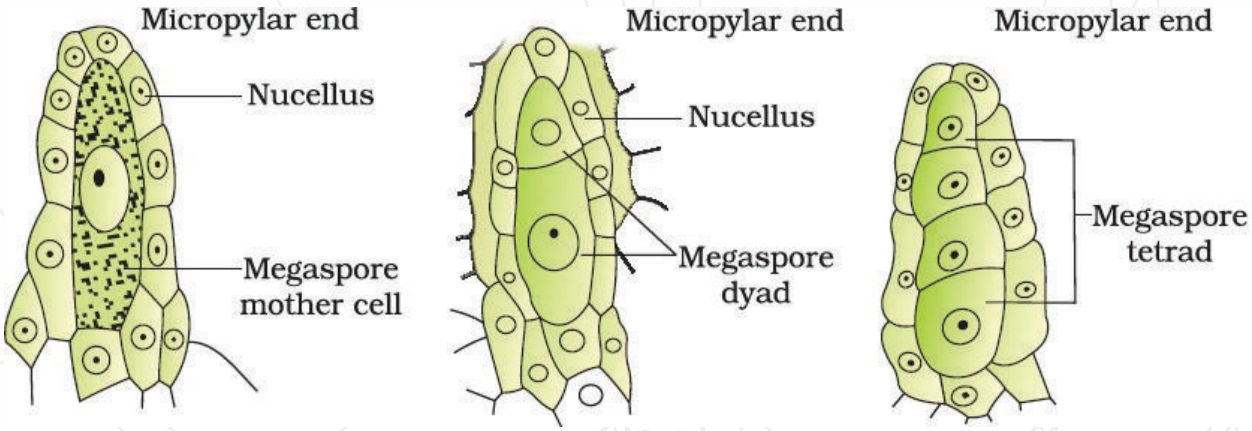
- It is a small structure attached to the placenta by means of a stalk **(funicle).** The junction where the body of ovule and funicle fuse is called **hilum.**
- Each ovule has one or two protective envelopes called integuments. **Integuments** encircle the ovule except at the tip where a small opening **(micropyle)** is present.
  - Opposite the micropylar end is the chalaza (basal part).
  - Enclosed within the integuments, there is a mass of cells called nucellus. Its cells contain reserve food materials.
  - Located nucellus in the is the embryo sac (female gametophyte). An ovule generally has a single embryo sac formed from a megaspore throughmeiosis.



MEGASPOROGENESIS:

It is the formation of megaspores from the **megaspore mother cell(MMC).**

- Ovules generally differentiate a single megasporemother cell in the micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus.
- The MMC undergoes meiotic division. It results in the production of **4 megaspores.**

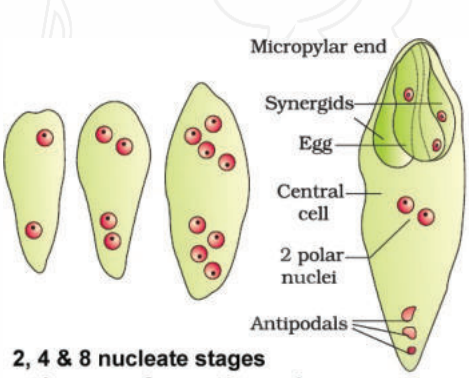


Female gametophyte (embryo sac):

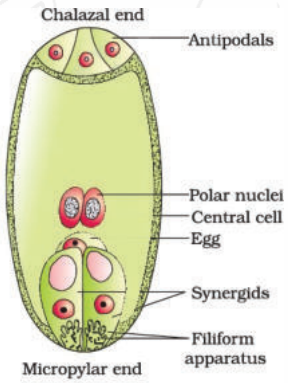
- In a majority of flowering plants, one of the megasporesis **functional** while the other three degenerate.
- The **functional megaspore** develops into the female gametophyte. This method of embryo sac formation froma single **megaspore** istermed **monosporic** development.

Formation of the embryo sac:

- The 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 timesforming **4-nucleateand 8-nucleate** stages of the embryo sac.



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



Mature embryo sac

- These divisions are strictly free nuclear, i.e. nuclear divisions are not followed immediately by cellwallformation.
- After the 8-nucleate stage, cell walls are laid down leading to the organization of the typical **female gametophyte or embryo sac.**
- 6 of the 8 nuclei are surrounded by cellwalls and organized.

into cells. Remaining 2 nuclei (polar nuclei) are situated below the egg apparatus in the large **central cell.**

DISTRIBUTION OF THE CELLS WITHIN THE EMBRYO SAC:

A typical mature embryo sac is **8-nucleate** and **7-celled.**
• 3 cells are grouped at the **micropylar** end and form **egg apparatus.** It consists of **2 synergids** and one **egg cell.**
• Synergids have special cellular thickenings at the **micropylar** tip called **filiform** apparatus. It helps to guide the pollen tubes into the synergid.
•3 cells at the **chalazal** end are called the antipodals.
• The large central cell has two **polarnuclei.**

POLLINATION

It is the transfer of pollen grains from the anther to the stigma of a pistil.
-Some external agents help the plants for pollination.
Depending on the source of pollen, pollination is 3types.

a. Autogamy (self-pollination): In this, pollen grains transfer from the anther to stigma of the sameflower. 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 lie close to each other. PlantslikeViola (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 pollen grains buds, come with for in contact stigma pollination.
Cleistogamous flowers produce assured seed-set even in the absence of pollinators.

b. Geitonogamy: In this, pollen grains transfer 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: In this, pollen grainstransfer from anther to the stigma of a different plant. It brings genetically different pollen grainsto the stigma.

AGENTS OF POLLINATIO

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 packedinto 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 ofpollen.
- The pollen grains are light and non-sticky so that they can be transported in wind currents.
- They often possess well-exposed stamens (for easy dispersion of pollens into windcurrents).
- 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..
- As against this, water is a regular mode of transport for the male gametes among the lower plants. It is believed, particularly for some bryophytes & pteridophytes, that their distribution is limited because of the need for 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 fromwetting.
- 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-pollinatedflowers:

- Large, colourful, fragrant and rich in nectar. Nectar & pollen grains are the floral rewards for pollination.
- When the flowers are small, they form inflorescence to make them visible.
- The flowers pollinated by flies and beetles secrete foul odours to attract these animals.
- The pollen grains are generally sticky. - 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, itresults inpollination.
- Some plants provide safe places as floralrewardto 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 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. It prevents autogamy.

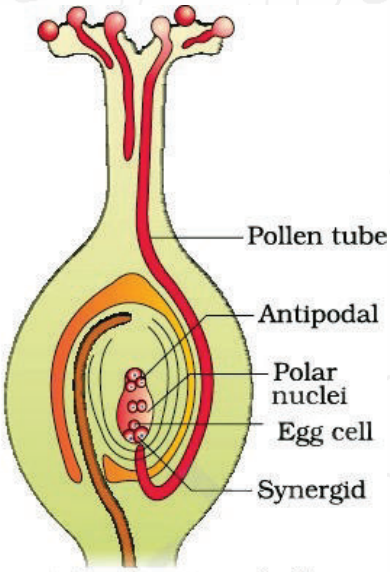
b. Arrangement of anther & stigmaat different positions:
This also prevents autogamy.

c. Self-incompatibility: Itis a genetic mechanism to prevent self-pollen (from the 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.

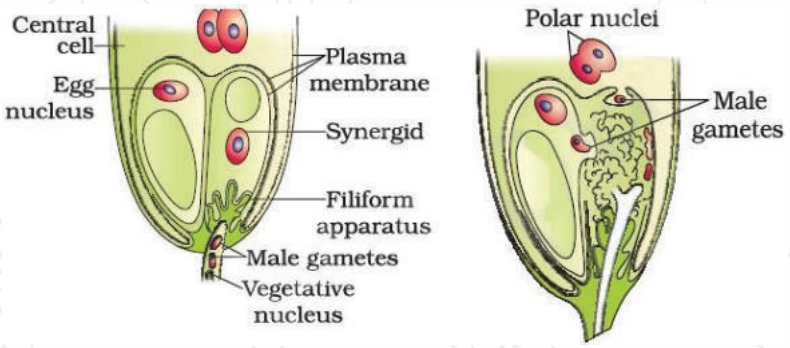
POLLEN-PISTIL INTERACTION:

- It is a process in which pistil recognizes compatible or incompatible pollen through the chemical components produced by them.
- If the pollen is **compatible** (right type), the pistil accepts it and promotes post-pollination events. Pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores. The contents of pollen grain move into the pollen tube. Pollen tube grows throughthetissues ofstigmaandstyleandreachestheovary.



Longitudinal section of a flower showing growth of pollen tube

- If the pollen is **incompatible (wrong type),** the pistil rejects pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.
- In some plants, pollen grains are shed at **2-celledcondition** (a vegetative cell & a generative cell). In such plants, the generative cell divides and forms the two male gametes during the growth of pollen tube in the stigma.
- In plants which shed pollen in the **3-celled condition,** pollen tubes carry 2 male gametes from the beginning.
- Pollen tube reaches the **ovary,** then enters the **ovule** through micropyle and then enters one of the synergids through the filiform apparatus. The filiform apparatus present at the micropylar part of the synergids guides the entry of pollen tube.



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

Artificial hybridisation:

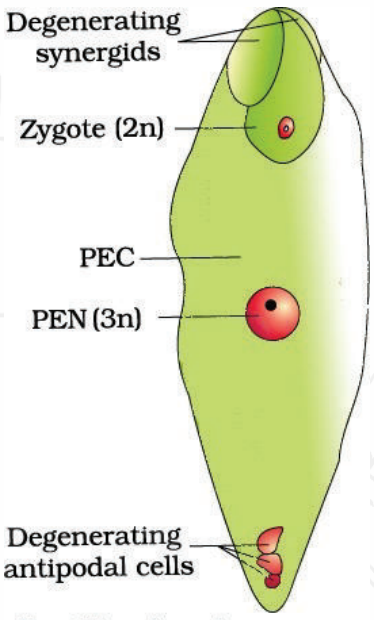
- It is a crop improvement programme in which desired pollen grains are used for pollination.
- This is achieved by following techniques:
- Emasculation: Removal of anthers from the bisexual flower bud of female parent before the anther dehisces.
- Bagging: Here, emasculated flowers are covered with a suitable bag (made up of butter paper) to prevent contamination of its stigma with unwanted pollen. When the stigma attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma. Then the flowers are rebagged and allowed to develop the fruits.
- For unisexual flowers, there is no need for emasculation. Female flower buds are bagged before the flowers open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

DOUBLE FERTILISATION

- After entering one of the synergids, the pollen tube releases the 2 male gametes into the cytoplasm of the synergid. One male gamete moves towards the egg cell and fuses with its nucleus **(syngamy).** Thisforms the **zygote** (a diploid cell).
- The othermale gamete moves towardsthetwopolar nuclei located in the central cell and fuses with them to produce a triploid primary endosperm nucleus **(PEN).** Asit 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 fusionbecomes the primary endosperm cell (PEC) and develops into the endosperm while the zygote developsinto 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.

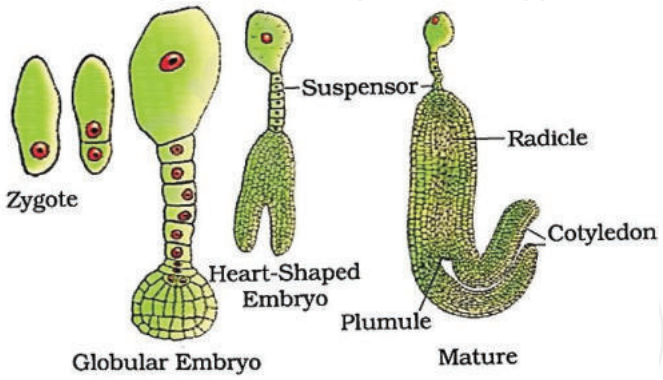
ENDOSPERM DEVELOPMENT

- The primary endosperm cell divides repeatedly and forms a **triploid endosperm tissue.**
- Endosperm cells are filledwith reserve food materials. They are used for **nutrition** of the developing embryo.
- In common endosperm development, the PEN undergoes successive nuclear divisions to give rise to free nuclei. This stage is called **free-nuclear endosperm.** The number of free nuclei varies greatly.
- The endosperm becomes cellular due to the cell wall formation. The tender **coconut water** is a **free-nuclear** endosperm (made up of thousands of nuclei) and the surrounding **white kernel** isthe **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 certain amount of endosperm. This is an adaptation to provide nutrition to the developing embryo.
- Though the seeds differ greatly, the embryogeny(early **embryonic** developments) is similar in monocots & dicots.
- Thezygote givesrise tothe **proembryo** and subsequently to the **globular, heart-shaped and matureembryo.**



Stages in embryo development in a dicot

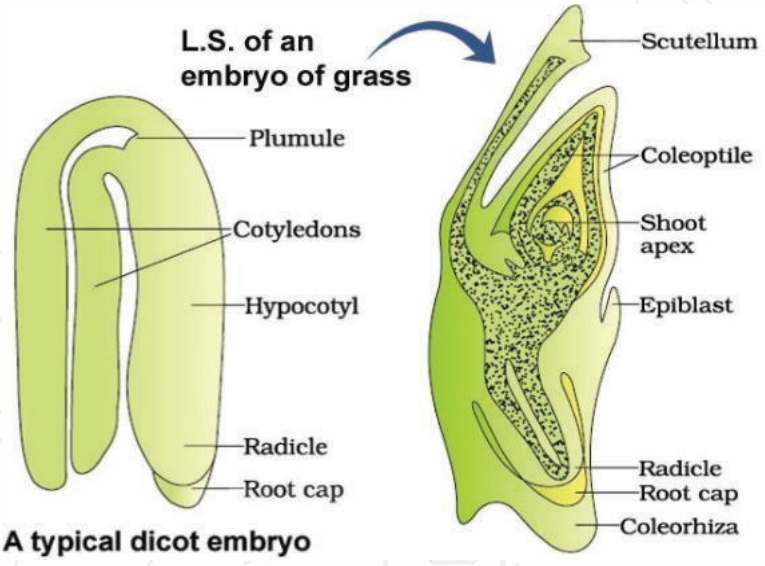
Dicotyledonous embryo

- It has an embryonal axis and 2 cotyledons.
- The portion of embryonal axis above the level of cotyledons is the epicotyl, which terminates with the 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.
- In the grass family, the cotyledon 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 foliarstructure).



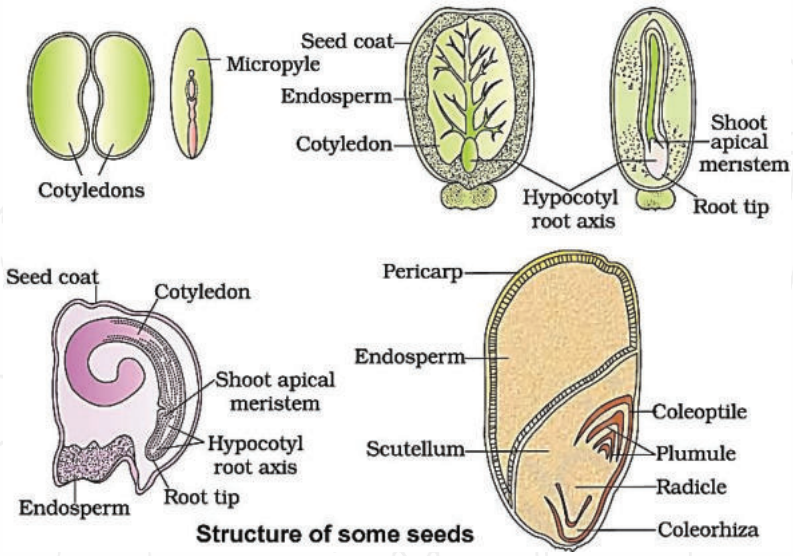
A typical dicot embryo

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 embryoaxis.
- The cotyledons are simple, generally thick and swollen due to storage food (as in legumes).
- Mature seeds are 2 types:
  - **Non-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 as it is not completely used up during embryo development (e.g., wheat, maize, barley, castor, coconut, sunflower).
- 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 O2& water enter into the seed during germination.
- As the seed matures, its water content is reduced and seeds become dry (10-15 % moisture by mass). The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity **(dormancy).** If favourable conditions are available (adequate moisture, oxygen and suitable temperature), theygerminate.

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).

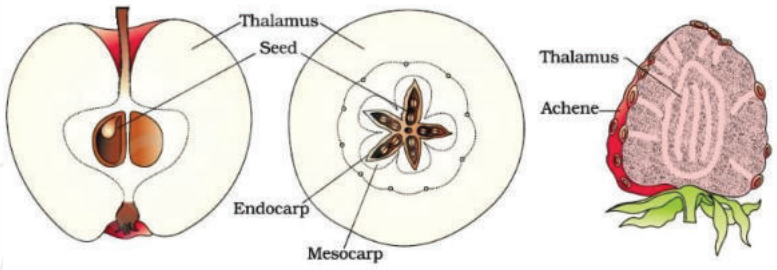


Structure of some seeds

- The fruits may be **fleshy** (e.g. guava, orange, mango, etc.) or dry (e.g. groundnut, mustardetc.).
- Fruits are 2 types:

• True fruits: In most plants, the fruit develops only from the ovary and other floral parts degenerate and fall off. They called truefruits.

• False fruits: In this, the thalamus also contributes to fruit formation. **E.g.** apple,strawberry, cashewetc.



False fruits of apple and strawberry

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 areseedless.

Advantages of seeds:

• Since pollination and fertilisation are independent of water, seed formation is moredependable.

- Seeds have better adaptive strategies for dispersal to new habitats and help the species to colonize in other areas.
- They have foodreserves. So young seedlings are nourished until they are capable ofphotosynthesis.
- The hard seed coat protects the youngembryo.
- Being products of sexual reproduction, they generate new genetic combinations leading tovariations.
- Dehydration and dormancy of mature seeds are crucial for storage of seeds. It can be used as food throughout the year and also to raise crop in the next season.

Viability of seeds after dispersal:

- In a few species the seeds lose viability within a few months. 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 dacty lifera) discovered during the archeological excavation at King Herod's palace near the Dead Sea.

APOMIXIS AND POLYEMBRYONY

Apomixis is the production of seeds withoutfertilisation.

E.g. Some species of Asteraceae and grasses.

- It is a form of asexual reproduction that mimics sexual reproduction.
- **Development of apomictic seeds:**

In some species, the diploid egg cell is formed without reduction division and developsinto the embryo without fertilisation.

In many species (e.g. manyCitrus & Mango varieties)some of the nucellar cells surrounding the embryo sac divide, protrude into the embryo sac and develop into the embryos. In such species 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, the plants in the progeny willsegregate and lose hybrid characters.
- Production of hybrid seeds is costly. Hence the cost of hybrid seeds is also expensive for the farmers.
- If the hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year.

CHAPTER
03

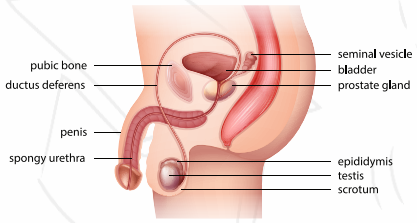
HUMAN REPRODUCTION

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

HUMAN REPRODUCTIVE SYSTEM

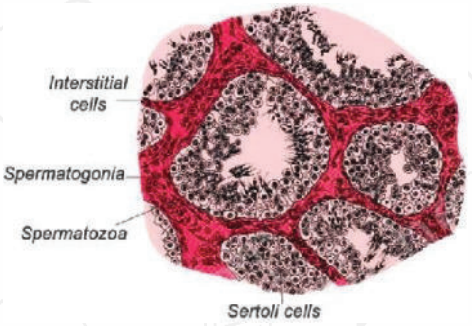
1. Male Reproductive System

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



A. PAIRED TESTES

- Primary sexorgans 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 inguinalcanal.
- The low temperature **(2-2.5o 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 (supportingcells).**
- 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 spermsfrom 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 **common 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.

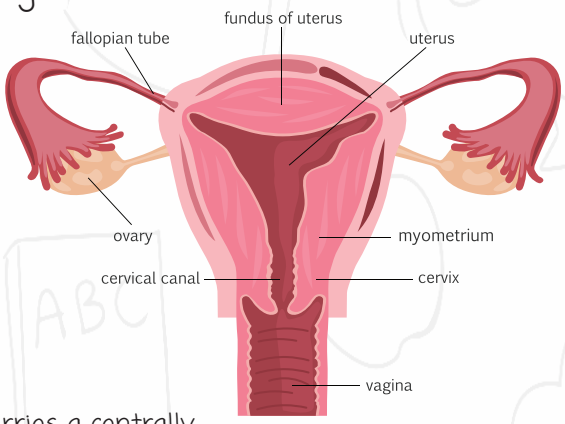
D. PENIS (EXTERNAL GENITALIA)

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 & Externalgenitalia.

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 3parts:
• **Infundibulum:** Funnel-shaped opening provided with many finger-like **fimbriae** . It helps to collect the ovum.
• **Ampulla:** Wider part.
• **Isthmus**: Narrow part. It joins theuterus.
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.
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 ORPUDENDUM)

- Consist of Mons pubis, vestibule, hymen & clitoris.

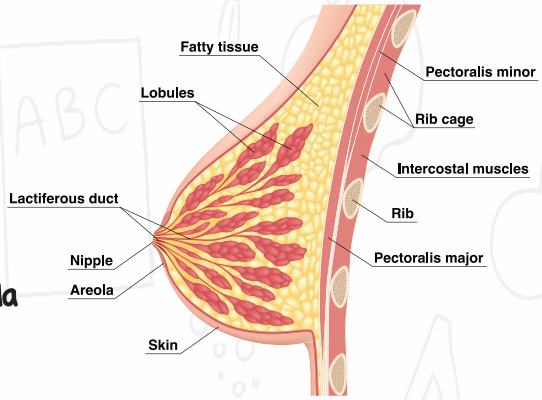
Mons pubis: A cushion of fatty tissue covered by pubic hair.

- **Vestibule:** A median channel. It includes
  - **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 whichpartially 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; activeparticipation in some sportsitems etc.
  In some women, hymen persists after coitus. So the hymen is not a reliable indicator ofvirginity.
- **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 mammarylobes containing clusters of cells **(mammaryalveoli).**
- 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 issucked 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, Spermatogonia (Sperm mother cells or immature 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

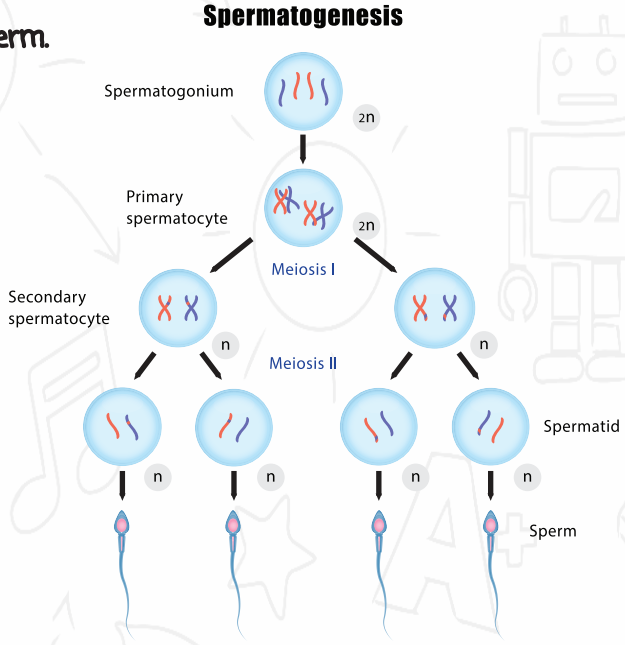
Sec. spermatocytes -n (23)

↓ 2nd meiotic division

Spermatids (n)

↓ Differentiation

Spermatozoa (n)



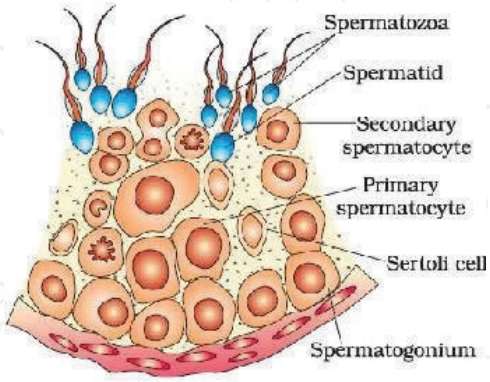
- **4 spermatids** are formed from each primaryspermatocyte.
- After spermiogenesis, sperm heads become embedded in the Sertoli cells. Then they are released to lumen of seminiferous tubules. It is called **spermiation.**

ROLE OF HORMONES iN SPERMATOGENESiS

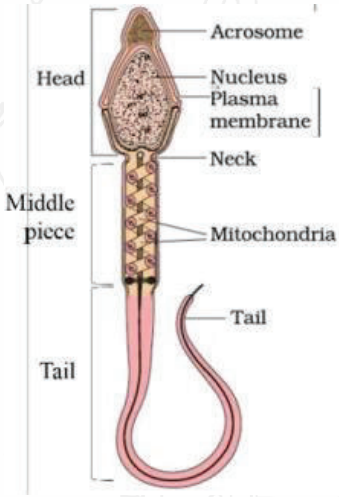
- Hypothalamus releases Gonadotropin releasing hormone (GnRH).
- GnRH stimulates the anterior pituitary gland to secrete 2 **gonadotropins such as Luteinizing hormone (LH)** and

follice 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 ofsperm.
- **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

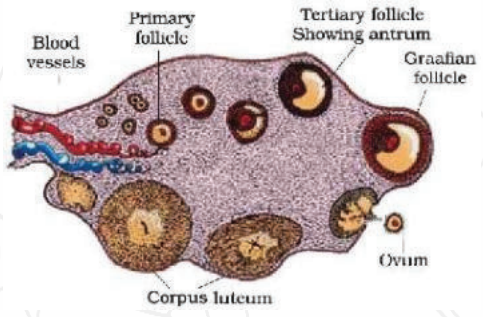
- It is the process of formation and maturation of **ovum.**
- It takes place in **Graafian follicles.**

Oogenesis is initiated in embryonic stage when millions 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 **primaryfollicle.**

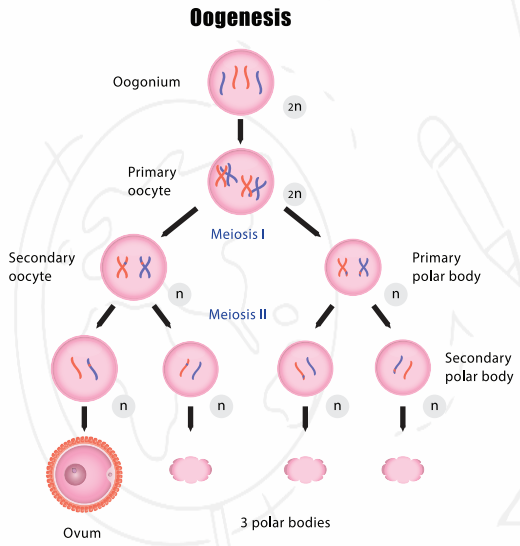
Many primary follicles degenerate during the phase from birth to puberty. Therefore, at puberty, only **60,000-80,000** primary follicles are left in each ovary.



Primary follicles get surrounded by more layers of granulosa cells and a new **theca** toform **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 insize)

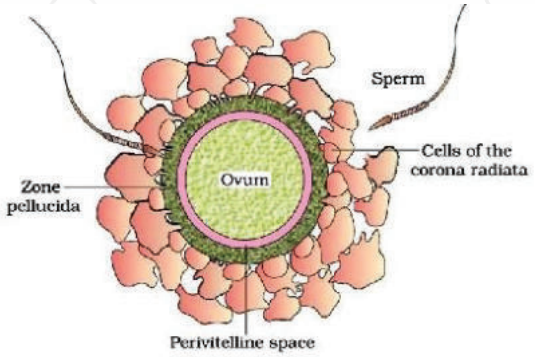
↓ 1st meiotic division (prior toovulation)

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 indiameter.
- 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 grow th phase	Elaborated grow th 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 tosenility.	Begins at embryonic stage but suspends up to puberty. It ceases around the age of f ifty.

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 29days.**
- 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 healthetc.
- **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 Graafianfollicles.
- Secretion of oestrogens by **Graafian follicles.**

- Oestrogens stimulate

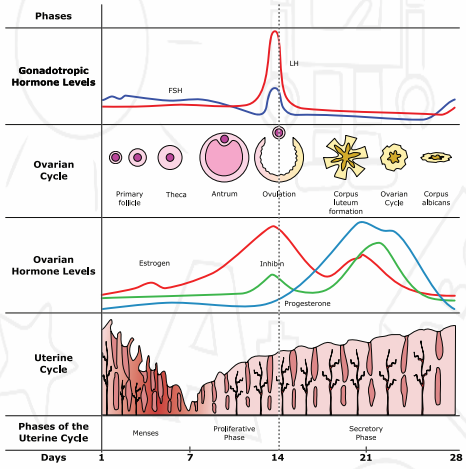
- **Proliferation** of **ruptured uterine endometrium** and mucus lining of **oviduct & vagina.**
  - Development of secondary sexual characters.
  - Suppression of FSHsecretion.
  - Secretion of LH (Luteinizing hormone).

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 into a yellow endocrine mass called **Corpus luteum**. It secretes **progesterone.**
- **Functions of progesterone:**
  - Makes the endometrium **maximum vascular, thickand soft**. Thus, the uterus gets ready forimplantation.
  - 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.**



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-isthmic junction** of fallopian tube.

Sperms - vagina - cervical canal - uterus - isthmus

↓

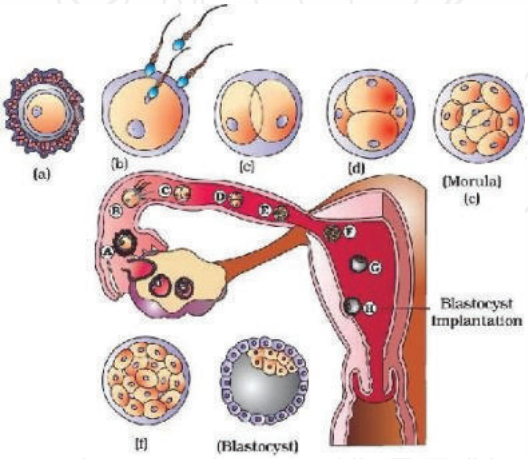
Fertilization - Ampullary- isthmicJunction

↓

Ovum (from ovary)- fimbriae- infundibulum- ampulla-

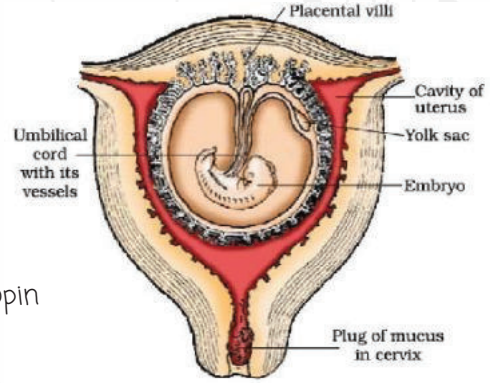
- Fertilization happens only if **ovum & sperms** are transported simultaneously. So all copulations do not lead to fertilization & pregnancy.
- A sperm contacts with **zona pellucida.** It induces changes in the membrane that block entry of additional sperms.
- The secretions of the **acrosome** help 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 totrophoblast.
- 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 theembryo.



PREGNANCY AND EMBRYONIC DEVELOPMENT

After implantation, finger-like projections **(chorionic villi)** appear on the trophoblast which is surrounded by the 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** fromfoetus.
- 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: 21months).**

CHANGES iN EMBRYO DURiNG PREGNANCY

- **After one month:** Heart isformed.
- **End of second month:** Limbs and digits aredeveloped.
- **End of 12 weeks (first trimester):** The 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 (secondtrimester):** 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 isinduced 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 essentialto develop resistance for the new born babies.

CHAPTER
04

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.

REPRODUCTIVEHEALTH: 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 dealthe 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 EXPLOSION & BIRTH CONTROL

In 1900, the world population was around 2 billion (2000 million). By 2000, it rocketed to about 6 billion.
- In India, population was nearly 350 million at the time of independence. It crossed 1 billion in May 2000. It means every sixth person in the world is an Indian.
- According to the 2001 census report, our population growth rate was still around 1.7% (i.e. 17/1000/year), a rate at which our population could double in 33 years.

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 HamareDo (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).

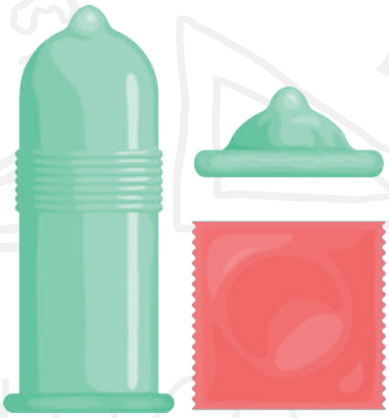
PROPERTIES OF AN IDEAL CONTRACEPTIVE

- User-friendly, easily available, effective and reversible.
- No or least side-effects.
- It should not interfere with sexualdrive, 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 prevention of conception by breastfeeding the child because ovulation and the cycle do not occur during the period of lactation. This is effective up to 6 months following parturition. It has no side effect. But chances of failure are high.

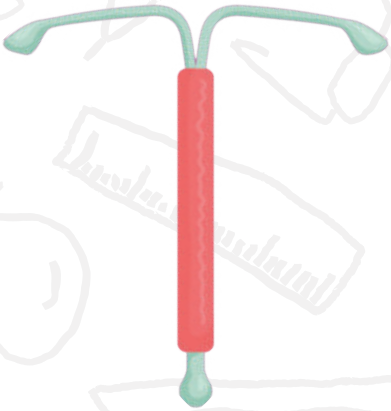


2. BARRIERS

They prevent physical meeting of sperm & ovum. E.g.
- Condoms (E.g. Nirodh): Made of rubber/latex sheath.
  Condoms for male: Cover thepenis.
  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 popularbecause:
  - It protects the user from STDs and AIDS.
  - Easily available.
  - It is disposable.
  - It can be self-inserted and thereby give privacy to user.

3. INTRA UTERINE DEVICES(IUDS)

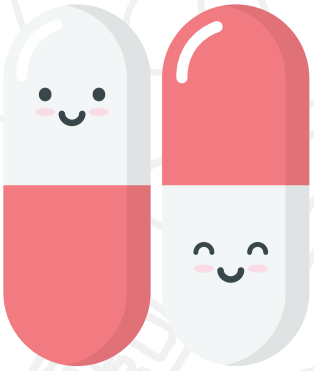
These are inserted by doctors or nurses in the uterus through vagina. They increase phagocytosis of sperms.



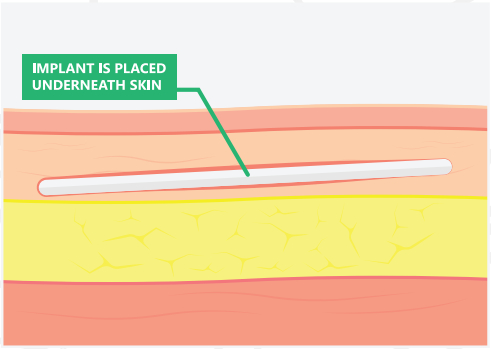
Types ofIUDs:
- Non-medicated IUDs: They retard sperm motility. Also have spermicidal effect. E.g. Lippes loop.
- Copper releasing IUDs: Cu ions suppress motility and fertilising capacity of sperms. E.g.CuT, Cu7, Multiload 375.
- Hormone releasing IUDs: They make the uterus unsuitable for implantation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

IUDs are ideal contraceptives for the females who want to delay pregnancy or space children.

4. ORAL CONTRACEPTIVES



- Oral administration of progestogens or progestogen-estrogen combinations in the form of tablets (pills).
- Pills are taken daily for 21 days starting within the first five days of menstrual cycle. After a gap of 7 days (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

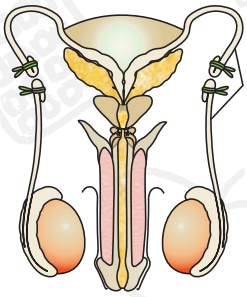
- Progestogens or Progestogens-oestrogen combination are used by females as injections or implants underskin.
- Their mode of action is like that of pills and their effective periods are much longer.

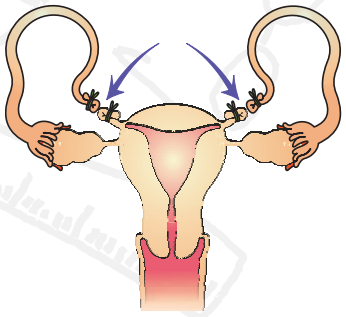
Progestogens or progestogen-oestrogen combinations & IUDs are used as emergency contraceptives within 72 hours of coitus. It avoids pregnancy due to rapeor casual intercourse.

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 throughvagina.





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 inducedabortion.

- 45 to 50 million MTPs are performed in a year all over the world (i.e. 1/5th of total number of conceivedpregnancies).
- MTP helps to decrease the population.
- Many countries have not legalised MTP due to emotional, ethical, religious and socialissues.
- 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 (a foetal sex determination test based on the chromosomal pattern of foetal cells in the amniotic fluid). If the foetus is female, it is followed by MTP. Such practices are dangerous for the young mother and foetus.

SEXUALLY TRANSMITTED DISEASES (STDS)

- Diseases transmitted through sexual intercourse are called Sexually transmitted diseases (STDs) /Venereal diseases (VD) or Reproductive tract infections (RTI). E.g. Gonorrhoea, syphilis, genital herpes, chlamydiasis, genital warts, trichomoniasis, hepatitis-B & HIV leading to AIDS.
- Hepatitis-B & HIV are alsotransmitted
  - By sharing of injection needles, surgical instruments etc.
  - By transfusion ofblood.
  - From infected mother to foetus.
- Except hepatitis-B, genital herpes & HIV, other diseases are completely curable if detected early and treatedproperly.
- 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, ectopic pregnancies, abortions, still births, cancer of the reproductive tract etc.
- All persons are vulnerable to STDs. These are very high among persons in the age group of 15-24 years.

- **Prevention:**

i. Avoid sex with unknown partners/multiple partners.
ii. Always use condoms duringcoitus.
iii. In case of doubt, go to a qualified doctor for early detection and get complete treatment.

- 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 countsetc.

5. Surrogacy

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

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.

CHAPTER

5

PRINCIPLES OF INHERITANCE AND VARIATION

IMPORTANT TERMS

- Genetics: Study of inheritance, heredity and variation of pair characters or Study of genes and chromosomes.
- Inheritance/ Heredity: Transmission of characters from parents to offspring. It results in resemblance between offspring and their parents.
- 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 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.

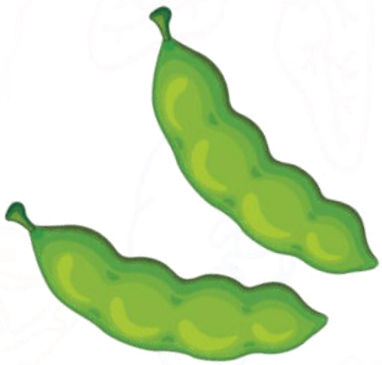
MENDEL'S LAWS OF INHERITANCE

Gregor Mendel is the Father of genetics. He conducted some hybridization experiments on garden peas (*Pisum sativum*).

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

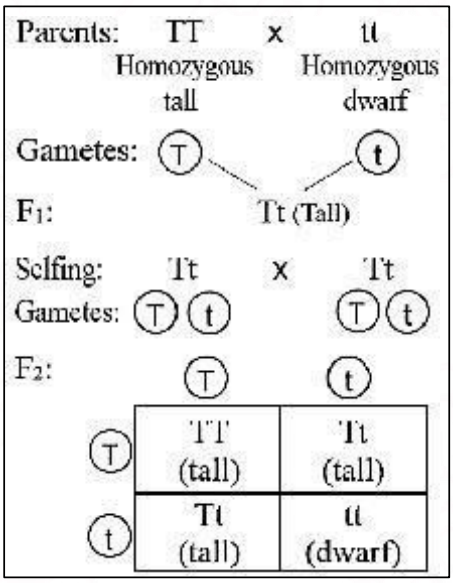
Monohybrid genotypic ratio:
1 Homozygous tall (TT):
2 Heterozygous tall (Tt):
1 Homozygous dwarf (tt): = 1:2:1

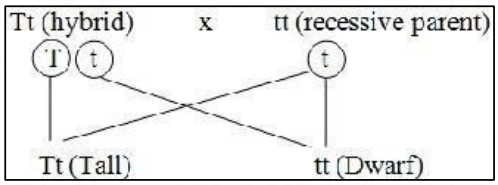
Mendel made similar observations for other pairs of traits. He proposed that some factors were inherited from parent to offspring. Now it is called as genes. Do not use *T* for tall and *d* for dwarf because it is difficult to
remember whether *T* & *d* are alleles of same gene or not. The F1 (Tt) when 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.
1/4th of the random fertilization leads to TT (. TT).
1/2 (2/4) of the random fertilization leads to Tt (. Tt).
1/4th of the random fertilization leads to tt (. tt).

Tt x Tt

Binomial expression = (ax + by) 2
Hence, (. T + . t)2 = (. T + . t) (. T + .t)
= . TT + . Tt + . Tt + . tt
= . TT + . Tt + .tt

Mendel self-pollinated the F2 plants. He found that dwarf F2 plants continued to generate dwarf plants in F3 & F4. He
concluded that genotype of the dwarfs was homozygous- *tt*.

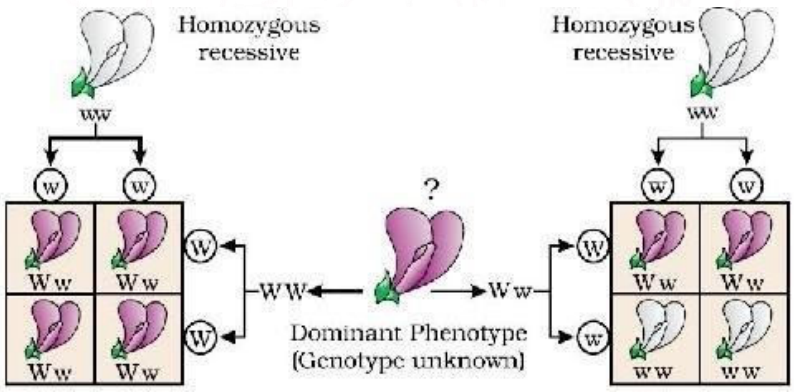




BACKCROSS AND TESTCROSS

- **Back cross:** Crossing of hybrid with its any parent.
- **Testcross:** Crossing of hybrid with recessive parent. E.g.

Hence monohybrid test cross ratio= 1:1
Test cross is used to find out the unknown genotype of a Character. E.g.



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 round shaped & yellow coloured seeds (RRYY) and wrinkled shaped & green coloured seeds (rryy).

Parents: RRYY X rryy
Gametes: RY ry

F1: RrYy (Round yellow)

Selfing: RrYy X RrYy

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

	(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 F2, 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 more than one pair of characters are involved in a cross, factor pairs independently segregate from 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:

o Unmodified (normal or functioning) allele: It is generally dominant and represents original phenotype.
o 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 2ndand 3rd cases: The phenotype will dependent only on the functioning of the unmodified allele. Here, 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). Here, phenotypic and genotypic ratios are same.
  Phenotypic ratio= 1 Red: 2 Pink: 1 White
  Genotypic ratio= 1 (RR): 2 (Rr): 1(rr)
  This means that R was not completely dominant over r.
- Pea plants also show incomplete dominance in other traits.

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 IA, IB & i.
- IA and IB 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	$I^A i$	A
I^B	I^A	$I^A I^B$	AB
I^B	I^B	$I^B I^B$	B
I^B	i	$I^B i$	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

- Here, more than two alleles govern the same character.
- E.g. ABO blood grouping (3 alleles: IA, IB &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

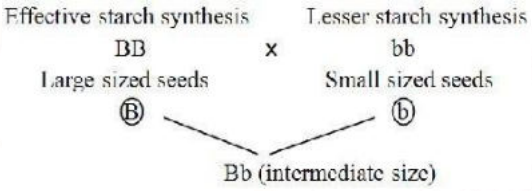
- Assume that 3 genes A, B, C control human skin colour. The dominant forms A, B & C responsible for dark skin colour and recessive forms a, b & c for light skin colour.
- Genotype with all the dominant alleles (AABBCC) gives darkest skin colour. Genotype with all the recessive alleles (aabbcc) gives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

5. PLEIOTROPY

- Here, a single gene exhibits multiple phenotypic expressions. Such a gene is called pleiotropicgene.
- 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.
- Mendel could not provide physical proof for the existence of factors.

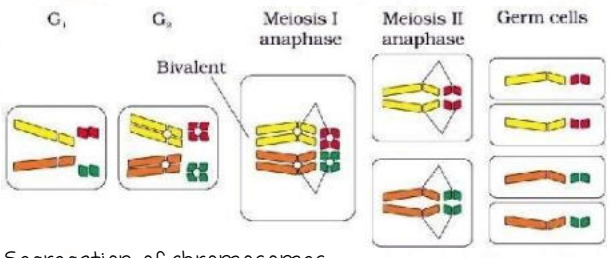
In 1900, de Vries, Correns & vonTschermak independently rediscovered Mendel's results.

CHROMOSOMAL THEORY OF INHERITANCE (1902)

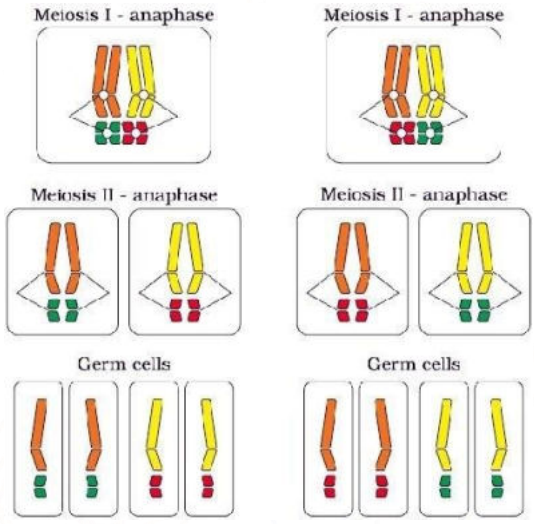
Walter Sutton & Theodore Boveri said that the pairing and separation of a pair of chromosomes lead to segregation of a pair of factors they carried. Sutton united chromosomal segregation with Mendelian principles and called it the chromosomal theory of inheritance. It states that,

- 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



Possiblity I Possiblity II

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

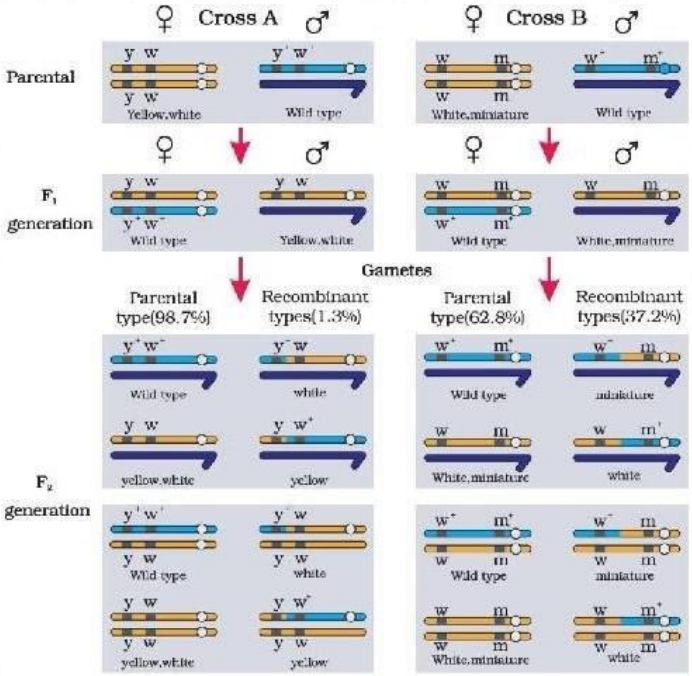
Brown-bodied, red-eyed males (wild type)

Cross 2:

White-eyed, miniature winged

X

Red eyed, large winged (wild type)



Morgan intercrossed their F1 progeny. He found that

- The two genes did not segregate independently of each other and the F2 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.

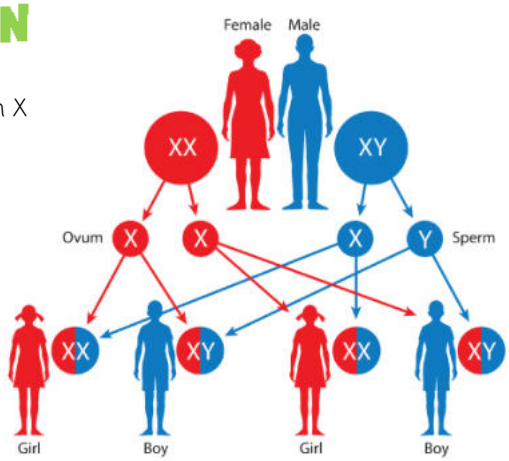
Genetic maps are used as a starting point in the sequencing of genomes. E.g. Human Genome Project.

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).

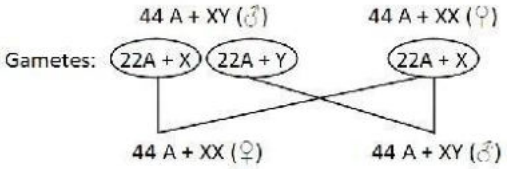
MECHANISM OF SEX DETERMINATION

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.



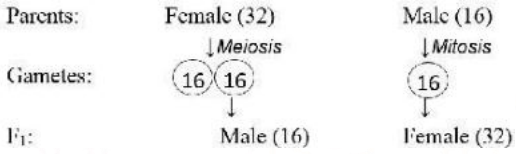
SEX DETERMINATION IN HUMANS (XX-XY TYPE)

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 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: It is the mutation due to change 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. The pattern of inheritance of Mendelian disorders can be traced in a family by the pedigree analysis. E.g. Haemophilia, Colour blindness, Sickle-cell anaemia, Phenylketonuria, Thalassemia, Cystic fibrosis etc. 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. Myotonicdystrophy)
(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.
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).

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

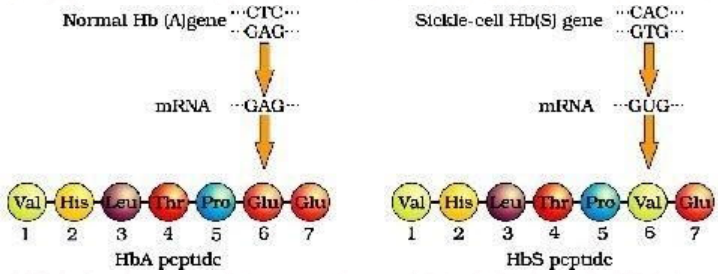
COLOUR BLINDNESS-

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 areX-linked. Normal allele is dominant (C). Recessive allele (c) causes colour blindness. The son of a heterozygous woman (carrier, XCXc) has a50% 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 (XcY).

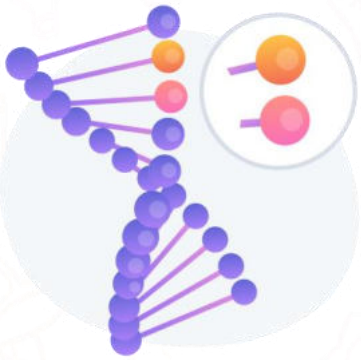
SICKLE-CELL ANAEMIA-

This is an autosome linked recessive disease. It can be transmitted from parents to the offspring when both the partners are carrier for the gene (or heterozygous). The disease is controlled by a pair of allele, HbA and HbS.
Homozygous dominant (HbAHbA): normal Heterozygous (Hb Hb): carrier; sickle cell trait Homozygous recessive (HbSHbS): 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.

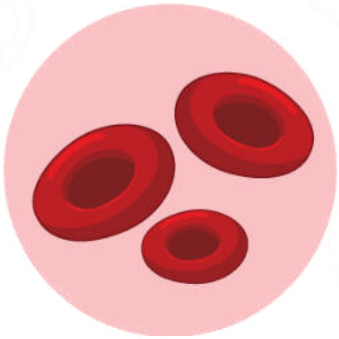


PHENYLKETONURIA



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:

- 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.
- 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 roundhead.
- Broad flat face.
- Furrowed big tongue and partially open mouth.
- Many "loops" on finger tips.
- Palm is broad with characteristic palm 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 + XO (i.e. 45 chromosomes).

FEATURES

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

CHAPTER
21

MOLECULAR BASIS OF INHERITANCE

Nucleic acids (DNA & RNA) are the building blocks of genetic material. DNA is the genetic material in most of the organisms. RNA is the genetic material in some viruses. RNA mostly functions as messengers.

THE DNA

STRUCTURE OF POLYNUCLEOTIDE CHAIN

Polynucleotides are the polymer of nucleotides. DNA & RNA are polynucleotides. A nucleotide has 3 components:

1. A nitrogenous base.
2. A pentose sugar (ribose in RNA & deoxyribose inDNA).
3. A phosphate group.

Nitrogen bases are 2 types:

- Purines: It includes Adenine (A) and Guanine (G).
- Pyrimidines: It includes Cytosine (C), Thymine (T) & Uracil (U). Thymine (5-methyl Uracil) present only in DNA and Uracil only in RNA.

A nitrogenous base is linked to the pentose sugar through an N-glycosidic linkage to form nucleoside.

Nucleosides in RNA	Nucleosides in DNAt
Adenosine	Deoxyadenosinet
Guanosine	Deoxyguanosine
Cytidine	Deoxycytidine
Uridine	Deoxythymidine

Nitrogen base + sugar + phosphate group = Nucleotide (deoxyribonucleotide).

In RNA, every nucleotide residue has an additional -OH group present at 2'-position in the ribose (2'- OH).
2 nucleotides are linked through 3'-5' phosphodiesterbond to form dinucleotide.
When more nucleotides are linked, it formspolynucleotide.

STRUCTURE OF THE DNA

- Friedrich Meischer (1869): Identified DNA and named it as 'Nuclein'.
- James Watson & Francis Crick (1953) proposed double helix model of DNA. It was based on X-ray diffraction data produced by Maurice Wilkins & RosalindFranklin.

- DNA is made of 2 polynucleotide chains coiled in a righthanded fashion. Its backbone is formed of sugar & phosphates. The bases project inside.
- The 2 chains have anti-parallel polarity, i.e. one chain has the polarity 5'-3' and the other has3'-5'.
- The bases in 2 strands are paired through H-bondsforming base pairs (bp).

A=T (2 hydrogen bonds) C-G (3 hydrogenbonds)

- Purine comes opposite to a pyrimidine. This generates uniform distance between the 2 strands.
- Erwin Chargaff's rule: In DNA, the proportion of A is equal to T and the proportion of G is equal toC.

$$[A] + [G] = [T] + [C]$$

$$\text{or } [A] + [G] / [T] + [C] = 1$$

- Φ 174 (a bacteriophage) has 5386nucleotides.
- Bacteriophage lambda has 48502 base pairs(bp).
- E. coli has 4.6×10^6bp.
- Haploid content of human DNA is 3.3×10^9bp.

Length of DNA = number of base pairs X distance between two adjacent base pairs.

Number of base pairs in human = 6.6×10^9

Hence, the length ofDNA = $6.6 \times 10^9 \times 0.34 \times 10^{-9}$

= 2.2m

In E. coli, length ofDNA =1.36 mm (1.36×10^{-3}m)

1.36×10^{-3}

The number of base pairs $= 0.34 \times 10^{-9}$

$= 4 \times 10^6$bp

PACKAGING OF DNA HELIX

- In prokaryotes (E.g. E. coli), the DNA is not scattered throughout the cell. DNA, being negatively charged, is held with some positively charged proteins and form 'nucleoid'.
- In eukaryotes, there is a set of positively charged, basic proteins called histones.
- Histones are in positively rich charged basic amino acid residues lysines and arginines.

- 8 histones form histone octamer.
- Negatively charged DNAis wrapped around histone octamer to give nucleosome.
- A typical nucleosome contains 200 bp.

Therefore, the total number of nucleosomes in human =

$6.6 \times 10^9 bp = 3.3 \times 107$

200

- Nucleosomes constitutfeo rtmhe repeating unit to chromatin. Chromatin is the thread-like stained bodies.
- Nucleosomes in chromatin = 'beads-on-string'.
- Chromatin is packaged -chromatin fibres - coiled and condensed at metaphase stage - chromosomes.
- Higher level packaging of chromatin requires nonhistone chromosomal (NHC) proteins.
- Chromatins include

Euchromatin: Loosely packed and transcriptionally active chromatin and stains light.

Heterochromatin: Densely packed and inactive region of chromatin and stains dark.

THE SEARCH FOR GENETICMATERIAL

1. GRIFFITH'S TRANSFORMING PRINCIPLE EXPERIMENT

Griffith used mice &Streptococcus pneumoniae.

Streptococcus pneumoniae has 2 strains-

- Smooth (S) strain (Virulent): Has polysaccharide mucus coat. Cause pneumonia.
- Rough (R) strain (Non-virulent): No mucus coat. Does not cause Pneumonia.

Experiment:

S-strain ---- Inject into mice ---- Mice die

R-strain ---- Inject into mice ---- Mice live

S-strain (Heat killed) ---- Inject into mice ---- Mice live

S-strain (HK) + R-strain (live) ---- Inject into mice ---- Mice die

He concluded that some 'transforming principle', transferred from heat-killed S-strain to R-strain. It enabled R-strain to synthesize smooth polysaccharide coat and become virulent. This must be due to thetransfer of genetic material.

2. BIOCHEMICAL CHARACTERIZATION OF TRANSFORMING PRINCIPLE

- Oswald Avery, Colin MacLeod & Maclyn McCarty worked to determine the biochemical nature of transforming principle' in Griffith's experiment.

- They purified biochemicals (proteins, DNA, RNA etc.) from heat killed S cells using suitable enzymes.

- They discovered that

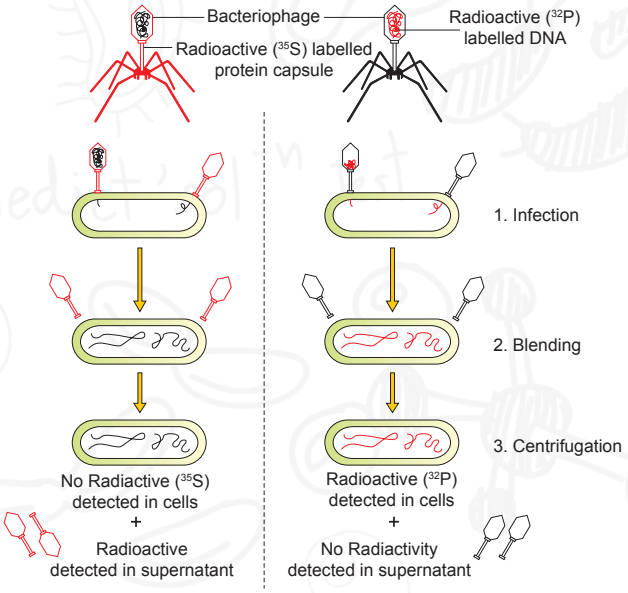
Digestion of protein and RNA (using Proteases and RNases) did not affect transformation. So, the transforming substance was not a protein or RNA.

Digestion of DNA with DNase inhibited transformation. It means that DNA caused transformation of R cells to S cells, i.e. DNA was the transforming principle.

3.HERSHEY-CHASE EXPERIMENT (BLENDERE XPERIMENT)

- Hershey & Chase grew some bacteriophage viruses on a medium containing radioactive phosphorus (P^{32}) and some others on medium containing radioactive sulphur (S^{35}).

- Viruses grown in P32 got radioactive DNA because only DNA contains phosphorus. Viruses grown in S35 got radioactive protein because protein contains sulphur.
- These preparations were used separately to infect E. coli.
- After infection, the E. coli cells were gently agitated in a blender to remove the virus particles from the bacteria.
- Then the culture was centrifuged to separate lighter virus particles from heavier bacterial cells.



- Bacteria infected with viruses having radioactive DNA were radioactive. i.e., DNA had passed from the virus to bacteria. Bacteria infected with viruses having radioactive proteins were not radioactive. i.e., proteins did not enter the bacteria from the viruses. This proves that DNA is the genetic material.

PROPERTIES OF GENETIC MATERIAL (DNA V/S RNA)

A genetic material may have the following properties:
Ability to generate its replica (Replication).
Chemical and structural stability.
Provide the mutations that are required for evolution.
Ability to express as 'Mendelian Characters'.

Reasons for stability (less reactivity) ofDNA	Reasons formutability (high reactivity) ofRNA
Double stranded	Single stranded
Presence of thymine	Presence of Uracil
Absence of 2'-OHin sugar	Presence of 2'-OHin sugar

- RNA is unstable. So, RNAviruses (E.g. Q.Bbacteriophage, Tobacco Mosaic Virus etc.) mutate and evolve faster.
- DNA strands are complementary. On heating, they separate. In appropriate conditions, they come together. In Griffith's experiment, some properties of DNA of the heat killed bacteria did not destroy. It indicates the stability of DNA.
- For the storage of genetic information, DNA is better due to its stability. But for the transmission of genetic information, RNA is better.
- RNA can directly code for the protein synthesis, hence can easily express the characters. DNA is dependent on RNA for protein synthesis.

RNA WORLD

- RNA was the first genetic material.
- It acts as genetic material and catalyst.
- Essential life processes (metabolism, translation, splicing etc.) evolved around RNA.
- DNA evolved from RNA for stability.

CENTRAL DOGMA OF MOLECULAR BIOLOGY

It is proposed by Francis Crick. It states that the genetic information flows from DNA - RNA - Protein.
In some viruses, flow of information is in reverse direction (from RNA to DNA). It is called reverse transcription.

DNA REPLICATION

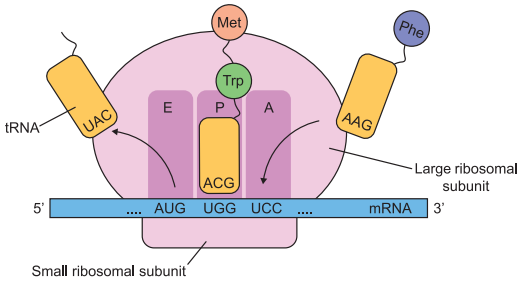
Replication is the copying of DNA from parental DNA.
Watson & Crick proposed Semi-conservative model of replication. It suggests that the parental DNA strands act as template for the synthesis of new complementary strands.
After replication, each DNA molecule would have one parental and one new strand.
Matthew Messelson & Franklin Stahl (1958) experimentally proved Semi-conservative model.

MESSELSON & STAHL'S EXPERIMENT

-They cultured E. coli in a medium containing 15NH4Cl (15N: heavy isotope of N).15N was incorporated into both strands of bacterial DNA and the DNA became heavier.
-Another preparation containing N salts labeled with 14N is also made. 14N was incorporated in both strands of DNA and became lighter.
These 2 types of DNA can be separated by centrifugation in a CsCl density gradient.

- They took E. coli cells from 15N medium and transferred to 14N medium. After one generation (i.e. after 20 minutes), they isolated and centrifuged the DNA. Its density was intermediate (hybrid) between 15N DNA and 14N DNA.
This shows that the newly formed DNA one strand is old (15N type) and one strand is new (14N type). This confirms semi-conservative replication.
After II generation (i.e. after 40 minutes), there was equal amounts of hybrid DNA and light DNA.

Translation Process



Taylor & colleagues (1958) performed similar experiments on Vicia faba (faba beans) using radioactive thymidine to detect distribution of newly synthesized DNA in the chromosomes. It proved that the DNA in chromosomes also replicate semi-conservatively.

THE MACHINERY AND ENZYMES FOR REPLICATION

DNA replication starts at a point called origin(ori).
A unit of replication with one origin is called a replicon.
During replication, the 2 strands unwind and separate by breaking H-bonds in presence of an enzyme, Helicase.

Unwinding of theDNA molecule at a point forms a structure 'Y'-shaped called replication fork. The separated strands act as templates for the synthesis of new strands. DNA replicates in the 5'-3' direction.

Deoxyribonucleoside triphosphates (dATP, dGTP, dCTP & dTTP) act as substrate and provide energy for polymerization.

Firstly, a small RNA primer is synthesized in presence of an enzyme, primase.

In the presence of an enzyme, DNA dependent DNA polymerase, many nucleotides join with one another to primer strand and form a polynucleotide chain (new strand).

The DNA polymerase forms one new strand (leading strand) in a continuous stretch in the 5'-3' direction (Continuous synthesis).

The other new strand is formed in small stretches (Okazaki fragments) in 5'-3' direction (Discontinuous synthesis).

The Okazaki fragments are then joined together to form a new strand by an enzyme, DNA ligase. This new strand is called laggingstrand.

If a wrong base is introduced in the new strand, DNA polymerase can do proof reading.

E. coli completes replication within 38 minutes. i.e. 2000 bp per second.

In eukaryotes, the replication of DNA takes place at Sphase of the cell cycle. Failure in cell division afterDNA replication results in polyploidy.

TRANSCRIPTION

- It is the process of copying genetic information from one strand of the DNA into RNA.
- Here, adenine pairs with uracil instead of thymine.
- During transcription, both strands are not copied because
- The code for proteins is different in both strands. This complicates the translation.
- If 2 RNA molecules are produced simultaneously, this would be complimentary to each other. It forms a double stranded RNA and prevents translation.

TRANSCRIPTION UNIT

- It is the segment of DNA between the sites of initiation and termination of transcription. It consists of 3 regions:
- A promoter (Transcription start site): Binding site for RNA polymerase.
- Structural gene: The region between promoter and terminator where transcription takes place.
- A terminator: The site where transcriptionstops.
- The DNA- dependent RNA polymerase catalyzes the polymerization only in5'-3'direction.
- 3'-5' acts as template strand. 5'-3' acts as coding strand.

3'-ATGCATGCAT GCATGCATGCATGC-5'te mplate strand.
5'-TACGTACGTACGTACGTA CGTACG-3' codingstrand.

TRANSCRIPTION UNIT ANDGENE

Gene: Functional unit of inheritance. It is the DNA sequence coding for RNA molecule.

Cistron: A segment of DNA coding for a polypeptide. Structural gene in a transcription unit is 2 types:

- Monocistronic structural genes (split genes): It is seen in eukaryotes. Here, coding sequences (exons or expressed sequences) are interruptedby introns(intervening sequences).
- Polycistronic structural genes: It is seen in prokaryotes. Here, there are no splitgenes

STEPS OF TRANSCRIPTION IN PROKARYOTES

- Initiation: Here, the enzyme RNA polym erase binds at the promoter site of DNA. This causes the local unwinding of the DNA double helix. An initiation factor(σ factor) present in RNA polymerase initiates the RNA synthesis.
- Elongation: RNA chain is synthesized in 5'-3' direction. In this process, activated ribonucleoside triphosphates (ATP, It is the sequence of nucleotides (nitrogen bases) in mRNA
that contains information for protein synthesis (translation).
- The sequence of 3 bases determining a single amino acid is called codon

20 TYPES OF AMINO ACIDS INVOLVED IN TRANSLATION

1. Alanine (Ala)
2. Arginine (Arg)
3. Asparagine (Asn)
4. Aspartic acid (Asp)
5. Cystein (Cys)
6. Glutamine (Gln)
7. Glutamic acid (Glu)
8. Glycine (Gly)
9. Histidine (His)
10. Isoleucine (Ile)
11. Leucine (Leu)
12. Lysine (Lys)
13. Methionine (Met)
14. Phenyl alanine (Phe)
15. Proline (Pro)
16. Serine (Ser)
17. Threonine (Thr)
18. Tryptophan (Trp)
19. Tyrosine (Tyr)
20. Valine (Val)

- George Gamow suggested that for coding 20 amino acids, the code should be made up of 3 nucleotides.
- Har Gobind Khorana devineloped the chemical method synthesizing RNA molecules with defined combinations of bases (homopolymers & copolymers).
- Marshall Nirenberg developed cell-free system for protein synthesis.
- Severo Ochoa (polynucleotide phosphorylase) enzyme is used to polymerize RNA with defined sequences in a template independent manner.

SALIENT FEATURES OF GENETIC CODE

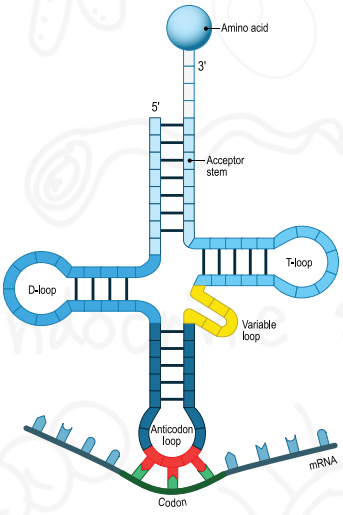
Triplet code (three-letter code).
61 codons code for amino acids. 3 codons (UAA, UAG& UGA) do not code for any amino acids. They act as stop codons (Termination codons or non-sensecodons).
Genetic code is universal. E.g. From bacteria to human UUU codes for Phenylalanine. Some exceptions are found in mitochondrial codons, and in some protozoans.
No punctuations b/w adjacent codons (comma less code).
The codon is read in mRNA in a contiguous fashion.
Genetic code isnon-overlapping.
A single amino acid is represented by many codons (except AUG for methionine & UGG for tryptophan). Such codons are called degenerate codons. Genetic code is unambiguous and specific. i.e. one codon specifies only one amino acid.
AUGhas dual functions. It codes for Methionine and acts as initiator codon. In eukaryotes, methionine is the first amino acid and formyl methionine in prokaryotes.

MUTATIONS AND GENETICCODE

- Relationship between genes & DNA are best understood by mutation studies. Deletions & rearrangements in a DNA may cause loss or gain of a gene and so a function.
- Insertion or deletion of one or two bases changes the reading frame from the point of insertion ordeletion.
- Insertion/ deletion of three or its multiple bases insert or delete one or multiple codon. Hence one or multiple amino acids are inserted /deleted. The reading frame remains unaltered from that point onwards. Such mutations are known as frame-shift insertion or deletionmutations.
- It proves that codon is a triplet and is read contiguously.

TYPES OF RNA

mRNA (messenger RNA): Provide template for translation
(protein synthesis).
rRNA (ribosomal RNA): Structural & catalytic role during translation. E.g. 23S rRNA in bacteria acts asribozyme.
tRNA (transfer RNA or sRNA or soluble RNA): Brings amino acids for protein synthesis and reads the genetic code.
tRNA is called adaptor molecule because ithas
An Anticodon (NODOC) loop that has bases complementary to the codon.
An amino acid acceptor end to which amino acid binds.
Ribosome binding loop.
Enzyme binding loop.



- For initiation, there is another tRNA called initiator tRNA.
- There are no tRNAs for stopcodons.
- Secondary (2-D) structure of tRNA looks like a cloverleaf.
3-D structure looks like inverted 'L'.

TRANSLATION (PROTEIN SYNTHESIS)

It takes place in ribosomes. It includes 4steps:

1. Charging oft RNA
2. Initiation
3. Elongation
4. Termination

1. CHARGING (AMINOACYLATION) OFTRNA

Formation of peptide bond needs energyobtained fromATP. For this, amino acids are activated (amino acid + ATP) and linked to their cognate tRNA in presence of am inoacyl tRNA synthetase. Thus, the tRNAbecomes charged.

2.INITIATION

It begins at the 5'-end of mRNA in the presence of an initiation factor. The mRNA binds to the small subunit of ribosome. Now the large subunit binds to the small subunit to complete the initiation complex.
Large subunit has 2 binding sites for tRNA- aminoacyl tRNA binding site (A site) and peptidyl site (P site).
Initiation codon for methionine is AUG. So methionyl tRNA complex would have UAC at the Anticodonsite.

3.ELONGATION

At the P site, the first codon of mRNA binds with anticodon of methionyl tRNA complex.
Another aminoacyl tRNA complex with an appropriate amino acid enters the ribosome and attaches to A site. Its anticodon binds to the second codon on the mRNA and a peptide bond is formed between first and second amino acids in presence of an enzyme, peptidyl transferase.
First amino acid and its tRNA are broken. This tRNA is removed from P site and second tRNAat the A site is pulled to P site along with mRNA. This is called translocation.
Then 3rdcodon comes into A site and a suitable tRNA with 3rdamino acid binds at the A site. This process is repeated.

4.TERMINATION

When aminoacyl tRNA reaches the termination codon like UAA, UAG & UGA, the termination of translation occurs.
The polypeptide and tRNA are released from the ribosomes.
The ribosome dissociates into large and small subunits at the end of protein synthesis.
A group of ribosomes associated with a single mRNA for translation is called a polyribosome (polysomes).
An mRNA has additional sequences that are not translated (untranslated regions or UTR). UTRs are present at both 5'-end (before start codon) and 3'-end (after stop codon). They are required for efficient translation process.

REGULATION OF GENE EXPRESSION

In eukaryotes, gene expression occurs by following levels:
1. Transcriptional level (formation of primary transcript).
2. Processing level (splicing etc.).
3. Transport of mRNA from nucleus to thecytoplasm.
4. Translational level (formation of a polypeptide).

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

In E. coli, the beta-galactosidase enzyme hydrolyses lactose into galactose & glucose. In the absence of lactose, the synthesis of beta-galactosidase stops.

The development and differentiation of embryo into adult are a result of the expression of several set of genes.

If a substrate is added to growth medium of bacteria, a set of genes is switched on to metabolize it. It is called induction.

When a metabolite (product) is added, the genes to produce it are turned off. This is called repression.

OPERON CONCEPT

- Each metabolic reaction is controlled by a set of genes"
- All the genes regulating a metabolic reaction constitute an Operon. E.g. lac operon, trp operon, ara operon, his operon, val operon etc.

Lac Operon in E. coli: The operon controlling lactose

a) A regulatory or inhibitor (i) gene: Codes for the repressor

b) 3 structural genes:

i. z gene: Codes for galactosidase (hydrolyze lactose to galactose and glucose).

ii. y gene: Codes for permease (increase permeability of the cell to lactose).

iii. a gene: Codes for a transacetylase.

- The genes present in the operon function together in the same or related metabolic pathway. There is an operator region for each operon.
- If there is no lactose (inducer), lac operon remains switched off. The regulator gene synthesizes mRNA to produce the repressor protein. This protein binds to the operator genes and blocks RNA polymerase movement. So the structural genes arenot expressed.
- If lactose is provided in the growth medium, the lactose is transported into the E. coli cells by the action of permease. Lactose (inducer) binds with repressor protein. So repressor protein cannot bind to operator gene. The operator gene becomes free and induces the RNA polymerase to bind with promoter gene. Then transcriptionstarts.
- Regulation of lac operon by repressor is called negative regulation.

HUMAN GENOME PROJECT(HGP)

The entire DNA in the haploid set of chromosomes of an organism is called a Genome.

In Human genome, DNA is packed in 23chromosomes.
Human Genome Project (1990-2003) is the first mega project in identifying the sequence of nucleotides and mapping of all the genes in human genome.
Human genome contains about 3x109bp.

GOALS OF HGP

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

Methodologies of HGP: 2 major approaches.
Expressed Sequence Tags (ESTs): Focused on identifying all the genes that are expressed as RNA.
Sequence annotation: Sequencing whole set of genome containing all the coding & non-coding sequence and later assigning different regions in the sequence with functions.
Procedure:
Isolate total DNA from a cell - Convert into random fragments - Clone in suitable host (e.g. BAC & YAC) for amplification - Fragments are sequenced using Automated DNA sequencers (using Frederick Sanger method) -- Sequences are arranged based on overlapping regions
Alignment of sequences using computer programs

BAC= Bacterial Artificial Chromosomes
YAC= Yeast Artificial Chromosomes

HGP was closely associated with Bioinformatics.
Bioinformatics: Application of computer science and information technology to the field of biology & medicine.

SALIENT FEATURES OF HUMANGENOME

a. Human genome contains 3164.7 million nucleotidebases.
b. Total number of genes= about 30,000.
c. Average gene consists of 3000 bases, but sizes vary. Largest known human gene (dystrophin on Xchromosome) contains 2.4 million bases.

d. 99.9% nucleotide bases are same in all people. Only 0.1% (3x106 bp) difference makes every individual unique.
e. Functions of over 50% of discovered genes are unknown.
f. Chromosome I has most genes (2968) and Y has the fewest (231).
g. Less than 2% of the genome codes for proteins.
h. Very large portion of human genome is made of Repeated (repetitive) sequences. These are stretches of DNA sequences that are repeated many times. They have no direct coding functions. They shed light on chromosome structure, dynamics and evolution.
i. About 1.4 million locations have single-base DNA differences. They are called SNPs (Single nucleotide polymorphism or 'snips').

DNA FINGERPRINTING (DNAPROFILING)

It is the technique to identify the similarities and differences of the DNA fragments of 2 individuals.
Developed by Alec Jeffreys (1985).

BASIS OF DNA FINGERPRINTING

DNA carries some non-coding repetitive sequences called variable number tandem repeats (VNTR).
Number of repeats is specific from person to person.
The size of VNTR varies from 0.1 to 20 kb.
Repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation.
The bulk DNA forms a major peak and the small peaks are called satelliteDNA. Satellite DNA is classified as micro-satellites, minisatellites etc. based on base composition (A:T rich or G:C rich), length of segment and number of repetitive units.
VNTR belongs to mini-satellite DNA.
Any difference in the nucleotide sequence (inheritab le mutation) observed in a population is called DNA polymorphism (variation at genetic level).
Polymorphism is higher in non-coding DNA sequence because mutations in these sequences may not have any immediate effect in an individual's reproductive ability .
These mutations accumulate generation after generation and cause polymorphism. For evolution & speciation, polymorphisms play important role.

STEPS OF DNA FINGERPRINTING (SOUTHERN BLOTTINGTECHNIQUE)

a. Isolation of DNA.
b. Digestion of DNA by restriction endonucleases.
c. Separation of DNA fragments by gel electrophoresis.
d. Transferring (blotting) DNA fragments to synthetic membranes such as nitrocellulose or nylon.
e. Hybridization using radioactive labelled VNTR probe.
f. Detection of hybridized DNA by autoradiography.

The image (in the form of dark& light bands) obtained is called DNA fingerprint. It differs from individual to individual except inmonozygotic (identical) twins.

The sensitivity of the technique has been increased by use of polymerase chain reaction (PCR). Therefore, DNA from a single cell is enough for DNA fingerprinting.

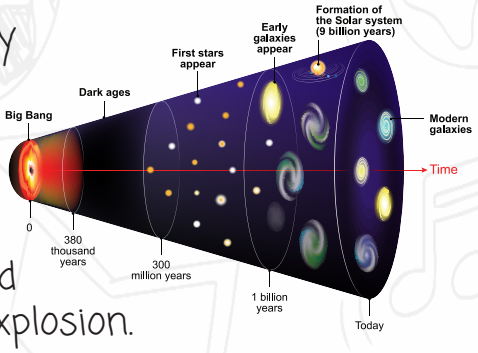
APPLICATION OF DNAFINGERPRINTING

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

CHAPTER
07

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,CH4, **CO_2 & NH_3** released from molten mass covered thesurface.
- 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, CO2 etc.
- The ozone layer was formed. As it cooled, the water vapour fell as rain to formoceans.
- Life appeared almost **four billion** years ago.

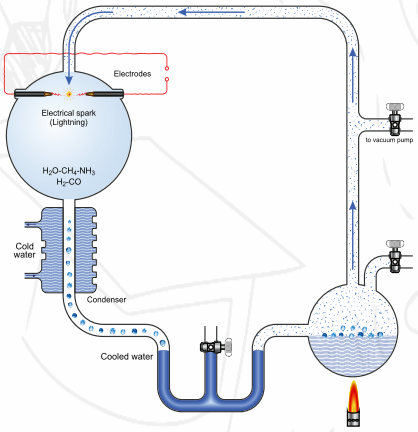
THEORIES OF ORIGIN OF LIFE

1. **Theory of spontaneous generation (Abiogenesis):** It states that, life came out of decaying and rotting matter like straw, mud etc.
Louis Pasteur demonstrated that life comes only from pre-existing life and disproved this theory.
He showed that in pre-sterilized flasks, life did not come from killed yeast. In another flask open to air, new livin g organisms arose.
2. **Biogenesis:** Proposed by Francisco Redi, Spallanzani & Louis Pasteur. It states that, life originates from pre existing 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 &non living was 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 CH4, NH3, H2O, 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 CH4, NH3, H2O, H2 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 areformed.
- In similar experiments, others observed formation of sugars, nitrogen bases, pigment and fats.

First non-cellular form of life originated 3 billion years ago. They were RNA, proteins, Polysaccharidesetc.

EVIDENCES FOR EVOLUTION

1. Paleontological evidences

Paleontology: It is the study of fossils.
Fossils are remnants oflife formsfound in rocks**(earth crust).**
Fossils are written documents of evolution.

Significance of fossils:

a. To study phylogeny (evolutionary history or race history). E.g. Horse evolution.
b. To study the connecting link between two groups of organisms. E.g. Archaeopteryx.
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 structuralfeatures. This can be explained asfollows:

a. Homologous organs

- Homologous organs are the organs having fundamental similarity in 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 ofCucurbita.
- The origin of homologous organs is due to Divergent evolution. It isthe 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).

EVOLUTION

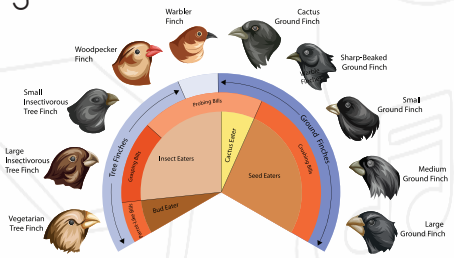
- Flipper of Penguins andDolphins.
- Sweet potato (modified root) & Potato (modified stem).
- Trachea of insects (from ectoderm) and lungs of vertebrates (from endoderm).

Origin of analogous organs is due to Convergent evolution. It is the evolution by which unrelated species becomemore similar to survive and adapt in similar environmentalcondition.

3. ADAPTIVE RADIATION (BIOGEOGRAPHICAL EVIDENCES)

Adaptive radiation **(evolution by adaptation)** is the evolutio n of different species in a geographical area starting from a point. **Eg.**

- Darwin'sfinches 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.**
Eg. Australian Marsupials and Placentalmammals.

PLACENTAL MAMMALS	AUSTRALIAN MARSUPIALS
Mole	Marsupial mole
Ant eate	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.
- **Eg.** 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 by which the organisms that are best suited for their environment survive and reproduce. 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 whitelichens 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. Under this condition the white winged moth did not survive because the predators identified them easily. Dark winged moth survived because of suitable dark background.

NATURALSELECTION BY ANTHROPOGENIC ACTION:

- It is the development of resistant varieties in organisms due to human action. **E.g.** Excess use of herbicides, pesticides, antibiotics or drugs etc.

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 develop by use and 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 insnakes.
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 ThomasMalthus on populationsinfluenced 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 forfitness

.

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 **EVOLUTION**

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 orspeciation.

MECHANISM OF EVOLUTION

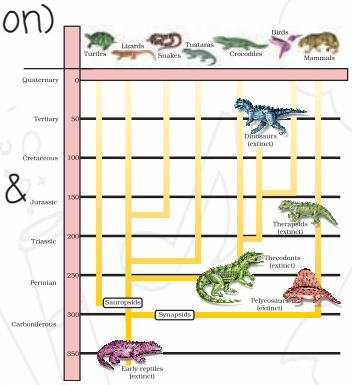
- **Hugo de Vries** proposed **Mutation Theory** of evolution.
- He conducted experiments on **Oenothera lamarckiana** (evening primrose) and believed that evolution takes place through mutation and not by minor variation.

- **Darwinian** variation is minor, slow and directional. Due to this, gradual evolution occurs.

- **Mutation** is sudden, random and directionless variation. Here, speciation is by saltation (single step, largemutation).
- Mutation is the origin of variation for evolution.

HARDY-WEINBERG PRINCIPLE

- It states that allele frequencies in a population are stable and constant f rom generation to generation in the absence of other evolutionary influences.
- The gene pool (total genes and their allelesin a population) remains a constant. This is called genetic equilibrium **(Hardy-Weinberg equilibrium).**
- Sum total of all the allelic frequencies = 1
- **Eg.** In a diploid, p and q are the frequencies of alleles A & a respectively.



The frequency of AA = p^2
The frequency of aa = q^2
The frequency of Aa =2pq
Hence $p^2 + 2pq + q^2 = 1$ [binomial expansion of $(p+q)^2$]
Change of frequency of alleles in a population causes disturbance in genetic equilibrium. This is due to evolution.

FACTORS AFFECTING HARDY-WEINBERG EQUILIBRIUM

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

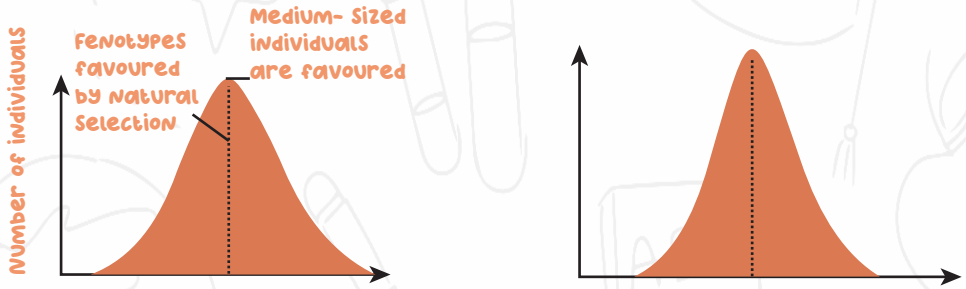
c. Mutation: Mutations result in formation of new phenotypes. Over few generations, this leads to speciation.

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

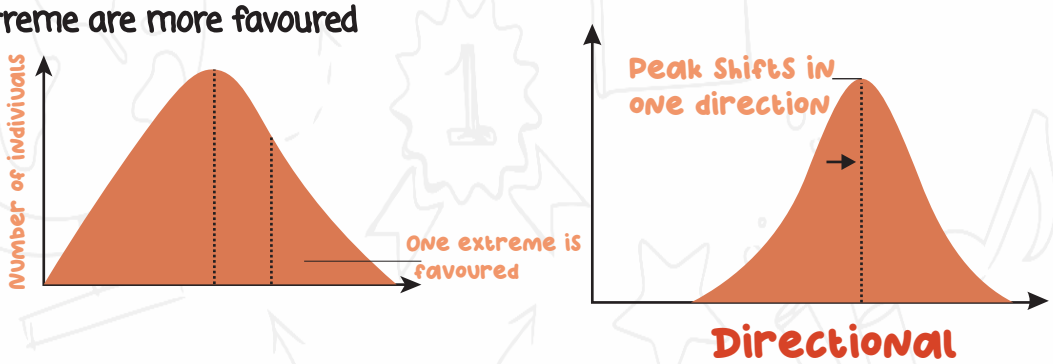
e. Natural selection: It is 3 types.

i. Stabilizing selection: Here, more individuals acquire mean character value and variation is reduced. **E.g.** consider the body size of organisms.

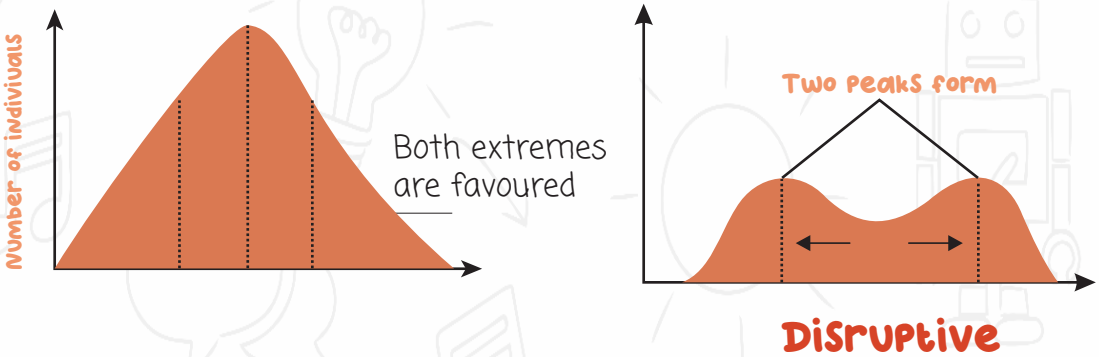
I. Stabilizing selection: Here, more individuals acquire mean character value and variation is reduced. E.g. consider the body size of organisms.



II. Directional selection: Here, individuals of one extreme are more favoured



III. Disruptive selection: Here, individuals of both extremes 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)

- First cellular forms of life appeared (**2000 mya**).
-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 **(285mya).**

- **500 mya:** Invertebrates were formed.
- **450 mya:** First land organisms (plants) appeared.
- **400 mya:** Arthropods invaded the land.
- **350 mya:** Jawless fishes were evolved. Fishes with stout and strong fins could move on land and go back to water. In **1938,** a Coelacanth fish (lobefins) was caught in South Africa which was thought to be extinct. This fish was evolved into first amphibians (ancestors of modern day frogs and salamanders).

- **320 mya:** Sea weeds and few plants wereexisted.
- 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 depositsslowly

3. Mesozoic era (252 - 66 mya) - Age ofreptiles

- It has 3 periods: Triassic **(230 mya)**, Jurassic (208mya) & 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, Pteranodon, Stegosaurus, Brachiosaurus etc.) T. rex was the largest dinosaur (20 feet in height, huge fearsome dagger-like teeth).

- First toothed birds were emerged.

4. Cenozoic era (66 - 0mya)

- Age of Mammals & Angiosperms.
- It has 2 periods: Tertiary (66 mya) & Quaternary (2mya
- Age ofman).
- 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 smallsized.

In South America, there were mammals resembling horse, hippopotamus, bear, rabbit etc. Due to continentaldrift, when South America joined North America, these animals were overridden by North Americanfauna.
- 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. Height up to 4 feet. 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 eatmeat.

• **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 & CentralAsia. 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.
Agriculture & settlements: **10,000** years ago

CHAPTER

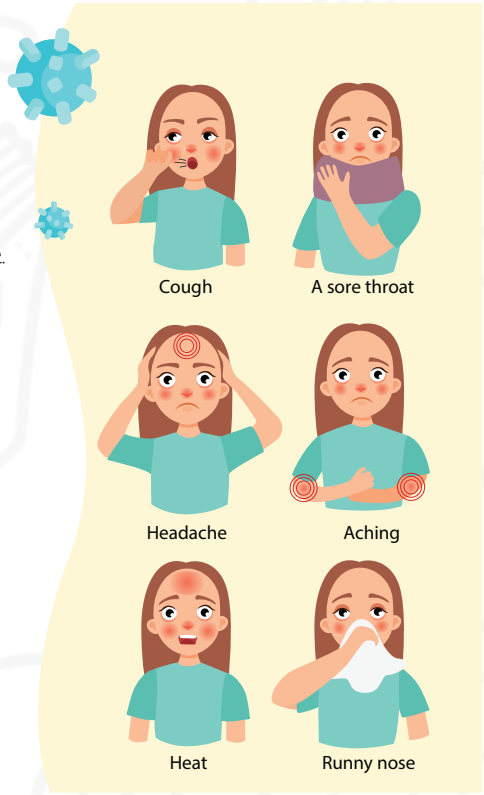
08

HUMAN HEALTH & DISEASES

Health is a state of complete physical, mental & social well-being. Health is affected by genetic disorders, infections, change in life style (food, water, rest, exercise, habits etc). Mind influences immune system (through neural and endocrinesystems). When the functioning of organs or systems ofthe body is adversely affected, it is called a disease. Diseases may be infectious(transmits from one person to another) or non-infectious. Disease causing organisms are called Pathogens. Parasites are pathogensas they harm the host.

COMMON INFECTIOUS DISEASES IN MAN

1. BACTERIAL DISEASES



A) TYPHOID: Pathogen is Salmonellatyphi.

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

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 infectedperson.
- **Symptoms:** Respiratory problems, fever, chills, cough, headache. In severe cases, lips and finger nails turn gray to bluish colour.

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 contaminatedobjects.
- **Symptoms:** Nasal congestion & discharge, sore throat, cough, hoarseness, headache, tiredness etc. Lastfor3-7days

3. PROTOZOAN DISEASES

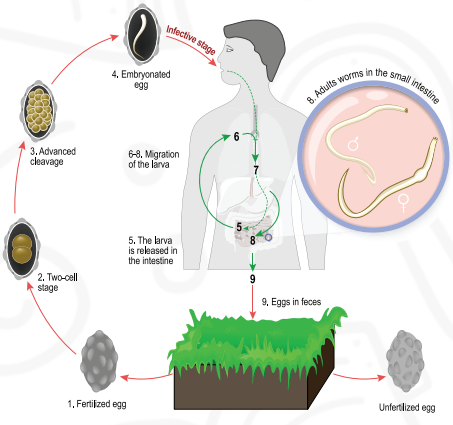
A) MALARIA: Pathogen is Plasmodium sp. (P. vivax, P.malariae & P. falciparum). Most serious (malignant) malaria is caused by P.falciparum.

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

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 mucous and blood clots.

4. HELMINTHDISEASES



A) ASCARIASIS: Pathogen is Ascaris(Intestinalparasite).

- **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 Culexmosquito.
- **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 toesetc.

- **Mode of transmission:** From soil or by using towels, cloths, comb etc. Heat and moisture help fungito grow.

• **Symptoms:** Dry, scaly lesions on skin, nails, scalp etc. Intenseitching.

PREVENTION AND CONTROL OF DISEASES

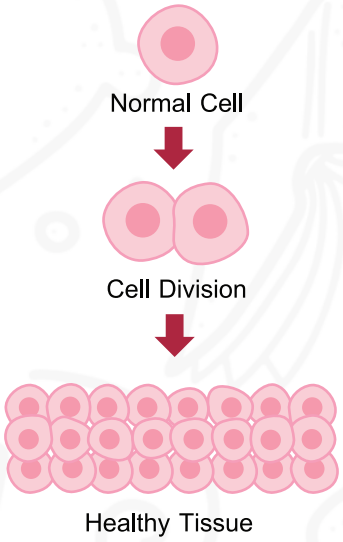
PERSONAL HYGIENE

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

PUBLIC HYGIENE

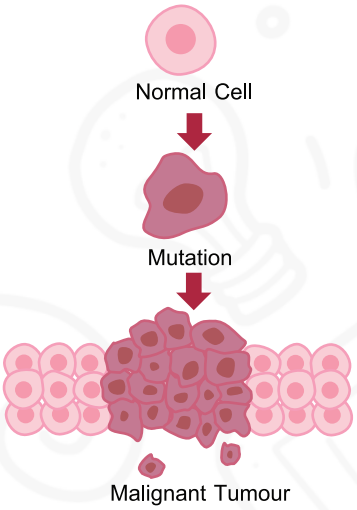
a) Proper disposal of wastes andexcreta.
b) Periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks.
c) Avoid contact with infected persons or theirbelongings (to control air-bornediseases).
d) Standard practices of hygiene in public catering.
e) Control and eliminate the vectors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

These precautions can avoid vector borne diseases like Malaria, Filariasis, Dengue & Chikungunya



IMMUNE SYSTEM

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



1. LYMPHOID ORGANS

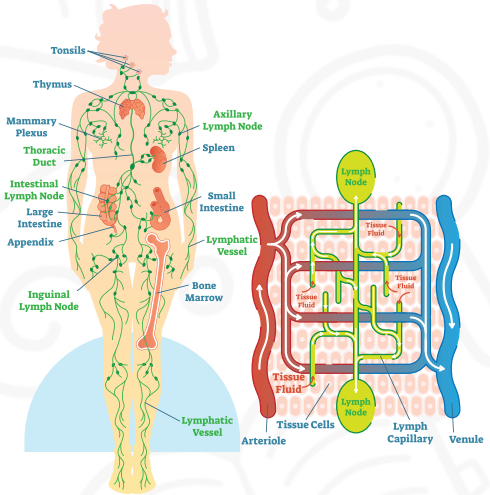
These are the organs where origin, maturation & proliferation of lymphocytes occur. 2 types: Primary & Secondary.

A) PRIMARY LYMPHOID ORGANS

- Here, immature lymphocytes differentiate into antigen sensitive lymphocytes. E.g. Bone marrow &thymus.
- Bone marrow is the site of formation of blood cells.
- Thymus is large during birth but gradually reduces in size and becomes very small size inpuberty.

B) SECONDARY LYMPHOID ORGANS

- The organs, to which matured lymphocytes migrate, interact with antigens and then proliferate to become effector cells. E.g. Spleen, lymph nodes, tonsils, Peyer's patches, Mucosal 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.



2. 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:

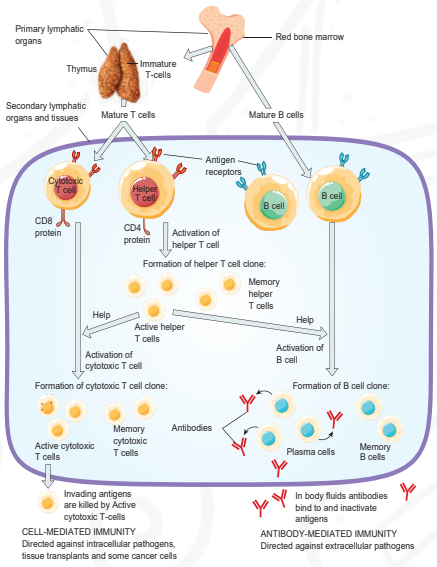
a.) Physical barriers: E.g. Skin (Prevent entry of foreign bodies), Mucus coating of the respiratory, gastro-intestinal and urino-genital tracts to trapmicrobes.
b) Physiological barriers: E.g. gastric HCl, saliva, tear etc.
c) Cellular barriers: Phagocytes like WBC [e.g. neutrophils or Polymorphonuclear leukocytes (PMNL), monocytes and natural killer lymphocytes], macrophages etc.

d) Cytokine barriers: Virus infected cells secrete proteins called interferon which protect non-infected cells from further viral infection.

2. Acquiredimmunity

- 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.
b. T-lymphocytes : Help B-cells to produce antibodies.



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

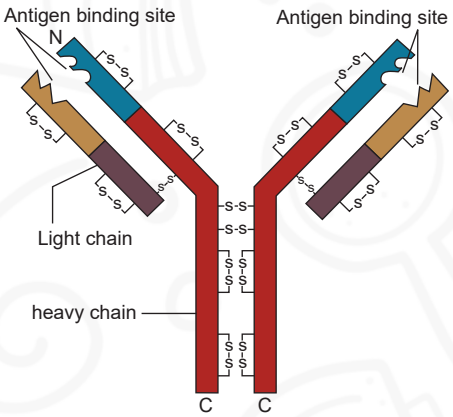
This is based on 'memory' of the immune system. 2 types:

1. Active Immunization (Vaccinati on)

- 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 vaccineetc.
- Vaccines are produced using DNA recombinant technology (E.g. Hepatitis B vaccine produced fromYeast).

2. Passive Immunization

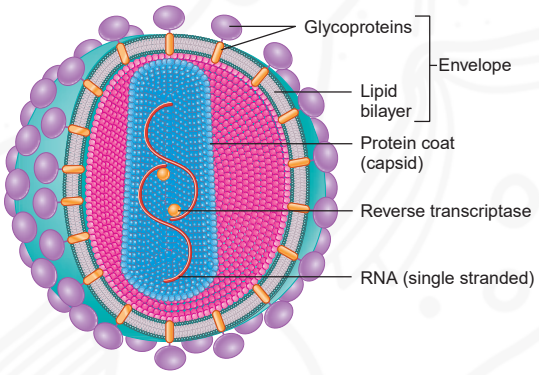
- It is the direct injection of pre-formed antibodies or antitoxin. It requires for quick immune response.
- E.g. Immunization against Tetanus, snake venom etc



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 of IgEtype.
- Allergy is due to the release of chemicals like histamine and serotonin from the mast cells.

- **Symptoms:** Sneezing, watery eyes, running nose, difficulty in breathing, 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 results lowering of immunity and more sensitivity toallergens.



AUTOIMMUNITY

- It is the condition in which the body attacks self-cells due to genetic and other unknownreasons.
- It leads to auto-immune disease. E.g. Rheumatoid arthritis

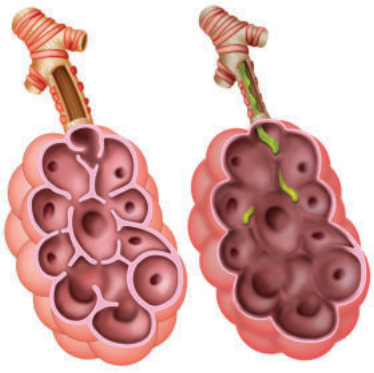
AIDS (ACQUIRED IMMUNO DEFICIENCY SYNDROME)

- It is the deficiency of immunesystem.
- It is caused by HIV (Human Immunodeficiency Virus), a retrovirus having RNA genome.
- AIDS was first reported in America (1981).
- Transmission:
  - Sexual contact with infected person.
  - Transfusion of contaminated blood & blood products.
  - Sharing of infected needles.
  - From infected mother to her child throughplacenta.
- High risk people of getting HIV:
  - Individuals with multiple sexual partners.
  - Drug addicts who take drugsintravenously.
  - 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

LIFE CYCLE:
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 producevirus particles – HIV enters into helper T-cells (TH) – Replicates & produce progeny viruses – Attack other helper T-cells – T-cells decrease – Weaken immunity.

- HIV infected person may be infected with Mycobacterium, viruses, fungi and parasites likeToxoplasma.
- Diagnosis: ELISA test (Enzyme-linked immuno-sorbent Assay).
- Treatment: Anti-viral drugs partially effective. They can only prolong the life of the patient.

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

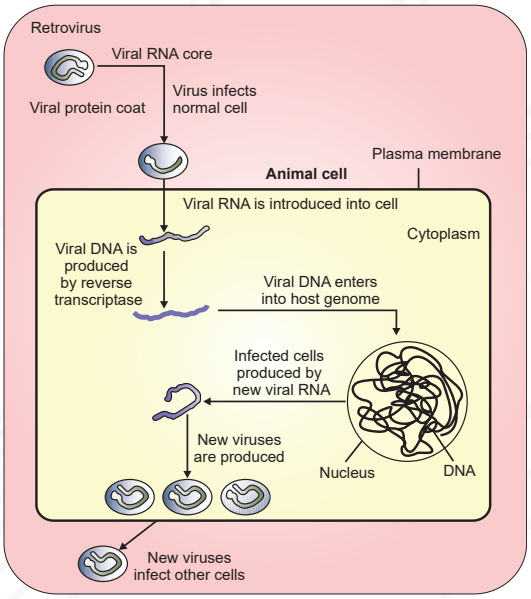


CANCER

- 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 normalcells 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 cellcounts.
- Radiography (use of X-rays), CT (Computerized tomo graphy) scan & MRI (Magnetic Resonance Imaging).
- 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

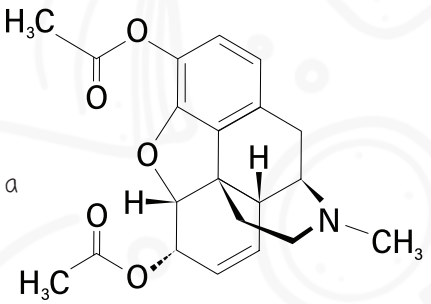
- Radiotherapy: Tumour cells are irradiated lethally, without damaging surrounding normal tissues.
- Chemotherapy: Use of chemotherapeutic drugs. Many drugs have side effects like hair loss, anaemia etc.
- Immunotherapy: The patients are given biological response modifiers (e.g. α- interferon) which 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 (OPIOIDS, CANNABINOIDS & COCAALKALOIDS)

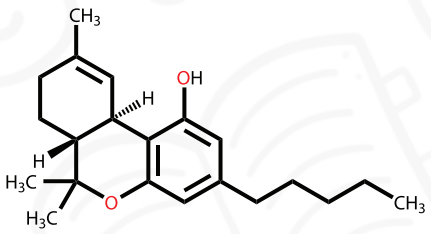
OPIOIDS:

- They bind to specific opioid receptors in CNS and gastrointestinal tract. E.g. morphine, heroin, brown sugar.
- Morphine is extracted from the latex of poppy plant, Papaver som niferum. It is a sedative and painkiller, and useful for 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



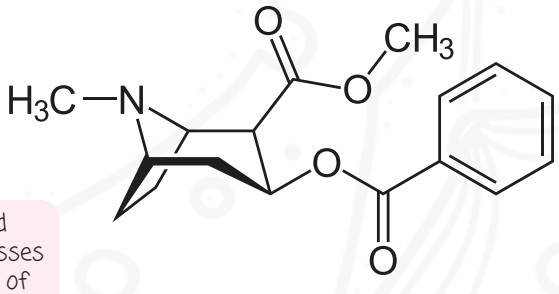
CANNABINOIDS:

- They interact with cannabinoid receptors in thebrain.
- 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 cardiovascularsystem.
- Cannabinoids are abused by some sports persons.



COCA ALKALOID OR COCAINE (COKE OR CRACK):

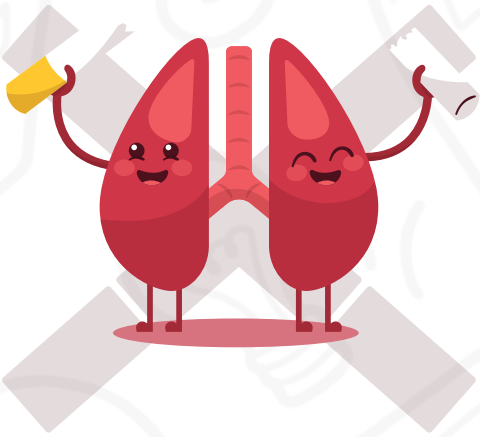
- It is obtained from coca plant Erythroxylumcoca.
- It interferes with transport of neurotransmitter dopamine.
- Cocaine is usually snorted.
- It stimulates CNS producing euphoria & increased energy.
- Excessive dosage of cocaine causeshallucinations.
- Atropa belladona & Datura are also hallucinogenic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



Drugs like barbiturates, amphetamines, benzodiazepines, lysergic acid diethylamides (LSD), etc. are used as medicines to treat mental illnesses like depression and insomnia. But their abuse results in impairment of physical, physiological or psychological functions

SMOKING

- Tobacco issmoked, chewed or used as asnuff.
- Tobacco contains 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, gastriculcer etc. Tobacco chewing causes oral cancer.
- Smoking increases CO content in blood and reduces oxyhaemoglobin. This causes O2 deficiency in the body



ADOLESCENCE

- 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 andExperimentation.
- Need for adventure and excitement.
- To escape facingproblems.
- Stress from pressure to excelin 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.

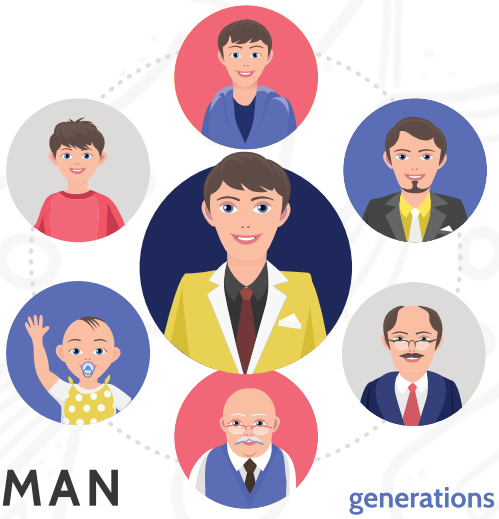
EFFECTS OF DRUG/ALCOHOL ABUSE

- Reckless behaviour, vandalism and violence.
- Coma and death due to respiratory failure, heart failure or cerebral haemorrhage.
- Drugs in combination with alcohol may lead to 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 personalhygiene.
- Withdrawal andisolation.
- 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.
- Increased aggressiveness.
- Decreased sperm.
- Breast enlargement.
- Enlargement of prostate gland
- Mood swings & depression
- Reduced testicles.
- Kidney & liverdysfunction.
- Premature baldness

IN FEMALES:

- Mood swings & depression
- Excessive hair growth
- Deepening ofvoice
- Masculinisation
- Increased aggressiveness
- Abnormal menstrualcycle
- Enlargement ofclitoris

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 dangersigns.
5. Seeking professional and medicalhelp.
   a. Psychologists and psychiatrists.
   b. De-addiction and rehabilitation programs.

CHAPTER

09

STRATEGIES FOR ENHANCEMENT IN FOOD

ANIMAL HUSBANDRY

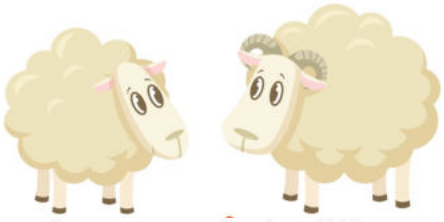
- It is the scientific agricultural practice of breeding and raising livestock.
- It deals with the care & breeding of livestock (buffaloes, cows, pigs, horses, cattle, sheep, camels, goats etc.) poultry farming and fisheries.
- More than **70%** of the world livestock population is in India & China.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

- This is 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 productivity in milk production, growth rate in beef cattle, etc.
- It helps to overcome inbreeding depression.

ii) CROSS-BREEDING:

- In this method, superior males of one breed are mated with superior females of another breed.
- 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 Marino 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 animals 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, with FSH-like activity, to induce follicular maturation and 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 stages are recovered 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 for the production of 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 any area where there are sufficient 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 of 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 and pisciculture 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 resistant.
- 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 that breeders have tried to incorporate:
  - Increased crop yield.
  - Improved quality.
  - Increased tolerance to environmental stresses (salinity, extreme temperatures & drought), resistance to pathogens.
  - Increased tolerance to insect pests.

STEPS OF BREEDING

(i) COLLECTION OF GENETIC VARIABILITY

- In many crops pre-existing genetic variability is availab le from wild relatives of the crop.
- 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

- It is the process in which 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 of the 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 the research fields and recording their performance under idealfertiliser 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 our country, food production has increased by the development of high yielding varieties of wheat and rice in the mid-1960s **(Green Revolution)**.
- During the period 1960-2000, wheat production increased from 11 million tons to 75 million tons. The rice production went up from 35 million tons to 89.5 million tons.

- Nobel laureate Norman E. Borlaug (International Centre for Wheat & 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.

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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 wellin 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

- It enhances 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:

Include conventional breeding techniques & mutation breeding.

1. CONVENTIONAL METHOD:

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 Snow ball K-1	Black rot and curl Blight black rot
Cow pea	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.

2. MUTATION BREEDING:

Mutation (sudden genetic change) can create new desirable characters not found in the parental type.
Plants having these desirable characters can be multiplied directly or can be used in breeding.
Mutation breeding is the breeding by mutation using chemicals or radiations (like gamma rays), and selecting and using the plants that have desirable character 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 are introduced into the high-yielding cultivated varieties. E.g. Resistance to yellow mosaic virus in *bhindi (Abelmoschus esculentus)* was transferred from a wild species and resulted in a new variety called *Parbhani kranti.*

- Transfer of resistance genes is achieved by sexual hybridisation between the target and the source plant.

PLANT BREEDING FOR DEVELOPING RESISTANCE TO INSECT PESTS

- Insect resistance in host crop plants may be due to morphological, biochemical or physiological characteristics.
  - 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.
  - Vegetable crops rich in vitamins & minerals: released by Indian Agricultural Research Institute, New Delhi.
    E.g. vitamin A enriched carrots, spinach, pumpkin; vitamin C enriched bitter gourd, *bathua*, mustard, tomato; iron & calcium enriched spinach & *bathua*; and protein enriched beans (broad, lablab, French & garden peas).

III. SINGLE CELL PROTEIN (SCP)

- It is an alternate source of proteins for animal and human nutrition. E.g. microbes like *Spirulina*.
  Spirulina is rich in protein, minerals, fats, carbohydrate & 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 200 g of protein/day. In the same period, 250g of a micro-organism like *Methylophilus methylotrophus* produce 25 tonnes of protein.

IV. TISSUE CULTURE

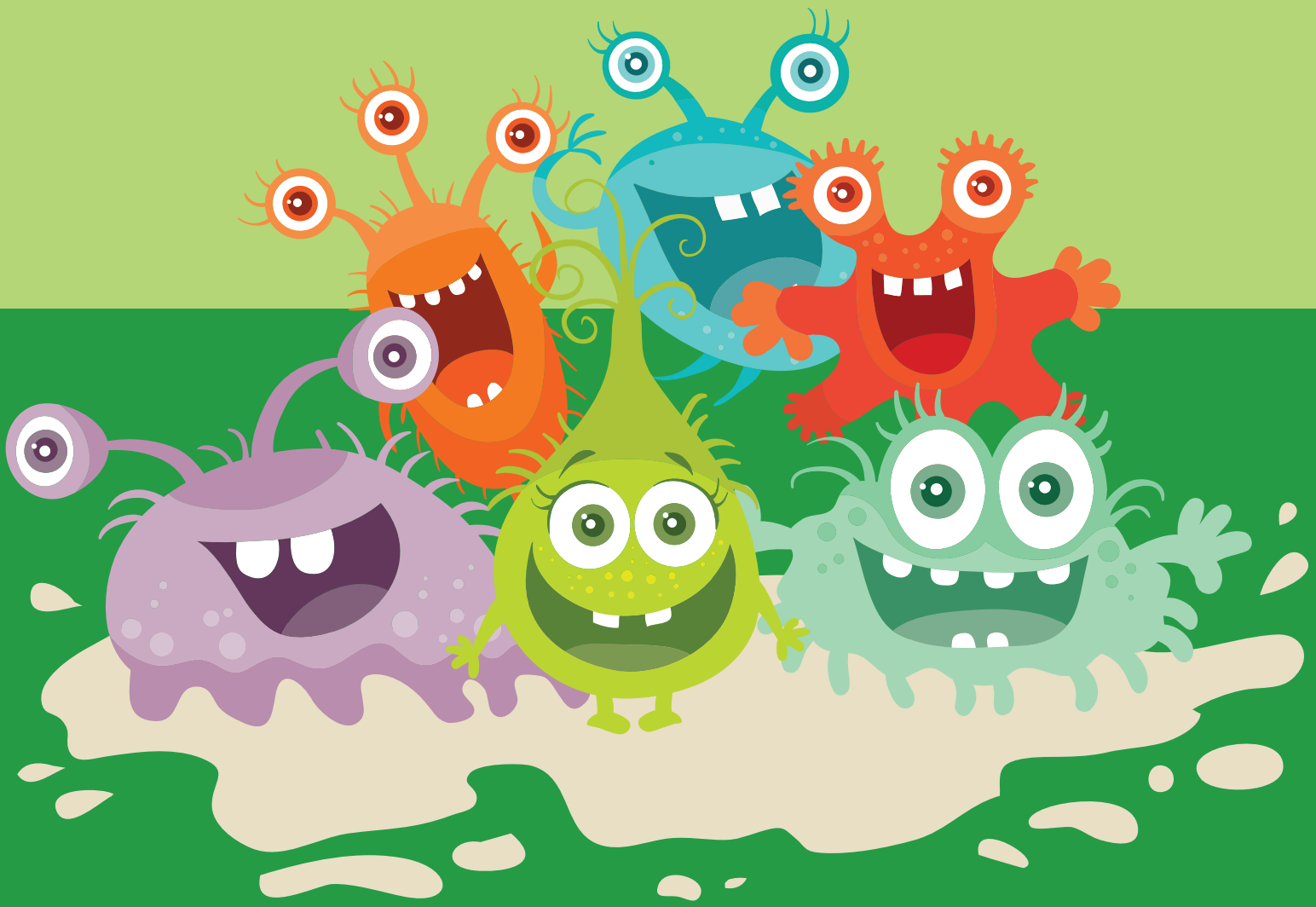
- A technique of growing plant cells/tissues/organs in sterile culture medium under controlled aseptic conditions.
- The ability to generate a whole plant from any cell/explant is called totipotency. An explant is any part of a plant that is grown in a test tube under sterile nutrient media.
- The nutrient 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 using this method.

- Tissue culture is also used for recovering healthy plants from diseased plants. The meristem (it will be free of virus) from infected plant is removed and grown it *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 single cells of plants.
  A protoplast of tomato has been fused with that of potato, to form new hybrid plants with the characteristics of tomato and potato. But it has no all desired characteristics for its commercial utilization.

CHAPTER

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:

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 B12 in curd.
- In stomach, LAB helps to checkpathogens.

• 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.

BAK ER'S YEAST (SACCHAROMYCES CEREVISIAE): It is used to make bread by fermenting dough.
• Toddy is made by fermenting sap frompalms.
• 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 on them.

MICROBES IN INDUSTRIAL PRODUCTS

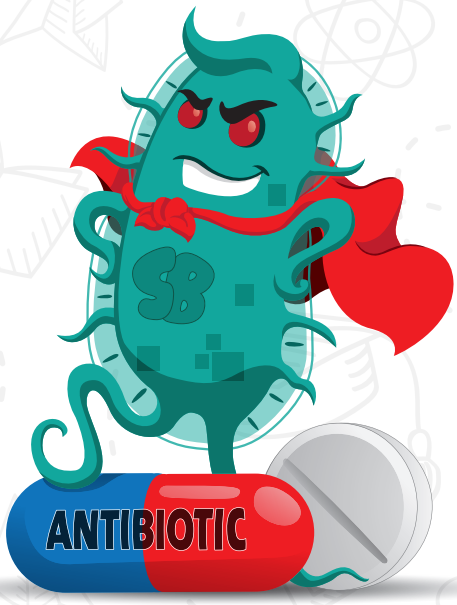
Production of beverages, antibiotics etc. on an industrial scale, requires growing microbes in very large vessels(fermentors).

FERMENTED BEVERAGES

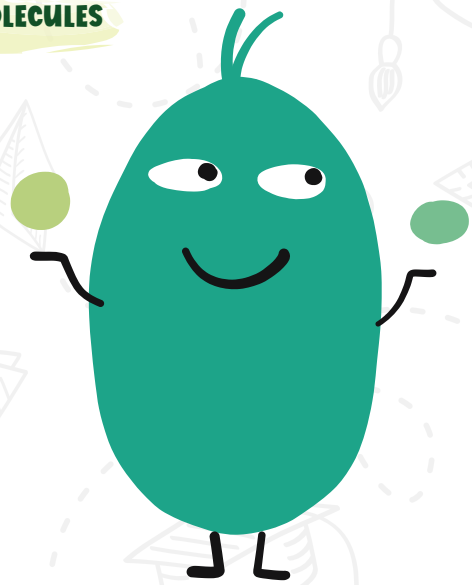
- Saccharomyces cerevisiae (Brewer's yeast) is used in the production of beverages by fermenting malted cereals and fruit juices to produce ethanol.
- Wine & Beer are produced without distillation.
- Whisky, Brandy, Rum, Gin, Arrack etc. are produced by distillation of fermented broth.

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 fromit.
- 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.
- Streptok inase: Produced by Streptococcus. Used as 'clot buster' to remove clots from the blood vessels of patients who have myocardialinfarction.

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.

Sewage (municipal waste-water) contains large amount of organic matter andmicrobes. 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 O2 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 moreis 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 CH4, H2S and CO2. These gases form the biogas. The effluent is released into natural water bodies like rivers and streams.
The Ministry of Environment & Forests has initiated Gang a Action Plan & Yamuna Action Plan to save from water pollution.

MICROBES AS BIOCONTROL AGENTS

- Biocontrol is the use of biological methods for controlling plant diseases and pests.
- Chemical pesticides and insecticides kill both useful and harmful organisms and cause pollution.

MICROBIAL BIOCONTROLAGENTS

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 isreleased 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 severalplant pathogens.

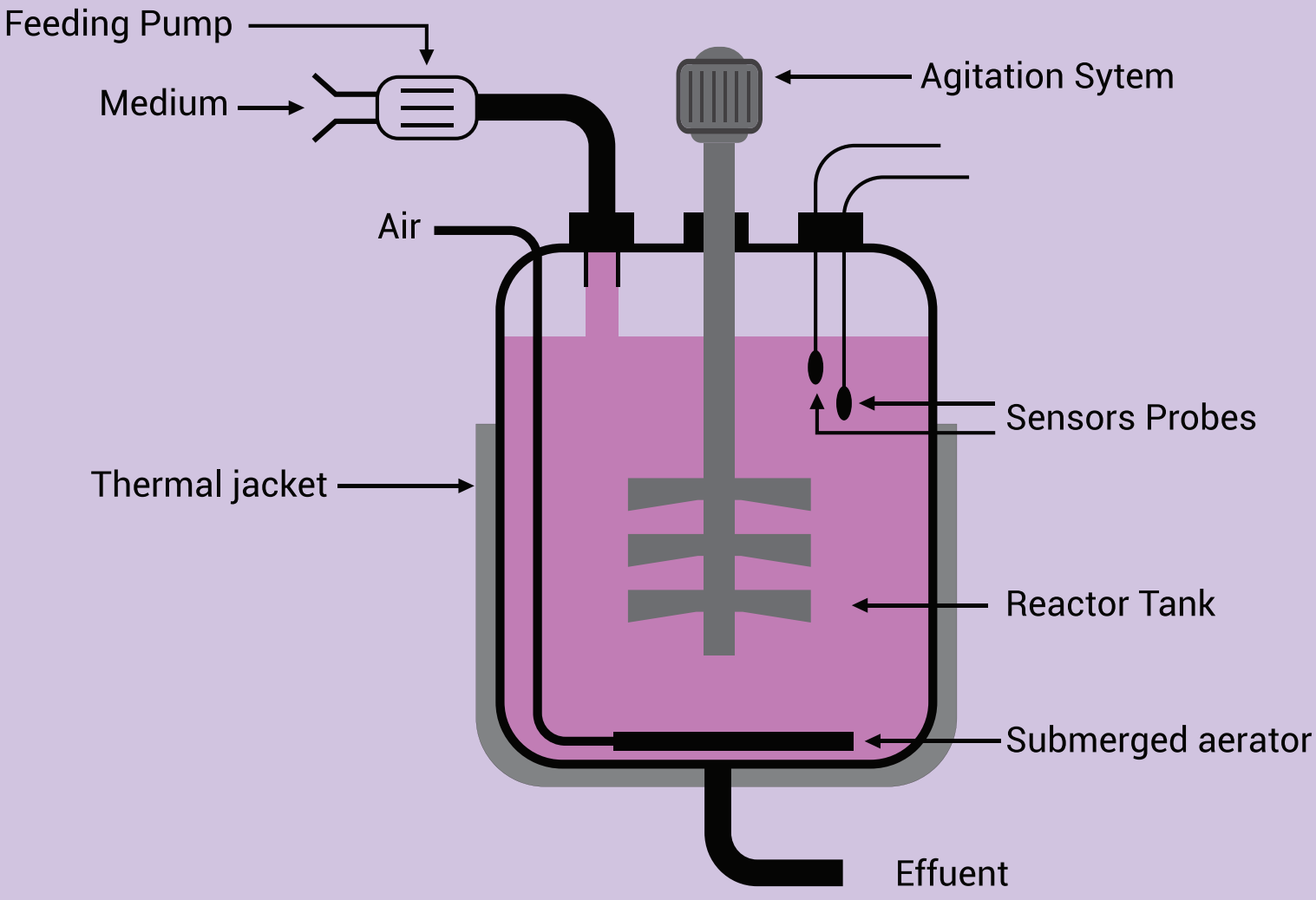
Baculoviruses (Especially genus Nucleopolyhedro-virus): Attacks insects and other arthropods. These are suitable for species-specif ic, narrow spectrum insecticidal applications. This is desirable in IPM (Integrated Pest Management) program to conserve beneficialinsects.

MICROBES AS BIOFERTILISERS

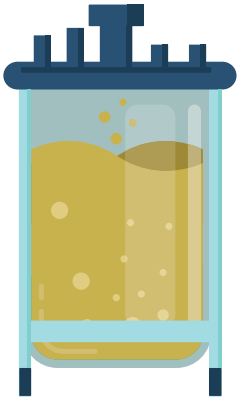
- Biofertilisers are organisms that enrich nutrient quality of the soil. E.g. Bacteria, fungi, cyanobacteria etc.
- Rhizobium (symbiotic bacteria in root nodules of leguminous plants) fix atmospheric N2.
- Free-living bacteria in the soil (E.g. Azospirillum and Azotobacter) enrich the nitrogen content 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:
  - o Absorb phosphorous from soil and passes it to the plant.
  - o Give resistance to root-borne pathogens and tolerance to salinity and draught.
  - o Give overall increase in plant growth anddevelopment.
- 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.

CHAPTER 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

1. 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.
- Maintenance of sterile ambience: It is necessary is chemical engineering processes for growing desired microbe/ eukaryotic cell for the manufacture of antibiotics, vaccines, enzymes etc.

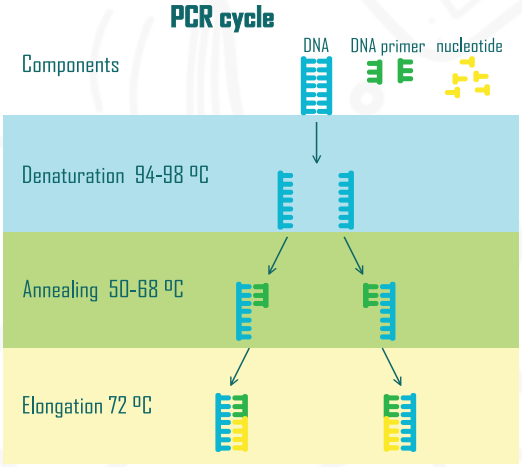
2. BASIC STEPS IN GENETICALLY MODIFYING AN ORGANISM

a) Identification of DNA with desirable genes: Traditional hybridisation techniques lead to inclusion and multiplication of undesirable genes along with desired genes. Genetic engineering helps to isolate and introduce only desirable genes into the target organism.

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.

First recombinant DNA (rDNA) was produced by Stanley Cohen & Herbert Boyer (1972). They isolated an antibiotic resistance gene by cutting out a DNA piece from a plasmid. This gene was linked with a native plasmid of Salmonella typhimurium



TOOLS OF RECOMBINANT DNA TECHNOLOGY

1. RESTRICTION ENZYMES ('MOLECULAR SCISSORS')

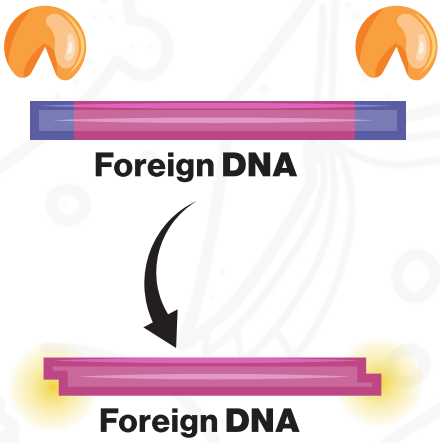
- These are the enzymes which cut DNAat specific sites into fragments.
- They belong to a class of enzymes called nucleases.
- In 1963, two enzymes responsible for restricting growth of bacteriophage in E. coli were isolated. One enzyme added methyl groups to DNA. The other (restriction endonuclease) 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 and the second two letters indicate species of the prokaryotic cell from which they were isolated.
  E.g. EcoRI comes from E. coli RY 13 (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 theDNA.
- They bind to specific recognition sequence of the DNA and cut the two strands at specificpoints.
- 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



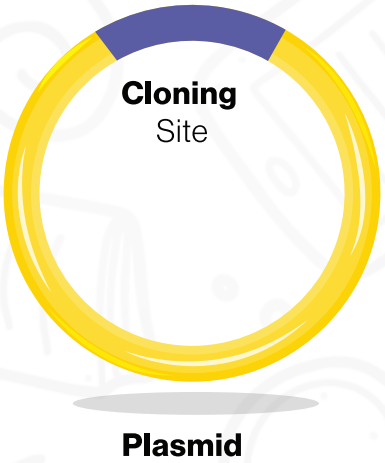
- Restriction endonuclease recognizes a specific palindromic nucleotide sequences in the DNA. It is a sequence of base pairs that read the same on the two strands in 5' – 3' direction and in 3' – 5' direction. E.g.
  5' –– GAATTC –– 3'
  3' –– CTTAAG –– 5
- Restriction enzymes cut the strand a little away from the centre of the palindrome sites, but between the same two bases on the opposite strands. This leaves single stranded overhanging stretches at the ends. They are called sticky ends. They form H-bonds with their complementary cut counterparts. This stickiness facilitates action of the enzyme DNA ligase.
- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of sticky-ends and these are joined together by DNA ligases.

SEPARATION AND ISOLATION OF DNA FRAGMENTS:

- DNA fragments are separated by a technique called gel
- 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. This is called elution. These purified DNA are used to construct recombinant DNA by joining them with cloning vectors.

2. CLONING VECTOR

- It is a DNA molecule that can carry a foreign DNA segment and replicate inside the hostcells. 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 bacterialcells.
- 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)

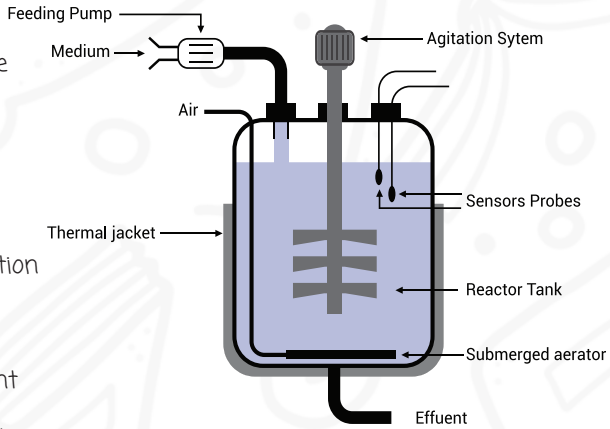
- This is a sequence where replicationstarts.
- A piece of DNA linked to ori can replicate within the host cells. This also controls the copy number of linked DNA. So, for getting many copies of the target DNA, it should be cloned in a vector whose origin support high copy number.

B. SELECTABLE MARKER (MARKER GENE)

- It is a gene that helps to select the transformants and eliminate the non-transformants.
- Transformation is a procedure through which a piece of DNA is introduced in a host bacterium. Such bacterium is called 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

- To link the alien DNA, the vector needs a single or very few recognition sites for restrictionenzymes.
- 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. ligation of foreign DNA at Bam H I site of tetracycline resistance gene in vector pBR322. As a result, recombinant plasmid is formed. If ligation does not occur, it is called non-recombinant plasmid.
- **Restriction sites:** Hind III, EcoR I, BamH I, Sal 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.
- The recombinant plasmids lose tetracycline resistance due to insertion of foreignDNA.
- 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 toampicillin.

- 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 selectrecombinants.
- Selection of recombinants due to inactivation of antibiotics requires simultaneous plating on 2 plates having different antibiotics. Therefore, alternative selectable markers have developed to differentiate recombinants from non recombinants based on their ability to produce colour in the presence of achromogenic substrate.
- In this, a recombinant DNA is inserted within the coding sequence of an enzyme, β -galactosidase. So, the enzyme is inactivated. It is called insertional inactivation. Such colonies do not produce any colour. These are identified as recombinant colonies.
- If the plasmid in bacteria have no an insert, it gives blue coloured colonies in presence of chromogenic substrate.

D. VECTORS FOR CLONING GENES IN PLANTS & ANIMALS

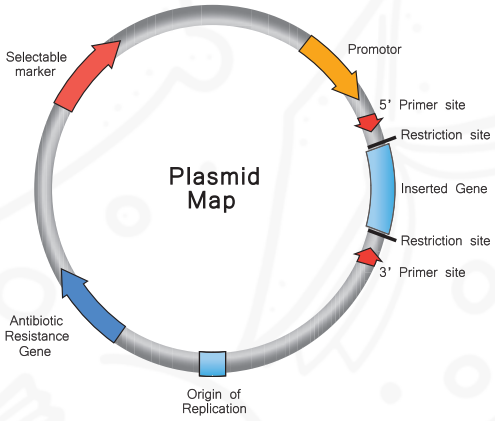
- Genetic tools of some pathogens can be transformed into useful vectors for delivering genes to plants & animals.
  E.g. Agrobacterium tumifaciens (a pathogen of many dicot plants) can deliver a piece of DNA (T-DNA) to transform normal plant cells into a tumor. These tumor cells produce the chemicals required by the pathogen. The tumor inducing (Ti) plasmid of A. tumifaciens is modified into a cloning vector which is not pathogenic to the plants but is able to use the mechanisms to deliver genes of interest into plants.
  Retroviruses in animals can transform normal cells into cancerous cells. So, they are used to deliver desirable genes into animal cells.

3. COMPETENT HOST (FOR TRANSFORMATION WITH RECOMBINANT DNA)

- DNA is a hydrophilic molecule. So, it cannot pass through cell membranes.
- To avoid this problem, bacterial cells are treated with a specific concentration of a divalent cation (e.g. calcium). So, DNA enters the bacterium through pores in cell wall.
- Such cells are incubated with recombinant DNA on ice. Then they are placed briefly at 420C (heat shock) and put them back on ice. This enables the bacteria to 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 issuitable for plants.
- **Disarmed pathogen' vectors :** They infect the cell and transfer the \ recombinant DNA into the host.



PROCESSES OF RECOMBINANT DNA TECHNOLOGY

1. ISOLATION OF THE GENETIC MATERIAL (DNA)

- The bacterial cells/plant or animal tissue are treated with enzymes like lysozyme (bacteria), cellulase (plants), chitinase (fungus) etc. The cell is broken releasing DNA & other macromolecules (RNA, proteins, polysaccharides and 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 at optimal conditions. As a result, DNA digests.
- Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion. DNA is negatively charged. So it moves towards the anode. The DNA fragments separate 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 isrepeated with the vector DNAalso.
- After cutting the source DNA and vector DNA, the cut-out gene of interest from source DNA and cut vector aremixed 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 oligo nucleotides that are complementary to the regions of DNA.
- The enzyme extends the primers using the nucleotides and genomic DNA (template). Through continuous replication , the DNA segment is amplified up to 1 billion copies.
- For amplification, a thermostable DNA polymerase (isolated from a bacterium, Thermus aquaticus) is used. It remains active in high temperature during the denaturation of double stranded DNA.
- The amplified fragment can be used to ligate with a vector for further cloning.

4. INSERTION OF RECOMBINANT DNA INTO HOSTCELL

- Using any methods, the ligated DNA is introduced into recipient cells. 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

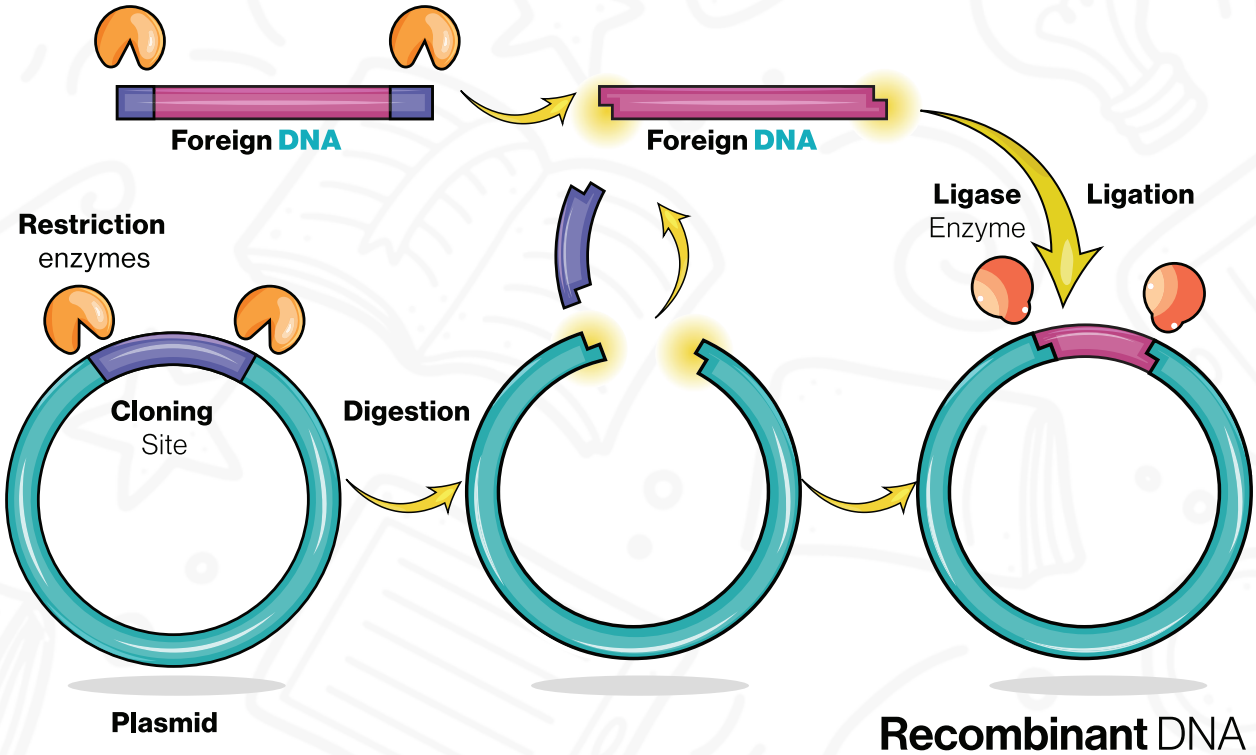
- These are the vessels in which raw materials are biologically converted to specific products, enzymes etc., using microbial plant, animal or human cells.
- Bioreactors are used to produce large quantities of products. They can process 100-1000 litres of culture.
- A bioreactor provides the optimal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



CHAPTER
12

BIOTECHNOLOGY AND IT'S APPLICATION

Biotechnology has a wide range application such as biopharmaceuticals,therapeutics, diagnostics, genetically modified crops for agriculture, 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 pure 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

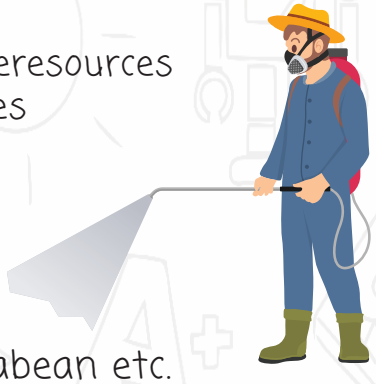
3 options for increasing food production:

a. Agro-chemical based agriculture.
b. Organic agriculture.
c. Genetically engineered crop-based agriculture.

Genetically Modified Organisms (GMO) or transgenic organisms are the plants, bacteria, fungi & animals whose genes are altered bymanipulation

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 helps to reduce post-harvest losses.
It increases efficiency of mineral usage by plants (it prevents early exhaustion of fertility of soil).
It enhances nutritional value of food. E.g. Vitamin enriched rice.
To create tailor-made plants to supply alternativeresources (starches, fuels, pharmaceuticals etc.) to industries

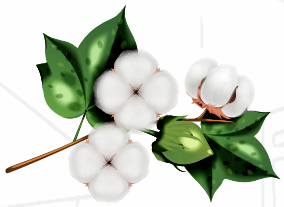


PEST RESISTANTPLANTS

- 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 **(tobaccobudworm, armyworm)** & dipterans **(flies, mosquitoes).**



- B. thuringiensis forms a toxic insecticidal protein **(Bt toxin)** crystal during a particular phase of their growth. It does not kill the Bacillus as it exists as inactive protoxins
- When an insect ingests the toxin, it becomes active due to the alkaline pH of the gut which solubilise the crystals. The toxin binds to the surface of **mid-gut epithelial cells** and creates 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. The toxin is coded by a gene named cry. E.g. proteins encoded by the genes **crylAc & crylIAb** control the cotton bollworms that of crylAb controls corn borer

NEMATODE RESISTANCE IN TOBACCO PLANTS:

- A **nematode Meloidogyne** incognitia 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 RNAintermediate.
- Using Agrobacterium vectors, nematode-specific genes **(DNA)** are introduced into host plant. 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 INMEDICINE

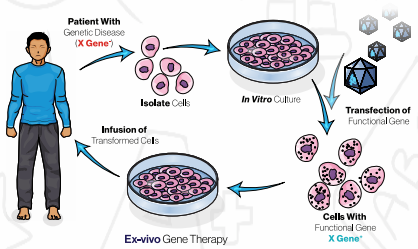
- The recombinant **DNA** technology helps for the mass production of safe and more effective therapeutic drugs.
- The products from non-human sources induce unwanted immunological responses. But recombinant therapeutics does not have such problems.
- At present, about **30** recombinant therapeutics 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 It needs become**(pro-insulin)**.processing to 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 humaninsulin

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.** The disorder is caused due to the deletion of the gene for adenosine deam inase **(an enzyme crucial for the immune system to function).**
- This can be cured by bone marrow transplantation or by enzyme replacement therapy **(injection of functional ADA).** But these approaches are not completely curative.
- In gene therapy, lymphocytes from the patient's blood are grown in a culture. Then, a functional **ADA cDNA (using a retroviral vector)** is introduced into these lymphocytes. Then, they are returned to the patient. This should be periodically repeated as these cells are not immortal. If the **ADA** gene **(from marrow cells)** is introduced into cells at early embryonic stages, it could be a permanent cure.

3. MOLECULAR DIAGNOSIS

- Early diagnosis of diseases using conventional methods **(serum and urine analysis)** are notpossible
- **Recombinant DNA technology, PCR & ELISA** are some techniques for early diagnosis.

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 **AIDS** patients.
- To detect gene mutations in suspected cancer patients.
- To identify many other genetic disorders.

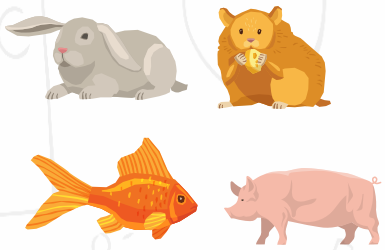
- A single stranded **DNA or RNA,** tagged with a radioactive **molecule (probe)** is hybridized to its complementary **DNA** in a clone of cells followed by detection using autoradiography. The clone having mutated gene will not appear on the photographic film, because the probe will not have complementarity with the mutated gene.

ELISA (ENZYME LINKED IMMUNO-SORBENT ASSAY):

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

TRANSGENIC ANIMALS

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



Benefits of transgenic animals

To study the regulation of genes and their action on normal physiology & development:
E.g. study of complex factors such as insulin-like growth factor. Genes **(from other species)** that alter the formation of this factor are introduced and the biological effects are studied. This gives information about the biological role of the factor in the body.
To Study the contribution of genes in the development of a disease and thereby new treatments: **E.g.** transgenic models for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis & Alzheimer's.
Biological products: Some medicines contain expensive biological products. Transgenic animals are used to produce useful biological products by introducing genes which codes for a particular product.

E.g. human protein **(α-1-antitrypsin)** used to treat emphysema, products for treatment of phenylketonuria **(PKU)** and cystic fibrosis etc.
In 1997, **Rosie (first transgenic cow)** produced human protein-enriched milk **(2.4 gm per litre).** It contains the human a **-lactalbumin** and 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 ofvaccines.
Chemical safety testing (toxicity testing): Transgenic animals are made that 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.

Problems of patent: 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 companygot patent rights on Basmati rice through the US Patent and Trademark Office. This allowed the company to sell a **'new' variety of Basmati.**

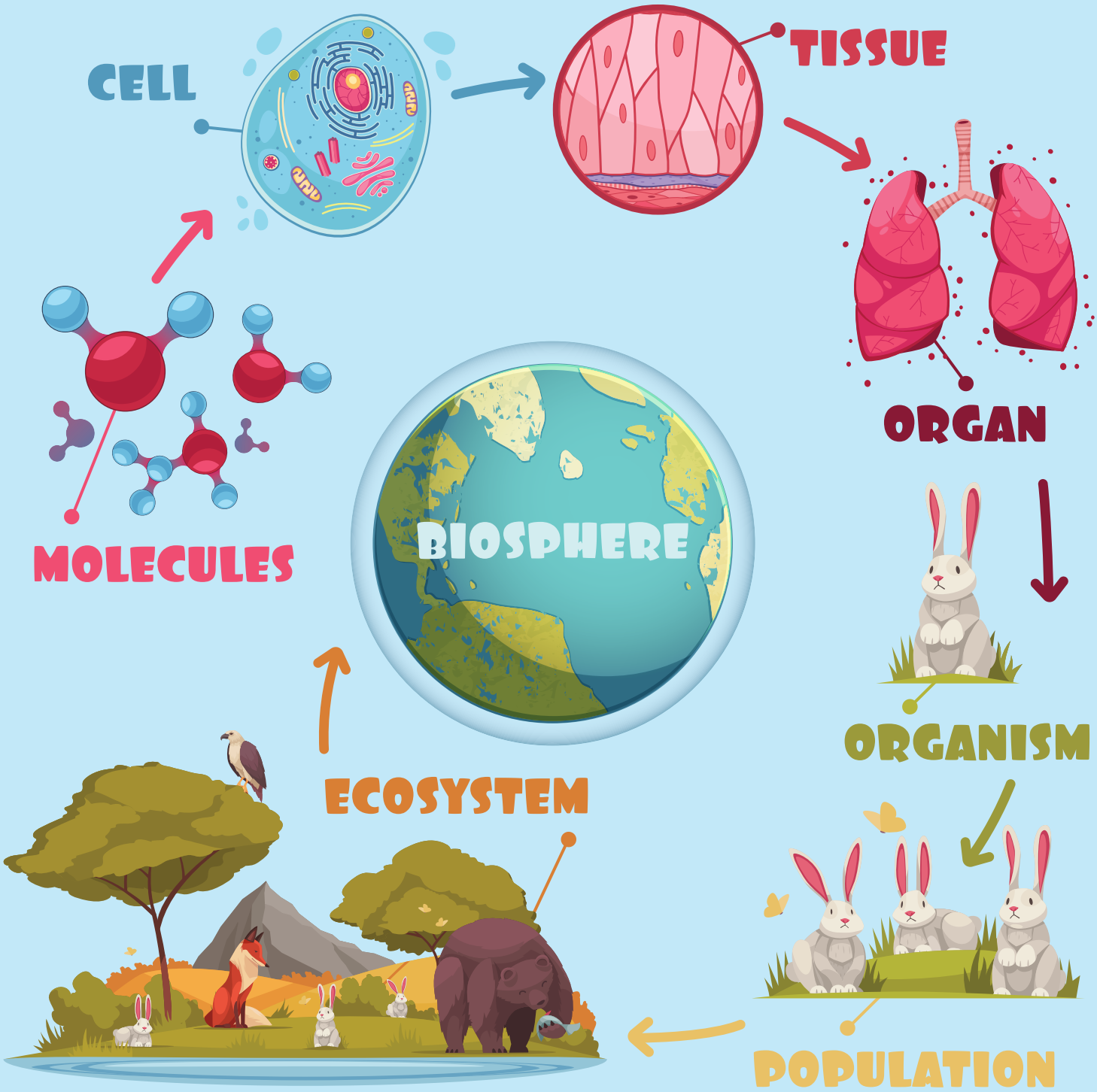
This was actually derived from Indian farmer's varieties. Indian Basmati was crossed with semi-dwarf varieties and claimed as a novelty. Other people selling **Basmati rice** could be restricted by patent.

Biopiracy: It is the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned. Most of the industrialized nations are poor in biodiversity and traditional knowledge. The developing and the underdeveloped world have rich biodiversity and traditional knowledge related to bio-resources.
It has to develop laws to prevent 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.

CHAPTER

13

ORGANISM AND POPULATION



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).

- Regional and local variations within a biome lead to the formation of different habitats.

- Life exists even in extreme and harsh habitats. E.g. Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, torrential streams, Polar Regions, high mountain tops, thermal springs and compost pits. Our intestine is a habitat for manymicrobes.

- The physico-chemical (abiotic) components (water, light, temperature, soil etc.) & biotic components (pathogens, parasites, predators, competitors etc .) lead to variation of different habitats.

ABIOTIC FACTORS

a. Temperature

- The most ecologically relevant environmental factor.

- Temperature on land varies seasonally. It gradually decreases from equator towards the poles and from plains to mountain tops. It ranges from subzero levels (in polar areas & high altitudes) to >500C (in tropical deserts).

- Average temperature in thermal springs & deep-sea hydrothermal vents is above 1000 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.

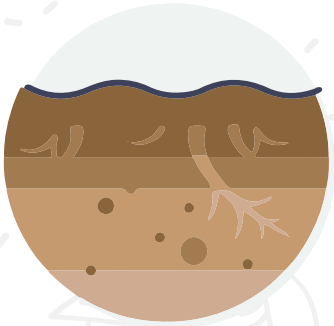
b. Water

- 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% 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, canopiedtrees.
- Many plants depend on sunlight for photoperiodism (e.g. flowering).
- Many animals use the 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 process, 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 constant internal environment (hom eostasis) 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 (370C), sweating occurs. This results in evaporative cooling and brings down body temperature. In winter, when the temperature is below 370C, shivering occurs. It produces heat and raises the body temperature.

b. Conform

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

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 desertplants:

- Presence of thick cuticle on leaf surfaces. Their stomata are arranged in deep pits to minimise water loss through transpiration.
- A special photosynthetic pathway (CAM) that 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 bio-chemical adaptations:

- Archaebacteria are found in hot springs & deep sea hydrothermal vents where temperature is >1000C. Many fish thrive in Antarctic waters (temperature is below00C).
- 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 startsincreasing.
- 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.

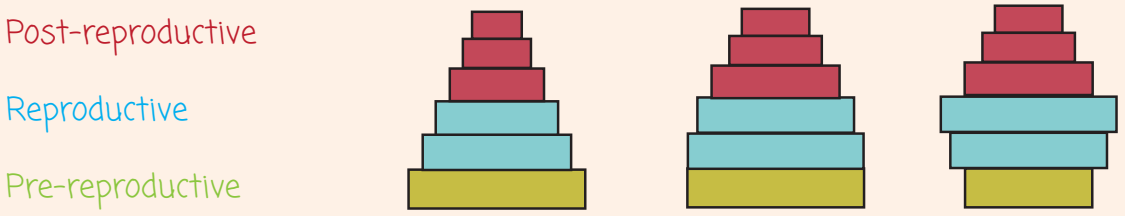
Hence, the current population = 28
The birth rate = 8/20 = 0.4 offspring per lotus per year.

- Death rates: Refer to per capita deaths. E.g. 4 individuals in a laboratory population of 40 fruit lies 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 single 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:

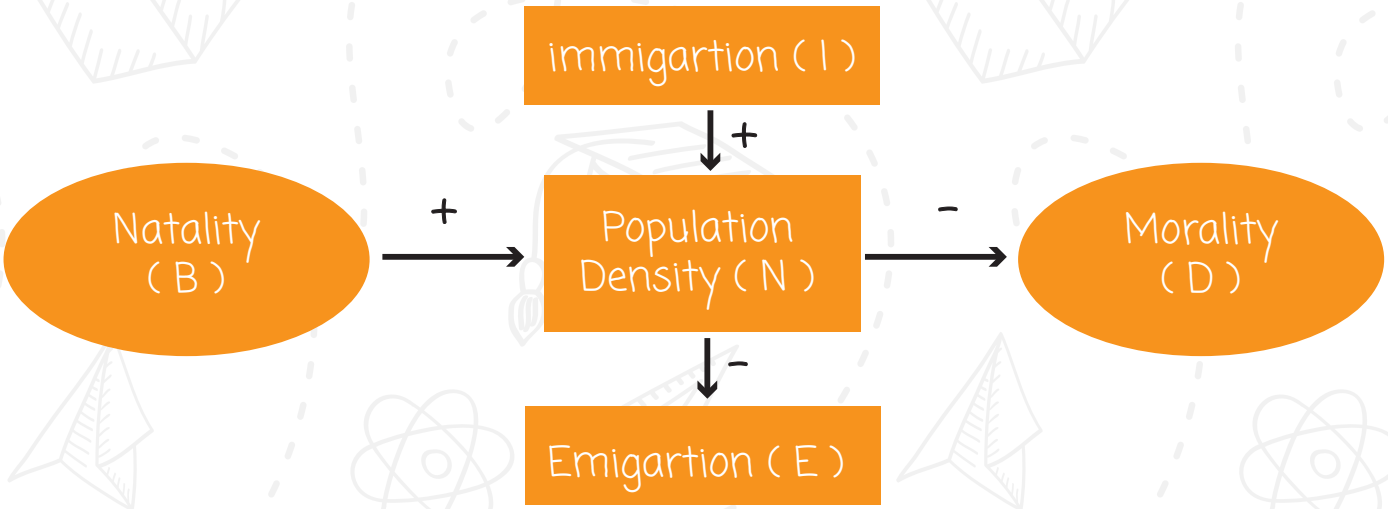
a. Natality (B): It is the number of births in a population during a given period.

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

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

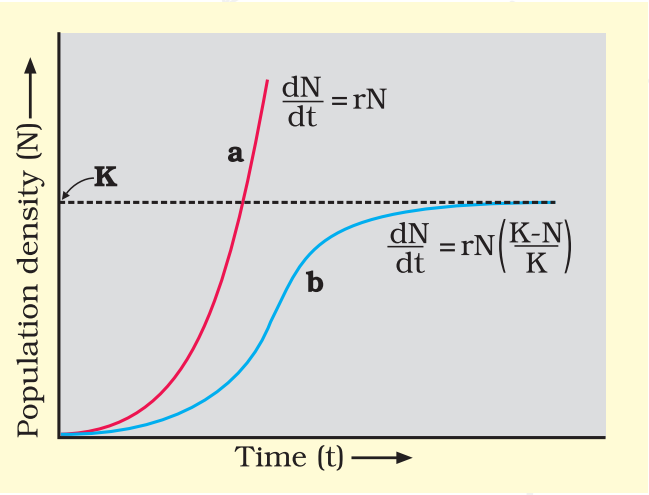
Let (b-d) = r, then

$$dN/dt = rN$$

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)
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 finite the logistic growth model is more realistic one.

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

SPECIES A	SPECIES B	NAME OF INTERACTION
+	+	Mutualism
-	-	Competition
+	-	Predation
+	-	Parasitism
+	0	Commensalism
-	0	Amensalism

- 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 in the invaded land. E.g. the prickly pear cactus introduced into Australia in the early 1920's caused havoc by spreading. Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) was introduced into the country.

- Biological control methods are based on the ability of the predator to regulate prey population. Predators maintain species diversity in a community, by reducing the intensity of competition among competing prey species. E.g. the starfish Pisaster is a predator in the rocky intertidal communities of the American Pacific Coast. In an experiment, when all the starfishes were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year, due to interspecific competition.

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

Gause's 'Competitive Exclusion Principle':

- It states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This may be true in limited resources, but not otherwise.

- Species facing competition may evolve mechanisms that promote co-existence rather than exclusion. E.g. 'resource partitioning'.

- Resource partitioning: If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different for aging patterns. E.g. MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their for aging 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 has to evolve mechanisms to counteract them, in order to be successful 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 morecomplex.

- 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 the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from nest.

- 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 frompredators.

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 and no other species. The female wasp pollinates the fig inflorescence while searching for suitable egg-laying sites in fruits. The fig offers the wasp some developing seeds, as food for the wasp larvae.

2. Orchids show 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.

CHAPTER
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.
- Inanecosystem,bioticandabioticcomponentsinteract 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 bottomlayers.

- 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 such as o Conversion of inorganic into organic material using solar radiant energy by the autotrophs.

o Consumption of the autotrophs by heterotrophs.

o 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

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 (kcalm-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: It is the rate ofproduction of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants in respiration.
- Net primary productivity (NPP): It is the available biomass for the consumption to heterotrophs (herbivores & decomposers).

DECOMPOSITION

- It is the breakdown of complex organic matter by decomposers into inorganic substances like CO2, water and nutrients. It is largely an oxygen-requiringprocess.
- 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

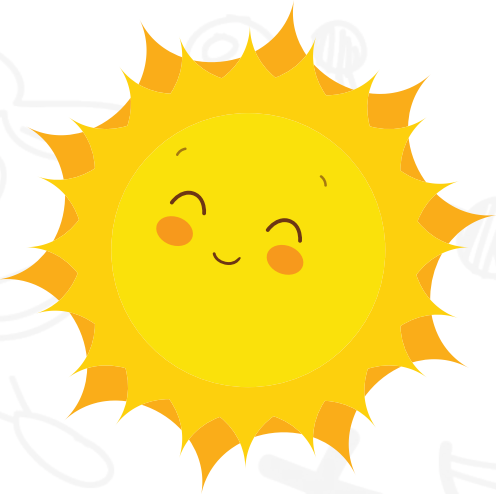
a. Fragmentation: It is the breakdown of detritus into smaller particles by detritivores (e.g. earthworm).
b. Leaching: Water soluble inorganic nutrients go down into soil horizon and precipitate as unavailable salts.
c. Catabolism: Degradation of detritus into simpler inorganic substances by bacterial 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 in nature it serves as a reservoir of nutrients.
e. Mineralization: It is the release of inorganic nutrients due to the degradation of humus by some microbes.

FACTORS INFLUENCING DECOMPOSITION

• Chemical composition of detritus: Decomposition rate is slower in detritus rich in lignin & chitin. It is quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.

• Climatic factors (temperature & soil moisture): Warm and moist environment favour decomposition. Low temperature and anaerobiosis inhibit decomposition resulting in buildup of organicmaterials.

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 & chemosynthetic 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 either 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:

o Primary consumers (herbivores): Feed on plants. E.g. insects, birds, mammals, molluscs etc.

o Secondary consumers (primary carnivores): Feed on herbivores. E.g. frog, fox, man etc.

o 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 etc.) are omnivores. Such interconnections of food chains make a food web.

- A specific place of organisms in the food chain is known as their trophic level.

Ter. Consumer	4th tropic level (top carnivore) E.g. Man, lion etc.
Sec. Consumer	3rd tropic level (Consumer) E.g. Birds, fishes, wolf etc.
Primary Consumer	2nd trophic level (herbivore) E.g. zooplankton, grasshopper, cow etc.
Primary Producer	1st tropic level (plants) E.g. Phytoplankton, grass, tress etc.

- The amount of energy decreases at successive trophic levels. When an organism dies it becomes dead biomass (detritus). It is an energy sourcefor decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy.
- Each trophic level has a certain mass of living material at a particular time called as the standing crop. It is measured as the biomass (mass of living organisms) or the number in a unit area.
- Biomass of a species is expressed in terms of fresh or dry weight. It is more accurate measurement.
- 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

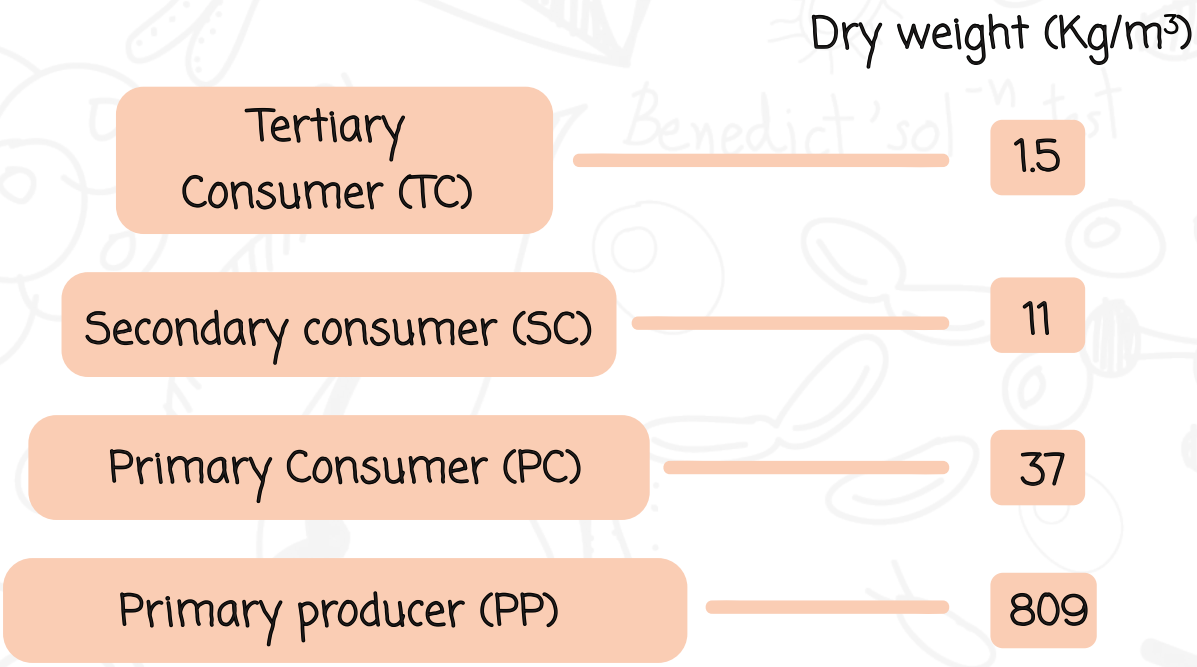
- The representation of a food chain in the form of a pyramid is called ecological pyramid.
- The base of a pyramid represents producers (first trophic level). The apex represents tertiary or top level consumer.
- Ecological pyramids are 3 types: Pyramid of number, Pyramid of biomass and Pyramid of energy.

A) PYRAMID OF NUMBER:

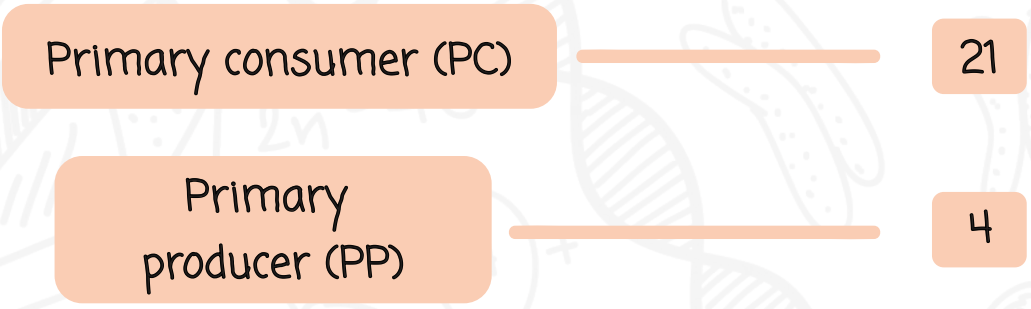
E.g. grassland ecosystem.

B) PYRAMID OF BIOMASS:

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



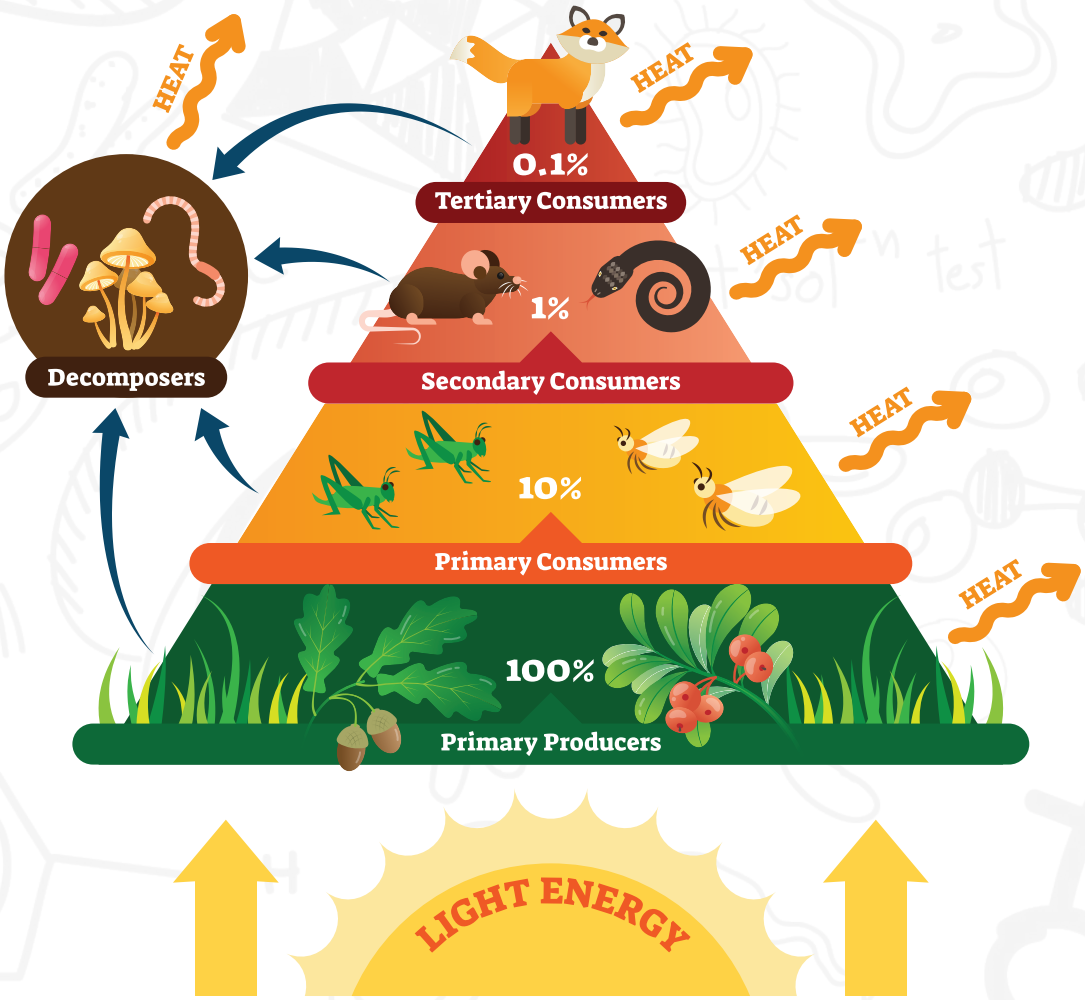
Inverted pyramid of biomass: Small standing crop of phytoplankton supports large standing crop of zooplankton.



C) PYRAMID OF ENERGY:

Primary producers convert only 1% of the energy in the sunlight available to them intoNPP.

ENERGY PYRAMID



- Any calculations of energy content, biomass, or numbers has to include all organisms at that trophic level.
- The trophic level represents a functional level, not a species as such. A given species may occupy more than one trophic level in the same ecosystem at the same time.

E.g. A sparrow is a primary consumer when it eats seeds, fruits, peas. It is a secondary consumer when it eats insects & worms.

- In most ecosystems, all the pyramids are upright, i.e., producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores. Also, energy at a lower trophic level is always more than at a higher level.

- Examples for inverted pyramids:

o Insects feeding on a big tree

o Pyramid of biomass in sea is inverted because the biomass of fishes far exceeds that of phytoplankton.

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

- Limitations of ecological pyramids:

o It does not consider the same species belonging to two or more trophic levels.

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

o Saprophytes are not included in ecological pyramids even though they play a vital role in theecosystem.

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).

- In the successive seral stages there is a change in species diversity, increase in number of species and organisms and an increase in the total biomass.

- The present-day communities are due to succession of millions of years. Succession and evolution would have been parallel processes at that time.

- Succession is 2 types:

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

o 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 condition of the soil, availability of water etc.

- In succession, changes in vegetation affect food & shelterof animals. Thus, as succession proceeds,thenumber and typesof animals & decomposers also change.

- 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 OFPLANTS

- Based on the nature of the habitat, succession of plants is 2 types: hydrarch andxerarch.

o Hydrarch succession: It takes place in wetter areas.The successional series progress from hydric to the mesic conditions.

o Xerarch succession: It takes place in dry areas. The series progress from xeric to mesic conditions.

- Hence, both hydrarch & xerarch successions lead to medium water conditions (mesic, the climaxcommunity).

- The species invading a bare area are called pioneer species.

- 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 - stable climax forest community (mesophytic).

The climax community remains stable as long as the environment remains unchanged.

- PRIMARY SUCCESSION IN WATER:

Phytoplankton (pioneers) - free-floating angiosperms - rooted hydrophytes - sedges, grasses - trees (climax community is a forest). With time, the water body is converted into land.

NUTRIENT CYCLING

- The amount of nutrients like carbon, nitrogen, phosphorus, calcium etc. present in the soil at any given time, is referred to as the standing state. It varies in different kinds of ecosystems and also on a seasonal basis.

biological cycle

Soil fertility

Food nutritional quality

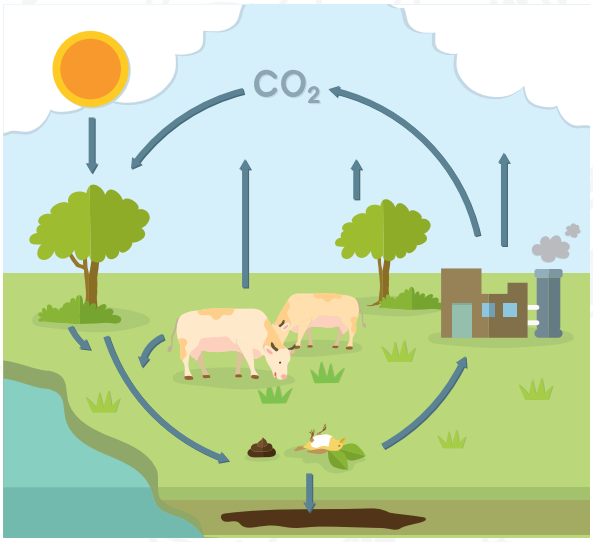
- Nutrients are never lost from the ecosystems. They are recycled again and again. The movement of nutrient elements through various components of an ecosystem is called nutrient cycling (biogeochemicalcycles).

- 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 CO2), fossil fuel etc.
- Carbon cycling occurs through atmosphere, ocean and through living and dead organisms.
- 4 1013 kg of carbon is fixed in the biosphere through photosynthesis annually.
- A major amount of carbon returns to the atmosphere as CO2 through respiration.
- Processing of wastes & dead organic matter by decomposers also release CO2.

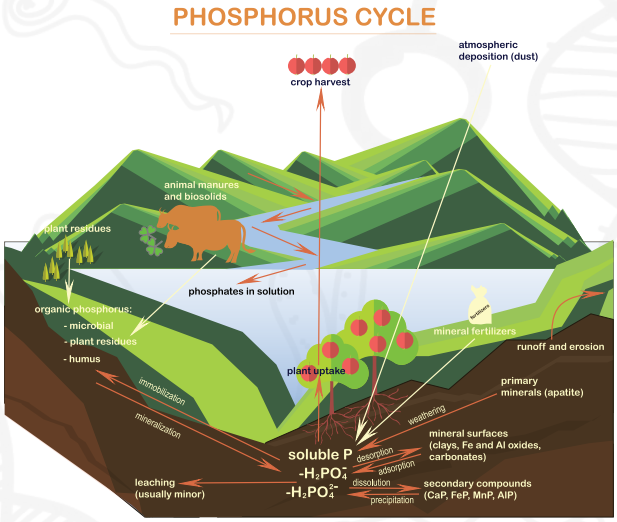
- Some amount of the fixed carbon is lost to sediments and removed from circulation.
- Burning of wood, forest fire and combustion of organic matter, fossil fuel and volcanic activity are other sources for releasing CO2 in the atmosphere.



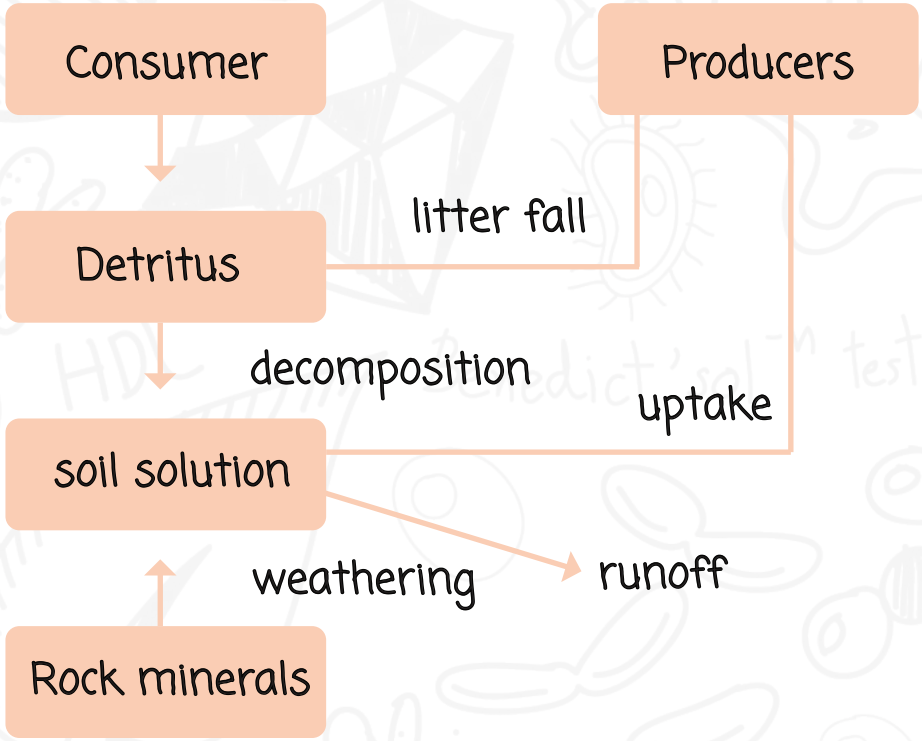
- Role of human activities in carbon cycle: Deforestation, burning of fossil fuel etc. has increased the rate of release of CO2 into the atmosphere.

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 AND 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. healthy 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 Constanza 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, soilformation 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.

CHAPTER

04

BIODIVERSITY AND CONSERVATION

Biodiversity is the diversity of biological organisation ranging from cellular macromolecules to biomes.

Edward Wilson popular ized t he t er m ' biodiver s it y

LEVELS OF BIODIVERSITY

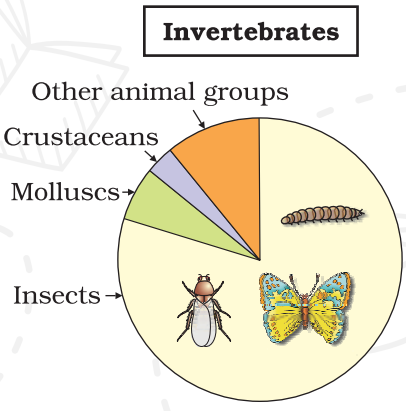
1. **GENETIC DIVERSITY:** Diversity shown by a single species at genetic level. E.g. Rauwolfia vomitoria (Himalaya) shows genetic variation in the potency & concentration of the chemical reserpine. India has more than 50,000 different strains of rice and 1000 varieties of mango.

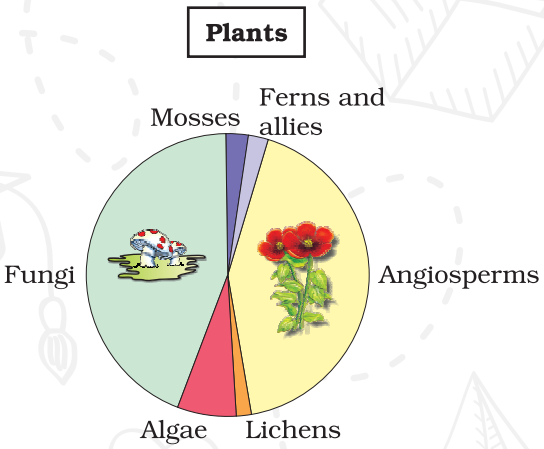
2. **SPECIES DIVERSITY:** Diversity at species level. E.g. Western Ghats have greater amphibian species than Eastern Ghats.

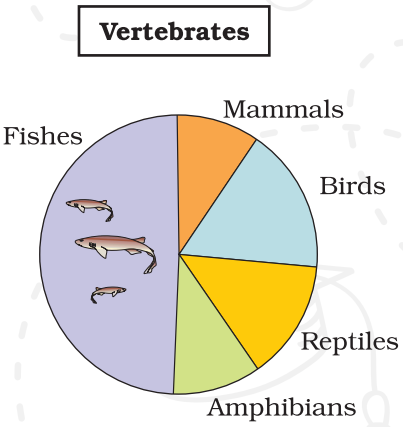
3. **ECOLOGICAL DIVERSITY:** Diversity at ecosystem level. E.g. In India, deserts, rain forests, mangroves, coral reefs, wet lands, estuaries & alpine meadows are seen.

TOTAL NUMBER OF SPECIES ONEARTH (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.







o 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 fromIndia.

o Applying May's global estimates, India would have more than 1 lakh plant species and 3 lakh animal species.

o 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 23.5o N to 23.5o S) have more species than temperate or polar areas.

E.g. Number of bird species in different latitudes:
o Colombia (near equator): about 1400 species.
o India (in tropics): > 1200 species.
o New York (41o N): 105 species.
o Greenland (71o N): 56 species.

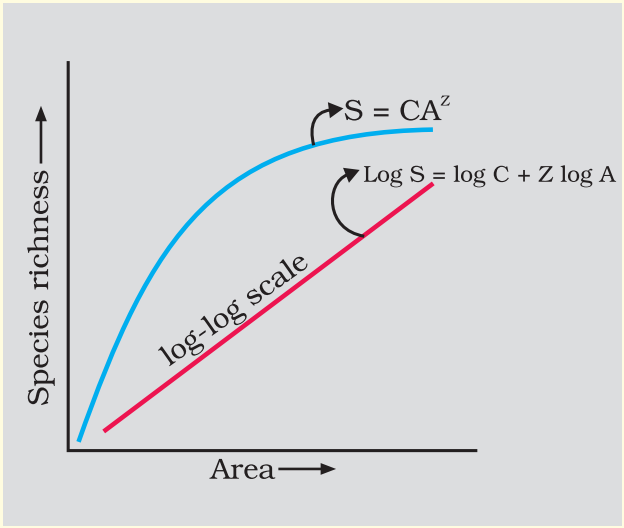
- Tropical forest region like Equador has up to 10 times of vascular plant species as compared to a temperate forest region like the Midwest of USA.

- Tropical Amazonian rain forest (South America) is the greatest biodiversity on earth. It contains :-
o > 40000 species of plants
o 3000 species of fishes
o 1300 species of birds
o 427 species of mammals
o 427 species of amphibians
o 378 species of reptiles
o > 1,25,000 species ofinvertebrates

- Biodiversity (species richness) is highest in tropics because
o Tropics had more evolutionary time.
o Relatively constant environment (less seasonal).
o 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= CAz
Where,
S= Species richness
A= Area
C= Y-intercept
Z= slopeof the line
(regression co- efficient)

- On a logarithmic scale, the relationship is a straight line described the equation Log S = log C + Z logA

- 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 together using 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 to flight safety than loss of a few rivets on the seats or windows inside the plane.

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

o Decline in plant production.

o Environmental perturbations such as drought.

o Increased variability in ecosystem processes such as plant productivity, water use and pest and disease cycles.

CAUSES OF BIODIVERSITY LOSSES ('THE EVIL QUARTET')

1. HABITAT LOSS AND FRAGMENTATION: Most important cause.

- E.g. Tropicalrain forests (lossfrom14% to 6%).

- Thousands hectares ofrain forestsis being lost within hrs.

- 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, Passengerpigeon 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 posing a threat to the indigenous cat fishes 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.
- Co-evolved plant-pollinator mutualism where extinction of one leads to the extinction of the other.

BIODIVERSITY CONSERVATION

There are 3 categories of reasons for conservation.

A. NARROWLY UTILITARIANARGUMENTS
- Human derive economic benefits from nature such as food, firewood, fibre, construction material, industrial products (tannins, lubricants, dyes, resins, perfumes) andmedicines.
- 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. ETHICALARGUMENTS
- 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 (ONSITE)
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): E.g.
• Sacred groves in Khasi & Jaintia Hills in Meghalaya

• Aravalli Hills of Rajasthan

• WesternGhat regions of Karnataka & Maharashtra

• Sarguja, Chanda & Bastar areas (MadhyaPradesh).

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 safariparks, 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.

International Efforts for conservingbiodiversity

- **The Earth Summit (Rio de Jeneiro, 1992) - 3 objectives:**
a. Conservation of biodiversity

b. Sustainable use of biodiversity

c. Sharing of benefits in the utilization of genetic resources.
- The World Summit on Sustainable Development (Johannesburg, South Africa, 2002): 190 countries pledged to reduce the current rate of biodiversity loss.

CHAPTER
09

ENVIRONMENTAL ISSUES

POLLUTION

Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil. Human population explosion increases the demand for food, water, home, electricity, automobiles etc. It leads to pollution. The Government of India has passed **The Environment (Protection) Act, 1986** to control environmental pollution and protect and improve the quality of our environment.

AIR POLLUTION AND ITS CONTROL

1. CAUSES OF AIR POLLUTION

- Particulate & gaseous air pollutants from smokestacks of thermal power plants, smelters etc.
  According to **Central Pollution Control Board (CPCB),** particulate size of less than 2.5µm in diameter (PM 2.5) causes greatest harm to human health.
- Pollutants fromautomobiles.

2. HARMFUL EFFECTS OF AIR POLLUTION

- Particulates cause respiratory problems, irritation, inflammations & damage to lungs and premature deaths.
- Reduction in growth and yield of crops and premature death of plants.

3. CONTROL OF AIR POLLUTION

- Separate/filter out particulate matters before releasing the harmless gases into the atmosphere.
- Use of lead-free petrol or diesel.
- Use of catalytic converters.
- Phasing out of old vehicles.
- Use of low-sulphur petrol and diesel.
- Application of pollution-level norms for vehicles, etc.
- Use of **Compressed Natural Gas (CNG).** It is used in Delhi, in public transport (buses).

ADVANTAGES OF CNG:

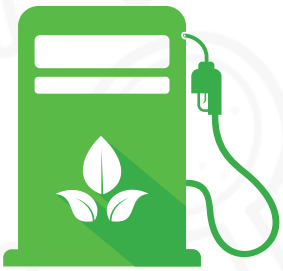
- It is better and cheaper than petrol & diesel. It burns almost completely.
- It cannot be siphoned off by thieves and adulterated.

MAIN PROBLEM OF CNG: Difficulty of laying down pipelines to deliver CNG through distribution points/pumps.

CATALYTIC CONVERTER: It is the device to reduce emission of poisonous gases. It has platinum-palladium & rhodium as catalysts. This converts

- Unburnt hydrocarbons – CO2+ water
- Carbon monoxide – CO2
- Nitric oxide – Nitrogen

Motor vehicles having catalytic converter should use unleaded petrol because lead in petrol inactivates the catalyst.



ELECTROSTATIC PRECIPITATOR: (For figure see TB page: 271)

- It isthe device to remove particulatematter
- It can remove over 99% particulate matter present in the exhaust from a thermal powerplant.
- The electrons released from electrode wires (at several thousand volts) attach to dust particles giving a negative charge. The collecting plates attract charged dust particles.
- The velocity of air between the plates must be low enough to allow the dust to fall.
- A scrubber removes gases like SO2. In this, the exhaust is passed through a spray of water or lime.
- Very small particulates are not removed by this precipitator.

NOISE POLLUTION AND ITS CONTROL

Noise is undesired high level of sound. In India, the **Air (Prevention & Control of Pollution) Act (1981)** was amended in 1987 to include noise as an air pollutant.

1. SOURCES OF NOISE POLLUTION:

- Music instruments, loudspeaker, crackers, industries etc.

2. HARMFUL EFFECTS OF NOISE:

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

3. CONTROL OF NOISE POLLUTION:

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

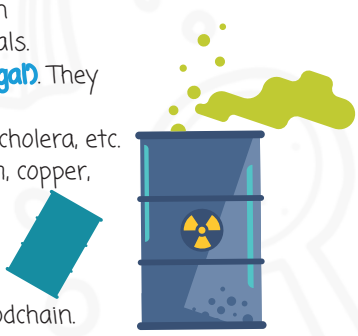
LAWS & POLICIES IN INDIA TO CONTROL VEHICULAR POLLUTION:

- **AUTO FUEL POLICY:** To cut down vehicular pollution in Indian cities.
- **EURO II NORMS:**
- Control sulphur content at 350 ppm (parts per million) in diesel and 150 ppm in petrol.
- Level of aromatic hydrocarbonsis to be at 42% of the fuel.
- In future: Reduce sulphur to 50 ppm in petrol & diesel and bring down the level to35%.
- Upgrade vehicle engines.

WATER POLLUTION AND ITS CONTROL

1. DOMESTIC SEWAGE AND INDUSTRIAL EFFLUENTS

- 0.1 % impurities make domestic sewage unfit for human use. They include
  - **SUSPENDED SOLIDS:** Sand, silt, clay etc.
  - **COLLOIDAL MATERIALS:** Faecalmatter, bacteria, cloth, paper fibres etc
  - **DISSOLVED MATERIALS:** Nutrients like nitrate, NH3, phosphate, Na, Ca etc.
- Removal of dissolved materials, organic compounds and toxic metal ions are most difficult.
- Domestic sewage contains biodegradable organic matter. It is decomposed by microorganisms.
- The amount of biodegradable organic matter in sewage water is estimated by measuring **Biochemical Oxygen Demand (BOD)**.
- During biodegradation, microbes consume O2. It results in a sharp decline in dissolved O2. This causes death of aquatic organisms.
- Presence of more nutrients in water causes excess growth of planktonic algae **(algal bloom).** It imparts a distinct colour to the water bodies and deteriorates the water quality resulting in death of fishes. Some bloom-forming algae are extremely toxic to human beings and animals.
- **Water hyacinth (Eichhornia crassipes)** is the most problematic aquatic weed **(Terror of Bengal)**. They grow abundantly in eutrophic water bodies.
- Sewage from homes & hospitals contain pathogens that cause dysentery, typhoid, jaundice, cholera, etc.
- Industrial waste water contains toxic substances like DDT, heavy metals (mercury, cadmium, copper, lead, etc.) and organic compounds



2. BIOLOGICAL MAGNIFICATION (BIOMAGNIFICATION)

- It is the accumulation of the toxicant (mercury, DDT etc.) at successive trophic levels of a foodchain.
- Organisms cannot metabolize or excrete the toxicant. So, it is passed on to the next trophiclevel.

BIOMAGNIFICATION OF DDT IN AN AQUATIC FOOD CHAIN:

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

3. EUTROPHICATION

- It isthe natural aging of a lake by nutrient enrichment.
- In a young lake, water is cold and clear. With time, streams draining into the lake introduce nutrients (N2, P etc.). It increases lake's fertility.

- Thus plants & animals grow rapidly, and organic remains are deposited on the lake bottom. So, the lake grows shallower and warmer, with warm-water organisms.
- Marsh plants take root in the shallows and fill in the original lake basin. Eventually, the lake becomes land.
- Depending on climate, size of the lake and other factors, the eutrophication may span thousands of years. However, pollutants like effluents from industries and homes accelerate eutrophication. This phenomenon is called **Cultural or Accelerated Eutrophication.**
- The prime contaminants are nitrates & phosphates. They overstimulate the growth of algae. It causes unsightly scum and unpleasant odors, and robs the water of dissolved oxygen. It leads to death of otherorganisms.
- **Heated (thermal) wastewater** from electricity-generating units (e.g. thermal power plants) eliminates organisms sensitive to high temperature. It may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

4. INTEGRATED WASTE WATER TREATMENT

It includes artificial and natural processes. The townspeople of Arcata (northern coast of California) and biologists from the Humboldt State University created an integrated waste water treatment process. The cleaning occurs in 2 stages:

- **SEDIMENTATION, FILTERING & CHLORINE TREATMENTS :** After this, remaining pollutants like dissolved heavy metals were removed using an innovative approach.
- Biologists developed a series of six connected marshes over 60 hectares of marshland. Appropriate plants, algae, fungi & bacteria were seeded into this area. They neutralize, absorb & assimilate pollutants. Thus, as the water flows through marshes, it gets purified naturally.

Friends of the Arcata Marsh (FOAM) is a citizens group for the up keep and safeguarding of this project.

5. ECOLOGICAL SANITATION

- It is a sustainable system for handling human excreta, using dry composting toilets.
- This is a practical, hygienic, efficient and cost-effective solution to human wastedisposal.
- Human excreta can be recycled into a resource (as natural fertilizer). It reduces the need for chemicalfertilizers.
- There are 'EcoSan' toilets in Kerala & Sri Lanka.

Government of India has passed the Water (Prevention & Control of Pollution) Act, 1974 to safeguard water resources.

WASTES AND THEIR EFFECTS

1. SOLID WASTES

- Solid wastes refer to everything that goes out in trash.
- Municipal solid wastes are wastes from homes, offices, stores, schools, hospitals, etc. that are collected and disposed by the municipality.
- All solid wastes cannot be completely burnt. Open dumps serve as the breeding ground for rats and flies.
- Sanitary landfills are the substitute for open-burning dumps. In sanitary landfill, wastes are dumped in a depression or trench and covered with dirt.

2. LIMITATIONS OF LANDFILLS:

- Amount of garbage especially in metros has increased so much that these sites are getting filled too.
- Seepage of chemicals, from the landfills pollutes the underground water resources.

Solid wastes are 3 types:

(a) Bio-degradable: They undergo natural breakdown.

(b) Non-biodegradable: E.g. plastic packets, polybags, polystyrene etc.

Eco-friendly packaging can be used instead of plastics. E.g. Carrying cloth, natural fibre carry-bags etc.

(c) Recyclable: E.g. Plastics, e-wastes etc.

Hospital wastes containdisinfectants, harmfulchemicals, and pathogenic micro-organisms. They are incinerated.

3. E-WASTES (ELECTRONIC WASTES):

- All irreparable electronic goods are known as e-wastes.

- They are buried in landfills or incinerated.
- Recycling isthe only eco-friendly solution for the treatment of e-wastes. But during recycling, the workers are exposed to toxic substances present in e-wastes.
- Over half of the e-wastes in developed world are exported to developing countries (China, India, Pakistan etc.), where many metals (Cu, Fe, Si, Ni & Au) are recovered during recycling process.

4. POLYBLEND: A REMEDY FOR PLASTIC WASTE

- **Ahmed Khan** (A plastic sack manufacturer in Bangalore) developed Polyblend. It is a fine powder of recycled modified plastic. Polyblend is mixed with the bitumen and is used to lay roads.
- Blend of Polyblend and bitumen enhances the bitumen's water repellant properties and helps to increase road life.

5. AGRO-CHEMICALS AND THEIR EFFECTS

- Inorganic fertilisers, pesticides, herbicides, fungicides, etc. are toxic to non-target organisms that are important components of the soil ecosystem. These are biomagnified in the terrestrial ecosystems.
- Chemical fertilisers cause eutrophication.

6. INTEGRATED ORGANIC FARMING

- It is a cyclical, zero-waste procedure, where waste products from one process are cycled in as nutrients for other processes. This allows the maximum utilization of resource and increases the efficiency of production.
- Ramesh Chandra Dagar (a farmer in Sonipat, Haryana) included bee-keeping, dairy management, water harvesting, composting & agriculture in Integrated Organic Farming.

ITS ADVANTAGES ARE GIVEN BELOW:

- They support each other and allow an economical and sustainable venture.
- No need of chemicalfertilizers, as dung is used as manure.
- Crop waste is used to create compost (natural fertilizer) or to generate natural gas (provides energy for the farm).

Dagar has created the Haryana Kisan Welfare Club, with a membership of 5000 farmers to spread information on the practice of integrated organic farming.

7. RADIOACTIVE WASTES

- Use of nuclear energy has two very serious problems:
- Accidental leakage. E.g. Three Mile Island incident & Chernobyl incident.
- Safe disposal of radioactive wastes.
- Nuclear radiation causes mutations. It is lethal at high doses. At lower doses, it causes disorders such as cancer.
- It is recommended to store nuclear wastes in shielded containers buried within rocks, about 500 m deep below the earth's surface. But, the public opposes this method.

GREENHOUSE EFFECT & GLOBAL WARMING

- Greenhouse is a small glass house used for growing plants during winter. The glass panel lets the light in, but does not allow heat to escape. Thus the greenhouse warmsup.
- Greenhouse effect is a natural phenomenon that causes heating of Earth's surface and atmosphere. It maintains the present average temperature (15°C).
- Without greenhouse effect, the average temperature at Earth surface would have been at -18°C.
- Clouds & gases reflect 1/4th of the incoming solar radiation and absorb some of it. But half of it falls on Earth's surface heating it, while a small amount is reflected back. Earth's surface re-emits heat as infrared radiation. But a part of it is absorbed by atmospheric gases (CO2, CH4 etc.) and so cannot escape into space. These gases (greenhouse gases) radiate heat energy. It comes to Earth's surface, heating it up again. It causes the greenhouse effect.
- Overheating of Earth due to increased level of greenhouse gases is called global warming.
- During the past century, the temperature of Earth has increased by 0.6o C, most of it during the last 3 decades.
- Contribution of greenhouse gases to total global warming: CO_2 (60%), CH_4 (20%), CFCs (14%) & N_2O(6%).

1. IMPACTS OF GLOBAL WARMING:

- Climatic changes (e.g. El Nino effect).
- Melting of polar ice caps, Himalayan snow capsetc.
- Future impact: Rise in sea level submerging coastal areas.

2. CONTROL OF GLOBAL WARMING:

- Reduce the use of fossilfuel.
- Improve efficiency of energy usage.
- Reduce deforestation and plant trees.
- Slowing down the growth of human population.

International initiatives are also being taken to reduce the emission of greenhouse gases

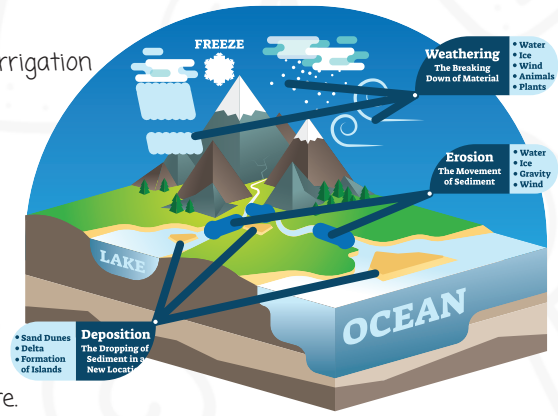
OZONE DEPLETION IN THE STRATOSPHERE

- 'Bad' ozone is formed in troposphere (lower atmosphere). It harms plants and animals.
- 'Good' ozone is found in the stratosphere. It acts as a shield absorbing ultraviolet radiation from the sun.
- UV rays are highly injurious since they cause mutation.
- The thickness of the ozone (O3) in a column of air from the ground to the top of the atmosphere is measured in terms of Dobson units (DU).
- In stratosphere, UV rays act on molecular oxygen (O_2) causing the production of ozone. UV rays also causethe degradation of ozone to O2. These processes arebalanced.
- But this balance is disrupted due to ozone degradation by chlorofluorocarbons (CFCs- used as refrigerant).
- CFCs move upward and reach stratosphere. UV rays act on them releasing Cl atoms. In presence of Cl (catalyst) ,ozone degrades to O_2. This causes ozone depletion. It has formed Ozone hole over the Antarctic region.
- UV radiation of wavelengths shorter than UV-B, are almost completely absorbed by Earth's atmosphere. But, UV-B causes DNA mutation. It causes aging of skin, damage to skin cells and skin cancers. A high dose of UV-B causes inflammation of cornea (snow-blindness), cataract etc. It permanently damages the cornea
- The Montreal Protocol: An international treaty (Canada, 1987) to control emission of ozone depleting substances.

DEGRADATION BY IMPROPER RESOURCE UTILISATION & MAINTENANCE

1. SOIL EROSION AND DESERTIFICATION:

- Human activities like over-cultivation, deforestation, grazing and poor irrigation practices, leads to soil erosion. It results in arid patches of land and desertification.
- Increased urbanization also creates desertification.



2. WATER LOGGING AND SOIL SALINITY:

- These are the problems as a part of Green Revolution.
- Irrigation without proper drainage of water leads to water logging in the soil.
- It draws salt to the surface of the soil. The salt is deposited on the land surface or collects at the plant roots. This damages the agriculture.

DEFORESTATION

- It is the conversion of forested areas to non-forested ones.
- Almost 40% forests have been lost in the tropics, compared to only 1% in the temperate region.
- National Forest Policy (1988) of India hasrecommended 33% forest cover for the plains and 67% for the hills. But we have only 19.4% of forest cover (it was about 30% at the beginning of 20th century).

1. REASONS OF DEFORESTATION:

- Conversion of forest to agricultural land.
- For timber, firewood, cattle ranching etc.

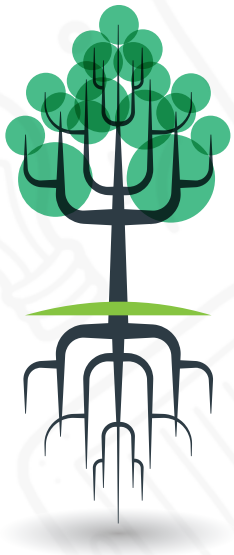
- Slash & burn agriculture (Jhum cultivation) in the north-eastern states of India. In this, the farmers cut down the forest trees and burn the plant remains. The ash is used as a fertiliser and the land is used for farming or grazing. After cultivation, the area is left for several years to allow its recovery. In earlier days, enough time-gap was given for recovery. Overpopulation & repeated cultivation decreased the recovery phase, resulting in deforestation.

2. CONSEQUENCES OF DEFORESTATION:

- Atmospheric CO_2 is enhanced because trees that could hold a lot of carbon in their biomass are lost.
- Loss of biodiversity due to habitat destruction.
- Disturbs hydrologic cycle.
- Soil erosion & Desertification.

Reforestation: The process of restoring a forest that once existed in the past. It may occur naturally in a deforested area. We can speed it up by planting trees.

PEOPLE'S PARTICIPATION IN CONSERVATION OF FORESTS



1. BISHNOI MOVEMENT

- In 1731, the king of Jodhpur in Rajasthan asked to arrange wood for constructing a new palace. The minister and workers went to a forest near a village, inhabited by Bishnois. The Bishnois thwarted them from cutting down the trees. A Bishnoi woman Amrita Devi hugged a tree. The king's men cut down the tree along with Amrita Devi. Her three daughters and hundreds of Bishnois were also lost their lives saving trees.
- Government of India has instituted the Amrita Devi Bishnoi Wildlife Protection Award for individuals or communities from rural areas for extraordinary courage and dedication in protecting wildlife.

2. CHIPKO MOVEMENT OF GARHWAL HIMALAYAS

- In 1974, local women participated to protect trees from the axe of contractors by hugging them. Government of India in 1980s introduced the concept of Joint Forest Management (JFM) to work closely with the local communities for protecting and managing forests. In return for their services, the communities get benefit of forest products (fruits, gum, rubber, medicine, etc.).