- Life span is the period from birth to the natural death of an organism.
- After the death of living organisms also, the population is maintained by the process of reproduction.
- Reproduction is the biological process by which an organism produces its offspring similar to itself.
- The offspring grows, matures and in turn produces new offspring.
- By the process of reproduction, all living organisms maintain their population and ensure the continuity of species.

Fig. Reproduction in plants and animals give rise to similar off springs

- Reproduction is of two types- 1) asexual reproduction 2) sexual reproduction.

- The reproduction in which an offspring is produced by single parent without the fusion of gametes is called asexual reproduction.
- A single parent produces offspring and the off springs are exact copies of their parents.
- The off springs are genetically and morphologically similar and are referred to as **clones**.
- Characteristics of asexual reproduction
- A single parent is involved and so no fusion of gametes.
- Only mitosis takes place.
- Rapid multiplication.

Modes of asexual reproduction

- Binary fission- the parent body divides in to two equal halves and each half grows in to an adult.

Example- Amoeba, Paramecium.

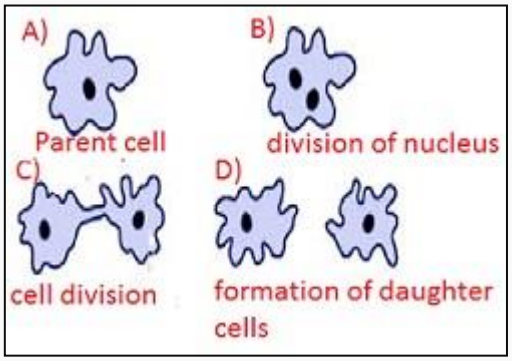


Fig. binary fission in amoeba

- Budding- small bud is produced due to the cell division at one particular site which remains attached initially to the parent cell and eventually gets separated and matures into a new individual.

Example- yeast

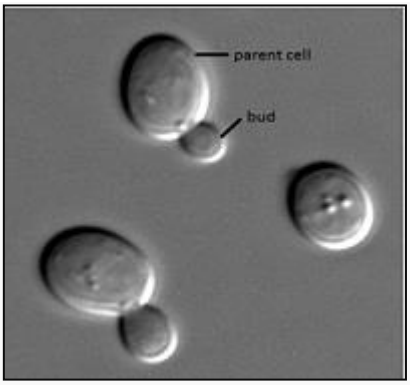
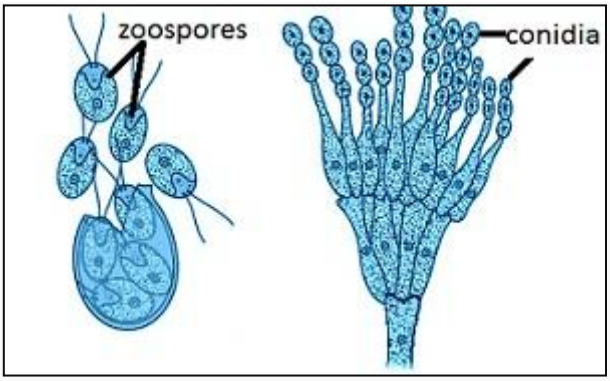


Fig. budding in yeast

Asexual reproductive structures-

- Members of kingdom fungi and simple plants reproduce through special reproductive microscopic motile structures called as Example- *chlamydomonas*
- Other common structures are conidia in ***Penicillium***, buds in **Hydra**, gemmules in **sponge**.



Vegetative propagation-

In plants, the vegetative parts of the body of the plant called as **vegetative propagules** give rise to new offspring

- Example- runner, rhizome of ginger, suckers of chrysanthemum, offset of water hyacinth, bulb of onion, eyes of potato can give rise to new offspring.

Vegetative propagules develop from some other specialized parts present in the vegetative propagules.

- Example- eyes of potato, rhizomes of banana, ginger arise from nodes present in the modified stem of these plants , adventitious buds of *Bryophyllum* arise from the notches present at margin of leaves.

As the progenies arise from a single parent, the progenies do not show genetic variation and do not contribute to evolution.

Sexual reproduction

- The reproduction in which the gametes of two parents fuse to give rise to a zygote is called sexual reproduction.
- Male and female gametes are formed either by the same individual or different individual of the opposite sex.

- Because of the fusion of male and female gametes, sexual reproduction results in off springs that are not identical to the parents.
- All the sexually reproductive organism have three phases in their life-
- Juvenile phase- the period of growth from birth to reproductive maturity in animalsis called juvenile phase and in plants this inter flowering period is known as **vegetative phase.**
- Reproductive phase- the phase in which the organisms reproduce sexually is called reproductive phase.
- Senescent phase- the phase between reproductive maturity and death of an organism is called senescent phase, characterized by gradual deterioration in the body leading to the death of an organism.

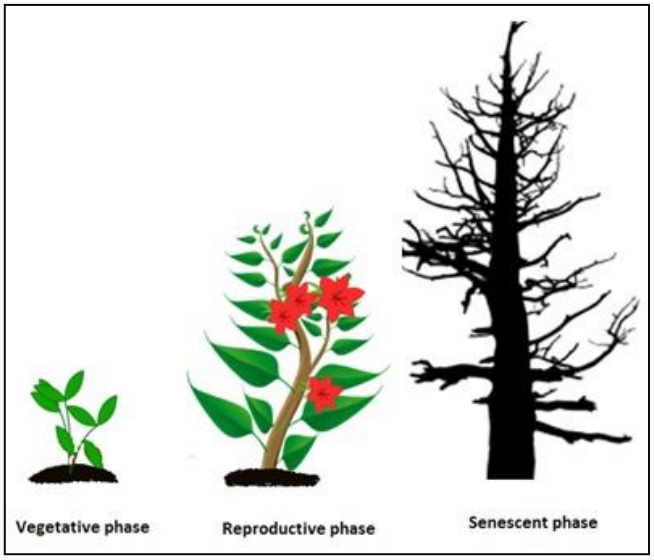


Fig. phases of growth in a hibiscus plant

Based on the life span of plants, plants can be differentiated into 3 types-

1. Annual plants- live for one year and start flowering at the end of the year.
2. Biennuals plants- live for two years and start flowering in the second year.
3. Perennial plants- live for several years but flower only once in their life time.

Example- bamboo species flower only once in 50-100 years.

Strobilanthuskunthiana flowers once in 12 years.

Fig. strobilus plant

- Many mammals reproduce only during favorable season in their reproductive phase and hence these organisms are called as **seasonal breeders**. Example- cow, buffalo.
- Some mammals actively reproduce throughout their reproductive phase and hence are called as **continuous breeders**. Example- man, rabbit.

- Some cyclic changes occur in the female reproductive system of female mammals which is called as **reproductive cycle**.
- Reproductive cycle is of two types –

1. Menstrual cycle- the cycle of primates in which changes carry on all the year with one ovulation in a month is called menstrual cycle. Example- apes, humans.
2. Oestrous cycle- the reproductive cycle in non-primate females is called oestrous cycle which consists of a short period during which female receives the male for mating followed by the events of sexual reproduction Example- cow, tiger etc.

Events in sexual reproduction

- Events of sexual reproduction is grouped under three categories-
- Pre-fertilization events-
- The events of sexual reproduction which occurs before fertilization are called pre-fertilization events.
- Pre- fertilization events are a) gametogenesis and b) gamete transfer.
- Fertilization events- The process of fusion of male and female gametes to form a zygote is called fertilization or **syngamy**.

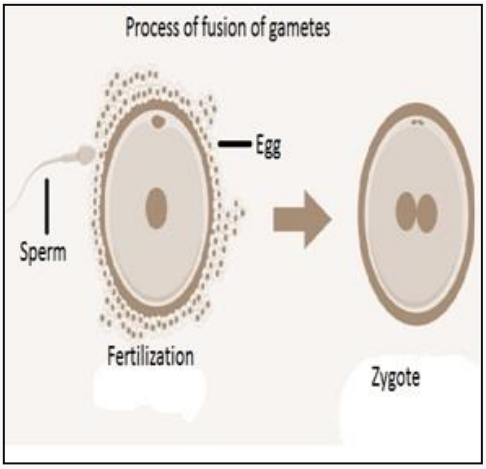


Fig. fusion of sperm and egg

Post- fertilization events-

- A diploid zygote is formed as a result of fertilization and later the zygote develops into a new organism.
- The process of development of embryo from the zygote id called embryogenesis.

Pre- fertilization

- The events of sexual reproduction which occurs before fertilization are called pre-fertilization events.
- Pre- fertilization events are a) gametogenesis and b) gamete transfer.

1. Gametogenesis-

- The process of formation of gametes is called gametogenesis.
- Gametes are the specialized haploid cells and are of two types- male and female gametes.

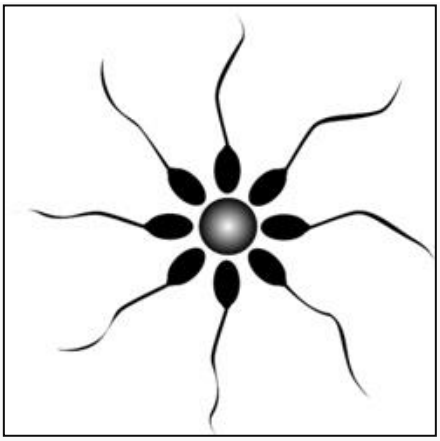


Fig.male gametes, sperms are surrounding the female gametes, egg.

- When both the gametes are similar in appearance that these can be distinguished, these gametes are called **homogametes** or **isogametes**. Example- algae.

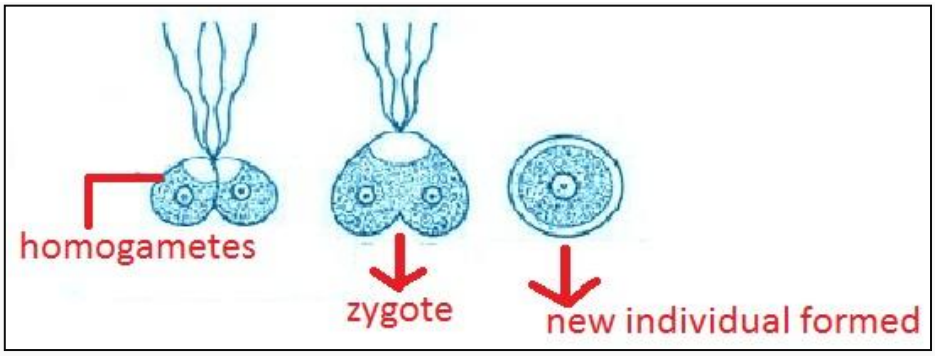


fig. homogametes of algae

- When both the gametes are dissimilar in appearance, the gametes are called heterogametes or **anisogametes** and the male gamete is called **antherozoid** or **sperm** and the female gamete is called **egg** or **ovum**. Example- human, higher plants.

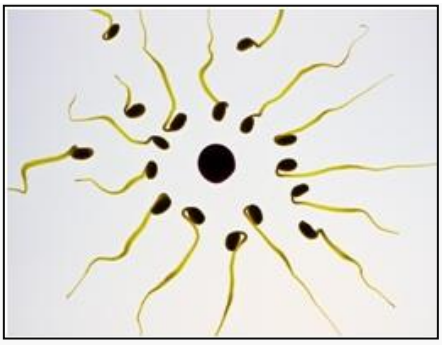


Fig. heterogametes

Gametes are haploid even though the parent body is diploid.

- If the parent is haploid, the parents produce gamete by mitosis. Example- monera, algae.
- In diploid parents, the parents produce gametes by meiosis, the reduction division to produce haploid gametes. Example- human beings, higher plants.

- In diploid organisms, the gamete mother cells which undergo meiosis to produce gametes are called meiocytes, as a result at the end of meiosis only one set of chromosome gets incorporated into each gamete hence, the gamete becomes haploid.
- Human beings are diploid organisms and have 46 chromosomes and so the gametes contain 23, half of the number of chromosome by reduction division.

1. Gamete transfer-

- The process of bringing together of male and female gamete for fertilization is called gamete transfer.

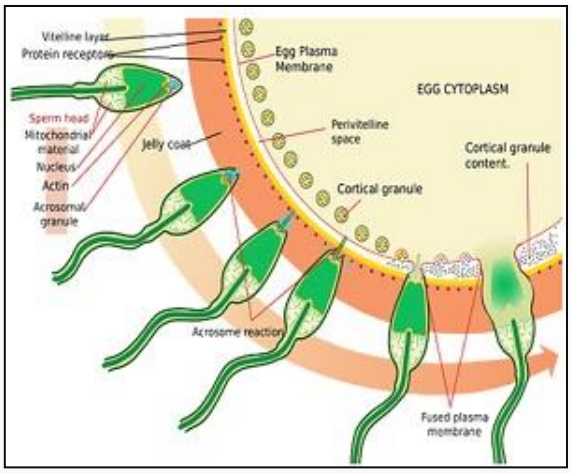


Fig. transfer of gametes

In majority of organisms male gametes are motile and female gametes are non-motile while in algae and fungi both the types of gametes are motile.

- In bryophytes and pteridophytes, gamete is transferred through water.
- In seed producing plants, pollens are transferred to the stigma by pollination.
- In bisexual self-fertilizing plants, anthers and stigma are located close to each other and so transfer of pollen grains is easy. Example- pea.
- In cross-pollinating plants, the agents like wind, insects moving for collecting nectar from the flowers help in pollination.

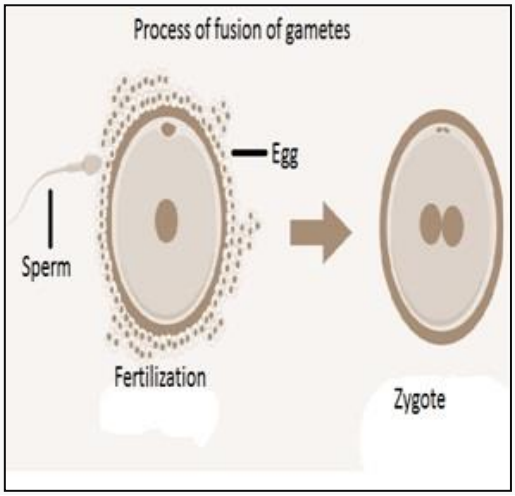
Fig. pollination by insect

Fig. pollination

Fertilization

The process of fusion of male and female gametes to form a zygote is called fertilization or **syngamy**.

Fig. fusion of sperm and egg



- Fertilization is of two types-
- In rotifers, insects, lizards female gametes develop in to new organisms without fertilization, the process is called as

External fertilization-

- In this type of fertilization, syngamy occurs outside the body of organism. Example- in most aquatic organisms like algae, fish, amphibians.
- The major disadvantage of external fertilization is they produce a large number of off springs but the off springsare vulnerable to predators.

Fig. external fertilization and release of eggs in water

Internal fertilization-

- Syngamy occurs inside the body of organisms. Example- fungi, birds, mammals.
- Male gametes are released close to the female gametes.

Post- fertilization events

Zygote formation

- In some organisms like fungi and algae, the zygote develops a thick wall around it which is resistant to damage and undergoes a period before germination.
- Further development of zygote depends on the type of life cycle of organisms and the environment in which they are surviving.
- In all sexually reproducing organisms, a diploid zygote is formed as a result of fertilization and later the zygote develops into a new organism.

Embryogenesis

- The process of development of embryo from the zygote is called embryogenesis.
- Embryogenesis includes cell division and cell differentiation in the zygote.
- Cell division increases the number of cells and cell differentiation helps to form tissues and organs to form a fully developed organism.

Fig. embryogenesis

- Depending on the development of zygote inside or outside the body of the female parent, animals are classified into oviparous and viviparous animals.
- Oviparous animals are those which lay eggs and the eggs develop into new organisms. Example- amphibians, fishes, birds, reptiles etc.
- Viviparous animals are those which give birth to their young ones. Example- mammals.
- In some oviparous animals like reptiles and birds the fertilized eggs remain covered by hard calcareous shell and such eggs are called **cleidoic**
- In flowering plants, the zygote is formed inside the ovule and the sepals, petals, stamens of the flower usually fall off.
- The zygote develops into embryo
- Ovules develop into seeds
- The ovary develops into the fruit.
- The ovary wall develops into a protective layer called **pericarp**.

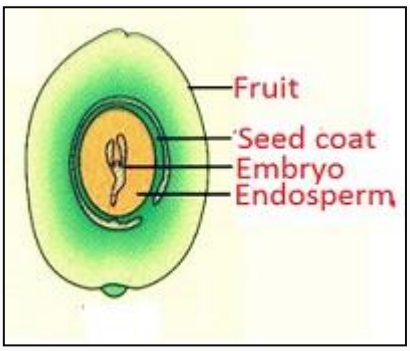


Fig. fruit and seed formation

Sexuality in organisms

The flowers having either male or female reproductive structure are called **unisexual** or **dioecious** or **heterothallic** Example- papaya, date palm.

Fig. papaya flowers

The flowers having both male and female reproductive structures are called **bisexua**l or **monoecious** or **homothallic** Example- hibiscus, coconuts.

Fig. hibiscus

In plants the unisexual male flower is **staminate** as it bears stamen and unisexual female flower is **pistillate** as it bears pistil.

Some animals possess both male and female reproductive organs. Such animals are called as **bisexual** or **hermaphrodites** or Example- earthworm, frog, bird.

Fig. earthworm

Animals having either male or female reproductive structures are called **unisexual** or **dioecious** Example- human.

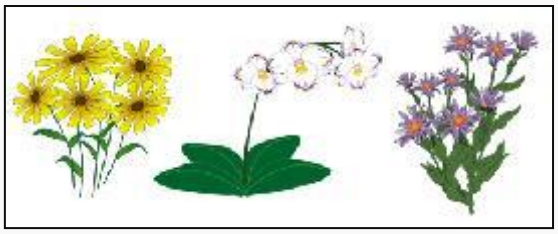
Introduction

Plants can reproduce both sexually & asexually.

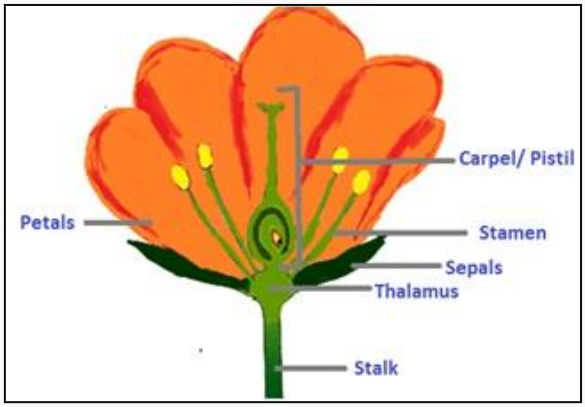
We will here learn about the sexual mode of reproduction.

Flower being the reproductive organ of a plant, plays the most important role in the process of sexual reproduction.

Let's first understand the structure of a flower.



Structure of a Flower



Stalk: Holds the flower

Thalamus: Swollen upper portion of stalk

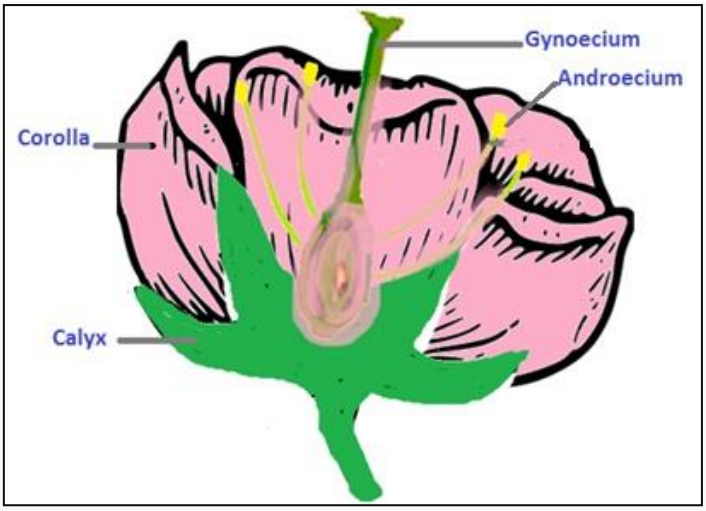
Petals: Colored parts of a flower which attracts insects

Sepals: Ensures protection

Stamen: Male reproductive organ which produce male gametes (pollen grains)

Carpel: Female reproductive organ which produce female gametes (ovum/egg)

A flower has 4 whorls arranged successively.



Calyx

- Outermost whirl
- Members are termed as ‘sepals’
- Green colored
- Protect the bud which later becomes a flower

Corolla

- Whirl before calyx
- Members are termed as ‘petals’
- Bright colored
- Attract insects for pollination

Androecium

- Inner whirl next to Corolla
- Members are termed as ‘stamens’
- Male reproductive organ

Gynoecium

- Inner most whirl
- Members are termed as ‘carpels’
- Female reproductive organ

Pre-fertilization events in a flower

Events that take place before fertilization are termed as Pre-fertilization events. Following events would occur before actual fertilization takes place in a plant:

- Gametogenesis
  - Development of male & female reproductive structures
  - Formation of male & female gametes
- Gamete transfer

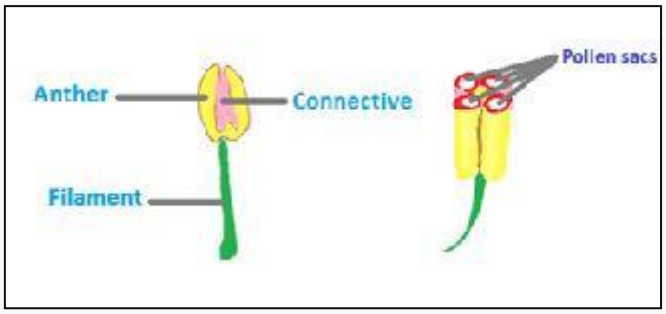
- Bringing together male & female gamete
- Pollination occurs in plants to facilitate gamete transfer

We will now understand the formation of male & female gametes in a plant. It is important to understand the structure of male & female reproductive parts in detail.

Male reproductive structure in a Flower : Stamen

Stamens are the male reproductive structures in a plant. The structure of a stamen consists of 3 important parts:

- **Filament**
  - Stalk that bears anthers
- **Anther**
  - Bilobed, dithecous structure at the tip of filament
  - Each lobe has 2 pollen sacs/ microsporangia
  - A total of 4 microsporangia are present in a anther
  - Each microsporangia produce spores, which later develop into pollen grains
- **Connective**
  - Part attached to the back of anther



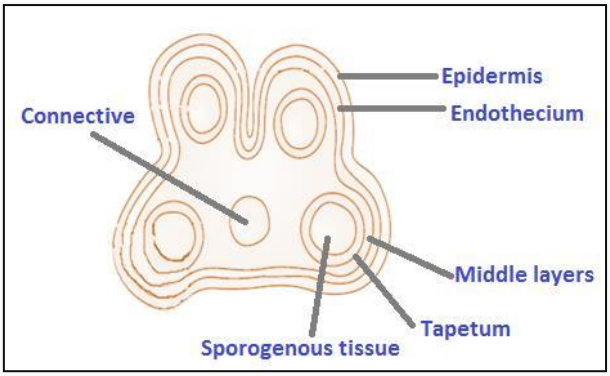
Detailed structure of Microsporangium

If the transverse section of a microsporangium is observed carefully, it is seen that there are 4 layers surrounding the microsporangia:

- Epidermis
- Endothecium
- Middle layers
- Tapetum

The first three ensure protection of the microsporangium, while the innermost layer, Tapetum provides nourishment to the pollen grains.

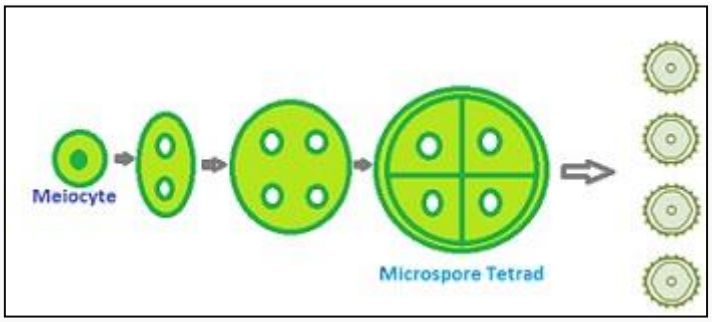
Sporogenous tissue is present at the centre of each microsporangium.



Microsporogenesis

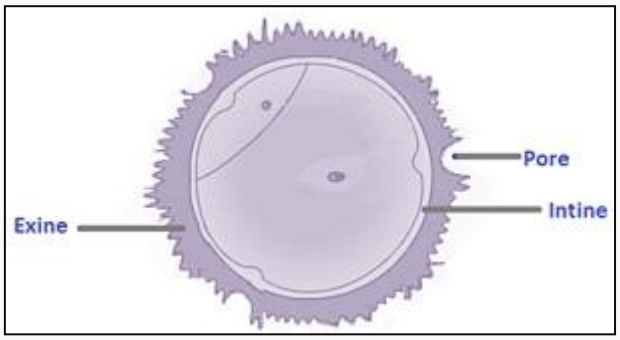
Formation of microspores is termed as Microsporogenesis. Microspores are formed inside microsporangium.

- Sporogenous cells differentiate to form meiocytes
- Meiocytes under meiosis
- 4 haploid microspores are formed (Microspore tetrad)
- Microspores dissociate & develop to form Pollen grains
- Pollen grains are male gametophyte



Pollen grains

Each pollen grain is a tiny spherical structure, surrounded by 2 layers:



Exine

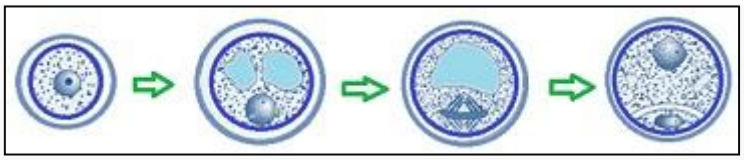
- Hard, outer layer
- Composed of sporopollenin
- Highly resistant

Intine

- Thin inner layer
- Composed of cellulose & pectin

Formation of a pollen grain from microspore involves the following changes:

- Expansion of the microspore
- Formation of a large vacuole
- Microspore nucleus displaced to an eccentric position against microspore wall
- Nucleus undergoes first pollen mitosis
- A large vegetative cell & a small generative cell are formed. This is the 2-cell stage. In many plants, pollen grains are released at this 2-celled stage. However, in some others, they are released at a 3-celled stage.
- Generative cell detaches from pollen grain wall
- Generative cell is engulfed by the vegetative cell
- 'Cell within a cell' structure is formed
- Generative cell again undergo mitosis
- Two sperm cells are formed enclosed within the vegetative cell cytoplasm



Characteristics of Vegetative & Generative cell:

- Vegetative cell is bigger in size, while the generative cell is smaller
- Vegetative cell has an irregularly shaped nucleus, and the generative cell is spindle-shaped with dense cytoplasm & nucleus.
- Vegetative cell is also termed as Tube cell as it is responsible for growth of pollen tube
- Generative cell floats in the cytoplasm of vegetative cell

Uses of Pollen grains

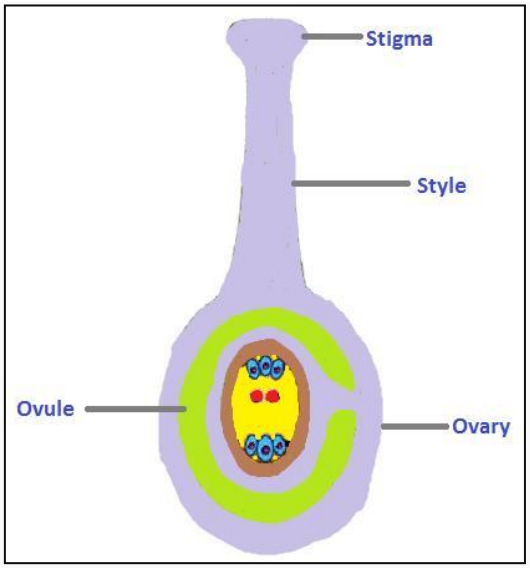
- Rich in nutrients
- Can cause respiratory disorders
- Cause pollen allergy
- Help in crop-breeding programmes

Female reproductive structure in a flower: Carpel

Carpel has 3 important parts in a flower

- **Ovary**
  - Basal enclosed part of carpel
  - Ovarian cavity is termed as Locule
  - Encloses ovule (megasporangium) in it
  - Ovules are attached to cushion-like structure called Placenta

- **Style**
  - Tube like structure that connects the Ovary & Stigma
- **Stigma**
  - Located at the exposed end of Style
  - Acts as the receptive surface for pollen grains

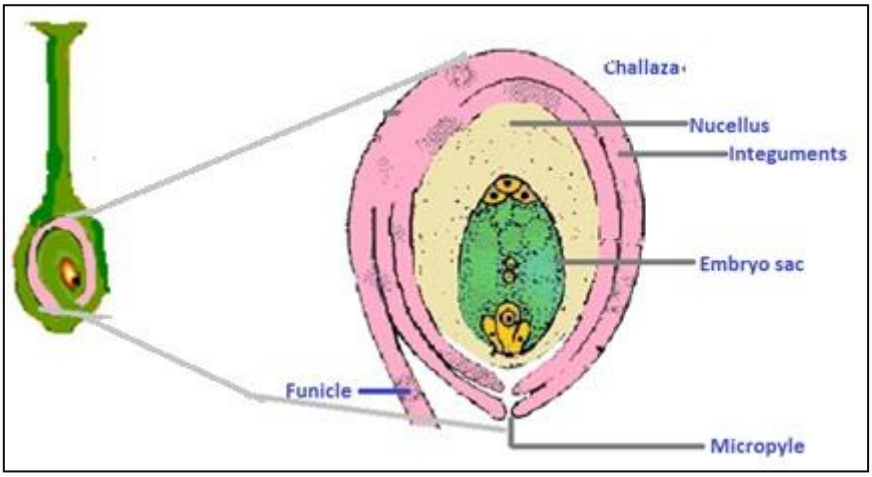


Megasporangium

Megasporangium or Ovule is the structure inside ovary where megaspore formation takes place.

The internal structure of the Ovule consists of the following parts:

- **Funicle:** Stalk that attached ovule to placenta
- **Hilum:** Junction between ovule & funicle
- **Integuments:** One or many protective envelopes around ovule
- **Micropyle:** A small opening at the tip of integuments
- **Chalaza:** Basal part of ovule
- **Nucellus:** Mass of cells enclosed within integuments used for food storage
- **Embryo sac:** Female gametophyte located in nucellus



Megasporogenesis

Formation of megaspores is termed as Megasporogenesis. Megaspores are formed inside Megasporangium.

- Ovules differentiate to form one Megaspore Mother Cell (MMC)
- MMC undergo meiosis
- 4 haploid megaspores are formed (Megaspore tetrad)

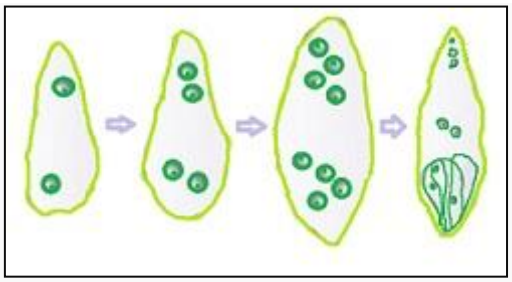
One of these megaspores develops into female gametophyte. The other megaspores degenerate.

Only the basal megaspore remains functional & develops into a female gametophyte (embryo sac).

This process of formation of embryo sac from a single megaspore is termed as Monosporic development.

Following changes lead to Monosporic development:

- Nucleus undergo mitotic division
- 2-nucleate embryo-sac is formed
- Nuclei undergo mitotic division again
- 4-nucleate embryo-sac is formed
- Nuclei undergo yet another mitotic division
- 8-nucleate embryo-sac is formed
- Cell wall formation takes place
- Embryo sac is formed



The nuclei formed inside get rearranged to form the final structure of Embryo sac as follows:

Mature embryo-sac is 7-celled, but 8-nucleate.

Egg apparatus

- 2 synergids, 1 egg cell
- Located at micropylar end

Antipodals

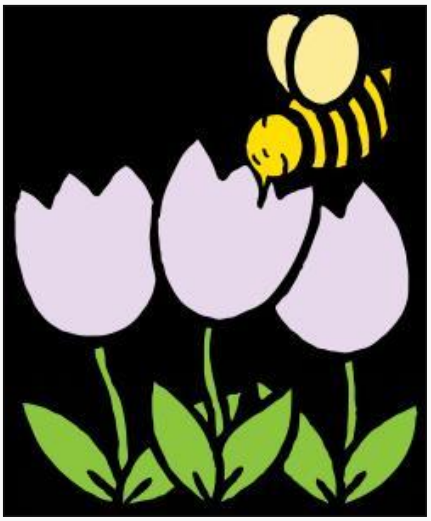
- 3 cells at basal end of ovule
- Located at chalazal end

Central cell

- 2 polar nuclei fused together

Pollination

Transfer of pollen grains from anther to stigma is termed as Pollination. This transfer of pollen grains occurs with the help of pollinating agents like wind, water, insects, birds etc.



There are 2 types of pollination:

- Autogamy
- Transfer of pollen grains from anther to stigma of the same flower
- Seen in plants which produce Chasmogamous & Cleistogamous flowers
    - Chasmogamous flowers
        - Exposed anther & stigma
    - Cleistogamous flowers
        - Closed flower
        - Anther & stigma lie very close to each other
        - Example: Viola, polygala
- Geitonogamy
    - Transfer of pollen grains from anther to stigma of another flower of same plant
    - It is functionally cross-pollination, but genetically self-pollination

- Xenogamy
    - Transfer of pollen grains from anther to stigma of a different plant
    - Genetically as well as functionally cross-pollination

Pollinating agents

Agents which carry pollen grains from anther to stigma of same/different plant are termed as Pollinating agents. They are of 2 types:

Biotic agents

- Living organisms which act as agents of pollination
- Insects, Birds

Abiotic agents

- Non-living objects which act as agents of pollination
- Pollination occurs by chance
- Wind, water
- **Pollination by Insects**

- Bees are the most common biotic pollinating agent. Not only insects, but some of the animals like rats, lizards, bats also help in pollination. Plants are specially adapted based on their pollinators. Therefore, not just any animal/ insect can pollinate a plant.

- Some of the factors that attract insects are attractive color of the flower, fragrance and nectar. In some cases, the insect & the plant exhibit a mutual relationship. For example, the Yucca-moth relationship is a mutual one. The insect Moth helps in pollinating the Yucca flower, whereas the flower provides a space in its locule for the moth to lay eggs. The larvae feed on the yucca seed within the fruit.

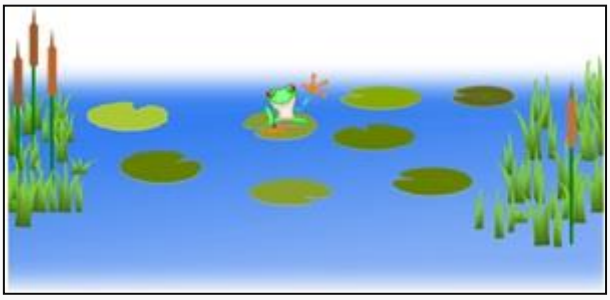
- 

Pollination by Water

This is a less common mode of pollination. Water pollination can occur in a number of ways:

- Water acts as a medium for gamete transfer in lower plants. Example: bryophytes
- Female flowers reach the water surface by a stalk where male gametes were already released. Example: Vallisneria
- Male gametes are released inside water where flowers remain. Example: Seagrass

In water pollination, pollen grains are prevented from being wet by a mucilaginous covering.



Pollination by Wind

Pollen grains are carried by wind from anther to stigma. Wind pollination is very commonly seen in grasses. Characteristics of a plant pollinated by wind are:

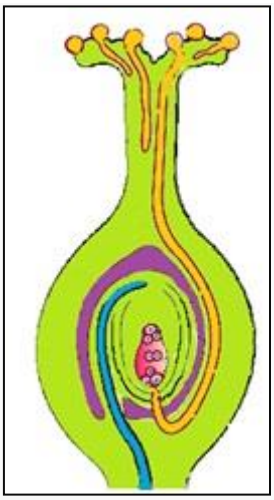
- Light pollen grains
- Non-sticky pollen grains
- Well-exposed stamens
- Large, feathery stigma

Pollen-Pistil interaction

The pollen landing on stigma of pistil might be compatible or incompatible with the stigma. Therefore the acceptance or rejection of the pollen by stigma depends on the compatibility.

If the pollen & pistil are compatible with each other, following events will take place:

- Pistil accepts pollen
- Formation of pollen tube
- Pollen tube reaches ovary
- Pollen grains move into pollen tube
- Pollen tube enters ovule through micropyle
- Pollen tube enters a synergid through filiform apparatus
- Fertilization occurs



On the other hand, If the pollen & pistil are incompatible with each other, following events will take place:

- Pistil rejects pollen
- Prevents pollen tube growth
- Prevents fertilization

Therefore, Pollen-Pistil interaction can be defined as follows:

Pollen-pistil interaction is a dynamic process of pollen recognition followed by promotion or inhibition of the pollen. Chemical components of the pollen interact with those of the pistil.

Artificial Hybridization

Knowledge on Pollen-pistil interaction helps in crossing different species/genera to produce commercially superior varieties, the technique we now know as Artificial Hybridization.

Artificial hybridization is the process in which only desired pollen grains are used for pollination & fertilization. Artificial hybridization is achieved using the following techniques:

- Emasculation
  - Removal of anthers from bisexual flowers of female parent plant
  - This is done before anthers mature
  - Prevents self-pollination
- Bagging
  - Covering the emasculated flower to prevent contamination
  - Prevents contamination with unwanted pollen
- Desired pollen grains are dusted on stigma
- Flowers are bagged again

Fertilization

Fusion of male & female gametes is termed as Fertilization. In a flowering plant, 2 male gametes enter into the cytoplasm of synergid through the micropylar end of ovule. These 2 male gametes undergo fusion inside the ovule as follows:

Syngamy

- One male gamete fuse with egg cell
- Zygote is formed
- Zygote later develops into Embryo
- This fusion is termed as Syngamy

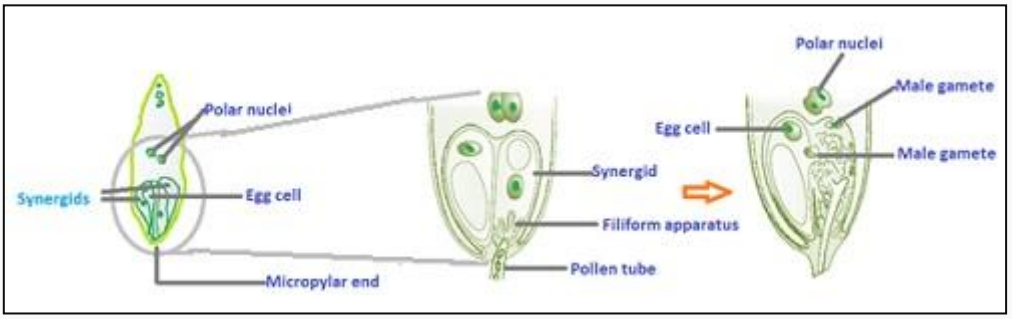
Triple fusion

- Other male gamete fuse with polar nuclei
- Primary endosperm cell (PEC) is formed
- PEC later develops into Endosperm
- This fusion is termed as Triple fusion as three haploid nuclei fuse together

Antipodal cells degenerate

Synergids degenerate

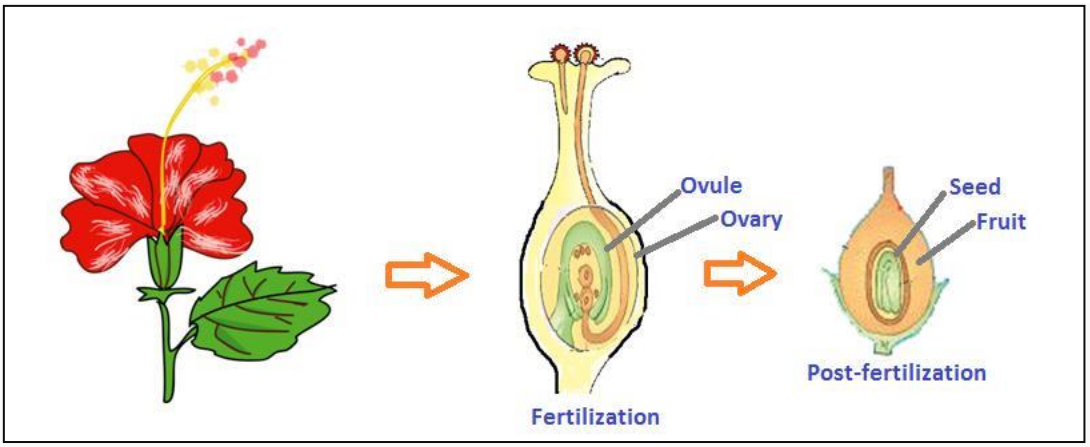
Since 2 types of fusion take place inside the embryo sac, therefore this fertilization is said to be Double fertilization in flowering plants.



Post-fertilization events in a flowering plant

Events which take place in a flowering plant after double fertilization are termed as Post-fertilization events. Important post-fertilization events are:

- Development of Endosperm from PEC
- Development of Embryo from Zygote
- Development of Seed from Ovule
- Development of Fruit from Ovary



Seed

Seed is a fertilized ovule. Integuments of ovule harden to form Seed coat, however micropyle is still present on the seed coat.

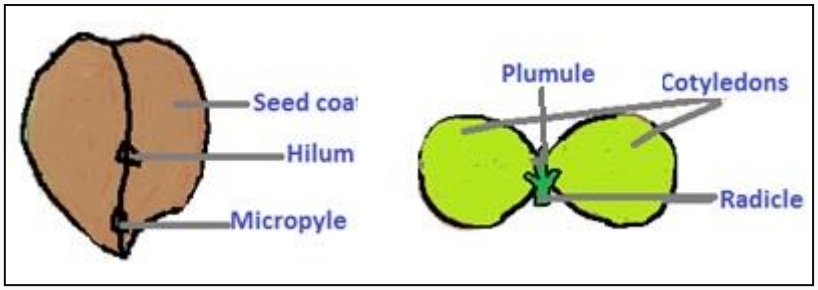
Basic structure of a seed consists of the following parts:

- Seed coat: Hard outer covering of the seed
- Radicle: Root tip which later gives rise to the entire root system
- Plumule: Shoot tip which later gives rise to the entire shoot system
- Cotyledons: Seed leaves

Based on the number of cotyledons, there are 2 types of seeds:

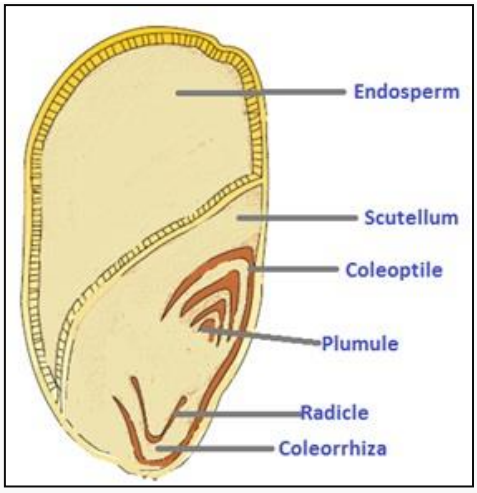
- Dicotyledonous seed: Seed with 2 cotyledons
- Monocotyledonous seed: Seed with 1 cotyledon

A dicotyledonous seed has the following important parts:



- **Seed coat**
  - Outer covering of the seed which is composed of 2 layers
  - Testa : thick outer layer
  - Tegmen: thin inner layer
- **Hilum**
  - Scar on seed coat through which the seed was attached to the fruit
- **Micropyle**
  - A small pore on the seed through which oxygen & water exchange occurs during seed germination
- **Cotyledons**
  - Seed leaves
  - Food storage
  - Provide nourishment to the developing radicle & plumule
- **Radicle**
  - Embryonic root
- **Plumule**
  - Embryonic shoot

A monocotyledonous seed has the following important parts:



Seed coat

- Fused with pericarp
- **Endosperm**
- Bulky part within which lies the small embryo
- Massive & starchy endosperm
- **Aleurone layer**
- Special tissue surrounding the endosperm

Cotyledon

- Single cotyledon termed as Scutellum
- In contact with endosperm through an epithelial layer
- **Plumule**
- Embryonic shoot covered by protective layer **Coleoptile**

Radicle

- Embryonic root covered by protective layer **Coleorrhiza**

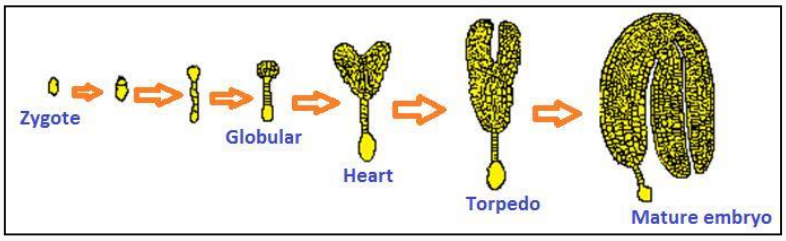
Seeds are extremely useful in agriculture. Some of the important applications of seeds are:

- Help plant species to be colonized in different areas
- Provide nourishment to young seedlings
- Ensure protection to the young embryo
- Results in variations with new genetic combinations
- Can be easily stored for future usage
- Long term viability of most of the seeds.

Embryo

Embryo is a diploid cell developing from zygote. It starts to develop at the micropylar end. Development of zygote to form embryo starts only after endosperm formation has started. This is because endosperm provides nutrition needed for the embryo to develop.

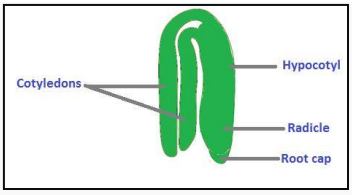
Stages of embryo development are same in both monocot & dicot embryo. Embryogeny refers to the stages of embryo development. The embryo development starts with the fertilized egg (zygote), then passes through the 2- cell stage, 8-cell stage, Globular, Heart shaped stage, Torpedo stage and finally the mature embryo.



The structure of a dicotyledonous embryo is little different from that of a monocot embryo.

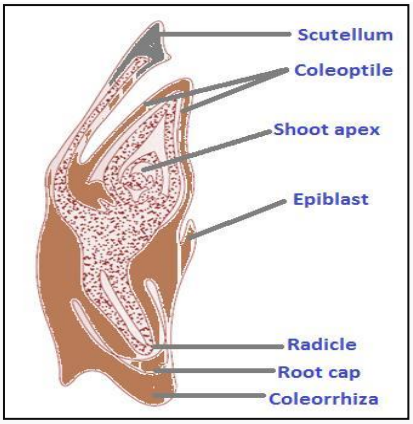
Dicotyledonous embryo has the following important parts:

- Embryonal axis
  - Main axis of the embryo which divides it into different regions
- Cotyledons
  - Seed leaves
  - Helps in Food storage
  - Provide nourishment to the developing radicle & plumule
- Epicotyl
  - Part of embryonal axis above the cotyledons
  - Terminates at plumule
- Hypocotyl
  - Part of embryonal axis below the cotyledons
  - Terminates at radicle
- Plumule : Stem tip
- Radicle : Root tip
- Root cap: Covering of root tip



Monocotyledonous embryo has the following important parts:

- Embryonal axis
  - Main axis of the embryo which divides it into different regions
- Cotyledon
  - Only one seed leaf exists
  - Termed as Scutellum
  - Located at one side of axis
- Plumule : Shoot tip
- Radicle : Root tip
- Coleorrhiza : Sheath enclosing radicle & root cap
- Coleoptile : Sheath enclosing plumule & a few leaf primordia



Apomixis

Apomixis is a mechanism to produce seeds without fertilization. This mechanism produces clones, hence can be considered as a form of asexual reproduction.

Apomixis can occur in a number of ways, some of which are mentioned below:

Nucellar cells which are diploid & located outside the embryo sac continuously divide and enter inside embryo sac and later develop into embryos. In this way, multiple embryos can exist inside one ovule. This is termed as Polyembryony. It is seen commonly in Citrus, mango etc..

Sometimes, the egg cell is not formed as a result of reduction division, hence diploid. This diploid egg cell later directly develops into an embryo.

Apomixis is extremely useful these days because of the following reasons:

- Clonal reproduction through seeds
- New hybrids produced in lesser time
- Disease free plants can be produced
- Cost-effective

Introduction

Human beings are sexually reproducing organisms and are viviparous.

Fig. sexual reproduction in human gives rise to off springs of their own type

The events of sexual reproduction in human beings are-

1. Gametogenesis- the process of formation of gametes is called as gametogenesis.
2. Insemination- the process of transfer of sperms into the ovum is called insemination.
3. Fertilization- the process of fusion of male and female gamete to form a single celled zygote is called fertilization.
4. Implantation- the process of attachment of embryo to the endometrial wall of uterus of female is called implantation.
5. Gestation- the period of embryonic developmentis called gestation, also referred as
6. Parturition- the process of delivery of the baby is called parturition.

Male reproductive system

Male reproductive system is located in the pelvis region. It Consists of – a pair of testis, glands, accessory ducts, external genitalia.

Testes-

- Smooth organ situated outside the abdominal cavity within a pouch called
- The scrotum helps in maintaining the low temperature of the testis which is 2-2.5^{o}C which is below than the normal internal body temperature.
- Each testisis 4 to 5 cm in length and 2 to 3 cm in width in adults.
- Each testis contains about250 compartments called **testicular lobules.**
- Each testicular lobules contain one to three highly coiled **seminiferous tubules**, in which sperms are produced.
- The wall of each seminiferous tubuleis lined by two types of cells called **male germ cells (spermatogonia)** and **Sertoli cells.**
- The male germ cells undergo meiosis leading to sperm formation and Sertoli cells provide nutrition to the germ cells.
- The regions outside the seminiferous tubules called **interstitial spaces** contain small blood vessels and **interstitial cells** or **Leydig cells.**
- Leydig cells synthesize and secrete testicular hormones called **androgens**.

Accessory ducts-

- The male accessory ducts include **rete testis**, **vasa efferentia**, **epididymis** and **vas deferens.**
- The seminiferous tubules of the testis open into the vasa efferentia through rete testis.
- The vasa efferentia leave the testis and open into epididymis located along the posterior surface of each testis.

- The epididymis leads to vas deferens that ascends to the abdomen and loops over the urinary bladder.
- Vas deferens receives a duct from seminal vesicle and opens into urethra as the ejaculatory duct.
- The urethra originates from the urinary bladder and extends through the penis to its external opening called **urethral meatus.**

Accessory glands-

- The male accessory glands include paired **seminalvesicles**, prostate gland and paired bulbourethral glands.
- Accessory glands secrete **seminal plasma** which is rich in fructose, calcium and some enzymes
- Secretion of bulbourethral gland also helps in lubricating the penis.

External genitalia-

- The penis is the male external genitalia.
- Some special tissues make up the penis which helps in the erection of the penis.
- The enlarged end of penis called the **glans penis**.
- **Foreskin**, a loose fold of tissue covers the glans penis.

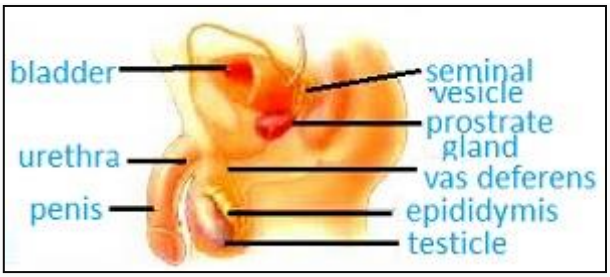


Fig. male reproductive system

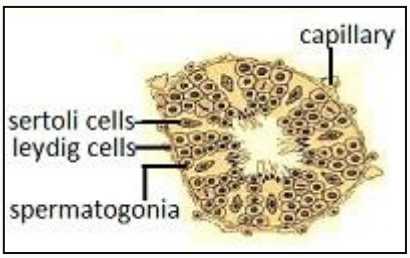


Fig. seminiferous tubule with accessory ducts

Female reproductive system

Female reproductive system is located in the pelvic region. It consists of - a pair of ovaries, a pair of oviducts, uterus, cervix, vagina and the external genitalia. A pair of mammary glands is also integrated structurally and functionally with the parts of female reproductive system to support the process of ovulation, fertilization, gestation, parturition and care of the baby after birth. A pair of oviducts, uterus, cervix, vagina constitute the female accessory ducts.

Ovaries-

- The primary female sex organs that produce the ovum and several ovarian hormones, steroid in nature.
- Located one on each side of the lower abdomen.
- Each ovary is covered by a thin epithelium which encloses the **ovarian stroma.**
- The ovarian stroma is divided into two zones – **a peripheral cortex** and an **inner medulla**.

Oviduct (fallopian tube)-

- 10-12 cm in length.
- Extends from the periphery of each ovary to the uterus.
- Part closer to the ovary is the funnel shaped
- **Fimbriae** are the finger like projections located on the edges of the infundibulum.
- Fimbriae help in collection of the ovum after ovulation.
- The infundibulum leads to the **ampulla** which is the wider part of the oviduct.
- The last part of the oviduct is **isthmus** which has a narrow lumen and it joins the uterus.

Uterus-

- Uterus is also called **womb**.
- The shape of the uterus is like an inverted pear.
- Ligaments attached to the pelvic wall support the uterus.
- The narrow **cervix** opens the uterus into the vagina.
- **Cervical canal** is the cavity of the cervix which forms **birth canal** along with vagina.
- Three layers of tissues are present in the uterus wall- the outer thin membrane bound **perimetrium**, middle thick layer of smooth muscle called **myometrium**, inner glandular layer called **endometrium**.
- Endometrium lines the uterine cavity.
- During menstrual cycle, endometrium undergoes cyclical changes but the myometrium exhibits strong contraction during parturition.

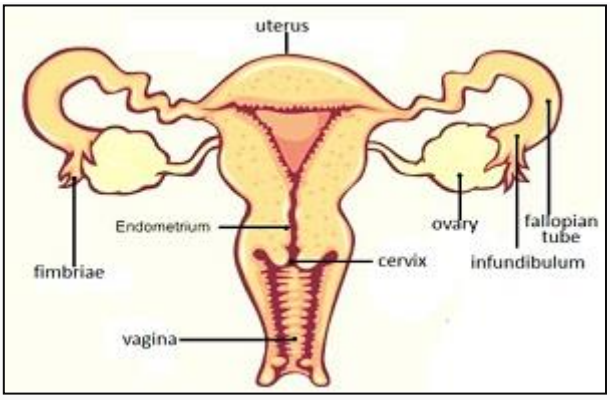


Fig. female reproductive system

External genitalia

- Vagina is the female external genitalia.
- Vagina includes mons pubis, labia majora (labia majus), labia minora (labia minus), hymen and clitoris.
- Mons pubis is a cushion of fatty tissue covered by skin and pubic hair.
- The labia majora are folds of tissue extend down from the mons pubis and surround the vaginal opening.

- Under the labia majore, there are paired tissue folded to form labia monora.
- Hymen is membrane covering the opening of the vagina.
- A tiny finger-like structure which lies at the upperjunction of the two labia minora above the urethral opening is called clitoris.

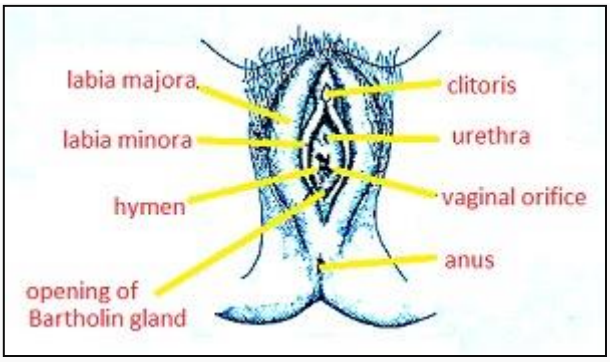


Fig. external genitalia with other parts in female reproductive system

Mammary glands

- Paired structures containing glandular tissues and fats, the amount of fat varies from person to person.
- The glandular tissue of each breast is divided into 15-20 mammary lobes containing clusters of cells called
- The cells of alveoli secrete milk, which is storedin the cavities called as **lumens** of alveoli.
- The alveoli open into mammary tubules and the tubules of each lobe join to form a mammary duct which joins to form a wider **mammary ampulla**.
- Mammary ampulla is connected to **lactiferous duct** through which milk is sucked out.

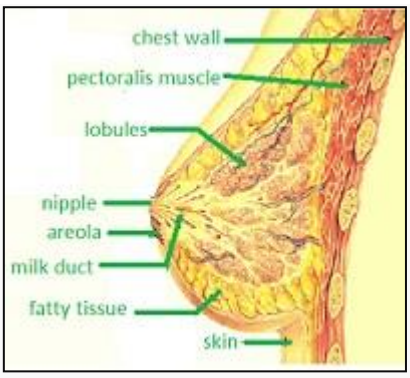


Fig. mammary gland

Gametogenesis

The process of formation of gametes in primary sex organs is called Gametogenesis.

Gametogenesis includes-

- spermatogenesis and spermiogenesis in males
- oogenesis in females.

The process of formation of sperms is called spermatogenesis. It involves 3 phases-

- multiplication phase

- growth phase
- maturation phase.

The conversion of spermatids into sperms is called spermiogenesis.

The process of formation of a mature female gamete is called oogenesis.

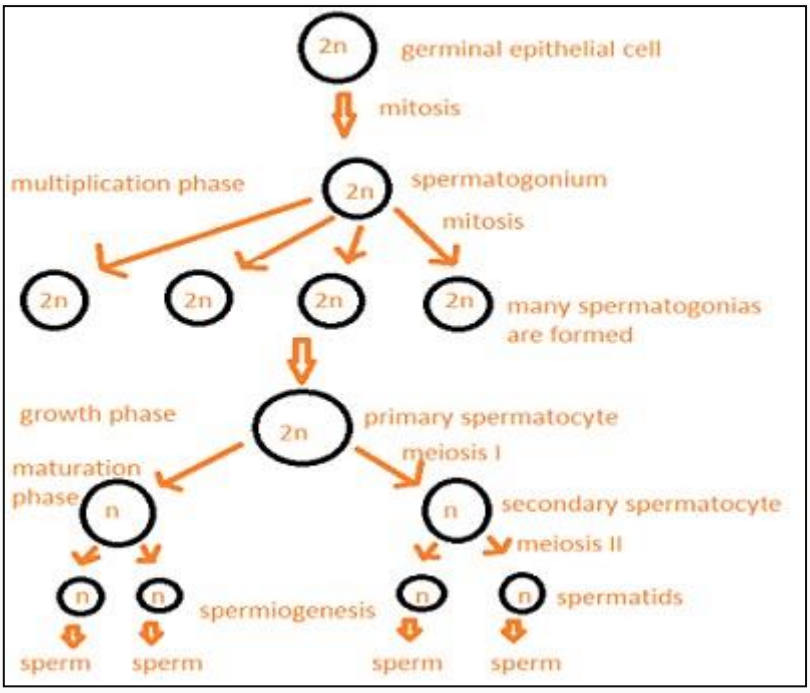
Spermatogenesis

The process of formation of sperms is called spermatogenesis. It involves 3 phases- multiplication phase, growth phase, maturation phase.

- In multiplication phase, male germ cells also called as **spermatogonia** undergo mitotic divisions to form large number of spermatogonia.
- In growth phase, spermatogonia increases their size by accumulation of nutrition in the cytoplasm and are ready for meitoic division and the spermatocytes are called as **primary spermatocytes** with **46 chromosomes**.
- In maturation phase- A primary spermatocyte completes the first meiotic division leading formation of two equal, haploid cells called **secondary spermatocytes**, which have only **23 chromosomes** each and the secondary spermatocytes undergo the second meiotic division to produce four equal, haploid **spermatids**

Spermiogenesis-

- The spermatids are transformed into sperms, also called as **spermatozoa** by the process called spermiogenesis.
- After spermiogenesis, sperm heads become embedded in the Sertoli cells and are released from the seminiferous tubules by the process called **spermiation**



Fi. Spermatogenesis

Hormonal control of spermatogenesis

- Spermatogenesis starts at the age of puberty due to significant increase in the secretion of gonadotropin releasing hormone (GnRH) from hypothalamus.
- The increases level of gonadotropin releasing hormone stimulates the **anterior pituitary** to secrete **luteinizing hormone(LH)** and **follicle stimulating hormone(FSH).**
- LH acts at the Leydig cells and stimulates synthesis and secretion of androgens.
- Androgens stimulate the process of spermatogenesis.
- FSH acts on the Sertoli cells and secrete two factors- **androgen binding protein (ABP)** and **inhibin** which helps in spermiogenesis.

Structure of a sperm

- It is a microscopic, motile structure composed of a head, neck, a middle piece and a tail.
- Whole body is covered by plasma membrane.
- The sperm head contains an elongated haploid nucleus and the anterior portion is covered by a cap-like structure **acrosome**
- The middle piece contains numerous mitochondria which produce energy for sperm motility needed for fertilization.
- Tail helps the sperm cell to swim to reach the egg cell.
- Seminal plasma along with sperm constitutes the **semen**.

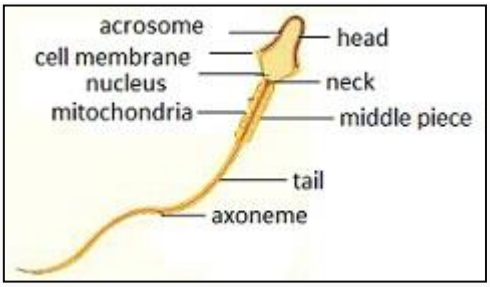


Fig. structure of a sperm

Oogenesis

- The process of formation of a mature female gamete is called oogenesis.
- Some of the germinal epithelial cells divide by mitosis to produce a large number of gamete mother cells or **oogonia**
- Oogoniamultiply by mitosis and form **primary oocytes**.

Growth phase-

- Each primary oocyte then gets surrounded by a layer of **granulosa** cells and called **primary follicle.**
- The primary oocytes enlarge and mature by obtaining food from follicle cells.
- The primary follicles get surrounded by more layers ofgranulosa cells and a new theca and called **secondary follicles.**
- The secondary follicle soon transforms into a tertiary follicle which is characterised by a fluid filled cavity called **antrum**
- The theca layer isorganised into an inner **theca interna** and an outer **theca externa.**
- The primary oocyte within the tertiary follicle grows in size and completes its first meiotic division which is an unequal division and forms a large **secondary oocyte** and tiny first **polar body.**
- The tertiary follicle changes into the mature follicle or **Graafian follicle.**
- The secondary oocyte forms a new membrane called **zonapellucida**

- The Graafian follicle then ruptures to release the secondary oocyte from the ovary by the process called **ovulation**
- If a sperm can enter the secondary oocyte through zonapellucida layer, the secondary oocyte completes meiosis II and thus results in the formation of second polar body and an ovum.

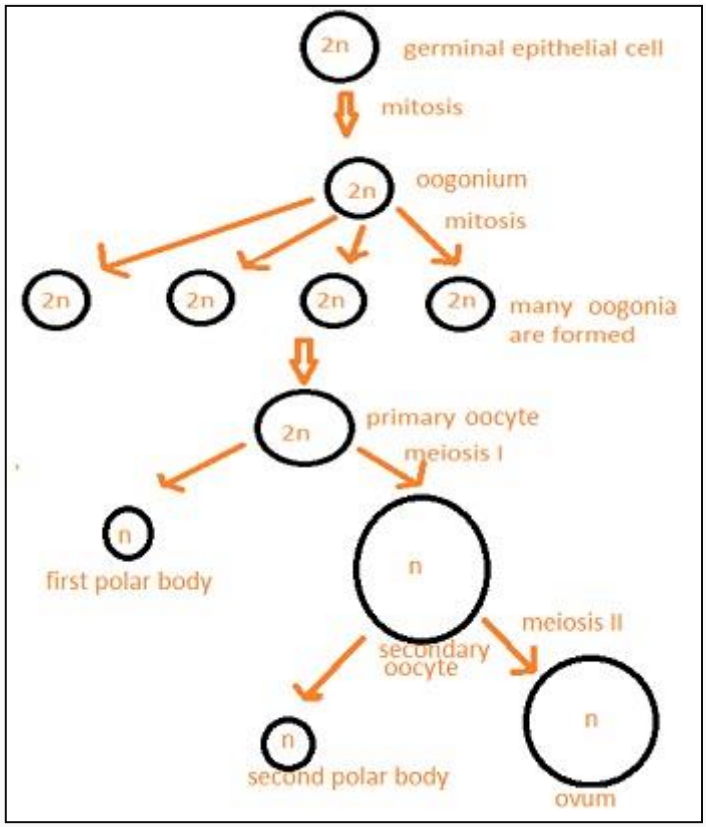


fig. Oogenesis

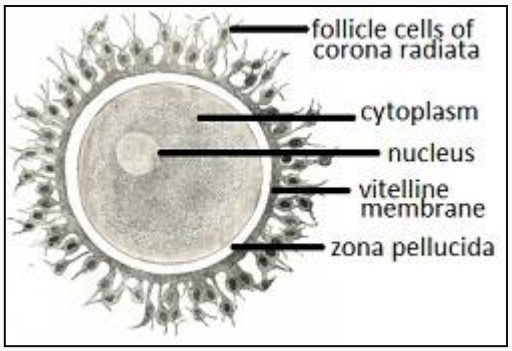


Fig. structure of human ovum

Menstrual cycle

The reproductive cycle starting from the one menstruation till the next one in the female primates is called menstrual cycle. The first menstruation which begins at puberty and is called **menarche .** The cycle is repeated at an interval of 28-29 days. Menstrual cycle involve three phases- menstrual phase, follicular phase and luteal phase.

Menstrual phase-

- Menstrual flow occurs and lasts for about 3-5 days.
- The **endometrial lining** of the uterus breaks along with the blood vessels which forms a red fluid and results in menstrual flow.
- If the ovum is fertilized by a sperm menstrual flow does not occur and hence indicates pregnancy.

Follicular phase-

- In this phase, the primary follicles in the ovary grow to become a fully matured graafian follicle.
- Endometrium regenerates through proliferation.
- Changes in Pituitary hormone and ovarian hormones induce the formation of graafian follicle and regeneration of endometrium.
- The secretion of gonadotropins like **luteinizing hormone** and **follicular stimulating hormone** increases gradually during this phase and stimulates follicular development as well as secretion of estrogens by the growing follicles.
- Both LH and FSH attain a peak level in the middle of cycle about 14th day.
- Rapid secretion of LH leading to its maximum level during the mid-cycle called **LH surge** induces rupture of Graafian follicle and thereby the release of ovum known as **ovulation**

Luteal phase-

- In this phase, the ruptured part of Graafian follicle transforms into yellow body called **Corpus luteum**.
- The corpus luteum secretes large amounts of **progesterone** hormone which maintains the endometrium for implantation of the fertilized ovum.
- During pregnancy all events of the menstrual cycle stop and there is no menstruation.
- In the absence of fertilization, the corpus luteum degenerates hence causes disintegration of the endometrium leading to menstruation and a new cycle begins.

In human beings, menstrual cycles ceases around 50 years of age and known as **menopause.**

Fertilization

- The fusion of haploid male gamete, sperm and haploid female gamete, ovum is called fertilization.
- During coitus, sperm is released by male partner into the vagina of the female partner is called as **insemination**
- The motile sperms swim and pass the cervix to enter into the uterus and finally to reach the ovum released by the ovary in the **ampulla-isthmic junction.**
- Fertilization takes place in the ampulla-isthmic junction.
- All copulations do not lead to fertilization because fertilization can only occur if the ovum and sperms are transported simultaneously to the ampulla-isthmic junction.

- The sperm after reaches the ovary in the ampulla-isthmic junction comes in contact with the zona-pellucidalayer of the ovum and block the entry of the additional sperms thus only one sperm fertilizes the ovum.
- The secretions of acrosome help the sperm to enter into the ovum through zonapellucida and the plasma membrane and thus secondary oocyte completes meiosis II and results in the formation of a second polar body and haploid ovum.
- The haploid nucleus of the sperm and ovum fuse together to form a zygote which develops into new individual.

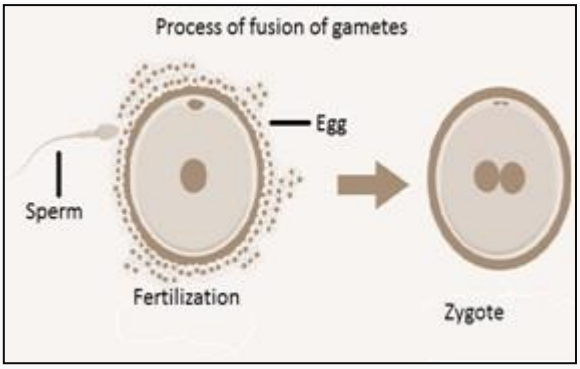


Fig. fusion of sperm and egg

Sex determination in human

- Male has two sex chromosomes X and Y hence male produces 50% of sperms carrying X and 50% carrying Y, while female has two X chromosomes.
- After fusion of the male and female gametes the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilized the ovum.
- The zygote carrying XX would develop into a female baby and XY would form a male.

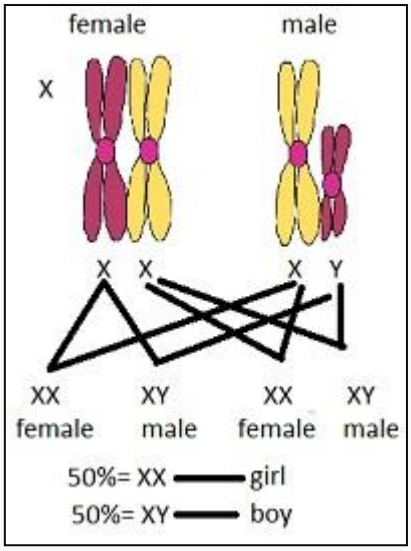


Fig. sex determination

Cleavage

- Cleavage is the mitotic division which starts as the zygote moves through the isthmusof the oviducttowards the uterus and forms2, 4, 8, 16 daughter cells called as **blastomeres**
- The embryo with 8 to 16 blastomeres is called a **morula**
- The morula divides further as it moves further in to the uterus and transforms into **blastocyst**
- Theblastomeres in the blastocyst are arranged in to an outer layer called **trophoblast** and inner mass of cells attached to trophoblast is called as **inner cell mass.**
- The trophoblast layer then gets attached to the endometrium of the uterus and the inner cell mass divide to cover the blastocyst hence blastocyst becomes embedded in the endometrium of the uterus and the process is called as implantation.

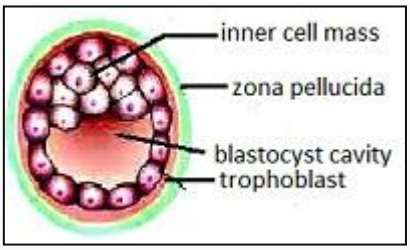


Fig. blastocyst

Pregnancy and embryonic development

- After implantation, finger like projections appear on the trophoblast called as **chorionic villi**.
- Uterine tissue and maternal blood surrounds the chorionic villi.
- The chorionic villi and uterine tissue together form a structural and functional organic structure between developing embryo and tissues of the mother called as **placenta**

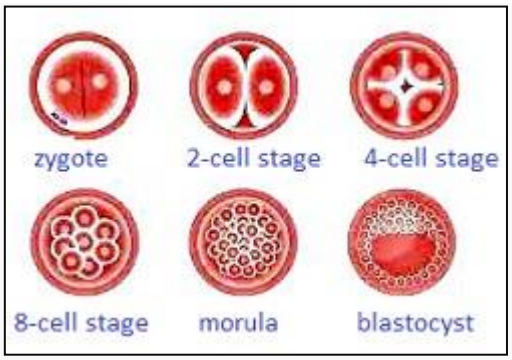


fig. foetus with placenta

Functions of placenta-

- The placenta facilitates the supply of oxygen and nutrients to the embryo.
- Help in the removal of carbon dioxide and excretory/waste materials produced by the embryo.
- The placenta is connected to the embryo through an **umbilical cord** which helps in the transport of substances to and from the embryo.
- Placenta also acts as an endocrine tissue and produces several hormones like **human chorionic gonadotropin (hCG),human placental lactogen (hPL),estrogens**, **progestogen**. etc.
- A hormone called **relaxin** is secreted by the ovary in the later phase of pregnancy.
- hCG, hPL and relaxin are produced in women only during pregnancy.

- Levels of other hormones like **estrogens, progestogens, cortisol, prolactin, thyroxine**, etc., are increased several folds in the maternal blood.
- Increased production of all the hormones is essential for supporting the fetal growth, metabolic changes in the mother and maintenance of pregnancy.
- After implantation, the inner cell mass is differentiated into outer layer called **ectoderm** and an inner layer called **endoderm** with a middle
- Three layers give rise to all organs in adults.
- The cells which have the potency to give rise to any types of cells in the body are called **stem cells.**
- The human pregnancy lasts for 9 months, heart develops after one month of pregnancy, limbs develop by the end of second month,major organ systems are formed by the end of 3 months.
- First movement and appearance of hairs are during fifth month of pregnancy.
- By the end of 24 weeks, the body covers with fine hair, eye-lids separate, eyelashes form.
- By the end on nine month, the fetus fully develops.

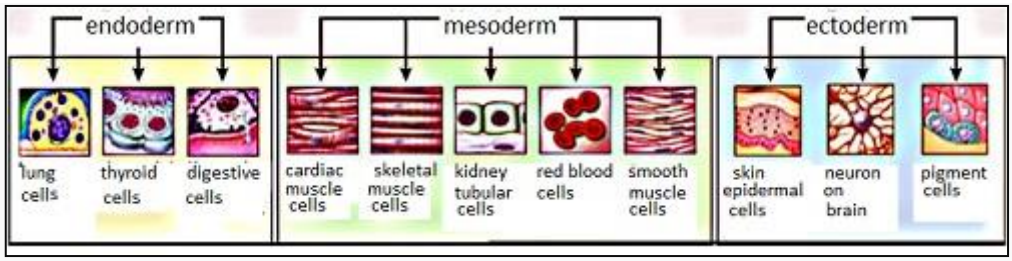


Fig. embryonic development

Parturition and lactation

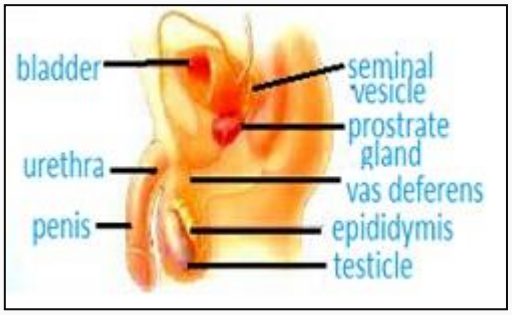
- The average duration of human pregnancy is about 9 months called as the **gestation period**.
- Vigorous contraction of the uterus atthe end of pregnancy causes expulsion/delivery of the fetuscalled as parturition.
- The signals for parturition originate from the fully developed fetus and the placenta which induces mild uterine contraction is called **fetal ejection reflex.**
- Fetal ejection reflex releases **oxytocin** hormone from the pituitary gland of mother which acts on the uterine muscle and causes contraction of uterus which in turn stimulates further oxytocin secretion.
- Production of milk at the end of pregnancy by the differentiation of mammary glands is called lactation.
- He milk produced during the first few days of lactation is called colostrum.
- Colostrum contains antibodies necessary to develop resistance against diseases of the new born baby.

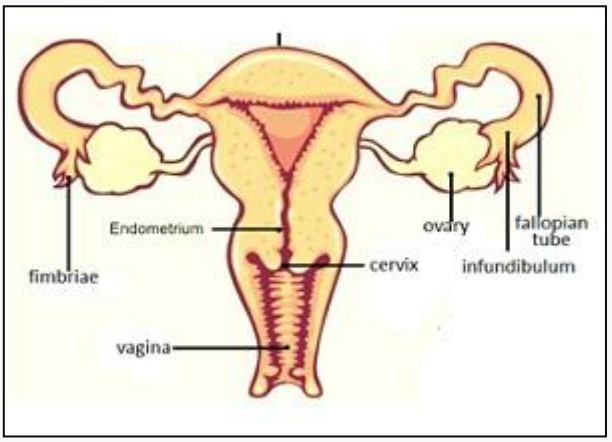
fig. parturition

Introduction

A total wellbeing in all aspects of reproduction such as physically, mentally and emotionally is called reproductive health.

All the reproductive organs should be healthy with normal functions.





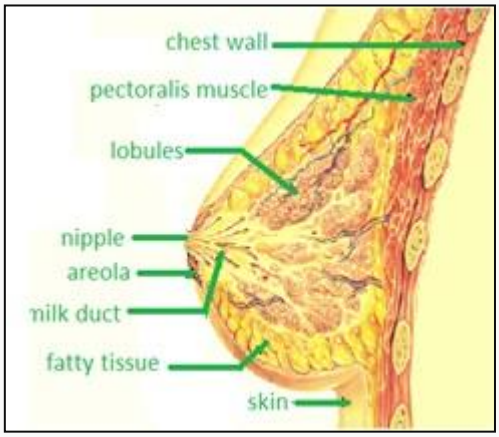


Fig. reproductive organs- male reproductive system, female reproductive system, mammary gland

Reproductive health- problems and strategies

Major problems associated with reproductive health

- Over population- explosion in population causes a scarcity of every basic need and hence affect the well-being of reproductive health.
- Sex education- due to lack of sex education people are not concerned about safe and hygienic sexual practice.
- Adolescence related changes- the changes which take place in adolescent can lead to sex abuse and hence can affect reproductive health.

- Sexually transmitted diseases- sexually transmitted diseases can affect the reproductive health.
- Sex abuse and sex related crimes- sex abuse can cause physical injury, unwanted pregnancy, vaginal discharge, pelvic pain etc.
- Female foeticides- female foeticides can affect reproductive and sexual health of a woman.

Strategies

Family planning-

- The increase in human population, health and education of all the children as well as marriage and child bearing capacity of individuals are some special concerns for the overall reproductive health.
- Keeping in view the concerns of reproductive health, Government of India initiate 'Family Planning' programme in 1951 and 'Reproductive and Child Healthcare' programme (RCH) in 1997.
- The major objectives of the programme are to create awareness among people about various reproductive aspects and maintain a total wellbeing of the reproductive organs.
- Awareness about reproduction and social evils- Government and non-government agencies have taken various steps to create awareness about consequences of uncontrolled population growth, social evils like sex abuse, sex related crimes etc.

Sex education-

- Introduction of sex- education in schools and colleges is another step to provide right information to the youth.
- Sex education save the young people from myths and misconceptions about sex related issues.
- Knowledge about birth control methods and care of mother and child- It is important to provide information to the couples and also who are in marriageable age group about birth control methods, care of pregnent mothers, importance of breast feeding, equality to the sex and equal opportunities to the male and female child etc.

Infrastructural facilities and material support-

- Medical assistance be provided should and people should be cared in reproduction related problems like pregnancy, delivery. STDs, abortions, menstrual problems etc.
- Implementation of better techniques and new strategies from time to time is also required to provide more efficient care and assistance to people.

Ban on amniocentesis-

- Amniocentesis is a foetal sex determination test based on the chromosomal pattern in the amniotic fluid surrounding the developing embryo.
- Amniocentesis is done to determine sex legally should be banned as it increases female foeticide.

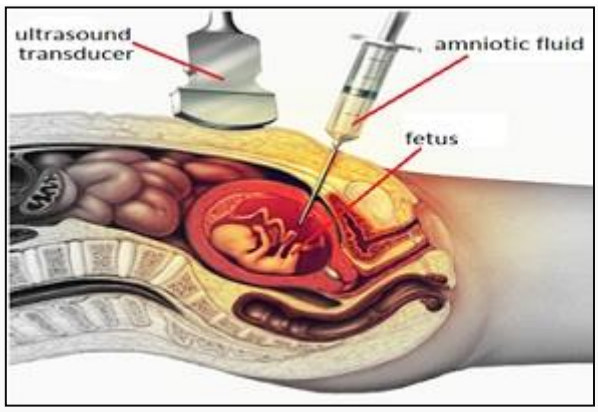


Fig. amniocentesis

Massive child immunization programme should be implemented to achieve the goal of reproductive health

Population explosion

- The rapid increase in human population over a relatively short period of time is called population explosion.
- Due to overall development in various fields like increased health facilities, better living conditions the quality of life of people has been increased which had a great impact on growth of population.

Reasons for population explosion

- A rapid decline in death rate, Maternal Mortality Rate (MMR) and Infant Mortality Rate(IMR).
- An increase in number of people in reproducible age.
- Control of diseases and better public health care with greater medical attention.

Steps to control population explosion

- People should be educated about the advantages of smaller family.
- Statutory raising the marriageable age of male and female is an effective mean to control the population.
- The couples of reproductive age are motivated to family planning by adopting birth control measures.

Fig. population explosion

Birth control

- Various contraceptives methods are available to control the birth of a child like natural method, barrier methods, intra uterine devices, oral contraceptives, injecting hormones, surgical methods.
- Natural methods- this method avoid chances of meeting of sperms and ovum.

Periodic abstinence-

1. In this method, couples avoid coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected.
2. This period is also called as **fertile period** as the chances of fertilization is very high during this period.

Withdrawal or coitus interruptus- In the method, the male partner withdraws the penis from the vagina just before ejaculation to avoid insemination.

Lactational amenorrhea-

1. The menstrual cycle and ovulation do not occur during intense lactation and so the chances of pregnancy are low.
2. This method is effective only upto six months after child birth.

Barrier methods- here, barriers are used to prevent the physical contact of sperms and ovum.

Condoms-

1. The barriers which are made of thin rubber latex sheath to cover the penis or vagina in males and females respectively are called condoms.
2. Also prevent the spread of sexually transmitted diseases

- Condoms trap the ejaculate and prevent semen from entering the vagina

Example- **Nirodh,** is a popular brand of condoms for males.

Diaphragms, cervical caps and vaults- made up of rubber which are inserted in female reproductive tract to cover the cervix during coitus to prevent conception by blocking the entry of sperms through the cervix.

Intra uterine devices-

- Inserted by doctors in the uterus through the vagina which increases the phagocytosis of sperms within the uterus.
- These are available as non-medicated IUDs such as **CuT, Cu7, multiload 375** and hormone releasing IUDs such as **LNG-20, Progestasert.**

Oral contraceptive pills-

- Small doses of progesterone or **progesterone- estrogen** combinations are used by the females in the form of tablets.
- These are taken daily for 21 days starting from the fifth day of menstrual cycle and after a gap of 7 days it has to be repeated again.

- Hormonal pills prevent ovulation and implantation by inhibiting the secretions of FSH and LH from the pituitary glands.
- **Saheli**, an oral contraceptive pill is a non- steroid preparation used by females.

Fig. contraceptive pills

Injections of hormones-

- **Progesterone** along with other **estrogen** are used by females as injections under the skin,
- The effective period is longer than pills but action is similar.

Surgical methods-

Vasectomy-

1. The sterilization process in males is called vasectomy.
2. In this process, a small part of the vas deferens is removed or tied up through a small incision on the scrotum.

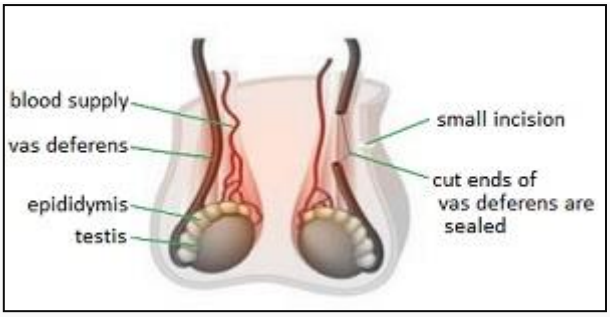


Fig. vasectomy

Tubectomy-

1. The sterilization procedure in the females is called as tubectomy.
2. In this method, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina.

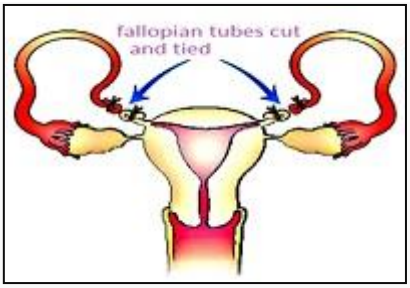


Fig. Tubectomy

Medical termination of pregnancy (MTPs)

- Intentional or voluntary termination of pregnancy is called medical termination of pregnancy.
- Medical termination of pregnancy is also termed as
- MTPs are used to get rid of unwanted pregnancies and the pregnancies which could be harmful or fatal to the mother or to the foetusor both.
- MTPs are safe upto 12 weeks i.e. the first trimester or pregnency.
- Government of India legalized MTP in 1971.

Fig. abortion

Sexually transmitted diseases(STD's)

Diseases which are transmitted through sexual intercourse with infected person are called sexually transmitted diseases or **venereal diseases** or **reproductive tract infections. (RTI)**

Gonorrhea, syphilis, genital herpes, genital warts, hepatitis, AIDS, chlamydiasis are sexually transmitted diseases.

STD's can transmit through-

- Sexual contact with infected persons.
- Sharing of needles or surgical instruments contaminated with infected blood.
- Transfusion of contaminated blood.
- STDs can also be transmitted from an infected mother to the foetus.

STDs can be prevented by taking preventive measures like-

- Avoid sex with unknown persons or multiple persons.
- Always use condoms during sex.
- If the early symptoms like itching, fluid discharge, slight pain, swellings occur in the genital regions, one must consult a doctor.

STDs if left untreated can lead to pelvic inflammatory diseases, abortions, still births, ectopic pregnancies, infertility or even cancer of the reproductive tract.

Infertility

Inability to give birth to a child or inability to conceive is called infertility.

The reasons for infertility can be physical, hereditary, drugs, psychological etc.

The couples could be assisted to have their own child through certain special techniques called as **assisted reproductive technologies.**

Assisted reproductive technologies-

1. In vitro fertilization (IVF)-

- IVF involves fertilization of ovum outside the body followed by embryo transfer (EF).
- Ova from the wife/donor female and sperms from the husband/donor male are collected and are induced to get fuse to form zygote in the laboratory.
- The zygote is then transferred into the fallopian tube called as **zygote intra-fallopian transfer (ZIFT).**
- If the embryo is with more than 8 blastomeres, it is transferred into the uterus called as **intra uterine transfer (IUT).**
- The transferred embryo completes their further development within the uterus.

Fig. embryo formed by IVF

2. Gamete intra fallopian transfer (GIFT)- Here, ovum is collected from a donor female and is transferred into the fallopian tube of another female who cannot produce ovum, but can provide suitable environment for fertilization and further development of embryo.

3. Intra cytoplasmic sperm injection (ICSI)- In this method, sperm is directly injected into the ovum under lab conditions.

Fig. injection of sperm into ovum

4. Artificial insemination or intra uterine insemination - Here the semen collected either from the husband or a healthy donor is artificially introduced either into the vagina or into the uterus of the female.

INTRODUCTION

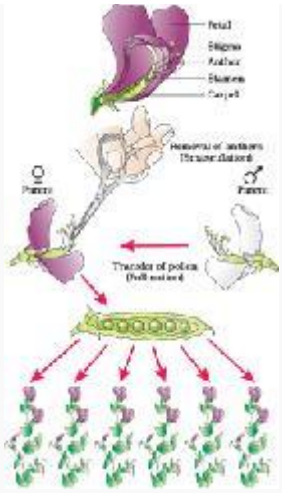
- Genetics is the branch of biology which deals with inheritance and variations of characters from parents to offspring.
- Father of Genetics is Gregor Johann Mendel.
- Inheritance is the process of passing characters from parent to progeny. It is the basis of heredity.
- Variations is the degree by which progeny differs from parents. Variations can be in terms of physiology, morphology and behavioral characteristics of individual belonging to same species. Variations arise due to reshuffling of chromosomes, crossing over, mutations and effect of environment.

MENDEL'S LAW OF INHERITANCE

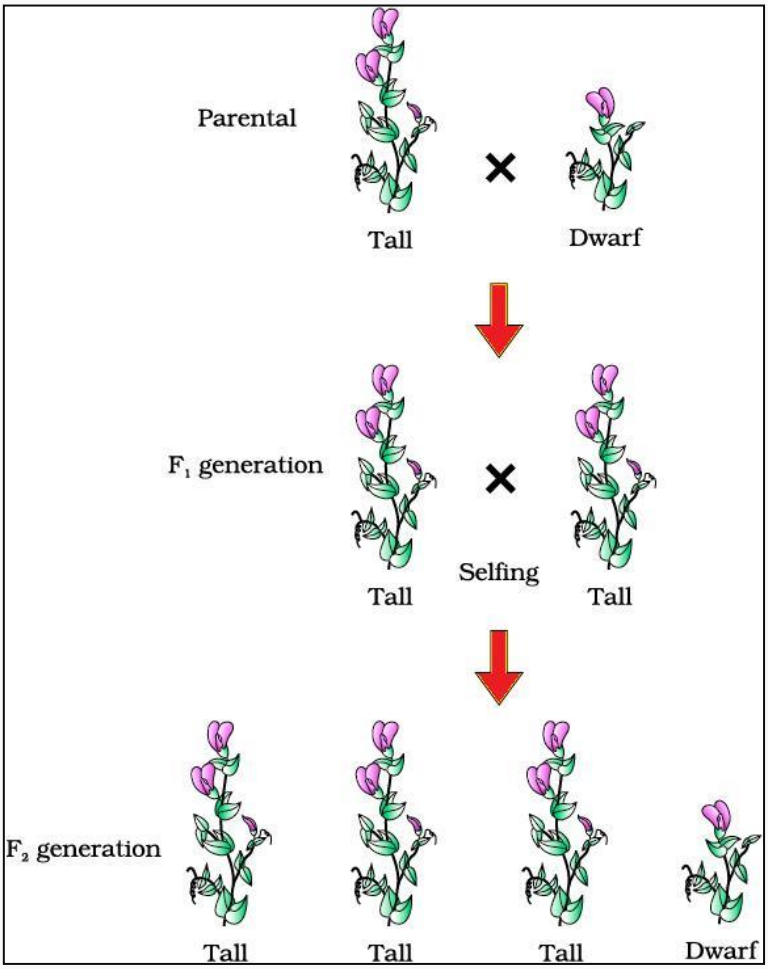
- Mendel conducted hybridization experiments on garden peas for seven years (1856-1863). On the basis of these experiments he proposed the laws of inheritance.
- He selected the characters that has two opposing traits and concluded his hybridization experiments on 14 true-breeding pea plant varieties. True-breeding means a breeding line which has undergone continuous self-pollination and shows stable trait inheritance and expression for many generations.

S. No.	Character	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

- Reasons for selecting garden pea plant:
- Easily available on large scale.
- There are many varieties with distinct characteristics.
- They are self-pollinated and can be cross-pollinated easily.
- They have a short life cycle.
- Reason for success of Mendel:
- He studied one character at a time.
- He used available techniques to avoid cross pollination by undesirable pollen grains.
- He applied mathematics and statistics to analyze the results obtained from him.
- Mendel selected seven contrasting characters for the experiment.
- INHERITANCE OF ONE GENE (MONOHYBRID CROSS)
- Mendel crossed tall and dwarf pea plant and collected the seeds from them. Seeds were used to generate plants of first generation (F_1 or Filial progeny). Mendel observed that all the first generation plants were tall, none of them were dwarf. He made similar observations for the other pairs of traits. He concluded that F_1 generation resembled either one of the parents.

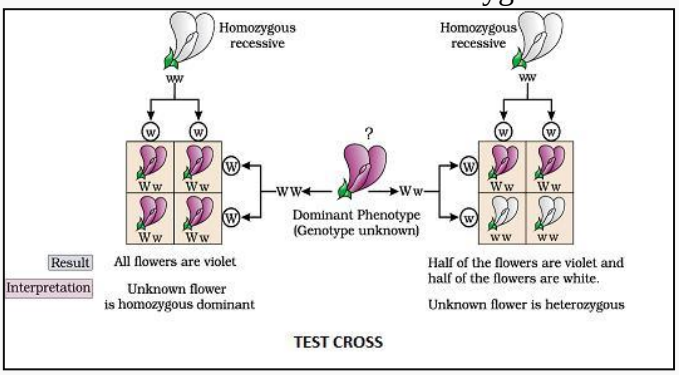


- Pic shows STEPS IN MAKING A CROSS IN PEA
- He then self-pollinated the tall F_1 plants and he observed that some of them were dwarf. Out of all, ¼th were dwarf and 3/4th were tall.

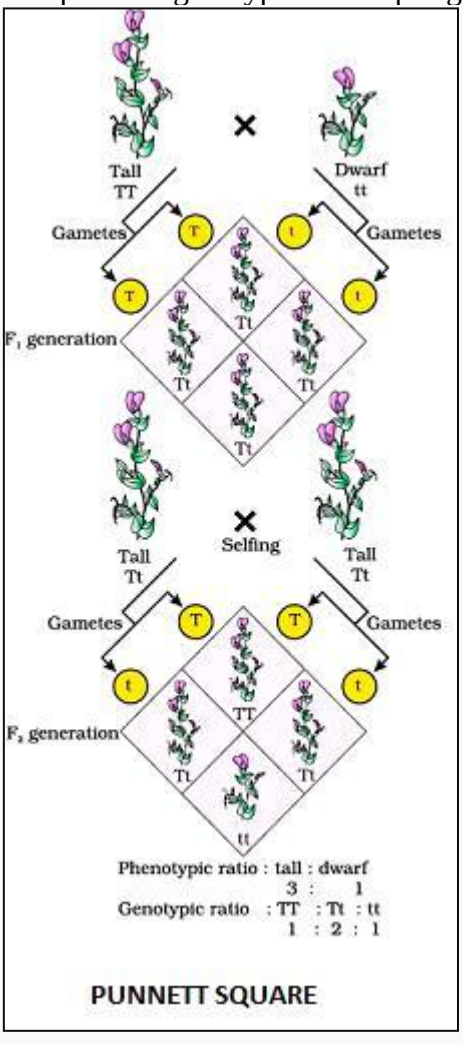


- Pic shows Monohybrid cross.
- Similar results were obtained for other traits too. In F_2 generation, both the traits were expressed in proportion of 3:1. Dominant trait in F_2 is about thrice of the recessive from. These contrasting traits did not show any blending at either F_1 or F_2 stage.
- Based on these observations, he concluded that something was being stably passed from one generation to the other. He named it 'factors' which are now called as 'genes'.
- Gene is the unit of inheritance. It contains information that is required to express a particular trait in an organism. Genes which code for a pair of contrasting traits are known as 'alleles'. They are slightly different for a same gene.

- For representing traits using alphabetical symbols, capital letter is used for the trait expressed at F_1 generation and small letter is used for the other one.
- For example: T for tall trait
- t for dwarf.
- T and t are alleles of each other. Pair of alleles for height in the plants are TT, Tt and tt.
- TT and tt are homozygous. TT and tt are called genotype of the plant while the description terms tall and dwarf are phenotype. Tt represents heterozygous.
- Test cross is the cross between an individual with dominant trait and a recessive organism. It helps us to understand whether the dominant trait is homozygous or heterozygous.



- Pic shows Test Cross.
-
- The production of gametes by the parents, formation of zygotes can be easily understood by Punnett square. It was given by British geneticist RC Punnett. It is a graphical representation used to calculate probability of all possible genotypes of offspring in a genetic cross.



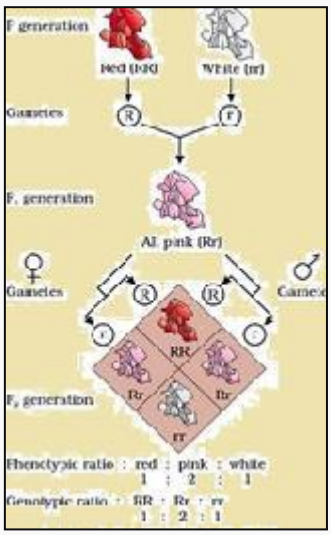
- Pic shows Punnett Square.

- It is typically used for monohybrid cross conducted by Mendel between true-breeding tall plants and true-breeding dwarf plants.

LAW OF DOMINANCE

The dominant allele masks the effect of recessive allele. It explains the expression of only one of the parental characters in a monohybrid cross in F_1 and expression of both in F_2.

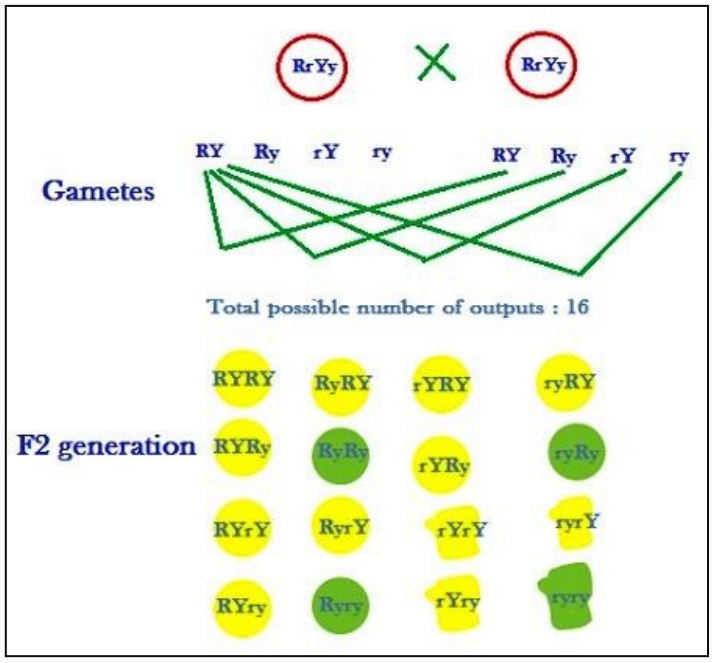
- Characters are controlled by discrete units called factors.
- In a dissimilar pair of factors one member of pair dominate the other. For example: allele of tallness (T) is dominant over allele of dwarf (t).
- LAW OF SEGREGATION
- It states that every individual possess two alleles of a gene and these alleles segregate from each other during gamete formation (at the time of meiosis). Alleles do not blend and both the characters are recovered during gamete formation in F_2 generation.
- Homozygous individuals produce one type of gametes while heterozygous individuals produce two types of gametes each having one allele with equal proportion.

- **INCOMPLETE DOMINANCE**
- When the experiments were repeated on other traits on other plants, sometimes it was found that F_1 progeny does not resemble either of the parent, it was a mixture of two.
- For example: Snapdragon or Antirrhinum sp. or dog flower – inheritance of flower color.
- 

- Pic shows Incomplete dominance.
- Genotypic ratio was same as we would expect in Mendelian monohybrid cross but phenotypic ratio is changed.

CO-DOMINANCE

- The two alleles are able to express themselves independently when present together.
- For example: ABO blood grouping in humans is controlled by gene I. It has three alleles I^A, I^B and i.
- I^A, I^B are dominant over i. If I^A and I are present, only I^A expresses. I^A and I^B are present both of them express each other.
- ABO blood grouping is also a good example of multiple alleles.
- Mendel also worked with two characters on pea plant. He chose color and shape of the seed to explain the inheritance of two genes.
- Y – dominant yellow color
- y – recessive green color
- R – round shape of the seed
- r – wrinkled shape of the seed

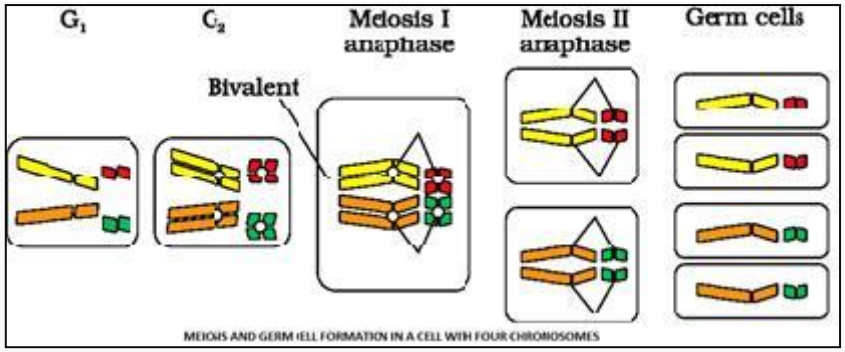


- Phenotypic Ratio:
- Round yellow : round green : wrinkled yellow : wrinkled green
- 9 : 3 : 3 : 1
- Pic shows Dihybrid cross.

CHROMOSOMAL THEORY OF INHERITANCE

- Mendel published his work on inheritance of characters in 1865 but was unrecognized till 1900.
- In 1900, de Vries, Correns and von Tschermak worked independently and rediscovered Mendel's results.
- In 1902, Walter Sutton and Theodore Boveri studied the chromosomal movement during meiosis.
- According to this theory,

1. Genes are located at specific locations on the chromosomes.
2. Chromosomes as well as gene both occur in pairs.
3. Homologous chromosomes separate during meiosis.
4. Fertilization restores chromosome number to diploid condition.
5. Chromosomes segregate as well as assort independently.



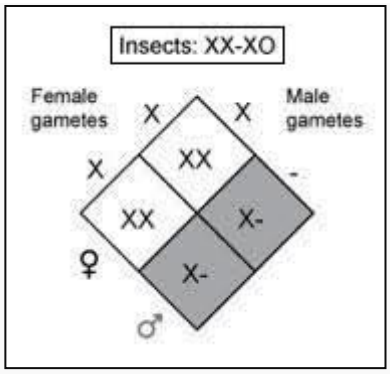
Pic shows Meiosis and Germ cell formation in a cell with four chromosomes.

LINKAGE AND RECOMBINATION

- Morgan carried out several dihybrid crosses in *Drosophila* to study genes that were sex-linked.
- Morgan hybridized yellow-bodied, white-eyed females to brown-bodied, red-eyed males and intercrossed those F_1
- According to him, two genes did not segregate independent of each other and F_2 ratio deviated from 9:3:3:1. This concluded that genes are linked. This process is called linkage.
- Recombination is the rearrangement of genetic material. The generation of non-parental gene combination during dihybrid cross is called recombination. When genes are located on same chromosome, they are tightly linked and show less linkage. This is responsible for variation.

SEX DETERMINATION

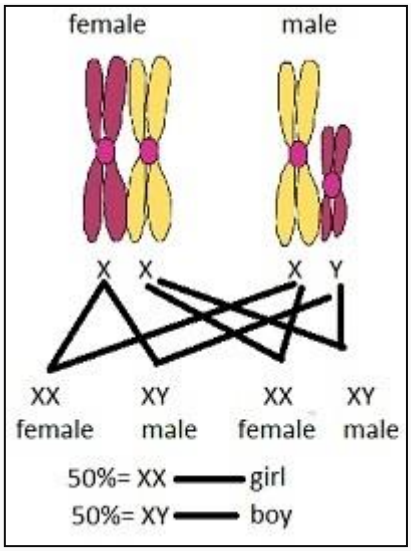
- Different organisms have different types of sex determination.
- Cytological observations in insects led to the development of concept of genetic or chromosomal basis of sex-determination.
- In 1891, Henking traced a specific nuclear structure all through spermatogenesis in few insects.
- He observed specific nuclear structure is located on 50 per cent of sperms only. The discovered X-body but was unable to explain its significance.
- In insects, XO type of sex determination is present. All the eggs have an additional X-chromosome besides the autosomes. Some sperms bear X-chromosome where as some do not.
- Eggs fertilized by sperm having having X-chromosome become females and those fertilized by sperms that do not have an X-chromosome becomes males.
- For example: grasshopper (males have only one X-chromosome besides autosomes and females have a pair of X-chromosomes)



Pic shows Sex determination in Insects.

SEX DETERMINATION IN HUMANS

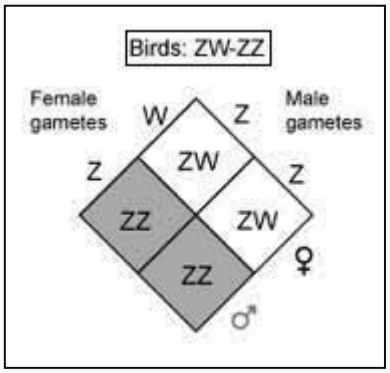
- XY type of sex determination
- Males (XY), Females (XX)
- Drosophila also has XY type of sex determination.



Pic shows sex determination in humans.

SEX DETERMINATION IN BIRDS

- ZW type of sex determination is seen in birds.
- Females have ZW and males have ZZ chromosomes.
- In birds sex is determined by type of ovum.
- In birds, females are heterogametic.



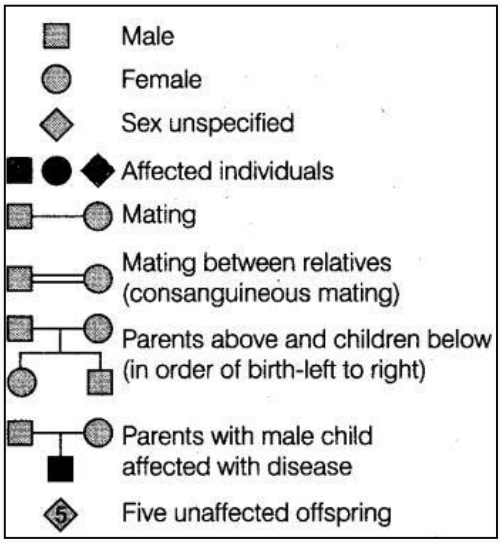
Pic shows Sex determination in birds.

MUTATION

- Mutation is any change in DNA sequence.
- It is a heritable change.
- Mutations can affect genotype as well as phenotype.
- It also leads to variations.
- Types of mutations: Point mutations, frame-shift mutations.
- Mutations that occur due to change in a single base pair of DNA is called as point mutations. For example: sickle cell anemia
- When there is deletion or insertion of base pairs of DNA, it causes frame-shift mutations.
- Mutagens are the chemical and physical factors that induce mutations. UV rays can also cause mutations.

GENETIC DISORDERS

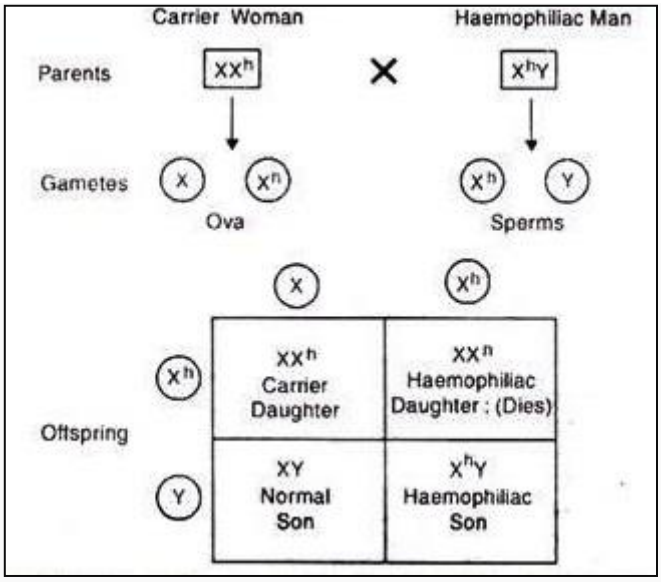
- Analysis of traits in several generations of family is called pedigree analysis.
- Inheritance of a particular trait is represented in the family tree over generations.
- Symbols used in pedigree analysis



Pic shows symbols of pedigree analysis.

MENDELIAN DISORDERS

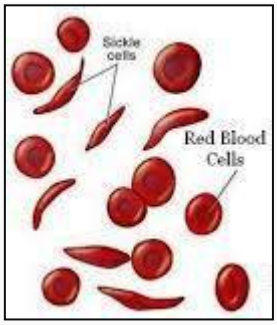
- Autosomal disorders – cystic fibrosis, sickle cell anaemia, myotonic dystrophy
- Sex-linked – haemophilia, colour blindness
- HAEMOPHILIA – sex-linked recessive disease
- A single protein that is a part of the cascade of proteins involved in the clotting of blood is affected.
- In affected individual, a simple cut will result in non-stop bleeding.
- Heterozygous female (carrier) can transmit the disease to son.
- Possibility of female becoming a haemophilic is extremely rare.



Pic shows cross between carrier haemophilic women and haemophilic man.

SICKLE-CELL ANAEMIA

- Autosome linked recessive trait
- It can be transmitted from parents to the offspring when both the parents are carrier for the gene.
- Disease is controlled by a single pair of allele, Hb^A and Hb^S.
- $Hb^S Hb^S$ homozygous shows the diseased phenotype.



Pic shows the difference between normal and sickle cells.

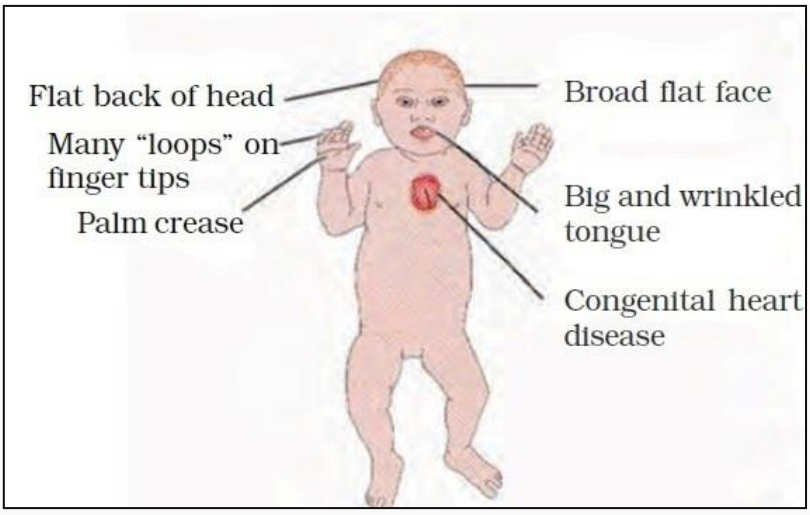
- Heterozygous individuals $Hb^A Hb^S$ show normal phenotype but they are carrier of the disease.
- The defect is caused due to substitution of Glutamic acid (Glu) by Valine (Val) at the sixth position of the beta globin chain of the haemoglobin molecule. It results from single base substitution from GAG to GUG at sixth codon of the beta globin.
- Due to this, mutant haemoglobin is formed. It undergoes polymerization under low oxygen tension causing the change in the shape of the RBCs from biconcave to elongated sickle-like.

PHENYLKETONURIA

- Inborn error of metabolism, autosomal recessive trait.
- Affected individual lacks an enzyme that converts the amino acid phenylalanine into tyrosine.
- Due to which, phenylalanine gets accumulated and converted into phenylpyruvic acid and other derivatives.
- This causes mental retardation.

CHROMOSOMAL DISORDERS

- It is caused due to absence or excess or abnormal arrangement of one or more chromosomes.
- Aneuploidy – failure of segregation of chromatids during cell division cycle results in the gain or loss of chromosome.
- Polyploidy – Failure of cytokinesis after telophase stage of cell division results in an increase in a whole set of chromosomes in an organism.
- Down’s syndrome – gain of extra copy of chromosome 21 (trisomy 21)
- It was first described by Langdon Down (1866).
- Affected individual is short with small round head, furrowed tongue and partially open mouth.
- Broad palm with characteristic palm crease.
- Physical, psychomotor and mental development is retarded.



Pic shows baby suffering from Down's syndrome.

- Turner's syndrome – loss of an X-chromosome in human females i.e. 45 with XO
- Such females are sterile as ovaries are rudimentary
- Klinefelter's syndrome – presence of an additional copy of X-chromosome resulting into karyotype, 47, XXY.
- Sterile individuals

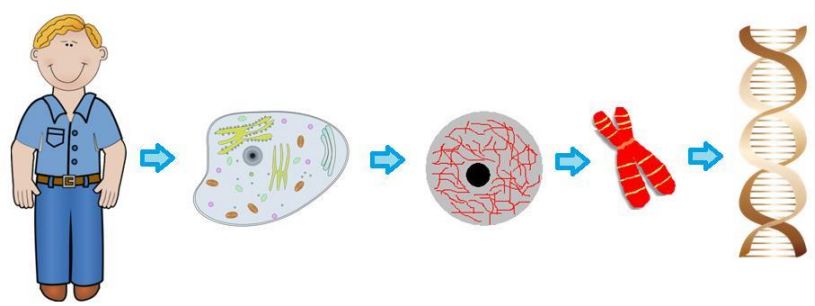
Introduction

We will look at the phenomenon of Inheritance at a molecular level.

DNA is the genetic material for most of the organisms, except for few exceptions like viruses where RNA is the genetic material.

DNA helps in synthesis of RNA, which in turn helps in protein synthesis, and these proteins control traits of individuals.

In this lesson, we will learn how DNA was discovered to be the genetic material, and how this entire process of protein synthesis takes place.



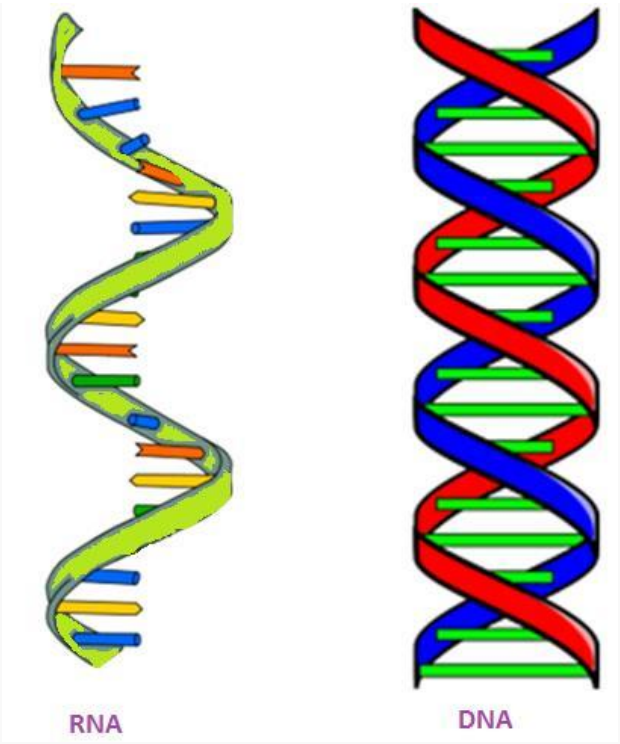
Structure of Nucleic Acids

Nucleic acids are the biomolecules which play a very important role in the process of Inheritance.

Two types of nucleic acids exist: DNA (Deoxyribo Nucleic Acid) and RNA (Ribo Nucleic Acid).

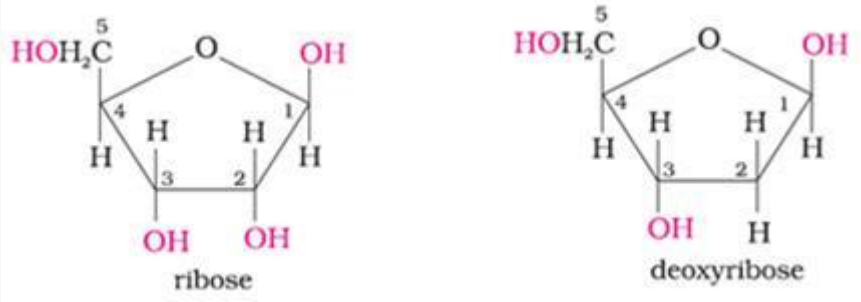
DNA has a double-stranded structure. It is a polynucleotide whose monomer units are deoxyribonucleotide. Length of DNA is determined by number of nucleotides in it.

RNA, on the other hand, has a single-stranded structure. It is also a polymer whose monomer units are ribonucleotide.

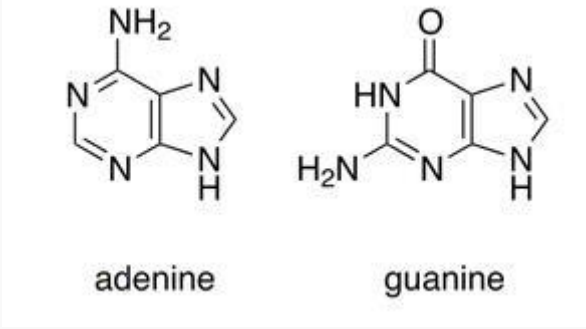


A nucleotide has 3 components:

- Pentose sugar
  - Monosaccharide with 5 Carbon atoms
  - Ribose sugar in RNA
  - Deoxyribose sugar in DNA

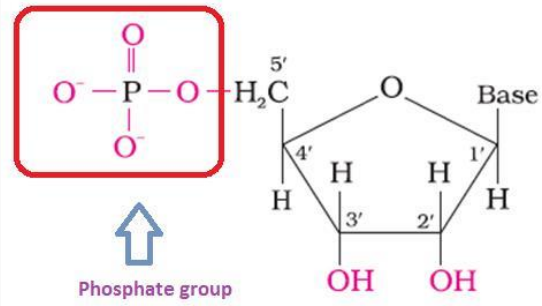


- Nitrogenous base
  - Nitrogen containing compound with properties of a base
  - 2 types: Purines, Pyrimidines
    - Purine
      - Heterocyclic aromatic organic compound
      - 9-membered ring
      - Examples: Adenine, Guanine



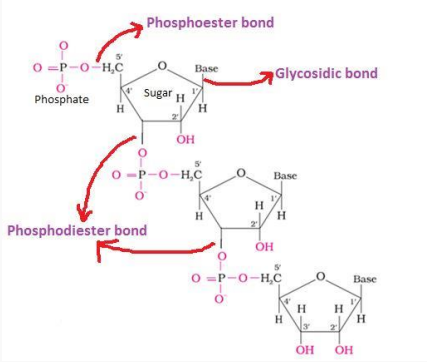
- Pyrimidine
  - Heterocyclic aromatic organic compound
  - 6-membered ring
  - Examples: Cytosine, Uracil, Thymine

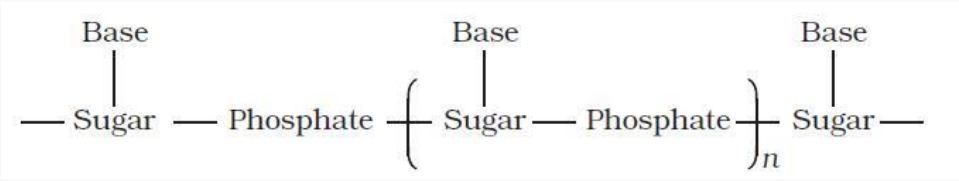
- Phosphate group
  - Inorganic salt of phosphorus
  - Forms backbone of polynucleotide chain along with the sugar



Formation of a polynucleotide takes place using the following linkages:

1. Nitrogenous base is linked to the pentose sugar through a N-glycosidic bond to form a **nucleoside**
2. A phosphate group is linked to 5'-OH of a nucleoside through phosphoester bond to form a **nucleotide**
3. Multiple nucleotides are joined together through 3'-5' phosphodiester bond to form a polynucleotide

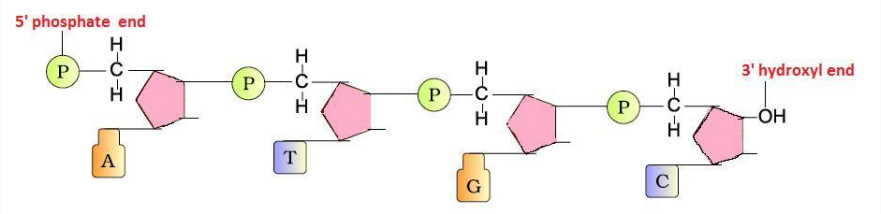




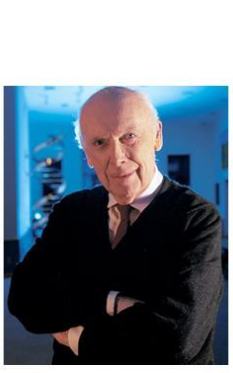
Detailed structure of DNA

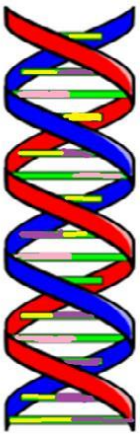
DNA polynucleotide chain has two free ends:

- 5’ end
  - Free phosphate moiety at 5'-end of ribose sugar
- 3’ end
  - Free 3'-OH group of ribose sugar



Watson & Crick were the first to propose the Double helix structure of DNA, based on X-ray diffraction technique.





DNA Double-helix model

- DNA is composed of two polynucleotide chains
- Sugar-phosphate forms the backbone
- Nitrogenous bases form the interior, paired through H- bonds

- Complementary base pairing is an important feature of DNA structure
- The two polynucleotide chains have anti-parallel polarity
- Two chains are coiled in a right handed fashion forming a right-handed helix
- Uniform distance is maintained between the two strands of helix

Packaging of DNA helix

- Length of DNA is found to be far greater than dimension of a typical nucleus

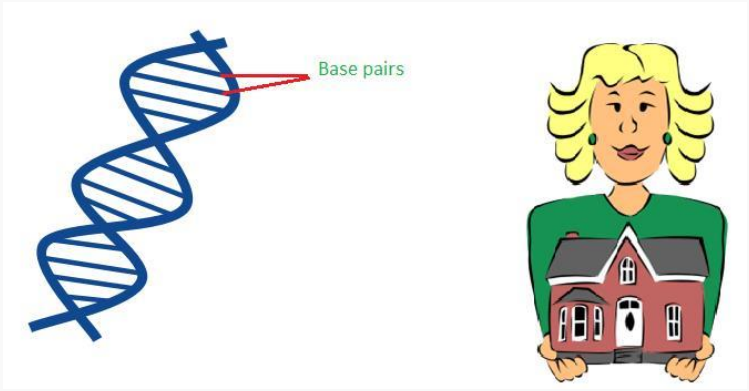
Total number of base pairs in a typical mammalian cell= $6.6 * 10^9$

Distance between two base pairs= 0.34nm

Therefore, Length of DNA= $0.34 *10^{-9} *6.6 *10^9 = 2.2m$

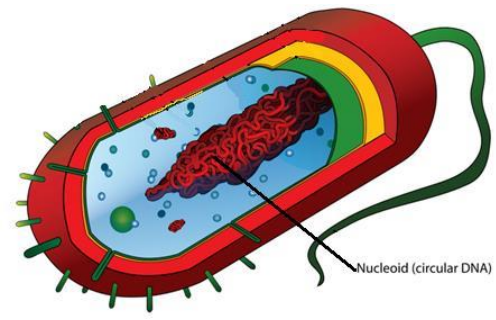
Size of a nucleus is of the order of $10^{-6}m$

So, Length of DNA is greater than the size of nucleus (It is as if the house is smaller than the person who wants to stay in).

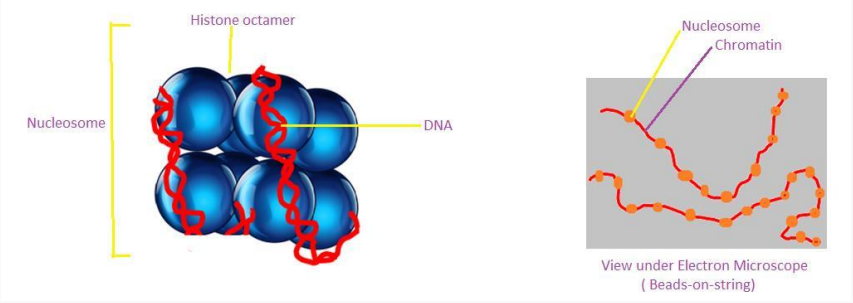


DNA is packaged very strategically to fit inside the nucleus.

- In Prokaryotes, DNA is organized into loops held by proteins. The region where DNA is present is termed as ‘Nucleoid’.

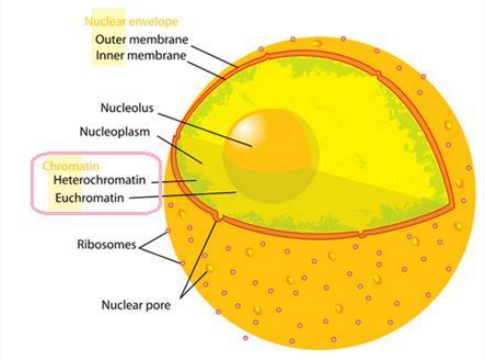


- In Eukaryotes, there exist positively charged basic proteins called Histones.
- DNA wrap around the histone octamer (group of 8 histone proteins) to form a Nucleosome. Each nucleosome contains 200 base pairs of DNA helix. Nucleosomes in chromatin are seen as ‘beads-on-string’ under Electron microscope.



Based on different types of DNA packaging, there are two forms of Chromatin.

- Euchromatin
  - Less condensed structure with looser DNA packaging
  - Lightly stained when observed under microscope
  - Contains less DNA
  - Transcriptionally active
  - Found in eukaryotes & prokaryotes
- Heterochromatin
  - Highly condensed structure with tighter DNA packaging
  - Dark stained when observed under microscope
  - Contains more DNA
  - Transcriptionally inactive, as those regions of the genes which need to interact with proteins for transcription is inaccessible.
  - Found in eukaryotes



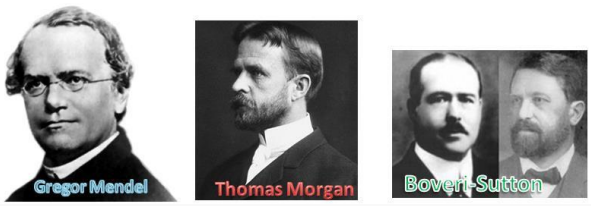
Search for the Genetic Material

The study of Genetics started with Gregor Mendel who introduced ‘factors’ for inheritance. Boveri-Sutton theory later gave the chromosomal theory of inheritance.

The concept of inheritance was understood at the level of chromosomes further when Morgan came up with the concept of linkage & recombination at chromosomal level.

It was taken a step forward in 1926 when experiments were being performed to understand Inheritance at a molecular level.

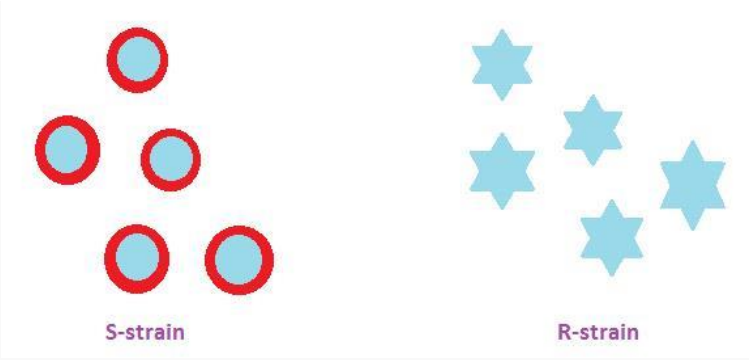
The search was for the molecule which acts as a genetic material.



Griffith's Experiment

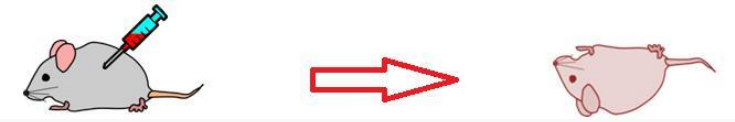
Griffith experimented with *Streptococcus pneumoniae* bacteria. This bacteria causes Pneumonia.Two strains of this bacteria were used R-strain & S-strain.

- S strain
  - Smooth mucous polysaccharide coat
  - Resistant to immune system
  - Virulent
- R strain
  - Lacks the coat
  - Destroyed by immune system of the host
  - Non-virulent

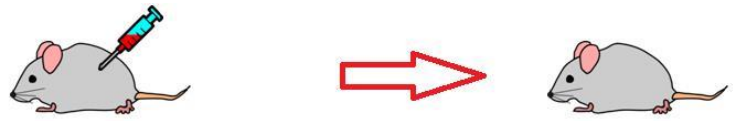


The experiment was performed in multiple steps.

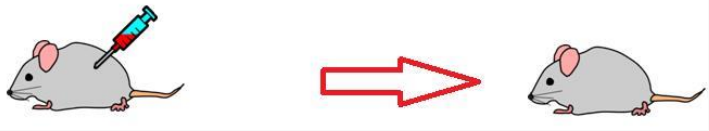
1. S-strain (virulent) was injected into mouse. It was found that the mouse died of pneumonia



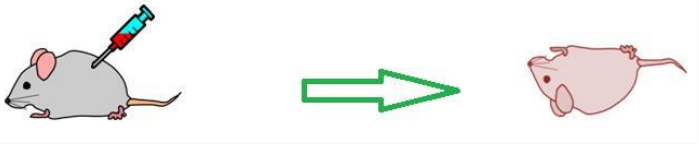
2. R-strain (non-virulent) was injected into mouse. It was found that the mouse remained alive



3. Heat killed S-strain (S-strain bacteria were killed by heating) was injected into mouse. It was found that the mouse remained alive



4. Heat killed S-strain & live R-strain were injected into mouse. It was found that the mouse died of pneumonia



Griffith found that Live S-strain bacteria could be recovered from the dead mouse (Step 4).

Griffith thus arrived at the following conclusion:

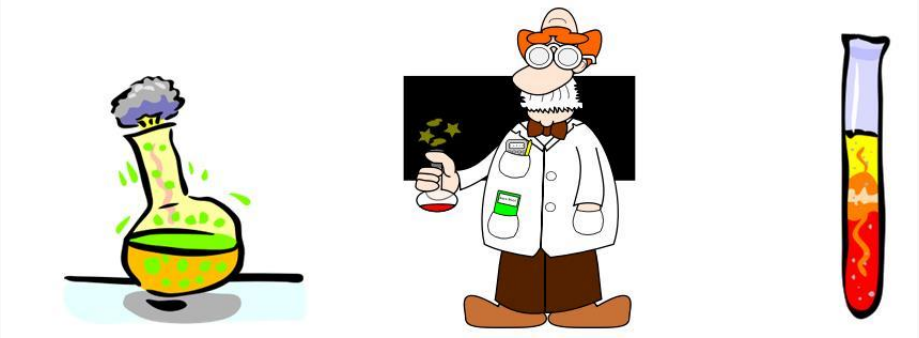
- Something caused bacteria to change from one type (R) to another type (S)
- Some 'Transforming principle', transferred from heat-killed S strain to R strain and transformed it virulent.

However, the biochemical nature of the 'Transforming principle' was still unknown.

Biochemical nature of Transforming Principle

Bacteriologists performed a series of experiments to identify the Transforming Principle.

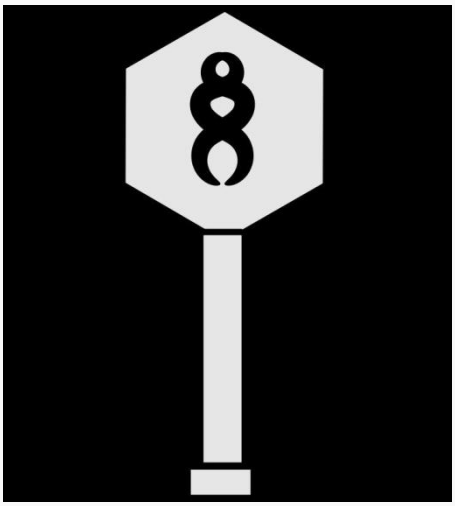
- Transforming principle precipitated with alcohol. This showed it was not Carbohydrate.
- Transforming principle could not be destroyed with Proteases. Thus, it was not Protein.
- Transforming principle could not be destroyed with Lipases. This proved it was neither Lipids.
- Transforming principle could not be inactivated with Ribonuclease, hence not RNA.
- Transforming principle could be inactivated with Deoxyribonuclease.



Transforming principle was DNA. Therefore, DNA was the genetic material.

Hershey-Chase Experiment

Hershey-Chase experiment was performed in 1952 to further confirm that DNA was the genetic material. They experimented with Bacteriophages. Bacteriophages are the viruses that infect & replicate within bacteria.



Bacteriophages were grown in two different mediums.

- Some bacteriophages were grown in **radioactive phosphorus medium**. It was found that these Bacteriophages came up with **radioactive DNA**
- Some bacteriophages were grown in **radioactive sulfur medium**. It was found that these Bacteriophages with **radioactive protein**.

1. Bacteriophages with Radioactive DNA were brought in contact with bacteria
2. Bacteria got infected
3. Agitated in a blender to separate phage particles from bacterial cells
4. Centrifugation leaves Phage particles as supernatant
5. Bacterial cells were found to be radioactive
6. No radioactivity was detected in the phage particles

2. Bacteriophages with Radioactive protein were brought in contact with bacteria
3. Bacteria got infected
4. Agitated in a blender to separate phage particles from bacterial cells
5. Centrifugation leaves Phage particles as supernatant
6. Phage particles were found to be radioactive
7. No radioactivity was detected in the bacterial cells

It was therefore concluded that it was not the proteins, rather DNA which entered into the bacteria. Therefore, DNA causes the replication of viruses inside the bacteria.

DNA was thus proved to be the genetic material.

Criteria for Genetic Material

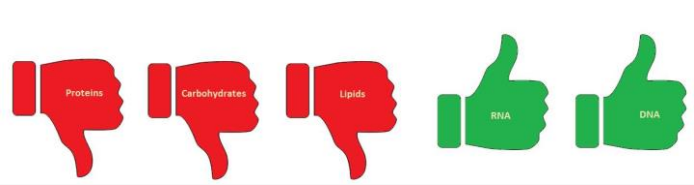
DNA was found to be the prominent genetic material in most organisms.

Exceptions were some viruses where RNA was the genetic material.

What made DNA eligible to be the genetic material, and not other molecules like proteins, carbohydrates etc.

Important criteria to be fulfilled to be a genetic material are:

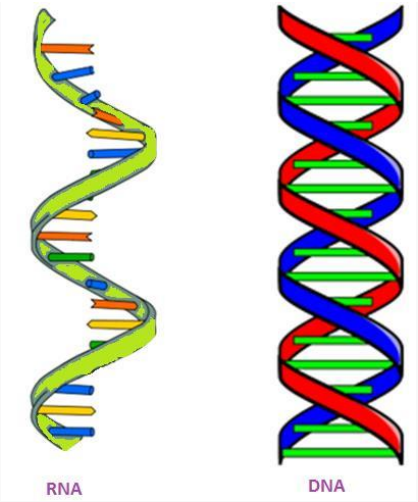
- Capable of replicating itself
- Chemically & structurally stable
- Provide scope for mutation which can lead to evolution
- Capable of expressing itself in the form of 'Mendelian Characters'



Most of the other molecules like proteins, carbohydrates, lipids failed to fulfill the above mentioned criteria.

However, RNA could also fulfill the criteria; still DNA was a preferred genetic material over RNA because of the following reasons:

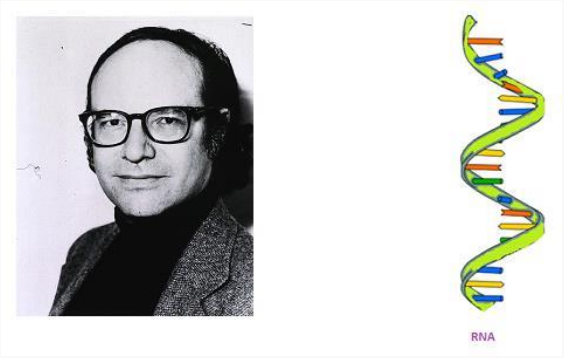
- DNA is structurally more stable than RNA
- DNA is chemically more stable than RNA
- DNA has double-stranded structure which provides better ability to rectify errors during replication
- DNA can't code directly for protein synthesis & thus depends on RNA



DNA was thus used for storage of genetic information due to its structural & chemical stability. RNA, on the other hand was used for expression of genetic information as it could directly code for proteins.

RNA World

The question that was bothering everyone was which molecule (DNA or RNA) started to exist in the world before. Walter Gilbert in 1986 hypothesized that there was once an RNA world. According to this hypothesis, all that we see today has descended from an RNA world.



RNA world was a kind of hypothetical world where RNA performed all the activities which are today performed by DNA & proteins. DNA later evolved from RNA with chemical modifications which made it more stable.

There are many scientists who do not agree to this hypothesis. Research is still going on to validate the RNA world hypothesis.

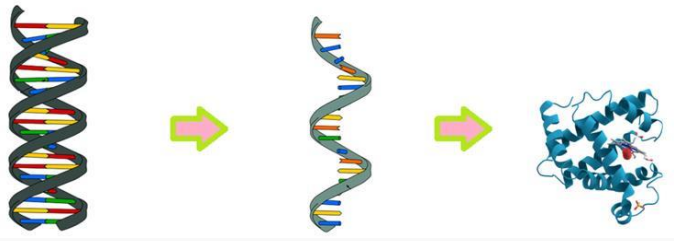
Central Dogma of Molecular Biology

Francis Crick in 1956 proposed the hypothesis of Central Dogma This explains the flow of genetic information in any biological system.

Three major classes of biopolymers are involved in this flow: DNA, RNA and Proteins.

With these 3 categories of biopolymers, a total of 9 transfers can be possible which are grouped under the following categories:

1. General transfers: These transfers occur in most of the organisms
2. a) DNA -> DNA (Replication)
3. b) DNA -> RNA (Transcription)
4. c) RNA -> Proteins (Translation)



In this lesson, we will discuss about these General transfers in detail.

2. Special transfers: These occur in viruses where RNA is the genetic material
3. a) RNA -> RNA
4. b) RNA -> DNA

5. c) DNA -> Proteins
6. Unknown transfers: These transfers might be possible but yet not known
7. a) RNA -> RNA
8. b) RNA -> DNA

c) DNA -> Proteins

NA Replication

Replication is the process of reproducing or creating a copy of something. In this topic, we will see how DNA creates a copy of itself.

Various hypotheses were proposed by various scientists regarding the replication model of DNA i.e. how DNA replicates. Some of these were:

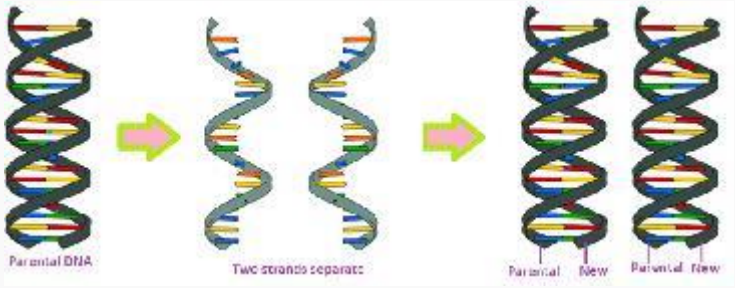
- Semi-conservative DNA replication model
- Conservative DNA replication
- Dispersive DNA replication

Semi-conservative DNA replication model

Watson & Crick suggested the '**Semi conservative DNA replication**' model. According to this model, the two strands of DNA separate.

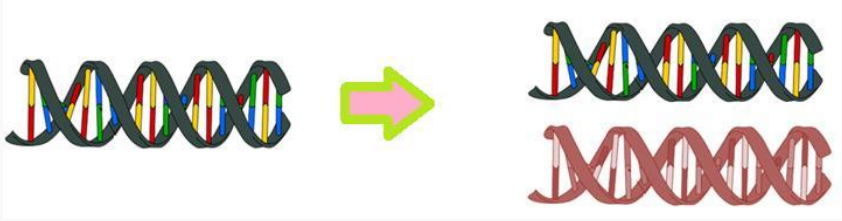
Each strand act as template for synthesis of a new strand. The new strand is synthesized based on complementary base pairing with the template.

Each new DNA molecule has 1 parental strand & 1 one newly formed strand. This is how the original DNA molecule (1 copy) gives rise to two copies.



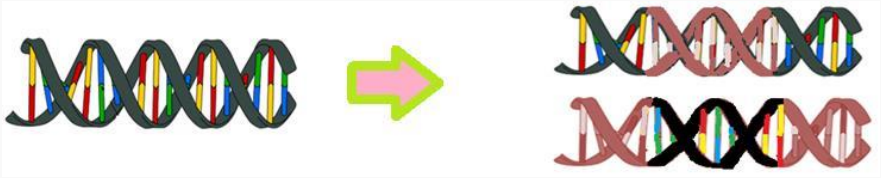
Conservative DNA replication

According to this model, Complete DNA molecule (and not just one strand) acts as a template for new synthesis.



Dispersive DNA replication

According to the Dispersive model, the new DNA is synthesized in short pieces. A part of the old strand is attached to the end of a part of newly synthesized strand.



Meselson-Stahl Experiment

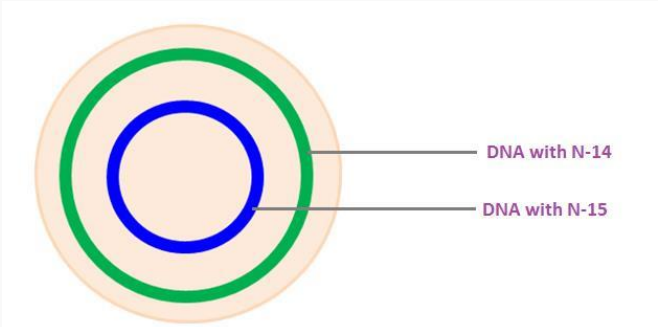
This experiment was performed to prove the **semi conservative nature** of DNA replication. Matthew Meselson & Franklin Stahl experimented with bacteria E.coli in 1958.

Basis of the Experiment

1. If E.coli was grown in a medium with N-15 (isotope of Nitrogen), the E.coli had DNA with N-15 isotope.

2. If E.coli was grown in a medium with N-14 (more abundant isotope of Nitrogen), the E.coli had DNA with N-14 isotope.

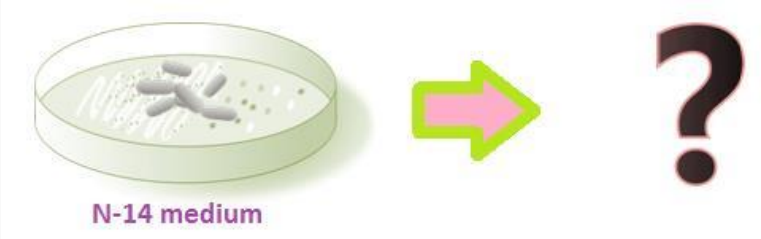
It was then observed with Centrifugation that DNA with N-15 is heavier than that of N-14.



Making use of the fact that DNA with N-15 is heavier than DNA with N-14, this experiment was performed.

Step 1. E.Coli was grown in a medium with N-15 for several generations

Step 2. E.coli with only N-15 in their DNA were transferred to a medium with N-14

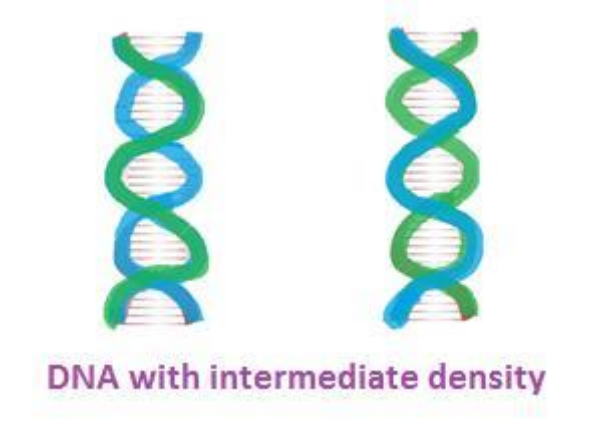


Cells of E.coli were allowed to divide. Sample was taken and DNA was extracted periodically as cell division continued to check what type of DNA is being formed now. One replication in E.coli takes around 20 minutes. So, generation I is formed in 20 minutes.

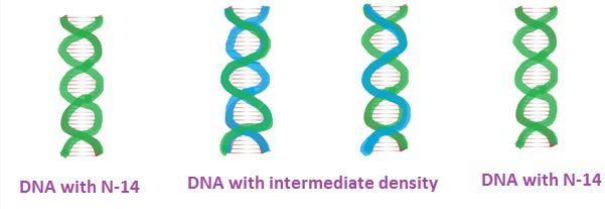
Therefore samples are taken after 20 minutes, then again after 40 minutes. Densities of DNA from the sample were measured to reach to results & conclusion.

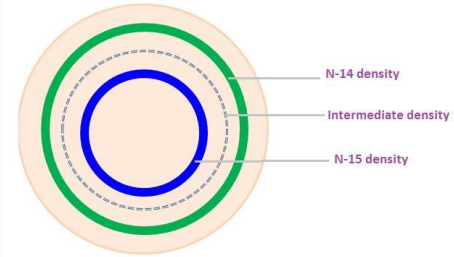
Results

Generation I: DNA was found to have intermediate density after 1 replication



Generation II: Equal amounts of DNA with two different densities were found





Conclusion

- Presence of a hybrid/ intermediate density excluded Conservative hypothesis. Had it been Conservative hypothesis, Generation 1 would have been either Blue(N-15) or Green(N-14); and not an Intermediate one.
- Presence of N-14 DNA in Generation II excluded Dispersive hypothesis. If it was Dispersive, each DNA should have had the same density. But, in Generation II, we could see 50% of the DNA have intermediate density, whereas remaining 50% have N-14 density.
- Semi-conservative hypothesis could explain the entire experimental result. Separation of strands concept could explain the outcomes of Generation I & II.

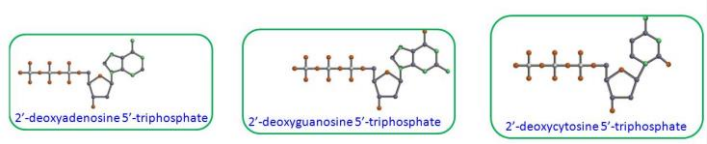
Thus, it was proved that **DNA replication is Semi-conservative in nature**.

Machinery & Enzymes for Replication

Enzymes play an important role acting as catalysts during the process of DNA replication. Some of the important enzymes are:

- DNA polymerase
- Helicase
- Primase
- DNA ligase

Energy source is needed to provide energy during the replication process. **Deoxyribonucleoside triphosphates** act as substrates & provide energy for polymerization reaction.



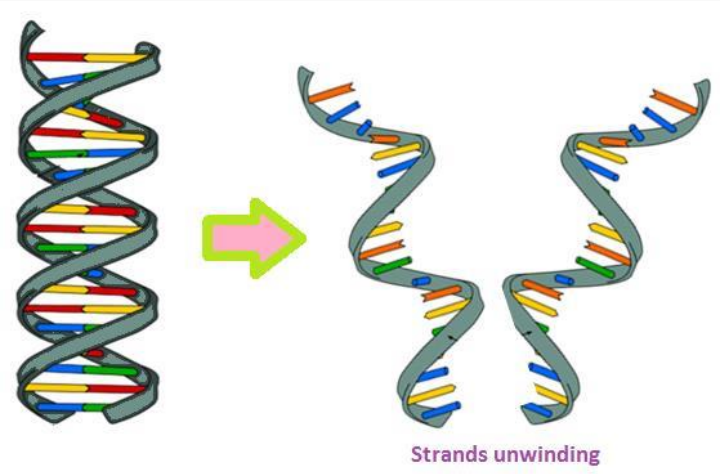
DNA polymerase

DNA polymerase creates DNA from nucleotides. It reads the existing DNA strands to create two new strands that match the existing ones. This enzyme is needed every time a cell divides so that one copy of DNA can be passed to each daughter cell.

DNA polymerase is a highly efficient enzyme, as it can replicate a large number of base pairs in a very short time. Rate of replication or Rate of polymerization is approx 2000 bp per second. A total of 4.6 * 10^6 base pairs are replicated within 18 minutes. DNA polymerase also catalyze with high degree of accuracy. A mistake is made once in every 1 billion base pairs copied. DNA polymerase proof reads to check for errors. However, these errors if remain can cause mutations.

Helicase

Enzyme Helicase unwinds DNA from tightly double stranded structure. Only after the strands are separated, DNA polymerase can do its job of creating the new strands. This enzyme separates the strands by breaking the hydrogen bonds between the bases of the two strands.



Primase

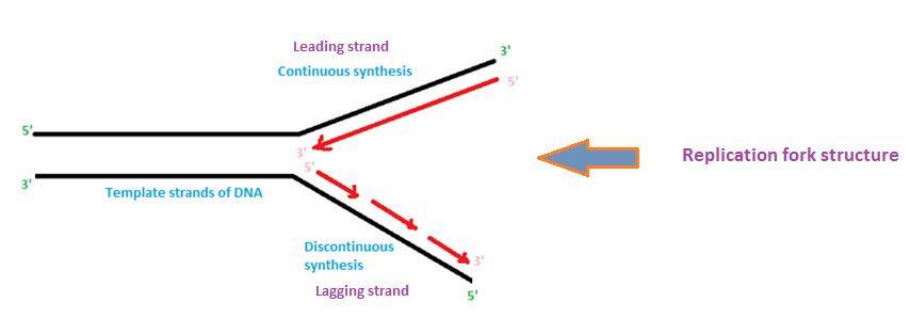
This enzyme creates a short fragment of RNA (primer) paired with the template DNA strand. This enzyme initiates the process of creation of new strands. DNA polymerase cannot initiate the process on its own. Therefore, primase initiates the same.

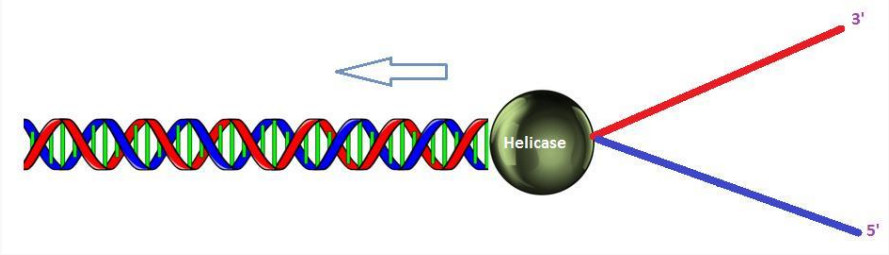
Process of DNA replication

Replication cannot be initiated in any random part of DNA. Region in a DNA where replication initiates is termed as 'Origin of Replication'.

Step 1.

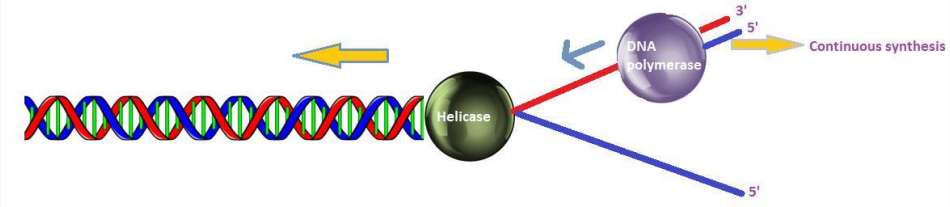
Enzyme Helicase breaks hydrogen bonds, thus separating the two strands of DNA. Replication fork structure is formed.





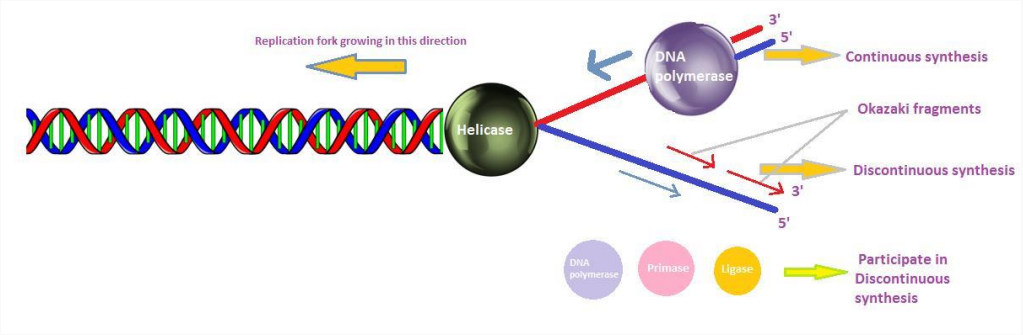
Step 2.

1. **Continuous synthesis** takes place in the Leading strand. In this strand, DNA is synthesized in the same direction as the growing replication fork. Observe the direction of movement of Helicase & DNA polymerase.



1. **Discontinuous synthesis** takes place in the Lagging strand. Synthesis in this strand is more complicated than the Leading strand. DNA polymerase can add new free nucleotides to the 3' end of the new strand. In the lagging strand, no free 3'-OH end is available. Therefore, DNA polymerase is unable to initiate the process. Enzyme Primase initiate the process by creating a small RNA fragment called Primer. DNA polymerase then extends the primed segments adding free nucleotides. RNA primers are replaced with DNA. Thus, we have DNA fragments. Observe the direction of synthesis in Lagging strand (It is opposite to the direction of growing replication fork). DNA Ligase now joins the DNA fragments and forms a complete DNA.

These DNA fragments are termed as 'Okazaki fragments' after the name of the scientist who first described the process of Discontinuous synthesis on Lagging strand.



This entire process of DNA replication occurs during S-phase of cell cycle in eukaryotes. Research is still going on for more detail on the replication process.

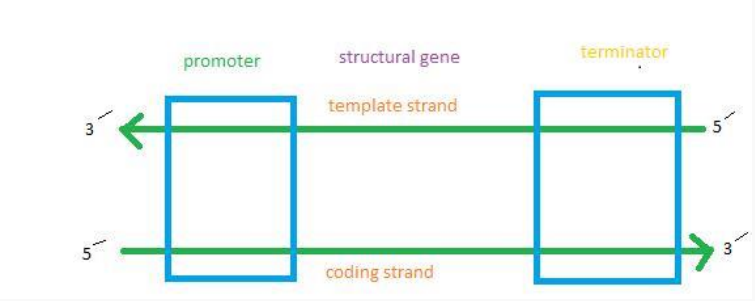
Transcription

- The process of copying genetic information from one strand of the DNA into RNA is termed as transcription.
- In transcription only a segment of DNA and only one of the strands is copied into RNA because
- if both strands act a template, they would code for RNA molecule with different sequences and the sequences of amino acids in the coded protein would be different.
- the two RNA molecules would be complementary to each other and would form a double stranded RNA which would prevent translation.

Transcription unit

A transcription unit consists of

- A Promoter
- The Structural gene
- A Terminator



A transcription unit (source link- self drawn)

- The two strands of the DNA in the structural gene of a transcription unit is termed as **template strand and coding strand.**
- The strand that has the polarity 3'→5' acts as a template, and is referred as template strand.
- The other strand which has the polarity (5'→3') is referred as coding strand.
- The promoter and terminator flank the structural gene in a transcription unit.
- The promoter is located towards 5'-end (upstream) of the structural gene which provides binding site for RNA polymerase.
- The terminator is located towards 3'-end (downstream) of the coding strand which defines the end of the process of transcription.

Structure of a gene

- A gene is defined as the functional unit of inheritance.
- A gene also referred as a **cistron** can be defined as a segment of DNA coding for a polypeptide.
- The structural gene in a transcription unit could be said as **monocistronic** mostly in eukaryotes or **polycistronic** mostly in bacteria or prokaryotes.
- **Exons** are the coding sequences or expressed sequences that appear in mature or processed RNA.
- **Introns** are the intervening sequences which interrupt exons and do not appear in mature or processed RNA.

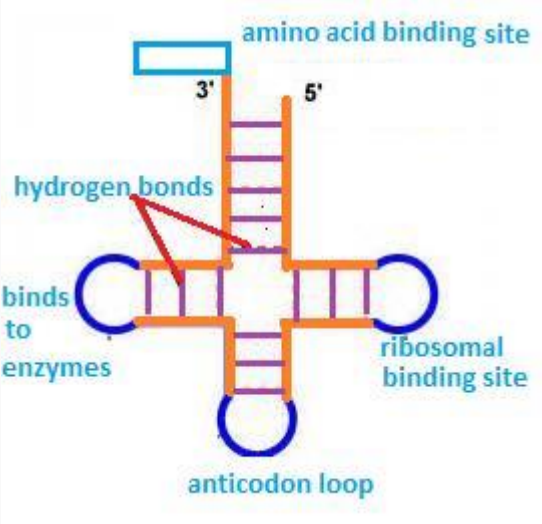
Types of RNA

- There are three major types of RNAs
- mRNA (messenger RNA),
- tRNA (transfer RNA),
- rRNA (ribosomal RNA).

- All three RNAs are needed to synthesize a protein in a cell.
- The mRNA provides the template, tRNA brings amino acids and reads the genetic code, and rRNAs play structural and catalytic role during translation

Structure of tRNA

- The tRNA, also called as sRNA (soluble RNA) has a role as an adapter molecule.
- tRNA has an anticodon loop that has bases complementary to the code.
- It has an amino acid accepter end to which it binds to amino acids.
- The secondary structure of tRNA looks like a clover-leaf.
- In actual structure, the tRNA is compact molecule which looks like inverted L.



tRNA

Process of transcription

In prokaryotes

Transcription takes place in three steps

- Initiation
- RNA polymerase binds to promoter and initiates transcription.
- Initiation factor or sigma (σ) recognizes the promoter of the DNA.
- Elongation
- RNA polymerase facilitates opening of the helix and continues elongation.
- RNA polymerase uses nucleoside triphosphates as substrate and polymerizes in a template depended fashion following the rule of complementarity.
- Only a short stretch of RNA remains bound to the enzyme.
- Termination
- Once the polymerases reaches the terminator region RNA polymerase binds with the termination-factor (ρ) to terminate transcription.
- The nascent RNA falls off with the RNA polymerase which results in termination of transcription.
- The transcription and translation can be coupled in bacteria as the mRNA does not require any processing to become active, and also transcription and translation take place in the same compartment

In eukaryotes

- There are two additional complexities in eukaryotes.

1. The first complexity is that there are at least three RNA polymerases in the nucleus.

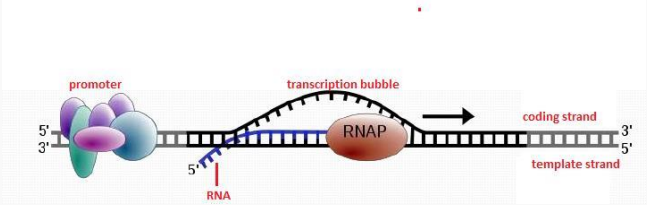
- The RNA polymerase I transcribes rRNAs (28S, 18S, and 5.8S)
- The RNA polymerase III is responsible for transcription of tRNA, 5srRNA, and snRNAs (small nuclear RNAs).
- The RNA polymerase II transcribes precursor of mRNA, the heterogeneous nuclear RNA (hnRNA).

1. The second complexity is that the primary transcripts contain both the exons and the introns and are non-functional.

- Primary transcripts are subjected to a process called **splicing** where the introns are removed and exons are joined in a defined order.
- hnRNA undergo two additional processing called as **capping** and **tailing**.
- In capping an unusual nucleotide (**methyl guanosine triphosphate**) is added to the 5'-end of hnRNA.
- In tailing, **adenylate** residues (200-300) are added at 3'-end in a template independent manner and the fully processed hnRNA is called **mRNA**
- mRNA is transported out of the nucleus for translation.

Significance of complexities

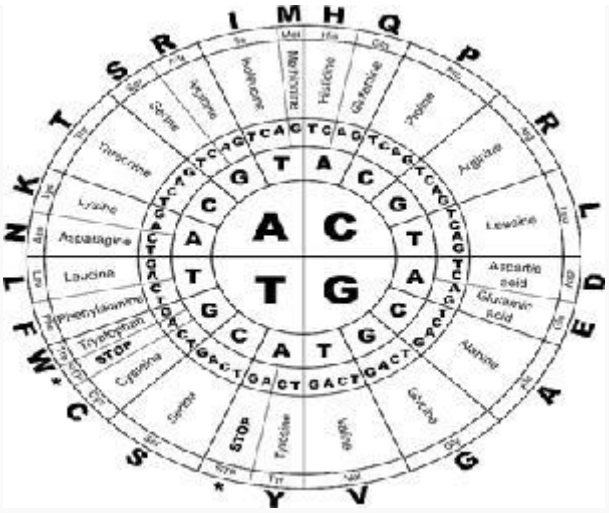
- The split-gene arrangements represent probably an ancient feature of the genome.
- The presence of introns is reminiscent of antiquity, and the process of splicing represents the dominance of RNA-world.



Transcription

Genetic code

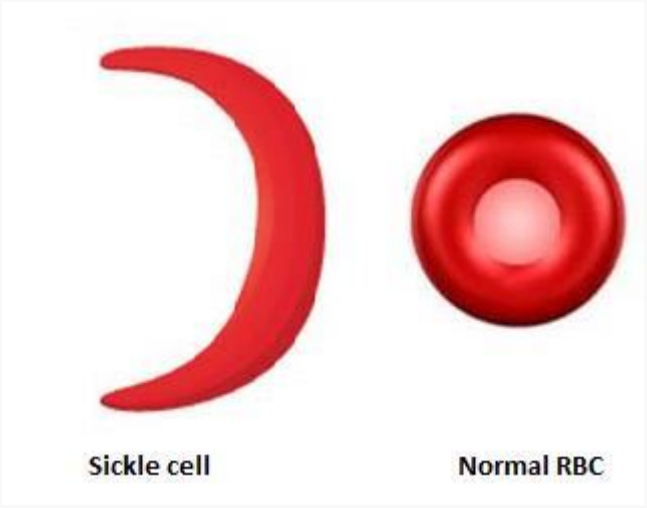
- The sequence of nucleotides on DNA which determines the sequence of amino acids in a polypeptide chain is termed as Genetic code.
- The process of translation requires transfer of genetic information from a polymer of nucleotides to a polymer of amino acids but there is no complementarity between nucleotides and amino acids which led to the proposition of a genetic code that could direct the sequence of amino acids during synthesis of proteins.
- The salient features of genetic code are as follows:
- The codon is triplet, 61 codons code for amino acids and 3 codons do not code for any amino acids, hence they function as stop codons.
- One codon codes for only one amino acid thus it is unambiguous and specific.
- Some amino acids are coded by more than one codon, hence the code is degenerate.
- The codon is read in mRNA in a contiguous fashion, there are no punctuations.
- The code is nearly universal. For example, from bacteria to human UUU would code for Phenylalanine (phe).
- AUG has dual functions, it codes for Methionine (met) , and it also act as initiator codon.



Mutation and genetic code

- The relationships between genes and DNA are best understood by mutation studies.
- Point mutation is the insertion or deletion of a single gene in the structural gene.

Example- point mutation is a change of single base pair in the gene for beta globin chain that results in the change of amino acid residue glutamate to valine, which results into a diseased condition called as **sickle cell anaemia.**



Sickle cell shaped RBC

- Frame shift mutation is the insertion and deletion of three or its multiple bases which insert or delete one or multiple codon hence one or multiple amino acids, and reading frame remains unaltered from that point onwards.

Example- cystic fibrosis.

Translation

- Translation refers to the process of polymerization of amino acids to form a polypeptide.
- The order and sequence of amino acids are defined by the sequence of bases in the mRNA and the amino acids are joined by a bond which is known as a **peptide bond.**

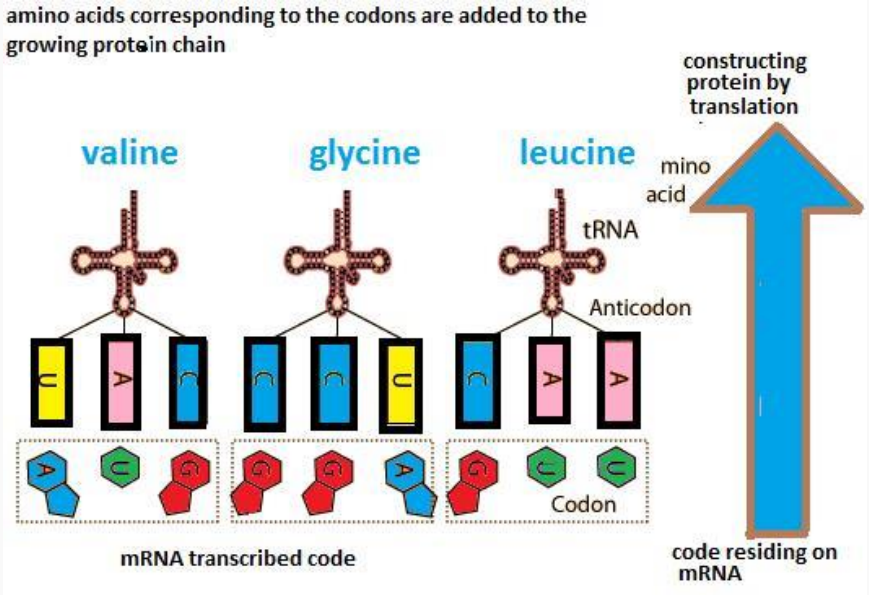
- Formation of a peptide bond requires energy and thus amino acids are activated in the presence of ATP and linked to their cognate tRNA by the process of **charging of tRNA** or **aminoacylation** of tRNA.
- If charged tRNAs are brought close enough, a peptide bond forms which is enhanced by the presence of a catalyst such as ribosome.
- Ribosome in its inactive state exists as two subunits; a large subunit and a small subunit.
- There are two sites in the large subunit, for subsequent amino acids to bind to and thus become close enough to each other for the formation of a

peptide bond.

- A translational unit in mRNA is the sequence of RNA that is flanked by the start codon (AUG) and the stop codon and codes for a polypeptide.
- An mRNA also has some additional sequences that are not translated and are referred as **untranslated regions (UTR).**
- The UTRs are present at both 5'-end (before start codon) and at 3'-end (after stop codon) which are required for efficient translation process.
- After activation of amino acids, translation starts with its three steps-
- Initiation
- Elongation
- Termination

Let’s discuss the steps in detail:

- Initiation-
- For initiation, the ribosome binds to the mRNA at the start codon (AUG) that is recognised only by the initiator tRNA.
- Elongation-
    - The ribosome proceeds to the elongation phase of protein synthesis.
    - During elongation stage, complexes composed of an amino acid linked to tRNA, sequentially bind to the appropriate codon in mRNA by forming complementary base pairs with the tRNA anticodon.
    - The ribosome moves from codon to codon along the mRNA.
    - Amino acids are added one by one, translated into Polypeptide sequences dictated by DNA and represented by mRNA.
- Termination-
    - At the end, a release factor binds to the stop codon, terminating translation and releasing the complete polypeptide from the ribosome.



Regulation of gene expression

Gene expression results in the formation of a polypeptide and it can be regulated at several levels such as

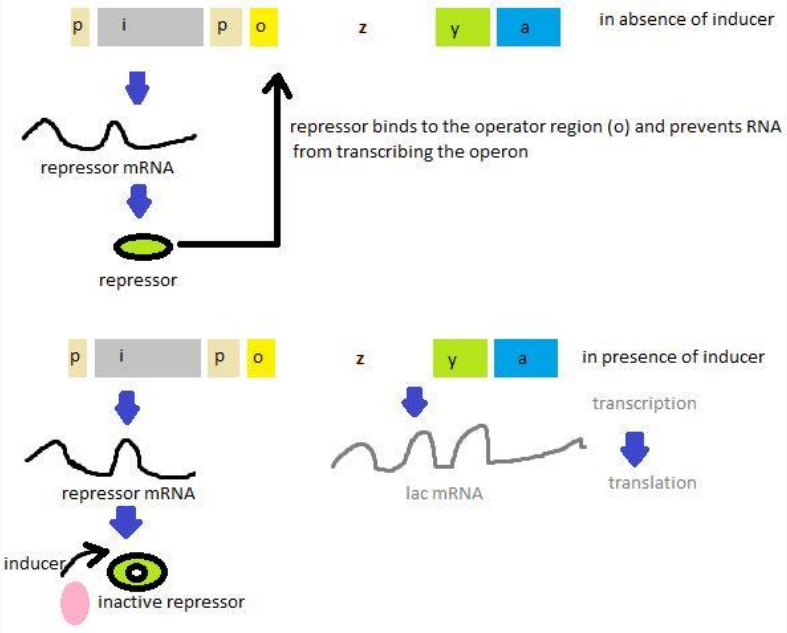
- transcriptional level (formation of primary transcript),
- processing level (regulation of splicing),
- transport of mRNA from nucleus to the cytoplasm,
- translational level.

In prokaryotes, control of the rate of transcriptional initiation is the predominant site for control of gene expression.

In a transcription unit, the activity of RNA polymerase at a given promoter is in turn regulated by interaction with accessory proteins which can act both positively (activators) and negatively (repressors). Regulation of gene expression can be studied with the help of Lac operon.

Lac operon

- Lac refers to lactose in lac operon.
- The lac operon consists of one regulatory gene the i gene which codes for the repressor of the lac operon and three structural genes (z, y, and a).
- The z gene codes for beta-galactosidase (β-gal), which hydrolyses disaccharide, lactose into galactose and glucose.
- The y gene codes for permease, which increases permeability of the cell to β-galactosides.
- The a gene encodes a transacetylase.
- Lactose is termed as inducer as lactose is the substrate for the enzyme beta-galactosidase and it regulates switching on and off of the operon.
- In the absence of inducer
- The repressor of the operon is synthesized (all-the-time – constitutively) from the i gene.
- The repressor protein binds to the operator region of the operon and prevents RNA polymerase from transcribing the operon.
- In the presence of inducer
- The repressor is inactivated by interaction with the inducer which allows RNA polymerase access to the promoter and transcription proceeds.
- Regulation of lac operon by repressor is referred to as negative regulation.



Lac operon

Human genome project

- The scientific project which deal with the study of base sequences of DNA molecules of complete set of chromosomes is called human genome project.
- HGP was closely associated with the rapid development of a new area in biology called as
- Goals of Human Genome Project
- Identify all the approximately 20,000-25,000 genes in human DNA.
- Determine the sequences of the 3 billion chemical base pairs that make up human DNA.
- Store this information in databases;
- Improve tools for data analysis;
- Transfer related technologies to other sectors, such as industries;
- Address the ethical, legal, and social issues (ELSI) that may arise from the project.

Methodologies

- To identifying all the genes that expressed as RNA referred to as **Expressed Sequence Tags (ESTs).**
- Simply sequencing the whole set of genome that contained all the coding and non-coding sequence, and later assigning different regions in the sequence with functions is called as **Sequence Annotation.**
- The total DNA from a cell is isolated and converted into random fragments of relatively smaller sizes and cloned in suitable host using specialised vectors.
- The cloning resulted into amplification of each piece of DNA fragment.
- The commonly used vectors are **BAC (bacterial artificial chromosomes)**, and **YAC (yeast artificial chromosomes).**
- The fragments were sequenced using automated DNA sequencers.
- Specialized computer based programmes were developed for the alignment of the sequences.
- The sequences were subsequently annotated and were assigned to each chromosome.
- The sequence of chromosome 1 was completed only in May 2006.

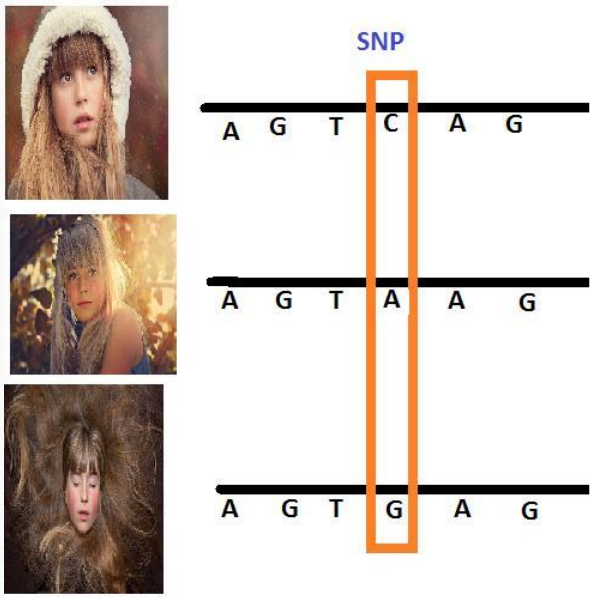
Automated DNA sequencer

Salient Features of Human Genome

- The human genome contains 3164.7 million nucleotide bases.
- The average gene consists of 3000 bases with the largest known human gene being **dystrophin** at 2.4 million bases.

The largest known human gene- dystrophin

- The total number of genes is estimated at 30,000.
- 9 per cent nucleotide bases are exactly the same in all people.
- The functions are unknown for over 50 per cent of discovered genes.
- Less than 2 per cent of the genome codes for proteins.
- Repeated sequences make up very large portion of the human genome.
- Repetitive sequences are stretches of DNA sequences that are repeated many times.
- Chromosome 1 has most genes (2968), and the Y has the fewest (231).
- Scientists have identified about 1.4 million locations where single base DNA differences (**SNPs – single nucleotide polymorphism**) occur in humans.



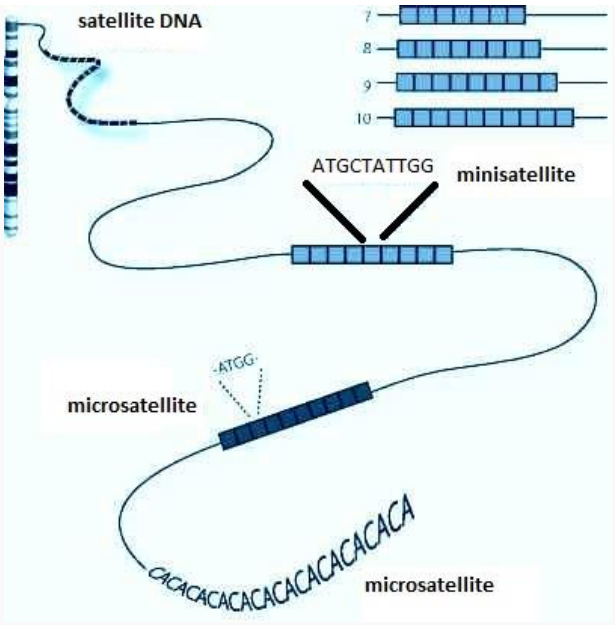
Single nucleotide polymorphism (self-drawn)

Applications of HGP

- All the genes in a genome can be studied together.
- Helps to understand how tens of thousands of genes and proteins work together in interconnected networks.
- Helps to diagnose and treat genetic diseases.

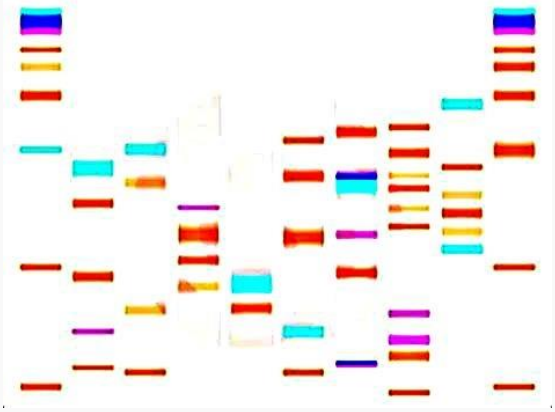
DNA fingerprinting

- The process of comparison of DNA from different sources to establish the identity is called **DNA fingerprinting**.
- DNA fingerprinting involves identifying differences in some specific regions in DNA sequence called as **repetitive DNA.**
- Repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation.
- The bulk DNA forms a major peak and the other small peaks are referred to as **satellite DNA.**
- Satellite DNA is of two types based on base composition, length of segment, and number of repetitive units
- micro-satellites
- mini-satellites



Satellite DNA

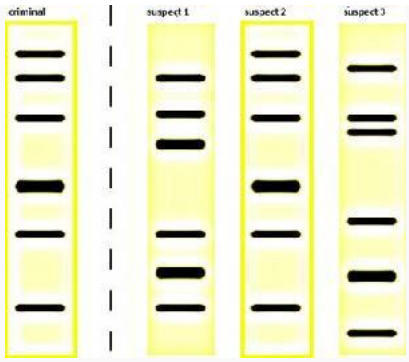
- Satellite DNA sequences normally do not code for any proteins, but they form a large portion of human genome.
- Satellite DNA sequence show high degree of polymorphism and form the basis of DNA fingerprinting.
- An inheritable mutation occurring in a population at high frequency, is referred to as **DNA polymorphism.**
- Repeated nucleotide sequences in the non-coding DNA of an individual is called **Variable Number of Tandem Repeats (VNTR).**
- The size of VNTR varies in size from 0.1 to 20 kb.
- DNA fingerprinting includes the following steps
- isolation of DNA
- digestion of DNA by restriction endonucleases
- separation of DNA fragments by electrophoresis
- transferring (blotting) of separated DNA fragments to synthetic membranes, such as nitrocellulose or nylon.
- hybridization using labelled VNTR probe
- detection of hybridized DNA fragments by autoradiography.



Fragments of DNA

Applications

- In identification of criminals.
- In determining population and genetic diversities.
- In solving parental disputes.



DNA fingerprinting in identification of criminals

Introduction

- Evolutionary biology is the study of history of life forms on earth.
- The process of gradual modification of simpler forms into the present complex forms over millions of years is called evolution.

Fig. evolution

Origin of life

- The universe is almost 20 billion years old.
- Huge clusters of galaxies comprise the universe.
- Galaxies contain stars and clouds of gas and dust.
- A scientific theory called big bang theory explains that, the unimaginable large explosion created the universe.
- As the universe expanded and cooled, the temperature came down and materials condensed under the influence of gravitation to form present day galaxy.
- Our galaxy is called **Milky Way** formed 4.5 billion years back.
- There was no atmosphere on early earth.
- Water vapour, methane, carbon dioxide and ammonia released from molten mass covered the surface.
- The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H_2
- Oxygen combined with ammonia and methane to form water, CO_2 and others.
- The ozone layer was formed, as it cooled, the water vapor fell as rain, to fill all the depressions and form oceans.
- Life appeared 500 million years after the formation of earth, i.e., almost four billion years back.
- Different scientists had put different views about the origin of life.

Fig. early earth

Fig. Milky way

Evolution of life forms- a theory

- Conventional religious literature reveals about the theory of special creation based on three connotations-
- All living organisms were created as such.
- The diversity in all organisms always the same since creation and will be the same in future.
- Earth is about 4000 years old.
- All the ideas were challenged during 19^{th}
- **Charles Darwin** concluded that existing living forms share similarities to varying degrees not only among themselves but also life forms that existed millions of years ago.

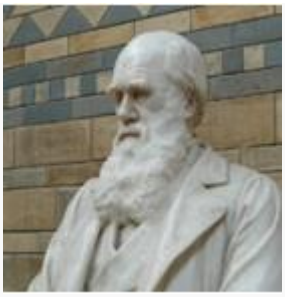


fig. Charles Darwin

- Many life forms do not exist anymore because of extinctions of different life forms and there has been gradual evolution of life forms.
- Darwin's theory of natural selection is based on the fact that those who are better fit in an environment, leaves more progeny than others and the progenies will survive more hence are selected by the nature which he implied as mechanism of evolution.
- Alfred Wallace stated that all the existing life forms share similarities and shares some common ancestors which are present at different periods in the history of earth.
- The geological history of earth closely correlates with the biological history of earth and a final conclusion is that earth is not thousand years old as was thought, but millions of years old.

Evidences for evolution

Evidences of evolution comes from-

Paleontological evidence-

- Paleontology is the study of fossils.
- Fossils are remains of hard parts of life forms lived in past but found in rocks or sediments.
- Rocks from sediments and a cross section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth.
- Different aged rock sediments contain fossils of different life forms that probably died during the formation of the particular sediment which represent extinct organisms.
- A study of fossils in different sedimentary layers indicates the geological period in which the organisms existed.
- The study showed that life forms varied over time and certain life forms are restricted to certain geological time spans.
- New forms of life have arisen at different times in the history of earth.

Fig. fossils

Comparative anatomy and morphology-

- Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago.

<u>Homologous organs-</u>

- The organs whose structure or origin is same but functionally different. Example- i) Vertebrate hearts or brains. ii) In plants, the thorns and tendrils of Bougainvillea and Cucurbita. iii) The fore limbs of whale, bats, cat and human share similarities in the pattern of forelimb bones.
- All the animals have similar anatomical structure in their fore limb bones such as humerus, radius, ulna, carpals, metacarpals and phalanges.
- Though the forelimbs have similar anatomical structure but they perform different functions.
- The same structure developed along different directions due to adaptations to different needs.
- Homology is based on divergent evolution.
- Homology indicates common ancestry.

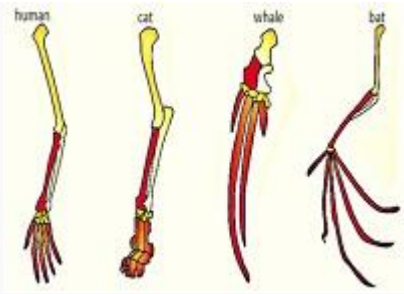


Fig. forelimbs of human, cat, whale and bat

Analogous organs-

- The organs whose structure or origin is not similar but functionally active are called analogous organs. Example- i) The wings of bird and butterfly perform similar functions. ii) Eye of octopus and mammals. iii) The flippers of penguins and dolphins. iv) In plants, sweet potato and potato.

- Similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry.
- It is the similar habitat that has resulted in selection of similar adaptive features in different groups of organism but towards the same function.

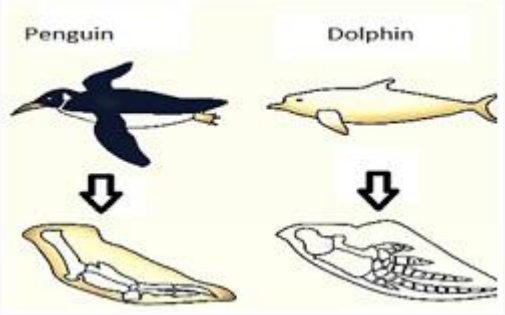


Fig. flippers of whale and bat

Natural selection-

Industrial melanism-

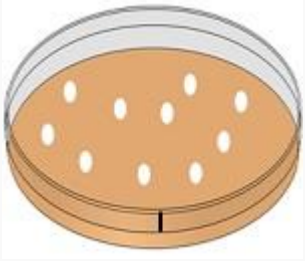
- Before industrialization, in Great Britain it was observed that there were more white winged moths on trees than dark or melanised moth.
- After industrialization, there were more dark-winged moths.
- Before industrialization, almost white-coloured lichen covered the tree trunks and in that background the white-winged moths survived but the dark coloured moths were eaten by predators.
- During post industrialization period, the tree trunks became dark due to industrial smoke and under such condition the white- winged moths did not survive sue to predators and the dark-winged moths' survived hence industrial melanism supports evolution by natural selection.

Fig. white and black winged moths

Antibiotic resistant bacteria

- By employing antibiotics to bacterial colonies, the colonies sensitive to penicillin died, whereas the others that were resistant to penicillin survived.

- Probably the bacteria that survived underwent a chance mutation there by possessing a gene that contributed to their resistance to the penicillin drug and hence selected by the nature, in course of time was considered as fittest and established as new species.



Adaptive radiation

The evolution of different species in a given geographical area starting from its original character and radiating to other geographical area is called adaptive radiation. Examples-

Finches in Galapagos island-

- During Darwin's journey to Galapagos Island he observed small black birds called **Darwin's Finches.**
- The finches were diverse in their food habitats like original from seeds eating features to many other forms with altered beaks arose enabling them to become insectivorous and vegetarian finches.

Fig. Darwin's finches

Australian marsupials

- A number of marsupials, each different from the other evolved from an ancestral stock but all within the Australian continent.

Examples- Tasmanian wolf, tiger cat, marsupial rat, kangaroo, wombat, sugar glider etc.

Fig. tiger cat

Fig. kangaroo

Placental mammals-

- In Australia adaptive radiation is exhibited where placental mammals are evolved into varieties each of which appears to be similar to a corresponding marsupials.

Example- placental wolf and Tasmanian wolf marsupial.

Biological evolution

Darwin's theory of evolution

- The essence of Darwinian Theory about evolution is natural selection.
- Theory of natural selection states that individuals that are less adapted to the environment are eliminated and selecting those better adapted by the nature.
- The rate of appearance of new forms is linked to the life cycle or the life span.
- There must be a genetic basis for getting selected and to evolve.
- Some organisms are better adapted to survive in an otherwise hostile environment.
- Adaptive ability is inherited and it has genetic basis.
- Nature selects for fitness.
- Fitness is the end result of the ability to adapt and get selected by nature.
- Fitness is based on characteristics which are inherited.
- Branching descent and natural selection are the two key concept of Darwinian Theory of evolution.

Lamarck's theory of evolution

- Lamarck had said that evolution of life forms had occurred but driven by use and disuse of organs.
- Lamarck gave the example of Giraffes who in an attempt to forage leaves on tall trees had to adapt by elongation of their necks and they passed on this acquired character of elongated neck to succeeding generations.
- Giraffe, slowly over the years came to acquire long necks.

Fig. elongated necks of giraffe due to an attempt to forage leaves on tall trees

Mechanism of evolution

- Evolution needs variations.
- Origin of variation and reason for speciation is inheritable factors influencing phenotype.
- Mendel explained the influence of inheritable actors on phenotype.
- Darwin mentioned that natural selection is the reason for evolution
- Hugo de Vries based on his work on evening primrose believe that mutation causes evolution.
- Evolution for Darwin was gradual while de Vries believed that mutation caused speciation and hence called it

fig. evening primrose

Hardy- Weinberg principle

- Hardy- Weinberg principle is also called genetic equilibrium.
- Gene frequency remains constant from generation to generation and is stable, this is called genetic equilibrium.
- Sum total of allelic frequencies is 1 and individual frequencies can be named as p,q etc. hence, p+q = 1, where P and q represent the frequency of allele A and allele a.
- In diploids, the frequency of AA is p^2, aa is q^2 and of Aa is 2pq.

Hence, the formula is $p^2 + 2pq + q^2$ which is a binomial expansion of $(p+q)^2$ which can be applied to any population to find out the gene frequency.

- When frequency measured differs from expected value, the difference indicates the extent of evolutionary change.

Factors affecting Hardy- Weinberg principle are-

Gene flow –

- The transfer of section of population to another place resulting in a change in gene frequencies in both old and new population is called gene flow.
- New genes and alleles are added to new population which are genetically different but can interbreed.

Genetic drift-

- The random change in gene frequency occurs by chance is called genetic drift.
- Sometimes, the change in allelic frequency is so different in the new population,that they become a different species and the original drifted population becomes founders hence the effect is called **founder effect**.

Mutation-

- The spontaneous change in the genetic makeup of an individual is called mutation.
- Pre-existing advantageous mutations when selected will result in observation of new phenotypes and over few generations this would result in

Genetic recombination-

- Exchange of genes between non sister chromatids of homologous chromosomes during gametogenesis is called genetic recombination.
- Variation due to recombination during gametogenesis, or due to gene flow or genetic drift results in changed frequency of genes and alleles in future generation.

Natural selection-

- The process by which better adapted individuals with useful variations are selected by nature and leave greater number of progenies is called natural selection.
- Natural selection can lead to-
    - Stabilizing selection- here, more individuals acquire mean character value.
    - Directional change – here, more individuals acquire value other than the mean character value.
    - Disruptive selection- here, more individuals acquire peripheral character value at both ends of the distribution curve.

<u>Problem based on Hardy- Weinberg principle</u>

Question. The frequency of two alleles in a gene pool is 0.15 (A) and 0.75 (a). Assume that the population is in Hardy-Weinberg equilibrium.

Calculate the percentage of heterozygous individuals in the population.

Solution- According to Hardy-Weinberg equilibrium equation, heterozygotes are represented by the 2pq term. Therefore, the number of heterozygous individuals (Aa) is equal to 2pq which equals 2x 0.15x 0.75 =0.225 = 22.5 %.

Calculate the percentage of homozygous recessives in the population.

Solution- The homozygous recessive individuals (aa) are represented by the q^2 term which equals 0.75x 0.75= 0.562 = 56.25 %

A brief account of evolution

- About 2000 million years ago (mya) the first cellular forms of life appeared on earth.
- Some cellular forms had the ability to release O_2 and slowly single cell organisms became multicellular organisms.
- By the time of 500 mya, invertebrates were formed and active.
- Jawless fish probably evolved around 350 mya.
- Sea weeds and few plants existed probably around 320 mya.
- First organisms that invaded land were plants.
- Fish with stout and strong fins could move on land and go back to water was about 350 mya.
- In 1938, a lobe finned fish caught in South Africa happened to be a **Coelacanth** which evolved into first amphibians that lived on both land and water and these were the ancestors of modern day frogs and salamanders.

Fig. Coelacanth

- The amphibians evolved into reptiles which lay thick shelled eggs which do not dry up in sun.
- The modern day descendants of reptiles are the turtles, tortoises and crocodiles.
- In the next 200 million years or so, reptiles of different shapes and sizes dominated on earth.
- Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly.

Fig. ferns

- Some of the reptiles went back into water to evolve into fish like reptiles around 200 mya.
- The land reptiles were the **dinosaurs** and the biggest of them is Tyrannosaurus rex was about 20 feet in height and had huge fearsome dagger like teeth.

Fig. dinosaurs

- About 65 mya, the dinosaurs suddenly disappeared from the earth, some of them evolved into birds or might be killed by the climatic changes.
- The first mammals were like shrews and their fossils were small sized.
- Mammals were viviparous and protected their unborn young inside the mother's body.
- Mammals dominated the earth when the population of reptiles came down.
- In South America there were mammals resembling horse, hippopotamus, bear, rabbit, etc.
- Due to continental drift, when South America joined North America, these animals were overridden by North America.
- Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.
- Some mammals live wholly in water.

Examples- Whales, dolphins, seals and sea cows.

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Origin and evolution of man

The stages of evolution of man are-

1. **Dryopithecus and Ramapithecus-**

- About 15 mya, primates called Dryopithecus and Ramapithecus were existing.
- They were hairy and walked like gorillas and chimpanzees.
- Ramapithecus was more man-like while Dryopithecus was more ape-like.
- Few fossils of man-like bones have been discovered in Ethiopia and Tanzania.
- These revealed hominid features leading to the belief that about 3-4 mya, man-like primates walked in eastern Africa.

Fig. Dryopithecus

Fig. Ramapithecus

2. **Australopithecus-**

- About two mya, Australopithecines probably lived in East African grasslands.
- They hunted with stone weapons but essentially ate fruit.
- Some of the bones among the bones discovered were different.
- They were intermediate between apes and man.

Fig. Australopithecus

3. **Homo habilis-**

- The brain capacities were between 650-800cc.
- They probably did not eat meat.
- They were the makers of stone tools.

Fig. Homo habilis

4. **Homo erectus-**

- About 1.5 mya, Homo erectus arose.
- Homo erectus had a large brain around 900cc.
- Homo erectus probably ate meat.

Fig. Homo erectus

5. **Neanderthal man-**

- The Neanderthal man with a brain size of 1400cc lived in near east and central Asia between 1, 00,000-40,000 years back.
- They used hides to protect their body and buried their dead.

Fig. Neanderthal man

6. **Homo sapiens or modern man-**

- Arose in Africa and moved across continents.
- During ice age between 75,000-10,000 years ago modern Homo sapiens arose.
- Pre-historic cave art developed about 18,000 years ago.
- Agriculture came around 10,000 years back and human settlements started.

Fig. Homo sapiens

Introduction

Health can be defined as a state of complete physical, mental and social well-being.

Health is affected by three factors-

- Genetic disorders- disorders which the child inherits from parents from birth.
- Infections- caused due to pathogens.
- Life style- includes the habits that we have or lack such as intake of food and water, rest and exercise which we give to our body etc.

When People are healthy they are more efficient to work which increases productivity and brings economic prosperity.

The factors which are responsible for maintaining good health are-

- Balanced diet- the diet which contains all kinds of essential nutrients in a proportionate manner.

Fig. Balanced diet

- Personal hygiene.
- Regular exercise, meditation, yoga.

Aspects which are needed to be added to achieve good health are-

- Awareness about diseases.
- Proper disposal of wastes.
- Control of vectors.
- Maintenance of hygiene.

Diseases

The conditions in which one or more organs of the body are not working properly, characterized by various signs and symptoms are called diseases.

The organisms which cause diseases are called **pathogens**

Diseases can be broadly classified into two types-

- Infectious diseases : Infectious diseases are those which are transmitted from an infected person to another healthy person.

- Non- infectious diseases : Non-infectious diseases are those which are not transmitted from an infected person to another person.

Infectious diseases includes-

- Bacterial diseases- caused by bacteria.
- Fungal diseases- causes by fungi.
- Viral diseases- caused by virus.
- Protozoan diseases- caused by protozoan.
- Helminth diseases- caused by helminth.

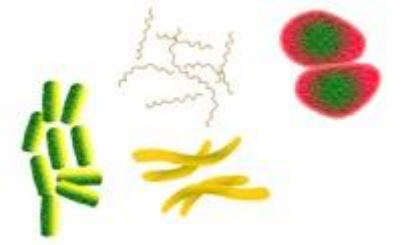

Fig. pathogens

Bacterial diseases

Typhoid

- Caused by *Salmonella typhi.*
- Affects small intestine and then migrates to other parts of the body through blood.
- Transmitted by contaminated food and water.
- Symptoms- Sustained high fever (39° to 40°C), weakness, stomach pain, constipation, headache and loss of appetite, intestinal perforation and death may occur in severe cases.
- Typhoid fever is confirmed by **Widal test.**

fig. *Salmonella typhi*

Pneumonia

- Caused by *Streptococcus pneumoniae* and
- Affects alveoli of lungs.
- Transmitted by dropelts released by infected person, sharing glasses and utensils.
- Common symptoms are fever, chills, cough and headache and in severe cases lips and finger nails turn gray to bluish colour.

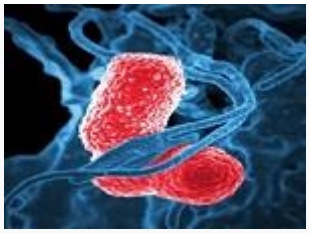

fig. *Streptococcus pneumonia*

Viral diseases

Common cold

- Caused by Rhino virus.
- Affects nose and respiratory organs.
- Transmitted by direct inhalation of droplets from cough and sneeze of infected person, through contaminated objects like pen, books, cups etc.
- Nasal congestion and discharge, sore throat, hoarseness, cough are common symptoms.

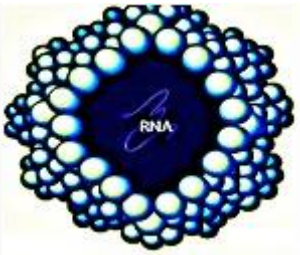

Fig. Rhino virus

Protozoan diseases

Malaria

Caused by *Plasmodium* (*vivax, P. malariaeand P. falciparum*).

Affects liver and RBC.

Transmits by biting of female anopheles mosquito which acts as a vector.

High fever occurring on alternate days, chill, vomiting are the common symptoms.

Malarial parasite requires two hosts to complete their life cycle-

- Human
- Anopheles mosquito.

Life cycle of malarial parasite.

- Female Anopheles mosquito bites a healthy human and injects sporozoites (infective stage) with bites.

- The parasites reach the liver by through blood and starts multiplying within the liver cells
- Parasites then attack the red blood cells and reproduce asexually in the red blood cells and rupture the red blood cells which release a toxic substance called haemozoin responsible for chill and high fever recurring every 3 to 4 hours.
- Some of the parasites differentiate into male and female gametocytes which are taken up by the mosquito during biting and sucking blood.
- Formation of gametes and fertilization takes place in the intestine of mosquito.
- The zygote develops and forms thousands of sporozoites which migrate into the salivary gland of the mosquito.
- When the mosquito bites another human, the sporozoites are injected.

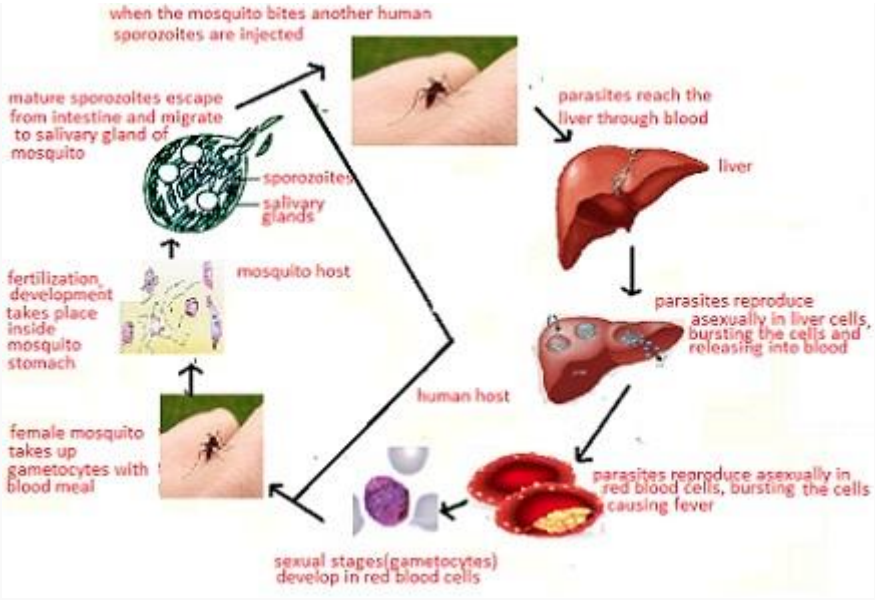

Fig. life cycle of malarial parasite

Amoebiasis (amoebic dysentery)

Caused by *Entamoebahistolytica*.

Affects large intestine of man.

Transmitted by house flies which as mechanical carrier and food contaminated with cysts of *Entamoeba*

Constipation, abdominal pain, cramps, stools with mucous and blood clots are common symptoms.

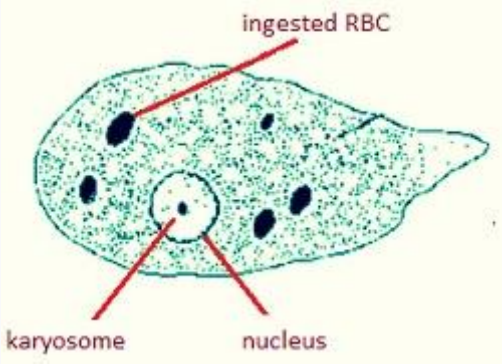

Fig.*Entamoeba*

Helminth diseases

Ascariasis

- Caused by *Ascarislumbricoides*
- Affects intestine of man.
- Transmitted by contaminated water, vegetable fruits etc.
- Internal bleeding, muscular pain, fever, anemia, blockage of intestinal passage are common symptoms.

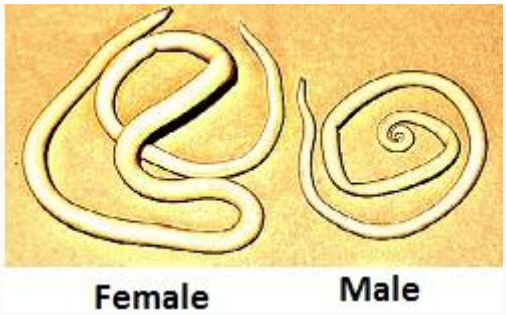

Fig.Ascaris

Filariasis or elephantiasis

- Caused by *Wuchereriabancrofti* and *Wuchereriamalayi*
- Affects lymphatic vessels of the lower limbs, genital organs.
- Transmitted by biting of infected female culex mosquito.
- Chronic inflammation of the organs where they live, abnormal swellings of the lower limbs, scrotum, penis are common symptoms.

Fig. elephantiasis

Fungal disease

Ringworm

- Caused by *Microsporum, Trichophyton, Epidermophyton.*
- Affects skin, nails, folds of skin, groin.
- Transmitted by sharing towel, clothes, or even comb with infected person.
- Appearance of dry skin, scaly lesions in nails and scalp with intense itching are some of the common symptoms.
- Heat and moisture help these fungi to grow.

Fig.Trichophyton.

Prevention and control of diseases

Maintenance of hygiene is very important for prevention and control of diseases.

Measures for hygiene include keeping the body clean; consumption of clean drinking water, food, vegetables, fruits, proper disposal of waste and excreta; periodic cleaning and disinfection of water reservoirs, pools, cesspools and tanks.

In case of air borne diseases, close contact with the infected person and his belongings should be avoided.

For vector borne diseases such as malaria and filariasis, the measures to control diseases are-

- Control or eliminate thevectors and their breeding places.
- Avoidingstagnation of water in and around residential areas.
- Regular cleaning of household coolers.
- Use of mosquito nets.
- Introducing fishes like Gambusiain ponds that feed on mosquito larvae.
- Spraying of insecticides in ditches,drainage areas and swamps, etc.
- Doors and windows shouldbe provided with wire mesh to prevent the entry of mosquitoes.

The use of vaccines and immunization programmes has enabled to control diseases like smallpox, diphtheria, polio, pneumonia, tetanus etc.

Fig. maintaining hygiene, vaccination can control diseases

Immunity

The overall ability of the body to fight against disease causing microorganisms with the help of immune system is called immunity.

Immunity is of two types-

1. Innate immunity.

2. Acquired immunity.

Innate immunity

The immunity which occurs by birth is called innate immunity.

Innate immunity is non-specific type of defense.

Innate immunity consists of various barriers which prevent the entry of microorganisms into the body.

Innate immunity consists of four types of barriers.

- Physical barriers-Skin on our body is the main barrier which prevents entry of the micro-organisms and mucus coating of the epithelium lining the respiratory, gastrointestinal and urogenital tracts also help in trapping microbes entering our body.
- Physiological barriers- Acid in the stomach, saliva in the mouth, tears from eyes–all prevent microbial growth.
- Cellular barriers – Certain types of leukocytes (WBC) of our body like **polymorpho-nuclear leukocytes (PMNL-neutrophils**), **monocytes** and **natural killer (type of lymphocytes)** in the blood as well as macrophages in tissues can phagocytose and destroy microbes.
- Cytokine barriers- Virus-infected cells secrete proteins called**interferons** which protect non-infected cells from further viral infection.

Acquired immunity

The immunity which develops during lifetime by exposure to suitable foreign agents like microorganisms is called acquired immunity.

Acquired immunity is pathogen specific and it ischaracterized by memory.

When the body first encounters a pathogen it produces a response which takes long time to develop and of low intensity called as **primary immune response**and if the body encounters the same pathogen it produces highly intensified and quick response called as **secondary immune response.**

After responding to the foreign microorganisms and elimination of the pthogen, the immune system keeps the memory of the that encounter (primary response) and during its second encounter with the same pathogen produces a highly intensified immune response (secondary response).

The primary and secondaryimmune responses are carriedout with the help of twospecial types of lymphocytes present in our blood,

- **B-lymphocytes :**The B-lymphocytes produce an army of proteins in response to pathogens into our blood to fight with them called as **antibodies**
- **T-lymphocytes :** The T-cells themselves do not produce antibodies but help B cells to produce them

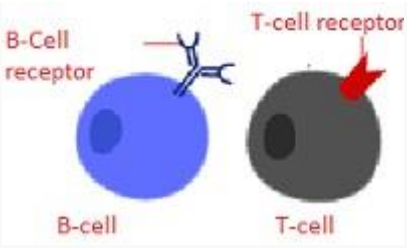

Fig. B-lymphocyte and T-lymphocyte

Structure of antibody

Each antibody molecule has four peptide chains, two long chains and two short chains arranged in a Y shaped structure.

Two long chains are called heavy chains and two short chains are called light chains, hence an antibody is represented as H2L2.

Antibodies are also called as **immunoglobulins (Ig).**

Different types of antibodies are produced in our bodies which are IgA, IgM, IgE, IgG.

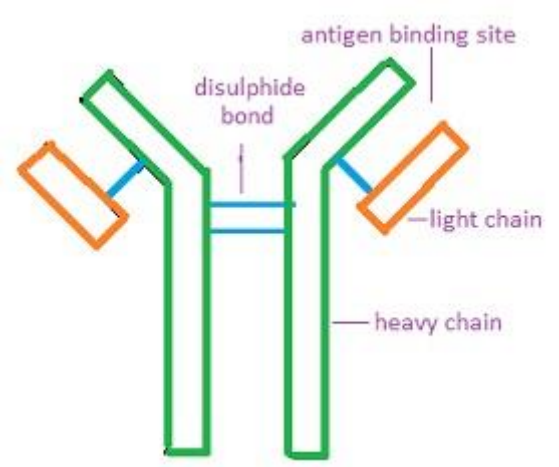

Fig. an antibody molecule

Types of immunity

Based on the type of immune cell acting against the antigens, immunity can be classified into two types-

- **Humoral immunity**- the immunity which is mediated by antibodies produced by B-lymphocytes is called humoral immunity.
- **Cell- mediated immunity**- The immunity which is mediated by T- lymphocytes by directly attaching themselves to the antigens is called cell mediated immunity.

During organ transplantation, tissue matching and blood group matching are essential before undertaking any graft/transplant and even after this the patient has to take immuno–suppresants all his/her life because the body is able to differentiate 'self ' and 'nonself' and the cell-mediated immune response is responsible for the graft rejection.

Based on the nature of antibodies, immunity is divided into two types-

- **Active immunity**- When a host is exposed to antigens, which may be in the form of living or dead microbes or other proteins, antibodies are produced in the host body, this type of immunity is called active immunity. Example- antibody produced when any microorganism enters the body.
- **Passive immunity**- When ready-made antibodies are directly given to protect the body against foreign agents this type of immunity is called passive immunity.

Example- The yellowish fluid colostrum secreted by mother during the initial days of lactation has abundant antibodies (IgA) to protect the infant. Vaccination and immunization

Vaccination is the process of introduction of vaccines into the body to produce antibodies against the antigens to neutralize the effect of pathogens during actual infection.

Vaccines are the dead or weakened pathogens introduced into the body.

The dead or weakened pathogen leads to the production of antibodies which neutralizes the pathogenic agents during actual infection with the same pathogen.

Immunization is the process where performed antibodies against the toxin are introduced into the body.

Example- performed antibody injection against snake venom.

Using recombinant DNA technology antigenic polypeptides of pathogens in bacteria or yeast.

Example- hepatitis B vaccine produced from yeast.

Fig. vaccination

Allergy

The exaggerated response of the immune system to certain antigens present in the environment is called allergy.

The substances to which immune response is produced are called **allergens**.

Common examples of allergens are mites in dust, pollens, animal dander etc.

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

The antibodies produced to these are of IgE type.

Symptoms of allergic reactions include sneezing, watery eyes, running nose and difficulty in breathing.

The patient is diagnosed by injecting or exposing the patient to very small doses of allergens.

Drugs like anti-histamine, adrenalin and steroids quickly reduce the symptoms of allergy.

Fig. allergy

Auto immunity

The immune system of body can is able to identify and differentiate between self and non self.

Due to genetic and other unknown reasons, the body attacks self-cell which results in damage to the body and is called auto-immune disease.

Rheumatoid arthritis is an auto-immune disease.

Fig. rheumatoid arthritis

Immune system in the body

Immune system consists of-

- Lymphoid organs
- Lymphoid tissues
- B- cells and T-cells
- Antibodies

Lymphoid organs-

The organs where origin and/or maturation and proliferation of lymphocytes occur are called lymphoid organs.

Lymphoid organs are of two types-

1. Primary lymphoid organs

2. Secondary lymphoid organs.

The primary lymphoid organs are bone marrow and thymus where immature lymphocytes differentiate into antigen-sensitive lymphocytes.

The bone marrow is the main lymphoid organ where all blood cells including lymphocytes are produced.

The thymus is a lobed organ located near the heart and beneath the breastbone.

Spleen, tonsil, lymph node, Peyer's patches of small intestine and appendix are secondary lymphoid organs where proliferation of lymphocytes take place.

The secondary lymphoid organs provide the sites for interaction of lymphocytes with the antigen, which then proliferate to become effector cells.

The spleen is a large bean shaped organ mainly contains lymphocytes and phagocytes which acts as a filter of the blood by trapping blood-borne microorganisms and has a large reservoir of erythrocytes.

The lymph nodes are small solid structures located at different points along the lymphatic system.

Lymph nodes serve to trap the antigens and these antigens trapped are responsible for the activation of lymphocytes and cause the immune response.

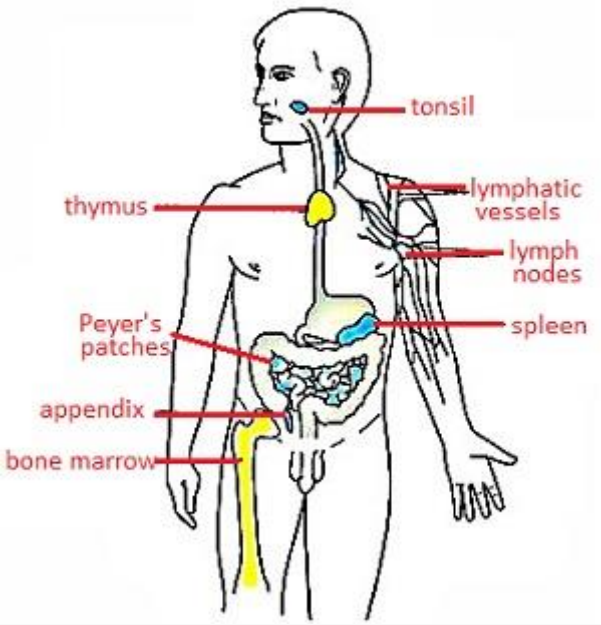

Fig. lymphoid organs

Lymphoid tissue-

Lymphoid tissue are located within the lining of the respiratory, digestive and urogenital tracts.

Lymphoid tissues are also called **mucosalassociated lymphoid tissue (MALT)** which constitutes about 50 per cent ofthe lymphoid tissue in human body.

AIDS

The term AIDS stands for Acquired Immuno Deficiency Syndrome.

The disease is acquired during life time.

AIDS is caused by **human immune deficiency virus (HIV).**

HIV is a retrovirus having RNA as the genetic material.

Mode of transmission-

- Sexual contact with infected persons.
- Bytransfusion of contaminated blood and blood products.
- By sharinginfected needles as in the case of intravenous drug abusers.
- From infected mother to her child through placenta.

Life cycle of HIV

- After getting into the body the virus enters into macrophages or T-helper cells.
- The viral RNA genome replicated to form viral DNA with the enzyme called **reverse transcriptase.**
- The viral DNA gets incorporated into the host cell's DNA and directs the infected cells to produce virus particles and the macrophages continue to produce virus.
- Viruses released from macrophages attack T-helper cells and cause a progressive reduction in the number of T-helper cells and due to which the person starts suffering from infections with several other microorganisms.

Diagnosed by **ELISA (enzyme linked immune-sorbent assay).**

Treated with anti-retroviral drugs but that is only partially effective.

Prevention of AIDS-

- To follow safe blood transfusion.
- To use disposable needles.
- To distribute free condoms.
- To prevent drug abuse.

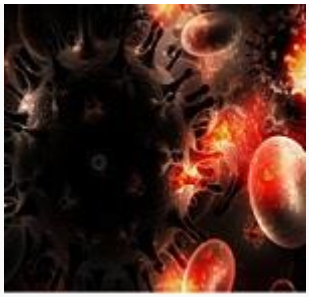

Fig. HIV virus

Cancer

Cancer is the uncontrolled cell division leading to the formation of a mass of cells called as a tumor.

Contact inhibition is the property of normal cells by virtue of which contact with other cells inhibits their uncontrolled growth.

Cancer cells lost the property of contact inhibition and as a result of this, cancerous cells continue to divide giving rise to masses of cells called tumors.

Tumors are of two types: **benign and malignant.**

Benign tumors normally remain confined to their original location and do not spread to other parts of the body.

The malignant tumors are a mass of proliferating cells called neoplastic or tumor cells.

Malignant tumors grow very rapidly and invade and ultimately damage surrounding tissues.

The property by which cancer cells moves to distant places from their origin by blood and invade the normal cells and make them cancerous is called as **metastasis**

Causes of cancer-

- Transformation of normal cells into cancerous cells may be induced by physical, chemical or biological agents called as **carcinogens**
- Physical carcinogens- ionizing radiation like X-rays, gamma rays and non-ionizing radiations like UV radiation of sun.
- Chemical carcinogens- tobacco smoke and some other chemicals.
- Biological carcinogens-

1. Cancer causing viruses are called **oncogenic viruses** have genes called **viral oncogenes.**

2. Cellular oncogenes or proto-oncogenes in normal cells, when get activated lead to oncogenic transformation of normal cells.

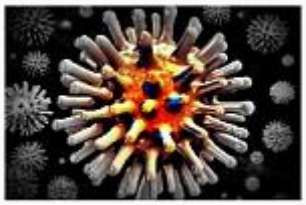

Fig. oncogenic virus

Detection of cancer-

- Biopsy and histo-pathological study of the tissues.
- Radiography by using X-rays, CT (computed tomography).
- MRI (magnetic resonance imaging).
- Use of antibodies against cancer-specific antigens.

Treatment of cancer-

- Surgery
- Radiation therapy.
- Chemotherapy
- iological response modifiers- alpha-interferon which activate the immune system and help in destroying the tumor.

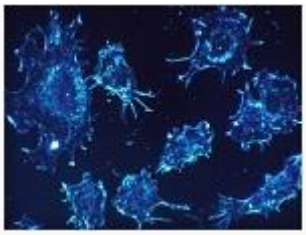

Fig. cancer cells

Drugs and alcohol abuse

The drugs which are commonly abused are opioids, cannabinoids and coca alkaloids.

Opoids-

- Opioids are the drugs which bind to specific opioid receptors present in our central nervous system and gastrointestinal tract.
- **Heroin** commonly called smack is chemically diacetylmorphine which is a white, odourless, bitter crystalline compound and is obtained by acetylation of morphine extracted from the latex of poppy plant *Papaversomniferum*
- Heroin is a depressant and slows down body functions.

Fig.*Papaversomniferum*

Cannabinoids

- Cannabinoids interact with cannabinoid receptors present principally in the brain.
- Natural cannabinoids are obtained from the inflorescences of the plant *Cannabis sativa.*
- The flower tops, leaves and the resin of cannabis plant are used in various combinations to produce marijuana, hashish, charas and ganja.
- Effects on cardiovascular system of the body.

Fig.*Cannabis sativa*

Fig. marijuana

Coca alkaloid

- Coca alkaloid or cocaine is obtained from coca plant *Erythroxylum coca.*
- Coca alkaloid interferes with the transport of the neuro-transmitterdopamine.
- Cocaine, commonly called as **coke** or **crack** .
- It has a potent stimulating action oncentral nervous system, producing a sense of euphoriaand increased energy.
- Excessive dosage of cocainecauses hallucinations.

Fig.*Erythroxylum coca* leaves

- Some plants withhallucinogenic properties are *Atropabelladona* and.

Fig.*Atropa belladonna*

- Drugs like barbiturates, amphetamines,benzodiazepines, lysergic acid diethyl amides (LSD) are used asmedicines to help patients cope with mental illnesseslike depression and insomnia, are often abused.
- Morphine is a very effective sedative and painkiller is often abused.

Tobacco-

- Tobacco conatins nicotine, an alkaloid.
- Nicotine stimulates adrenal gland to release adrenaline and nor-adrenaline into blood circulation, both of which raise blood pressure and increase heart rate.
- Smoking of tobacco is associated with increased incidence of cancers of lung, urinary bladder, throat, oral cavity, bronchitis, emphysema, coronary heart disease, gastric ulcer etc.

Fig. tobacco leaves

Adolescence and Drug/Alcohol Abuse

Adolescence means both ‘a period’ and ‘a process’ during which a child becomes mature in terms of his/her attitudes and beliefs for effective participation in society.

12-18 years of age may be thought of as adolescence period.

Adolescence is accompanied by several biological and behavioural changes.

Curiosity, need for adventure and excitement, and experimentation, constitute common causes, which motivate youngsters towards drug and alcohol use.

Fig. adolescence

Addiction and Dependence

Addiction is a psychological attachment to certain effects –such as euphoria and a temporary feeling of well-being – associated with drugs and alcohol.

With repeated use of drugs, the tolerance level of the receptors present in our body increases and consequently the receptors respond only to higher doses of drugs or alcohol leading to greater intake and addiction.

Dependence is the tendency of the body to manifest a characteristic and unpleasant withdrawal syndrome if regular dose of drugs/alcohol is abruptly discontinued.

Withdrawal syndrome is characterised by anxiety, shakiness, nausea and sweating.

Fig. addiction

Effects, prevention and control of Drug/Alcohol Abuse

Immediate effects are reckless behavior, vandalism and violence.

Excessive doses of drugs may lead to coma and death due to respiratory failure, heart failure or cerebral hemorrhage.

Those who take drugs intravenously can get infected with AIDS, hepatitis B.

The chronic use of drugs and alcohol damages nervous system and cause liver cirrhosis.

The use of drugs and alcohol during pregnancy is also known to adversely affect the foetus.

Use of anabolic steroids in females can cause masculinisation, increased aggressiveness, mood swings, depression, abnormal menstrual cycles, excessive hair, growth on the face and body, enlargement of clitoris, deepening of voice.

In males anabolic steroids can cause acne, increased aggressiveness, mood swings, depression, reduction of size of the testicles, decreased sperm production, potential for kidney and liver dysfunction, breast enlargement, premature baldness, enlargement of the prostate gland.

Prevention and Control

The measures useful for prevention and control of alcohol and drugs abuse among adolescents-

- Avoid undue peer pressure on children.
- Children should be educated and counseled to bear problems and stress in life.
- The child should seek help from parents and elders.
- Affected individuals should seek medical help ofqualified psychologists, psychiatrists, and deaddiction and rehabilitation programmes.

Fig. parents help and consultation with qualified psychiatrists can prevent and control alcohol and drug abuse

9.Strategies for Enhancement in Food Production

Introduction

- Production of sufficient food against ever increasing population is a challenging task.
- Several biological methods are developed to increase food production.
- Techniques like animal husbandry, apiculture, plant breeding have a major role in increasing food production.
- Several new techniques like embryo transfer technology and tissue culture techniques are going to play a pivotal role in further enhancing food production.

Fig. food produced for human consumption

Animal husbandry

- Animal husbandry is the agricultural practice of breeding and raising livestock.
- Animal husbandry deals with the care and breeding of livestock like buffaloes, cows, pigs, horses, cattle, sheep, camels, goats etc.
- Extended form of animal husbandry is poultry farming and fisheries.
- Fisheries include rearing, catching, selling, etc., of fish, molluscs (shell-fish) and crustaceans.
- Poultry farming deals with domesticated fowl (birds) used for food or for their eggs.

Fig. animal husbandry

Management of farm and farm animals

Dairy farm management

- Dairying is the management of animals for milk and its products for human consumption.
- Dairying deals with processes and systems that increase yield and improve quality of milk.

Important measuresfor improvement of dairy farm-

- Selection of good breeds having high yielding potential.

- The animals have to be housed well, should have adequate water and be maintained disease free.
- Providing good quality and quantity of fodder.
- Maintenance of hygienic environment.
- A regular visit to a veterinary doctor is mandatory.

Fig. dairy farm

Poultry farm management

- Poultry is the class of domesticated fowl (birds) used for food or for their eggs.
- Poultry include chicken and ducks, turkey and geese.

Important measures for improvement of poultry farm-

- Selection of disease free and suitable breeds.
- Proper and safe farm conditions
- Proper feed and water
- Maintenance of hygiene and proper care of health should be taken.

Fig. poultry farm

Animal breeding

- The process of creating a new breed with superior characters in the offspring is called animal breeding.
- A group of animals related by descent and similar in most character like general appearance, features, size and configuration is called a **breed**
- Breeding is of two types-

1. Inbreeding

2. Outbreeding

- When breeding is between animals of the same breed it is called inbreeding.

- Superior males and superior females of the same breed are identified and mated in pairs.
- In case of cattle, superior female is the cow or buffalo produces more milk per lactation and a superior male is the bull which gives rise to superior progeny as compared to those of other males.
- Inbreeding increases homozygosity.
- Inbreeding exposes harmful recessive genes that are eliminated by selection.
- It also helps in accumulation of superior genes and elimination of less desirable genes.
- Continued inbreeding usually reduces fertility and even productivity, which is called inbreeding depression.
- Out breeding programme is the solution to overcome in-breeding depression.
- Crosses between different breeds are called outbreeding.
- Out breeding is of three types-

1. Out crossing- Mating of animals within the same breed, but having no common ancestors on either side of their pedigree up to 4-6 generations is called outcrossing and the resulting offsprings are called out cross.

2. Cross- breeding— Mating of superior male of one breed and superior female of another breed is called cross breeding. Desirable qualities of two breeds can be combined by this process. **Hisardale** is a new breed of sheep developed in Punjab by crossing **Bikaneri ewes** and **Marino rams.**

3. Interspecific hybridization- the process in which male and female of different species of animals are mated is called interspecific hybridization.

Example- mule, a hybrid of donkey and horse.

Fig. mule

Controlled breeding experiments

- The experiments which are carried out to improve the quality of animals are called controlled breeding experiments.
- Controlled breeding experiments are carried out using artificial insemination and multiple ovulation embryo transfer technology.

Artificial insemination

- The semen is collected from the male and injected into the reproductive tract of the selected female by the breeders.
- The semen can be used immediately or can be frozen for using later.
- The semen can be transported in frozen form to where the female is housed.
- Artificial insemination can overcome several problems of normal matings and desirable matings can be carried out.

Fig. semen is injected into the reproductive tract of the female

Multiple ovulation embryo transfer technology (MOET)

- Cow is administered with hormones having FSH like activity which induces follicular maturation and produces 6-8 eggs instead of one egg called as
- The super ovulated animal is mated with elite bull or artificially inseminated.
- The eggs are removed at 8-32 cells stage non-surgically and one is transferred to a surrogate mother.
- The genetic mother can again be used for superovulation.
- High milk yielding breeds of females and high quality meat yielding bulls of cattle, sheep, rabbits etch have been bred successfully to increase herd size in a short time.

fig. mating of super ovulated female with a male

Bee keeping

- Bee keeping can also be termed as **apiculture**
- The maintenance of hives of honey bees for the production of honey is called bee keeping.
- Honey produced by honey bees has high nutritive value.
- Honey bee also produces bee wax which is widely used in the preparation of cosmetics and polishes of various kinds.
- There are species of honey bees which can be reared and the most common species is

Benefits of honey bees-

- Bees are pollinators of many crop species such as Sunflower. Brassica, Apple and Pear.
- Keeping of bee hives increase pollination in crop fields and improve yield.
- Honey bees are beneficial for crop yield and honey yield.

Requirements for successful bee keeping

- Knowledge of the nature and habits of honey bees.
- Selection of suitable location for keeping the bee hives.
- Catching and hiving of swarms.
- Management of beehives during different seasons.

- Handling and collection of honey and bees wax.

Fig. bee keeping

Fisheries

- Fisheries are also termed as pisciculture.
- The industries which practice catching, processing or selling of fish, shellfish or aquatic animals are called fisheries.
- **Catla,Rohu, Carp** are common marine fishes.
- **Hilsa, Sardines, Mackerel** and **Pomfrets** are fresh water fishes.
- Aquaculture is the rearing, breeding of aquatic animals and aquatic plants.

Fig. fishery

Fig. aquaculture of aquatic plants

Plant breeding

Plant breeding is the manipulation of plant species in order to create desired plant types that are better suited for cultivation, give better yields and are disease resistance.

Plant breeding is done to-

- Increase crop yield.
- Improve quality.
- Increase tolerance to environmental stresses.
- Make the plants resistant to pathogens.
- Increase tolerance to insect pest.

Steps in plant breeding technique

1. Collection of genetic variability or germplasm

- Collection and preservation of all the different wild species and relatives of the cultivated species.
- Evaluation of their characters.
- The entire collection having all the diverse alleles for all genes in a given crop is called germplasm collection.

2. Evaluation and selection of parents

- The germplasm is evaluated to identify plants with desirable combination of characters.
- The selected plants are multiplied and used in hybridization.
- Pure line is created wherever desirable and possible.

3. Cross hybridization among the selected parents

- Cross hybrisdisation of two selected parents by emasculation and bagging, to produce hybrids of combined character of both parents. For example- high protein quality of one parent may need to be combined with disease resistant from another parent.

- Usually one in few hundred to a thousand crosses offspring's shows desirable combinations.

4. Selection and testing of superior recombinants

- Selection is done from the progeny of hybrids produced by cross hybridization.
- Hybrids plants that are superior to both of the parents are selected.
- Hybrids are self pollinated for several generations till they reach a state of homozygosity.

5. Testing, release and commercialization of new cultivars

- Selected pure lines are evaluated in the research field for their yield and other agronomic traits of quality, disease resistance etc.
- Testing is done in the fields of farmers at least for three generations.
- The material is compared with best available local crop cultivar.

Indian hybrid crops of high yielding varieties

Wheat and rice

- Due to the development of semi-dwarf varities of wheat and rice, rice production went up to from 35 million to 89.5 million tones.
- **Sonalika** and **Kalyansona**are the varieties of wheat which were introduced all over the wheat growing belt of India.
- Semi- dwarf rice varites were derived from **IR-8** from Philippines and **Taichung Native-1** from Taiwan.
- Better yielding semi dwarf varities**Jaya** and **Ratna** were developed later in India.

Fig. wheat

Sugarcane

- *Saccharumbarberi*was originally grown in North India but had poor sugar content and yield.
- *Saccharumofficinarum*was tropical cane grown in South India, had thicker stems and higher sugar content, but did not grow well in North.
- Both the species were successfully crossed to get sugarcane varieties combining the desirable qualities of high yield, thick stems, high sugar and ability to grow in the all sugar cane areas of North India.

Fig. sugar cane

Millets

- Hybrid Maize, Bajra with high yielding property have been successfully developed in India.

Fig. millet Plant breeding for disease resistance

- To prevent the plants from bacterial, fungal, viral infections, cultivars resistant to diseases is developed which reduce the dependence on fungicide or insecticide.
    - Fungi can cause brown rust of wheat, red rot of sugarcane, late blight of potato.
- Bacteria can cause black rot of crucifer.
- Virus can cause tobacco mosaic, turnip mosaic etc.

Method of breeding for disease resistant-

- Screening of germplasm for resistance sources.
- Hybridization of selected parent.

- Selection and evaluation of hybrids.
- Testing and release of new varieties.

Sl no.	Crop	Variety	Resistance to diseases
1	Wheat	Himgiri	Leaf and stripe rust, hill bunt
2	Brassica	Pusaswarnim	White rust
3	Cauliflower	Pusashubhra	Black rot and curl blight rot
4	Cow pea	Pusakomal	Bacterial blight
5	Chili	Pusasadabahar	Chily mosaic virus, tobacco mosaic virus and leaf curl.

Mutation breeding

- Conventional breeding is often constrained by the availability of limited number of disease resistance genes that are present and identified in various crop varieties or wild relatives.
- Inducing mutations in plants through diverse means and then screening the plant materials for resistance sometimes leads to desirable genes being identified.
- Mutation is the process by which genetic variations are created through changes in the base sequence within genes resulting in the creation of a new character or trait not found in the parental type.
- Inducing mutations artificially through use of chemicals or radiations, and selecting and using the plants that have the desirable character as a source in breeding – this process is called **mutation breeding.**

Example- i) In **mung bean,** resistance to yellow mosaic virus and powdery mildew were induced by mutation. ii) Resistance to yellow mosaic virus in bhindi (***Abelmoschusesculentus***) was transferred from a wild species and resulted a new variety of ***esculentus*** and ***Parbhanikranti.***

Fig, mutated mung bean resistant to yellow mosaic virus

Plant breeding for developing resistant to insect pest

Insect resistance in host crop is due to morphological, biochemical or physiological characteristics.

Some characters make the plans resistance to insect are-

- Hairy leaves in several plants make them resistant to insect pest.
    - Solid stem in wheat lead to non-preference by stem sawfly.
- Smooth leaves and nectar-less cotton variety do not attract bollworms.
- High aspartic acids, low nitrogen and sugar content in maize make them resistant to stem borers.
- Pusagaurav, a variety of Brassica is resistant to Aphids.

Fig. brasicca

- Pusa sem-2 and pusasem 3 varities of flat bean are resistant to jassids, aphids and fruit borer.

Fig. flat beans

- Pusasawani and pusa A-4 of Okra (bhindi) are resistant to shoot and fruit borer.

Plant breeding for improved food quality

- Around three billion people in the world suffer from deficiency of micronutrient, protein and vitamin which is called hidden hunger which can lead to increase the risk of diseases, reduce life span, reduce mental ability etc.
- Food production should be increases qualitatively and quantitatively.
- **Biofortification** is the process of breeding crops which produce higher levels of nutrients like vitamins, minerals, protein and healthier fats to improve public health.

Biofortification is done to improve-

- Protein content and quality.
- Oil content and quality.
- Vitamin content.
- Micronutrient and mineral content.

Example-

i) Hybrid maize developed with twice the amount of amino acids lysine and tryptophan compared with existing maize.

ii) Wheat variety atlas 66 having high protein content has been used as donor for improving cultivated wheat.

iii) Iron fortified rice developed with five times more iron content than existing variety.

Indian agricultural research institute (IARI) has developed following plants

- Vitamin A enriched carrots, spinach and pumpkin.

Fig. pumpkin

- Vitamin C enriched bitter gourd, bathua, mustard, tomato.

Fig.mustard

- Iron and calcium enriched spinach and bathua.

Fig. spinach

- Protein enriched beans like broad, lablab, French and garden peas.

Fig. garden pea

Single cell protein

- Production of protein biomass in large scale using microorganisms and growing them in low cost raw material is called single cell proteins.
- More than 25% of human population is suffering from malnutrition hence one of the alternating sources of protein for human and animal is SCP.
- Microbes like ***Spirulina***grow on waste from potato processing plants, straw, molasses, animal manure and even sewage, to produce large quantities and can serve as food rich in protein, mineral, fats, carbohydrates and vitamins.
- 250 kg cow produces 200gm of protein per day, in the same period 250gm of microorganism like ***Methylophilusmethylotophus*** expected to produce 25 tons of protein.

Fig. Protein produced from spirulina

Tissue culture

- The method of growing a plant cell, tissue or an organ in an artificial nutrient medium under aseptic conditions provided with controlled conditions of light and temperature.
- Whole plant can be generated from an explant.

- **Explant** is any part of plant like cell, tissue or organ grown in a test tube containing artificial nutrient medium under sterile condition.
    - **Totipotency**is the capacity of a plant cell to multiply and regenerate into a new plant.
- The nutrient medium provides a carbon source such as sucrose, inorganic salts vitamins, amino acids and growth regulators like auxin, gibberellins and cytokinins.
- The cells of explant start dividing in the medium and gives undifferentiated mass of tissue called
- The callus later gives rose to embryoids called **somatic embryoids** which generate into new plants.
- The method of production of thousands of plants through tissue culture is called **micro propagation.**
- Plants grown by micro propagation are genetically identical called soma clones, because they are produced by somatic cells.

Importance of tissue culture-

- Large number of plants from small or single cell can be produced in short duration.
- Many important plants like tomato, appleand banana have been developed by tissue culture.
- Production of disease free varieties through meristem culture.

Fig. tissue culture

Somatic cell hybridization

- The process of fusing the protoplast of two cells of desirable plants to obtain a hybrid protoplast.
- In somatic cell hybridization.
- Cells are isolated from two desirable plants.
- Digestion of cell walls of the cells.
- Protoplasts of two desirable plants with desirable characters are fused to form hybrid protoplast.
- The hybrid protoplast can be further grown into a new plant.

Example- production of plant like **pomato** from potato and tomato.

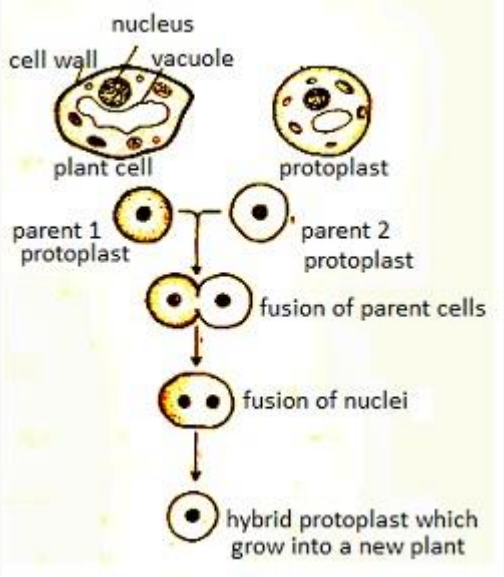

Fig. somatic hybridization

Introduction

Microbes are the major components of biological systems on this earth.

Microbes are present everywhere that is in soil, water, air, inside the body of plants and animals, inside thermal vents, deep in the soil, under the layers of snow several meters thick and in highly acidic environments.

Microbes are diverse such that they are protozoa, bacteria, fungi and microscopic plants viruses, viroids and prions that are proteinacious infectious agents.

Microbes like bacteria and many fungi can be grown on nutritive media to form colonies which can be seen with naked eyes.

Microbes cause a large number of diseases in human beings, animals and plants but all microbes are not harmful; several microbes are useful to man in diverse ways.

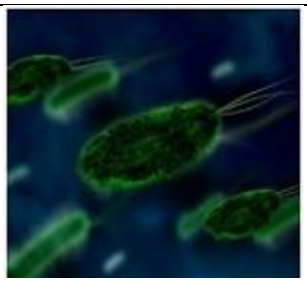			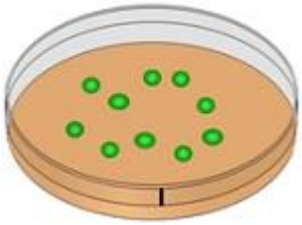
Fig. bacteria	Fig: virus	Fig: fungi	Fig. bacterial colony

Microbes in household products

1. Production of curd

- Milk is converted to curd by micro-organisms such as *Lactobacillus* and others commonly called **lactic acid bacteria (LAB)** which grow in milk and convert it to curd.
- During growth of bacteria, the LAB produce acids that coagulate and partially digest the milk proteins.
- A small amount of curd added to the fresh milk as inoculum or starter which at suitable temperatures multiply, thus converting milk to curd, which also improves its nutritional quality by increasing vitamin B12.
- In our stomach, the LAB play very beneficial role in checking disease causing microbes.

Fig. Lactobacillus

2. Fermentation

- The dough, which is used for making foods such as dosa and idli is also fermented by bacteria.
- The puffed-up appearance of dough is due to the production of CO_2

- The dough, which is used for making bread, is fermented using baker's yeast (*Saccharomyces cerevisiae*).
- A number of traditional drinks and foods are also made by fermentation by the microbes.
- Toddy, a traditional drink of some parts of southern India is made by fermenting sap from palms.
- Microbes are also used to ferment fish, soya bean and bamboo shoots to make foods.

Fig. dough

Fig. fermentor

3. Production of cheese

- Different varieties of cheese are known by their characteristic texture, flavor and taste, the specificity coming from the microbes used.
- The large holes in 'Swiss cheese' are due to production of a large amount of CO_2 by a bacterium named *Propionibacterium sharmanii*.
- The 'Roquefort cheese' are ripened by growing a specific fungi on them, which gives them a particular flavor.

Fig. cheese

Microbes in industrial products

Production on an industrial scale, requires growing microbes in very large vessels called **fermenters**

Beverages, antibiotics, enzymes are some of the industrial products produced by microbes.

Fermented beverages

- Microbes are used for the production of beverages like wine, beer, whiskey, brandy or rum.

- ***Saccharomyces cerevisiae***, is used for the production of fermented beverages.
- Malted cereals and fruit juices are fermented by S.cerevisiae to produce ethanol.
- Wine and beer are produced without distillation.
- Whisky, brandy and rum are produced by distillation of the fermented broth.

Fig. Saccharomyces cerevisiae

Antibiotics

- Antibiotics are the chemical substances which are produced by some microbes and can kill or stop the growth the growth of other microbes.
- Alexander Flemming discovered penicillin obtained from ***Penicillium notatum*** which was the first antibiotic to be discovered.
- Alexander Fleming while working on Staphylococci bacteria observed a mould growing in one of his unwashed culture plates around which Staphylococci could not grow and he found out that it was due to a chemical produced by *Penicillium notatum.*
- Antibiotics are used against the deadly diseases like plague, whooping cough, leprosy, malaria etc.

Fig. Penicillium notatum

Chemicals, enzymes and other bioactive molecules

- Microbes are used for the production of organic acids, alcohols and enzymes.

Examples-

1. *Aspergillus niger* (a fungus) is the producer of citric acid.

Fig. *Aspergillus niger*

1. *Acetobacter aceti* (a bacterium)produces acetic acid.

Fig. *Acetobacter aceti*

- *Clostridium butylicum* (a bacterium) is the producer of butyric acid and Lactobacillus (a bacterium).

Fig. Clostridium butylicum

1. Yeast (*Saccharomyces cerevisiae*) is used for commercial production of ethanol.
2. Lactobacillus (a bacterium) is the producer of lactic acid.

Enzymes produced by the microbes are-

1. Lipases- used in detergent formulations.
2. Pectinases and proteases- used in making bottled fruit juices clearer.

- Streptokinase produced by the bacterium Streptococcus is used as a ‘clot buster’ for removing clots from the blood vessels of patients who have undergone myocardial infraction leading to heart attack.

Bioactive molecules produced by microbes are-

1. Cyclosporin A- used as an immunosuppressive agent in organ-transplant patients, is produced by the fungus *Trichoderma polysporum*.
2. Statins- produced by the yeast *Monascus purpureus* is used as blood-cholesterol lowering agents which acts by competitively inhibiting the enzyme responsible for synthesis of cholesterol.

Microbes in sewage treatment

Municipal waste-water which contains large amounts of organic matter is called sewage.

Before disposal, hence, sewage is treated in sewage treatment plants (STPs) by the heterotrophic microbes to make it less polluting.

Sewage treatment is carried out in two stages.

1. **Primary treatment –**

- These treatment steps basically involve physical removal of large and small particles.
- Initially, floating debris is removed by sequential filtration and then the grit are removed by sedimentation.
- All solids that settle form the primary sludge, and the supernatant forms the effluent.
- The effluent from the primary settling tank is taken for secondary treatment.

1. **Secondary treatment or biological treatment-**

- The primary effluent is passed into large aeration tanks where it is constantly agitated which allows vigorous growth of useful aerobic microbes into flocs.
- Flocs are the masses of bacteria associated with fungal filaments to form mesh like structures.
- While growing, the microbes significantly reduces the **BOD (biochemical oxygen demand)** which is the amount of oxygen required to oxidize total organic matter in the effluent.
- The BOD test measures the rate of uptake of oxygen by micro-organisms, the greater the BOD of waste water, more is its polluting potential.
- The effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment and the sediment is called **activated sludge** .
- A small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum.
- The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters** where other kinds of bacteria grow anaerobically which digest the bacteria and the fungi in the sludge.
- During digestion, bacteria produce a mixture of gases such as methane, hydrogen sulphide and carbon dioxide which form biogas .
- The effluent from the secondary treatment plant is generally released into natural water bodies like rivers and streams.

Fig. sewage plant

Microbes in the production of biogas

Biogas is a mixture of gases (containing predominantly methane) produced by the microbial activity.

Certain bacteria grow anaerobically on cellulosic material and produce large amount of methane along with CO_2 and H_2 which are collectively called as methanogens.

One common methanogen is ***Methanobacterium***

These bacteria are commonly found in the anaerobic sludge during sewage treatment and in the rumen of cattle to digest **cellulose** in the food of the cattle , thus the excreta of cattle, commonly called **gobar** can be used for generation of biogas, commonly called **gobar gas.**

Biogas plant

- The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed.

- A floating cover is placed over the slurry, which keeps on rising as the gas is produced in the tank due to the microbial activity.
- The biogas plant has an outlet, which is connected to a pipe to supply biogas to nearby houses.
- The spent slurry is removed through another outlet and may be used as fertilizer.
- The biogas thus produced can be used for cooking and lighting.

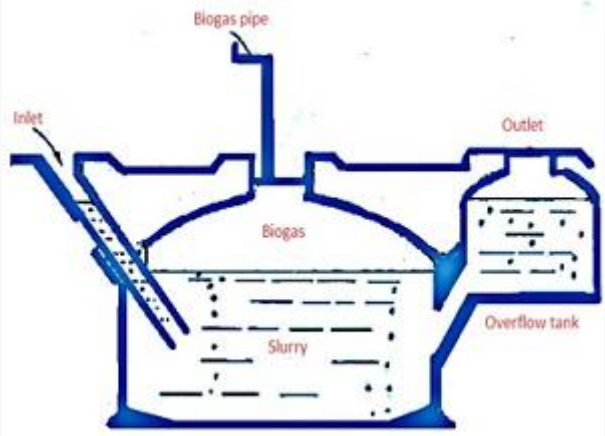

Fig. biogas plant

Microbes as biocontrol agents

Biocontrol refers to the use of biological methods for controlling plant diseases and pests.

Chemicals, insecticides and pesticides are extremely harmful to human beings and also these pollute our environment.

The use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.

Biocontrol agents are which are useful in controlling plant diseases and pests are-

- The ladybird, a beetle with red and black markings and dragon flies are useful to get rid of aphids and mosquitoes respectively.

Fig. ladybird

- Bacteria *Bacillus thuringiensis* (Bt) is used to get rid of butterfly caterpillars where dried spores of Bacillus thuringiensis are mixed with water and sprayed onto vulnerable plants such as brassicas and fruit trees and these are eaten by the insect larvae and in the gut of the larvae, the toxin is released and the larvae get killed.

Fig. *Bacillus thuringiensis*

- Trichoderma species are free-living fungi found in the root ecosystem these are effective as biocontrol agents of several plant pathogens.
- Baculoviruses are pathogens that attack insects and other arthropods and the majority of baculoviruses used as biological control agents are in the genus Nucleopolyhedrovirus.

Microbes as biofertilizers

Biofertilizers are organisms that enrich the nutrient quality of the soil.

The main sources of biofertilizers are bacteria, fungi and cyanobacteria.

Some microbes used as biofertlizers are-

- Rhizobium form root nodules in leguminous plants and fix atmospheric nitrogen into organic forms, which is used by the plant as nutrient.
- Free living bacteria like Azospirilium and Azotobacter fix atmospheric nitrogen, hence increases nitrogen content of the soil.
- Many members of the genus Glomus form Mycorrhiza, which is the symbiotic association of fungi with roots of the plants.

The fungal symbiont in these associations absorbs phosphorus from soil and passes to the plants.

Plants having symbiotic association show resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development.

Fig. Mycorrhiza

Cyanobacteria are autotrophic microbes which can fix atmospheric nitrogen. Example - Anabaena, Nostoc, Oscillatoria

Blue green algae also add organic matter to the soil and increase its fertility

Fig. anabaena

Introduction

- Biotechnology deals with the techniques of using living organisms or enzymes from organisms to produce products useful to humans.
- The processes like in vitro fertilization leading to a 'test-tube' baby, synthesizing a gene and using it, developing a DNA vaccine or correcting a defective gene, are all parts of biotechnology.
- Biotechnology can be defined as- 'The integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services'.

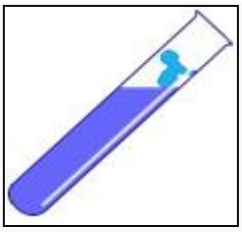

Fig. test tube baby

Principles of biotechnology

The two core techniques that enabled birth of modern biotechnology are –

1. Genetic engineering

2. Maintenance of sterile conditions.

Genetic engineering is the technique of altering the chemistry of DNA and RNA so that it can be introduced into the host organism to change the phenotype of the host organism.

- Sterile conditions should be maintained to enable growth of only the desired microbe or eukaryotic cell in large quantities for the manufacture antibiotics, vaccines, enzymes, etc.
- Hybridization procedures often lead to inclusion and multiplication of undesirable genes along with the desired genes.
- The techniques of genetic engineering which include **creation of recombinant DNA, use of gene cloning and gene transfer** allows us to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organism.

Three basic steps in genetically modifying an organism —

- Identification of DNA with desirable genes
- Introduction of the identified DNA into the host
- Maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

Fig. genetic engineering

Tools of recombinant DNA technology

Important tools of recombinant DNA technology are-

- Restriction enzymes- Restriction enzymes are called as **molecular scissors** because these enzymes cut DNA at specific sites.
- Cloning vector- Plasmids and bacteriophages have the ability to replicate within bacterial cells independent of the control of chromosomal DNA.
- Competent host- The host should be competent enough to take up the foreign DNA.
- Bioreactors- Bioreactor is the cylindrical vessel in which biological processes is carried out on a large scale.

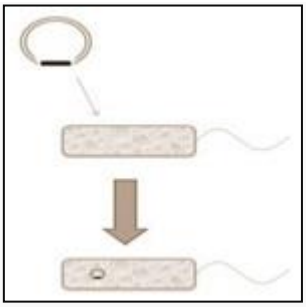

Fig. recombinant DNA technology

Restriction enzymes

- Restriction enzymes belong to a larger class of enzymes called
- Restriction enzymes are called as molecular scissors because these enzymes cut DNA at specific sites.
- The first restriction endonuclease is Hind II.
- The restriction enzymes cut DNA at specific base sequence, and these specific base sequence is known as the **recognition sequence.**
- The convention for naming restriction enzymes –
- The first letter of the name comes from the genus.
- The second two letters come from the species of the prokaryotic cell from which they were isolated, e.g., EcoRI comes from Escherichia coli RY 13.
- In EcoRI, the letter 'R' is derived from the name of strain.
- Roman numbers following the names indicate the order in which the enzymes were isolated from that strain of bacteria.
- 900 restriction enzymes that have been isolated from over 230 strains of bacteria.

These are of two kinds

1. Exonucleases

2. Endonucleases

- Exonucleases remove nucleotides from the ends of the DNA whereas, endonucleases make cuts at specific positions within the DNA.
- Each restriction endonuclease recognizes a specific **palindromic nucleotide sequences** in the DNA.
- The palindrome in DNA is a sequence of base pairs that reads same on the two strands when orientation of reading is kept the same.

Example- the following sequences reads the same on the two strands in 5' à 3' direction, this is also true if read in the 3' à 5' direction.

5' —— GAATTC —— 3’

3' —— CTTAAG —— 5'

- Restriction enzymes cut the strand of DNA a little away from the center of the palindrome sites, but between the same two bases on the opposite strands which leaves a single stranded portions at the ends and the overhanging stretches called **sticky ends** on each strand.
- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of ‘sticky-ends’ and, these can be joined together using DNA ligases.

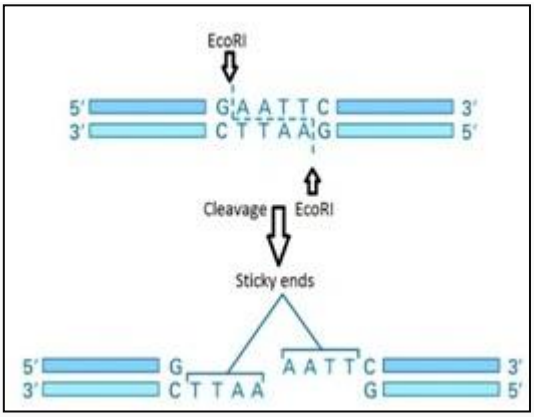

Fig. restriction digestion

Cloning vectors

- A cloning vector is a small piece of DNA, taken from any organism into which a foreign DNA fragment can be inserted for cloning purposes.
- Plasmids and bacteriophages have the ability to replicate within bacterial cells independent of the control of chromosomal DNA.
- If an alien piece of DNA with bacteriophage or plasmid DNA, we can multiply its numbers equal to the copy number of the plasmid or bacteriophage.

The following are the features that are required to facilitate cloning into a vector are-

- Origin of replication (ori)
- Selectable marker
- Cloning sites

Origin of replication (ori)- This is the sequence from where replication starts and any piece of DNA when linked to this sequence can be made to replicate within the host cells

Selectable marker-

- It helps in identifying and eliminating non transformants and selectively permitting the growth of the transformants.
- Transformation is a procedure through which a piece of DNA is introduced in a host bacterium.
- The genes encoding resistance to antibiotics such as ampicillin, chloramphenicol, tetracycline or kanamycin, etc., are useful selectable markers for E. coli as the normal E. coli cells do not carry resistance against any of these antibiotics.

- Antibiotic resistance genes help in selecting recombinants from non-recombinants by a method called **insertional inactivation** where a recombinant DNA is inserted within the coding sequence of an enzyme β-galactosidase in the presence of a chromogenic substrate which results into inactivation of the enzyme.
- The presence of a chromogenic substrate gives blue colored colonies if the plasmid in the bacteria does not have an insert.
- Presence of insert results into insertional inactivation of the β-galactosidase and the colonies do not produce any colour, these are identified as recombinant colonies.

Cloning sites-

- Cloning sites are the recognition sites of the restriction enzymes.
- The ligation of alien DNA is carried out at a restriction site present in one of the two antibiotic resistance genes.

For example- ligation of a foreign DNA at the Bam H I site of tetracycline resistance gene in the vector pBR322.

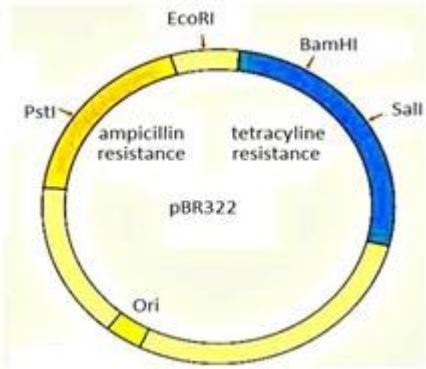

Fig. pBR322

- Vector for cloning genes in plants is *Agrobacterioum tumifaciens*, a pathogen of several dicot plants which delivers a piece of DNA known as 'T-DNA' to transform normal plant cells into a tumor and direct these tumor cells to produce the chemicals required by the pathogen.
- The **tumor inducing (Ti) plasmid** of *Agrobacterium tumifaciens* has now been modified into a cloning vector.

Fig. tumor formation by *Agrobacterium tumifaciens*

- Vector for cloning genes in animals is **retrovirus** which transforms normal cells into cancerous cells.
- Retroviruses have been disarmed and used to deliver desirable genes into animal cells.

Competent host

- Since DNA is a hydrophilic molecule, it cannot pass through cell membranes so the bacterial cells must first be made 'competent' to take up DNA.
- Several methods are followed to make the bacterial cells competent-
- Treating them with a specific concentration of a divalent cation, such as calcium, which increases the efficiency with which DNA enters the bacterium through pores in its cell wall.
- Recombinant DNA can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42°C (heat shock), and then putting them back on ice which enables the bacteria to take up the recombinant DNA.
- Recombinant DNA can be directly injected into the nucleus of an animal cell by a method called **micro-injection**.
- In **biolistics or gene gun** method, cells are bombarded with high velocity micro-particles of gold or tungsten coated with DNA
- Disarmed pathogen vectors can be allowed to infect the cell to transfer the recombinant DNA into the host.

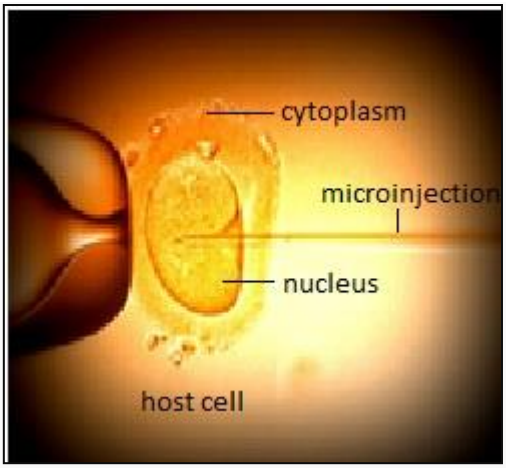

Fig. DNA is injected into the nucleus of the host cell by the process of micro-injection.

Bioreactors

- Bioreactor is the cylindrical vessel in which biological processes is carried out on a large scale.
- The recombinant cells can be multiplied in a continuous culture system wherein the used medium is drained out from one side while fresh medium is added from the other to maintain the cells.
- Bioreactors vessels in which raw materials are biologically converted into specific products, individual enzymes, etc., using microbial plant, animal or human cells.
- A bioreactor provides the optimal conditions for achieving the desired product by providing optimum growth conditions such as temperature, pH, substrate, salts, vitamins, oxygen.
- Bioreactors are of two types-

1. Simple stirred tank bioreactor

2. Sparged stirred-tank bioreactor

- A stirred-tank reactor is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents and the stirrer facilitates even mixing and oxygen availability throughout the bioreactor.
- In sparged stirred-tank bioreactor sterile air is sparged through the reactor.
- The bioreactor has an agitator system, an oxygen delivery system and a foam control system, a temperature control system, pH control system and sampling ports so that small volumes of the culture can be withdrawn periodically.

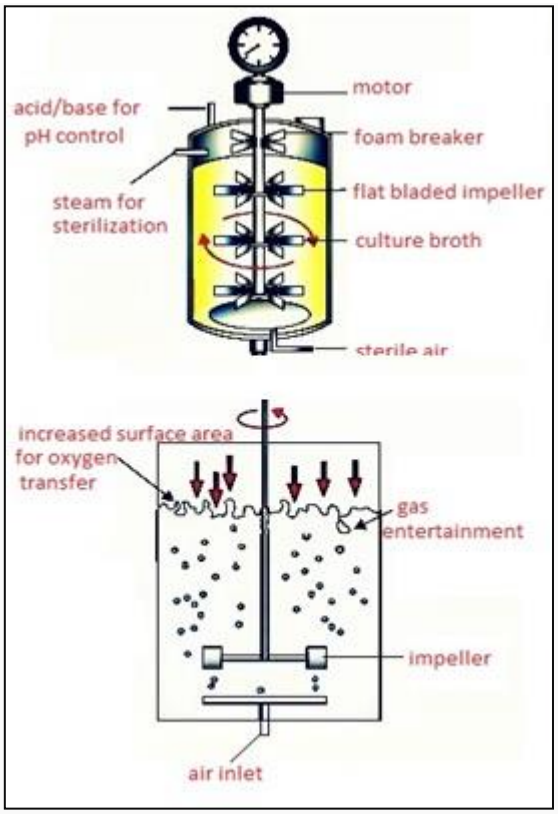

Fig. simple stirred-tank bioreactor and sparged stirred-tank bioreactor

Process of recombinant DNA technology

Isolation of the Genetic Material (DNA)-

- The cells are broken and opened to release DNA along with other macromolecules such as RNA, proteins, polysaccharides and also lipids which can be achieved by treating the cells with enzymes such as **lysozyme** (bacteria), **cellulase** (plant cells), **chitinase** (fungus).
- The RNA can be removed by treatment with **ribonuclease** whereas proteins can be removed by treatment with **protease** and purified DNA ultimately precipitates out after the addition of chilled ethanol which can be seen as collection of fine threads in the suspension.

Fig. DNA precipitate

Cutting of DNA at Specific Location-

- Restriction enzyme digestions are performed by incubating purified DNA molecules with the restriction enzyme, at the optimal conditions for that specific enzyme which results in the fragments of DNA.
- The fragments are separated by a technique known as **gel electrophoresis**.
- Since DNA fragments are negatively charged molecules they can be separated by forcing them to move towards the anode under an electric field through agarose.

- The DNA fragments separate according to their size through sieving effect provided by the agarose gel.
- The smaller the fragment size, the farther it moves and the separated DNA fragments can be visualized only after staining the DNA with a compound known **as ethidium bromide** followed by exposure to UV radiation.
- Bright orange coloured bands of DNA can be observed in an ethidium bromide stained gel exposed to UV light.
- The separated bands of DNA are cut out from the agarose gel and extracted from the gel piece by the process known as

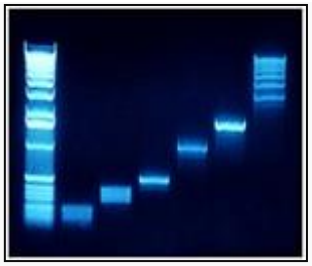

Fig . DNA bands

Amplification of Gene of Interest using PCR

- PCR stands for Polymerase Chain Reaction.
- Multiple copies of the gene of interest is synthesized in vitro using two sets of primers and the enzyme DNA polymerase.
- Primers are small chemically synthesized oligonucleotides that are complementary to the regions of DNA.
- PCR includes three major steps-

1. Denaturation

2. Annealing

3. Extension

- Denaturation is the process of heating of target DNA at 94^{o}C to seperate the two strands of DNA.
- Annealing is the process of pairing of primers with complimentary base sequences of the two separated strands.
- Extension is the process of adding complimentary deoxyribonucleotides one by one to the 3$^{/}$OH ends of primers by the activity of DNA polymerase and as a result new DNA strand is synthesized.
- If the process of replication of DNA is repeated many times, the segment of DNA can be amplified to approximately billion times by the use of a thermostable DNA polymerase isolated from a bacterium, *Thermus aquaticus.*
- The amplified fragment can be used to ligate with a vector for further cloning.

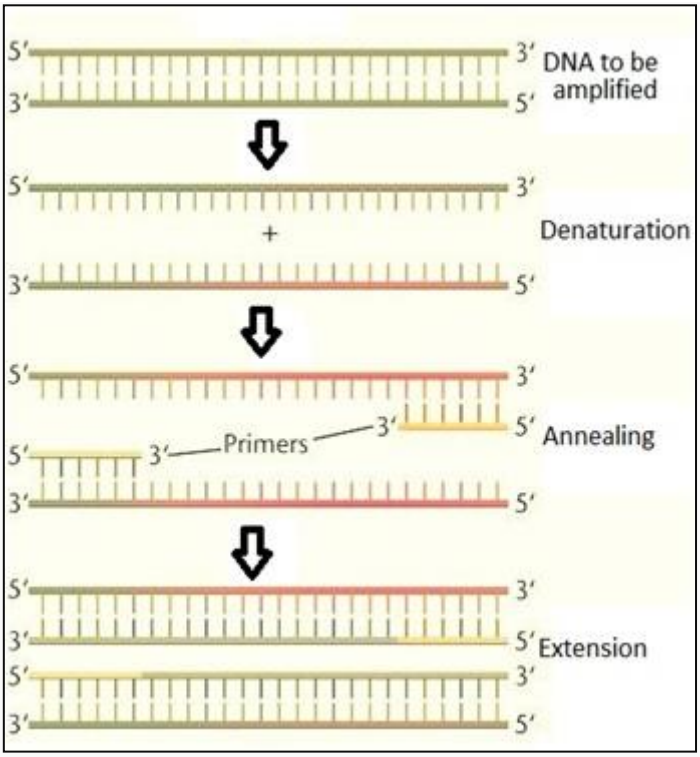

Fig. polymerase chain reaction

Insertion of Recombinant DNA into the Host Cell/Organism

- Recipient cells after making them ‘competent’ to receive, take up DNA present in its surrounding.
- If a recombinant DNA bearing gene for resistance to an antibiotic is transferred into E. coli cells, the host cells become transformed into ampicillin-resistant cell.

Obtaining the Foreign Gene Product

- The foreign gene when gets expressed under appropriate conditions, produces desirable proteins.
- If any protein encoding gene is expressed in a heterologous host, is called a **recombinant protein**.
- The cells harboring cloned genes of interest may be grown on a small scale in the laboratory or on a large scale in a bioreactor.

Downstream Processing

- Downstream processing is the separation and purification of the product.
- The product has to be formulated with suitable preservatives and the formulation has to undergo thorough clinical trials.

Introduction

- Biotechnology deals with industrial scale production of biopharmaceuticals and biologicals using genetically modified microbes, fungi, plants and animals.
- Applications of biotechnology include therapeutics, diagnostics, genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production.
- Human beings have used biotechnology to improve the quality of human life especially in the field of food production and health.

Fig. applications of biotechnology include genetics, therapeutics, diagnostics, waste treatment

Biotechnological applications in agriculture

- Methods opted for increasing food production are-
- Agro-chemical based agriculture.
- Organic agriculture.
- Genetically engineered crop-based agriculture.
- Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called **Genetically Modified Organisms (GMO).**

Fig. genetically modified mouse, tomato

- Genetic modification has-
- Made crops more tolerant to abiotic stresses.
- Reduced reliance on chemical pesticides.
- Helped to reduce post-harvest losses.
- Increased efficiency of mineral usage by enhanced nutritional value of food, e.g., Vitamin ‘A’ enriched rice.
- To produce vitamin ‘A’ enriched rice two genes from daffodil and one from the bacterium *Erwinia uredovora* were inserted in the rice genome and these three genes produce the enzymes necessary to produce provitamin-A. When golden rice is ingested, the human body splits the provitamin-A to make vitamin A.
- The production of pest resistant plants such as **Bt cotton** and tobacco plants decreased the amount of pesticide used.

Bt Cotton

- Some strains of ***Bacillus thuringiensis*** produce protein crystals during a particular phase of their growth.
- The crystals contain a toxic insecticidal protein that kill certain insects such as **lepidopterans** (tobacco budworm, armyworm), **coleopterans** (beetles) and **dipterans** (flies, mosquitoes).
- The toxin does not kill the Bacillus because the Bt toxin protein exists as inactive protoxins but once the insect ingests the inactive toxin, it is converted into an active form

of toxin due to the alkaline pH of the gut which solubilize the crystals.

- The activated toxin binds to the surface of midgut epithelial cells and create pores that cause cell swelling and lysis and cause death of the insect.
- The toxin is coded by a gene named **cry**.
- There are a number of genes acting against the insects , for example, the proteins encoded by the genes **cryIAc** and **cryIIAb** control the **cotton bollworms**, that of **cryIAb** controls **corn borer.**
- Specific Bt toxin genes were isolated from *Bacillus thuringiensis* based on the crop and the targeted pest which is then incorporated into the several crop plants.

Fig. Bt cotton plants

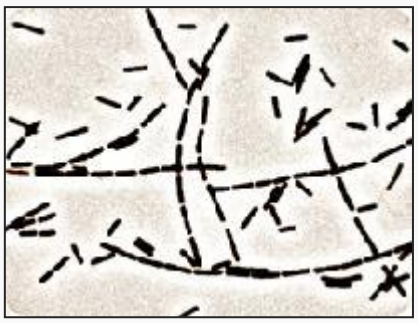

Fig. *Bacillus thuringiensis*

Tobacco plants

- A nematode ***Meloidegyne incognitia*** infects the roots of tobacco plants.
- The process of RNA interference was adopted to prevent the infection of tobacco plants.
- The process of RNA interference (RNAi) involves silencing of a specific mRNA due to a complementary dsRNA (double stranded RNA) molecule that binds to and prevents translation of the mRNA, also referred as **RNA silencing**.
- The source of this complementary RNA could be from an infection by viruses having RNA genomes or **transposons** which are mobile genetic elements that replicate via an RNA intermediate.

- Using Agrobacterium vectors, nematode-specific genes were introduced into the host plant such that it produced both sense and anti-sense RNA in the host cells.
- Two RNA's being complementary to each other formed a double stranded RNA (dsRNA) that initiated RNAi and thus, silenced the specific mRNA of the nematode.

Fig. *Meloidegyne incognitia*

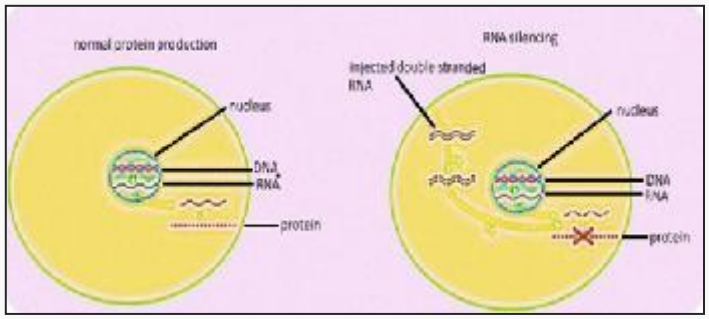

Fig. RNA silencing

Applications of biotechnology in medicine

- The recombinant DNA technological processes have made immense impact in the area of healthcare by enabling mass production of genetically engineered medicines such as insulin, by creating methods like gene therapy, recombinant DNA technology, polymerase Chain Reaction (PCR) and Enzyme Linked Immuno-sorbent Assay (ELISA).
- About 30 recombinant therapeutics have been approved for human-use over the world.

Genetically Engineered Insulin

- Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs which caused some patients to develop allergy.
- Insulin consists of two short polypeptide chains: chain A and chain B that are linked together by disulphide bridges.

- In mammals, including humans, insulin is synthesized as a pro-hormone which contains an extra stretch called the **C peptide** and the C peptide is not present in the mature insulin which is removed during maturation into insulin.
- Two DNA sequences were prepared corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.
- Chains A and B were produced separately, which were extracted and combined by creating disulfide bond to form human insulin.

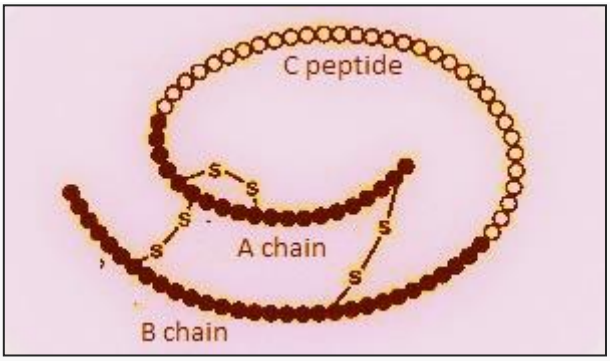

Fig. proinsulin

Gene Therapy

- Gene therapy is a collection of methods that allows correction of a faulty gene by a healthy and functional gene.
- Correction of a genetic defect involves delivery of a normal gene into the cells or tissues to take over the function of and compensate for the non-functional gene.
- The first clinical gene therapy was given in 1990 to a 4-year old girl with **adenosine deaminase (ADA**) deficiency which is caused due to the deletion of the gene for adenosine deaminase.
- ADA enzyme is crucial for the immune system to function.
- Lymphocytes from the blood of the patient are grown in a culture outside the body and a functional ADA cDNA (using a retroviral vector) is then introduced into these lymphocytes using a retroviral vector which are returned to the patient.
- In some children, ADA deficiency can be cured by bone marrow transplantation or by enzyme replacement therapy in which functional ADA is given to the patient by injection.

Fig. lymphocyte culture

Molecular diagnosis

- Recombinant DNA technology, Polymerase Chain Reaction (PCR) and Enzyme Linked Immuno-sorbent Assay (ELISA) are some of the molecular diagnosis that serve the purpose of early diagnosis to understand the pathophysiology of the disease.
- PCR is used to detect HIV in suspected AIDS patients, to detect mutations in genes in suspected cancer patients too.
- Very low concentration of a bacteria or virus can be detected by amplification of their nucleic acid by PCR.
- A single stranded DNA or RNA, tagged with a radioactive molecule (probe) is allowed to hybridize to its complementary DNA in a clone of cells followed by detection using autoradiography where the clone having the mutated gene will hence not appear on the photographic film, because the probe will not have complementarity with the mutated gene.
- ELISA is performed based on the principle of antigen-antibody interaction, infection by pathogen can be detected by the presence of antigens or by detecting the antibodies synthesized against the pathogen.

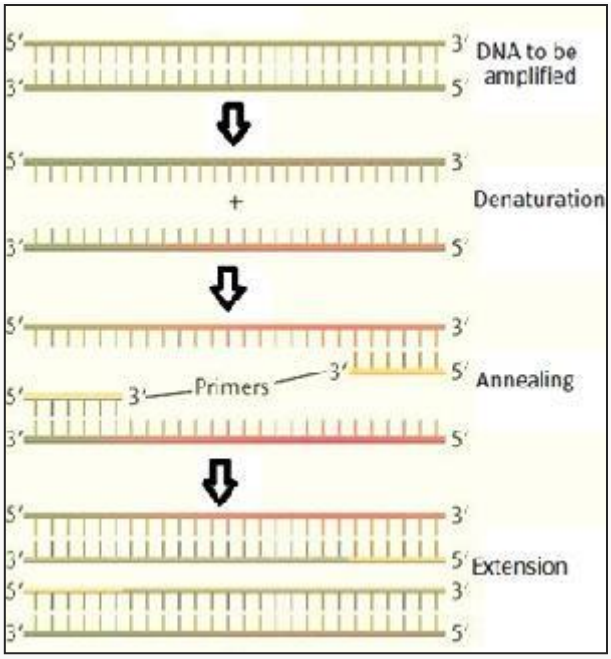

Fig. PCR technique

Transgenic animals

- Animals that have had their DNA manipulated to possess and express a foreign gene are known as transgenic animals. Example- Transgenic rats, rabbits, pigs, sheep etc.
- Transgenic animals are created-
- To study how genes are regulated, and how they affect the normal functions of the body and its development. Example- study of complex factors involved in growth such as insulin-like growth factor.
- to study how genes contribute to the development of disease.
- to produce biological products such as human protein (α-1-antitrypsin) used to treat emphysema, proteins to treat phenylketonuria and cystic fibrosis, human alpha-lactalbumin enriched milk. Example- the first transgenic cow, Rosie, produced human protein-enriched milk 2.4 grams per litre.
- for testing the safety of vaccines before they are used on humans. Example- Transgenic mice are being used to test the safety of the polio vaccine.
- for testing toxicity of drugs.

Fig. transgenic cow, Rosie

Ethical issues

- Genetic modification of organisms can have unpredictable results when such organisms are introduced into the ecosystem, hence the Indian Government has set up organizations such as **GEAC (Genetic Engineering Approval Committee)**, to make decisions regarding the validity of GM research and the safety of introducing GM-organisms for public service.
- The modification/usage of living organisms for public services has also created problems with patents granted for the same.
- Patent is the right granted by the Government to a producer to prevent other from using his product.
- An American company got patent rights on Basmati rice but the variety of Basmati had actually been derived from Indian farmer's varieties.
- Several attempts have also been made to patent uses, products and processes based on Indian traditional herbal medicines. Example- turmeric, neem.
- Biopiracy is the term used to refer to the use of bio-resources by multinational companies and other organizations without proper authorization from the countries and people concerned without compensatory payment.
- Some nations are developing laws to prevent such unauthorized exploitation of their bio-resources and traditional knowledge.

Fig. basmati rice

Fig. turmeric plant

Introduction

Ecology is the study of the interactions among organisms and between the organism and its physical (abiotic) environment.

Ecology deals with four levels of biological organization –

- Organism- a living entity which can function on its own.
- Populations- sum of all living organisms of the same species living in a particular geographical area.
- Communities- a group of people living together in one place.
- Biomes- a large geographical area of various plants and animals.

Fig. deer, an organism

Fig. population of deer

Fig. deer, elephant and tiger form a community

Fig. a biome with different plants and animals

Organisms and population

Different organisms are adapted to their environments in terms of both survival and reproduction.

Rotation of earth around the sun and the tilt if its axis cause annual variations in the intensity and durations of temperature which results into distinct seasons.

Variations of temperature along with annual variations in precipitation such as rain and snow form major biomes such as desert, rain forest and tundra.

Regional and local variations such as temperature, water. Light and within each biome lead to the formation of a wide variety of habitats.

Both abiotic and biotic components characterize the environment.

Fig. desert, rain forest, tundra

Major abiotic factors of the ecosystem

Temperature

- The average temperature on land varies seasonally, decreases progressively from the equator towards the poles and from plains to the mountain tops.
- Thermal springs and deep-sea hydrothermal vents are unique habitats where average temperatures exceed 1000^{o}
- Temperature affects the kinetics of enzymes and through it the basal metabolism, activity and other physiological functions of the organism.
- Organisms which can tolerate and thrive in a wide range of temperatures, they are called eurythermal organisms.Example- cat, dog etc.
- Organisms which can tolerate a narrow range of temperatures such organisms are called stenothermal organisms. Example- fish, reptile etc.

Fig. thermal springs

Water

- Life on earth originated in water and is unsustainable without water.
- For aquatic organisms the chemical composition, pH of water is important.
- The salt concentration varies in aquatic environment.

- The salt concentration (measured as salinity in parts per thousand), is less than 5 per cent in inland waters, 30-35 per cent the sea and > 100 per cent in some hyper saline lagoons.
- The organisms which can tolerate a wide range of salinities, they are called euryhalineorganisms. Example- the green crab.
- The organisms which tolerate a narrow range of temperature, they are called stenohalineorganisms. Example- goldfish.

Fig. green crab, gold fish

Light

- Plants are dependent on light to produce food through the process of photosynthesis.
- Many plants are dependent on sunlight to meet their photoperiodic requirement for flowering.
- Animals use the diurnal and seasonal variations in light intensity and duration (photoperiod) as cues for timing their foraging, reproductive and migratory activities.

Fig. photosynthesis

Soil

- Soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils, which along with parameters such as pH, mineral composition and topography determine the vegetation in any area.
- In the aquatic environment, the sediment-characteristics often determine the type of benthic animals that can thrive there.

Fig. benthic animals

Responses to Abiotic Factors

Abiotic conditions of many habitats may vary drastically in time and the organisms living in such habitats cope with stressful conditionsby maintaining the constancy of their internal environment.

The process of maintain a constant internal environment is called homeostasis

The organisms which are able to maintain homeostasis are called regulators and the organisms which are not able to maintain homeostasis are called conformers

Organisms are able to maintain homeostasis by physiological and behavioral means which ensures constant body temperature, constant osmotic concentration.

All birds and mammals, very few lower vertebrate and invertebrate species are capable of thermoregulation and osmoregulation.

Human maintain a constant body temperature of 37^0

Humans maintain homeostasis by sweating in summer and shivering in winter.

Conformers cannot maintain a constant internal environment and their body temperature changes with the ambient temperature.

In aquatic animals, the osmotic concentration of the body fluids change with that of the ambient water osmotic concentration.

Conformers had not evolved to become regulators because thermoregulation is energetically expensive for many organisms as heat loss or heat gain is a function of surface area.

Small animals have a larger surface area relative to their volume, they tend to lose body heat very fast when it is cold outside then they have to expend much energy to generate body heat through metabolism that is why very small animals are rarely found in polar regions.

Conformers cope with the stressful conditions by various alternate responses which are-

- Migrate –the birds move temporarily to hospitable areas from stressful habitat. For example- birds from Siberia and extremely cold regions migrate to Keolado National Park (Bharatpur) in Rajasthan.

Fig. Bharatpur, Rajasthan

- Suspend

Sporulation- thickwalled spores are formed which help the organisms to survive under unfavorable conditions and the spores germinate on availability of suitable environment. Example- bacteria, fungi, lower plants.

Dormancy – to tide over the periods of stress seeds of higher plants and other vegetative reproductive structures reduce their metabolic activity and go into a state of dormancy which germinate to form new plants under favorable conditions.

Hibernation and aestivation- if the organisms are unable to migrate they avoid the stress by escape in time where the organisms sleep in winter called as hibernation or sleep in summer called as aestivation. Example- bears sleep in winter and snail sleeps in summer.

Diapause- the process of delay in the development during adverse environmental conditions is called diapause. Example- zooplanktons.

Fig. zooplankton

Adaptation

Adaptation is morphological, physiological and behavioral attribute of the organism that enables the organism to survive and reproduce in its habitat.

Examples-

Adaptation of animal in desert

- In the absence of an external source of water, the kangaroo rat in North American deserts is capable of meeting all its water requirements through its internal fat oxidation.
- Kangaroo rat has the ability to concentrate its urine so that minimal volume of water is used to remove excretory products.

Fig. kangaroo rat

Adaptation of plants in desert

- Thick cuticle on the leaf surfaces of the desert plants reduces transpiration.
- Stomata is sunken to reduce transpiration.
- Desert plants follow a special photosynthetic pathway called Crassulean acid metabolism (CAM), in which stomata remains closed during day time and open during night time.
- In some plants like Opuntia , leaves are modifies into spines to reduce transpiration and photosynthesis takes place in flat green stem called as **phylloclade**

Fig. Opuntia

Adaptation of animal in cold climate

- Mammals from colder climates generally have shorter ears and limbs to minimize heat loss, called as 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.

Fig. a seal

Adaptation in high altitude

- When a person moves to high altitude place, develops altitude sickness because in the low atmospheric pressure of high altitudes, the body does not get enough oxygen.
- Symptoms include nausea, fatigue and heart palpitations.
- The body compensates low oxygen availability by increasing red blood cell production, decreasing the binding capacity of hemoglobin and by increasing breathing rate.

Fig. red blood cells carrying hemoglobin

Behavioral adaptation

- Desert lizards deal with the high temperatures of their habitat, by managing to keep their body temperature fairly constant by behavioural adaptation.
- Desert lizards bask in the sun and absorb heat when their body temperature drops below the comfort zone and move into shade when the ambient temperature starts increasing.
- Some species are capable of burrowing into the soil to hide and escape from the above-ground heat.

Fig. desert lizard

Population

A group of individuals living in a geographical area who can interbreed and share or compete for similar resources is called a population.

A population has certain attributes such as birth rates and death rates and in a population these rates refer to per capita births and deaths, respectively.

The rates are expressed as increase or decrease in number of the members of the population. For example-

- If in a pond there are 20 lotus plants last year and through reproduction 8 new plants are added, taking the current population to 28, the birth rate is calculated as 8/20 = 0.4 offspring per lotus per year.
- If 4 individuals in a laboratory population of 40 fruitflies died in a week, the death rate in the population during that period is 4/40 = 0.1 individuals per fruitfly per week.

Another attribute characteristic of a population is sex ratio.

An individual is either a male or a female but a population has a sex ratio.

A population at any given time is composed of individuals of different ages.

If the age distribution is plotted for the population, the resulting structure is called an age pyramid.

The shape of the pyramids reflects the growth status of the population whether it is growing or stable or declining.

Population size is more technically called population density, designated as N.

Population density can be measured by

- Counting the number.
- Percent cover.
- Pug marks and fecal pellets for tiger census.

Population growth

The size of a population keeps changing in time, depending on various factors including food availability, predation pressure and reduce weather.

The density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes which are-

- Natality refers to the number of births during a given period in the population that are added to the initial density.
- Mortality is the number of deaths in the population during a given period.
- Immigration is the number of individuals of the same species that have come into the habitat from elsewhere during the time period under consideration.
- Emigration is the number of individuals of the population who left the habitat and gone elsewhere during the time period under consideration.

If N is the population density at time t, then its density at time t +1 is $N_{t+1} = N_t + [(B + I) – (D + E)]$, where

B= number of births

I= number of immigrants

D= number of deaths

E= number of emigrants

N= population density

t= time period.

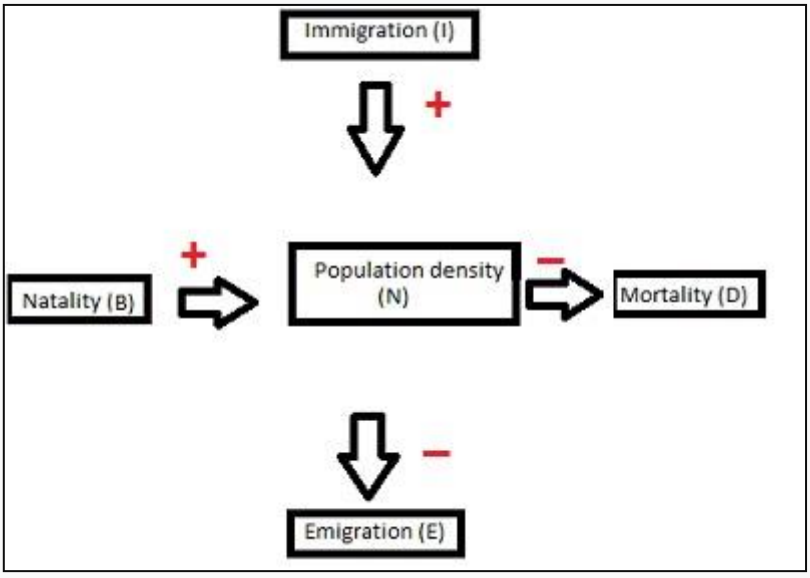

Fig. four basic processes which fluctuates population density

Growth models : Exponential growth

When resources in the habitat are unlimited, each species grow in number and reach enormous population density in a short time.

If in a population of size N, the per capita birth rates and per capita death rates are represented as b and d respectively, 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 in this equation is called the '**intrinsic rate of natural increase'.**

The integral form of the exponential growth equation as $N_t = N_0e^{rt}$, 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).

Growth models : Logistic growth

When the resources in the habitat are finite, it limits the growth of the species.

A population growing in a habitat with limited resources show initially a lag phase, followed by phases of acceleration and deceleration and finally an asymptote, when the population density reaches the carrying capacity.

This type of population growth is called **Verhulst-Pearl Logistic Growth**and is described by the following equation:

dN/dt = rN (K-N/N), where

N = Population density at time t

r = Intrinsic rate of natural increase

K = Carrying capacity

Population interaction

Interspecific interactions arise from the interaction of populations of two different species.

Interspecific interactions could be beneficial, detrimental or neutral to one of the species or both.

Both the species benefit in mutualism and both lose in competition in their interactions with each other.

In both parasitism and Predation only one species benefits

The interaction where one species is benefitted and the other is neither benefitted nor harmed is called commensalism.

In amensalism on the other hand one species is harmed whereas the other is unaffected. Predation, parasitism and commensalisms share a common characteristic– the interacting species live closely together.

Predation

It is an interspecific interaction where organisms of higher trophic levels feed on organisms of lower trophic level.

Herbivores are predators as they feed on grass.

Exotic species have no predators hence they grow very rapidly. Example- The prickly pear cactus introduced into Australiaand the invasive cactus was brought under control only after a cactus-feeding moth was introduced in the country.

Fig. cactus

Importance of predation in an ecosystem are –

- Predator keeps prey populations under control.
- Predator acts as a passage for transfer of energy across trophic levels.
- Predators help in maintaining species diversity in a community by reducing the intensity of competition among competing prey species.

Some species of insects and frogs are cryptically-colored (camouflaged) to avoid being detected easily by the predator.

Fig. colored frogs

Some are poisonous and therefore avoided by the predators.

The Monarch butterfly is highly distasteful to its predator (bird) because of a special chemical present in its body which is acquired by feeding a poisonous weed during caterpillar stage.

All insects are known to be phytophagous as these feed on plant sap and other parts of plants.

Thorns in Acacia, cactus are morphological means of defense against insects.

Many plants produce and store some chemical which make the herbivores sick if eaten and even kill the predators.

Calotropisproduce poisonous cardiac glycosides against herbivores.

Fig. calotropis

Nicotine, caffeine, quinine, opium are produced by plant as defenses against the grazers and browsers.

Competition

Competition is struggling by the organisms for the same resources like food, shelter and sex.

The competition is between two organisms belonging to same species, this is called intraspecific competition.

The competition between organisms belonging to different species is called interspecific competition. For example- in some shallow South American lakes visiting flamingoes and resident fishes compete for their common food, the zooplankton in the lake.

Fig. flamingoes

Resources need not be limiting for competition to occur. For example- Abingdon tortoise in Galapagos Islands became extinct within a decade after goats were introduced on the island, apparently due to the greater browsing efficiency of the goats.

Fig. Abingdon tortoise

The occurrence of competition in nature comes from competitive release.

Competitive release is the process in which a species whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the competing species is experimentally removed.

Connell's elegant field experiments showed that on the rocky sea coasts of Scotland, the larger and competitively superior barnacle Balanus dominates the intertidal area, and excludes the smaller barnacle Chathamalus from that zone.

Gause's 'Competitive Exclusion Principle' states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually

Species facing competition might evolve mechanisms like resource partitioning that promote co-existence rather than exclusion.

If two species compete for the same resource, they could avoid competition by choosing different times for feeding or different foraging patterns, this is called resource partitioning.

MacArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

Parasitism

Parasitism is the association between two organisms in which one organism is benefitted and another organism is harmed.

Some of the parasitic adaptations are-

- Loss of unnecessary sense organs
- Presence of adhesive organs or suckers to cling on to the host.
- Loss of digestive system.
- High reproductive capacity.
- The life cycles of parasites are often complex, involving one or two intermediate hosts or vectors to facilitate parasitisation of its primary host.
- The human liver fluke depends on two intermediate hosts, a snail and a fish to complete its life cycle.

Effects of parasites on the host-

- Majority of the parasites harm the host.
- They may reduce the survival, growth and reproduction of the host and reduce its population density.
- They might render the host more vulnerable to predation by making it physically weak.

Parasites that feed on the external surface of the host organism are called ectoparasites. Examples-

- The lice on humans and ticks on dogs
- Many marine fish are infested with ectoparasiticcopepods.
- Cuscuta, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution and derives its nutrition from the host plant which it parasitizes.

Endoparasites are those that live inside the host body at different sites. Example- tape worm, liver fluke.

Brood parasitism is the process in which the parasitic bird lays its eggs in the nest of its host and lets the host incubate them.

The eggs of the host is similar with the egg of the host. For example- cuckoo lays eggs in the nest of the crow.

Fig. lice on human

Commensalism

The type of interaction in which one species benefits and the other is neither harmed nor benefited is called commensalism. Example-

- An orchid growing as an epiphyte on a mango branch.
- Barnacles growing on the back of a whale.
- Clown fishes living among stinging tentacles of sea anemone.

Fig. Barnacles growing on the back of a whale

Mutualism

Mutualism is the interaction between two living organisms where both the organisms are equally benefitted and no one is harmed. Examples-

- Lichens represent an intimate mutualistic relationship between a fungus and photosynthetic algae or cyanobacteria.

Fig. lichens

- Mycorrhizae are associations between fungi and the roots of higher plants, where the fungi help the plant in the absorption of essential nutrients from the soil while the plant in turn provides the fungi with energy-yielding carbohydrates.
    - Plants provide nectar and pollen for pollinating agents and the pollinating agents in turn pollinate the flowers of plants.
- Animals disperse the seeds of plants and plants provide juicy fruits for seed dispersers.
- Fig tree is pollinated by a species of wasp only where the wasp pollinates the fig inflorescence while searching for suitable egg-laying sites and in return for the favor of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

Fig. fig tree

Amensalism

The interaction in which one species is harmed while the other is neither benefitted nor harmed is called amensalism.

Example- Penicilium inhibits the growth of various bacteria by secreting penicillin.

Fig. penicilium

Sexual deceit

Sexual deceit is the process in which petal of its flower bears an uncanny resemblance to the female of the bee in size, colour and markings. Example- the Mediterranean orchid Ophrys.

The male bee is attracted to what it perceives as a female, ‘pseudocopulates’ with the flower, and during that process is dusted with pollen from the flower.

When this same bee ‘pseudocopulates’ with another flower, it transfers pollen to it and thus, pollinates the flower.

Fig. the Mediterranean orchid Ophrys

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Introduction

An ecosystem can be defined as a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.

An ecosystem is divided into two basic categories

- Terrestrial ecosystem. Example- forest, desert.
- Aquatic ecosystem. Example- pond, lake, wetland.

Ecosystem- structure and functions

The various components of the environment are abiotic and biotic.

Interaction of biotic and abiotic components result in a physical structure that is characteristic for each type of ecosystem.

Biotic components are the living beings and abiotic components are the nonliving things of the ecosystem.

Vertical distribution of different species occupying different levels is called **stratification**.

The functional components of ecosystem are-

- Productivity
- Decomposition
- Energy flow
- Nutrient cycling

Fig. stratification- trees occupy the top level of the forest, shrubs the second and herbs and grasses the bottom layer.

Example of functional compoents of ecosystem is a pond ecosystem

The abiotic component is the water with all the dissolved inorganic and organic substances and the rich soil deposit at the bottom of the pond.

The solar input, the cycle of temperature, day-length and other climatic conditions regulate the rate of function of the entire pond.

The autotrophic components include the phytoplankton, some algae and the floating, submerged and marginal plants found at the edges.

The consumers are represented by the zooplankton, the free swimming and bottom dwelling forms.

The decomposers are the fungi, bacteria and flagellates especially abundant in the bottom of the pond.

Fig. a pond ecosystem

Productivity

The rate of biomass production is called productivity.

Productivity is of two types-

- Primary productivity
- Secondary productivity.

Primary productivity is defined as the amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis.

Primary productivity is expressed in terms of weight (g–2) or energy (kcal m–2).

Primary productivity can be divided into

- gross primary productivity (GPP)
- net primary productivity (NPP).

Gross primary productivity of an ecosystem is the rate of production of organic matter during photosynthesis.

Gross primary productivity minus respiration losses (R), is the net primary productivity (NPP).

GPP – R = NPP

Secondary productivity is defined as the rate of formation of new organic matter by consumers.

The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter.

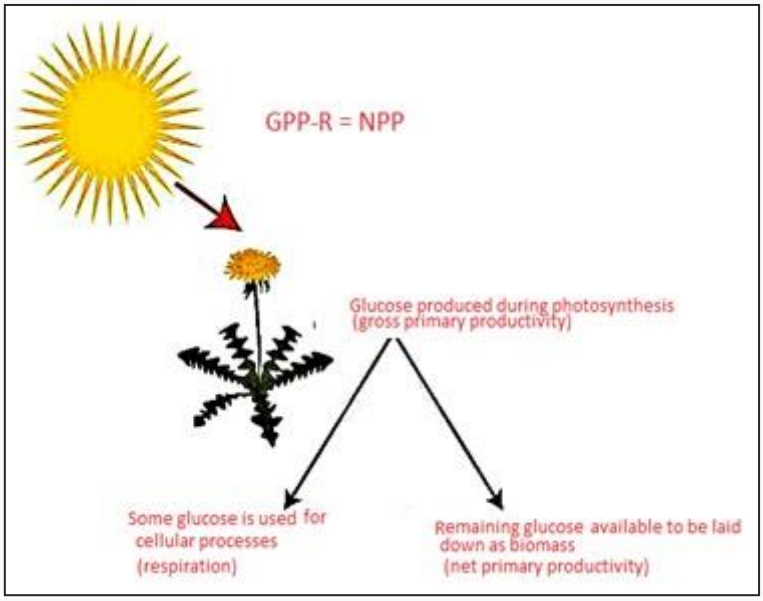

Fig. productivity

Decomposition

Decomposers break down complex organic matter into inorganic substances like carbon dioxide, water and nutrients and the process is called decomposition.

Dead plant remains such as leaves, bark, flowers and dead remains of animals, including fecal matter is called detritus.

Detritus is the raw material for decomposition.

Detritivores are the organisms break down detritus into smaller particles. Example- millipedes, dung flies, woodlice, burying beetles.

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

Fragmentation is thr breaking down of detritus into smaller particles.

The process by which watersoluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts is called as leaching.

Th eprocess by which bacterial and fungal enzymes degrade detritus into simpler inorganic substances called as catabolism.

Humification is the accumulation of a dark coloured amorphous substance called humus.

The humus is further degraded by some microbes and release of inorganic nutrients occur by the process known as mineralisation.

Factors affecting the rate of decomposition

Large amount of oxygen is required for decomposition as it is an energy requiring process.

Chitin and lignin present in detritus slower the rate of decomposition.

Nitrogen and water-soluble substances like sugars in detritus increases the rate of decomposition.

Warm and moist environment favour decomposition whereas low temperature, dryness and anaerobiosis inhibit decomposition.

Fig. millipedes, dung fly

Energy flow

Sun is the only source of energy for all ecosystems on Earth and except for the deep sea hydro-thermal ecosystem.

Less than 50 per of incident solar radiation is photosynthetically active radiation (PAR).

Plants capture only 2-10 per cent of the PAR.

All organisms are dependent for their food on producers.

Flow of energy in the ecosystem is unidirectional.

The green plant in the ecosystem are called producers. Example-In a terrestrial ecosystem, major producers are herbaceous and woody plants and in aquatic ecosystem phytoplankton, algae and higher plants are producers.

All animals depend on plants for their food needs are called consumers.

Consumers which feed on the producers, they are called primary consumers or herbivores. Example- grass

The animals eat herbivores, they are called secondary consumers or primary carnivores. Example- goat.

The animals which eat the primary carnivores are called tertiary consumers or secondary carnivores. Example- man.

Based on the source of their nutrition or food, organisms occupy a specific place in the food chain that is known as their trophic level.

Producers belong to the first trophic level, herbivores (primary consumer) to the second and carnivores (secondary consumer) to the third trophic level.

Food chain is the flow of energy from one trophic level to another trophic level by eating and being eaten.

Food chain if is two types-

- Grazing food chain
- Detritus food chain

Food chain which starts from producers and ends on carnivores through herbivores is called grazing food chain.

Grass --> goat --> man.

Fig. grass is eaten by goat and goat is eaten by men

Food chain which starts from dead organic matter and passes through detrivores to organisms feeding on detrivores is called detritus food chain.

Detrivores are decomposers which meet their energy and nutrient requirements by degrading dead organic matter or detritus, these are also known as saprotrophs.

Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials.

The interconnected matrix of food chain is called food web. For example- specific herbivore of one food chain may serve as food of carnivores in another food chain.

Each trophic level has a certain mass of living material at a particular time called as the standing crop.

The standing crop is measured as the mass of living organisms (biomass) or the number in a unit area.

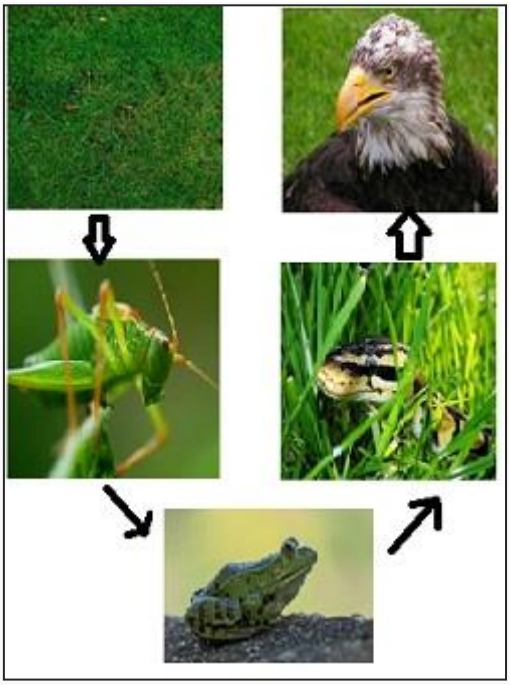

Fig. A food chain, where grass is eaten by insects and frogs eat the insects which in turn is eaten by the snakes and eagles eat the snakes

Ecological pyramid

Ecological pyramid is the graphical representation of various trophic levels of food chain designed to show their number, biomass and energy.

The base of a pyramid is broad and it narrows down at the apex.

The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer.

The three ecological pyramids that are usually studied are

- pyramid of number
- pyramid of biomass
- pyramid of energy.

A given species may occupy more than one trophic level in the same ecosystem at the same time. For example, a sparrow is a primary consumer when it eats seeds, fruits, peas, and a secondary consumer when it eats insects and worms.

Producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores so all the pyramids, of number, of energy and biomass are upright.

The pyramid of biomass in sea is also generally inverted because the biomass of fishes far exceeds that of phytoplankton.

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

Limitations of ecological pyramids

- It does not take into account the same species belonging to two or more trophic levels.
- It assumes a simple food chain, something that almost never exists in nature
- It does not accommodate a food web.
- Saprophytes are not given any place in ecological pyramids.

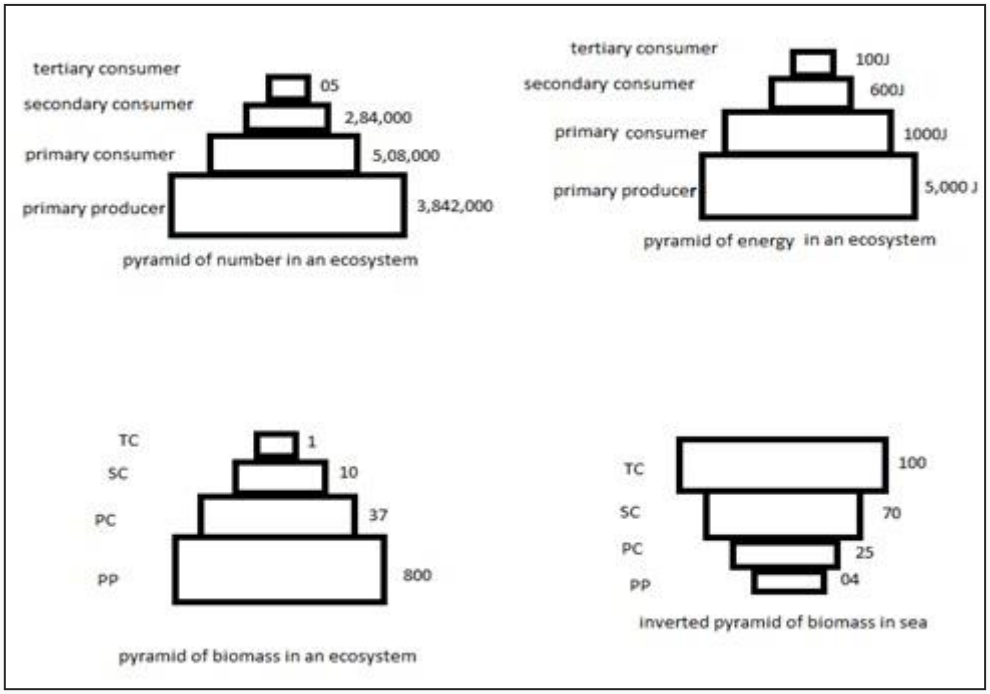

Fig. ecological pyramids

Ecological succession

The gradual and fairly predictable change in the species composition of a given area is called ecological succession.

The changes lead finally to a community that is in near equilibrium with the environment and that is called a **climax community.**

During succession some species colonise an area and their populations become more numerous, whereas populations of other species decline and even disappear.

The entire sequence of communities that successively change in a given area are called **sere(s).**

The individual transitional communities are called **seral stages.**

Ecological succession is of two types-

- Primary succession
- Secondary succession.

Succession that starts where no living organisms are there or these could be areas where no living organisms ever existed.

Primary succession can occur in newly cooled lava, bare rock, newly created pond or reservoir.

Succession that starts in areas where all the living organisms somehow lost that existed there is called secondary succession.

Secondary succession can occur in abandoned farm lands, burned or cut forests, lands that have been flooded.

Secondary succession is faster than primary succession because some soil or sediment is present.

Fig. bare rock, cooled lava, cut forest

Succession of Plants

Based on the nature of the habitat, whether it is water (or very wet areas) or it is on very dry areas – succession of plants is called **hydrach** or **xerarch** succession respectively.

Succession takes place in wetter areas and the successional series progress from hydric to the mesic conditions is called hydrach succession.

Succession takes place in dry areas and the series progress from xeric to mesic conditions is called xerarch succession.

Both hydrarch and xerach successions lead to medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).

Xerarch succession

The species that invade a bare area are called **pioneer species.**

In primary succession on rocks, thepioner species is lichens are able to secrete acids to dissolve rock, helping in weathering and soil formation and the little soil leads to the growth of bryophytes.

With time, the bryophytes are succeeded by bigger plants, and after several more stages, ultimately a stable climax forest community is formed and ultimately the xerophytic habitat gets converted into a mesophytic one.

Hydrach succession

The pioneers are the small phytoplanktons which are replaced with time by free-floating angiosperms,

The free-floating angiosperms are replaced by rooted hydrophytes, sedges, grasses and finally the trees.

The climax again would be a forest and with time the water body is converted into land.

All succession whether taking place in water or on land, proceeds to mesic community.

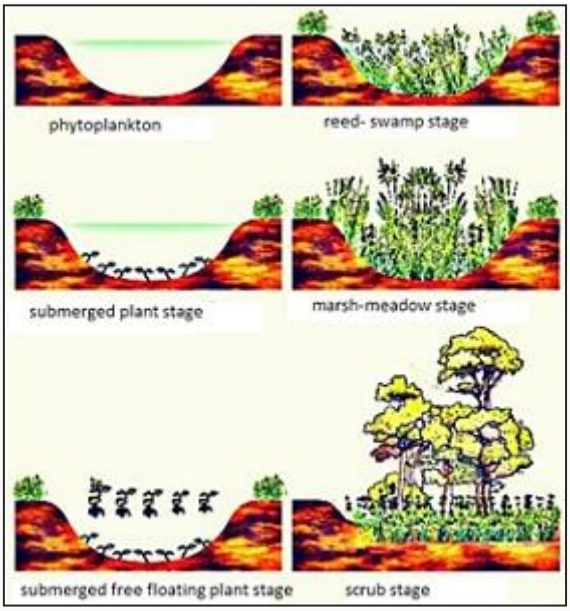

Fig. diagrammatic representation of hydrach succession

NUTRIENT CYCLE

The cyclic movement of the nutrients between biotic and abiotic components of the ecosystem is called nutrient cycle.

Organisms need a constant supply of nutrients to grow, reproduce and regulate various body functions.

The amount of nutrients present in the soil at any given time, is called as the **standing state**.

Nutrient cycling is also referred as **biogeochemical cycle.**

Nutrient cycles are of two types-

- Gaseous
- Sedimentary

Gaseous cycle is the cycling of carbon, nitrogen etc.

Sedimentary cycle is the cycling of sulphur, phosphorous etc.

The reservoir for gaseous type of nutrient exists in the atmosphere and for the sedimentary cycle the reservoir is located in Earth's crust.

Carbon cycle

Carbon constitutes of 49% of dry weight of organisms.

$4x10^{13}$ kg of carbon is fixed in the biosphere by photosynthesis.

Large amount of carbon returned to the atmosphere as carbon di oxide through respiration of producers and consumers.

Decomposers also return carbon dioxide to reservoir during decomposition process.

Some amount of carbon is lost to sediments and removed from circulation.

Burning wood, forest fire, combustion of organic matter, fossil fuel also release carbon dioxide to atmosphere.

Rapid deforestation and massive burning of fossil fuel for energy and transport have significantly increased the rate of release of carbon dioxide into the atmosphere.

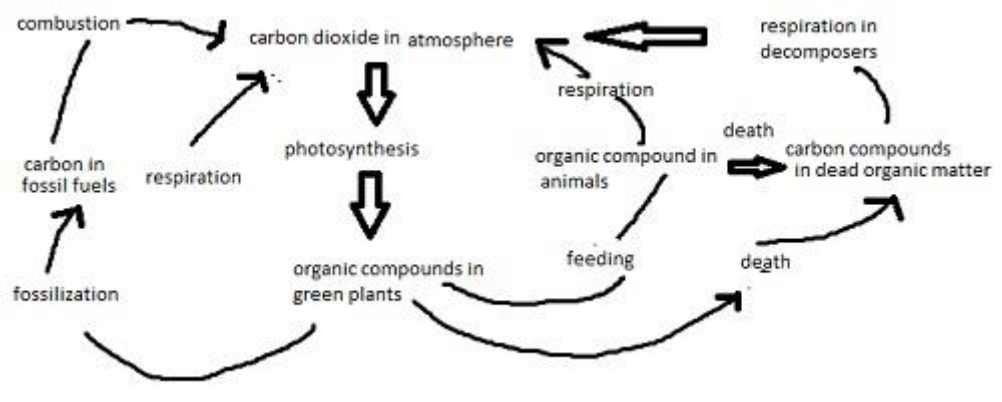

Fig. the carbon cycle

Phosphorus Cycle

Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems.

Many animals also need large quantities of this element to make shells, bones and teeth.

The natural reservoir of phosphorus is rock, which contains phosphorus in the form of phosphates.

When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants.

Herbivores and other animals obtain phosphorous from plants.

The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus.

Difference between carbon and phosphorous cycle is

- There is no respiratory release of phosphorus into atmosphere like carbon.
- Atmospheric inputs of phosphorus through rainfall are much smaller than carbon inputs.

- Gaseous exchanges of phosphorus between organism and environment are negligible.

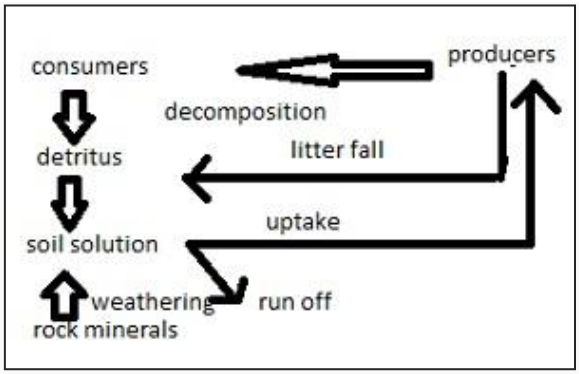

Fig. phosphorous cycle

Ecosystem services

The products of ecosystem processes are named as ecosystem services.

For example, 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 also provide aesthetic
- cultural and spiritual values

Fig. pollination

Introduction

- In our biosphere immense diversity (or heterogeneity) exists not only at the species level but at all levels of biological organization ranging from macromolecules within cells to biomes.
- Biodiversity can be defined as the combined diversity at all the levels of biological organization.
- Various types of biodiversity are-
- Genetic diversity- A single species might show high diversity at the genetic level over its distributional range. Example- The genetic variation of the medicinal plant *Rauwolfia vomitoria* in potency and concentration of the active chemical reserpine that the plant produces.

Fig. Rauwolfia

- Species diversity: The diversity at the species level. For example, the Western Ghats have a greater amphibian species diversity than the Eastern Ghats.

Fig. western ghats

- Ecological diversity: diversity at the ecosystem level. For example- deserts, rain forests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows of India has a greater ecosystem diversity than a Scandinavian country like Norway.

Fig. coral reefs

Number of species on earth and in India

- The total number of plant and animal species described so far is slightly more than 1.5 million.
- Robert May places the global species diversity at about 7 million.
- More than 70 per cent of all the species recorded are animals, while plants including algae, fungi, bryophytes, gymnosperms and angiosperms comprise no more than 22 per cent of the total.
- Among animals, insects are the most species-rich taxonomic group, making up more than 70 per cent of the total.
- India has only 2.4 per cent of the world's land area, its share of the global species diversity is an impressive 8.1 per cent and that is how makes India is one of the 12 mega diversity countries of the world.
- Nearly 45,000 species of plants and twice as many of animals have been recorded from India.

Fig. algae, fungi, bryophytes

Pattern of biodiversity

- Latitudinal gradients-
- Species diversity decreases as we move away from the equator towards the poles.
- Tropics harbor more species than temperate or polar areas.
- Colombia located near the equator has nearly 1,400 species of birds while New York at 41° N has 105 species and Greenland at 71° N only 56 species. India, with much of its land area in the tropical latitudes, has more than 1,200 species of birds.
- The largely tropical Amazonian rain forest in South America has the greatest biodiversity on earth- it is home to more than 40,000 species of plants, 3,000 of fishes, 1,300 of birds, 427 of mammals, 427 of amphibians, 378 of reptiles and of more than 1,25,000 invertebrates.
- Tropics have greatest biodiversity because

1. a) Unlike temperate regions subjected to frequent glaciations in the past, tropical latitudes have remained relatively undisturbed for millions of years.

2. b) Tropical environments are less seasonal and more constant and predictable which promote niche specialization and lead to a greater species diversity.
3. c) There is more solar energy available in the tropics, which contributes to higher productivity thus contributing indirectly to greater diversity.

Fig. amazon rain forest

- Species-Area relationships
- Alexander von Humboldt observed that within a region species richness increased with increasing explored area, but only up to a limit.
- The relation between species richness and area for a wide variety of taxa such as angiosperm plants, birds, bats, freshwater fishes turns out to be a rectangular hyperbola.
- On a logarithmic scale, the relationship is a straight line described by the equation log S = log C + Z log A where,

S= Species richness A= Area Z = slope of the line (regression coefficient) C = Y-intercept.

- The species-area relationships among very large areas like the entire continents, the slope of the line is much steeper (Z values in the range of 0.6 to 1.2).

For example, for frugivorous (fruit-eating) birds and mammals in the tropical forests of different continents, the slope is found to be 1.15.

The importance of species diversity to the ecosystem

- Communities with more species, generally, tend to be more stable than those with less species.
- A stable community should not show too much variation in productivity from year to year.
- David Tilman found that plots with more species showed less year-to-year variation in total biomass and increased diversity contributed to higher productivity.
- According to the rivet popper hypothesis, in an airplane (ecosystem) all parts are joined together using thousands of rivets (species).
- If every passenger travelling in airplane starts popping a rivet to take home (causing a species to become extinct), it may not affect flight safety (proper functioning of the ecosystem) initially, but as more and more rivets are removed, the plane becomes dangerously weak over a period of time.
- Loss of rivets on the wings is more serious threat to flight safety than loss of a few rivets on the seats or windows inside the plane.

Fig. a stable community

Loss of biodiversity

- The colonization of tropical Pacific Islands by humans is said to have led to the extinction of more than 2,000 species of native bird.
- The IUCN Red List (2004) documents the extinction of 784 species.
- Some examples of recent extinctions include the dodo (Mauritius), quagga (Africa), thylacine (Australia), Steller's Sea Cow (Russia) and three subspecies (Bali, Javan, Caspian) of tiger.
- Loss of biodiversity in a region may lead to
- Decline in plant production
- Lowered resistance to environmental perturbations such as drought
- Increased variability in certain ecosystem processes such as plant productivity, water use, and pest and disease cycles.

Fig. dodo, thylacine, javan

Cause of biodiversity loss

- Habitat loss and fragmentation
- Tropical rain forests covering more than 14 per cent of the earth's land surface, these rain forests now cover no more than 6 per cent.
- The Amazon rain forest called as the 'lungs of the planet' harboring probably millions of species is being cut and cleared for cultivating soya beans or for conversion to grasslands for raising beef cattle.
- Breaking of large areas into small fragments cause biodiversity loss.

Fig. tropical rain forest

- Over exploitation
- Many species extinctions in the last 500 years were due to overexploitation by humans. For example- Steller's sea cow, passenger pigeon.

Fig. passenger pigeon

- Alien species invasions
  - When alien species are introduced these cause decline or extinction of indigenous species.

Example- the Nile perch introduced into Lake Victoria in east Africa led eventually to the extinction of an ecologically unique assemblage of more than 200 species of cichlid fish in the lake.

- Introduction of the African catfish Clarias gariepinus for aquaculture purposes is posing a threat to the indigenous catfishes in our rivers.

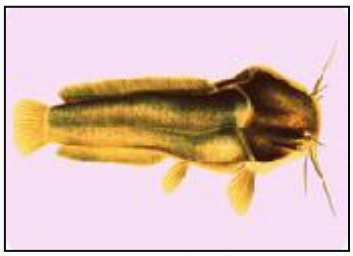

Fig. African cat fish

- Co-extinctions
- When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct.

Example-

- When a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate.
- In plant-pollinator mutualism extinction of one invariably leads to the extinction of the other.

Biodiversity conservation

- Reasons of conserving biodiversity is grouped into three categories

narrowly utilitarian¬

broadly utilitarian¬

Ethical.¬

- Narrowly utilitarian- humans derive countless direct economic benefits from nature such as cereals, pulses, fruits, firewood, fiber, construction material, industrial products like tannins, lubricants, dyes, resins, and perfumes.

Fig. human beings derive pulses, firewood, dyes from nature

- broadly utilitarian-
- Biodiversity plays a major role in many ecosystem services that nature provides.
- Amazon forest is estimated to produce, through photosynthesis, 20 per cent of the total oxygen in the earth's atmosphere
- Bees, bumblebees, birds and bats pollinate the flowers without which plants cannot give us fruits or seeds.

Fig. pollination

- The ethical argument for conserving biodiversity relates to what we owe to millions of plant, animal and microbe species with whom we share this planet.

Ways to conserve biodiversity

- Biodiversity can be conserved by In Situ and Ex Situ conservation.
- The process of protecting biodiversity at all levels by conserving and protecting the whole ecosystem is called in situ conservation.
- The process in which endangered and threatened animals are saved by taking urgent measures is called ex situ conservation.
- Biodiversity hotspots are the regions with very high levels of species richness and high degree of endemism.
- Three hotspots – Western Ghats and Sri Lanka, Indo-Burma and Himalaya – cover high biodiversity regions.

Fig. western Ghats and Himalaya

- Biodiversity-rich regions are legally protected as biosphere reserves, national parks and sanctuaries.
- India now has 14 biosphere reserves, 90 national parks and 448 wildlife sanctuaries.
- Sacred groves are the forests in which tracts of forest were set aside, and all the trees and wildlife within were venerated and given total protection. Examples- Khasi and Jaintia Hills in Meghalaya, Aravalli Hills of Rajasthan.

Fig. khasi hills

- In ex-situ conservation, threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care. Examples- Zoological parks, botanical gardens and wildlife safari park.
- Gametes of threatened species can be preserved in viable and fertile condition for long periods using cryopreservation techniques, eggs can be fertilized in vitro, and plants can be propagated using tissue culture methods.

Introduction

- Pollution is any undesirable change in physical, chemical or biological characteristics of air, land, water or soil.
- Pollutants are the agents that bring about an undesirable change in physical, chemical or biological characteristics of air, land, water or soil.

Fig. pollution

- Air pollution is any undesirable change in the physical, chemical or biological characteristics of air.

Harmful effects of air pollution

- Air pollutants cause injury to all living organisms.
- They reduce growth and yield of crops and cause premature death of plants.
- Air pollutants also deleteriously affect the respiratory system of humans and of animals.

Cause of air pollution

Automobiles are a major cause for atmospheric pollution.

- The use of lead-free petrol or diesel can reduce the pollutants they emit.
- Smokestacks of thermal power plants, smelters release particulate and gaseous air pollutants with harmless gases, such as nitrogen, oxygen, etc. which must be separated before releasing the harmless gases into the atmosphere.
- Fine particulates can be inhaled deep into the lungs which cause breathing and respiratory symptoms, irritation, inflammations and damage to the lungs and premature deaths.

Fig. smoke from thermal power plants

Control of air pollution

- Air pollution can be controlled by
- Catalytic converters

- Electrostatic precipitator
- Scrubber
- **Catalytic converters**having expensive metals namely platinum-palladium and rhodium as the catalysts, are fitted into automobiles for reducing emission of poisonous gases and when the exhaust passes through the catalytic converter, unburnt hydrocarbons are converted into carbon dioxide and water, and carbon monoxide and nitric oxide are changed to carbon dioxide and nitrogen gas, respectively.
- Electrostatic precipitator
- Electrostatic precipitator can remove over 99 per cent particulate matter present in the exhaust from a thermal power plant.
- It has electrode wires that are maintained at several thousand volts, which produce a corona that releases electrons.
- The electrons attach to dust particles giving them a net negative charge.
- The collecting plates are grounded and attract the charged dust particles.
- The velocity of air between the plates must be low enough to allow the dust to fall.

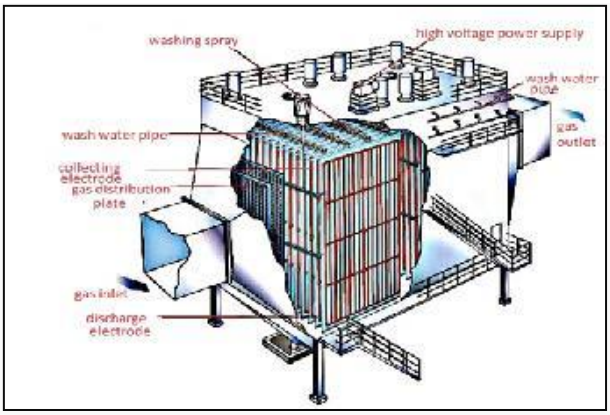

Fig. electrostatic precipitator

- Scrubber
- A scrubber can remove gases like sulphur dioxide.
- In a scrubber, the exhaust is passed through a spray of water or lime.

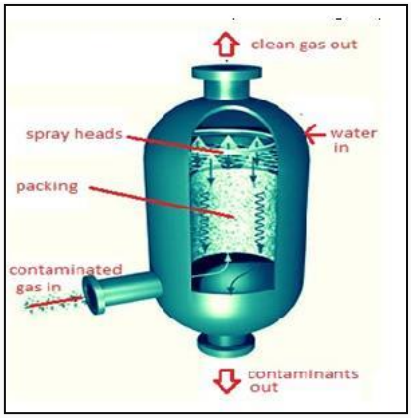

Fig. a scrubber

- In Delhi, Entire fleet of public transport switched over to **compressed natural gas (CNG)**because
- CNG burns most efficiently

- very little of it is left unburnt
- CNG is cheaper than petrol or diesel
- cannot be siphoned
- Cannot be adulterated like petrol or diesel.
- The problem of using CNG is the difficulty of laying down pipelines to deliver CNG through distribution points/pumps and ensuring uninterrupted supply.
- parallel steps taken in Delhi for reducing vehicular pollution include
- phasing out of old vehicles
- use of unleaded petrol
- use of low-sulphur petrol and diesel
- use of catalytic converters in vehicles
- Application of stringent pollution level norms for vehicles, etc.

Fig. catalytic converters

Noise pollution

- Noise pollution is undesired high level of sound.

Effects of noise pollution

- Psychological and physiological disorders in humans.
- High sound level, 150 dB or moredamage ear drums thus permanently impairing hearing ability..
- Chronic exposure to a relatively lower noise level permanently damage hearing abilities of humans.
- Causes sleeplessness, increased heart beating, altered breathing pattern.

Causes of noise pollution

- Burning of crackers.
- Transportation system.
- Air craft and rail traffic.

Control of air pollution

- Use of sound absorbent materials or by muffling noise.
- Making horn-free zones around hospitals and schools
- Using permissible sound-levels of crackers and of loudspeakers
- Laying down timings after which loudspeakers cannot be played.

Fig. noise pollution

Water pollution and its control

- Any undesirable change in the physical, chemical or biological characteristics of water is called water pollution.
- Sewage is a domestic waste contains biodegradable organic matter, nitrates, phosphates, and other nutrients, and toxic metal ions.
- The amount of organic matter in sewage water by measuring **Biochemical Oxygen Demand (BOD).**
- Biochemical oxygen demand is the amount of oxygen required by aerobic microorganisms to break down all organic matter.
- Harmful effects of water pollution
- Micro-organisms involved in biodegradation of organic matter in the receiving water body consume a lot of oxygen, and as a result there is a sharp decline in dissolved oxygen downstream from the point of sewage discharge which causes mortality of fish and other aquatic creatures.
- Sewage from our homes as well from hospitals contains many undesirable pathogenic microorganisms which can cause diseases like dysentery, typhoid, jaundice, cholera.

Causes of water pollution

- Presence of large amounts of nutrients in waters also causes excessive growth of planktonic (free-floating) algae, called an **algal bloom.**

Fig. algal bloom

- Algal blooms cause deterioration of the water quality and fish mortality and some bloom-forming algae are toxic to human beings and animals.
- Water hyacinth (*Eichhorniacrassipes*) called as **'terror of Bengal'** is the most problematic water weed which grow abundantly in eutrophic water bodies, and lead to an imbalance in the water ecosystem.

Fig. water hyacinth

- **Biomagnification**
- It is the increase in concentration of the toxicant at successive trophic levels.
- Biomagnification happens because a toxic substance accumulated by an organism cannot be metabolized or excreted, and is thus passed on to the next higher trophic level.
- Example of toxic substances- mercury, DDT.
- **Eutrophication**
- Eutrophication is the natural aging of a lake by biological enrichment of its water.
- **Natural eutrophication-**

1. Streams draining into the lake introduce nutrients such as nitrogen and phosphorus due to which aquatic organisms grow.
2. As silt and organic debris pile up, the lake grows shallower and warmer, with warm-water organisms supplanting those that thrive in a cold environment.

- Marsh plants take root in the shallows and begin to fill in the original lake basin.

1. Lake gives way to large masses of floating plants (bog), finally converting into land.

Cultural or Accelerated Eutrophication

1. Pollutants from man's activities like effluents from the industries and homes can radically accelerate the aging process and the process is called as Cultural or Accelerated Eutrophication.
2. It causes by Sewage, agricultural and industrial wastes.

1. Nitrates and phosphates, which act as plant nutrients.

- Sewage and plant nutrients overstimulate the growth of algae, causing unsightly scum and unpleasant odors, and robbing the dissolved oxygen from water, and other pollutants flowing into a lake may poison whole populations of fish, whose decomposing remains further deplete the water's dissolved oxygen content and thus a lake can choke to death.
- Thermal wastewaters flowing out of electricity-generating units are another cause of pollution.
- Thermal wastewater can eliminate the number of organisms sensitive to high temperature and also can enhance the growth of plants and fish in extremely cold areas but only after causing damage to the indigenous flora and fauna.

Control of water pollution

- The cleaning of waste water occurs in two stages –

1. The conventional sedimentation, filtering and chlorine treatments are given.
2. The biologists developed a series of six connected marshes over 60 hectares of marshland.

- Plants, algae, fungi and bacteria were seeded into this area, which neutralize, absorb and assimilate the pollutants.
- The water flows through the marshes, it gets purified naturally.
- A citizens group called **Friends of the Arcata Marsh (FOAM)** is responsible for the upkeep and safeguarding of this wonderful project.
- **Ecological sanitation** is a sustainable system for handling human excreta, using dry composting toilets.
- With the help of ecological sanitation human excreta can be recycled into a resource (as natural fertilizer).

Solid wastes

- Solid wastes refer to everything that goes out in trash.
- **Municipal solid wastes** are wastes from homes, offices, stores, schools, hospitals.

Fig. solid wastes

Types of solid wastes

1. Bio-degradable- the wastes which can be degraded by microorganisms. Example- food materials.
2. Recyclable- the wastes which can be converted into new materials. Example- glass, paper.

- Non-biodegradable-the wastes which cannot be degraded or takes long time to get degraded. Example – plastic.

Prevention of solid wastes

1. Reduction in use of plastics and use of eco-friendly packaging.
2. Carrying cloth or other natural fiber carry-bags.
3. Refusing polythene bags.

- Burning and open dumps are used to reduce the volume of the wastes.
- Open dumps serve as the breeding ground for rats and flies.
- Sanitary landfills were adopted as the substitute for open-burning dumps.

Fig. Landfill

- **Polyblend** is a fine powder of recycled modified plastic which is mixed with bitumen to lay roads.
- **Hospitals wastes** contain disinfectants, harmful chemicals and pathogenic micro-organisms.
- Incinerators are used to dispose hospital waste.
- Irreparable computers and other electronic goods are known as **electronic wastes (e-wastes).**
- E-wastes are buried in landfills or incinerated.

Fig. electronic wastes

- The chemicals which are used in agriculture are called agro-chemicals. Example- herbicides, fungicides, pesticides.
- Increasing amounts of artificial fertilizers can cause eutrophication.
- Integrated organic farming is a cyclical zero-waste procedure where waste products from one process are cycled in as nutrients for other processes.

Examples-

1. Cattle excreta (dung) are used as manure.
2. Crop waste is used to create compost, which can be used as a natural fertilizer or can be used to generate natural gas.

Fig. cattle dung used as manure

Radioactive wastes

- Radioactive wastes are those which contain radioactive materials.
- Radiation given off by nuclear waste causes mutations to occur at a very high rate.
- At high doses nuclear radiation is lethal but at lower doses it creates various genetic disorders such as cancer.
- Storage of nuclear waste after pre-treatment done in shielded containers buried within the rocks, about 500 m deep below the earth's surface.

Fig. shielded containers to store nuclear waste

Greenhouse effect and global warming

- The greenhouse effect is a naturally occurring phenomenon that is responsible for heating of Earth's surface and atmosphere.
- Carbon dioxide and methane are commonly known as greenhouse gases.
- Greenhouse effect is important to increase the temperature which is essential for the organisms to live.
- Due to the increase in the level of greenhouse gases the Earth gets heated which is known as**Global warming.**

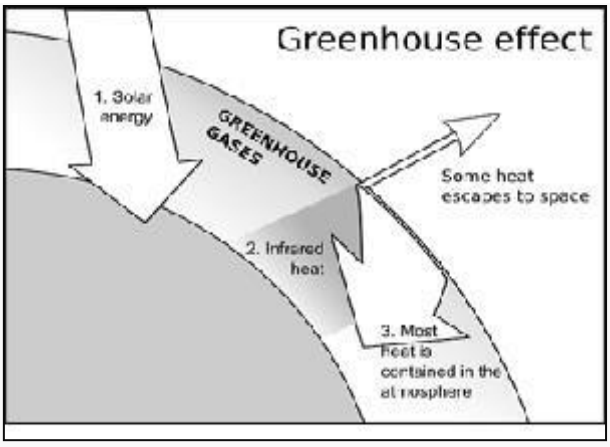

Fig. greenhouse effect

Effects of global warming-

1. Deleterious changes in the environment and resulting in odd climatic changes.
2. Increased melting of polar ice caps as well as of other places like the Himalayan snow caps.

- Rise in sea level that can submerge many coastal areas.

1. Cutting down use of fossil fuel
2. Improving efficiency of energy usage
3. Reducing deforestation,

- Planting trees and slowing down the growth of human population.

Ozone depletion in the stratosphere

- Upper part of the atmosphere is called the **stratosphere**.
- Ozone is a layer in the earth's stratosphere which acts as a shield absorbing ultraviolet radiation from the sun.

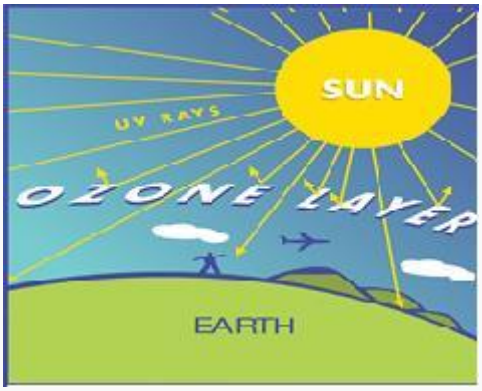

Fig. ozone layer

- UV rays are highly injurious toliving organisms as the chemical bonds within DNA and proteins of living organisms break by its high energy.
- The thickness of the ozone in a column of air from the ground to the top of the atmosphere is measured in terms of **Dobson units (DU).**
- Ozone gas is continuously formed by the action of UV rays on molecular oxygen, and also degraded into molecular oxygen in the stratosphere so there should be a balance between production and degradation of ozone in the stratosphere.
- The balance has been disrupted due to enhancement of ozone degradation by **chlorofluorocarbons (CFCs).**
- CFCs discharged in the lower part of atmosphere move upward and reach stratosphere.
- In stratosphere, UV rays act on them releasing Cl atoms.
- Cl degrades ozone releasing molecular oxygen, with these atoms acting merely as catalysts.
- Ozone depletion resulted in formation of a large area of thinned ozone layer, commonly called as the **ozone hole.**
- UV-B damages DNA and mutation may occur which causes aging of skin, damage to skin cells and various types of skin cancers.

- In human eye, cornea absorbs UV-B radiation, and a high dose of UV-B causes inflammation of cornea, called **snow-blindness cataract.**
- An international treaty **Montreal Protocol**, was signed at Montreal (Canada) to control the emission of ozone depleting substances.

Degradation by improper resource utilization and maintenance

- The degradation of natural resources can occurby improper resource utilization practices such as

1. Soil erosion and desertification
2. Soil erosion is the removal of the top layer of the soil.
3. Human activities such as over-cultivation, unrestricted grazing, deforestation and poor irrigation practices, results in arid patches of land which when extend and meet over time, a desert is created.

Fig. soil erosion

1. Waterlogging and soil salinity

- Irrigation without proper drainage of water leads to waterlogging in the soil.

1. Waterlogging draws salt to the surface of the soil which is then deposited as a thin crust on the land surface or starts collecting at the roots of the plants and damages the crop production.

Fig. water logging in the soil

Deforestation

- Deforestation is the conversion of forested areas to non-forested ones..
- Causes of deforestation

1. Slash and burn jhum cultivation.
2. Famers cut down the trees of the forest and burn the plant remains.

- Ash is used as fertilizer.

1. Land is used for farming or cattle grazing,
2. If land is left uncultivated for several years replenishment of minerals occur.

- Effects of deforestation

1. Enhanced carbon dioxide concentration in the atmosphere.

- Loss of biodiversity.
- Disturbs hydrologic cycle

1. Soil erosion
2. Desertification in extreme cases.

- Reforestation is the process of restoring a forest that once existed but was removed at some point of time.
- The Government of India has recently instituted **the Amrita Devi Bishnoi Wildlife Protection Award.**
- Government of India has introduced the concept of **Joint Forest Management (JFM)** so as to work closely with the local communities for protecting and managing forests.
- **Chipko movement** was started by local women of Garhwal Himalayas to protect trees.

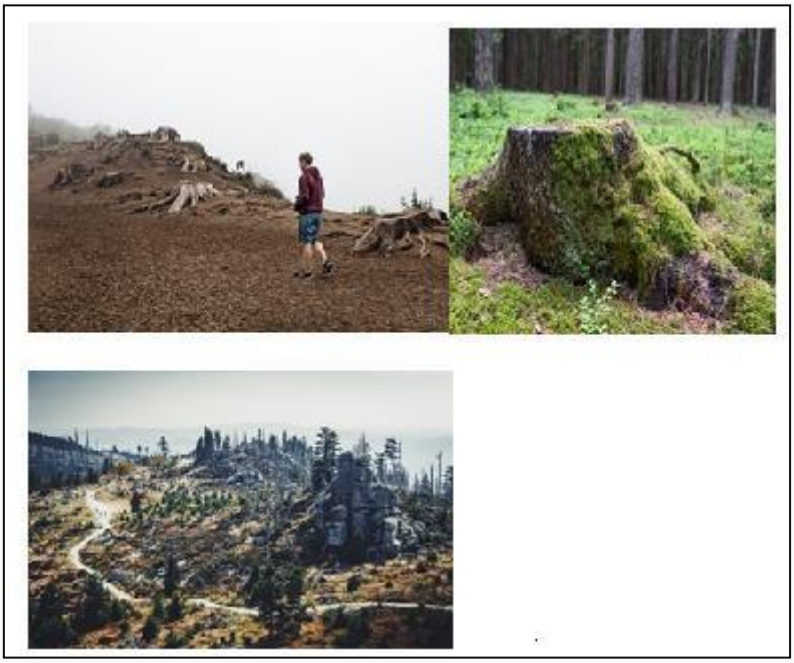

Fig. deforestation and Fig. reforestation