UNIT 1 IMMUNITY

- Immunity is a condition of being able to resist disease attack.
- Immunity in human beings is controlled by white blood cells. There are two types of white blood cells i.e. **lymphocytes** and **phagocytes**.

Lymphocytes

- Lymphocytes recognise the presence of foreign antigens in the body.
- They provide immunity by producing antibodies that attack pathogens.
- There are two main types of lymphocytes:
  (i) B- lymphocytes (B- cells) and
  (ii) T- lymphocytes (T- cells)

(i) B- Lymphocytes

- B- cells produce antibodies. Antibodies are proteins that attach themselves to **antigens**.
- Any foreign substances that can harm the body is called an antigen. Examples of antigens include: bacteria, viruses and fungi.

How B-Lymphocytes Respond to Antigen

- When B-cells come in contact with an antigen, they divide to produce two types of cells:
  a. Plasma cell clones
  b. Memory cells
- Plasma cell clones produce antibodies which destroy germs.
- Memory cells help the body to defend itself against further attack by the same antigen. Memory cells may last for years, and the body is said to be **immune** to the disease.

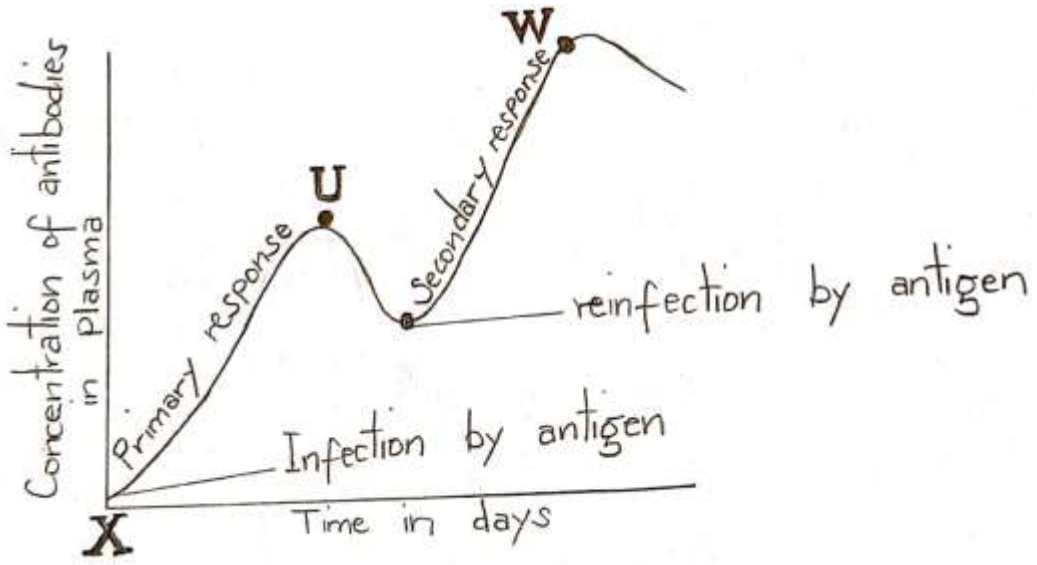


Fig. 1.1: Antibodies level for an infection in the body

How the Antibodies Destroy Antigens

1. Some antibodies kill the germ by dissolving them. These antibodies are called **lysins**.
2. Some antibodies cause germs to stick together in clumps which help to prevent their spread through the body. These antibodies are called **agglutins**.
3. Some antibodies combine with antigen material on the outer surface of germs. These antibodies are called **opsonins**. The antigen-antibody complex is readily engulfed by phagocytes which travel through circulatory system ingesting foreign material.

(ii) T- Lymphocytes

- There are four types of T- lymphocytes.

a. Killer T- Cells (Cytotoxic T- Cells)

- They kill cells infected with pathogen.

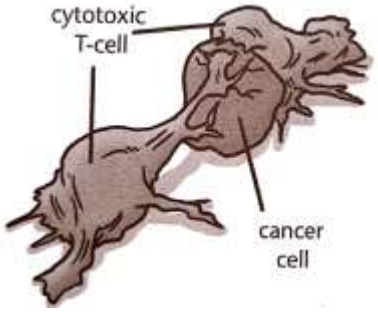


Fig. 1.2: Two T- cells attacking and killing a cancer cell

b. Helper T- Cells

- They direct other cells to engulf pathogens or kill cells infected with pathogens.

c. Memory T- Cells

- They are present after the body has fought off infection and help the body to deal more easily with any future infection of the same type.

d. Regulatory T- Cells (Suppressor T- Cells)

- They help to regulate other T- cells to prevent them targeting the body's own cells.

Phagocytes

- Phagocytes provide body's defence by engulfing and digesting germs. This is done by the flowing action of cytoplasm of phagocytes, a process called **phagocytosis**.

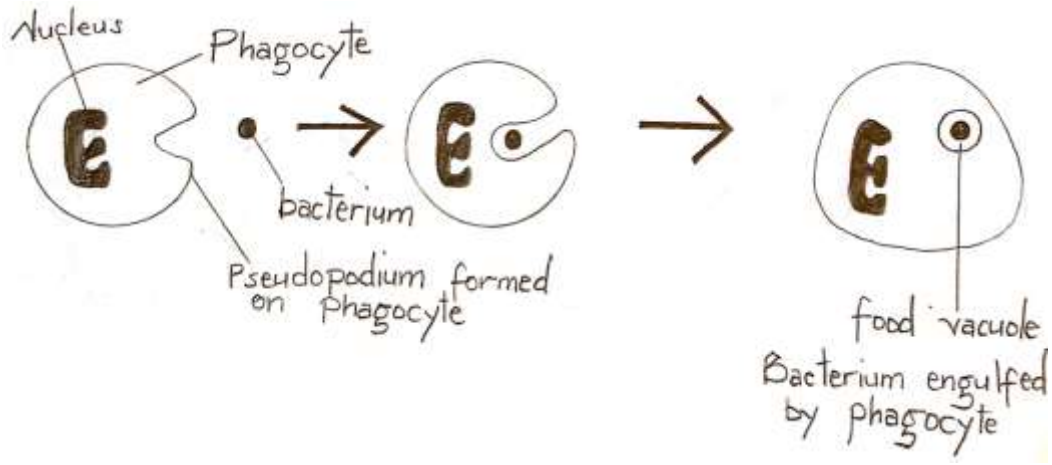


Fig. 1.1: Phagocytosis in a phagocyte

- It occurs at the site of infection.

Types of Immunity

- There are two types of immunity, namely:
  1. Natural immunity and
  2. Artificial immunity

1. Natural Immunity

- This is immunity that comes from the body itself. It can be:
  a. Active natural immunity or
  b. Passive natural immunity

a. Active Natural Immunity

- This is the type of immunity that develops after recovering from a disease.
- Once the organism recovers from the disease, it can produce antibodies quickly should the pathogen invade it again. This makes the organism immune in the sense that it cannot become sick due to invasion by the same antigen.
- For instance, if a person gets infected with measles and gets healed and is exposed to measles pathogens again, the disease will not affect the person. This is because as the pathogen enters the body, the memory T- cells recognise and killer T- cells are then produced to destroy the infected body cells.

b. Passive Natural Immunity

- This is immunity acquired by the foetus from the mother by getting antibodies against pathogens through the placenta and also through breast milk.

- This type of immunity is short- lived because antibodies are used up and are not replaced.

2. Artificial Immunity

- This is immunity that is acquired by deliberately exposing the body to antigens. It can be:
  a. Active artificial immunity or
  b. Passive artificial immunity.

a. Active Artificial Immunity

- Antigens are injected or taken orally as a vaccine. They cause the body to make its own antibodies.
- Vaccines are specific for the type of infection.

b. **Passive Artificial Immunity**

- This is the transfer of immunity in form of already made antibodies.
- This is immunity that comes from using antibodies produced in one organism to protect another organism from a specific disease. These antibodies are usually extracted from the serum of an animal that has recovered from the disease.
- This type of immunity is short- lived.

First Line Defence

- First line defence system prevents harmful microorganisms from entering the body.
- The following are examples of first line defences in the human body:
  1. Skin
  2. Ear wax
  3. Tears
  4. Mucus
  5. Hydrochloric acid
  6. Cilia
  7. Blood clotting
  8. Symbiotic bacteria

1. Skin

- The cornified layer of the skin prevents the entry of micro-organism into the body.
- Sebaceous glands in the skin produce an oily substance called subum that kills bacteria.

2. Ear Wax

- It protect the ear canal by trapping and killing bacteria.

3. Tears

- Tears are watery secretion produced by tear glands in the eye.
- Tears contain an enzyme called **lysozyme** which digest and break down harmful micro-organisms into harmless substances. Therefore, harmful micro-organisms cannot enter the body through the openings around the eye.

4. **Mucus**
    - Mucus trap microorganisms entering the nose, trachea and bronchi and therefore prevents microorganisms from invading and infecting the body cells.

5. **Hydrochloric Acid**
    - It kills bacteria that come into the stomach with food. This provides some immunity against infection.

6. **Cilia**
    - Cilia are tiny hair like structures that lie inside of some parts of the body e.g. trachea.
    - Cilia that line the trachea move back and forth to sweep micro-organisms in the trachea and prevent them from entering the lungs.

7. **Blood Clotting**
    - Blood clotting prevents the entry of micro-organisms into the body through wounds. This reduces the chances of infection.

8. **Symbiotic Defence**
    - The lining of the nose, skin and digestive system are covered with a community of symbiotic bacteria which act as a physical barrier protecting the human from being infected by harmful microorganisms.

Vaccination

- Vaccination refers to the introduction of vaccine into the body to stimulate immunity against a particular disease. It is also called **immunization** or **inoculation**.
- A vaccine is a biological preparation that is introduced into the body of an animal to increase its ability to produce antibodies against a particular disease causing micro-organism. It contains micro-organisms that have been killed or weakened. These treated micro- organisms do not cause the disease, but is still recognised as foreign material. Antibodies are then made to provide protection from that particular pathogen.

How Vaccination Works?

- The prepared vaccine is introduced into an individual's body in order to stimulate an immune response. The individual's body then produce antibodies that offer the required immunity against the disease.

Diseases Controlled by Vaccination

- Vaccines are available for the following diseases:
    1. Tuberculosis
    2. Measles
    3. Small pox
    4. Diphtheria
    5. Poliomyelitis
    6. Whooping cough
    7. Tetanus
    8. Rabies
    9. Viral diarrhoea
    10. Viral pneumonia

Importance of Immunization

(i) It protects one from serious illness and complications brought about by some illness.
(ii) It prevent the spread of some infectious diseases, hence saving lives.
(iii) It enables children and young people to grow strong and healthy.

How HIV Weakens the Immune System?

- HIV attacks and destroys the white blood cells called Helper T- cells. Helper T- Cells have the protein CD4 on its surface with which HIV uses to attach itself to the cell before gaining entry. It then starts to replicate in the cell by division. The Helper T- cells eventually dies. The new virus formed then leaves the dead cell to infect other Helper T- cells. The more the virus multiplies, the more Helper T- cells get killed. As a result of this, the number of Helper T- cells in the victim's body reduces drastically. As a result, they cannot carry out their function of directing other cells to engulf pathogens in the body or kill cells that have been infected with pathogens. Therefore, the body's immunity is weakened leading to opportunistic infections.

Organ Transplant

- Organ transplant is the moving of an organ from one body to another to replace a damaged or absent organ.
- The organs that are most often transplanted are kidneys, liver, heart, pancreas, lung, cornea of eye, skin and small intestine.

Factors to Considered before Organ Transplant

(i) Organ size
(ii) Blood type
(iii) Health condition of the donor
(iv) Age
(v) Genetic make up

The ABO Blood System

- Human blood is classified into four main groups- A, B, AB and O. This grouping is determined by the presence or absence of certain proteins called antigen A and antigen B that are found on the surface of red blood cells.
- The red blood cells of a person may carry either one, or both, or neither of these two types of antigens. So persons of blood group A have antigen A on their red blood cells. Those of blood group B have antigen B on their red blood cells, while those of blood group AB have both antigen A and B on their red blood cells. Those of persons of blood group O have neither antigen A nor antigen B on their red blood cells.
- Antibodies against these two types of antigens are found in blood plasma. One type of antibody acts against antigen A and is called anti-A. The other acts against antigen B and is called anti-B.

- The antibodies in one's bloodstream are always opposite of antigens on the surface of red blood cells. For example, if one's blood group is A, one will have anti-B antibodies in his plasma.

Types of Antigens and Antibodies Present in Different Blood Groups

Blood Group	Antigen on Red Blood Cells	Antibodies in the Plasma
A	A	Anti- B
B	B	Anti- A
AB	A and B	None
O	None	Anti-A and Anti-B

The Rhesus Blood System

- Human blood group can also be classified into Rhesus-positive or Rhesus- negative. This grouping is determined by the presence or absence of a protein called Rhesus factor (antigen D) on the surface of red blood cells.
- People with antigen D on their red blood cells are said to be **rhesus- positive** (Rh^+) while those who do not have are said to be **rhesus- negative**(Rh^-).
- There are no rhesus antibodies in plasma. However, individuals who are rhesus negative can make anti-D antibodies but rhesus positive people cannot make the antibodies.

Haemolytic Disease

- Haemolytic disease is a condition where the baby's blood cells are destroyed by antibodies in the pregnant mother's blood.
- This disease only occurs where the mother is rhesus negative and the baby in her uterus is rhesus positive, and the mother has also been previously sensitised to rhesus positive blood. The mother develop anti- Rh antibodies which will cross the placenta and enter the foetal circulation where they will cause haemolytic disease in the baby.
- These days pregnant women who are rhesus negative are carefully monitored and can be given injections of medication during the pregnancy to prevent haemolytic disease.

Blood Transfusion

- Blood transfusion refers to the transfer of blood from an external source into the body.
- Care must be taken when carrying out blood transfusion because the red blood cells carry **antigens** on their membrane, and blood plasma carries **antibodies** to these antigens. The blood types of donor and recipient must be carefully matched. This matching can ignore the antibodies from the donor, but must consider the antibodies of the recipient and antigens of the donor.
- Only compatible blood should be transfused, or **agglutination** (sticking together or clumping of red blood cells) may occur. Agglutinated (clumped) cells may block capillaries and cause kidney or brain damage, or even death. Haemolysed cells 'leak' haemoglobin so oxygen transport is affected.

  Blood Group Compatibility

Donor Group	Recipient Group			
	A	B	AB	O
A	-	+	-	+
B	+	-	-	+
AB	+	+	-	+
O	-	-	-	-

Key

- No Agglutination
+ Agglutination

- Blood group O can be given to anybody in transfusion because its red blood cells carry no antigens to be clumped by recipient antibodies. Blood group O is referred to as **universal donor**.
- Blood group AB cannot be given to any other than an AB recipient, because all other blood groups contain antibodies in their plasma which would cause agglutination. However, people with blood group AB can receive any type of blood as their plasma contains no antibodies to clump donor's red blood cells- so AB is known as the **universal recipient**.

Knowing a Person Blood Group

- To test the blood group of a person, doctors use the following procedure:
  1. **Anti-A serum** is put on a slide and then dried. The serum is called anti-A serum because it contains **Anti- A antibodies**.
  2. **Anti-B serum** is put on another slide and then dried. This serum contains **anti-B antibodies**.

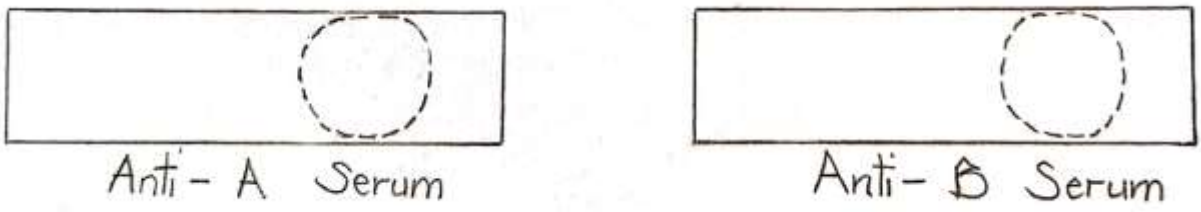


Fig. 1.3: Testing the blood group

- The sera act as recipient and the person whose blood gets tested acts as a donor.
  3. Blood samples from the person are put on the anti-A serum and anti-B serum.
- If agglutination occurs on anti-A serum but not on anti-B serum, it means that the person's blood has A antigens that have been agglutinated by anti-A antibodies in the anti-A serum but no B antigens. The blood group that has A antigens but no B antigens is blood group A. The person belongs to blood **group A**.

Fig. 1.4: Results of blood group A

- If agglutination occurs on anti-B serum but not on anti-A serum, it means the person's blood has B antigens that have been agglutinated by anti-B antibodies in anti-B serum but no A antigens. The blood group that has B antigens but no A antigens is blood group B. The person belongs to blood **group B**.

Fig. 1.5: Results of blood group B

- If agglutination occurs on both anti-A serum and anti-B serum it means the person's blood has both A and B antigens that have agglutinated by anti-A antibodies in anti-A serum and by anti-B antibodies in anti-B serum, respectively. The blood that has both A antigens and B antigens is AB. The person belongs to **group AB**.

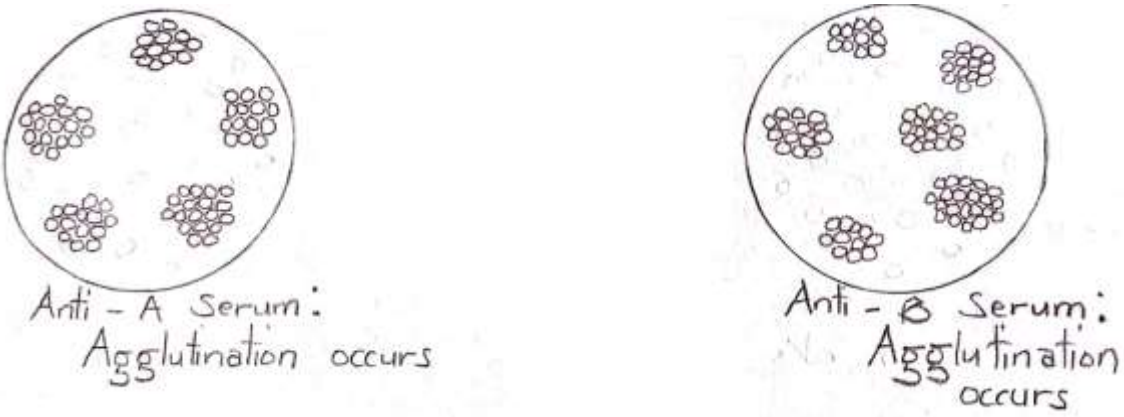


Fig. 1.6: Results of blood group AB

- If no agglutination occurs on either anti-A serum or anti-B serum it means the person's blood has neither A antigens nor B antigens. The person belongs to **group O**.

Fig. 1.7: Results of blood group O

Factors to be Considered before Blood Transfusion

1. **ABO Blood Group**
   - The blood groups of donor and recipient must be checked in order to find out whether the donor's red blood cells are compatible with the recipient's plasma or not. This helps in preventing agglutination of red blood cells which can block capillaries of the recipient resulting into death.
2. **HIV**
   - The blood of donor should be tested for HIV in order to prevent infecting the recipient since one way through which HIV is spread is by receiving infected blood in a transfusion.
3. **Anaemia**
   - The haemoglobin content of the donor should be checked in order to avoid death of donor due to insufficient oxygen supply.
4. **Hepatitis B**
   - The blood of donor should be checked for hepatitis B in order to avoid infecting the recipient.
5. **Syphilis**
   - The blood of donor should be checked for syphilis in order to avoid infecting the recipient.
6. **Age**
   - The age of the donor should be considered. The donor should not be too old or too young in order to avoid death of donor as replacement of blood may be too slow.
7. **Malaria**
   - The blood of the donor should be checked for malaria parasites in order to avoid infecting recipient.
8. **Blood Pressure**
   - The blood pressure of the donor should be considered in order to avoid death of donor due to low blood pressure.
9. **Rhesus Factor**
   - The rhesus factor of donor and recipient must be checked in order to avoid miscarriage to pregnancies.

Unit 2: Cell Division

- Cell division is the process by which a parent cell divides into two or more daughter cells.
- It usually occur to form new organisms, enable growth or the formation of gametes.
- It involves the division of all structures in a cell including chromosomes.

The Structure of the Nucleus of the Cell

- The nucleus is the largest organelle in the cell.
- A nucleus is surrounded by a nuclear membrane. A nuclear membrane is a double membrane containing may pores. The pores enable the nucleus to control the events in the cytoplasm since they allow chemicals to move in and out of the nucleus.
- The nuclear membrane encloses a jellylike fluid called **nucleoplasm**. Nucleoplasm consists of two main substances:
    1. Nucleic acid and
    2. Proteins

Nucleic Acid

- There are two types of nucleic acid, namely:
    1. Ribonucleic acid (RNA)
    2. Deoxyribonucleic acid (DNA)
- Ribonucleic acid is located outside the nucleus. RNA translates the genetic codes into instructions for making proteins in the cytoplasm of a cell.
- DNA is a molecule of genetic material of a cell. DNA is located inside the nucleus.
- When a cell is not diving, its DNA is combined with protein and forms a loose network of bumpy threads called chromatin that is scattered throughout the nucleus.
- When a cell is about to divide, chromatin threads coil, becomes shorter and thicker. As the threads shorten they take up the stain hence they are called **chromosomes**, which means "coloured bodies". Chromosomes become visible under the light microscope.

Chromosomes

- Chromosome are thread like structures in the nucleus of plant and animal cells.
- A chromosome is made up of DNA and proteins.
- A chromosome is a form in which DNA is carried from parent to offsprings.
- The number of chromosomes is unique and fixed in different species and they occur in pairs referred to as **homologous chromosomes**. Homologous chromosomes are similar in structure and size though they may have different genes. In man, there are 46 chromosomes occurring in 23 pairs.
- Gametes unlike body cells have half number of chromosomes i.e. 23 instead of 46. Such cells are said to have only one set of chromosomes and are termed **haploid**, and the number of chromosomes in such cells is called **haploid number**.
- The other body cells are said to have two sets of chromosomes and are termed **diploid**, and the number of chromosomes in such cells is called **diploid number**.

Deoxyribonucleic Acid (DNA)

- DNA molecule contains many genes.

- DNA carries genetic information from parents to offsprings.
- DNA has two strand which twist about one another in form of double helix. The strands are held together by hydrogen bonding between two bases.

Functions of DNA

1. It replicates itself exactly before a cell divides, thus ensuring that genetic information in every body cell is identical.
2. It provides the information which allows the cell to produce proteins. These proteins, in turn, are responsible for development of characteristics of the cell and organism of which the cell is part.

Model Part of DNA Molecule

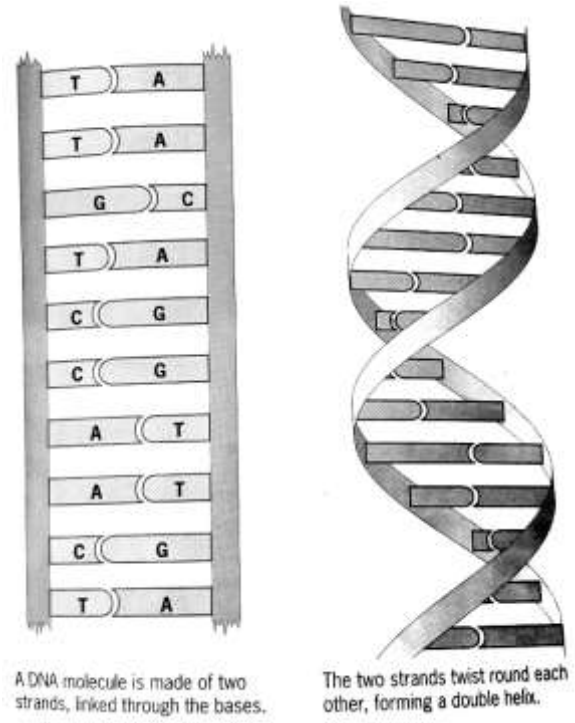


Fig. 1.1: Model Part of DNA molecule

Genes

- A gene is a basic unit of heredity.
- Genes are inherited from parent to offspring.
- Genes contain information which determine all inherited characteristics such as skin colour, whether one to roll his tongue or not.

The Cell Cycle

- The cell cycle has two main parts: cell growth and cell division.
- The phase of cell growth is called **interphase**- or resting stage and the phases of cell division are called **mitosis**.

Interphase

- The following activities take place during interphase preparing the cell for division:
    1. Metabolic activity increases in order to generate more energy for cell division.

2. DNA replicates; that is, it produces an exact copy of itself.
3. New cell organelles are formed.

- Chromosomes are not visible as distinct chromosomes but only appear as chromatin threads swollen at certain intervals.

Types of Cell Division

- There are two types of cell division:
  1. Mitosis and
  2. Meiosis

Mitosis

- Mitosis is the division of the nucleus to produce two daughter nuclei, each containing identical set of chromosomes of the original nucleus.
- Mitosis occurs in the body cells (somatic cells).

Stages of Mitosis

- Mitosis is divided into four stages:
  1. Prophase
  2. Metaphase
  3. Anaphase
  4. Telophase

1. **Prophase**
   - Chromatin threads shorten and thicken so that visible rod like bodies called **chromosomes** appears.
   - The centrioles separate from each other and begin to move towards opposite sides of the cell forming spindle fibres.
   - Each chromosome comprises of two strands joined at centromere. The two strands are referred to as **sister chromatids** as one is the original chromosome while the other is a product of replication.
   - Nuclear membrane breakdown and disappears.
   - Nucleolus also breakdown and disappears making the end of prophase.

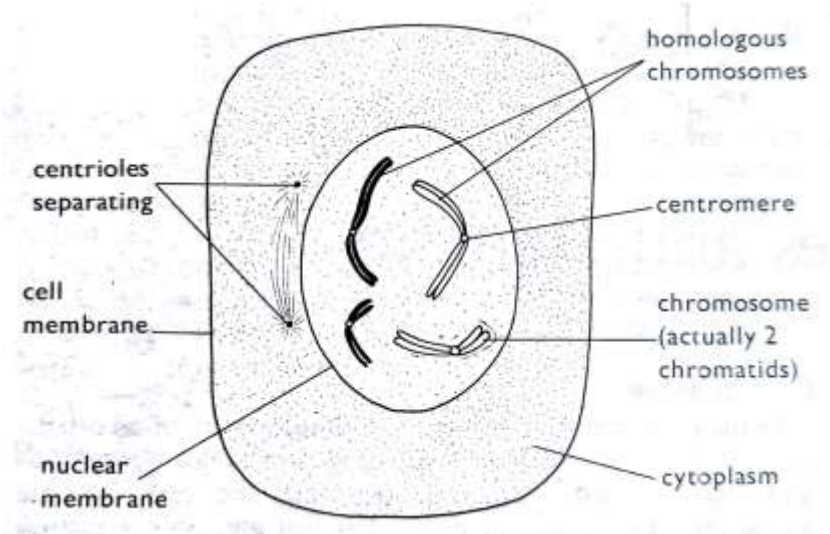


Fig. 1.2: Prophase

2. **Metaphase**
   - Chromosomes arrange themselves at the centre (equator) of the cell.
   - Spindle fibres increases in length.
   - Each centriole is at the pole.

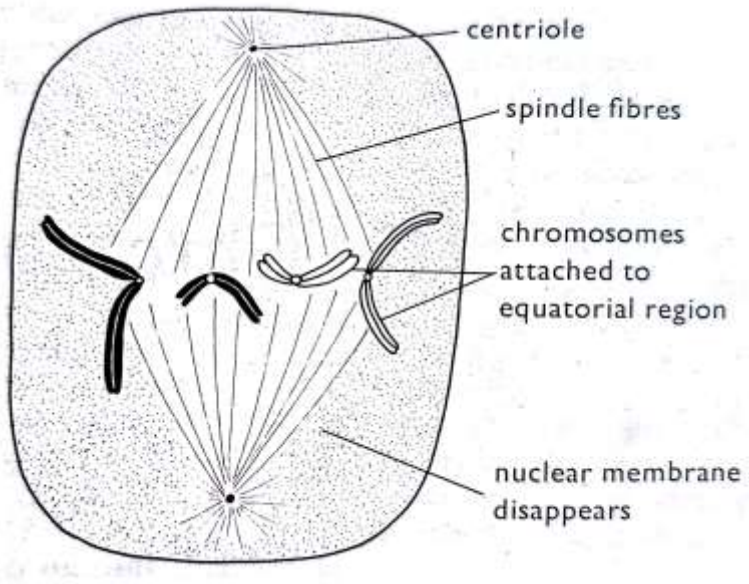


Fig. 1.3: Metaphase

3. **Anaphase**
   - The centromeres that have held the chromatids together split, and the chromatids (now called chromosomes again) begin to move slowly apart, towards opposite. Shorten of spindle fibres bring about the movement of the chromatids.

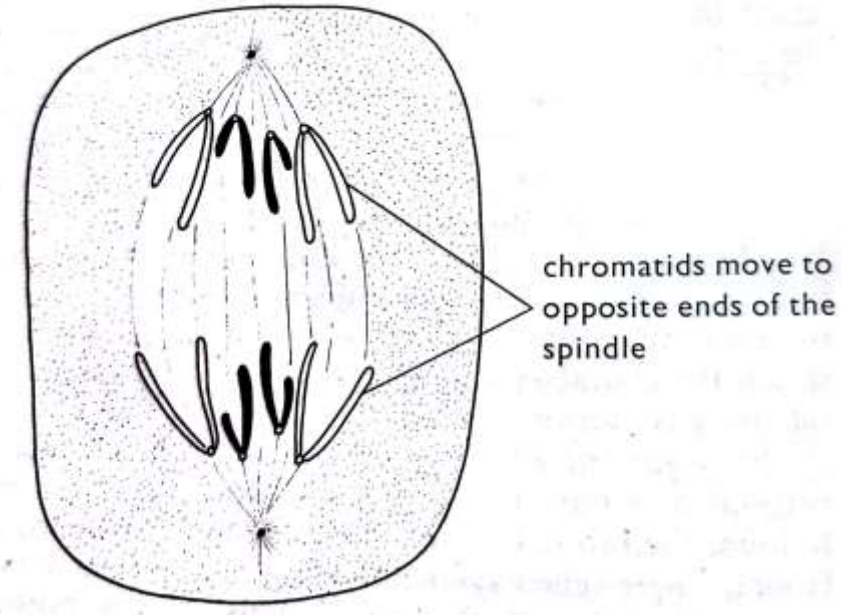


Fig. 1.4: Anaphase

4. **Telophase**
   - The chromosomes at the opposite ends of the cell uncoil to become threadlike chromatin again.

- The spindle fibres break down and disappear.
- A nuclear membrane forms around each chromatin mass
- Nucleolus develops in each of the daughter nuclei.

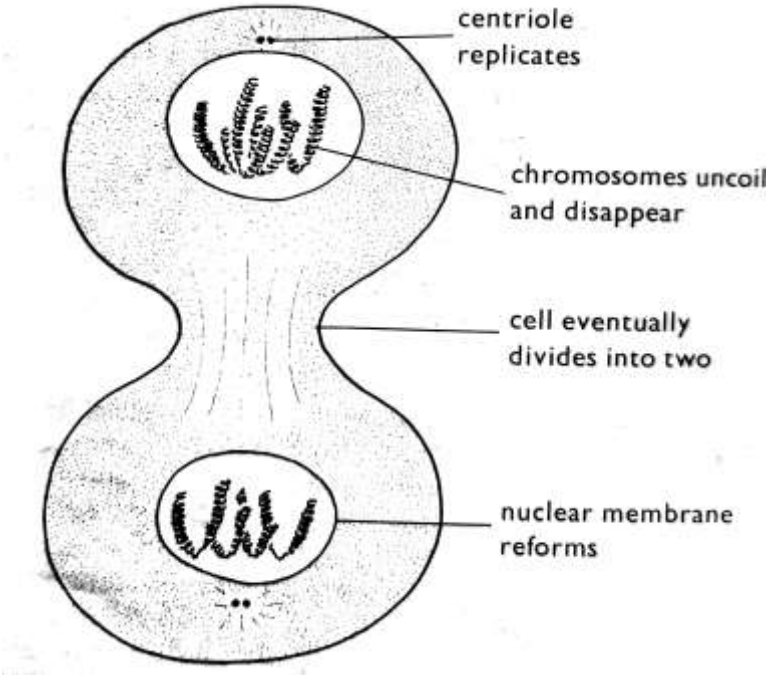


Fig. 1.5: Telophase

Cytokinesis

- It is the division of the cytoplasm.
- Cytokinesis begins during late anaphase and completes during telophase.
- At the end of mitosis, two daughter cells are produced. Each is smaller and has less cytoplasm than the mother cell, but it is genetically identical to it. The daughter cells grow and carry out normal cell activities until their turn to divide.

Importance of Mitosis

(i) It provides the new cells for growth in youth.
(ii) It helps in replacing dead cells.
(iii) It helps to maintain the genetic material of each cell.
(iv) It helps in asexual reproduction.

Meiosis: Reduction Division

- Meiosis is the division of the nucleus to produce four daughter nuclei, each containing half the number of chromosomes of the original nucleus.
- Meiosis occurs in reproductive organs such as anthers and ovaries in flowering plants, testes and ovaries in human beings.
- Meiosis occurs in two phases, namely:
    1. Meiosis I and
    2. Meiosis II
- In meiosis I each homologous chromosomes move to different daughter cells and hence it is termed a **reduction division**.
- Meiosis II is similar to mitosis hence sister chromatids separate and move to different cells.

Meiosis I

- This consists of prophase I, metaphase I, anaphase I and telophase I.

1. Prophase I

- Chromatin threads shorten and thicken so that visible rod like bodies called **chromosomes** appears.
- The centrioles separate from each other and begin to move towards opposite sides of the cell forming spindle fibres.
- Homologous chromosomes pair up and lie side by side a process referred to as **synapsis**. Each pair is called **bivalent**. Sister chromatids are joined at centromere. However, non sister chromatids may join at points called **chiasmata**. The joined portion may break off at the chiasmata and later rejoin to a different chromatid leading to exchange of genetic material between the two different homologous chromosomes, a process referred to as **crossing over**. Crossing over leads to variation in the offsprings.
- Nuclear membrane breakdown and disappears.
- Nucleolus also breakdown and disappears making the end of prophase.

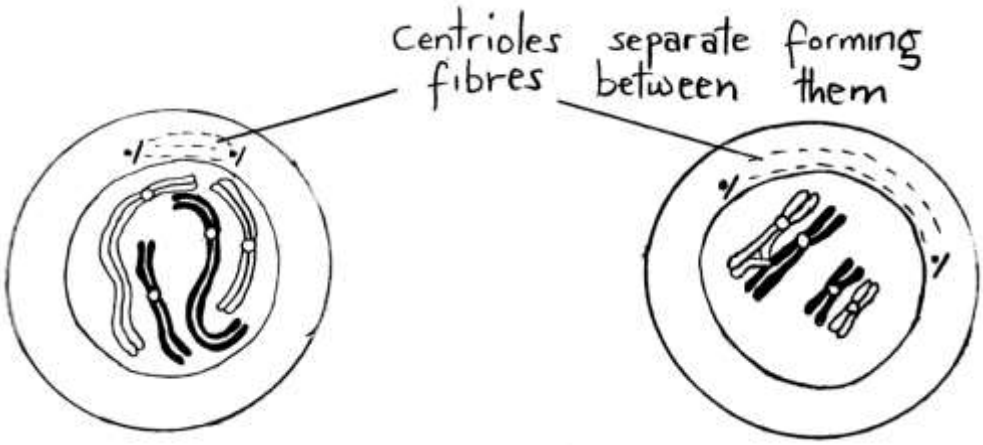


Fig. 1.6: Prophase I

2. Metaphase I

- The chromosomes arrange themselves at the centre of the cell.
- Spindle fibres increases in length.
- Each centriole is at the pole.

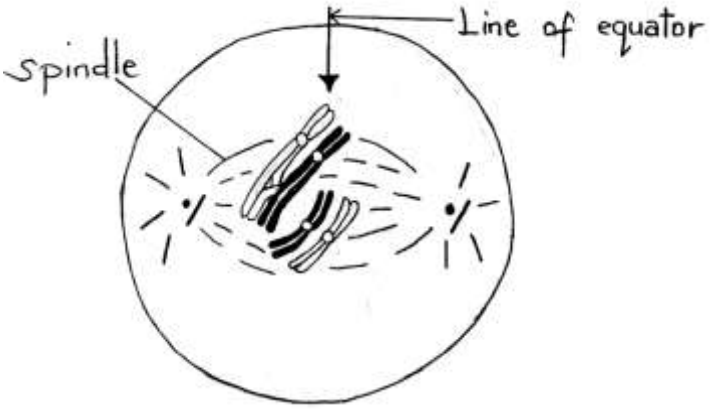


Fig. 1.7: Metaphase I

3. **Anaphase I**
    - Homologous chromosomes move to opposite poles of the cell with their sister chromatids remaining attached together at the centromere. Shortening of the spindle fibres bring about the movement of the chromatids.

Fig. 1.8: Anaphase I

4. **Telophase I**
    - The spindle fibres break and disappear.
    - Nuclear membrane forms around each set of chromosomes.
    - Cytokinesis occur forming two daughter cells.

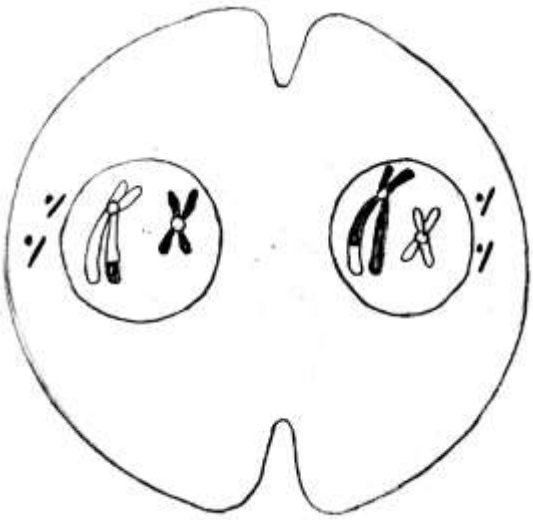


Fig. 1.9: Telophase I

Meiosis II

- This stage consists of prophase II, metaphase II, anaphase II and telophase II.

1. **Prophase II**
    - The centrioles separate from each other and begin to move towards opposite sides of the cell forming spindle fibres.

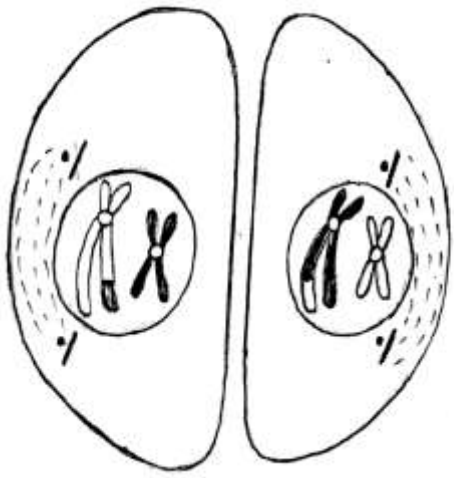


Fig. 1.10: Prophase II

2. Metaphase II

- The chromosomes (with their chromatids) arrange themselves on the equator of the cell.

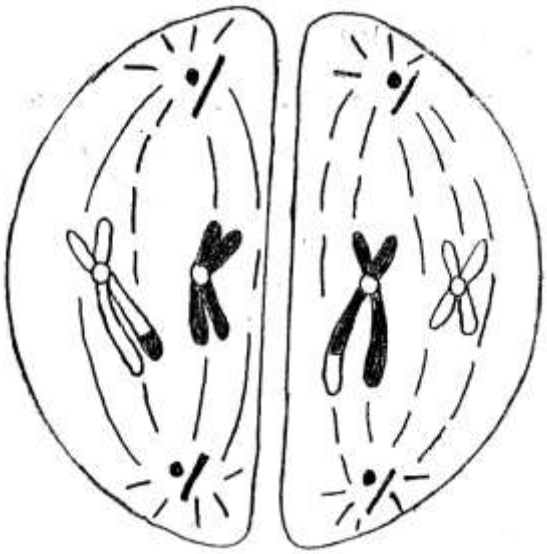


Fig. 1.11: Metaphase II

3. Anaphase II

- Chromatids of each chromosomes separate and are pulled to opposite poles of the cell.

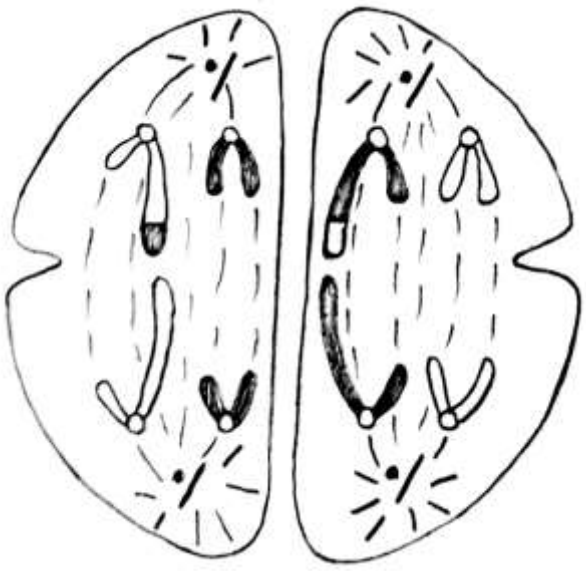


Fig. 1.12: Anaphase II

4. Telophase II

- The chromosomes at the opposite ends of the cell uncoil to become threadlike chromatin again.
- The spindle fibres break down and disappear.
- A nuclear membrane forms around each chromatin mass
- Nucleolus appears in each of the daughter nuclei.
- Cytokinesis occurs forming four daughter cells each with a haploid number of chromosomes.
- The four daughter cells formed at the end of meiosis are not gametes. These cells undergo the process of differentiation to form specialised cells called gametes.
- In animals, for example in humans, the daughter cells become specialised to form sperms in males and ova or eggs in females.
- In flowering plants, the daughter cells eventually form specialised structures called ovules in female part of flower and pollen grain in the male part of the flower.

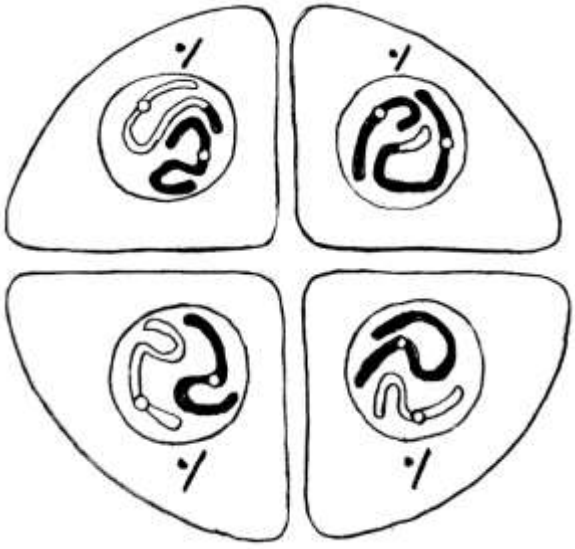


Fig. 1.13: Telophase II

Importance of Meiosis

1. It reduces the number of chromosomes in gametes from diploid to haploid.
2. It helps in generating new gene combination through crossing over which leads to variation.

Differences between Mitosis and Meiosis

Mitosis	**Meiosis**
1. Occurs in somatic cells (body cells)	Occurs in gonads (i.e. testes and ovary in human beings)
2. Produces two daughter cells	Produces four daughter cells
3. Homologous chromosomes do not pair up	Homologous chromosomes pair up in prophase I
4. Daughter cells are diploid	Daughter cells are haploid
5. No crossing over occurs.	Crossing over occurs. Crossing over leads to exchange of genetic material between non-sister chromatid hence resulting to variation.
6. Has one phase of cell division	Has two phases of cell division (meiosis I and meiosis II)
7. Daughter cells are identical to the parent cell	Daughter cells are not identical to the parent cell

Unit 3: Human Reproductive System

- Reproduction is the process by which living things produce new individuals of their species.
- Animals have organs that are specialised for the formation of gametes, such organs are called **reproductive organs** or **gonads**.
- The gonads that produce the male gametes or **sperm** are the **testicles** or testes (testis- singular), while those producing the female gametes- the **eggs** or **ova** (ovum- singular) are called the **ovaries**.
- In males, the structures of the reproductive system are suited to produce the male gametes and introducing them into the female reproductive system.
- In females, the structures are suited to make female gametes and receive male gametes.

The structure of Gametes

- The nucleus of a normal human body cell has 46 chromosomes in the form of 23 pairs of homologous chromosomes. One member of each pair of chromosome comes from one parent, the other from the other parent.
- Every sperm or egg has only 23 chromosomes because, in the testes or ovaries, the process of meiosis takes place.
- A gamete is a reproductive cell containing the haploid number of chromosomes.

Sexual Reproduction

- Sexual reproduction involves the fusion of two gametes.
- During fertilization, a sperm fuses with an egg to form a **zygote**.
- Since the sperm and the egg in human each have a haploid number of 23 chromosomes, the zygote formed will have a diploid number of 46 chromosomes. Then the zygote divide by mitosis resulting in all the body cells in the child having a diploid number of chromosomes.

The Structure and Functions of the Male Reproductive System

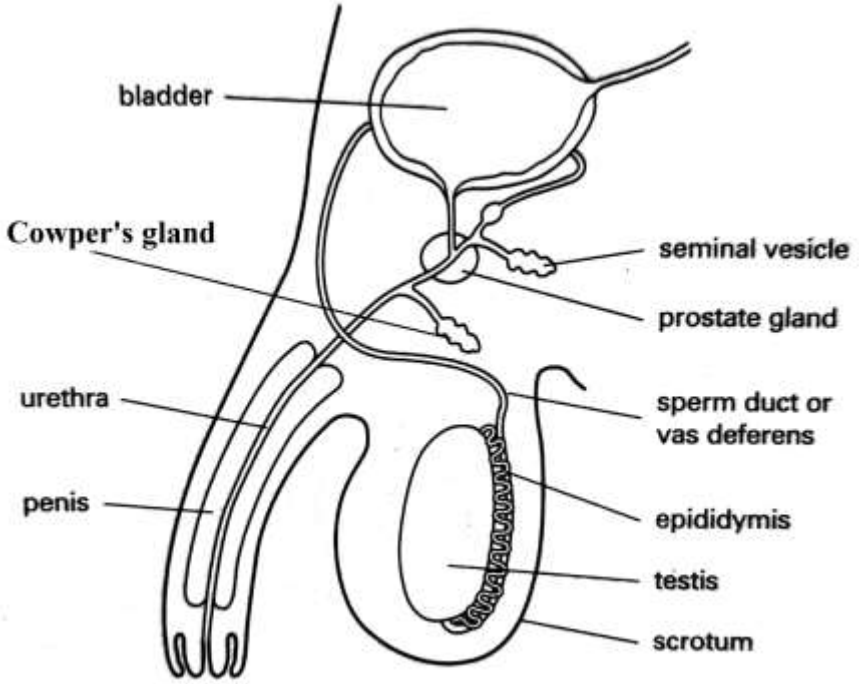


Fig. 2.1: The male reproductive system

- The male reproductive system is made up of the following parts:

Testes

- There are two testes in the male reproductive system.
- These are the organs where the sperms are made.
- They also produce the male sex hormone **testosterone**.

Seminiferous Tubules

- Each testis contains in it tightly coiled seminiferous tubules. The walls of these have specialised cells that produce sperms. Other specialised cells located in between the seminiferous tubules are known as **interstitial cells** which secrete the hormone **testosterone**.

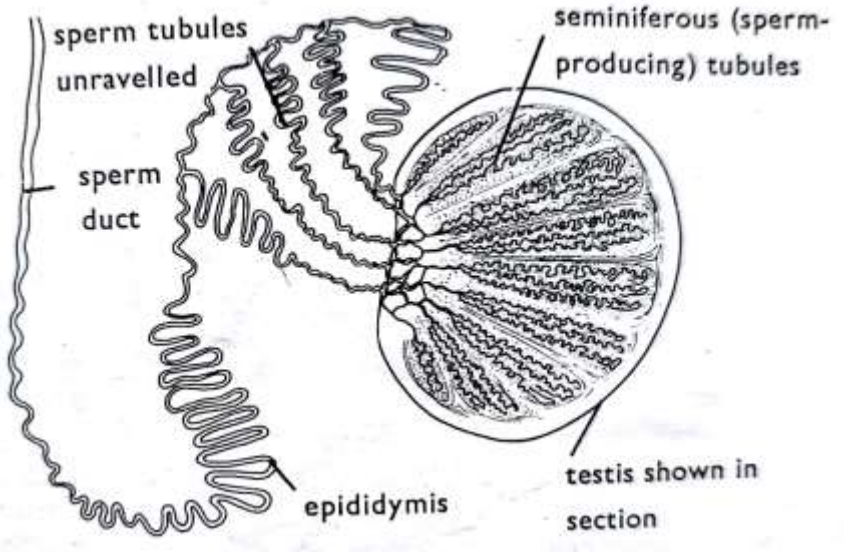


Fig. 2.2: Internal structure of the testis

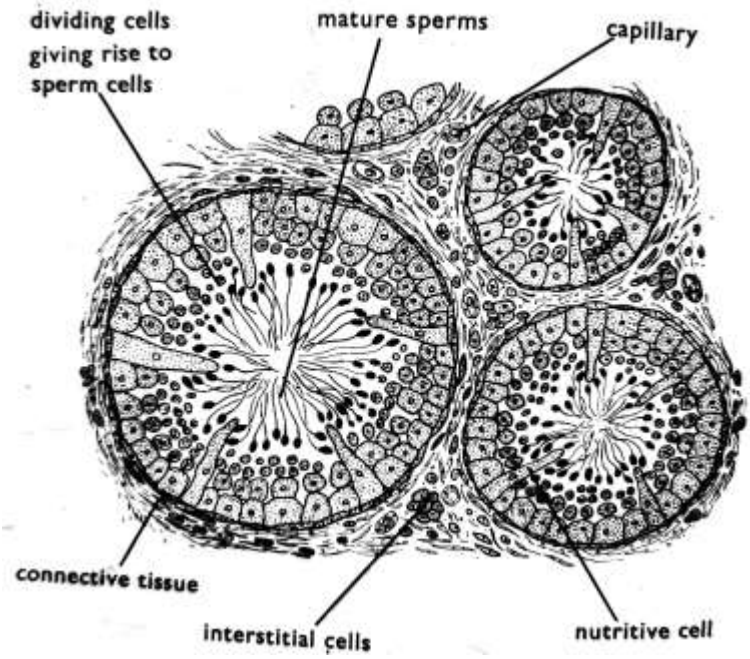


Fig. 2.3: Cross-section of seminiferous tubules with sperms

- In the seminiferous tubules, cells known as **sertoli cells** provide nourishment to the developing sperms.

Vas Efferentia

- These are tiny tubes that direct the sperm from seminiferous tubules to the epididymis.

Epididymis

- This is a coiled tube in which sperms continue to develop and mature.
- Epididymis temporarily store mature sperms.
- They are long and coiled to increase space for storage.

Sperm Duct (Vas Deferens)

- It helps to transfer sperms from epididymis to urethra during ejaculation.

Accessory Glands

- The seminal vesicles, a pair of cowper's gland and prostate gland are referred to as accessory gland.
  - **Prostate gland-** secretes mucus and slightly alkaline fluid that is released during ejaculation. It makes sperms more active and neutralises the any urine present.
  - **The Cowper's gland-** secrete a clearly, sticky slightly alkaline fluid which cleans the urethra prior to ejaculation by neutralising any urine present.
  - **The Seminal Vesicles-** produce mucus secretion which aids sperm movement. The mixture of secretions and sperms is called **semen**.
- Semen is made up of sperms, sugars that nourish the sperms making them more active, mucus that forms a semi- liquid that the sperms can swim in, alkaline substances that neutralise the acidic conditions in the urethra and vagina and hormones which help sperms reach the ovum by causing muscular contractions of uterus and oviducts.

The Scrotal Sac (Scrotum)

- It support the testes
- It protect the testes
- It ensures that the testes are located at lower temperature than that of the body. This because sperms require temperatures slightly lower than that of the body for their production. High temperatures reduce the lifespan of sperms.

Penis

- Penis is an erectile intermittent organ used during copulation.
- It has specialised tissue called **erectile tissue**. The tissue has spaces that fill up with blood during sexual excitement causing the penis to become rigid and erect in a process called **erection**.
- The tip of the penis is called the **glans**. It has sensory nerve endings that are stimulated by friction to cause the expulsion of semen through the process of ejaculation.
- The glans are covered by the foreskin (prepuce)
- Its role is to deposit sperms into the vagina of the female.

Human Sperm

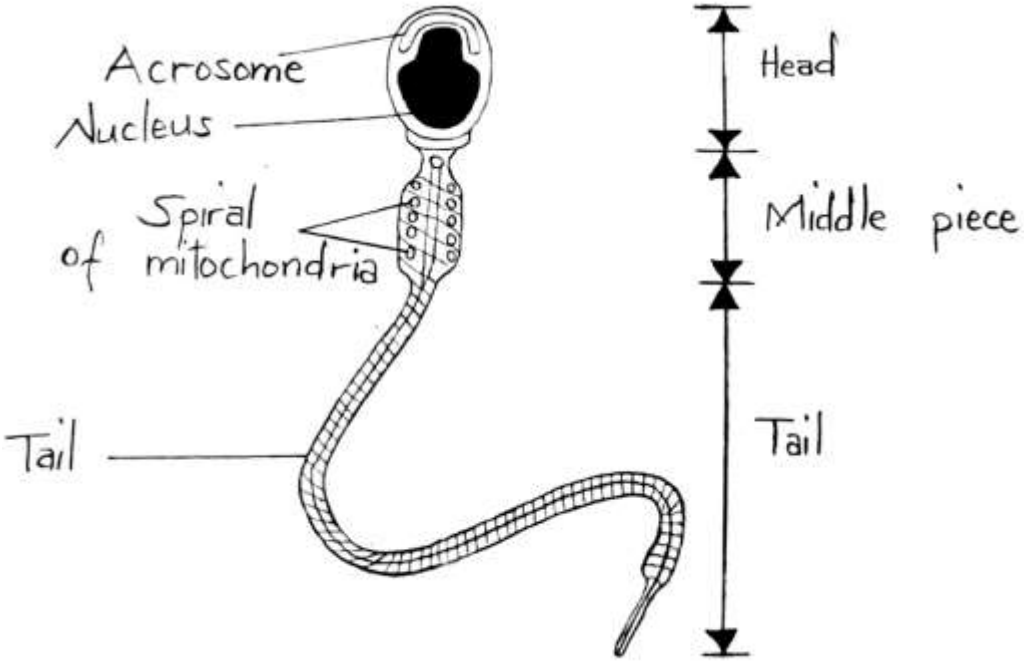


Fig. 2.4: A sperm cell

- The human sperm or spermatozoon is made up of:

1. **The Head**
   - The head contains a large nucleus with cytoplasm and an **acrosome**.
   - The nucleus carries haploid set of chromosomes from the male.
   - Acromosome is a sac containing enzymes. The enzymes dissolve (digest) the vitelline membrane of the ovum during fertilization.
2. **Middle Piece**
   - This is the middle section of the sperm.
   - It contains numerous mitochondria which produce energy for movement of sperm hence it is referred to as the **power house of the sperm**.
3. **The Tail (Flagellum)**
   - The tail is used by the sperm for swimming to the ovum.

Adaptations of the Sperm to its Function

1. It has a tail for swimming.
2. It has mitochondria which provide energy for movement.
3. It has an acrosome which allows the sperm to penetrate the egg.
4. It has streamline shape which reduces drag.

The Structure and Functions of the Female Reproductive System

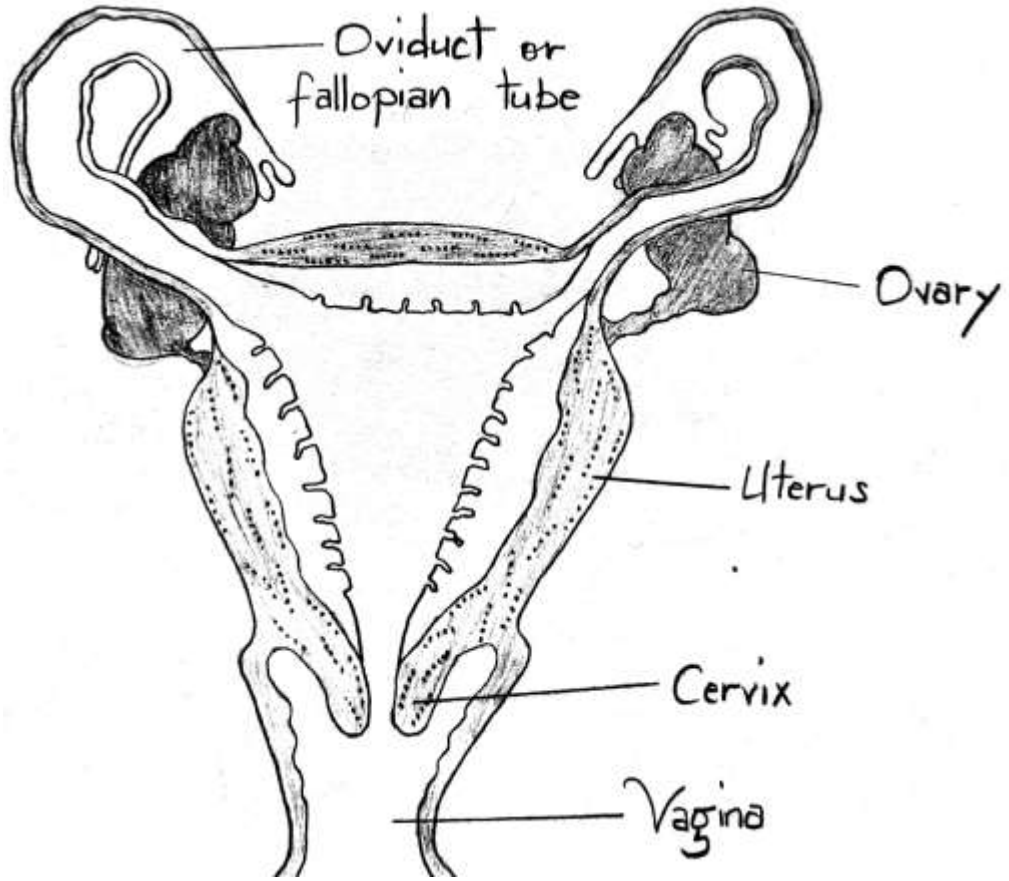


Fig. 2.5: The female reproductive system

- The female reproductive system is made up of the following parts:

Ovary

- Ovaries produce ova or eggs.
- The ovaries also produce the female sex hormone called **oestrogen** and **progesterone**.

Fallopian Tube (Oviduct)

- A muscular tube which provides a pathway between the ovary and uterus for ova, sperm and zygote (fertilized ovum).
- It is lined with cilia which help to propel the egg and zygote towards the uterus.
- It is where fertilization occurs.
- The oviduct has funnel shaped end to suck the ovum from the ovary.

Uterus (Womb)

- The organ in which the fertilized ovum implants and grows.
- It has elastic muscles which enables it to enlarge to accommodate the growing foetus during pregnancy.

Cervix

- It is a muscular ring of muscles located in between the uterus and vagina.
- It is usually closed during pregnancy to prevent the foetus from being expelled before full development.

Vagina

- It is the space between the vulva and the cervix.
- It has elastic walls that expand to allow the foetus to pass through during birth.
- It is a copulatory canal and birth canal.
- It receive sperms.

Vulva

- It is an external opening of the vagina to the outside.

The Ovum (Egg)

- This is the female gamete.

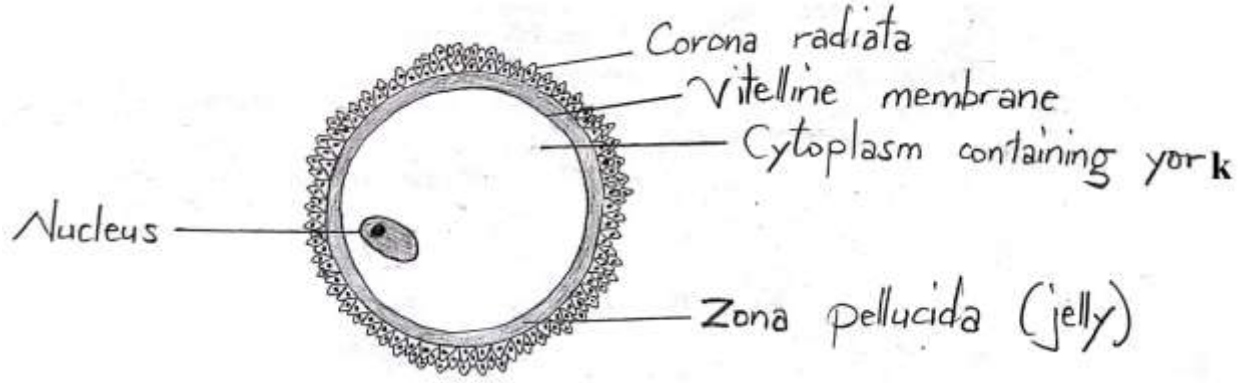


Fig. 2.6: An egg

- It has a large nucleus which contains a haploid set of chromosomes.
- It has a lot of cytoplasm.

Fertilization

- Fertilization is the fusion of male and female gametes to form a zygote.
- During sexual intercourse, the male releases semen into vagina of the female in a process called **ejaculation**.
- The spermatozoa contained in the semen then swim up through the cervix, uterus into the fallopian tube. They utilize the proteins, sugars, enzymes and salts in the semen to provide them with the necessary energy.
- Due to the long route from the vagina to the fallopian tube and the harsh acidic conditions from vaginal secretions, only a few sperms reach the oviduct as most die on the way.
- The cervical mucus also serves to screen spermatozoa and only allow those that are healthy to pass through.
- On reaching the ovum in the upper fallopian tube the acrosome of several sperms burst releasing enzymes that help to digest the follicle cells surrounding the ovum.
- In addition, enzymes also soften the vitelline membrane of the ovum.
- One of the sperms penetrates and enters the ovum. Only the head and middle piece enter the ovum while the tail is left outside.
- Meanwhile, the vitelline membrane of the ovum thickens and undergoes changes in texture that stops any other sperm from penetrating the egg. As a result, only one sperm fertilizes the egg.

- Once inside the egg, the sperm head burst releasing the nucleus which then fuses with the nucleus of the ovum to form a **diploid zygote**, a process called **fertilization**.

Conception

- Conception is the process whereby a zygote begins to carry out cell division to develop into new individual.

Development of the Embryo

- After fertilization, the fertilized ovum moves down the fallopian tube into the uterus assisted by cilia movement on the walls of the fallopian tube.
- As it moves down, mitotic divisions occur resulting into a hallow structure of cells called **blastocyst**.
- It is this blastocyst that gets attached into the endometrium of the uterus. This process is referred to as **implantation**.
- After implantation, blastocyst is now called **embryo**.

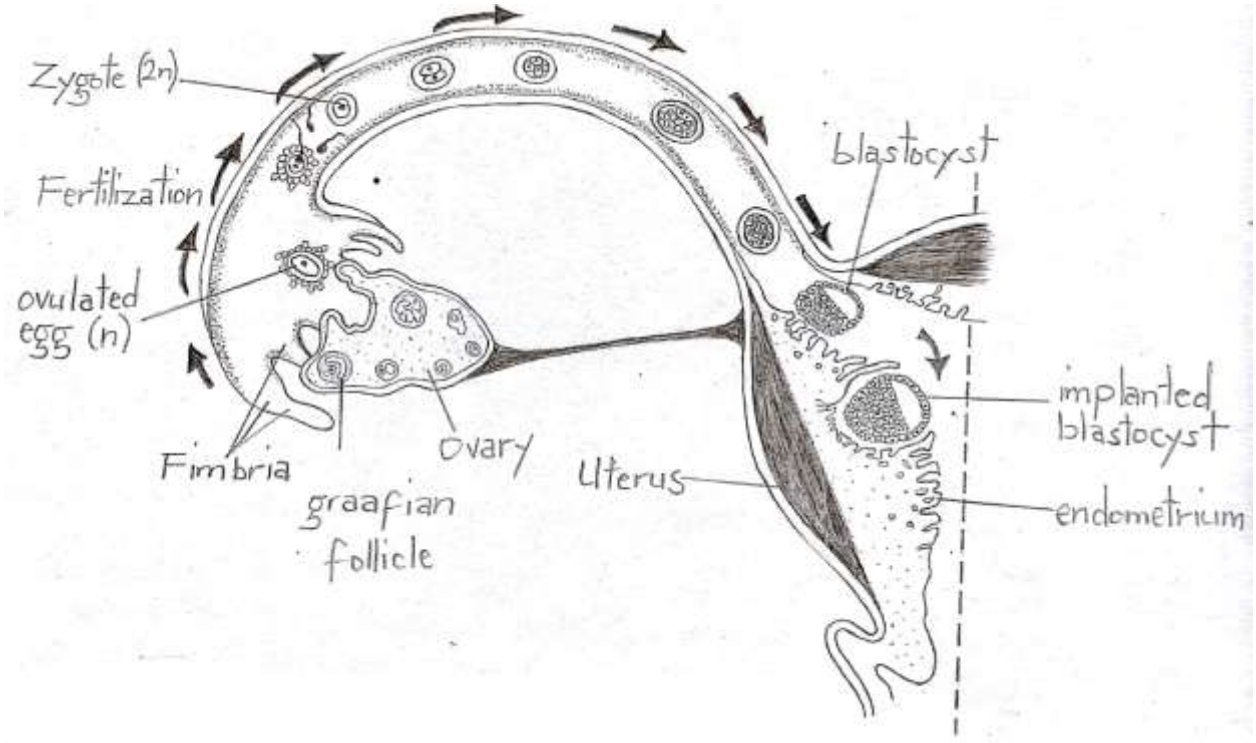


Fig 2.7: Section through one side of female reproductive tract showing development of a zygote

- Some cells of the embryo develop into a membrane called **amnion** that is separated from the embryo by a fluid filled cavity called the **amniotic cavity**. The fluid is referred to as **amniotic fluid**.

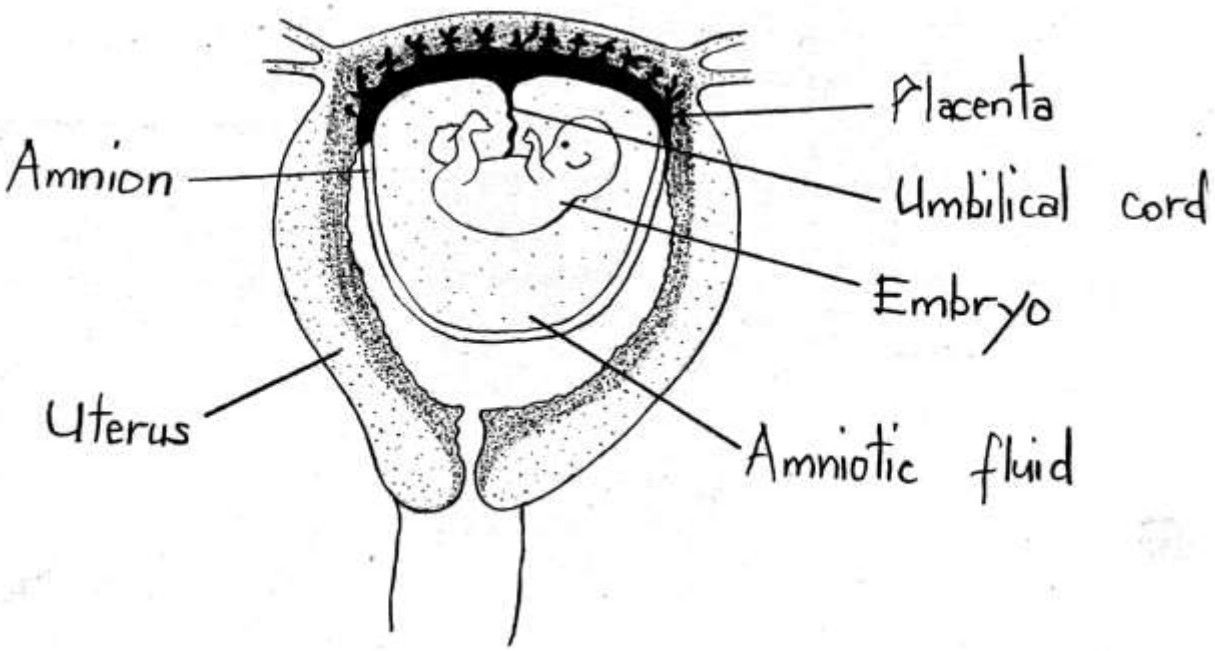


Fig.2.8: Side view of developing foetus inside uterus

Functions of Amniotic Fluid

1. It acts as a shock absorber, protecting the foetus from mechanical damage.
2. It supports the foetus and allows it to move freely during growth.
3. It maintains the external temperature of the embryo since it is an insulator which prevents exchange of energy between the embryo and the mother.
4. During birth, it lubricates the birth canal (vagina) thereby reducing frction.

The Placenta

- This is the structure that is closely attached to the lining of the uterus on one side and closely attached to the blood vessels of umbilical cord on the other side.

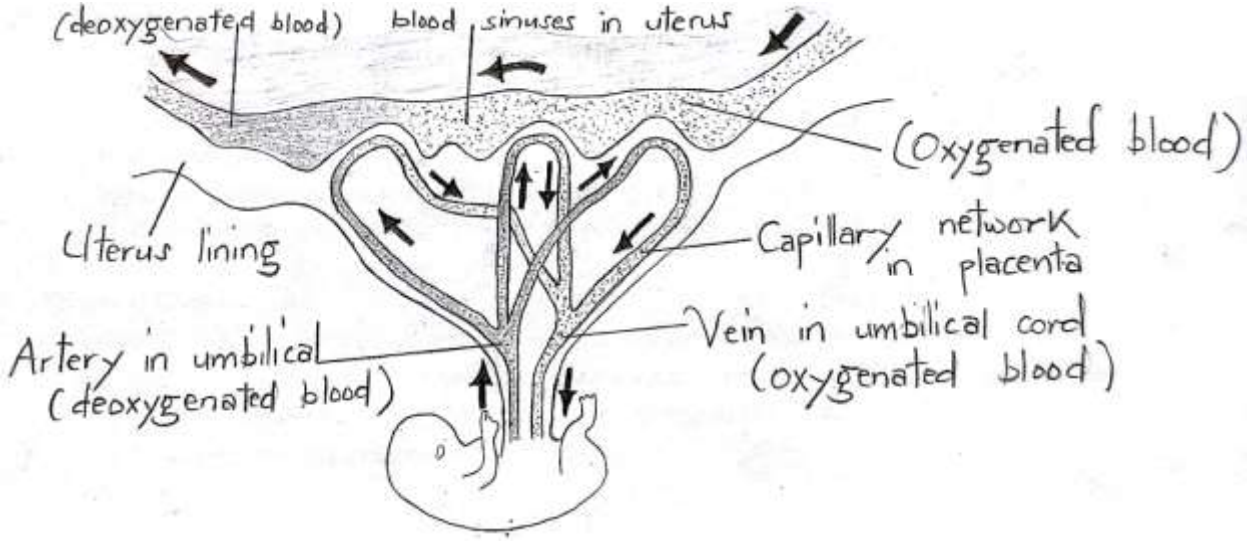


Fig. 2.9: Diagram showing relationship between blood supply of embryo, placenta and uterus

Functions of the Placenta

1. It is a place for exchange of substances between the mother's blood and the embryo's blood.
   - The placenta allows dissolved food substances such as glucose and amino acids, and oxygen to diffuse from the mother's blood into that of the embryo.
   - The placenta also allows metabolic waste products such as urea, uric acid and carbon dioxide to diffuse from embryonic blood into the mother's blood.
2. The placenta allows antibodies to diffuse from the mother's blood into that of the embryo.
   - Antibodies protect the embryo against certain diseases.
3. It secretes progesterone hormone that maintains pregnancy by keeping the uterine lining thick and well supplied with blood.
4. It secretes human placental lactogen hormone which stimulates the development of mammary glands in preparation of lactation.
5. It forms a barrier separating the embryo's blood system and the mother's blood system.
   - This function is important in the following ways:
     (i) It prevents the mother's high blood pressure from damaging the embryo's delicate blood vessels.
     (ii) It minimises the entry of harmful material e.g. germs such as plasmodia from the mother's blood into that of the embryo's blood.
     (iii) It prevents agglutination of red blood cells if the mother's and embryo's blood are incompatible which could result in death of both mother and the embryo.

Adaptations of the Placenta for Exchange of Materials

1. It has dense network of blood vessels for efficient transport of substances.
2. It has villi which increases the surface area for diffusion.
3. It has sinuses for efficient exchange of substances.
4. It has thin epithelium for short diffusion path.

Umbilical Cord

- The embryo is attached to the placenta by a tube called **umbilical cord**.
- Umbilical cord contains two umbilical arteries which carry deoxygenated blood from the foetus to the placenta, and one umbilical vein which transport oxygenated blood from and food substances from the placenta to the foetus.
- When the main organs of the embryo have been formed, the embryo is known as the foetus. At the end of nine months of pregnancy the baby is fully formed and ready to be born.

Process of Birth

- In the last stages of pregnancy, progesterone hormone levels in the mother's blood drops. This stimulates the pituitary gland to release a hormone called **oxytocin**. Oxytocin stimulates the muscles of the uterine wall to contract. The wave of contraction of these muscles results to pain commonly called **labour pain**. The contractions provide a force that starts to push the foetus from the uterus to the cervix.
- At the same time, the muscles of the cervix relax making the cervix to open and widen to allow the foetus to pass through. As the foetus moves to the cervix, the amnion break releasing the amniotic fluid through the cervix. The foetus is pushed downwards though the

cervix into the birth canal. The birth canal is elastic and widens allowing the baby to be born. The baby comes out through the vulva with its head first.

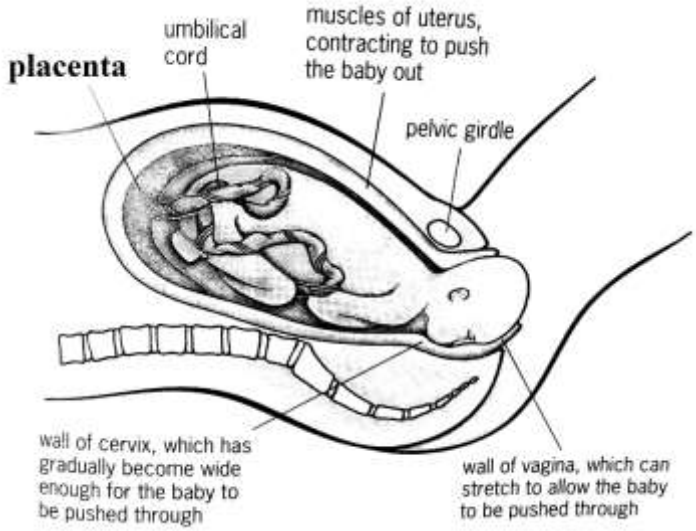


Fig 2.10: The process of birth

- After birth, the umbilical cord is cut by use of clean sterilized razor to separate the baby from the placenta. The baby takes its first breath and the lungs become functional. The placenta is then eliminated from the mother's womb as afterbirth.

Twins

- Twins are also referred as multiple births.
- A multiple birth occurs when more than one foetus develops in the uterus at the same time.
- There are two types of twins:
  1. Fraternal (Non- Identical/ Dizygotic) twins
  2. Identical (Monozygotic) twins.

1. Fraternal (Non- Identical) Twins

- Fraternal twins occur when the ovary produce two eggs at the same time and two eggs are fertilized by two different sperms and implanted in the uterine wall at the same time. The two eggs form two zygotes which do not contain the same genetic material.
- Fraternal twins may be of different sexes or may be of the same sex but do not look alike.
- Non-identical twins have two placenta, each having its own placenta.

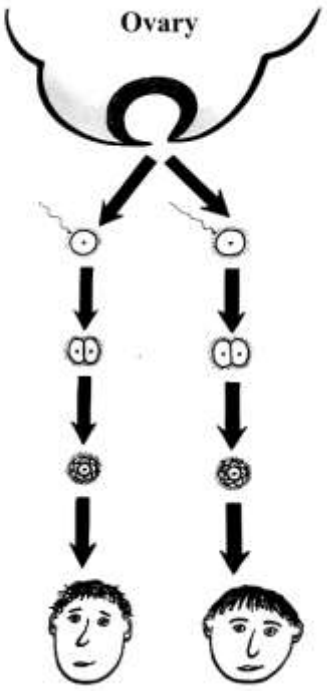


Fig. 2.11: Fraternal twins

2. Identical (Monozygotic) Twins

- Identical twins are produced by one zygote (fertilized egg). This zygote splits into two cells, each of which grows to become a baby. Since the two babies originate from one zygote they have the same genes and completely resemble each other.
- Identical twins are of the same sex.
- Identical twins shares one placenta.

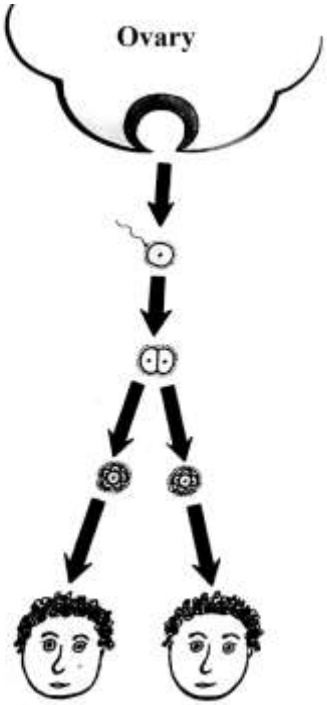


Fig. 2.12: Identical twins

Importance of Breast Feeding

1. Breast milk provides all the necessary nutrients in the proper proportion for growth and development of the baby.
2. Breast milk contains antibodies which help the baby to fight off infections.
3. Breast milk contains substances that cleans and activates the alimentary canal of infant to enable it to carry out digestion.
4. Breast milk contains a lot of calcium that enhances growth and development of strong bones and teeth.
5. Breast feeding acts as a birth control. Breast feeding delay the onset of menstruation for the mother hence delaying pregnancy. This is because breast feeding triggers the production of **oxytocin hormone** which inhibits thickening of endometrium.
6. It reduces infant mortality by ensuring that infant grows without any deficiency diseases.

Exclusive Breastfeeding and Bottle- Feeding

- Exclusive breastfeeding is a method of breast feeding whereby an infant receives only breast milk with no additional food or liquids not even water for six months.
- Bottle-feeding is a method of feeding a baby with milk (from a cow or formula) put in a bottle having a rubber teat from which the baby sucks. Formula is manufactured food designed and marked for feeding to infants under 12 months of age.

Advantages of Exclusive Breastfeeding over Bottle-Feeding

1. Breastfeeding is relatively cheap than bottle- feeding. Bottle-feeding is expensive since more money is spend on bottles, formula and rubber nipples.
2. Breast milk does not contain harmful bacteria. Bottle milk may contain harmful bacteria due to unhygienic handling of bottle and teat.
3. Breast milk increases resistance to infection since it contains antibodies, and therefore fewer incidents of illness and hospitalisation.
4. Breastfeeding reduces risk to **allergies**. Allergy is a condition in which the immune system reacts abnormally to foreign substances.
5. Baby experiences fewer stomach upsets and constipation. This is because breast milk is easily digested.
6. Breast feeding promotes mother- baby bonding.
7. Breastfed infants tend to have fewer cavities.

The Menstrual Cycle

- Menstruation is the shedding of uterine lining and blood through the vagina in females.
- Menstruation only takes when fertilization does not occur. These events are cyclic which means that the whole sequence repeats itself once in every month in what is called the **menstrual cycle**. In this cycle, the uterus is prepared for implantation.
- The average length of the menstrual cycle is 28 days. It can however be as short as 24 days or as long as 35 days. The first day of menstruation is regarded as the first day of menstrual cycle.

- The events of the cycle are controlled by the pituitary hormones and the hormones of the ovary.

The Roles of Hormones in Menstrual Cycle

1. **Follicle Stimulating Hormone (FSH)**
   - It is secreted by the pituitary gland.
   - It stimulates the development of the Graafian follicle in the ovary. The Graafian follicle contains an egg surrounded by follicle cells and a fluid space.
   - It also stimulates the ovary to secrete oestrogen.

2. **Luteinising Hormone (LH)**
   - It is secreted by the pituitary gland.
   - It causes ovulation. Ovulation is the process by which the Graafian follicle burst to release the mature ovum into the oviduct funnel.
   - It causes the formation of the corpus luteum, which secretes progesterone and some oestrogen.

3. **Oestrogen**
   - It is secreted by the Graafian follicle in the ovary.
   - It causes repair and growth of endometrium (uterine lining) after menstruation.
   - It stimulates the pituitary gland to secrete luteinising hormone.
   - A high concentration of oestrogen in blood inhibits FSH production.

4. **Progesterone**
   - It is secreted by the corpus luteum in the ovary and the placenta as from fourth month of pregnancy.
   - It inhibits the production of FSH and LH.
   - It keeps the uterine lining thick and well supplied with blood in readiness for implantation.

Completing the Menstrual Cycle

- If the egg is not fertilized, the corpus luteum lasts for about 10 to 12 days and then it degenerates because the level of oestrogen is low causing the corpus luteum to degenerate and the secretion of progesterone stops. The endometrium lining can longer be maintained so the capillaries break up and the endometrium is lost with some blood. The pituitary gland starts to secrete FSH again because the levels of progesterone is low. The pituitary gland is no longer inhibited to secrete FSH and the cycle repeat itself.
- If fertilization occurs, the zygote develops into the embryo which implants itself in the uterine lining. The embryo secretes a hormone which prevents the corpus luteum from degenerating so that corpus luteum continues to secrete progesterone until the placenta takes over the production of progesterone. This inhibits the production of follicle stimulating

hormone, so breaking the cycle until the baby is born. Then the menstrual cycle will start again.

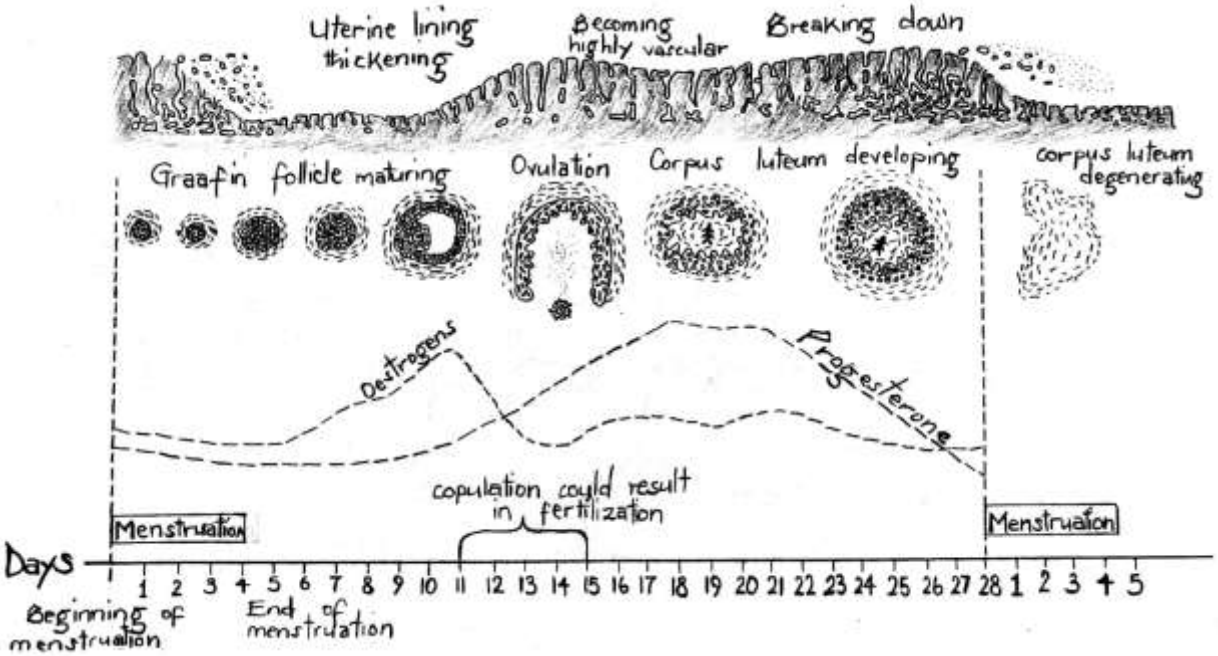


Fig. 2.13: Menstrual cycle

Contraception

- It refers to ways of preventing conception.
- It is also known as birth control or family planning.
- Contraception is important because it allows the mother to space the birth of children. This gives the mother enough time to regain her strength and energy and to take care of the new-born.

Methods of Contraception

1. **Coitus Interruptus**
   - The male withdraws the penis from the vagina just before ejaculation hence preventing fertilization.

   Advantages of Coitus Interruptus

   (i) It has no side effects

   Disadvantages of Coitus Interruptus

   (i) It is not reliable since some sperms may be deposited before withdrawal.

2. **The Rythm Method (Safe- Period Method)**
   - Sexual intercourse occurs in safe days hence preventing fertilization.
   - The woman using this method has to keep regular records of her menstrual cycle.
   - She may also need to record her daily body temperature for the whole cycle. Usually the body temperature is higher at the time of ovulation.

Advantages of Rythm Method

(i) It has no side effects.

Disadvantages of Rythm Method

(i) Depends on full co-operation of both partners.

(ii) It is not always easy to pinpoint ovulation so pregnancy can result.

3. Condoms (Sheath)

- These are made of thin rubber. In males they are put on the erect penis just before sexual intercourse. Female condoms have one closed and one open end and they fit into the vagina.
- Condoms prevents fertilization as sperms cannot enter the vagina.

Advantages of Condom

(i) It has no side effect.

(ii) It does not need medical advice.

(iii) It offers some protection against sexually transmitted diseases.

Disadvantages of Condom

(i) It can interrupt sexual intercourse

(ii) It may tear or get damaged during intercourse allowing semen to get through.

4. The Diaphragm

- The diaphragm is a dome-shaped rubber cap with an elastic rim.
- It is inserted into the top of vagina and placed over the cervix.
- The diaphragm prevents fertilization since sperms cannot pass into the uterus through the cervix.

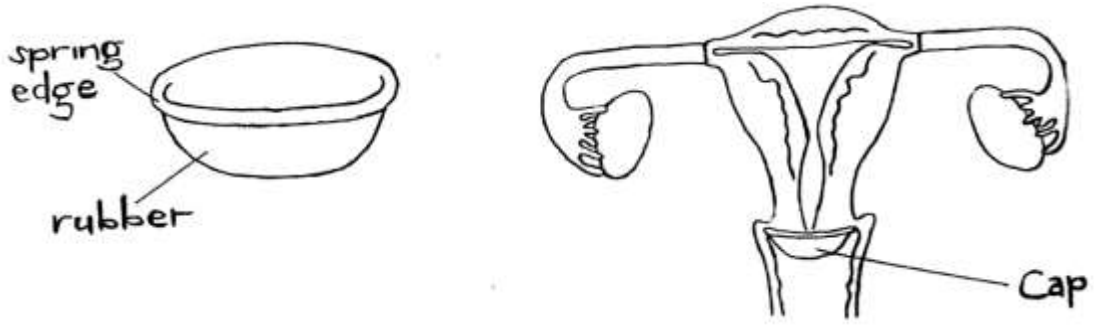


Fig. 3.14: Diaphragm

Advantages of Diaphragm

(i) It has no side effects.

(ii) It offers some protection against cervical cancer.

(iii) It is reliable if properly fitted.

Disadvantages of Diaphragm

(i) It must be initially fitted by doctor.

(ii) It may be incorrectly positioned or damaged and allow sperm pass.

(iii) Gives better protection when combined with spermicide.

5. The Intra-Uterine Device (IUD)

- It prevents implantation of embryo by creating a barrier.
- An intra- uterine device is made up of plastic and metal, which is inserted into the uterus by a doctor and remains there all the time.

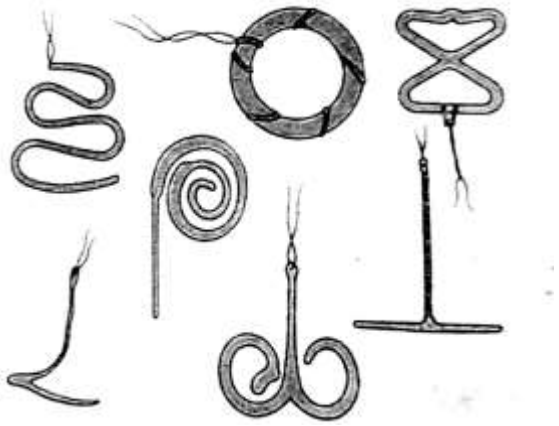


Fig. 2.15: Intra-uterine devices

Advantages of Intra- Uterine Device

(i) Once inserted, no further steps need to be taken.
(ii) Relatively effective at preventing implantation.

Disadvantages of Intra- Uterine Device

(i) Can cause pain and heavy periods.
(ii) Can cause uterine infections which may lead to infertility.

6. Spermicides

- These are chemicals which prevent fertilization by killing sperms.
- Spermicides are placed high into the vagina before intercourse.
- Spermicides may be in form of cream, jelly or tablets.

Advantages of Spermicides

(i) Readily available

Disadvantages of Spermicides

(i) When used alone they are unreliable at preventing pregnancy.

7. Contraceptive Pills

- It prevents occurrence of ovulation by inhibiting the production of L.H. and F.S.H.
- They contain oestrogen and progesterone.

Advantages of Contraceptive Pills

(i) The pills are taken at regular interval and so does not interfere with intercourse.
(ii) Almost 100% reliable if used according to instructions

Disadvantages of Contraceptive Pills

- It has side effects such as weight gain, nausea, increased risk of blood clotting and headaches.

8. Norplant

- This is the placement of contraceptive pills just beneath the skin on the upper side of the arm of the woman.
- The contraceptive remain under the skin for five years, releasing progesterone into the blood which prevent fertilization by preventing ovulation.

9. Vasectomy (Male Sterilzation)

- This involves the cutting of vas deferentia in males.
- Vasectomy prevents fertilization as sperms from testis cannot pass to vagina.

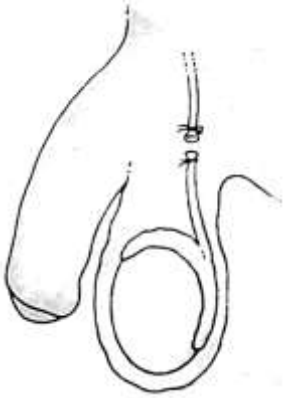


Fig. 2.16: Vasectomy

Advantages of Vasectomy

- It 100% reliable at preventing pregnancy.

Disadvantages of Vasectomy

(i) It does not protect against sexually transmitted diseases.
(ii) It is not easily reversible

10. Tubal Ligation (Female Sterilization)

- This involves the cutting of the oviduct in females.
- It prevents fertilization as sperms cannot reach the egg.

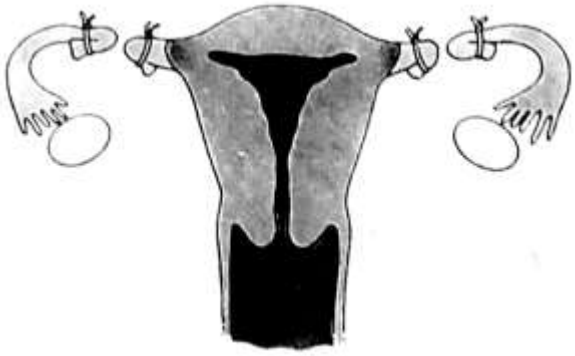


Fig. 2.17: Tubal ligation

Advantages of Tubal Ligation

- It 100% reliable at preventing pregnancy.

Disadvantages of Tubal Ligation

(i) It does not protect against sexually transmitted diseases.
(ii) It is not easily reversible

11. Continuous Breastfeeding

- It prevents ovulation.

12. Depoprovera (Injection) Method

- It prevents ovulation

13. Abstinence from Sex

- It prevents fertilization.

Abnormal Conditions Associated with Reproduction

1. Sterility

- This is the inability of an individual to reproduce.
- The problem may be inherited or may develop due to external factors. It may involve the following:
  a. Poorly developed reproductive organs
  b. Failure of reproductive organs to produce gametes.

2. Sexual Transmitted Infections (STI's)

- Sexual transmitted infections are diseases that are transmitted through sexual contact. They are also called **venereal diseases**. Common examples of venereal diseases include:
  (i) Gonorrhoea
  (ii) Syphilis
  (iii) AIDS
  (iv) Chancroid

3. Maternal Deaths

- It refers to all deaths of women that are related to child bearing.
- The death occur either during period of pregnancy or at the time of giving birth.
- The major causes of maternal death include:
  (i) Excessive bleeding during birth
  (ii) Infections during pregnancy especially by malaria
  (iii) High blood pressure during pregnancy
  (iv) Unsafe abortion
  (v) Complications during birth
  (vi) Complications brought about by HIV and AIDS infections
  (vii) Low nutritional status of the mother, resulting in weak body.

Prevention

(i) All pregnant mother should seek prenatal care in health centres as soon as they discover that they are pregnant
(ii) Avoid giving birth at home where qualified medical personnel are not available.

(iii) Proper diet during pregnancy
(iv) HIV positive mothers should seek help from health facilities during their pregnancy to enhance their safety and their babies during birth.

4. Anaemia

- It is a deficiency in the number of red blood cells or haemoglobin in the blood.
- It is common in female due to blood loss through menstruation and childbirth.

5. Cervical Cancer

- It is cancer which develop in the cervix.
- The cause of cervical cancer is Human Papilloma Virus (HPV)

Common Symptoms

(i) Bleeding in between the periods
(ii) Bleeding after sexual intercourse
(iii) Pelvic pain

Treatment

- Treatment for cervical cancer include radiotherapy, chemotherapy and surgery

6. Fistula

- A fistula is an abnormal hole or passage that is formed between two passages in the body.
- A fistula that is formed in the wall of vagina is called vaginal fistula. It can be formed between the vagina and the rectum or the vagina and the bladder during prolonged obstructed labour. After five to six days of labour and pushing of a baby that does not fit into the birth canal, an injury occurs. The labour produces contractions that push the baby's head against the mother's pelvic bone. The soft tissues between the baby's head and pelvic bones are compressed and do not receive adequate blood and this causes the delicate tissue to die. When formed between the vagina and rectum or the vagina and the bladder, the hole lets urine and faeces pass into the vagina in a way that cannot be controlled leading to a situation called incontinence.
- It is treated or repaired through surgical means.

7. Abnormal Menses

- Menses can be considered abnormal if they occur at wrong time and if the amount of flow is in appropriate for example:
  (i) If they occur less than two weeks from day one of the period to day one of the following period.
  (ii) If the person misses three or more periods
  (iii) Very heavy flow that last longer than 7 days
  (iv) Very light flow bleeding in between periods also known as spotting
  (v) If a girl is over the age of sixteen and has not had a period yet
  (vi) The period stops completely
  (vii) Infrequent periods, very painful periods and severe menstrual cramps.

- Co-ordination refers to the linking together of various processes in the body of an organism.
- Co-ordination is brought about by the **nervous system** and **endocrine system**.

The Nervous System

- The nervous system has two main parts:
  1. The ce**ntral nervous system** – it made up of the brain and the spinal cord.
  2. The **peripheral nervous system**- all the rest of the nervous system makes the peripheral nervous system. This includes the receptors, effectors and nerves.

Receptors

- These are structures that contain sensory cells that receive stimuli from internal and external environment and convert them into nerve impulses.
- Examples of receptors include sense organs such as the eye, the skin, the ear, the nose and the tongue.

Effectors

- These are structures that respond to a stimulus.
- They include muscles and glands.

Nerve Impulses

- These are electrical signals that are transmitted along the neurones of the nervous system and which cause a response.

Response

- It is the end-action e.g. muscle contracting to cause the movement of the arm.

The Neurones (Nerve Cells)

- These are the basic unit that make up the nervous system.
- Each neurone consist of:

1. **The Cell Body**
   - The cell body is where signals are received, processed and transmitted via the dendrites and axon.
   - It contain the nucleus, mitochondria and ribosomes.
   - It controls all cell function.

2. **Axon**
   - It transmits impulses away from the cell body.

3. **Dendrites**
   - Dendrites transmit impulses towards the cell body.
   - In sensory neurone the single, elongated dendrite is called a **dendron**.

4. Myelin Sheath

- Myelin sheath is a fatty layer that encloses many nerve fibres.
- The myelin sheath has the following functions:
  (i) It protects the nerve fibre from damage.
  (ii) It increases the rate of transmission of nerve impulses.
  (iii) It provides electrical insulation of the nerve fibre.

5. Node of Ranvier

- The myelin sheath has gaps at regular intervals known as **nodes of Ranvier**.
- The nodes of Ranvier increases the rate of transmission of impulses by forcing them to jump from one node of Ranvier to the next.
- The nodes of Ranvier also allows the nutrients and waste products to enter or leave the neurone.
- The node of Ranvier also allow nerve impulses to move along the neurone through the process called depolarisation and re- polarisation of the nerve membrane.

6. Schwan Cells

- These are special cells that are attached to the myelin sheath.
- Schwan cells manufacture myelin sheath around the axon.

Types of Neurones

- There are three types of neurones based on their functions:
  1. Sensory neurone
  2. Motor neurone
  3. Relay neurone

1. Sensory Neurone

- These are neurones that transmit impulses from sense organs to the central nervous system.
- They have one dendron which is longer than the axon.
- The cell body is along their length.

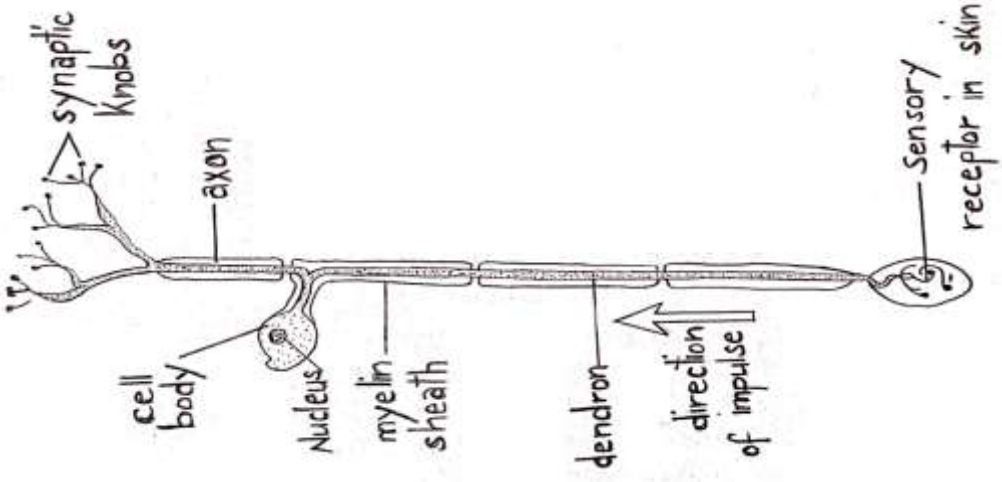


Fig. 5.1: Sensory neurone

2. Motor Neurone

- These are neurones that transmit impulses from the central nervous system to the effectors.
- They have long axon.

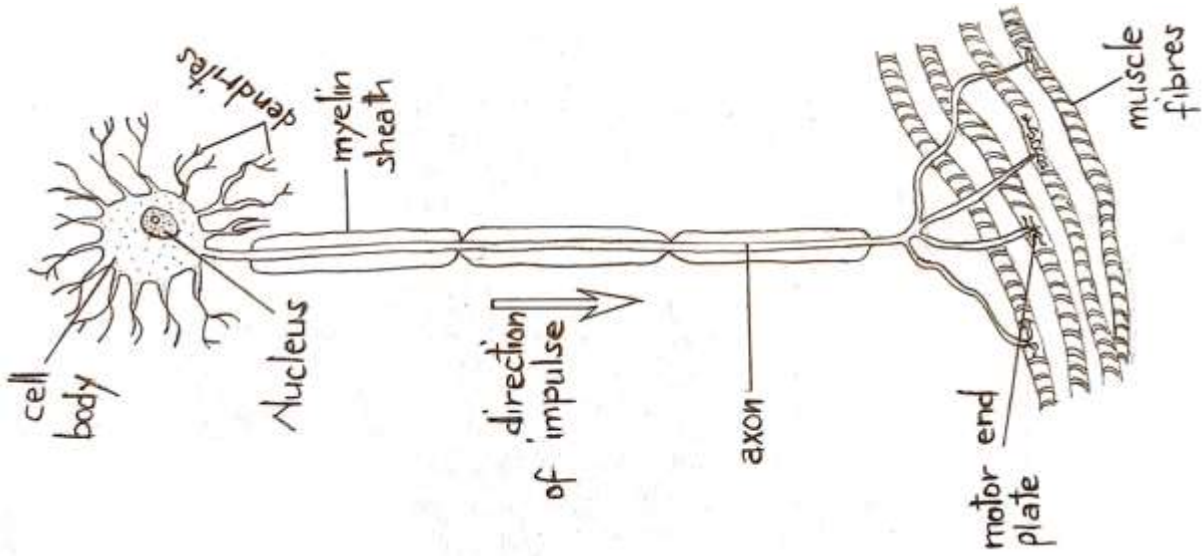


Fig. 5.2: Motor neurone

3. Relay (Intermediate) Neurone

- These are neurones that transmit impulses from a sensory neurone to a motor neurone.
- They are located in the brain and spinal cord.
- They have relatively short axons.

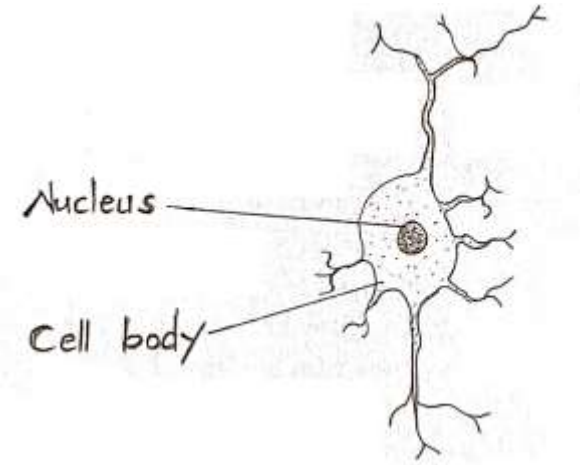


Fig. 5.3:Relay neurone

Transmission of Nerve Impulses

- Neurones transmit impulses from receptors to the central nervous system and from the central nervous system to the effectors to bring about a response.
- When a neurone is not transmitting an impulse, it is said to be in a **resting potential**. At this time, the potential difference is maintained between the inside and outside of the nerve cell. The inside of the nerve cell is negatively charged and the outside is positively. The neurone at this stage is said to be **polarised**.

- When a neurone is transmitting an impulse, the situation is reversed, the inside of the neurone become positive and the outside negative. This sudden reversal of resting potential which accompanies the impulse is called **action potential** and involves the **depolarization**. A change in the charges on one part disturbs the next part of the axon causing the disturbance to move along the axon. This transmits the impulse from one end to the other.
- After an impulse is transmitted, the neurone become **repolarised** by returning back to resting potential.

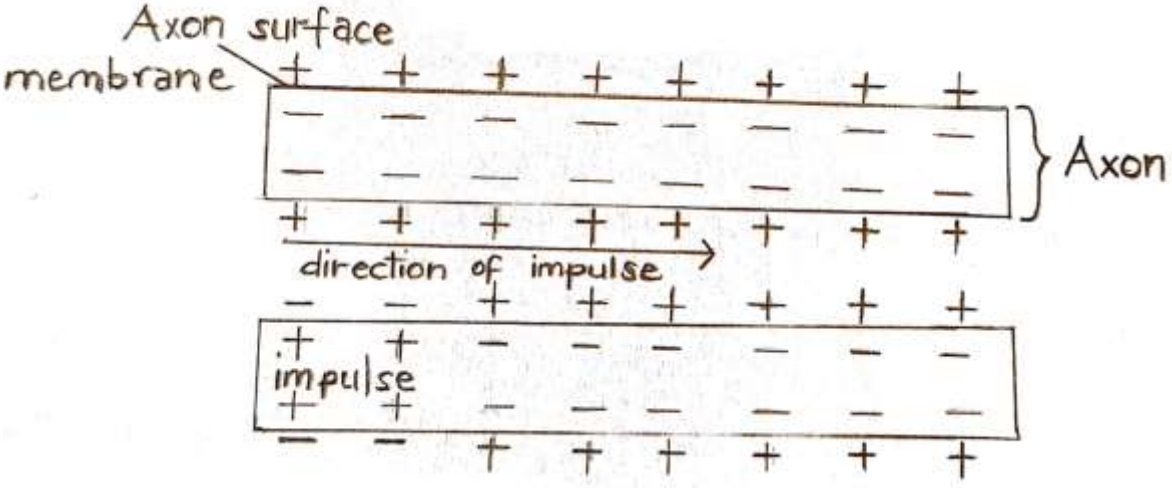


Fig. 5.4: Transmission of nerve impulse

The Synapse

- A synapse is a junction between two neurones.
- A synapse is composed of dendrites of cell body of one neurone and synaptic knobs of axon of another neurone.

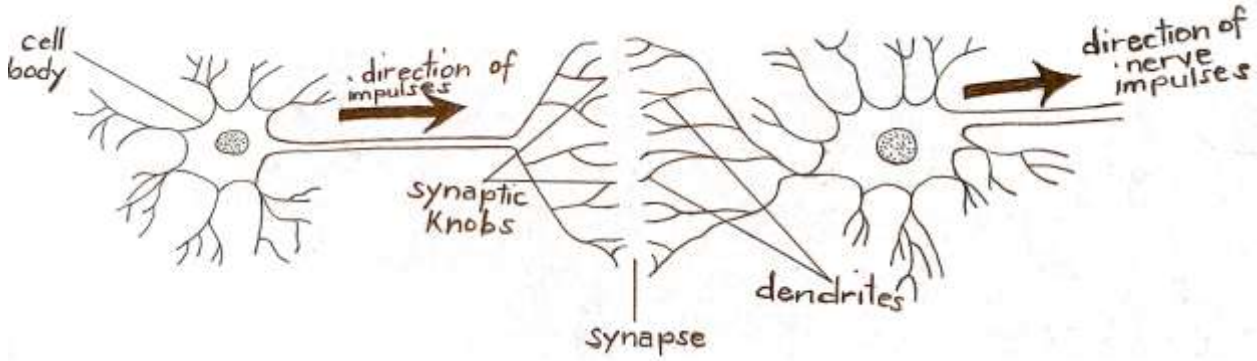


Fig. 55: A synapse

Mechanism of Impulse Transmission across a Synapse

- The cytoplasm of sypnatic knob contains numerous mitochondria, for production of energy and synaptic vesicles. These vesicles contain chemicals called neurotransmitters. An example of neurotransmitter is **acetylchlorine**.
- The arrival of nerve impulses in the synaptic knobs results in release of neurotransmitters. The released neurotransmitter will pass through the synapse and bind to dendrite of another neurone and cause the formation of the same impulse.

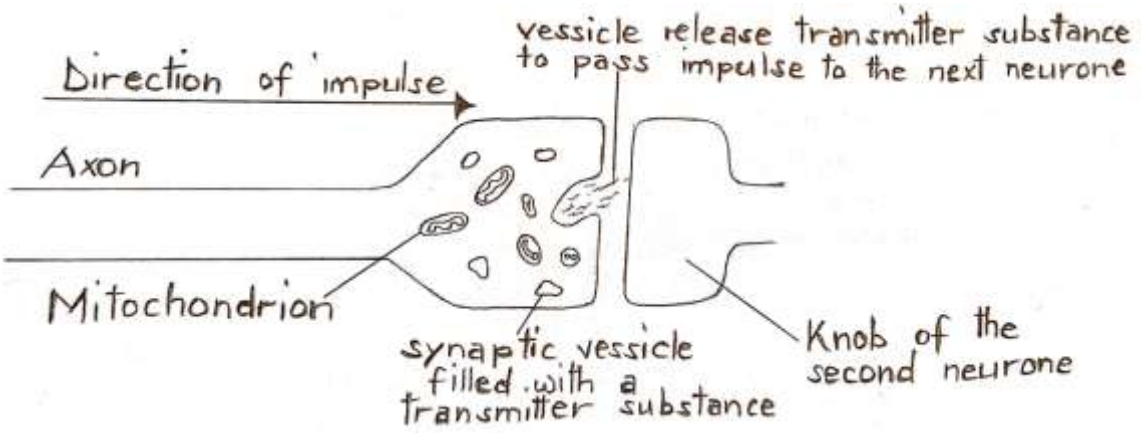


Fig. 5.6: Transmission of nerve impulse across a synapse

Functions of Synapses

1. It ensures that nervous impulses only travel in one direction. This so because neurotransmitter are only on one side of the gap.
2. It prevents weak impulses resulting from weak stimuli from passing to the next neurone.

Nerves

- Nerve cell fibres run together in bundles. These bundles are called **nerves**.

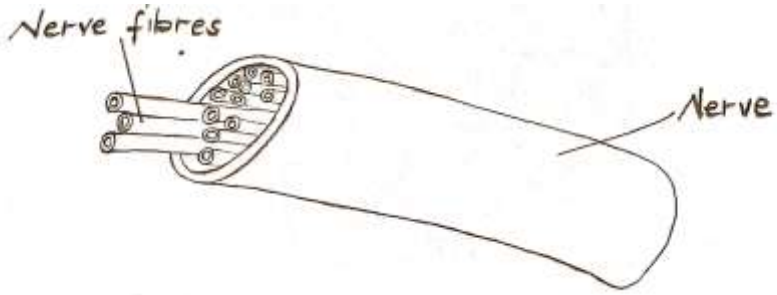


Fig. 5.7: Diagram to show nerve fibres grouped into a nerve

The Central Nervous System

- The nervous tissue of the central nervous system consists of two distinct regions:
  1. The grey matter
  2. The white matter

1. The Grey Matter

- The grey matter consists of mainly of the cell bodies of neurones which gives this area a greyish appearance.
- It forms the outer layers of the brain and the central portion of the spinal cord.

2. The White Matter

- The white matter consists mainly of nerve fibres.
- It forms the central part of the brain and outer layers of the spinal cord.

The Human Brain

- The brain is a very delicate organ consisting of millions of nerve cells.
- It is located inside the skull cavity. The skull protects the brain from external physical forces.

- The human brain is divided into two **hemispheres** i.e. the right hemisphere and the left hemisphere. The two hemispheres are interconnected by a group of nerves called **corpus callosum**. The right hemisphere controls activities of the left side of the body while the left hemisphere controls activities of the right side of the body.
- The outermost part of the brain is called **grey matter**. Beneath the grey matter is an inner larger part known as white matter.
- Two membranes known as **meninges** cover the brain. The outer membrane is tough and delicate and is known as the **dura matter**. This membrane protects the brain from mechanical damage. The inner membrane is known as **pia matter**. It is composed of blood capillaries and lymph vessels.
- Between the dura matter and pia matter is a space known as **arachnoid**. The arachnoid consists of connective tissue, blood vessels, and a fluid known as **cerebrospinal fluid**.
- Cerebrospinal fluid has the following functions:
  1. It distribute oxygen and nutrients to nerve tissues.
  2. It protects the brain against mechanical shock because of its cushioning effect.
  3. The fluid contains lymphocytes, which protects the brain against infections.
- The two hemispheres of the brain are organised into a number of parts, which include cerebrum, cerebellum, medulla oblongata, hypothalamus, thalamus, pons and pituitary gland as shown in **figure 5.8** below.

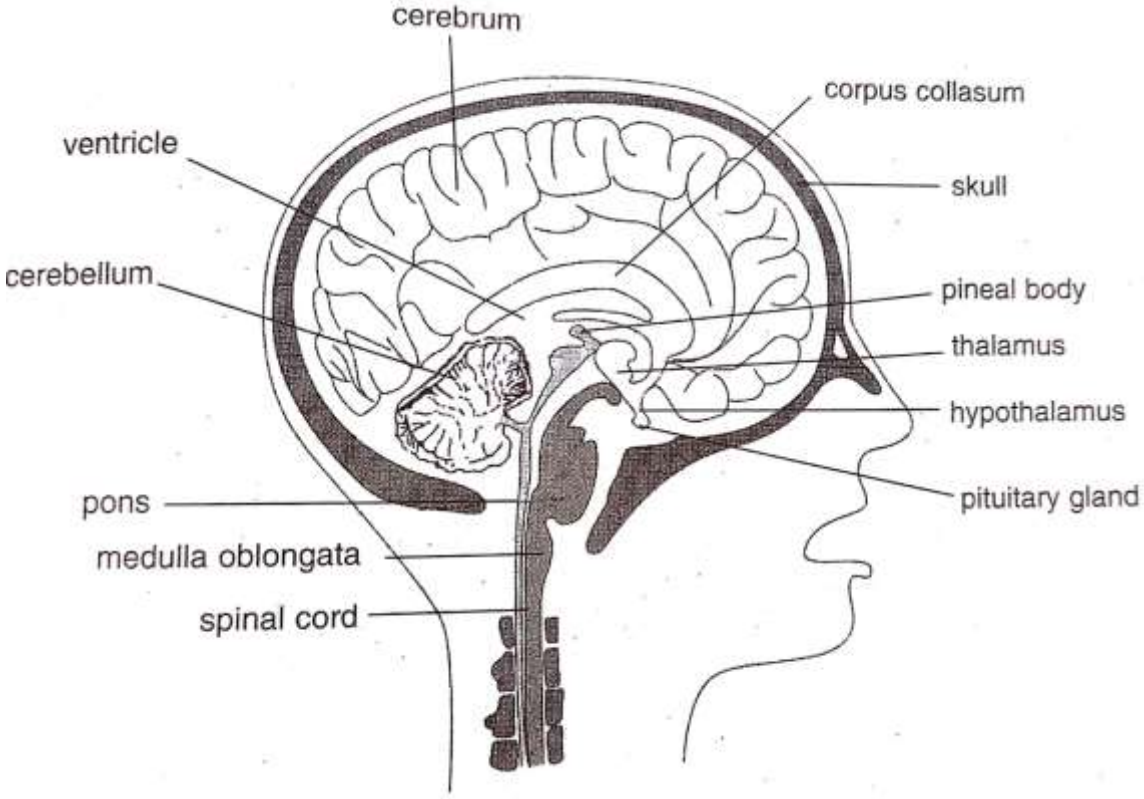


Fig. 5.8: Section through head to show brain

Functions of the Major Parts of the Brain

1. **Cerebrum**
   - This is the largest part of the human brain.

- It is made up of two halves called right cerebral hemisphere and left cerebral hemisphere.
- The cerebrum has an outer thin grey layer called **cerebral cortex**. The surface of cerebral cortex is highly folded, thereby increasing its surface area and hence a higher number of neurones.

Functions of the Cerebrum

a. It stores information as memory.
b. It receives and identifies sensory impulses from the sense organs. Its sensory area interprets these into vision, smell, taste, hearing or touch.
c. It is involved in voluntary control of body movements such as walking, dancing and jumping.
d. It is responsible for personality or character of a person.
e. It is responsible for emotions such as joy and sorrow.
f. It is the intelligence centre.
g. It is the thinking centre.
h. It is involved in learning, imagination and creativity.

2. Cerebellum

- It is situated at the back of the brain.
- Like the cerebrum, it consists of two halves called hemispheres.
- It is smaller in smaller in size than the cerebrum.
- It has folds on its outer layer that increase surface area and hence a higher number of neurones.

Functions of Cerebellum

a. It maintains body balance and posture.
b. It co-ordinates body movements.

3. Medulla Oblongata

- It is located beneath the cerebellum.
- It links the spinal cord to the rest of the brain.

Functions of the Medulla Oblongata

a. It regulates the heart rate.
b. It regulates blood pressure.
c. It controls constriction and dilation of blood vessels.
d. It controls the rate of breathing
e. It controls salivation, which is the secretion of saliva in the mouth.
f. It controls coughing, swallowing and vomiting.

4. Hypothalamus

- It controls secretion of hormones by the pituitary gland and so it is involved in **homeostatis** processes.

- Homeostatis is the maintenance of a constant internal environment.
- Hypothalamus is involved in temperature regulation.
- Hypothalamus also controls hunger, thirst, sleep and wakefulness.

5. **Pituitary Gland**
   - It is the main endocrine gland in the body. It work in close association with the hypothalamus.
   - It produces hormones that control the production of hormones in other endocrine glands. For this reason it is called **master gland**.

Other Parts of the Brain and their Functions

- **Pons-** works together with medulla oblongata to bring about involuntary activities.
- **Thalamus-** relay sensory information to other parts of the brain.
- **Corpus Callosum-** it is composed of axons that connect the left and right hemispheres.

The Spinal Cord

- The spinal cord is a cylindrical mass of nervous tissue extending from medulla oblongata to the end of vertebral column.
- The spinal cord is situated inside the neural canal that occurs at the centre of vertebrae.
- The spinal cord is also covered by meninges that protect it against mechanical damage.
- The spinal cord is made of the following parts:
  (i) A hallow centre called **central canal** or **spinal canal**.
    - The spinal canal contains cerebrospinal fluid which supplies food nutrients and ions to the spinal cord.
    - Cerebrospinal fluid also helps to remove waste materials from the spinal cord.

  (ii) The **grey matter**- is a region composed of nerve cell bodies.

  (iii) The **white matter**- is a region composed of nerve fibres.

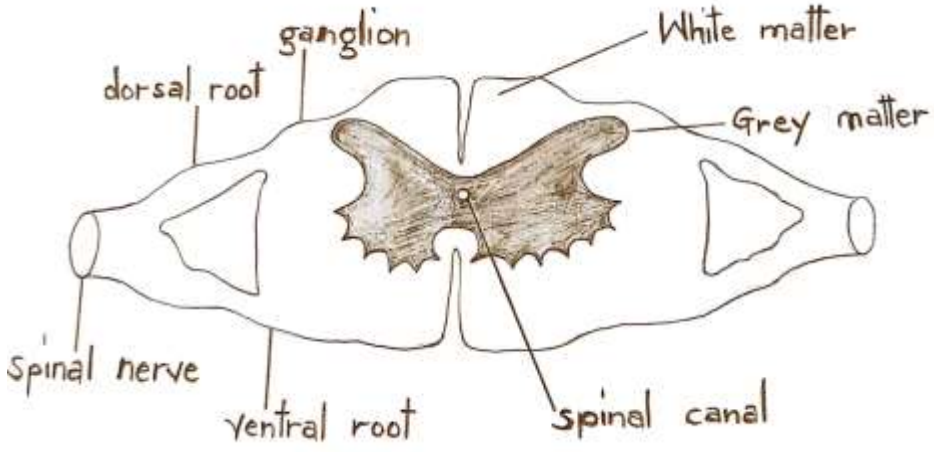


Fig. 5.9: A cross-section of spinal cord

- The dorsal root contains only sensory neurones. The cell bodies of these neurones aggregate in a small swelling known as **ganglion**. Their axons end in the grey matter of the spinal cord while their dendrons become the sensory fibres in the dorsal root and spinal nerve.
- The ventral root contains only **motor neurones**. The cell bodies of motor neurones lie in the spinal cord while their axons leave the spinal cord to enter the ventral root and spinal nerve.

- The dorsal root and ventral root unite outside the spinal cord to form spinal nerve.

Functions of the Spinal Cord

(i) It controls spinal reflex actions.
(ii) It links the nerves of the peripheral nervous system with the brain.

Reflex Action

- It is a rapid and automatic response to a stimulus.

Reflex Arc

- It is a pathway along which impulses travel during a reflex action.
- Reflex arc consist of;
  (i) The **receptor** that receive the stimulus and convert it into nerve impulse.
  (ii) The **sensory neurone** that transmit the impulses from the receptor to central nervous system.
  (iii) An **association neurone** or **relay neurone** which carries impulses from sensory neurone to the motor neurone.
  (iv) A **motor neurone** which carries impulses from the central nervous system to the effectors.
  (v) The **effectors** which gives a response to stimulus.

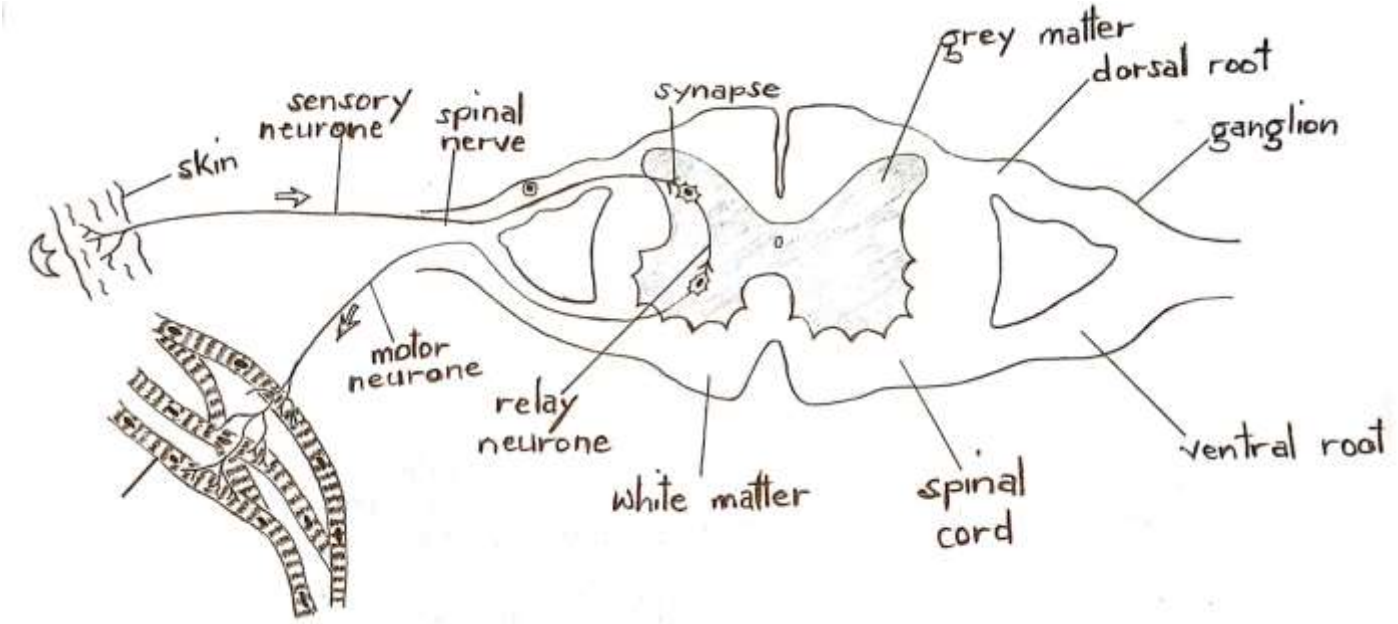


Fig. 5.10: A simple reflex arc

Types of Reflex Actions

- There are two types of reflex actions:
  1. The simple reflex action and
  2. The conditioned reflex action.

1. The Spinal Reflex Action

- Simple reflex actions are inborn and cannot be controlled by will power.

- Simple reflex actions are protective in nature since they help to prevent damage to the body organs.
- Simple reflex actions can be classified as:
  (i) Cranial reflexes and
  (ii) Spinal reflexes

(i) Cranial Reflexes

- Cranial reflexes are controlled by the brain and usually occur in the head region.
- Examples of cranial reflexes include salivation, coughing, blinking of the eye and contraction of the pupil of the eye.

(ii) Spinal Reflexes

- Spinal reflexes are controlled by the spinal cord.
- Examples of spinal reflexes include knee jerk, withdrawing a hand from a sharp object.

2. The Conditioned Reflex Action

- Conditioned reflexes are learned reflexes in which the final response has no natural relationship to the stimulus.
- These reflexes are coordinated by the brain.
- Learning forms the basis of conditioned reflexes.

Palvov Experiment

- He designed an experiment using weaned dogs.
- He wanted to find out if these dogs could salivate in the absence of food.
- The experiment was done in three steps:
  (i) He presented food to the dogs. He observed that the dogs salivated.
  (ii) He presented food to the dogs while ringing the bell. He observed that the dogs salivated.
  (iii) He rang the bell alone in the vicinity of the dogs. The same response was observed.

Steps in Conditioning an Organism

- There are three main steps involved in conditioning an organism:
  (i) The original stimulus is presented; the related response is made.
  (ii) The substitute stimulus is presented together with the original stimulus and the same response is made.
  (iii) The substitute stimulus is now presented alone; the same response is made.

Significance of Reflex Actions

1. They enable the body to adjust to changes in its environment. In this way the body responds to ensure that the changes in external environment do not bring harm.
2. They protect the body against mechanical injuries such as cuts and burns.
3. Some animals use reflex actions to catch prey and obtain food.
4. In humans, reflex actions are used in learning skills such as sewing, dancing and swimming.

Effects of Alcohol on the Central Nervous System

1. It slows down the activity of the brain hence leading to poor memory, poor coordination of muscles and poor judgement.
2. It slows down the transmission of impulses, which slows down the speed at which a person reacts to a stimulus.
3. Alcohol interferes with body balance resulting to convulsions and unconsciousness.
4. It increases the feeling of aggression resulting to increased violence.

Effects of Indian Hemp on the Central Nervous System

1. It contains chemicals that damage cells in the memory centre of the brain hence leading to poor memory.
2. It interferes with transmission of impulses from one neurone to another. This distorts the response process.
3. It damages the brain cells that control emotions. This results to distorted emotional reactions by an individual.
4. In high doses, it leads to total breakdown of mental co-ordination. This leads to total loss of efficient co-ordination leading to madness.

Abnormal Conditions of the Nervous System

1. Poliomyelitis (Polio)

- It is caused by a virus which multiplies in the spinal cord.
- The virus damages axons of motor neurones to the legs, arms hence no response of these organs. As a result, the muscles become weak, paralysed and small hence there is poor development of bones since there is no muscular stress on the bones.
- It is transmitted through contaminated food, water and droplet infection containing polio virus.
- Vaccination can be used in infants to avoid the risk of contracting the virus.

2. Tetanus (Lockjaw)

- Tetanus is a disease caused by a bacterium called *Clostridium tetani*. The bacterium is present in the soil. It enters the body through cuts.
- The bacteria produce chemicals that interfere with nervous transmission hence result in permanent contraction of muscles.
- Injections of antitoxins and muscle relaxing drugs help to cure tetanus. Use of antibiotics also helps to cure tetanus.

3. Stroke

- Stroke is brain damage caused by lack of blood flow to any part of the brain.
- It occurs when blood flow to a part of brain is interrupted because of blockage of an artery in the brain leading to a blood clot. If blood flow is stopped for more than several seconds, the brain cannot get food nutrients and oxygen as a result the brain cells starve to death.
- Symptoms of stroke include:
  (i) Difficulty walking
  (ii) Inability to see

(iii) Paralysis in one arm or one leg
(iv) Inability to speak
(v) Severe headaches

- It is usually enhanced by:
  (i) Old age
  (ii) Hypertension
  (iii) Diabetes
  (iv) Smoking
  (v) Alcoholism
  (vi) Injuries on the head
- Stroke can be managed by prompt medical attention to remove the clot.

4. Meningitis

- Meningitis is a disease caused mostly by a virus that attacks the meninges and in some cases bacteria and fungi. The meninges covering the brain swell, which can cause damage to nerves or brain itself.
- Signs and symptoms include:
  (i) Headache
  (ii) Neck stiffness
  (iii) Fever
  (iv) Convulsions
  (v) Vomiting
  (vi) Intolerance to bright light and loud sound
- Meningitis can lead to serious problems such as deafness, epilepsy and even death.
- Meningitis can be controlled by:
  (i) Prompt treatment
  (ii) Vaccination against viral diseases

5. Leprosy

- It is caused by a bacterium called *Mycobacterium leprae*.
- The infection attacks the skin and sensory neurones so that the sensation is lost in some parts of the skin.
- It causes permanent damage to the skin, nerves, limbs and eyes.
- Use of antibiotics helps to cure leprosy.

The Endocrine System

- The endocrine system produces hormones that work together with the nervous system to bring about co-ordination.
- Hormones are chemical substances produced in one part of the body and which bring about responses in another part of the body.
- Hormones are produced by **endocrine glands**. Endocrine glands are ductless. This means that they have no tube or duct to carry away the hormones they secrete. The hormones are released directly into the bloodstream.
- Once a hormone enters the bloodstream it is carried around the system and will reach the target organ.

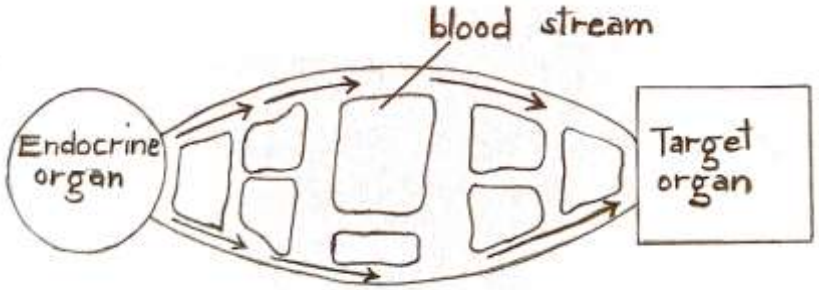


Fig. 5.11: The pathway followed by a hormone

Position of Endocrine Glands in Human Body

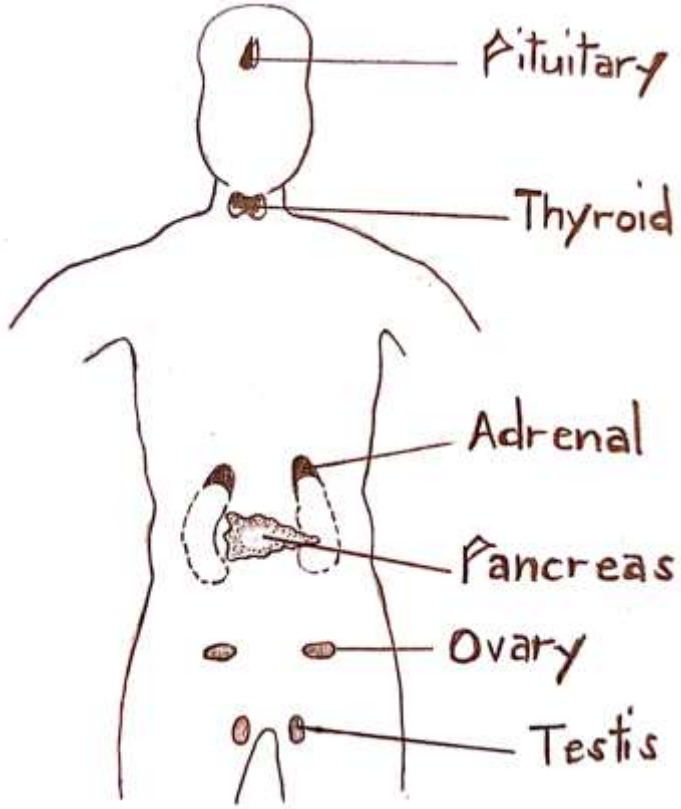


Fig. 5.12: Position of endocrine glands in the body

The Pituitary Gland

- The pituitary gland is also called '**master gland**' because some of the hormones it secretes controls the function of other endocrine glands.

Hormones of Pituitary Gland and their Functions

1. **Growth Hormone**
   - It stimulates growth of cartilage, bone and muscle tissue.
   - It also stimulates deposition of minerals, for example calcium in bone tissue.
   - Too much production results into **giantism** and too little production results into **dwarfism**.

2. **Follicle Stimulating Hormone**
   - It controls the formation of sperms in males.
   - In females, it stimulates the growth of Graafian follicles and secretion of oestrogen.

3. **Lutenising Hormone**
   - It stimulates testes to produce testosterone.
   - In female, it causes ovulation and development of corpus luteum.

4. **Anti-Diuretic Hormone (ADH)**
   - It stimulates the walls of the nephron tubule to be more permeable to water so that more water is reabsorbed from glomerular filtrate back to the blood. This restore blood water back to normal.

5. **Thyrotrophin (Thyroid Stimulating Hormone)**
   - It stimulates thyroid gland to secrete thyroxine.

6. **Prolactin**
   - It stimulates milk production in lactating mammals.

7. **Oxytocin**
   - It brings about contraction of the uterus at birth.
   - It causes expulsion of milk from mammary glands.

Ovaries

- Ovaries produce **oestrogen** and **progesterone**.

1. **Oestrogen**
   - It promote development of reproductive organs.
   - It promotes development of female secondary sexual characteristics (e.g. soft voice, breast development and rounding of the pelvis)
   - It stimulates the pituitary gland to secrete luteinising hormone.
   - It causes the lining of uterus to get thick and spongy.

2. **Progesterone**
   - It maintains lining of uterus thereby maintaining pregnancy.

Testes

- It is found in males.
- It produces **testosterone**
- Testosterone is responsible for:
  1. Sperm production
  2. Development of male secondary sexual characteristics such as:
     (i) Deep voice
     (ii) Appearance of hairs in pubic region and armpits
     (iii) Enlargement of penis

Thyroid Gland

- It produces a hormone called **thyroxine**
- Thyroxine is released by thyroid glands upon stimulation by another hormone known as **thyroid stimulating hormone (TSH)**.

Role of Thyroxine

- It controls the rate of chemical reactions in the cells (metabolism)
- It increases the effect of growth hormone, ensuring normal growth and mental development.

Pancreas- Islets of Langerhans

- The pancreas produces **insulin** and **glucagon**. Insulin and glucagon are produced in certain specialised cells called **Islets of Langerhans**.

Insulin

- It works in the liver
- Insulin decreases glucose concentration in the blood. Insulin stimulates the liver to convert glucose into glycogen when the level of glucose in the blood is high.
- Insulin also increases use of glucose to eliminate excess glucose in the blood.

Deficiency of Insulin

- If the pancreas produces insufficient insulin, an individual suffers from a disease called **diabetes mellitus** or **sugar disease**.

Diabetes Mellitus

- This is a disease in which an individual passes out sugar in his urine. This may result from failure of the islets of langerhans to produce insulin or produces inadequate amounts. This may be due to hereditary reasons or diseases affecting the islets of Langerhans.
- A person with diabetes mellitus has an abnormally high level of glucose in the blood.
- Patient of diabetes mellitus need regular injection of insulin in order to control blood glucose level so that they live a normal life.

Symptoms of Diabetes Mellitus

(i) Passing out urine frequently
(ii) Constantly feeling thirsty
(iii) Dehydration
(iv) Loss of weight
(v) Poor resistance to infection

Glucagon

- It work in the liver.
- It increases concentration of glucose in the blood. It stimulates the liver to convert glycogen into glucose when the level of glucose in blood is low.

Adrenal Glands

- Adrenal glands produce a hormone called **adrenaline**.
- Adrenaline is secreted as a response to such stimuli as fear, danger, anxiety, excitement or anger. In such situations, the brain generates nerve impulses that are transmitted through motor neurone to the adrenal gland which responds by secreting the hormone adrenaline into the bloodstream.
- Adrenaline is also described as the fight or flight hormone because it prepares the body for an action in case of emergency.
- Adrenaline stimulates high rate of respiration to produce more energy.

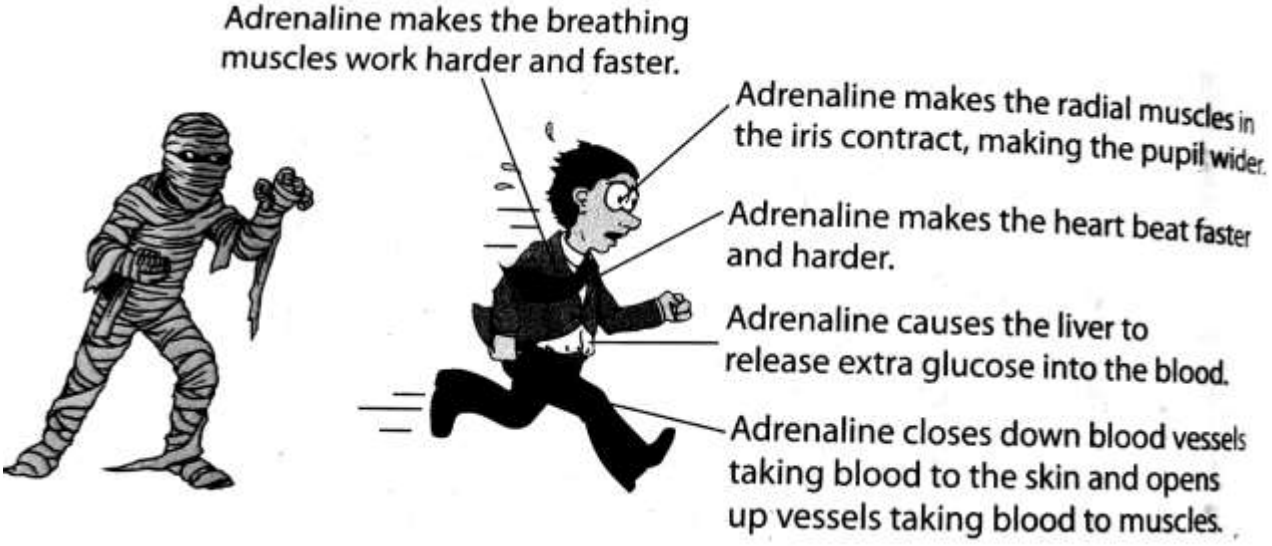


Fig. 5.13: The effects of adrenaline on its target organs

Similarities between Endocrine and Nervous Systems

1. Both stimulate response to specific stimuli
2. Both are involved in co-ordination of body activities.
3. Both stimulate responses that have survival value to specific stimuli.

Differences between Nervous and Endocrine Systems

Nervous System	**Endocrine System**
1. Responses are usually fast	Responses are usually slow
2. Impulses are transmitted through nerve fibres.	Hormones are transmitted through the blood
3. Nerve impulses are transmitted through nerve cells connected to specific parts of the body	Hormones reach all parts of the body
4. Impulses are short- lived and as a result, their effects last for a short time	Hormones stay longer in the blood and as a result their effects lasts longer
5. Uses electrical charges to relay impulses	Uses chemical substances (hormones) to relay impulses
6. Mostly involved in muscle contractions and stimulation of hormone secretion	Mostly involved in growth responses and some muscle activity

- Genetics is the study of heredity and variations in organisms.

Heredity

- Heredity is the process in which inheritable characteristics are transferred from parents to offsprings.
- These inheritable characteristics are also called **traits**.

Examples of Inheritable Characteristics

- These characteristics include:
  1. Skin colour
  2. Body size
  3. Finger length
  4. Tongue rolling
  5. Blood groups

Variations

- Variations refer to the observable differences among organisms.
- The organisms can be either members of one species or members of different species.
- Observable differences among organisms of one species are called **intraspecific variations**. Examples of intraspecific variations include height, skin colour, mass, blood groups, shape of face, knowledge and skill in human beings.
- Observable differences among organisms of different species are called **interspecific variations**, e.g. difference in shape of ears between a human being and a dog.

Causes of Variation amongst Organisms of the same Species

- Variation among organisms of one species is caused by:

1. **Environment**
   - This includes diet, climate and accident.
   - Environment may either enhance or suppress the expression of a gene. The environment in which an organism lives determine how much it will grow and how characteristics in it will develop. For example, a maize plant that is tall in nature will only grow to its fullest height if all factors necessary for growth are available. Absence or reduced quantities of some factors may end up making the plant to be dwarf. The environment therefore brings about variation in characteristics.
   - Skin colour, intelligence, stem length and height are examples of variations that are determined by the environment.

2. **Age**
   - Characteristics are known to develop with age.
   - Differences in age results to differences in the development of characteristics such as weight and height in offsprings produced from the same parent. This brings about

variations. For example, two individuals born by same parents will vary in weight of their bodies due to age even though they are brought up in the same environment.

3. Heredity

- There are variations that are inherited by organisms from their parents. These are called **genetic variations**. Height, nose shape and face shape are all examples of genetic variations.

Causes of Genetic Variation

(i) Crossing Over

- During crossing over in meiosis, genetic material is exchanged between non-sister chromatids of homologous pairs. Such process produces new combination of genetic material leading to formation of gametes that are not similar in composition. This leads to variation in offspring.

(ii) Independent Assortment

- Independent assortment occurs during metaphase I of meiosis.
- The homologous chromosomes line up in a random order giving many chromosome combinations in the gametes. This leads to variation in offspring.

(iii) Mutation

- It is a sudden change in the structure and amount of genetic material in the cells of an organism.
- Mutation cause changes in characteristics of offspring hence leading to variation. Examples include albinism and sickle cell anaemia.

(iv) Fertilization

- Any two gametes of opposite types can fuse together at fertilization, so there are many possible combinations of genes which may be produced in zygote. This leads to variations in offsprings.

Types of Variation

- There are two types of variation, namely:
  1. Continuous variation and
  2. Discontinuous variation

1. Continuous Variation

- It is where there is a complete range of measurement from one extreme to another.
- Continuous variation is under the influence of several genes.
- Continuous variations are also greatly influenced by the environment. Most continuous result from interaction of genotype with the environment.

Examples of Continuous Variations

a. Height in humans
b. Mass in humans
c. Skin colour in humans

d. Intelligence in humans
e. Stem diameter in plants
f. Length of leaves
g. Length of internodes in plant stems
h. Size of seeds and fruits
i. Length of fingers in humans

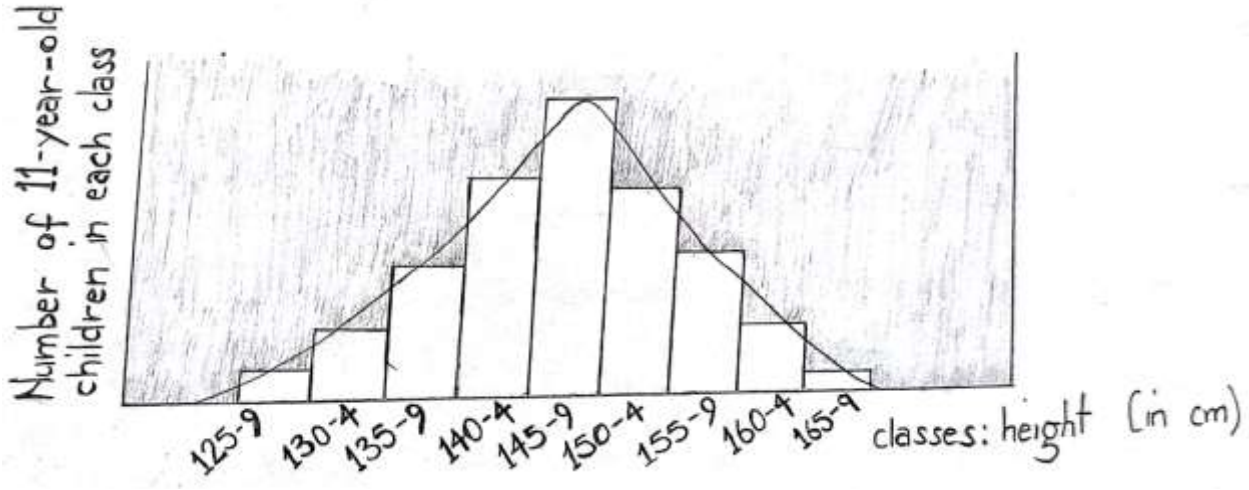


Fig. 3.1: The frequency of heights in a class of 11-year-olds

2. Discontinuous Variation

- It is where individuals fall into distinct categories with no intermediates between them.
- It is controlled by two or three genes.
- It is not under the influence of environment.

Examples of Discontinuous Variation in Animals

Characteristic	**Variation**
a. Tongue rolling	Able or not able to roll the tongue
b. Blood groups	A, B, AB or O
c. Sex	Male or female
d. Earlobes in humans	Free or attached
e. Finger print pattern in humans	Tentrarch, mixed, double, looped or pocked
f. Rhesus factor	Positive or negative

- Some characteristics like blood groups and finger print patterns have more than one variations.

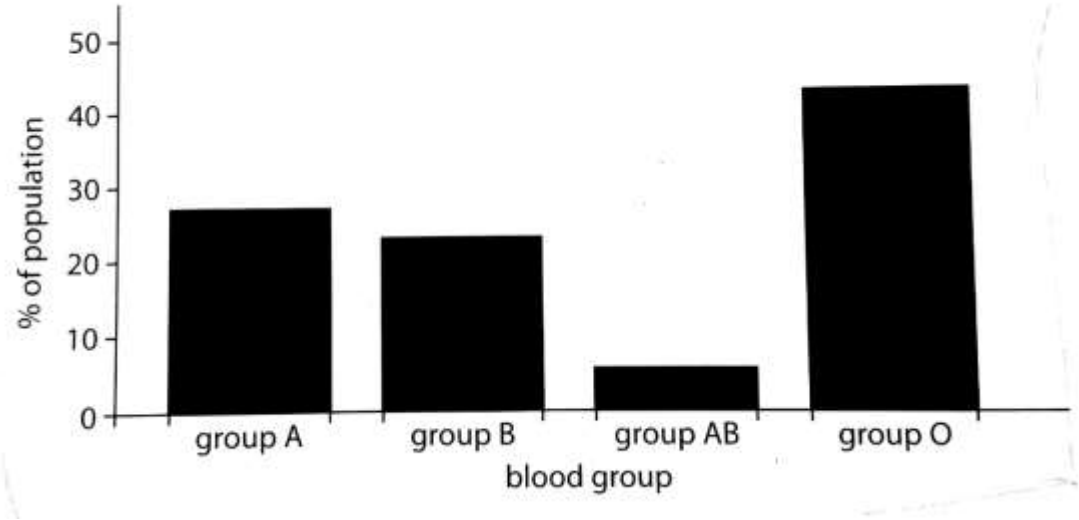


Fig. 3.2: The frequency of the four blood groups in west Africa

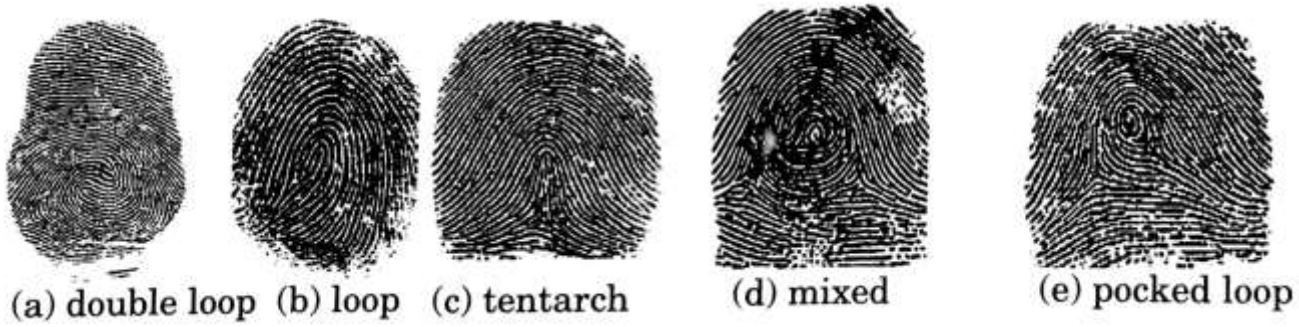


Fig. 3.3: Finger- print patterns showing discontinuous variation

Examples of Discontinuous Variation in Plants

Characteristic	**Variation**
a. Leaf venation	Parallel or network
b. Flower colour in garden peas	Red or pink
c. Pods shape in peas	Inflated or constricted

Genetic Terms

Genes

- A gene is a basic unit of heredity.
- Genes are found in the deoxyribonucleic acid (DNA) molecule in the chromosomes.
- Genes carries information needed to produce inherited characteristics such as skin colour.
- One chromosome has thousands of different genes for different characteristics.

Gene Locus

- It is the specific location of a gene on the chromosome
- Gene influencing the same characteristics are located at the same loci on separate homologous chromosomes.

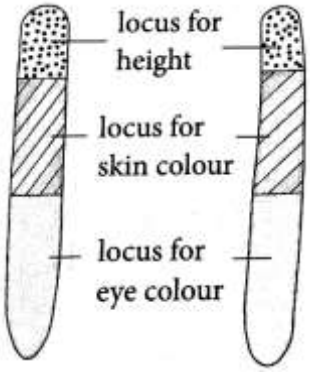


Fig. 3.4: Gene loci in a pair of chromosomes

Genotype

- It is the genetic makeup of an individual organism (i.e. the genes carried on its chromosome).
- The genotype describes an organism in terms of the alleles it contains. For example, a tall pea may have the genotype **TT**, or **Tt**.

Phenotype

- It is the visible characteristic of an individual resulting from interaction of genotype and environment.
- The phenotype of an individual is expressed in words. Black fur and white fur are examples of phenotypes.

Allele

- Alleles are different forms of the gene that code alternatives of the same characteristic.
- For example, allele **B** for black fur and allele **b** for white fur.

Homozygous Condition

- Homozygous condition refers to a condition in which a pair of similar genes controls a characteristic.
- **BB** and **bb** are homozygous condition.

Pure Breed (Homozygote)

- It is a term used to describe an organism with two similar alleles for a particular characteristic.
- Individuals with genotype **BB** and **bb** are pure breeds.

Heterozygous Condition

- It is a condition in which a pair of dissimilar genes controls a characteristic.
- **Bb** is heterozygous condition.

Heterozygote

- It is a term used to describe an organism which possesses two different alleles for a particular characteristic.
- An individual with genotype **Bb** is heterozygote.

F_1 Generation (First Filial Generation)

- The generations produced as a result of cross are called **filials**.
- F_1 generation consist of offspring from a cross between parents that are both homozygous for a particular characteristic.

F_2 Generation (Second Filial Generation)

- F_2 generation consists of offsprings produced when two hybrid plants from F_1 generation are crossed.

Dominant Allele

- A dominant allele is an allele that expresses itself (gives its phenotype) in both homozygous condition and heterozygous condition.
- For example, in peas the allele for tall, **T**, is dominant to that of short, **t**. Since the allele for tall is dominant, pea plant with the pairs of alleles **TT** (homozygote) or **Tt** (heterozygote) will be tall.
- A dominant allele is always represented by capital letter. Therefore genotype **TT** can be described as **Homozygous Dominant**.

Recessive Allele

- Recessive allele refers to an allele that expresses itself only in the homozygous condition.
- Allele **t** is recessive. A small letter always represents a recessive allele.
- Genotype **tt** can be described as **homozygous recessive**.

Mendel's Experiments

Monohybrid Inheritance (3:1 Ratio)

- Mendel conducted several breeding experiments in which he used the garden pea plant. He selected pea plants because of following reasons:
    1. Pea plants are easy to cultivate
    2. Have short generation gap
    3. Can be either self pollinated or cross pollinated
    4. Have a variety of traits which are easily distinguishable

Summary of Some of Traits Mendel Studied

Trait	Description
1. Stem length	Tall or short
2. Shape of pods	Inflated or constricted
3. Seed colour	Yellow or green
4. Shape of seed	Round or wrinkled
5. Position of flower	Terminal or axial
6. Flower colour	Purple or white

- Before carrying out his experiments, Mendel made sure that the parental plants were pure-breeding i.e. tall plants always gave rise to tall plants and dwarf ones always gave rise to dwarf plants.
- He crossed pollinated tall garden pea plants by dusting the pollen of tall plants on stigma of dwarf plants whose own anthers had been removed.
- He obtained offsprings that were tall. He called this first filial generation, denoted by the letter F_1.
- He then allowed the F_1 offsprings to self- pollinate and obtained what he called **second filial generation** or **F_2 generation**. He observed that of the 1064 plants he used, 787 were tall and 277 were dwarf. This approximately 3:1 ratio of tall to dwarf plants.

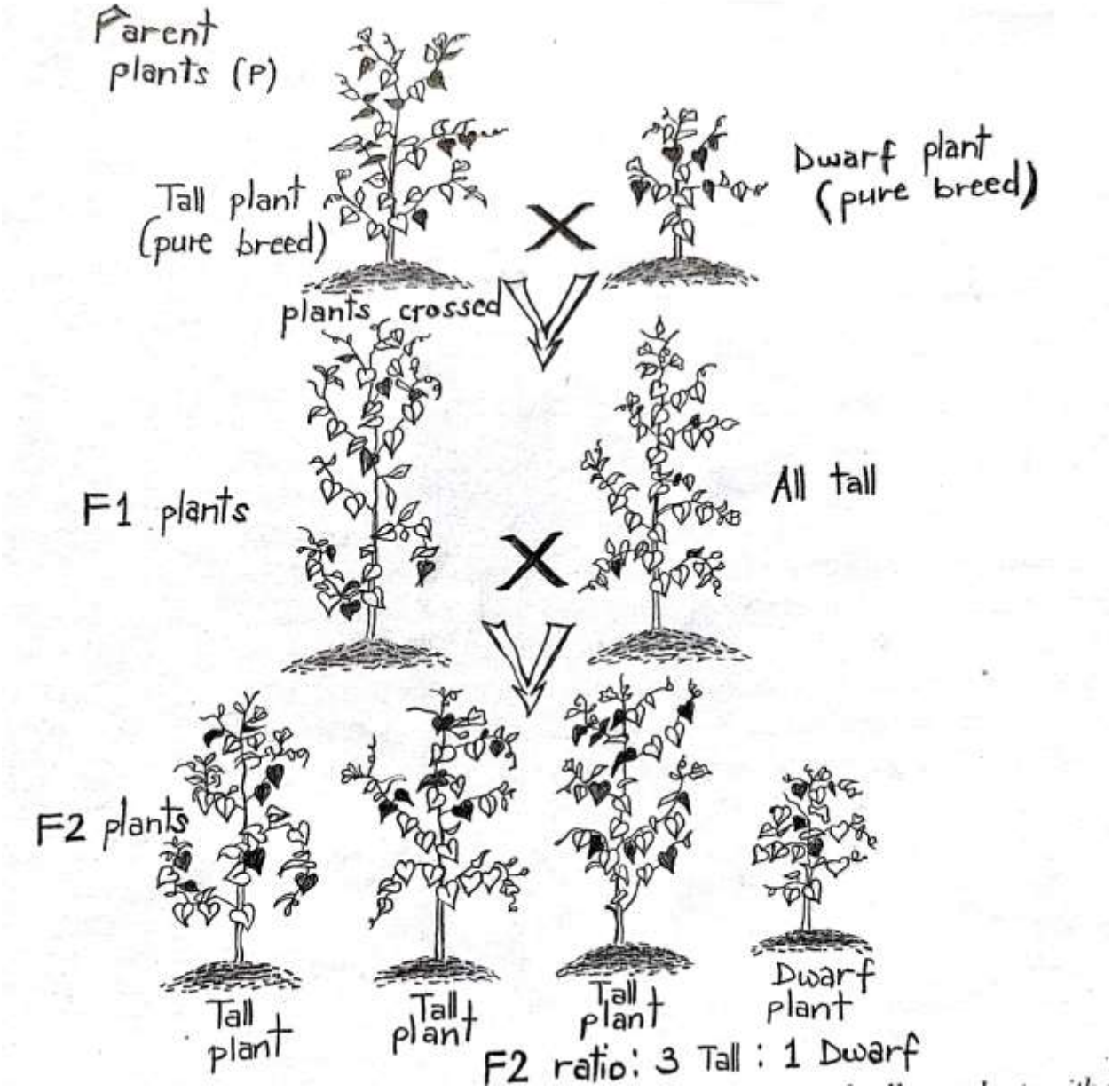


Fig. 3.5: Mendel's experiment on crossing pure breed tall pea plants with pure breed short pea plants

- In this case, Mendel investigated the inheritance of a single trait i.e. tallness in pea plants. This is called **monohybrid inheritance**.

Principles of Mendelian Genetics

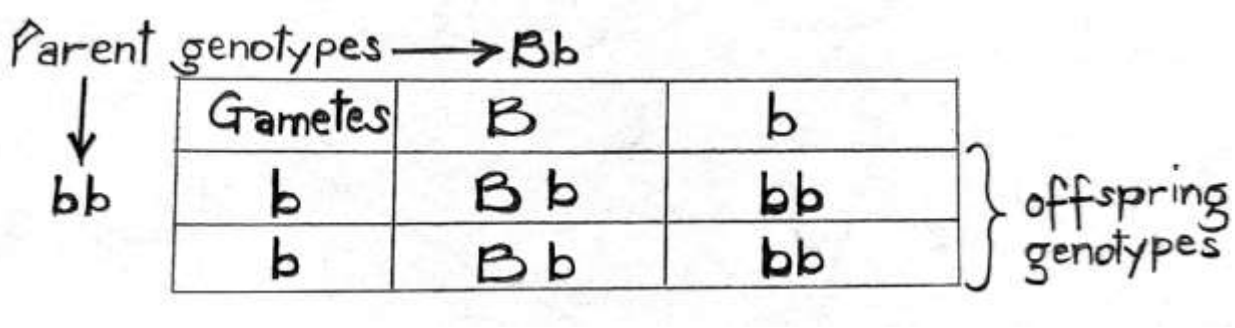
1. Alleles of the same genes do not blend
2. Alleles of same gene pass into separate cells during gamete formation. This is called law of segregation.
3. Alleles of the same gene are inherited independently.
4. Characters are controlled by pairs of genes (alleles)

Modelling Genetic Crosses

- Monohybrid crosses can be illustrated in two ways:
  1. Punnet square
  2. Cross diagram.

1. Punnet Square

Example 1



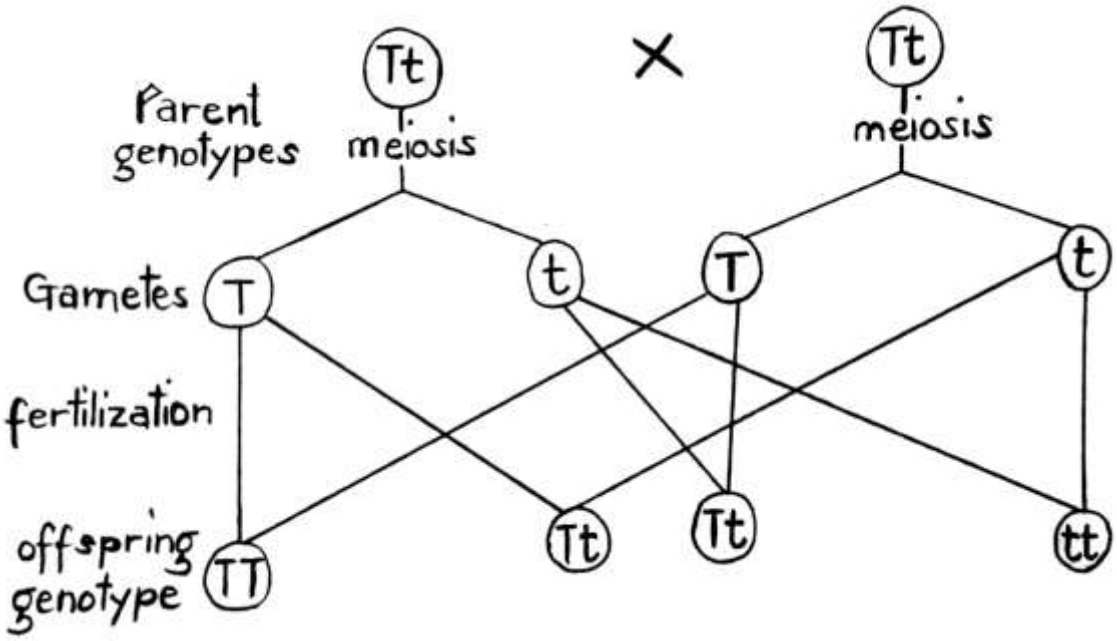
2. Cross Diagram

Example 2

- Dwarfism is a human characteristic in which a person is abnormally short. Gene **T** for tallness is dominant over gene **t** for shortness. If a man and woman who are both heterozygous for this trait marry,
  a. (i) draw a cross diagram to show how this family would produce a dwarf.
     (ii) indicate genotype of parents, gametes and offsprings.
  b. Write down the ratio of genotype and phenotype of the offsprings.

Solution

a.



b. (i) Genotypic ratio: 1TT: 2Tt: 1tt

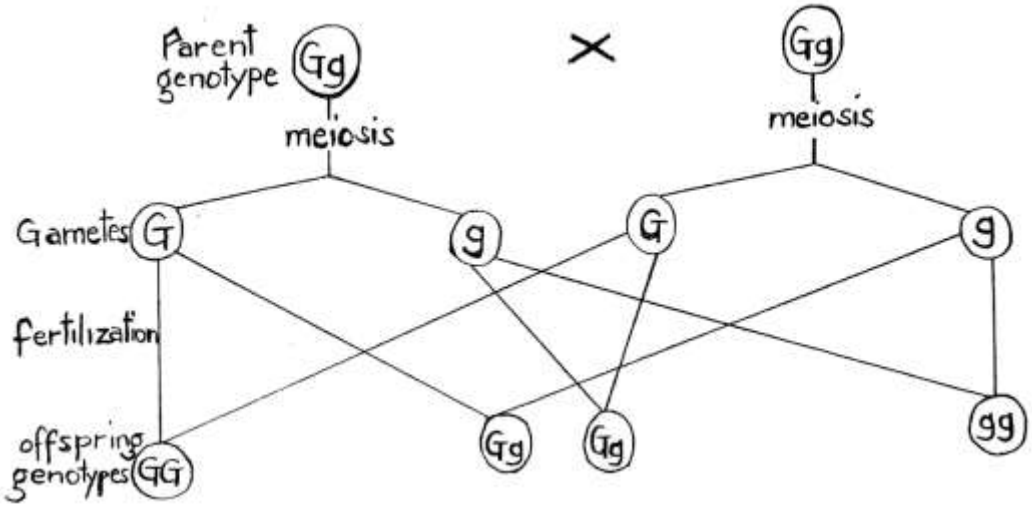
(ii) Phenotypic ratio: 3 tall: 1 dwarf

Example 3

- When a grey cock was mate with a grey hen, grey and white chicks were produced.
  a. Using **G** for grey colour and **g** for white colour draw a genetic diagram to determine the genotype of the offspring.
  b. Give the genotypic ratio of the chicks.
  c. If the parents produced 12 chicks, how many were white? Show your working.

Solution

a.



b. Genotypic ratio: 1GG: 2Gg: 1gg
c. Phenotypic ratio: 3 grey: 1 white

$$Total\ ratio = 3 + 1$$

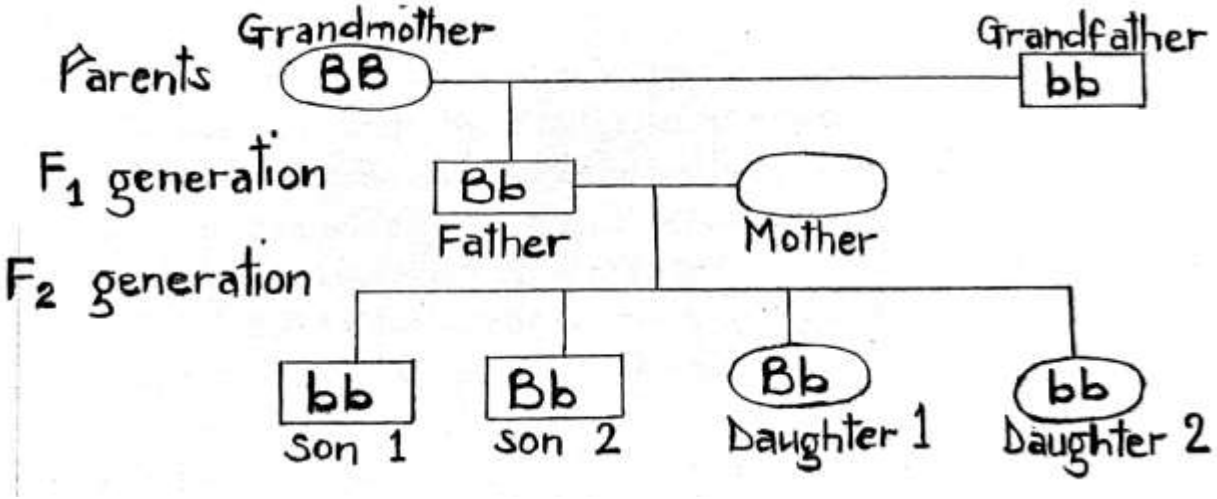
$$Total\ number\ of\ white\ chicks = \frac{1}{4} \times 12$$
$$= 3\ chicks$$

The 1:1 Ratio

- This 1:1 ratio of phenotypes in the offsprings is always what is expected when a heterozygous animal mates with homozygous recessive animal.

Example

In humans the gene for blue eyes (**b**) is recessive to the gene for brown eyes (**B**). **Figure below** represents part of a family tree in which some have brown and others have blue eyes.



a. What is the phenotype of the grandfather? **(1 mark)**
b. What is the ratio of individuals with brown eyes to those with blue eyes in the F_2 generation? **(1 mark)**
c. What is the genotype of the mother in **F_1** generation? **(1 mark)**
d. Write down the genotype of an individual an in the **F_2** generation who is homozygous and one who is heterozygous

Homozygous _____
Heterozygous_____ **(2 marks)**

The 3:1 Ratio

- This 3:1 ratio of phenotypes in offsprings is always what is expected when two heterozygous organisms are bred.

Incomplete Dominance

- Incomplete dominance is a condition in which the effect of recessive gene is not completely masked by a dominant gene in a character of an individual.
- When two parents produce a heterozygous offspring the phenotype is intermediate between them.

- In this type of inheritance both alleles are expressed and contribute equally to the phenotype.
- An example of incomplete dominance is flower colour in basalm plants.
- When basalm plants with red flower are crossed with white flowers, the entire offspring end up with pink flowers.

$$Parents:\ Red\ Flowers \times White\ flowers$$

$$\downarrow$$

$$Offspring:\quad All\ pink\ flowers$$

Co-Dominance

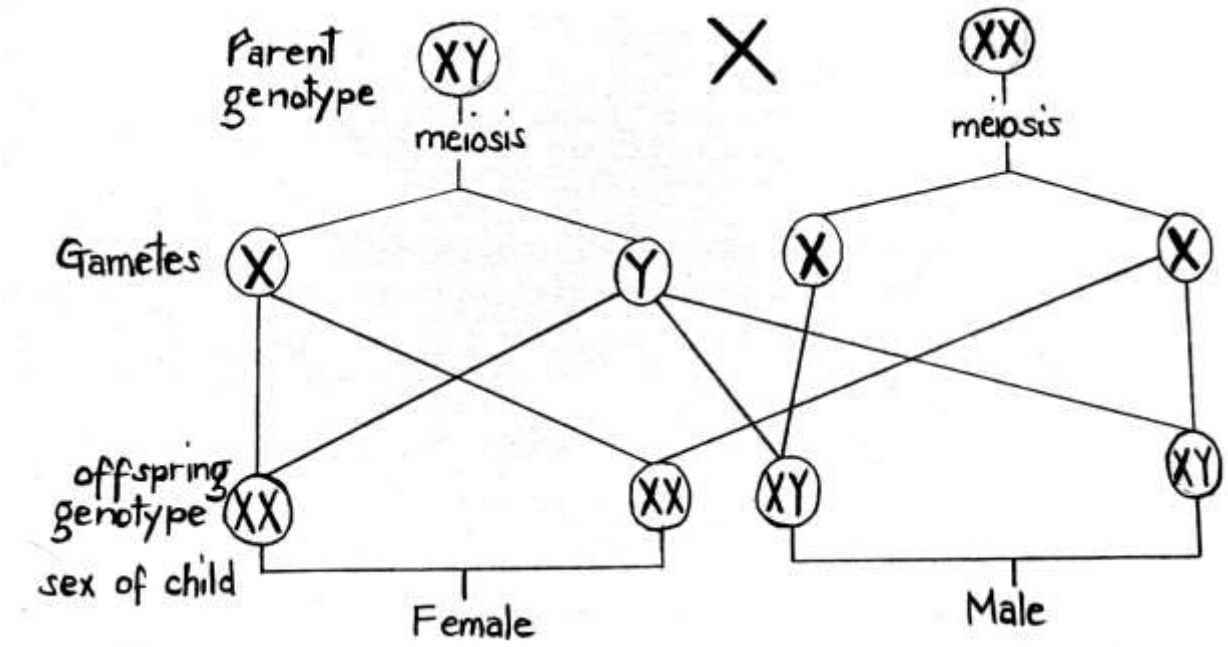
- It is a condition that arises when both genes in a pair produce their effect on an individual.
- The inheritance of the AB blood group in humans is an example of co-dominance. The A, B, AB or O phenotype is controlled by any two of three alleles **A**, **B** and **O**, acting at the corresponding site on homologous chromosomes. Allele **O** is recessive to both **A** and **B**, but **A** and **B** are co-dominant i.e. if a person inherits **A** from one parent and **B** from the other, he will be group **AB** because neither allele is dominant to the other. It follows that group O people have the genotype **OO**, while group A person could be **AA** or **AO**. Group B individuals could be **BB** or **BO**.
- Certain coat colours in cattle is another example of co-dominance. Reddish coat colour is not completely dominant to white. Animals that have both alleles have coats that are roan-coloured (red coats with spots of white hairs). The red hairs and white hairs are expressed fully and independently (not blended to produce pink).

Sex Determination in Human Beings

- The sex in humans is determined by sex chromosomes. Sex chromosomes carry genes that determine the sex of an individual. There are two types of sex chromosomes namely **X** and **Y** chromosomes. They are so called because of their shape. The X- chromosome appears roughly like the alphabet letter X while the Y chromosome is shorter and appears like the alphabet letter Y. The X- chromosome is longer than Y- chromosome.
- In humans, the sex chromosomes can occur in two combinations. Theses combinations represent the genotypes of the individual. If the genotype is **XX**, the individual develops female characteristics. The sex of the individual is therefore **female**. If the genotype is **XY**, the individual develops male characteristics. The sex of the individual is therefore **male**.
- Sex chromosomes separate at meiosis like all other chromosomes pairs, and only one goes into each gamete. Therefore all female gametes carry one X chromosome, while half the male gametes carry a Y chromosome and the other half an X chromosome.

Table 3.1 Sex Determination in Humans

Chromosomes (Genotype)	Examples of Sexual Characteristics Developed	Phenotype (Sex)
XX	• Ovaries • Uterus • Vagina	Female
XY	• Testes • Penis	Male



- From the crossing, the ratio of males to females is 1:1. In other words, a chance of either a male or female child being born is a half. This means that the chances of getting either a boy or a girl for every conception are the same.

Sex Ratio in Humans

- Sex ratio is the number of males per 1000 females in population of a society.
- More boys than girls are born each year, but the excess number of males at birth is gradually reduced by higher male death or mortality rate.
- Sex ratio is an important social indicator. It affects marriage rate and employment rates in women in labour market.

Sex Linkage Characteristics

- A characteristic is sex linkage if the gene that controls it is found on the X or Y chromosome.

Examples of Sex- Linkage Characteristics

1. Haemophilia
2. Red- green colour blindness
3. Hairy ears
4. Baldness

1. **Haemophilia**
   - Haemophilia refers to a condition in which blood fails to clot or takes long to clot.
   - Haemophilia occurs due to absence of clotting factor VIII. The inheritance of this factor is determined by two alleles which are found on the **X**- chromosome. One allele determines the production of normal clotting factor. This allele (**H**) is dominant. The other allele which has come as a result of mutation influence formation of a defective clotting factor. This allele (**h**) is recessive.
   - The relationship between genotypes in the inheritance of haemophilia is given in the table 6.2 below.

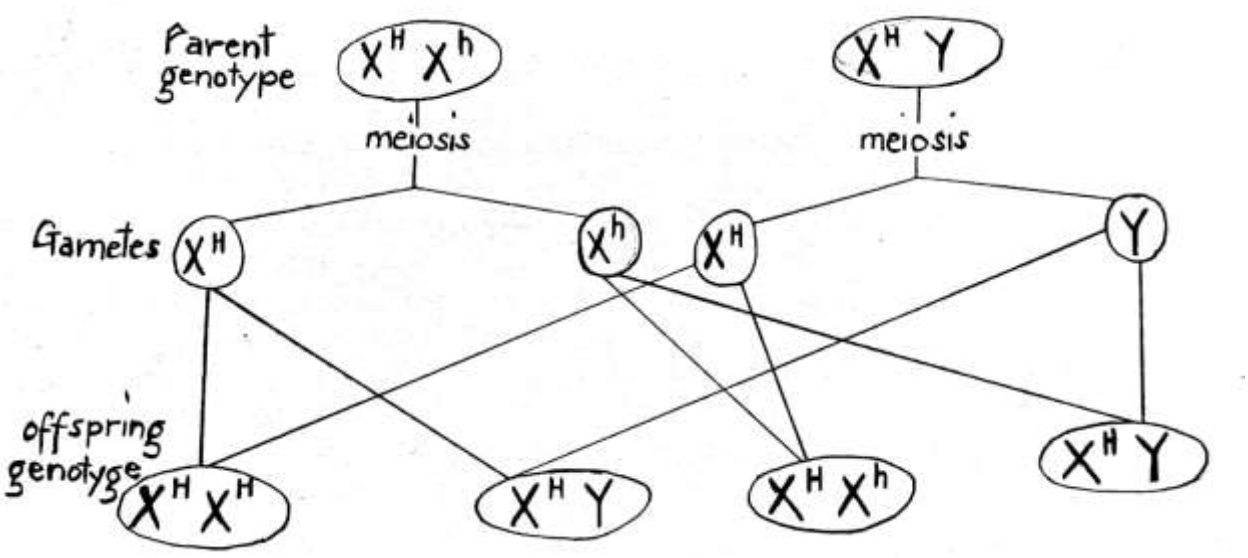
Table 6.2: Inheritance of Haemophilia

Genotype	Sex	Phenotype
$X^H X^H$	Female	Normal
$X^H X^h$	Female	Normal female (Carrier)
$X^h X^h$	Female	Haemophiliac
$X^H Y$	Male	Normal
$X^h Y$	Male	Haemophiliac

   - From the table, it can be noted that the male require only one recessive allele to be haemophiliac, while the female require two recessive alleles to be haemophiliac. In a population therefore, the chances of male being haemophiliac are higher than that of females.
   - The heterozygous female ($X^H X^h$) is also referred to as a carrier. This is because she has recessive allele for haemophilia which does not show phenotypically.

Example

   - A woman who is a carrier of haemophiliac gene married a normal male. Draw a cross diagram to show how this family would produce haemophiliac son.

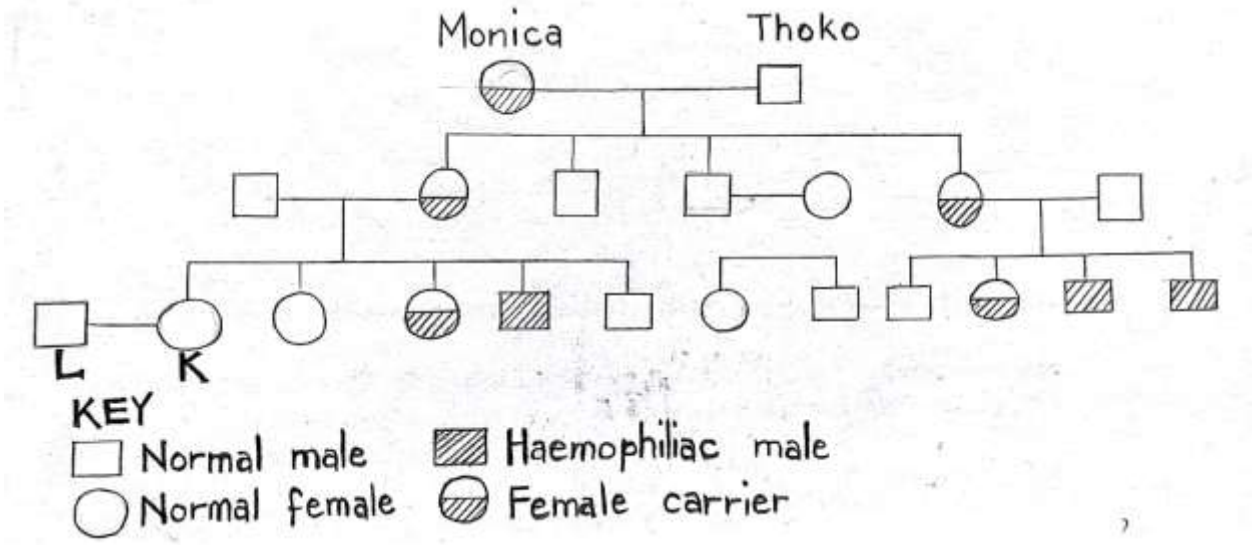


Pedigree Charts

- A pedigree is a flow diagram that shows record of inheritance of a particular characteristic over several generations.

Example

- **Figure below** shows a family tree in which there is inheritance of recessive gene that causes haemophilia. Males with single gene suffer from the disease while females are carriers of the disease.



a. How many individuals with a single recessive gene are there in the three generations?
   - 8

b. How many of Thoko's grandsons have haemophilia?
   - 3

c. What type of children with regard to haemophilia would **L** and **K** produce?
   - Normal children

d. State any **two** disorders in haemophiliac person.
   - Blood fails to clot
   - Blood lacks platelets
   - Blood lacks plasma proteins

e. Name the chromosome where the gene for haemophilia is located.
   - X- chromosome

f. How does the gene for haemophilia arise in a population?
   - By mutation

2. Red- Green Colour Blindness

- This is a disorder in one's vision.
- The colour blind person cannot distinguish red and green colours. This is because the gene that determines the formation of colour- sensitive cells (called **cones**) in the retina of the eye has undergone mutation.
- The gene for colour vision is located on the X- chromosome and it is transmitted to offsprings via the X- chromosome.

- The gene for colour blindness is recessive to the normal vision gene.
- A woman carrying the colour blindness gene on one of her pair of X- chromosomes does not suffer from colour blindness but she is a carrier for disorder.
- The relationship between the genotypes in the inheritance of colour blindness is given in the table 6.3 below.

Table 6.3: Inheritance of Red- Green Colour blindness

Genotype	Phenotype
$X^B X^B$	Normal Female
$X^B X^b$	Carrier Female
$X^b X^b$	Colour blind Female
$X^B Y$	Normal male
$X^b Y$	Colour blind Male

3. Hairy Ears

- This is a condition whereby a male is found to have long turfs of hair growing on the pinna of the ear.
- The allele that causes this is believed to be linked to the Y- chromosome only.
- The allele is absent in the X- chromosome and this means that it can only be transmitted by the father to sons only.

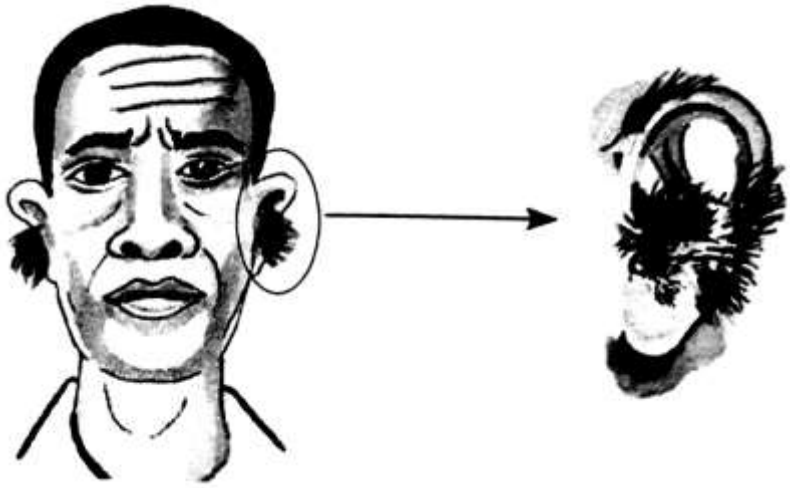


Fig 3. 6: Hairy ears

4. Baldness

- Premature baldness in males is also sex- linked.
- It is carried by the Y- chromosome only.

Mutations

- Mutation is a sudden change in gene or chromosome which may produce an alteration in characteristic under its control.

Types of Mutation

- There are two main types of mutations:
  1. Chromosomal mutations
  2. Gene mutation.

Chromosomal Mutation

- This involves sudden changes in the structure or number of chromosomes.

Examples of Chromosomal Mutation

a. **Down's Syndrome**
   - It arises when an ovum carries two copies of chromosome 21 so that the child has 47 chromosomes.
   - The child has three copies of chromosome 21 and this is called **trisomy (three copies) of chromosome 21**.
   - Down's syndrome children are typically short due to poor skeletal development and have poor mental development.
   - Trisomy of chromosome 21 is more common when the mother is over 40 years of age.

b. **Klinefelter's Syndrome**
   - It is due to acquisition of an extra X- chromosome in males so that the genotype is XXY.

   Characteristics of Klinefelter's Syndrome

   (i) Infertile (No sperm production)
   (ii) Very tall
   (iii) High unusual secretion of follicle stimulating hormone.
   (iv) Under developed male secondary sex characteristic i.e. high pitched voice, little beard, tiny testes, reduced size of the penis and breast development.

c. **Turner's Syndrome**
   - It arises when gamete which lacks an X or Y chromosome fuses with a gamete with an X- chromosome. The resulting zygote has only one sex chromosome, X. The human is a female and is sterile.

Gene Mutation

- This is a mutation that is caused by chemical change occurring inside an individual gene.
- Gene mutations in humans are associated with certain disorders. Some of these disorders include:
  1. Albinism
  2. Sickle cell anaemia
  3. Haemophilia
  4. Red- green blindness.

1. Albinism

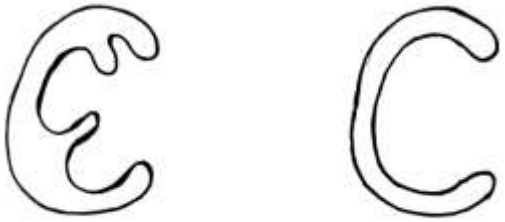
- Albinism is a condition whereby the skin of an individual fails to produce the skin pigment known as **melanin**.

- It occurs when mutation takes place in the normal gene that causes production of melanin. Due to mutation of the gene, melanin is not formed. The skin of the individual lacks melanin pigment hence albinism.
- Melanin gives the skin its colour. It also protects the skin and the eyes against harmful rays from the sun.
- The albino has pale skin, white hair and pink eyes.
- The mutation is recessive.

2. Sickle Cell Anaemia

- Sickle cell anaemia is a condition whereby red blood cells have an abnormal shape, that is, sickle shaped.
- It occurs when gene mutation takes place in the gene that causes production of normal haemoglobin. Due to mutation, abnormal haemoglobin is produced leading to sickle cell anaemia.
- The allele $\mathbf{Hb^A}$ allows the formation of normal haemoglobin.
- The mutant form $\mathbf{Hb^S}$ cause a disease known as **sickle cell anaemia** which usually results in an early death.
- The mutant allele ($\mathbf{Hb^S}$) has the following effects if it is inherited:

(i) Red blood cells which are sickle shaped instead of normal binconcave shape.



- Sickle shaped red blood cells have very small surface area on which oxygen is trapped by haemoglobin.

(ii) An enlarged spleen

- The spleen removes old and damaged red blood cells, and it becomes enlarged as a result of dealing with sickle shaped red blood cells.

(iii) Severe and eventually lethal anaemia.

- Many red blood cells are removed from circulation and destroyed by the spleen resulting into severe anaemia.

(iv) Pain in the abdomen and joints.

(v) Resistance to malaria in heterozygotes.

- The heterozygotes $\mathbf{Hb^AHb^S}$ result in individuals who produce both normal and abnormal haemoglobin. The individual suffer from mild anaemia and is said to have **sickle cell trait**.
- Under normal body conditions their red blood cells are disc shape.
- When malarial parasites are present in red blood cells the cells cannot cope with reduce oxygen tension, and they sickle as oxygen level falls. These mis-shaped cells are then removed by the spleen, incidentally getting rid of malarial parasites at the same time. Normal, unaffected cells are unharmed.

Practice Question

- Sickle cell anaemia is caused by a single gene. Using the symbols $\mathbf{Hb^A}$ for normal allele and $\mathbf{Hb^S}$ for sickle cell anaemia, write down the crossings between two parents who are heterozygous for sickle cell gene indicating parents genotype, gametes genotype and first offspring genotype.

Causes of Mutation

- Mutation are caused by factors known as mutagens.
- Mutagens include:

1. **Radiations-** exposure to high radiation such as gamma- rays, x-rays, ultraviolet light and beta rays can damage DNA and cause mutation.
2. **Chemicals** e.g. tar in tobacco smoke, colchicines, mustard gas and formaldehyde.

Effects of Mutation

1. Some mutations are lethal in the sense that the mutants are usually eliminated from the society by death before they reach adulthood.
2. Mutations may make an individual better adapted to the environment.
    - For example, new species of bacteria have been produced as result of mutation which has made them resistance to **penicillin**. In the same way, new types of mosquitoes have risen, that are resistant to DDT; and rats now exists which are resistant to rat poison called **warfarin**.
3. Mutation cause genetic disorders such as sickle cell anaemia, albinism, haemophilia and colour blindness.
4. Mutation leads to failure of development of some important body parts.

- Evolution is the gradual change in living organisms.
- Evolution can also be defined as the formation of new species from already existing species.

Evidence of Evolution

1. **Fossil Records (Paleontology)**
   - Paleontology is the study of history of life on earth as based on fossils.
   - Fossils are remains of dead organisms that have been preserved in sedimentary rocks.

   Formation of Fossils
   - Fossils are formed from hard part of animals like bones, teeth and shells. When an animal dies, these parts do not readily decay. They eventually get buried in the soil or in the sea. As the soft parts of the tissue of these structures decay, mineral forming a rock- like structure replace them. Such structures retain the shape of the original hard part of the organism, that is, bone. The soil or sediment in which these structure are buried eventually harden into rock. The structure is then called a **fossil**. The fossil remain distinct in the rock.

   How Fossil Records Provide Evidence of Evolution
   - Scientists called Paleontologists study fossils. Palaeontologists put together fossil information of related organisms by arranging them in such a way that they form a series according to their age starting from the oldest to most recent. This is referred to as **fossil records**.

Fig. 6.1: Skulls of primates

   - From such fossils records, differences are usually noted between related fossils. These specific differences reveal changes of development from one form of organism to another. These changes are believed to have occurred slowly over time during the life of the organism.
   - In summary fossil records reveals the following:
     (i) A gradual change in animals over a period of time
     (ii) The extinction of organisms due to presence of fossils of organisms that do not exist today

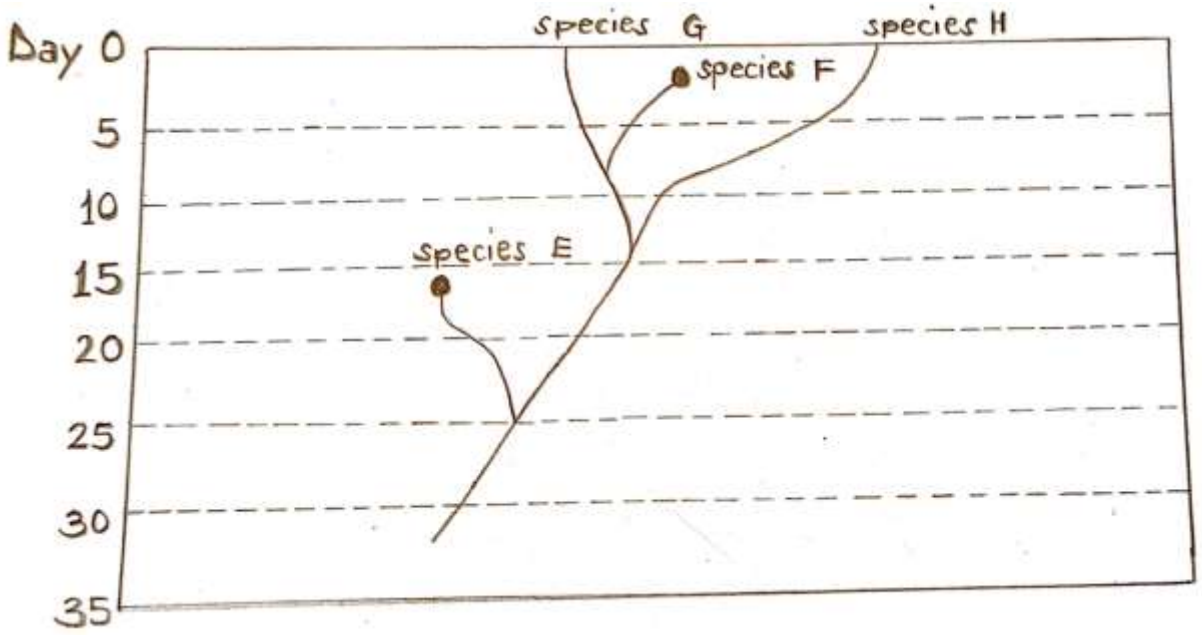
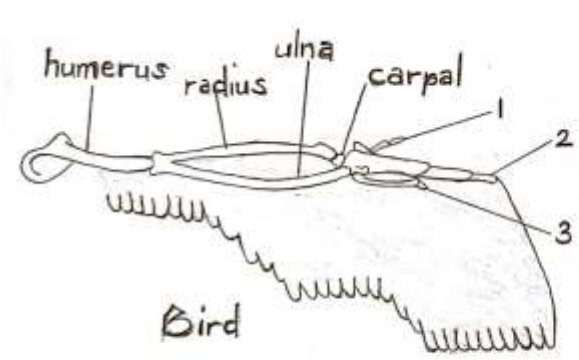


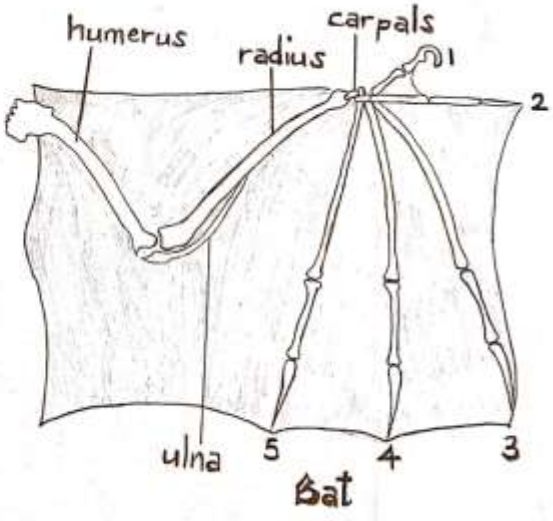
Fig. 6.2: Evolutionary tree of organisms

- In the figure above, for example, species **E** and **F** have become extinct because the tree shows them not reaching the present age. In this, species **E** evolved at day 35 and species **F** evolved at day 8. In this way, all species (including **E** and **F**) are like branches from a common stem which begins (evolves) from somewhere around day 32.
- Note that though this example has used real days, it takes millions of years for an organism to evolve.

2. Comparative Anatomy

- Comparative anatomy is the study of the structural similarities and differences between organisms.
- The forelimbs for different vertebrates have similar bones built on the same plan which suggests that they share a common ancestor.





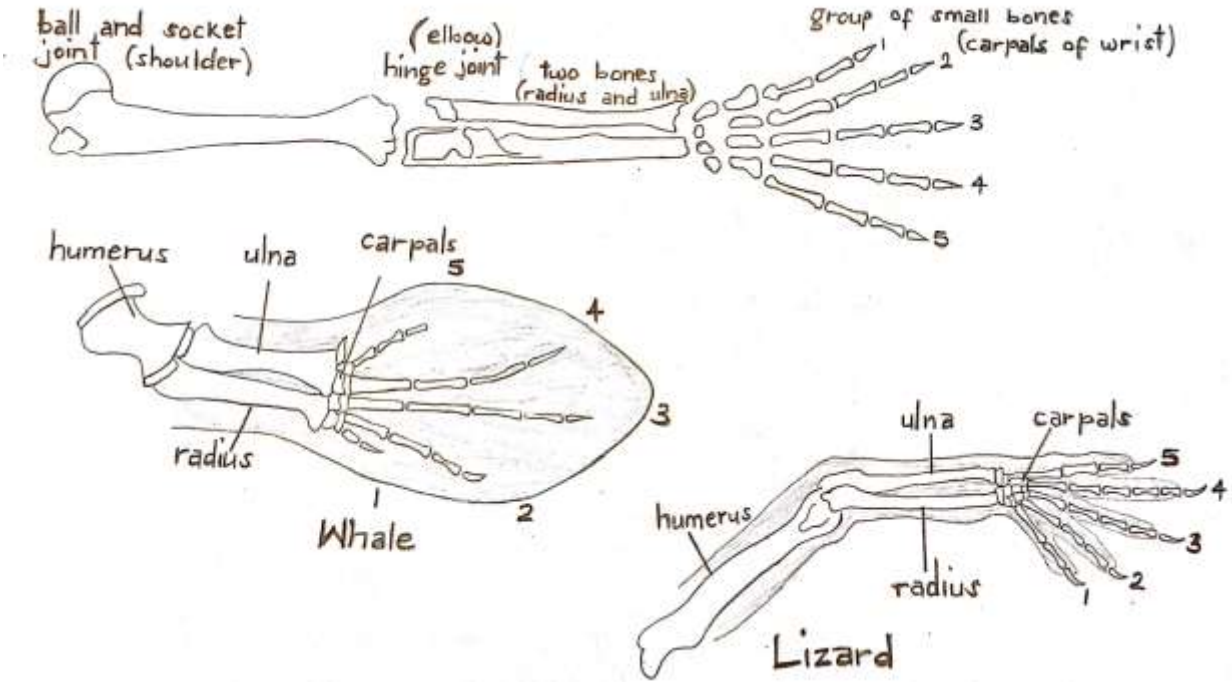


Fig. 6.3: Comparative anatomy of vertebrate

- The plan in vertebrate limb is called the **pentadactyl limb plan**. ('*Penta*' means 'five' and '*dactyl*' means 'digit')
- Body parts that have similar structure but different functions are called **homologous structures**.
- In biology, an ancestor is the species that gave rise to another species.

3. Geographical Distribution

- Observation of organisms living in the world today show that some plants and animals living in different parts of the world have many similarities in common. For example, the camel that is found in Africa and Asia is similar to Ilama that is found in Amazon forests in South America.
- The similarities support the idea that the organisms arose from a common ancestor many millions of years ago and have evolved differently due to geographical isolation.

4. Embryology

- When development patterns in embryos of vertebrates are compared, many similarities are noted in the early stages of embryonic development. All the embryos develop gill slits and they all have a tail. The similarities in the early embryos of all the vertebrate classes provide a strong evidence that they are related by evolution from a common ancestor.

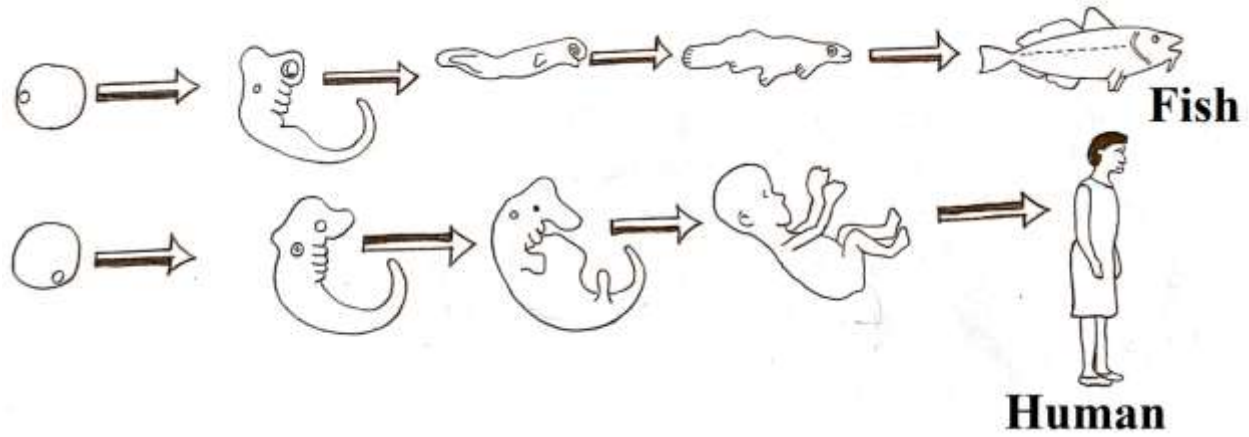


Fig. 6.4: Embryonic comparison in two animals

5. Cell Biology

- Study of the cells making up living organisms shows that they have similar cell organelles e.g. nucleus, cell membrane and ribosomes. Presence of similar cell organelles suggests that those organisms have a common ancestral origin.
- Blood pigments can also be used to group closely related animals. For example, haemoglobin is found in vertebrates. Presence of similar pigments point to a common ancestral origin.

The Theory of Natural Selection

- Charles Darwins argues that evolution has taken place and explains a possible mechanism by which evolution has come about and that is **Natural Selection**.
- The main arguments put forward were as follows:

First Argument

- Charles Darwins argued that more offsprings are produced than survive so there is **always a struggle for existence**, (a competition between members of the same species) so that many die before reaching reproductive stage.
- This struggle for existence may happen through competition for food, water, light, warmth and other factors affecting growth; through failure to escape from predators; death from diseases or accidental injury; and all hazards which wild organisms face.

Second Argument

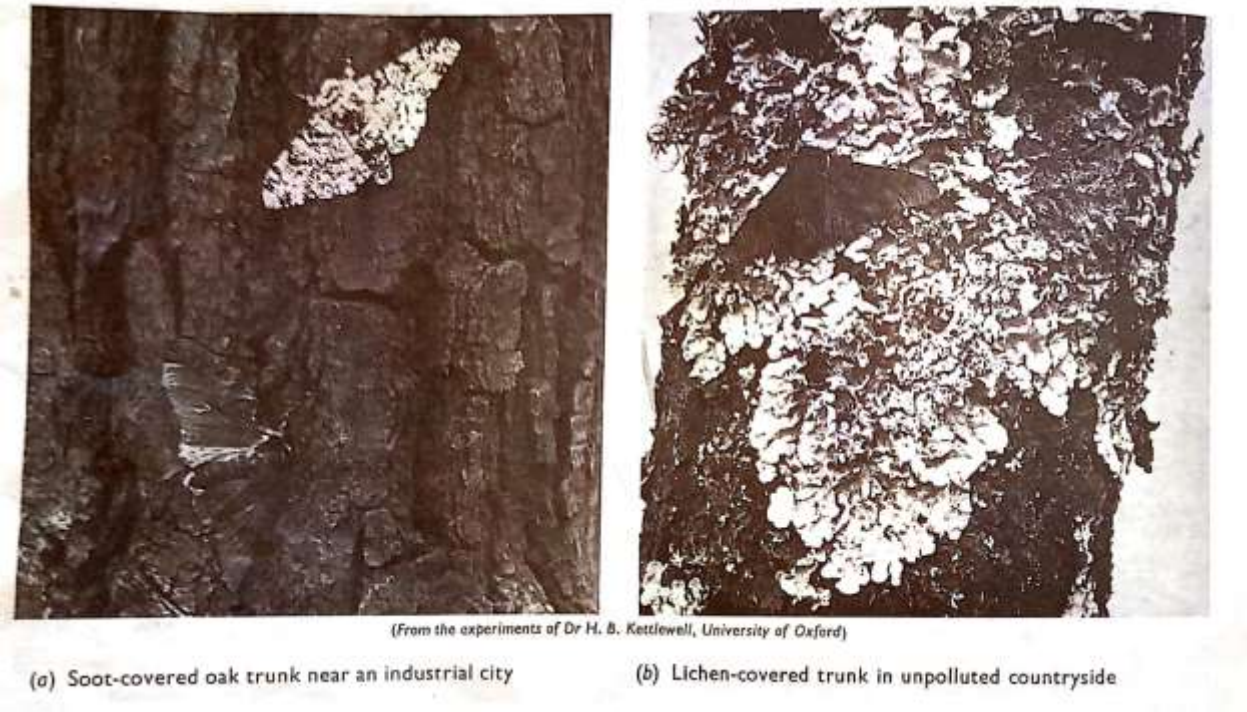
- Living organisms which reproduce sexually show a great variation in characteristic (e.g. their appearance, resistance to diseases or their ability to survive drought)
- Certain variations help organisms to survive for existence while others do not.
- Those organisms with favourable variations (variations that help organisms to survive for existence) are likely to survive longer and reproduce than those with unfavourable variations (variations that do not help organisms to survive for existence).
- Darwins called this **survival of the fittest**, meaning that in the struggle for existence the fittest, i.e. those with favourable variations, will survive while those with unfavourable variations are eliminated.

- Darwins also argued that the survival of the fittest is a selection process. That is "nature (i.e. the hazards of life in wild) selects" those organisms best suited for survival. Hence the phrase "**natural selection**".
- After natural selection has taken place, favourable variations are inherited by next generation i.e. the nature selects the favourable variations and inheritance preserves them by transmitting them to the young.
- If natural selection continues over a long period of time, favourable variations are accumulated over many generations and new species may gradually evolve from older species. The new species will be adapted to its environment. Natural selection therefore results in evolution.
  Note: Only genetically controlled variation influences natural selection.

Examples of Natural Selection in Action

1. **Resistance to Insecticides**
   - In ordinary population of weevils there are some weevils that are resistant to certain insecticides and some are not. For example, resistant individuals have slightly thicker cuticle so that insecticides does not penetrate, or possess an enzyme that break the poison.
   - In ADMARC store the insecticides kills the susceptible weevils, which therefore leave no offspring. The resistant ones survive and produce more resistant weevils.
   - In ADMARC stores an adverse environment has resulted in selection of only those organisms which can resist adversity.

2. **Selection of Peppered Moths in Industrial Areas**
   - Peppered moth, *Biston betularia*, are insects that are commonly found in England. They fly at night, resting on tree- trunks during the day. One variety of the peppered moth has light body colour while another variety is black (also called **melanic form**). The black body colour in the moth is due to pigment called melanin whose occurrence is due to mutation. They are eaten by birds.
   - Before industrialisation in England, the light moth was more abundant because they were well hidden on lichens growing on trees and rocks. This meant that there were less likely to be eaten by birds than melanic form, which was rare.
   - After industrialisation in England, it was observed that the number of melanic forms increased around the areas with higher number of development of industries. This because the factories produced dirty smoke that coated the trees with black soot. The lichens died. Black moths were hidden on the black tree-trunks than the light moths. Better hiding led to fewer black moths being eaten by birds so more light moths were eaten by birds. Therefore in industrial areas, the black variety became abundant and the light form became rare.



(From the experiments of Dr H. B. Kettlewell, University of Oxford)

(a) Soot-covered oak trunk near an industrial city (b) Lichen-covered trunk in unpolluted countryside

Fig. 6.6: Light and dark forms of the peppered moth at rest on tree trunk

3. Sickle Cell Anaemia

- There are three types of individuals in relation to sickle cell anaemia:
  (i) Normal individuals- whose red blood cells are all normal.
  (ii) Sickle cell anaemic individuals- whose red blood cells are all sickle shaped.
  (iii) Sickle cell trait individuals- whose red blood cells are a mixture of normal cells and sickle shaped cells.
- Individuals who have sickle cell anaemia are said to be carrying a less favourable variation. The sickle cells interfere with blood circulation. Without proper blood circulation and with low oxygen supply, the individual grow slowly and often die before reaching maturity. Nature therefore eliminates the individuals ensuring that they do not pass the defective genes to any generation.
- However, individuals with sickle cell trait survive better than normal individuals in malaria prone areas because they are more resistant to malaria. In this case, nature (malaria) selects individuals with sickle cell trait because of their favourable traits.

Other Examples of Natural Selection

(i) Resistant of some bacteria to antibiotics like penicillin, tetracycline.
(ii) Resistance to fungicides by fungi
(iii) Resistance to DDT by houseflies and mosquitoes
(iv) Resistance of the malaria parasite (plasmodium) to antimalarial drugs like chloroquine, fasdar.
(v) Resistance of ticks to various acarides.
(vi) Resistance of rats to warfarin.

Speciation

- Speciation is the formation of new species.
- A species is a group of living organisms that can freely mate to produce a fertile offspring.
- Charles Darwins used his arguments (**survival of the fittest** and **struggle for existence**) to show that new species can originate.
- Darwins pointed out variations, natural selection and inheritance, operating generation after generation on species for million years, could limit unfavourable variations and lead to accumulation of more favourable variations within species. The accumulation of variations with survival value could lead to a process of change and improvement. This could give rise to new species which is, in sense, an advancement on its ancestors because it possess characteristics with survival value that its ancestor lacked.

Emergence of New Species

- Isolation is the first step in the formation of new species. Two populations must be separated by physical barriers, for example deserts, mountains, oceans and seas, which they cannot cross.
- Each population continue to live and breed in its environment. If the two environments are different, then natural selection may favour different variations in the two populations. They will become less and less alike.
- After many years the two populations may become so different that they can no longer interbreed- they are said to be different **species**.

- An **ecosystem** is all the living organisms and non-living factors in a particular part of the environment.
- The study of ecosystems is called **ecology**.

Ecological Terms

1. **Community**- refers to all the populations of living organisms in a given area.
2. **Population**- refers to total number of organisms of the same species living in a given habitat.

   Examples of Populations

   (i) The population of tilapia in a lake.
   (ii) The population of lions in a National park or Game reserve.

3. **Habitat**- it is the actual place which a community occupies.

   Types of Habitat

   (i) Aquatic Habitat- are those that involve water. They include marine habitats, freshwater habitat such as lakes and rivers.
   (ii) Terrestrial Habitat- are land habitat such as grassland, woodlands, the soil and farmlands.

4. **Niche**- is a way of life which enables a species to occupy a particular place within a community. This "way of life" includes all things a species does to survive, such as type of food it eats, how it find its food and how it avoid predators.

Components of an Ecosystem

- An ecosystem is made up of three components:
  1. Physical factors
  2. Plant communities and
  3. Animal communities

1. Physical Factors

- These are the non- living factors in an ecosystem.
- They influence how organisms live.
- They include soil, water, amount of oxygen, light, temperature, humidity, pH, land and mineral salts.
- They are also known as the abiotic component of the environment.

2. Plant Communities in an Ecosystem

- These are populations of different species of plants growing in a given area including all other organisms that carry out the process of photosynthesis such as green algae and planktons found in aquatic habitats.

- Plant communities use light energy and simple compounds such as carbon dioxide, water and mineral salts to make food substances. The food substances made by plant communities support all other organisms in an ecosystem. Plant communities are therefore referred to as producers in a given ecosystem.

3. Animal Communities in an Ecosystem

- These are the populations of different animal species in a given area. They include all organisms that cannot carry out the process of photosynthesis and thus obtain food from plants and other organisms.
- All animal communities are said to be consumers because they get food from plants and other animal's bodies.
- The animal communities can be divided into groups according to how they obtain food.
  (i) **Herbivores-** They obtain food by feeding directly on plants. They include caterpillars, grasshoppers, rabbits, cattle, goats and zebras.
  (ii) **Carnivores-** They obtain food by feeding on other animals. For example spiders, chameleons, sharks, and leopards.
  (iii) **Omnivores-** They obtain food from both plants and animals. They include humans, pigs and chickens.

Effects of Physical Factors on Organisms

a. Light

- Many plants are directly affected by light availability since light is required for successful photosynthesis. There are many plants in the areas where there is more light than in the areas where there is less light.

b. Temperature

- There are few organisms in the areas where temperatures are very low and in areas where temperatures are very high (e.g. deserts)
- Organisms are many where temperatures are moderate, since enzymes in the body are more active than under low and very hot conditions.

c. Water

- Plants and animals tend to like areas close to water hence water affects distribution of organisms.
- There are more organisms in the areas where there is more water than in the areas where there is less water.

d. Humidity

- This refers to the amount of water vapour in the atmosphere. The degree to which the atmosphere is saturated with water will determine the rate of water loss from the bodies of animals and organs of plants.
- High humidity means less evaporation and low humidity means high rate of evaporation and transpiration.

- The distribution of plants and animals is influenced by humidity in the environment. For example, only a few specially adapted types of plants can survive in dry habitats with low humidity because of high rate of transpiration.

e. pH

- It is the measure of acidity or alkalinity.
- pH of the soil affects the availability of nutrients. Therefore pH affects the distribution of plants. For example, some plants do not grow well in alkaline soils because they are unable to absorb some elements e.g. Manganese and Iron.

f. Amount of Oxygen

- Most organisms are aerobers- they respire atmospheric oxygen to survive. These organisms cannot tolerate environments with low oxygen content. Therefore there are fewer organisms in the areas where there is low oxygen content.

g. Mineral Salts

- Mineral salts are found in soil and water. They determine the types of plants that grow in a given area. This also determines the type of animals to be supported by plants growing in a given area.
- Soils rich in mineral salts highly support plant life. This in turn supports many animal populations.

h. Land

- Land refers to the nature of the area, such as altitude, slope of the land and position of the area in relation to the sun.
- Land influences the amount of sunlight and rain that an area receives. It also influences the temperature of an area.
- The distribution of animals found in various habitats depends on the type of land. There are animals in lowlands while others are found on highlands.

i. Soil

- Soil vary according to their particle size, pH, amount of water they contain. All these variations have a large influence on the types of plants that grow in certain places.
- Soils that are rich in certain minerals are more suitable for certain types of plants.
- Some types of plants grow well in acidic soils, and other types of plants prefer more alkaline soils. Most plants prefer neutral or slightly acidic soils.

Sampling

- A **sample** or **representative sample** is a small group of organisms that represent the whole population.
- The method of obtaining a representative sample is called **sampling**.
- A sample gives an estimate. An estimate may be lower or higher than actual population by a particular margin.

- The difference between the actual population and a sample is small when a large sample is used than when a small sample is used. Therefore a large sample gives almost accurate results. It is therefore recommended that when sampling, use a larger number of organisms to represent the whole population.

Estimating Plant and Animal Populations

- Various methods are used to obtain samples and to estimate populations of organisms in different habitats. These methods include:
  1. Quadrat method
  2. Line transect
  3. Belt transect and
  4. Capture- recapture

1. Quadrat Method

- A quadrat is a framework used to get a representative sample of organisms over a large area being studied.
- A quadrat is mostly square in shape though some can be rectangular or circular.
- A quadrat is a framed area, and can be made from strong plastic piping or strong cardboard.
- A quadrat can be of any size, but one with sides of 50 cm by 50 cm is convenient size to use in a field.

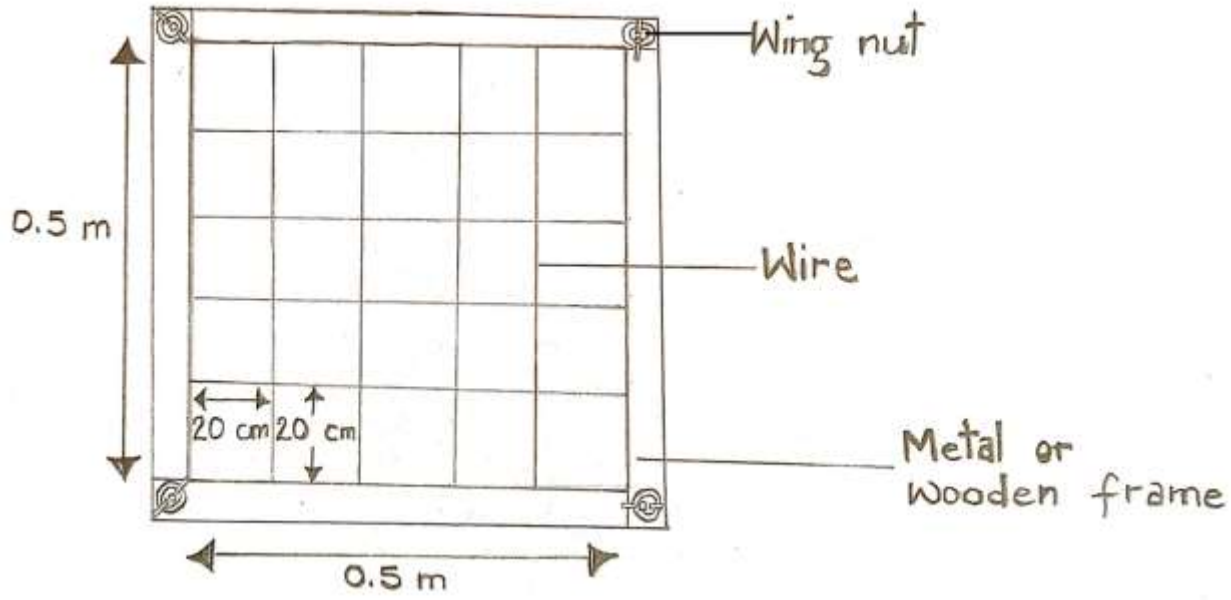


Fig. 7.1: A quadrat

- In quadrat method, a square frame usually of $0.25\ m^2$ is thrown randomly to land anywhere in an area in which an organism population is being sampled.
- The following procedure is used to estimate the population of a given organism in an area.
  (i) Select an area in which the organisms to be studied are found. For example, you can sample the population of tridax in a school playing field.

(ii) Estimate the size of selected area in square metres (m^2). For example, estimate the size of the school playing field.

(iii) Throw the quadrat randomly into selected area. This means throwing the quadrat anywhere in the playing field without deliberately deciding where it should land. Identifying the plants for example, tridax, whose population is being estimated in the quadrat. Count and record the number of these plants against quadrat throws in your notebook.

(iv) Repeat the third step in the procedure several times and record your results in the table like the one shown below.

Quadrat Throw	Number of Tridax
1	3
2	2
3	4
4	3
5	2
6	2
7	5

- The number of times of quadrat throws will depend on the size of the whole area. The larger the area, the more times the third step is repeated.

(v) Calculate the average number of plants in each quadrat.

- The number of organisms for example, the tridax may vary in different parts of the school playing field. Therefore it is important to calculate the average number of plants in each quadrat in order to get an approximate number of plants in $0.25\ m^2$.

$$\textit{Average number of tridax per quadrat} = \frac{3+2+4+3+2+2+5}{7}$$
$$= \frac{21}{7}$$
$$= 3$$

- Calculate the approximate number of organisms in the whole area by using the formula below:

$$\text{Estimated plant population} = \frac{Average\ number\ of\ plants\ in\ a\ quadrat \times Total\ area\ of\ the\ field}{Area\ of\ the\ quadrat}$$

- If the area the school playing field was *100 m^2* , the total population of tridax in the field would be:

$$\text{Total population} = \frac{3 \times 100\ m^2}{0.25\ m^2}$$

$$= 1200$$

Note:
The quadrat method of sampling organisms is most suitable for organisms which do not move about. For example plants.

Advantages of the Quadrat Method

(i) A quadrat is easy to make
(ii) It is easy to count organisms in a small area than counting all organisms in the whole area
(iii) Quadrats can be used to determine the percentage distribution of organisms in an area

Limitations of the Quadrat Method

(i) Quadrats can only be used to sample small plants
(ii) They cannot be used in all areas; for instance on very steep slopes.
(iii) They cannot be used to sample moving animals because they may easily move in and out of the quadrat.

2. Transect Method

- There are two types of transects:
  a. Line transect and
  b. Belt transect

a. Line Transect

- This method involves the use of straight line cutting across an area in which the organisms to be sampled are found.
- Quadrats are placed at a regular intervals along the line and the plant species of interest within the quadrat are identified, sampled, counted and recorded then analysis is done.
- This method is suitable for sampling in uniform habitats e.g. grassland.

b. Belt Transect

- This method involves the use of two parallel lines (transects), 1, 2 or 3 metres apart. These lines cuts across an area in which the organisms to be studied are found. The length of transect is measured. The whole area where organisms being sampled are found is determined. Species are then sampled by use of quadrat and line transect.

3. Mark and Recapture (Capture- Recapture) Method

- The method is also called capture- release- capture method.
- The method is ideal for estimating number of animals that are highly mobile such as grasshoppers.
- The method involves the following steps:
  (i) Organisms are captured using appropriate methods e.g. sweep net for grasshopper population. The organisms are then counted, marked, recorded in a notebook and then returned to their habitat. Nail varnish can be used to mark the captured organisms.

(ii) After a fixed interval of time the organisms are recaptured and noting those originally captured and recaptured by the way of marks.
(iii) The population size is then estimated using the formula:

Total population

$$= \frac{Number\ of\ organisms\ in\ initial\ capture\ \times Number\ of\ organisms\ in\ recapture}{Number\ of\ marked\ recapture\ organisms}$$

Example

- Precious and Parosh caught 200 grasshoppers in a school garden of area *40 m^2* and marked them with nail varnish. They released them into the same garden. After two hours Precious and Parosh captured 150 grasshoppers in the same area of which 50 had marks of nail varnish.
  a. Calculate the total population of grasshoppers for this area.
  b. Calculate the population density of grasshoppers.

Solution

a. Total population

$$= \frac{Number\ of\ organisms\ in\ initial\ capture\ \times Number\ of\ organisms\ in\ recapture}{Number\ of\ marked\ recapture\ organisms}$$

$$= \frac{200 \times 150}{50}$$

$$= 600\ grasshoppers$$

b. *Population density* $= \frac{Total\ population\ of\ grasshoppers}{Total\ area\ of\ school\ garden}$

$$= \frac{600\ grasshoppers}{40m^2}$$

$$= 15\ grasshoppers/\ m^2$$

Advantages of Capture- Recapture Method

(i) It is easy to estimate population of moving animals over a given area
(ii) It can be used to show the distribution of animals in a given area

Limitation of Capture- Recapture Method

(i) The method cannot be used to estimate plant population
(ii) It interferes with the environment of the animals
(iii) Some methods of trapping can cause harm to an animal resulting in migration from the area during the time of study

Identifying Organisms Using Local and Scientific Names

- Scientists use scientific names for organisms to avoid confusion since same plant or animal may have different names in different community.
- Scientific names for plants and animals are derived from their Latin names, and are always written in italics.

Identifying the Following Organisms Using Local Names

Organism	Scientific Name	Local Name (s)
Lion	*Panthera leo*	
Leopard	*Panthera pardus*	
Cow	*Bos taurus*	
Dog	*Canis domestica*	
Housefly	*Musca domestica*	
Cockroach	*Periplaneta americana*	
Bee	*Apis mellifera*	
Mango	*Mangifera indica*	
Maize	*Zea mays*	

Adaptations of Plants to Various Habitats

- Plants can be grouped into four classes depending on the habitats in which they are found.

A. Xerophytes

- Xerophytes are plants that live in dry environments e.g. deserts. The habitat is characterised by:
  - Low rainfall
  - High temperatures
  - Windy conditions
  - Low humidity
- Adaptations of xerophytes include the following:

1. Their leaves are modified into thorns which reduces the surface area for transpiration.
2. Have leaves with thick waxy cuticle which prevents excessive water loss through the leaf by evaporation
3. Some have succulent stems or leaves which store water.
4. They have deep roots that search out water deeper in the soil.
5. They have hairs that keep damp air near the surface. This reduces the diffusion gradient and lowers the rate of transpiration.
6. Some xerophytes have few stomata which are located on the lower epidermis to reduce rate of transpiration
7. Some have sunken stomata with moisture accumulating within the sub- stomatal air chamber. This causes low diffusion rate and therefore less transpiration rate.
8. Some xerophytes have reversed stomata rhythm i.e. stomata opens at night and closes during the day to reduce transpiration rate.
9. Some have curled leaves to expose few stomata thereby reducing transpiration rate.

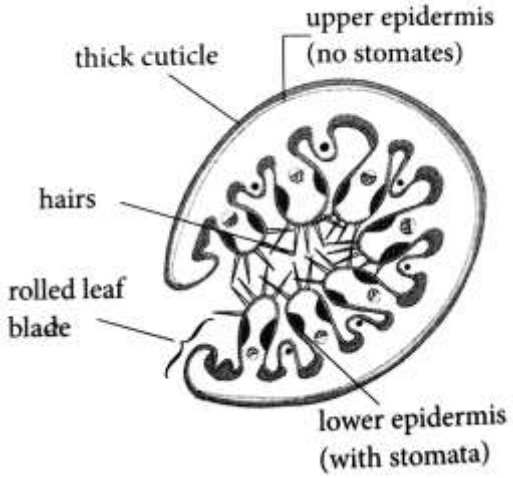


Fig. 7.2: Rolled leaf of murram grass (Ammophila)

10. Some xerophytes have life cycles that enable them to evade dry season. For instance:
    a. Some have very short life cycles. They grow very fast during the short rains, produce seeds and then die.
    b. Some have seeds that remain dormant in dry periods.

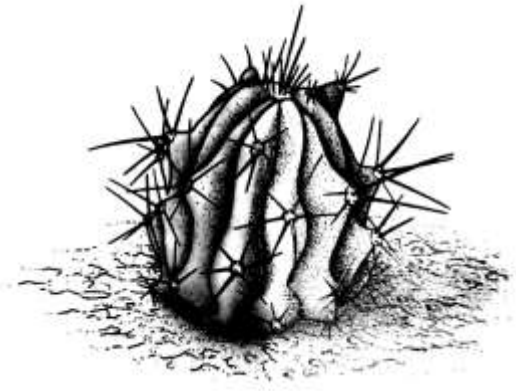


Fig. 7.4: Ferocactus- a plant adapted to live in deserts

B. Mesophytes

- Mesophytes are plants growing in environments with sufficient water supplies e.g. in savannah grassland or rain forests. The habitats are characterised:
  - Sufficient rainfall
  - High humidity
  - Moderate high temperatures
  - High water table
- Adaptations of mesophytes include the following:

1. They have thin leaves. This ensures rapid diffusion of gases from stomata to photosynthetic cells.
2. Their leaves are broad and flat to provide a large surface area for absorption of light and carbon dioxide

3. Mosaic arrangement of leaves on the plant, make sure that each leaf receives maximum sunlight
4. There is presence of stomata on both upper and lower leaf sides for efficient gaseous exchange and also for transpiration
5. The mesophyll layer in the leaves have air spaces that allow free circulation of gases.
6. Their leaves have cells with chlorophyll so that photosynthesis takes place.
7. They have thick transparent cuticles to prevent water loss
8. They have well developed root system with long tap or fibrous root and root hair cells for absorption of water
9. Have support devices to reach out for light. For example, climbing plants have tendris.
10. Exhibit fast growth rates in order to compete for light.

C. Hydrophytes

- Hydrophytes are plants growing in fresh waters. The habitat is characterised by fresh water with few dissolved gases and low penetration of light.
- Adaptations of hydrophytes include the following:

1. Have chloroplasts which are sensitive to low light intensity. This enables them to synthesise food even under low light intensity.
2. The plants develop aerenchyma tissue (air- filled tissues) which store the oxygen from photosynthesis to use in respiration and reduces density for buoyancy to stems and leaves.
3. Leaves emerge and float and have maximum number of stomata on the upper surface to provide a large surface area for gaseous exchange.
4. Leaves are covered with waxy substances to reduce excessive water absorption.
5. Floating species have long fibrous roots for absorption of mineral salts.
6. When submerged the plants have thinly divided leaves which are thread like to give a large surface area for maximum absorption of light.

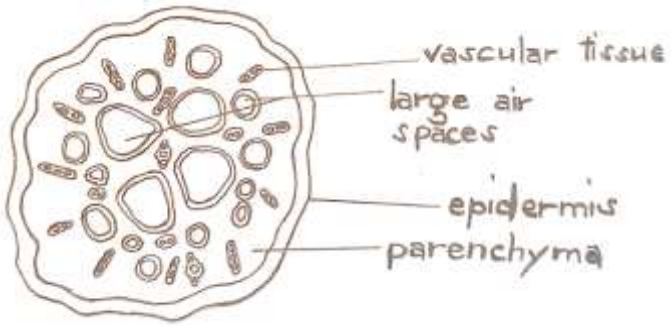


Fig. 7.5: A cross-section through the stem of a hydrophyte to show aerenchyma

D. Halophytes

- Halophytes are plants growing under saline conditions. The habitat is characterised by:
  - High mineral salt concentration

- Low concentration of dissolved gases
- Light of low intensity
- Currents and waves

- Adaptations of halophytes include the following:

1. They emerge above the water so as to carry out photosynthesis.
2. They have developed aerenchyma tissue for buoyancy and gaseous exchange.
3. They have prop roots for support
4. They have flexible stems which can sway with the current.
5. Some have breathing roots which emerge above the water surface for gaseous exchange
6. Some have root cells with ability to trap and concentrate salts so that the hypertonic level developed enables them to draw water by osmosis from their environment.

Adaptations of Animals to Various Habitats

Adaptations of Camels

1. They are capable of drinking a lot of water (up to 120 litres of water at one drinking session) so they can survive for long time without taking water
2. They store fat in their hump that are broken down to release metabolic water in times when water is not available
3. Their body temperature changes from 34˚C to 41.7˚C. This allows the camel to conserve water by not sweating as the environmental temperature changes.
4. Their feet are wide so they can walk on sand without sinking.
5. They have thick lips so they can eat the thorny desert plants.
6. Their ears are covered with hair to keep out sand or dust that might blow into the animal's ear.
7. They have two rolls of long eyelashes to protect their eyes against blowing sand and the hot air.
8. They are covered with thick fur for insulation
9. Their nostrils can be closed to keep out blowing sand
10. They have thick leathery patches on the skin of their knees to protect the knees from getting burnt when they kneel on the hot desert sand.
11. They have long legs to raise the body further away from the heat on the ground.

Adaptations of Polar Bears

- Polar bears are mammals that live in very cold areas under freezing temperatures

Fig. 7.6: Polar bear

- The adaptations of polar bears to their habitat include:
  1. They have long, stiff hair between pads of their feet. The hair protects bear's feet from cold and slipping when walking on ice cold
  2. They have hallow fur which traps air inside providing insulation between their warm bodies and the environment.
  3. They have small and rounded ear lobes. This prevents water from entering the bear's ears and freezing their eardrums.
  4. They have a thick layer of fat under their skin (about 10 cm in thickness) to insulate bear from cold temperatures.
  5. The skin under fur is black. This is to ensure that the polar bear has a better heat retention.

Adaptations of Goats

1. They have hooves with a soft spongy inner pad. This enables goats to climb cliffs with greater speed
2. They have rectangular pupil in their eyes that enables them to have excellent night vision.
3. Their hooves are flexible to assist balance on steep surfaces
4. Their hind legs are heavily muscular to assist in jumping of greater distance.
5. Their teeth are able to regrow after being worn out during feeding
6. They have four chambered stomachs for digestion of fibres found in plants materials they feed on
7. They are browsers hence can get food from twigs and from shrubs. This makes them not to rely on grass alone hence overcome competition with other herbivores

Adaptations of Sharks

1. Their bodies are pointed at both ends. This makes the bodies to be streamlined to enhance efficient swimming
2. Their bodies are covered with sharp scales to provide protection

3. Rather than bone, sharks have cartilage, which is much lighter and flexible. This makes their bodies to be more flexible during movement

Feeding Relationships

- Organisms eat each other and these feeding relationships can be expressed in a number of ways including food chains, food webs, pyramid of numbers, pyramid of biomass and pyramid of energy. These five are linked by a simple idea of energy flow through an ecosystem.
- To understand these ideas you first need to know about different ways of feeding.

Trophic Levels (Feeding Level)

- Organisms in an ecosystem may be grouped into trophic levels depending on the way they feed.

1. **Producers** - are plants which convert water and carbon dioxide into glucose using sunlight as source of energy.
2. **Primary (First Order) Consumers**- are animals that eat the producers and they include herbivores such as cow, zebras and grasshoppers.
3. **Secondary (Second Order) Consumers**- are animals that eat primary consumers and they include carnivores such as lions, and lizards.
4. **Tertiary (Third Order) Consumers**- are animals that eat secondary consumers. They can be either carnivores or omnivores.
5. **Detrivores** - are animals that feed on decomposing materials. They include animals such as beetles, earthworms and cockroaches
6. **Decomposers**- are organisms that utilize the energy stored in the remains of other organisms. They cause decay or decomposition. For example bacteria and fungi.

Energy Flow

- Energy flow is the process of energy transfer from one organism to another.
- The major source of energy in an ecosystem is the sun. This energy is trapped by green plants (producers) in form of light energy which is converted to chemical energy during photosynthesis. The chemical energy is stored in the glucose molecule. Part of the chemical energy is used up by plants for cell respiration which produces heat energy. This energy is lost to the environment. Some of the chemical energy is used by plants to build their own compounds which is made available to the next trophic level.
- First order consumers get energy by feeding on producers. However, not all the energy absorbed by plants is transferred to the first order consumers because the animals may be able to eat part of the plant, so that the energy in roots is unavailable to it and not all the parts eaten by animals is digested. Lignin and cellulose cannot be digested by many animals so that these energy- containing molecules are lost from animal's body as faeces. Altogether, a lot of energy is lost while being transferred from plant to an animal.
- Second order consumers get energy by feeding on first order consumers. Similarly, not all the energy stored in first order consumers would be transferred to the second order consumers. This so because most of the food that is digested by animals is used to produce energy for

heat which is lost from the ecosystem. Only a small proportion of food is used for growth which is made available to the next trophic level.

- Decomposers break down dead plants and animals to obtain energy and some of which is used to build their own body compounds.

Food Chains

- A food chain is the feeding relationship of the different organisms in the ecosystem.

Examples of Food Chains

a. $Grass \longrightarrow Antelope \longrightarrow Lion$

b. $Grass \longrightarrow Mouse \longrightarrow Snake \longrightarrow Eagle$

- The organisms have been arranged according to their trophic levels and arrows show the flow of energy from producers to primary consumers to secondary consumers.

Food Webs

- A food web represents several food chains that are interlinked. This is because of the fact that an organism may have more than one source of food. For example, a hawk does not only rely on the grasshopper for food but also on other animals such as praying mantis and chameleon.

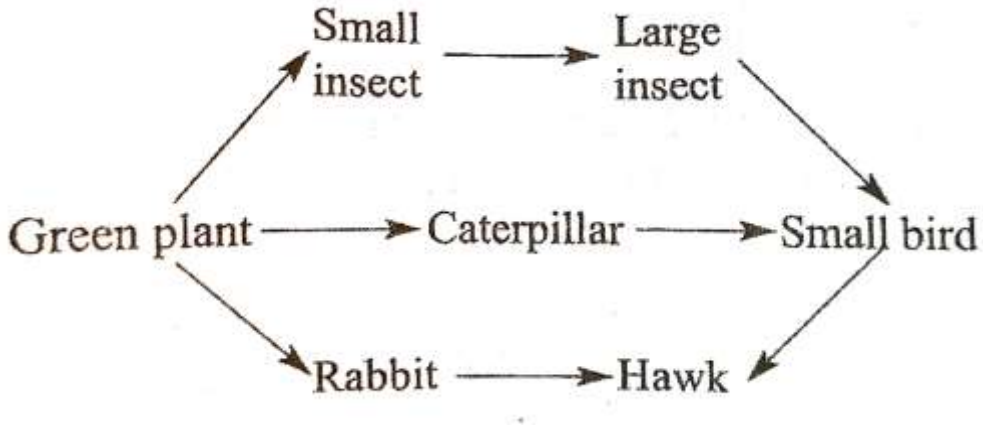


Fig. 7.6: A food web

Pyramid of Numbers

- Pyramid of numbers is the number of organisms present at each trophic level.
- The continual loss of energy means that the size of population must be reduced as you move along the food chain.

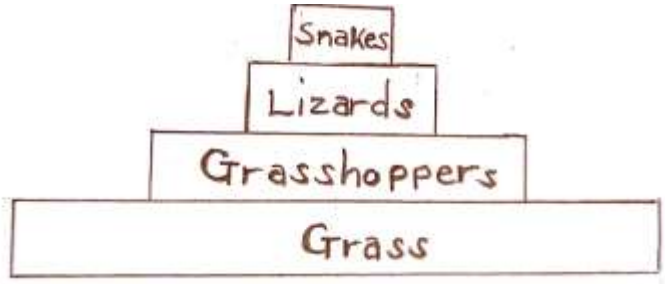


Fig. 7.7: Pyramid of numbers

Note: - The number of organisms at each trophic level is represented by length of a rectangle.

- Sometimes a pyramid of number may be inverted, particularly if the producers are fewer than other organisms in higher trophic levels.

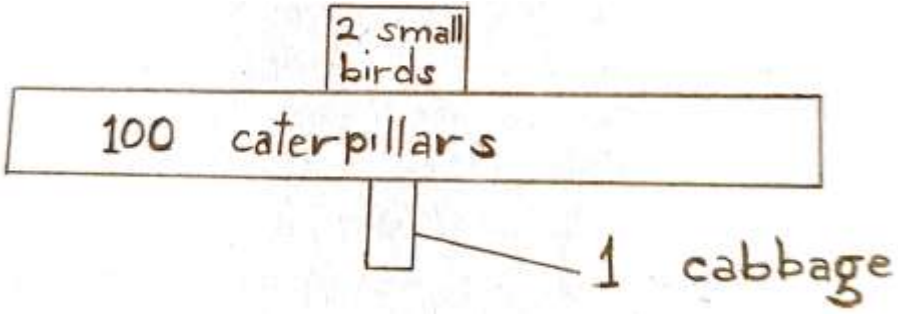


Fig. 7.8: An inverted pyramid of numbers

- This pyramid shows that one head of cabbage is supporting 1 000 caterpillars and small 2 birds are supported by 1 000 caterpillars. If you want to come up with a normal pyramid using the same organisms, then you need to draw a pyramid of biomass.

Pyramid of Biomass

- A pyramid of biomass is diagram showing the total mass of organisms present at each trophic level.

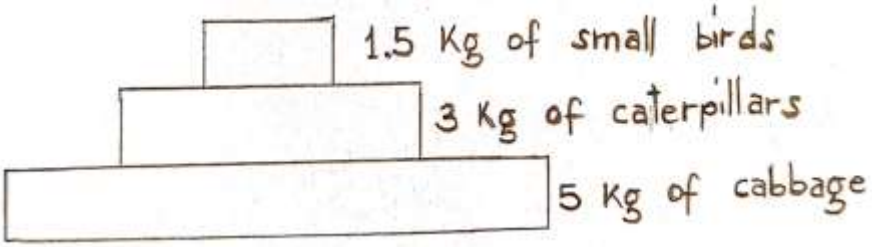


Fig. 7.9: Pyramid of biomass

Pyramid of Energy

- A pyramid of energy shows the amount of energy at each trophic level.
- Pyramid of energy are always upright. This means that the trophic levels at the bottom of the pyramid have more energy compared to those at the top of the pyramid. This because, as the lower trophic levels transfers energy to the upper trophic levels, some energy is lost.

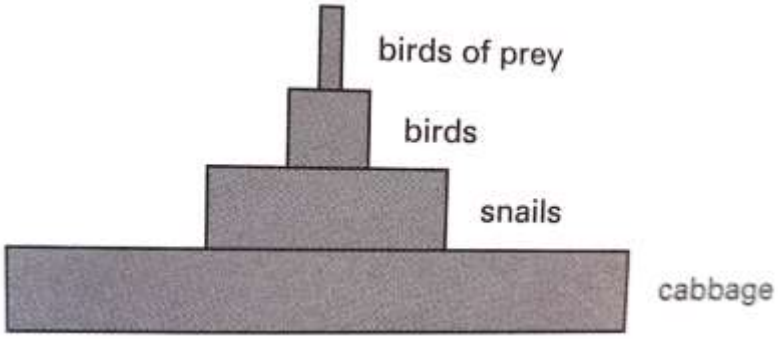


Fig. 7.10: Pyramid of Energy

Nutrient Cycles

- When living organisms die, their bodies decompose. However, the nutrients contained in dead bodies are not lost, but released into the environment and used again and again.
- The most important nutrients that are contained in living organisms are the elements hydrogen, oxygen, carbon and nitrogen. A nutrient element is taken up by a plant or animal, used, and then released again when that plant or animal dies. A new plant or animal takes up the nutrient. In this way, nutrients are recycled through the ecosystem.

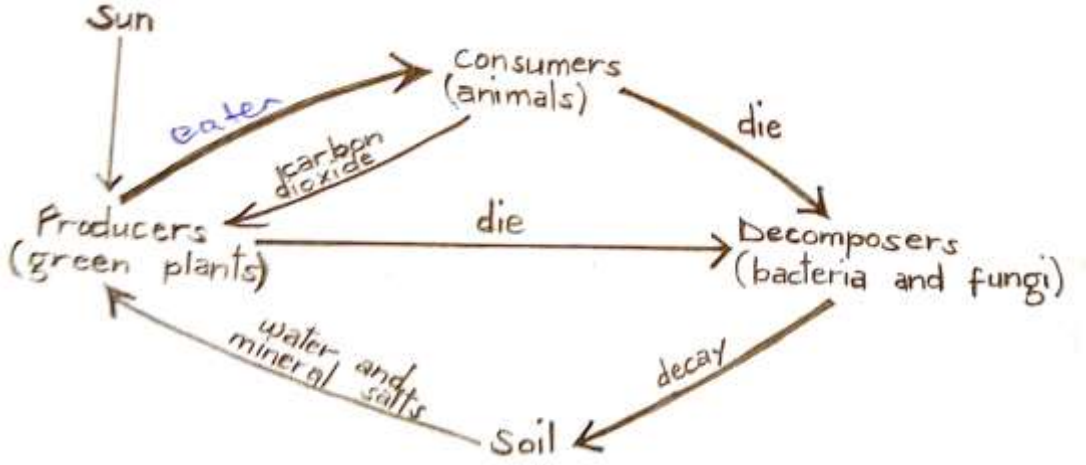


Fig. 7.10: Recycling in an ecosystem

The Nitrogen Cycle

- Nitrogen cycle is a pathway in which nitrogen of the air circulates between living tissues and the atmosphere. It becomes part of living tissues by being converted into organic forms. This happens by first, fixation of nitrogen into nitrates by various agents like free living bacteria in the soil and those found in the root nodules of leguminous plants. The nitrates are then converted into organic material by plants. These organic materials form tissues of plants. Animals feed on plants and obtain these organic materials. When both plants and animals die, the organic materials forming the tissues are broken down through decay and decomposition to release ammonium compounds into the soil. The ammonium compounds in the soil are in turn converted back into nitrates which are usually available for use by existing plants. Some of these nitrates are lost by leaching process or converted to nitrogen of the air through a process called **denitrification**.
- In summary the nitrogen cycle involves four processes.
    1. **Nitrogen Fixation**- the process by which atmospheric nitrogen is converted into nitrates. It is carried out through either of the following methods:
        (i) **Lightening**- catalyses the conversion of atmospheric nitrogen into nitrates through formation of nitrites (NO_2) which is then converted into nitrates.
        (ii) Nitrifying bacteria converts free nitrogen into nitrates. These bacteria include free living bacteria in the soil and rhizobium bacteria in the root nodules of leguminous plants.
        (iii) **Haber process**- is carried out by man during synthesis of ammonia from atmospheric nitrogen.
    2. **Nitrification**- this refers to conversion of ammonia to nitrites (NO_2) catalysed by **nitrosomonous bacteria** and then nitrite to nitrate (NO_3^-) catalysed by nitrobacter.

3. **Putrefication-** is the decomposition of dead matter. This can be plants or animals. The nitrogen in these organic matters is converted back to ammonia then to nitrates.
4. **Denitrification**- is the conversion of nitrate back to free nitrogen by denitrifying bacteria e.g. *Thiobacillus denificans*.

Summary of Nitrogen Cycle

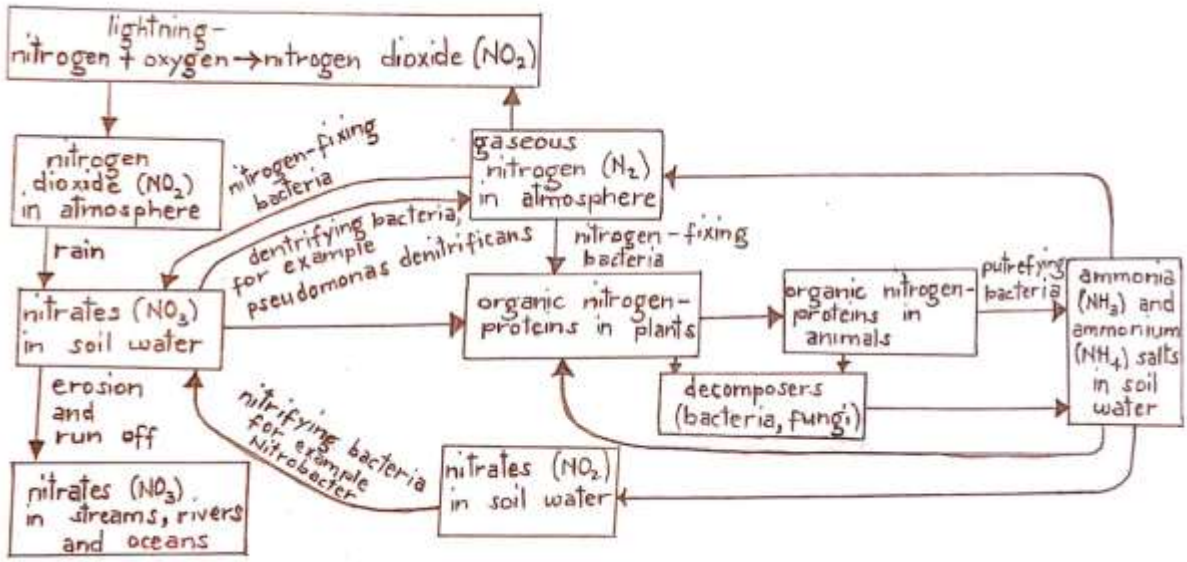


Fig. 7.11: Nitrogen cycle

The Carbon Cycle

- Carbon is found in form of carbon dioxide in the atmosphere. Carbon dioxide is also found dissolved in water.
- Photosynthetic organisms use carbon dioxide to make glucose. Glucose is used to make other complex organic substances. Movement of food substances from one consumer to another results in movement of carbon.
- The food substances in plant tissue are used by primary consumers. The primary consumers are eaten by secondary consumers. This transfers food substances containing carbon from one trophic level to another.
- Carbon is released back into the atmosphere in the following methods:
  1. Respiration
  2. Decomposition and
  3. Combustion

1. **Respiration**
   - During respiration, carbon dioxide is produced as a by- product. It is released back to the atmosphere
2. **Decomposition**
   - As the dead organisms decompose, carbon dioxide is released back into the atmosphere.
   - The wastes that are produced by organisms contain carbon compounds and when these wastes decompose, carbon dioxide is released back into the atmosphere.
3. **Combustion**

- Human activities releases a lot of carbon dioxide into the atmosphere. These activities include:
  (i) Use of fuels in homes for cooking
  (ii) Fires used to burn fields, vegetation and wastes
  (iii) Heating and burning fossil fuels especially in industries and fuels in engines of vehicles. Fuels contain carbon which when burned releases carbon dioxide into the atmosphere
  (iv) Use of limestone in industries. Limestone is formed deep in seas when carbon dioxide combines with calcium. The use of limestone results in release of carbon into the atmosphere.

Summary of Carbon Cycle

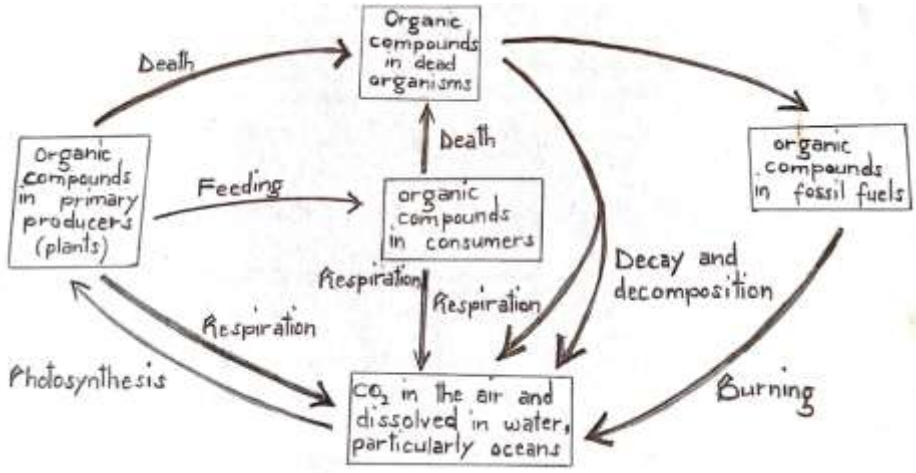


Fig. 7.12: Carbon cycle

Water Cycle (Hydrological Cycle)

- Water cycle describes the continuous movement of water from the atmosphere as rain to the surface of the earth, to bodies of living organisms, to water bodies and then release of water vapour back to the atmosphere.
- The cycle involves the following processes:
  1. Evaporation
  2. Condensation
  3. Precipitation and
  4. Infiltration

1. Evaporation

- Liquid water from bodies of living organisms, earth's surface and water bodies heats up and vaporises.
- When plants transpire, the water vapour escaping through the stomata evaporates into the atmosphere.
- Animals release wastes with some moisture. Due to the warmth in their bodies, some of the water is converted to water vapour and it evaporates into the atmosphere.
- Animals also lose water from the surfaces of their bodies through sweating and through evaporation. This water rises up into the atmosphere as water vapour.

2. **Condensation**
   - In the atmosphere, the water vapour undergoes condensation to form clouds.

3. **Precipitation**
   - Condensed water is released to fall back to the earth in form of rainfall. This is called **precipitation**.

4. **Infiltration**
   - After rainfalls, water goes to the ground. It is stored underground. Some of the underground water comes out to form rivers, springs and wells.
   - Excess water that cannot infiltrate into the soil flows on the ground due to gravity. This water forms surface runoff. It flows to the rivers that direct it to large water bodies such as lakes and seas.
   - Some of the water is taken by living organisms for use in their bodies.
   - The flow of water over the whole environment forms a continuous cycle.

Summary of Water Cycle

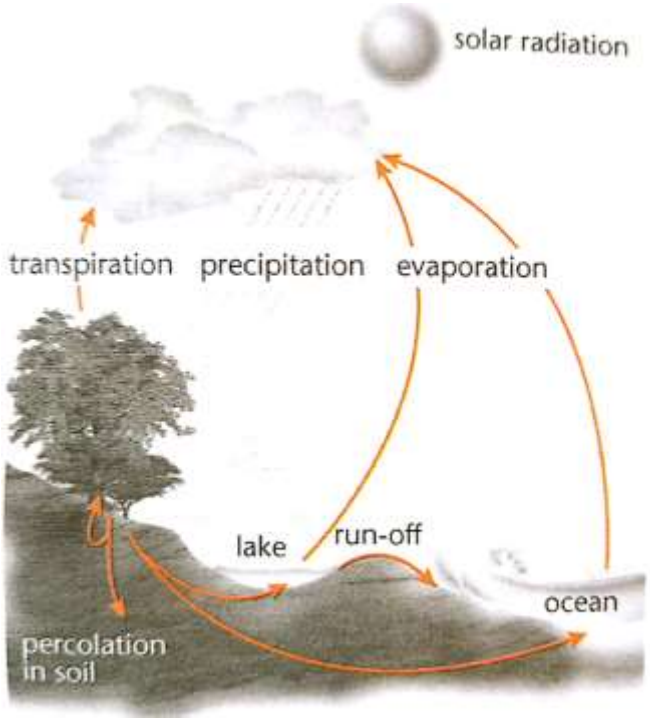


Fig. 7.12: Water cycle

Impacts of Human Activities on the Environment

1. **Land Degradation**
   - This is the temporary or permanent lowering of the productivity of land.
   - It can be caused by natural causes or through human activities.
   - Such land can also be described as damaged because it does not have the quality required to sustain plant growth and development effectively
   - Human activities such as deforestation, poor farming methods and overgrazing leads to soil erosion. Topsoil that is rich in organic matter and nutrients, capable to hold and

provide nourishment to plants is washed away. Without it the land becomes less fertile and its agricultural productivity reduces.

Reasons why Environment is degraded by Human Activities

a. Poverty

- When people are poor and hungry, and do not have the resources to feed themselves and their families, they care very little for the environment. This means that they harm the environment, without really meaning to do so. For example hungry people will let their livestock overgraze lands so that they can get meat and milk from the livestock.

b. Illiteracy

- Illiterate people may not understand the importance of caring the environment hence this may lead people to carry out some of activities which may degrade the environment.

c. Overpopulation

- Overpopulation places huge demand on natural resources and the environment which may lead to environmental degradation.

d. Attitude

- Many people have negative attitude towards conservation and caring for environment. They don't think about the future and whether the environment will be in good condition for future generations. Negative attitude leads to environmental degradation.

2. Pollution

- It is the addition of something to the environment which can damage the living organisms within it.
- The substances that cause pollution are called pollutants. These pollutants are released into the environment as a result of human activities such as combustion of fuels, use of pesticides and disposal of domestic sewage and industrial wastes.

Types of Pollution

- Types of pollution include:
  a. Water pollution
  b. Air pollution
  c. Soil pollution

a. Water Pollution

- Water pollution is the addition of harmful substances into water as a result of human activities.
- Some of sources of water pollution include:

(i) Pollution from Untreated Sewage

- The release of organic substances such as human faeces and sewage into water bodies like lakes and rivers causes water pollution.

- Sewage provides extra nutrients to algae and other surface plants so that they grow faster, and block out light for plants growing beneath them. These plants, and eventually the algae as well, die.
- The dead plants and algae provide food for bacteria, so populations of bacteria increase. These bacteria respire aerobically and use up oxygen from the water. Animals living in water cannot breathe, and so they have to move away or die.
- The whole process is called **eutrophication** (the outgrowth of aquatic plants resulting from an excess of nitrogenous salts reaching rivers). It can happen whenever plant nutrients get into ponds, lakes, rivers or sea. Eutrophication is also caused by fertilizers.

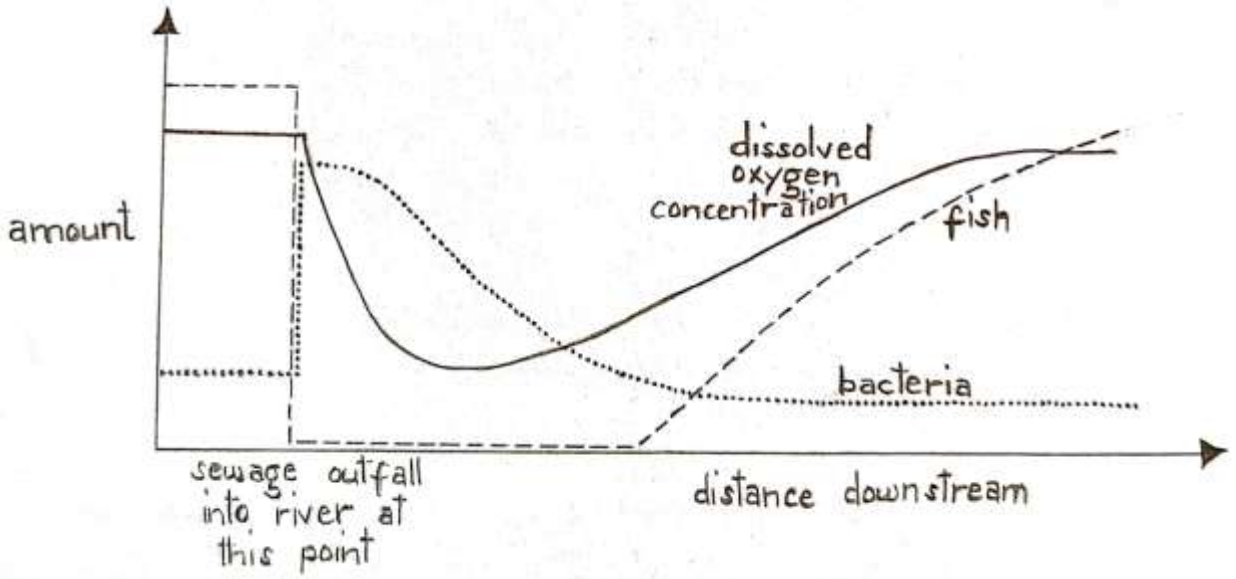


Fig. 7.13: Changes in dissolved oxygen, bacteria and fish, upstream and downstream of an outfall of untreated sewage

- Untreated sewage introduces into the water, organisms that cause diseases to humans such as typhoid, cholera and dysentery.

(ii) Agricultural Practices

- Pesticides are chemical compounds that are used to kill pests that damage crops.
- Pesticides and excess fertilizers may enter into rivers and lakes through runoff water after the rains.
- The pesticide is absorbed by water plant and then taken up by animals as they feed on plants. The pesticide is then passed on to the secondary consumer as they feed on the primary consumer.
- The pesticide, such as DDT, does not breakdown inside the body of organisms so that the concentration increases from one trophic level to the next since organisms at the top of the chain feed on more on those at lower feeding level. The pesticide may be toxic (and kill the carnivore) or may affect its metabolism. DDT used to control mosquitoes in malaria zones, severe reduced breeding success in birds.

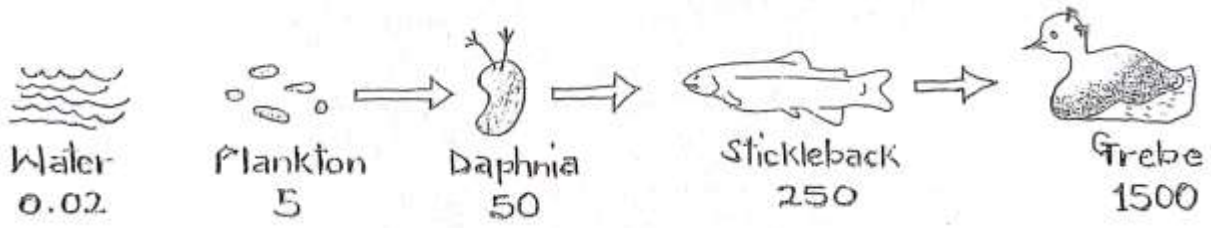


Fig. 7.14: DDT concentration in a food chain

- Excess fertilizers contains nitrates which causes eutrophication in water. Eutrophication causes death of aquatic organisms.

(iii) Industrial Wastes

- Industrial wastes for example from breweries, textiles and paper industries contain toxic chemicals. These chemicals are harmful to organisms even in small amounts. This is because they can accumulate in fish and other aquatic organisms and then be transferred along the food chain to other organisms including fish eating birds and humans.

(iv) Oil Spills

- Water gets polluted by oil that spill off from oil tankers in sea as a result of accidents. Such oils is toxic to aquatic plants and animals and kills many types of bacteria. Water birds die when they ingest the oil trying to clean it off from the feathers.
- Oil also reduces entry of oxygen into water and this leads to death of aquatic organisms.

(v) Detergents from Washing in Home

- Detergents releases phosphates into water. Phosphates causes frothing and eutrophication in water bodies.

(vi) Hot Water from Industries

- Some industries use water to cool hot engines. When the hot is released into water body, it causes release of oxygen from water. This leads to death of aquatic animals such as fish.

b. Air Pollution

- It is the addition of waste substances from human activities into the air.
- Some of the sources of air pollution include:
  - (i) Factories, this is in the form of industrial gaseous waste like carbon dioxide, sulphur dioxide and carbon monoxide
  - (ii) In burning of fossil fuels like coal and wood which produce carbon dioxide and carbon monoxide gases.
  - (iii) Motor vehicles which burn petrol to produce car exhaust fumes with lead from leaded petrol and carbon monoxide
  - (iv) Motor vehicle exhaust also produce nitrogen oxide and hydrocarbons.
  - (v) Soot from burning fuel is released to the air
  - (vi) Smog due to smoke produced by factories combining with fog.

(vii) Use of aerosols. Aerosols are liquid substances put under high pressure so as to release them as sprays for example, in pesticides.

Effects of Air Pollution

(i) Causes Acid Rain

- Fossil fuels, especially coal, contain small amounts of sulphur- containing compounds. When these burn, the sulphur combines with oxygen to form **sulphur dioxide**
- Sulphur dioxide causes **acid rain**. In the atmosphere, sulphur dioxide may be oxidised to sulphur trioxide. Sulphur trioxide dissolves in water droplets in clouds to form sulphuric acid, which then falls to the ground as rain.
- Acid rain can damage the leaves of trees.
- The acid rain also washes out aluminium ions from the soil which accumulates in rivers and lakes. Aluminium ions are toxic to fish, especially young ones, as they can stop the gills working properly.

(ii) It causes Greenhouse Effect

- The burning of fossil fuels produces and releases large amount of carbon dioxide into the atmosphere. The increased concentration of carbon dioxide traps the radiant energy of the sun. This raises the global temperatures by slowing down the loss of heat from the earth's surface to outer space.

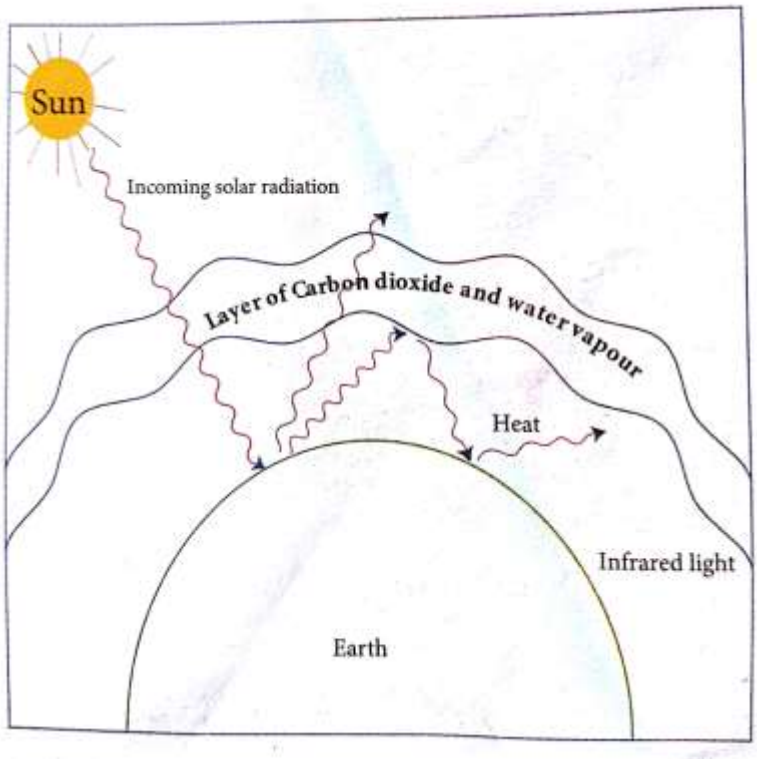


Fig. 7.15: Greenhouse effect

(i) Affects Breathing

- When polluted air is inhaled by human beings and other organisms, their respiratory systems are affected.

(ii) Depletion of the Ozone (O_3) Layer

- Air pollution by gases from aerosol cans and refrigerators react with and depletes the ozone layer.
- Thinner sections of the ozone layer allows more harmful ultraviolet radiation to the earth. This may increase the rate of skin cancer in humans, damage to crops and cases of cataracts.

(iii) Causes Lead Poisoning

- Lead compounds are usually added to petroleum to improve efficiency of its combustion. As a result, exhaust gases from vehicles contain certain lead compounds.
- The lead compounds are released into air and can be inhaled directly or can be incorporated in food crops. For example, crops grown along busy highways have a high level of lead.
- Exposure to high levels of lead for a short period of time can cause permanent brain damage in children.
- Exposure to low levels of lead for a long period of time results in loss of weight, weakness and anaemia in children.

(iv) Photochemical Smog

- Photochemical smog is a mixture of air pollutants. Photochemical smog destroys chlorophyll in plants, injures lung tissue and causes irritation in the eyes in humans.

c. Soil Pollution

- Soil pollution is the additional of harmful substances into the soil.
- The main sources of soil pollution are agricultural chemicals and disposal of solid wastes.

(i) Agricultural Chemicals

- Some pesticides such as copper sulphate which are used to control fungi in fruit orchards are insoluble. Therefore, they may accumulate in the soil and reach levels that kill soil organisms especially the nitrogen- fixing bacteria.

(ii) Solid Wastes

- There are two main types of solid wastes:
  a) **Biodegradable Wastes**- Solid wastes which can rot e.g. potato peelings and cabbage pieces
  b) **Non- Biodegradable Wastes**- Solid wastes which cannot rot e.g. plastics, metals and glass. When non-biodegradable are thrown away, they remain in the environment forever. They can be dangerous to small animals that get trapped in them.

3. **Introduction of Alien Species to a Habitat or Community**
   - Introduction of alien species to a habitat or community may lead to new species feeding on indigenous species (e.g. Nile Tilapia predates on the local fish) or competing for food with indigenous species. This may lead to extinction of indigenous species.

4. **Overgrazing**
   - Overgrazing is an environmental degradation that results from feeding large herd of animals on a small piece of land continuously. It causes depletion of plant species or may lead to desertification or siltation of rivers. Siltation cause floods

5. **Deforestation**
   - Deforestation results from wanton cutting down of trees. It leaves the land bare.
   - Deforestation causes soil erosion because vegetation that binds the soil is lost.
   - Deforestation reduces rainfall. This is because plants give off water vapour through their leaves. The water vapour increases humidity in air and helps clouds to form.
   - Deforestation causes changes in weather pattern. Plants absorb carbon dioxide from air for photosynthesis. Carbon dioxide forms a layer in the atmosphere that insulates the earth and prevents heat loss. This is known as **greenhouse effect (global warming)**.

6. **Climate Change**
   - Climate change is the gradual change in weather patterns a given area over a long period of time.
   - Climate change consists of stable or less changing weather conditions observed over a long period of time. These conditions include a given range of temperature, rainfall pattern and amounts, wind velocity, water levels in the sea and volume of water bodies. When the conditions that have been stable for many years change they result to climate change. It is characterised by:
     (i) Rise in temperature of a given area above what has been experienced for years.
     (ii) Changes in seasonal patterns or the months when a certain season starts.
     (iii) Increased winds in a given area.
     (iv) Increased volume of water at certain times.

   Causes of Climate Change
   - Climate change is caused by a combination of factors that are due to human activities. These includes:
     (i) Increased emission of greenhouse gases into the atmosphere i.e. carbon dioxide from burning of fossil fuels and methane gas from fermentation of organic substances.
     (ii) Clearing of forests (deforestation) to give way land for farming, establishment of urban centres and mining activities, leads to destruction of vegetation. Plants consume large proportion of carbon dioxide for photosynthesis. Their destruction causes accumulation of carbon dioxide in the atmosphere.

Impact of Climate Change

a. Floods

- Increased temperatures have led to increased rain intensity causing heavy rains within a short period of time. The rain falls heavily not giving the soil enough time to absorb it. This leads to speedy runoff forming floods within a short period of time. These floods cause destruction of crops, roads, bridges and houses in lowland.

b. Drought

- Climate change has resulted to changes in weather patterns. Unreliable rainfall patterns have made it difficult to time planting and harvesting seasons hence problems in food production.

c. Storm Winds

- Occurrence of strong winds called storm winds is attributed to climate change. These winds destroy houses and increase evaporation of water from the soil. Destruction of forests has led to increase of the storm winds since forests act as windbreakers.

d. Global Warming

- Increase of atmospheric temperatures has resulted in melting of ice caps leading to rise in the levels of seas and oceans. This causes flooding in lowlands.

Ways of Mitigating the Impact of Climate Change

- To **mitigate** means to make something harmful or less severe.
- The impact of climate change can be mitigated by the following ways:

1. **Reafforestation**
   - This is planting of trees in areas that once had trees. These trees will preserve the banks of rivers and hold soil on land to minimise erosion. It will also slow down speed of runoff hence allow infiltration of water into the soil.

2. **Use of Renewable Energy**
   - Increase use of renewable energy such as solar power to reduce dependence on non-renewable energy such as fossil fuels. This will in turn reduce greenhouse gas emissions.

3. **Use of Improved Crop Varieties**
   - Improved crop varieties can grow and mature under unfavourable rainfall patterns.

4. **Practice Conservation Agriculture**
   - Conservation agriculture minimises tilling of land. Land which is not tilled keeps carbon dioxide. In this case soil acts as carbon sink if not tilled because it traps carbon dioxide which would have been released into atmosphere.

5. **Reduce Car Emissions**
   - Use public transport instead of individual cars as this will mean fewer vehicles on road and a reduction in carbon emissions.

- Biotechnology refers to the use of living organisms and their body systems to develop new and useful products that help to improve human life.
- It is the use of knowledge in biology to come up with products, processes and methods that help to solve current problems hence improve life of human beings.
- Biotechnology is used to produce new breeds of plants and animals with better production output, new varieties of crops with higher output, medicines for humans and processes in industry.

Plant and Animal Breeding in Malawi

- Plant and animal breeding is a science that tries to balance yield with resistance to diseases and ability to tolerate environmental conditions such as flooding and drought.
- The department of research in the ministry of agriculture, private research organisations and plant and animal breeders have come up with new livestock breeds and new crop varieties that have boosted food production in Malawi. Examples include:

1. **New Maize Varieties**
   - These are new varieties produced by companies such as "Monsato" and "Pannar" in Malawi. These maize varieties are produced to suit various ecological regions in Malawi. They include:
     a. Early maturing varieties for dry lands such as "PAN 3434' that does well in dry lands and responds to irrigation.
     b. Late maturing varieties for high rainfall areas.
     c. Varieties with increased or doubled production such as "DK 9089" that is known to produce two cobs per stem thus high production.
     d. "Zm 309" commonly known as Msunga banja and "Lm 523" commonly known as Mwayi are the other maize variety that have been introduced in Malawi.

2. **New Dairy Breeds**
   - To increase milk production in Malawi, cross breeding of Malawi Zebu with exotic breeds such as **Friesian** and **Jersey** is being done to produce cross breeds. These cross breeds are well suited to almost all areas of Malawi even where exotic breeds cannot survive. This has increased milk production.

3. **New Poultry Breeds**
   - In attempt to improve the productivity of poultry, a programme of providing Black Australorp chickens for cross- breeding with indigenous chickens has been running for about 50 years. Cross- bred chickens are more productive than pure- bred indigenous chickens. Despite the programme, very few cross- bred chickens are found in rural areas. Farmers tend to keep the Black Australorp for eggs and meat and not for cross-breeding.

Application of Biotechnology

- The knowledge of biotechnology can be used to improve the quality of human life. It can be practically in the following area:

1. **Blood Transfusion**
   - Blood transfusion is the transfer of blood from one individual to another.
   - Successful transfusion is based on patients being given the right type of blood. This is possible by correctly determining the blood group of the donor and recipient through a process known as **blood typing**. Correct typing is based on the genetic knowledge of blood groups.

2. **Plant and Animal Breeding using Artificial Selection**
   - Artificial selection involves choosing individuals with certain desired characteristics and crossing them in such a way that all desired characteristics are inherited by the offsprings.
   - Artificial selection aims at improving the quality of plant and animal breed.
   - The knowledge of genetics has made artificial selection possible because it helps to understand the process of inheritance.

3. **Genetic Counselling**
   - Genetic counselling is a service provided by specialists in human genetic disorders.
   - It seeks to explain to parents with children already affected by genetic disorders the nature of this disorder and probability of them having further affected children. It helps families to reach a decision and take appropriate action in the light of information they obtain.
   - The profession of genetic counselling requires knowledge on genetics and counselling.

4. **Forensic Science**
   - Genetics is also used to determine the parents of children in disputes.
   - The DNA structure of parents and children are studied and then compared. Close similarities between two DNA structures studied suggest closeness in relationship.

5. **Genetic Engineering**
   - Genetic engineering is the process of taking a gene from one species and putting it into another species.
   - It is done to increase crop yield, improve quality of organisms and prevent genetic disorders in offsprings.
   - An organism whose DNA has been added an extra gene is called a **transgenic organism**.
   - Genetic engineering requires knowledge of the structure and function of genes.
   - Genetic engineering has application in the following fields:

a. In Medicine

(i) Genetic engineering is applied in controlling various diseases. For example, in control of *Diabetes mellitus*, the insulin hormone required can be produced using a bacteria.

- The gene that code for the production of the hormone insulin has been taken from human cells and put into bacteria. The bacteria use the instructions on the gene to make human insulin. These genetically engineered bacteria are grown in large, steel containers (fermenters). The fermenters contains all the nutrients needed for growth of bacteria. When fermentation is complete, the mixture containing bacteria is harvested. The bacteria are filtered off and broken open to release the insulin they have produced. The insulin is then purified and then packaged into bottles for distribution.

(ii) In some inheritance disorders, a defective gene can be removed and replaced with by a normal gene to treat the disorder. This technique is called **gene therapy**.

(iii) Vaccines and blood clotting factors are produced from viruses using genetic engineering.

- For example, a vaccine for hepatitis B is produced using genetically modified yeast.
- A vaccine for rabies and cholera are manufactured by genetically modified plants. Bananas are the best plant for manufacturing vaccines, because they grow easily, and the fruits is eaten raw. Cooking destroys the vaccine.

b. In Agriculture

- In agriculture, genetic engineering has been applied in the following areas:

(i) Improving Shelf- Life of Agricultural Produce

- For example, a genetic engineering has been used to lengthen the period required for tomatoes to rot. For instance, a gene is inserted into tomato. The gene prevents production of an enzyme that cause softening of tomato skin after harvesting. This makes tomato to ripen slowly and therefore a longer shelf life in the market.

(ii) Production of Genetically Modified Organisms (GMO)

- Introducing genes that determine certain desired characteristics can change genotype of an individual. For example, introducing genes that result into fast growth and high production modifies crops such as bananas and maize. Such crops are useful in alleviating food shortages.

(iii) Milk Production

- Cows are known to produce large quantities of milk due to influence of a hormone called *Bovine comatrophin* produced in the brain. This hormone stimulates growth and milk production.
- The gene for production of the hormone is removed and inserted in the DNA of bacteria. The bacteria produces the hormone in large scale. The hormone is injected into cows to stimulate high milk production.

The Process of Genetic Engineering

- A section of DNA, is extracted from organism, is translocated into bacterium or virus. The bacterium or virus used in genetic engineering is called a **vector**.
- Inside the bacterial cells is a structure called **plasmid**, where a foreign DNA is inserted. Once bacterium has taken up the piece of DNA successfully, it may divide repeatedly into population of bacterial cells all of which contain replicas of the foreign DNA. This production of large quantities of identical genes by means of genetic engineering is called **gene cloning**.

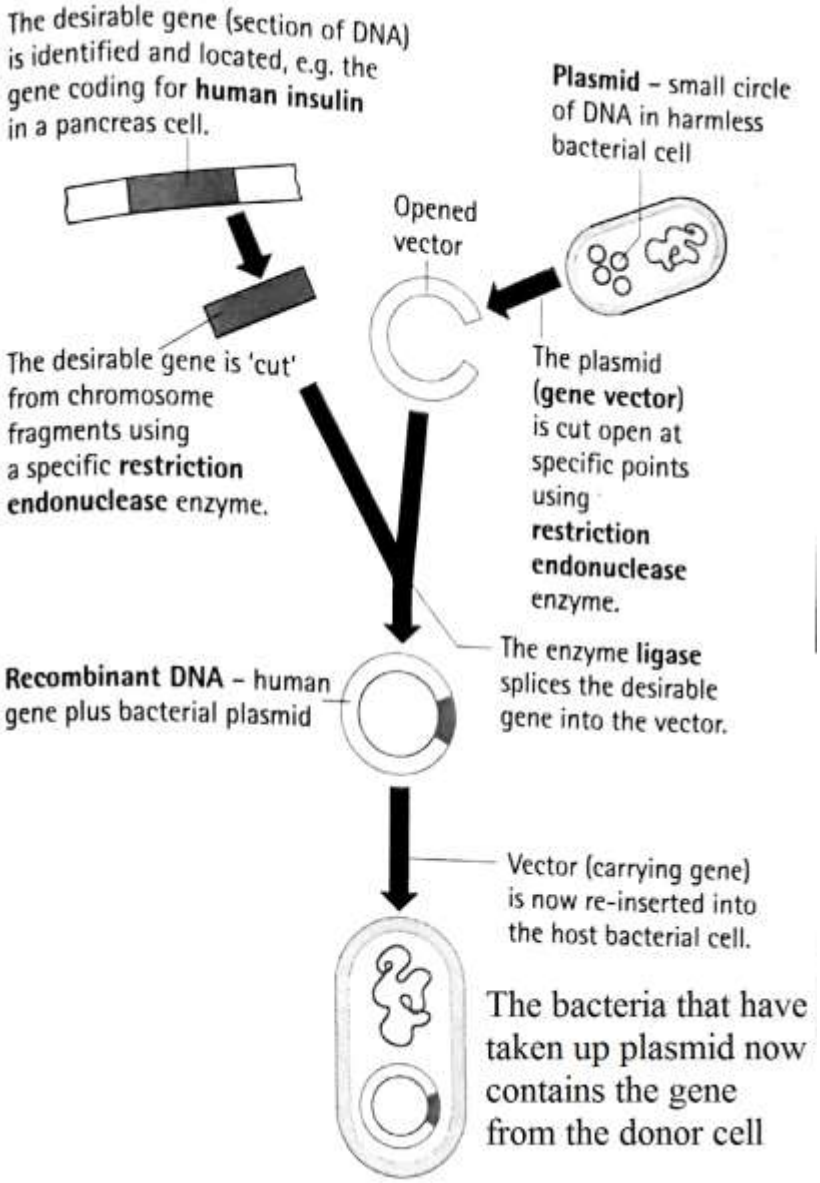


Figure 1.1: Stages in producing a transgenic bacterium

Ethical Issues in Biotechnology

- Ethics involves what people believe and holds to be right and acceptable for the whole population.
- Use of biotechnology raises various ethical issues that include:
  (i) The trans-genetic products may cause allergic reaction in people.

(ii) There has not been enough research on effect of inserting a gene from one species to another.
(iii) The new species may escape into the wild populations and super weeds could be formed by the cross- fertilization of wild species and transgenic species.
(iv) Business has control of the products being produced and their motive is profit, which may not be best interest of poor farmers.
(v) Genetic change in species is increased hence acceleration of evolution.
(vi) Production of harmful organisms due to mistakes made during genetic engineering.

Benefits of Biotechnology

(i) The genetic modifications increase a plant's resistance to diseases, pests, insecticides, herbicides and extreme weather conditions e.g. drought.
(ii) Genetic engineering alters a plant's nutritional make- up, making it richer in certain vitamins and minerals.
(iii) It has enhanced agricultural production for instance milk production thereby leading to food security.
(iv) Biotechnology has enabled scientists to change the way fruits and vegetables ripen. Genetically modified produce can be harvested when ripe, and the ripen process stops, giving them a longer shelf- life.

Problems Associated with Biotechnology

(i) It may lead to production of harmful organisms, which can be released to the environment.
(ii) Genetically modified crops are expensive because seeds has to be bought every year. The seed of genetically modified crops are sterile.
(iii) Some products like milk were found to have traces of antibiotics capable of triggering cancer in humans.