CHAPTER ONE
COMMUNICATION AND CO-ORDINATION

1.1. Introduction

Animals need to detect and respond suitably to change in the environment. Lower animals possess simple structures, where as higher animals have evolved elaborate structures for detection and co-ordination of the affecting responses.

Irritability in animals is brought about by the nervous system. In higher animals such as vertebrates, irritability is brought about by a more elaborate nervous (neuro-sensory) system and the endocrine (hormonal) system. The nervous (neurosensory) system provides the quickest means of communication in animals.

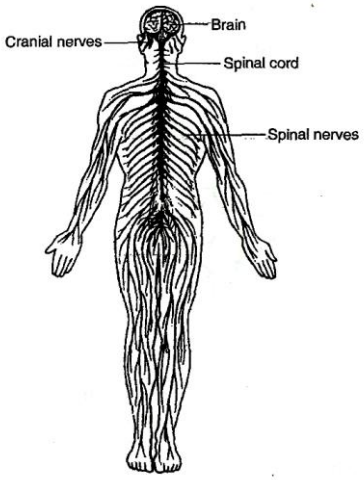


Fig. 1.1 (a): The human nervous system.

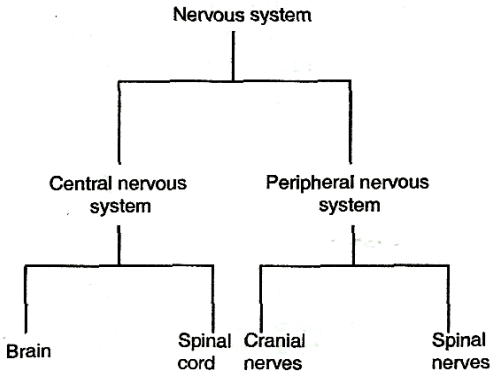


Figure: 1.1 (b) Summary of nervous system

1.2. The Nervous System

The human nervous system consists of the central nervous system (CNS) and peripheral nervous system.
See figure 1.1(a).

1. **Central Nervous System** is made up of the brain and spinal cord. It receives and integrate impulses from the receptors and then relays them to the effector organs.
   It is the centre of co-ordination.

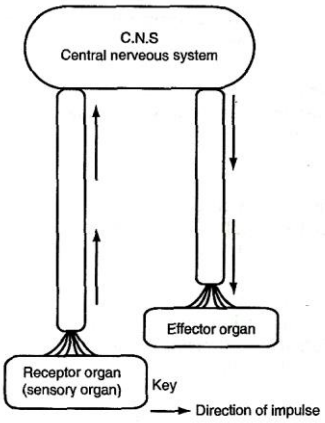


Figure: 1.2 Relationship of CNS and motor organs

2. **Peripheral nervous system** These is made up of sensory nerves and transmit nerve impulses from the receptors in sensory organs to the CNS and motor nerves that transmit impulses from CNS to effector organs. Figure 1.2 shows this relationship.

Structure and functions of Nerve Cells

The **nerve cell** or **neurone** is the basic functional unit of a nervous system. It is a cell which is modified to transmit impulses. A nerve impulse is an electrical signal that is transmitted along a nerve fibre. The neuron consists of a cell body (centron) and extensions called **dendrites.** In some neurones one of the dendrites is elongated to form an axon.

Each axon is filled with a specialised cytoplasm called **exoplasm,** which is usually continuous with the cytoplasm of the cell body. The axon is bound by a thin membrane which continues with plasma membrane of the cell body. The axon is in turn enclosed by a fatty sheath called **myelin or medullated sheath.**

The myelin sheath is surrounded by the **neurilemma** which is the membrane of the **Schwann-cell** but lies in intimate contact with axon. The schwann-cell secretes the myelin sheath. The myelin sheath is also broken at one-millimetre intervals by constrictions called **nodes of ranvier.** The nodes of ranvier help to propagate the nerve impulse and speed up the transmission of an impulse. The myelin sheath helps insulate the axon.

The neurones are described as unipolar, bipolar or multipolar according to how many dendrites project from the cell body. See figure 1.3.

The dendrites of the cell body make contact with neighbouring neurones in the central nervous system (CNS), while the terminal dendrites at the end of the axon make contact with effector organs. Several neurones link up to transmit impulses from a sensory organ to the central nervous system and also from the central nervous system to effector organs.

Types of Neurones

There are three types of neurones grouped according to the direction of impulse conduction:

(i) Sensory neurons (afferent).
(ii) Motor neurones (efferent).
(iii) Relay neurones (connector, intermediate or associative).

(i) **Sensory Neurons:** This nerve cell links the sense organs such as the ear, eye, skin, nose and tongue with the central nervous system. Its cell body is situated off the axon, and outside the central nervous system (CNS). Its receptor.

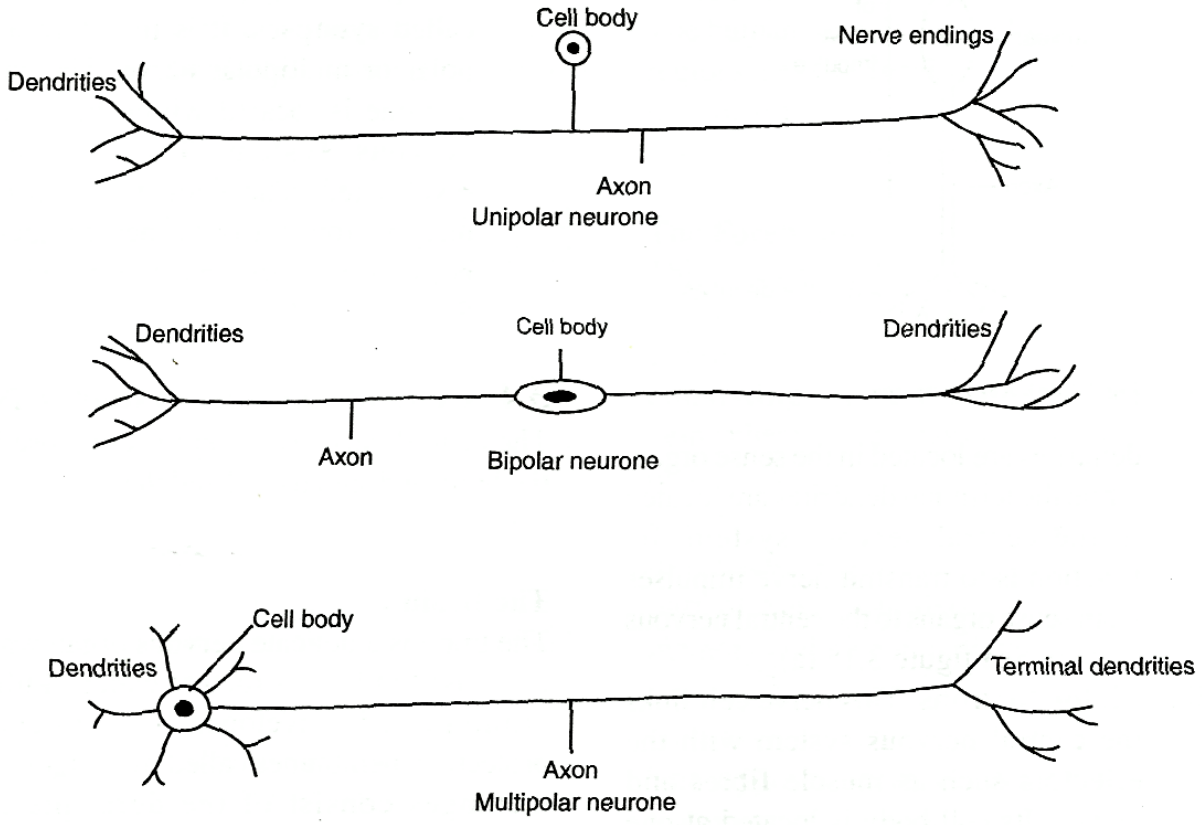


Figure: 1.3 Nerve cells

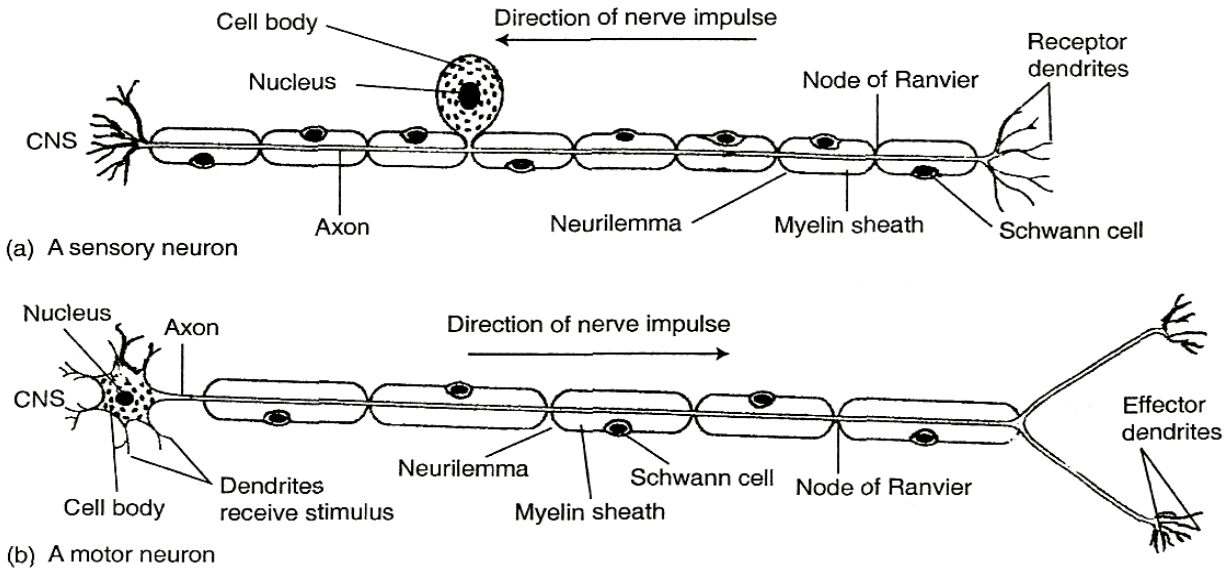


Figure: 1.4

dendrites are located in the sense organ, while the terminal dendrites are located in the central nervous system. Its function is to transmit nerve impulses from sense organs to the central nervous system. See figure1.4 (a).

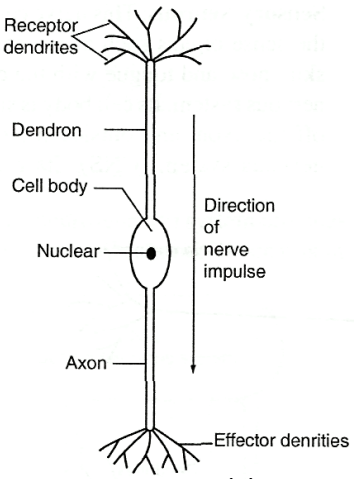


Figure: 1.4(c)

(ii) Motor Neurons: This nerve cell links the central nervous system with the effectors such as muscle fibres and glands. Its cell body is located at one end of the axon with the central nervous system; its motor end plates terminate in a muscle or gland. It transmits nerve impulses from the central nervous system to the effectors. See figure 1.4(b).

(iii) **Relay Neurons:** This neurone links a sensory nerve with a motor neuron through small gaps or neural junctions called **synapses.** It is therefore a bipolar or multipolar nerve. The entire neurone is located within the central nervous system. They are non-myelinated. The main function of a relay neurone is to relay nerve impulses between sensory and motor neurons. See figure 1.4(c).

1.3. Central Nervous System (CNS)

The central nervous system is composed of the brain and spinal cord arid their associated nerves.

The Brain

The brain is a delicate nervous organ which is encased in bony structure called **skull or cranium.** It is enveloped by a system of protective membranes called **meninges.** The meninges consist of the dura, pia and arachnoid.

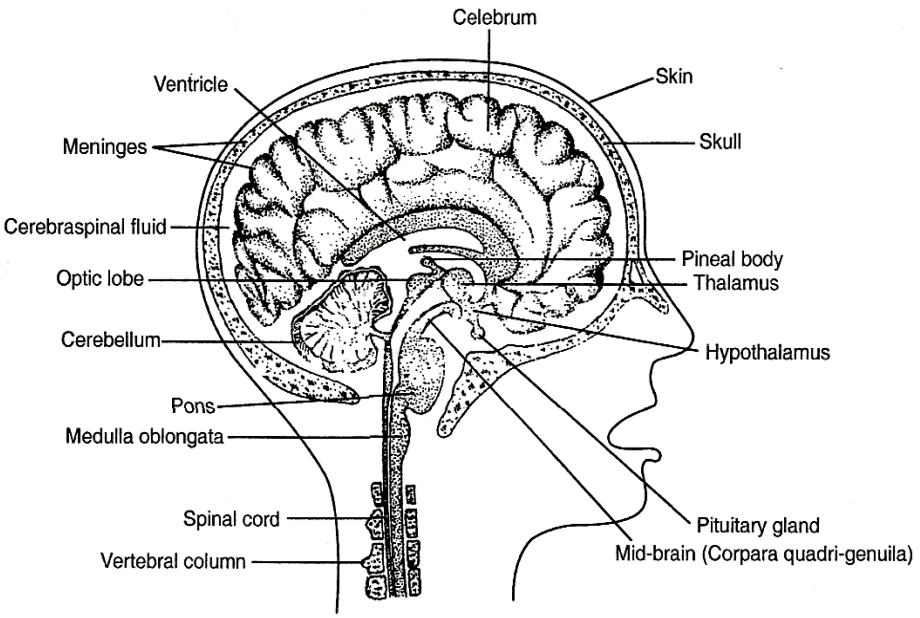


Fig. 1.5: The major parts of human brain

(i) The **dura matter** is the tough outer membrane covering the brain and spinal cord of vertebrates. It is composed of connective tissue and a rich network of capillaries.
(ii) The **pia matter** is the innermost membrane covering the brain and spinal cord. It possesses many blood capillaries and lymph vessels.
(iii) **Arachnoid layer** is a narrow space between the dura and pia matter. It is filled with cerebrospinal fluid from which oxygen and nutrients diffuse into brain cells.

Within the brain there is a system of cavities called ventricles which are filled with cerebrospinal fluid. This fluid is continuous with the spinal fluid of the central cord of the spinal cord. This fluid is similar to lymph. It provides nourishment to brain tissue and serves as a shock absorbs from mechanical damage.

Functions of Major Parts of the Brain

The human brain is divided into three major regions i.e. the **forebrain, mid-brain** and **hindbrain.** Each of these regions consists of various parts as in see figure 1.5.

The Forebrain

This consists of the cerebrum, the thalamus, hypothalamus and the pituitary gland. The cerebrum is a highly developed part consisting of left and right cerebral hemispheres. It is important for integration of sensory impulses such as vision, hearing and taste. It controls voluntary body movements e.g. limbs, lips and neck. This part of the brain also controls learning, memory and human individuality.

The thalamus is an important relay centre. It contains receptors for pain and pleasure. The hypothalamus is located below the thalamus. It has receptors for homeostatic functions such as thermoregulation and osmoregulation. It controls appetite and sleep.

Pituitary gland is attached to the hypothalamus and projects downwards from it. It is the master endocrine gland controlling the rest of the endocrine glands.

The Midbrain

The midbrain is also known as corpora quadrigemia. It is the connecting stalk between the forebrain and the hindbrain. It relays impulses between nerves from the spinal cord and the forebrain.

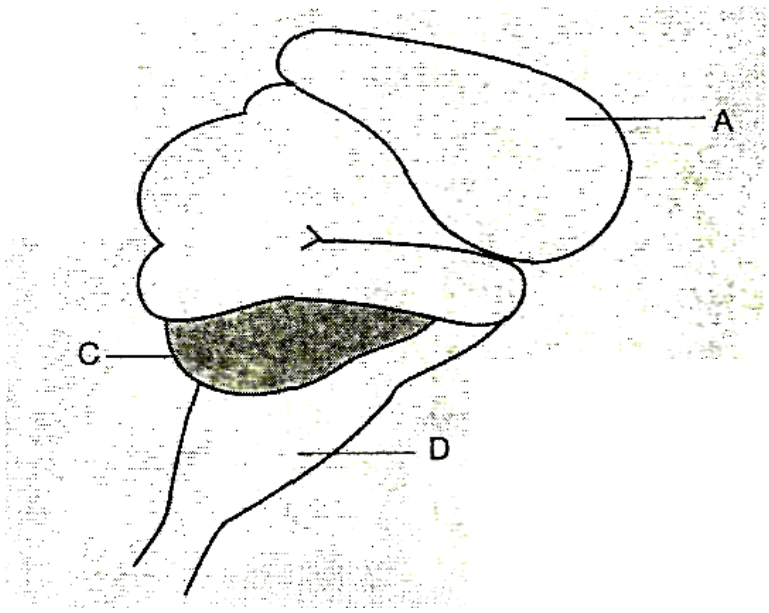
The Hindbrain

The major parts of the hindbrain are cerebellum and medulla oblongata. The cerebellum's main function is maintenance of body balance and posture. This is achieved by controlling and co-ordinating muscular movements.

Medulla oblongata controls involuntary activities such as breathing, swallowing, salivation, vomiting. It controls dilation or constriction of blood vessels thereby influencing blood pressure.

Study this question

The figure below shows the surface view of a human brain.



a) Name the parts labelled A, B and C.
b) State the functions of the part labelled A.

Cranial Nerves

These nerves arise from the brain and form part of the peripheral nerve system associated with receptors and effectors in the head. In human beings there are 12 pairs of cranial nerves confined to the head and neck. These may be purely sensory, motor or mixed. Some examples of the cranial nerves are optic, auditory, olfactory and facial nerves. In addition, there are sensory and motor nerves which innervate the face and jaws. The tenth cranial nerve - the vagus nerve -innervates the heart, lungs, diaphragm and the gut.

Spinal Cord

The spinal cord is the posterior extension from the brain to the tail. It is enclosed in meninges and protected by the vertebral column. It is made up of grey matter and white matter. The grey matter is H-shaped and surrounds a central canal which is filled with cerebrospinal fluid. This grey matter relays information between the sensory and motor neurons. It consists **of cell bodies** and dendrites of relay and motor neurons. These give it its darker appearance hence the term 'grey' matter.

Surrounding the grey matter is the white matter which consists of the **axons** of the sensory and motor neurons. The myelin sheath of these neurons gives this part its shiny white appearance. Arising from the spinal cord are dorsal and ventral roots of spinal nerves. See figure 1.6(a) and (b).

Spinal nerves innervate the skeletal muscles of the limbs and trunk. In association with cranial nerves they control all organs of the body below the head e.g. urinary bladder, the gut, liver, kidney and lungs.

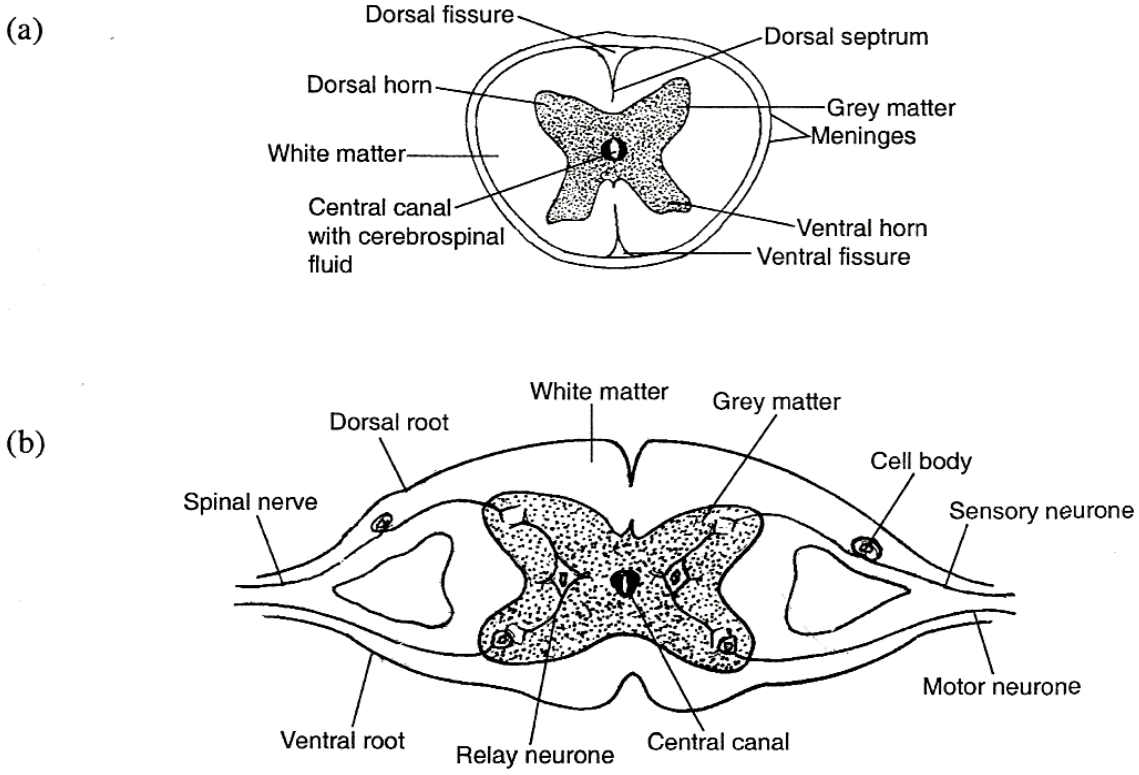


Figure: 1.6 Transverse section of the spinal cord

Reflex Action

Reflex action is a rapid automatic response to a certain stimulus. There are two types of reflex actions, the simple reflex and conditional reflex action.

Simple Reflex Action

In a simple reflex action there is a specific single and automatic response to a particular stimulus. It is the simplest form of reflex and does not depend on learning.

Examples of reflex action include withdrawal of finger from a hot or sharp object, blinking of the eye when an object passes close to it, coughing and sneezing, the knee jerk reflex when the knee is tapped, salivation, secretion of tears when an onion is cut, swallowing, and enlargement of the pupil in different light intensities. The structural basis of a reflex action is called the reflex arc, which is the pathway followed by the nerve impulse. The simplest reflex arc is made up of the three neurons: the receptors (sensory), relay and motor. They link the receptor with the effector through the spinal cord.

To illustrate a simple reflex arc let us consider the case of a pricked finger being quickly withdrawn. This is shown in figure 1.7.

When the finger is pricked, the pain receptors in the skin of the finger are stimulated. Nerve impulses are triggered off and transmitted via the sensory neurone to the grey matter of the spinal cord. The impulse is then transmitted to the relay neurone via a synapse then to the motor neurone through another synapse. Eventually through the ventral root the impulse is transmitted to the effector which is the bicep of the upper arm. The biceps contract and the forearm is withdrawn or raised.

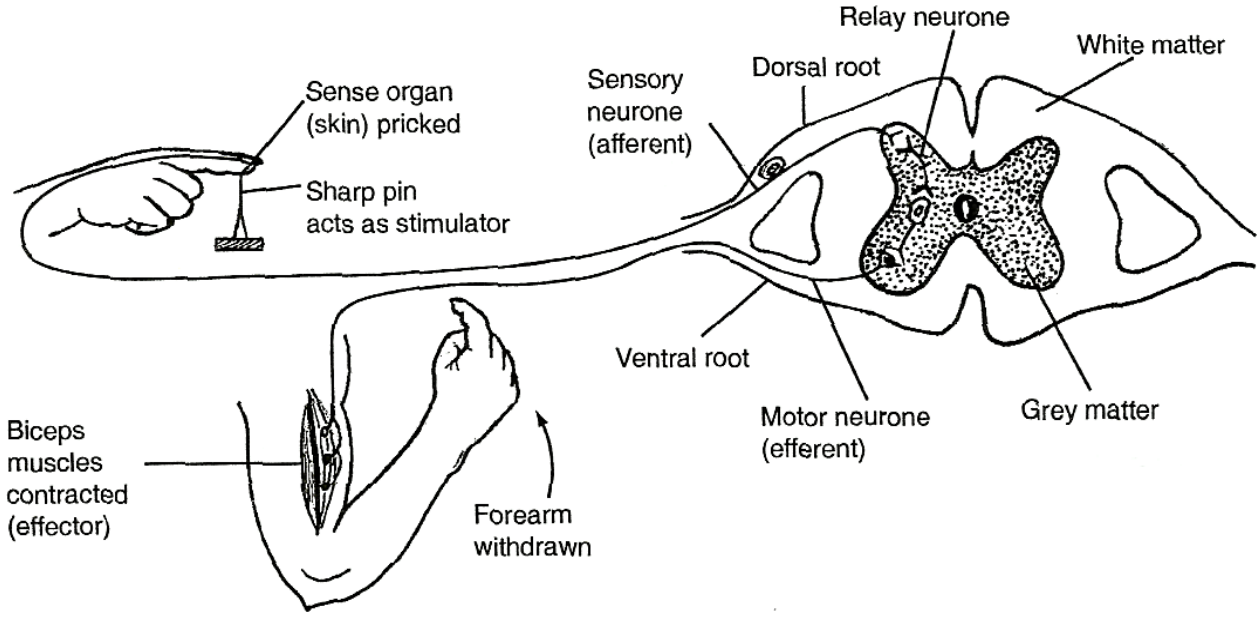


Figure: 1.7 The reflex arc

Conditioned Reflex Action

This is an automatic response which can be evoked from an animal by unrelated stimulus substituted for the one which normally elicits the response. This reflex action is formed from past experience and involves modification of behaviour through learning. For example, in a simple reflex action, a dog normally salivates when it sees food presented to it. But if a bell is rung just before food is presented to the dog, and the procedure is repeated several times, the dog will learn to associate bell ringing with food. Therefore, it will salivate as soon as it hears the sound of the bell whether food is presented or not.
Ivan Pavlov, who carried out these interesting experiments on dogs, called this response **conditioned reflex action.**

The conditioned reflex usually weakens with time, therefore, it must be reinforced by repeated stimulus or repeating the original experience if the same result is to be obtained. This forms the basis of learned behaviour. Examples of conditioned reflex action are walking, playing, cycling, writing, swimming and driving. Everyday practical applications of conditioned reflex action include training of dogs, learning processes, advertisements.

Table 1.1: **Differences between simple reflex action and conditioned reflex action**

Simple Reflex Action	***Conditioned Reflex Action***
1. Single stimulus to bring about response.	1. Repeated stimulus to bring about response.
2. Simplest form of behaviour and is independent of experience.	2. Involves modification of behaviour and dependent on experience.
3. Sensory and motor components are the same at all times.	3. Primary sensory component is replaced by a secondary sensory component but the motor component remains unchanged.

Transmission of Nerve Impulse

Resting potential

A nerve impulse is an electrical charge or wave of electrical disturbance arising from changes in ionic concentrations across the surface membrane of a nerve fibre (axon or dendrite). The ions involved in impulse transmission are sodium ions (Na"[1]") and potassium ions (K^+).

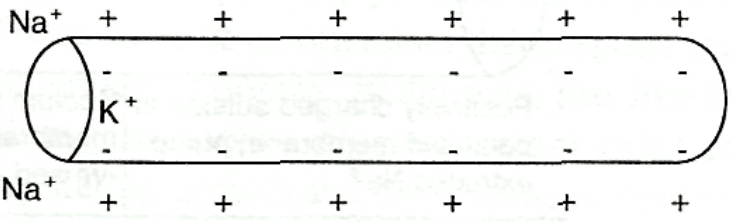


Figure: 1.8 (a) Axon at resting potential

A non-conducting nerve fibre is described to be **in** a **resting potential.** In this state there are more Na+ outside the axon membrane than inside in relation to the concentration of K^+ which is higher within the axoplasm. There are also relatively more anions (negatively charged ions) within the axoplasm. The net effect of this unequal distribution of ions is that there is positive charge outside the axoplasm and negative charge inside the exoplasm so that the membrane is said to be **polarised.** During resting potential, Na^+ are actively pumped out (extruded) by a mechanism called **sodium pump.** See figure 1.8(a). Meanwhile, the K^+ can diffuse freely in and out of the exoplasm. Figure 1.8(b) illustrates the transmission of an impulse.

Action Potential

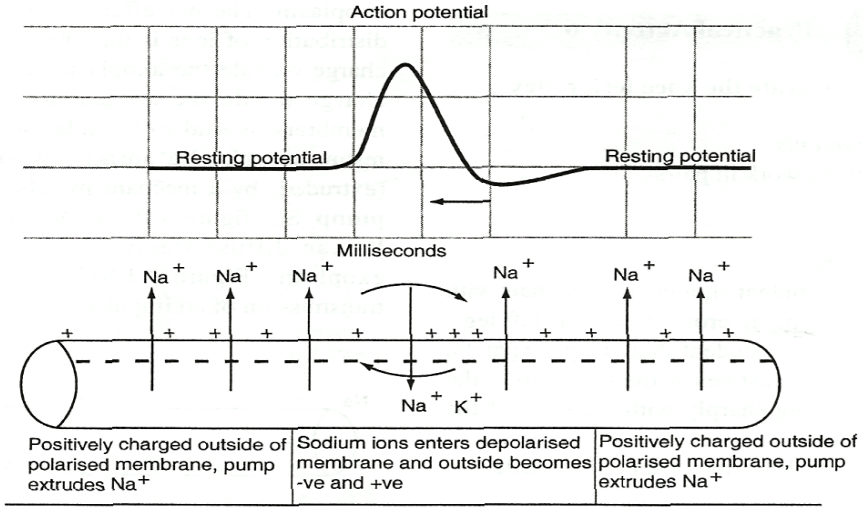


Figure: 1.8 (b) Transmission of impulse

An action potential is a localised change in electrical potential between the inside and outside of the nerve fibre when stimulated. The inside becomes positively charged while the outside becomes negatively charged. This is called depolirisation. The membrane becomes more permeable and because the sodium pump temporarily ceases, causing an influx by diffusion of Na^+ into the axoplasm. This raises the concentration of Na* ions within the axoplasm relative to the outside, causing the K^+ ions to diffuse out.

This localised charge stimulates the depolarisation of the membrane adjacent to it, thus propagating the depolarisation process. This is immediately followed by a recovery to the polarised state. The movement of this action potential along a nerve fibre constitutes an impulse.

Synapse or Neuro-junction

A synapse is the junction between dendrites of two adjacent neurones as shown in figure 1.9. Its function is to allow the transmission of nerve impulses from neurone to neurone.
In the pre-synaptic knob there are vesicles which contain a transmitter substance which is usually **acetylcholine.** When an impulse reaches the synaptic knob, it stimulates the vesicles to move towards the pre-synaptic embrane releasing the acetylcholine. This transmitter substance makes the membrane permeable. The transmitter substance then diffuses across the synaptic cleft to the post-synaptic membrane which them becomes depolarised. Sodium ions from the cleft then flow through the post-synaptic membrane into the post-synaptic knob causing an action potential at this point. This action potential is then transmitted as a nerve impulse along the neurone. Immediately afterwards the acetylcholine liberated in the synaptic cleft is destroyed by an enzyme called **cholinesterase** into inactive end 1-1 products namely; choline and acetic acid (ethanoic acid). These end-products are reabsorbed by the axon terminals and reconstituted into acetylcholine using energy in the form of ATP provided by mitochondria. This rapid breakdown of acetylcholine is necessary to re-polarise the pre-synaptic membrane for the next nerve impulse propagation so that there is no merging of the successive nerve impulse from neurone to neuron.

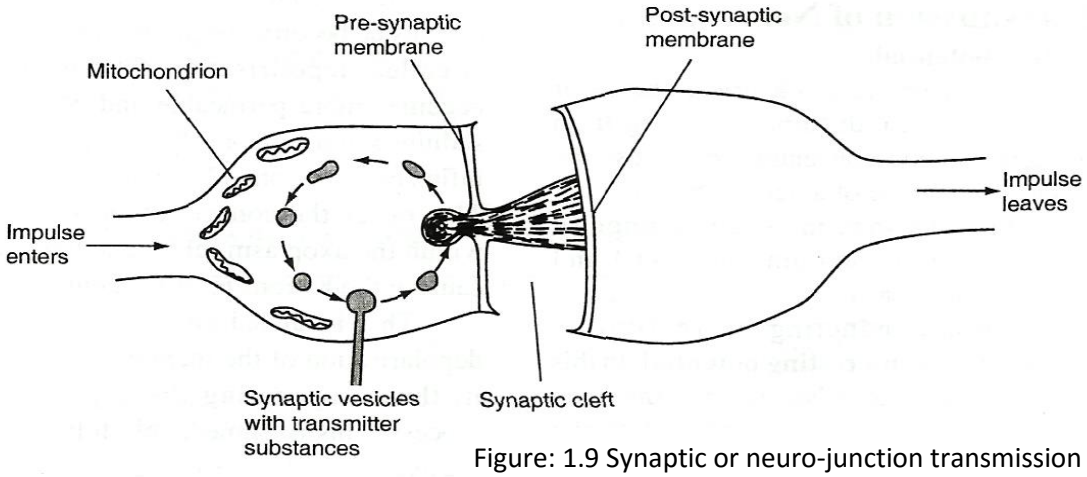


Figure: 1.9 Synaptic or neuro-junction transmission

1.4. The Endocrine System

This is another system for co-ordination in animals in addition to the nervous system. The system comprises of endocrine glands that are ductless which secrete hormones. Interaction between these hormones forms a communication network in the body of an animal.
Hormones are organic compounds which are either protein or steroids in nature. They are produced in minute quantities in cells in one part of the body and transported by blood stream to the other parts of the same organism, where they produce the response.
Those parts of an organism that respond are called target organs. In animals, just like in plants, hormones play important roles in regulating growth and development, control of behaviour of animals, during breeding and in proper functioning of cells.

The production of hormones from ductless glands is either directly or indirectly influenced by the nervous system. The endocrine glands are located in various parts of the body as shown in figure 1.10.

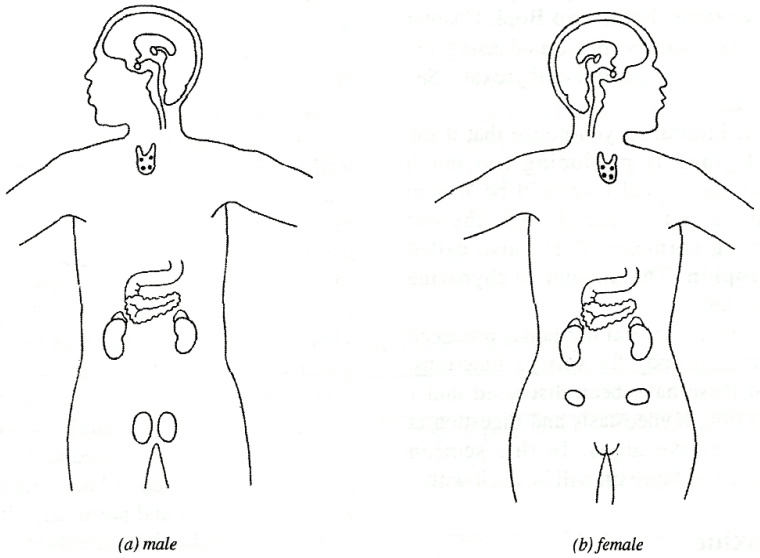


Figure: 1.10 Positive of major endocrine glands in human being.

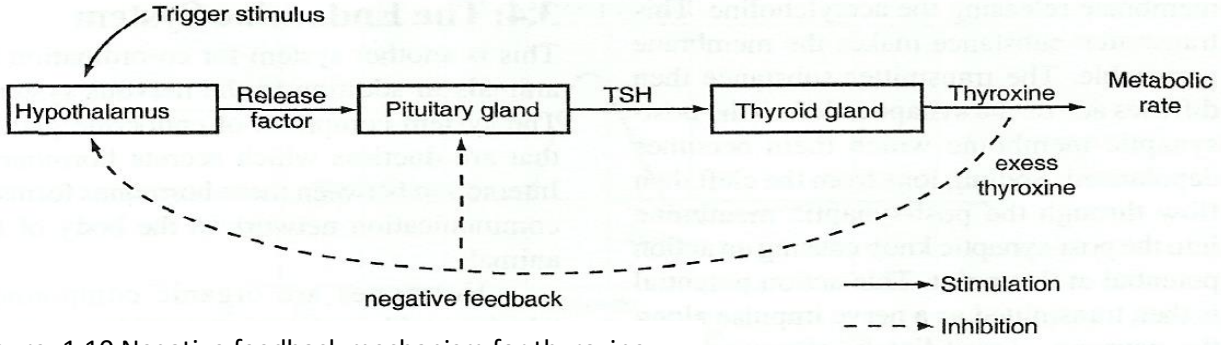


Figure: 1.10 Negative feedback mechanism for thyroxine

Pituitary gland is the master gland that controls the activities of the other endocrine glands. However its action is co-ordinated by the hypothalamus through nervous communication. The hypothalamus influences the activities of pituitary gland by monitoring the level of hormones and other chemicals in the blood passing through it. It also influences the secretions of the anterior lobe of the pituitary.

Hormones exercise control over their reactions through a feedback mechanism called **negative feedback** mechanism. Negative feedback mechanisms play an important role in controlling many biological processes (refer Form Two Book Chapter Three). This can be illustrated using the negative feedback control of thyroxine. See figure 1.11.

From the illustration you notice that if the thyroid gland is producing too much thyroxin, that signal level will be sent to pituitary gland to secrete less thyroid stimulating hormone (TSH), also called **thyrotrophin.** The amount of thyroxine therefore falls.

There are several hormones produced in the human body for various functions. Most of these have been discussed under reproduction, homeostasis and digestion at their respective areas. In this section adrenaline and thyroxin will be dealt with.

Thyroxine

The hormone thyroxine is produced by the thyroid gland found at the neck region. It is a compound of iodine.

Functions

Thyroxine controls basal metabolic activity. This is done by increasing glucose oxidation. It also enhances the effect of growth hormone (sornatotrophin). This ensures normal growth and mental development. Thyroxine also works in conjunction with adrenaline to enhance involuntary activities such as increased circulatory rates.

Effects of under-secretion (Hypothyroidism)

Under-secretion could lead to insufficient iodine in the diet or defective enzymatic reactions concerned with its formation. Hypothyroidism leads to cretinism in children and myxoedema in adults.

Cretin children have deformed legs, dry leathery skin, large tongue and general body sluggishness. Such children have poor mental development resulting in low intelligence.

Myxoedema in adults is shown by the swelling of the thyroid gland called **goitre.** This is due to overworking of the thyroid gland in an attempt to synthesis enough thyroxine. Due to the low thyroxine concentration, individuals have low metabolic rate as shown by reduced heartbeat and breathing rate and low body temperature. They are mentally and physically sluggish. The low physical activity results into weight gain (obesity), retention of excess fluid (oedema) hence swollen feet and puffy face. Hypothyroidism can be controlled by use of balanced diet supplemented by iodised table salt and administration of iodine tablets.

Effect of Overproduction of Thyroxine (Hyperthyroidism)

Over-secretion of thyroxine is often due to presence of plasma proteins that stimulate thyroid activity i.e. defective enzymatic reactions.

Hyperthyroidism leads to increased metabolic rate resulting in increased heartbeat, breathing rate and high temperature. Individuals show nervousness, restlessness and are easily irritable. Extreme hyperthyroidism can lead to heart failure, a condition known as **thyrotoxicosis.**

Hyperthyroidism can be controlled by treatment with radioactive iodine. Surgical removal of part of the thyroid gland can also be done.

Adrenaline

Adrenal glands are attached to the abdominal cavity, one above each kidney. Each is made up of two distinct regions; the outer adrenal cortex and an inner one called adrenal medulla.

The medulla receives nerve impulses from the brain and produces the hormone **adrenaline.** The cortex has no nerve supply and produces a number of hormones called corticosteroids.

Adrenalin prepares the body for emergency-fight or flight. The heartbeat increases, increasing the rate of circulation. It increases metabolic rate. The arterioles to the skin and digestive system constrict. In the liver, glycogen is converted to glucose. Skeletal muscles contract and relax which can allow movement. Breathing rate becomes faster and deeper. Fats are converted to fatty acids, which are available in the blood for muscle contraction.

Oversecretion of adrenaline can be brought about by the growth of tumour in the medulla of the adrenal glands. Symptoms include high blood pressure, severe headache, racing heart, sweating and faintness. The resultant effect is aging of major body organs such as kidney, heart and liver.

Comparison Between Endocrine and Nervous Systems

1. Both provide means of communication within the body of an organism.
2. Both involve transmission of a message triggered by a stimulus and a response.
3. The target organs of hormones are like the effector organs.
4. Both involve chemical transmission.
5. Both bring about survival response.

Table 1.2: Differences between endocrine and nervous systems

Endocrine system	***Nervous svstem***
(i) Chemical substance to evoke a response,	(i) Nerve impulse to evoke a response.
(ii) Chemical transmitted through blood,	(it) Impulse only through nerve fibre.
(iii) Responses slow but affect several parts of the body.	(iii) Responses quick, specific and localised.
(iv) Effects are long-lasting,	(iv) Effects rapid and short-lived.
(v) Response takes place involuntarily.	(v) Takes place voluntarily & involuntarily.

1.5: Effects of Drug Abuse on Human Health

A drug is any chemical substance which when taken into the body has **psychological and physiological effects.** Generally drugs are prescribed for medicinal purposes to alleviate pain or to cure illnesses. However, there are some substances which when introduced into the body also cause psychological and physiological effects that are not curative. Indiscriminate use of drugs with no regard to their side effects is called **drug abuse.**

Commonly abused drugs include khat *(mirad),* nicotine, *cannabis saliva* (bhang) and alcohol. Prolonged abuse of drugs can cause **addiction** (drug dependence).

Effects of Drug Abuse

Common effects of drug abuse include:

- Depressed appetite and poor feeding habits leading to emaciation.
- Interference with absorption of vital vitamins such as vitamin K and vitamin E which may lead to sterility and blindness.
- Lowers nervous co-ordination leading to loss of posture and balance. This decreases performance in sports and manual activity.

- Irritation of the lungs and the respiratory tract leading to frequent coughs and infections.
- May lead to cancer of the lungs, throat and that of the urinary bladder.
- May also cause stomach ulcers.
- Damage to many tissues of the heart and the liver leading to heart attacks and liver cirrhosis respectively.
- Interference of temperature regulation leading to excessive heat loss,
- Damage caused to the brain may lead to sleeplessness (insomnia), loss of memory (amnesia), deliriums, hallucinations and mental illness (madness).
- In women, drug abuse may lead to poor foetal development and pregnancy complications.
- Irreversible damage to vital body tissues and organs may eventually lead to death.
- Addicted persons have impaired judgement which may predispose them to accidents and infections such as HIV/ AIDS.

Sense Organs

In higher animals sensory cells have become associated together to form specialised sense organs with accessory structures. In mammals the main organs of special sense are: the eye for sight, the ear for hearing, the tongue for taste, the nose for smell and the skin for pressure, temperature and pain.

1.6: The Eye

The eye is a complex sense organ, whose function is to receive light by which an animal perceives and distinguishes objects in its immediate environment. The eye is located in a socket in the skull called **orbit** which offers protection against physical damage.

Within the orbit there is a fatty layer lining which provides further protection as a shock absorber against mechanical injury.

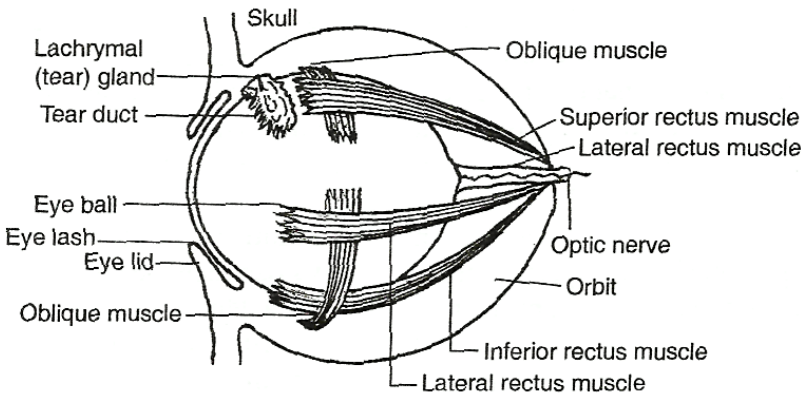


Figure: 1.12 Muscles of eyeball

In the socket, the eye is suspended by sets of muscles which move the eye. The lateral rectus muscles move the eye left and right. Superior and inferior rectus muscles move the eye up and down, while the oblique muscles steady the eye in its up and down movement. Figure 1.12 illustrates the muscles that move the eye ball.

In front of the eyeball, there are two thin folds of skin, the eyelids, which protect the eye. From the edge of the eyelids are many hairs called **eyelashes** which protect the eye from the entry of small foreign particles. The eyebrows are raised portions of the skin above the eye, thickly covered with hair, whose function is to prevent sweat and dust from entering the eye.

In land vertebrates there is a lachrymal gland that continuously secretes a watery, saline and antiseptic fluid called tears. The tears moisten the cornea and wash foreign particles out of the eye. The fluid drains through the lachrymal duct into the nose. In mammals, including human, the lachrymal gland is beneath the upper eyelid; while in other animals it is located beneath the lover eyelid. In amphibians, reptiles, birds, some fish and some mammals, e.g. cat, there is a transparent membrane called **nictitating membrane** which is drawn across the eye to clean it.

The human eye is a spherical, fluid-filled structure whose wall consists of three distinct layers:

1. The outer layer or sclera (Sclerotic layer).
2. The middle layer or choroids.
3. The inner layer or retina. See figure 1.13.

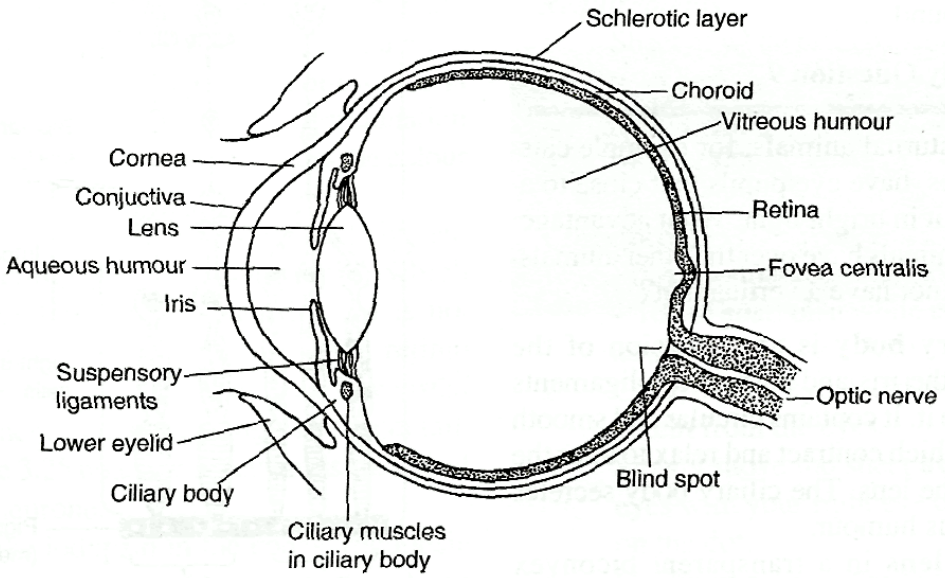


Figure: 1.13 Longitudinal section of human eye

Sclera

This is a white fibrous layer which protects the delicate inner parts of the eyeball and helps in maintaining its shape. The sclera continues and forms the cornea at the front of the eye. The cornea is a transparent layer which allows light to enter the eye. The cornea is a very important structure in refraction of light entering the eye. Covering the front portion at the cornea is a protective thin transparent membrane called **conjunctiva. It** is continuous with the epithelium of the eye lid.

Choroid

This is a dark-pigmented, membranous middle layer that contains numerous blood vessels. Its functions is to absorb stray light to prevent internal reflection within the eye and to provide nourishment to the eye. At the front of the eye, the choroid extends and forms the **ciliary** body and **iris.**

The **iris** is a thin round sheet of muscular tissue. It contains two sets of muscles. **Circular** and **radial** which control the diameter of the pupil. It is pigmented giving the eye its colour e.g. black, brown or blue.

The pupil is the opening in the iris which allows light to enter the eye. In some vertebrates such as cats, the pupil is narrow and slit-like, while in most vertebrates it appears round.

The **ciliary body** is an extension of the choroids, the iris and suspensory ligaments attached to it. It contains circular and smooth muscles which contract and relax to alter the shape of the lens. The ciliary body secretes the aqueous humour.

The **lens** in a transparent biconvex structure located immediately behind the pupil of the vertebrate eye. It is held in position by the suspensory ligaments, which become taut or loose to alter the shape of the lens. The lens divides the eyeball into anterior and posterior chambers. The anterior chamber i.e. that part behind the cornea, is filled with a watery fluid the **aqueous humour** while the posterior chamber i.e. the part between the lense and the retina is filled with a denser, jelly-like transparent material called the **vitreous humour.** These fluids help maintain the spherical shape of the eyeball, and also to refract incoming light towards the retina.

Retina

The **retina** is the light-sensitive layer composed of three regions:
1. An outer pigmented region in contact with the choroid.
2. A middle region of photoreceptors consisting of rods and cones.
3. An innermost region of neurones. These neurones run over the surface of the retina and join to form the optic nerve which transmits nerve impulses from the retina to the brain for interpretation. See figure 1.14.

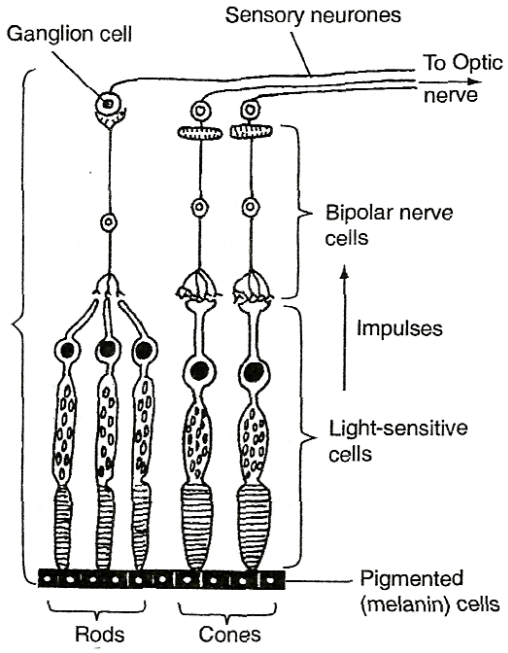


Figure: 1.14 The cones and the rods in the retina of the eye

Cones and Rods

The cones contain a photochemical pigment called **iodopsin** which perceives light of high intensity. In the presence of light, iodopsin breaks down to iodine and opsin. This breakdown brings about depolarisation of the cell membrane of the cones. Thus a nerve impulse is generated and transmitted along the neurones to the optic nerve, which carries impulses to the brain for interpretation. Greater concentration of cones occurs in the fovea centralis or yellow spot which is by far the most used region of the retina. Each cone has its own bipolar neurone which in turn links it with an optic nerve fibre, i.e. it lacks retinal convergence. See figure 3.24. This property of the cones enables them to have high **visual acuity.** Visual acuity is the ability of the eye to distinguish objects clearly.

In higher vertebrates there are three types of cone cells which enable them to differentiate the different colours they perceive the three types of cone cells distinguish light of the colours blue, green and red.

The **Trichromatic Theory** which suggests that the simultaneous stimulation of the three types of cones at different degrees bring about colour perception can explain colour vision. For example equal stimulation of red and green types of cone cells is perceived as yellow colour. Equal stimulation of all three types of cones produces the colour sensation of white.

Rods contain a photochemical pigment called **rhodopsin** (visual purple) which perceives light of low intensity, but is not sensitive to colour. The rods have retinal convergence, therefore they have low visual acuity, hence cannot distinguish fine detail. In figure 1.14 note that several rods are linked to one neurone.

Like iodopsin in the cones, rhodopsin degenerates to opsin (complex protein) and retinine (derivative of vitamin A) to bring about depolarisation of the cell membrane, and then triggers off an impulse. The amount of rhodopsin in the rods is increased in the dark, raising the sensitivity of the rods to dim light. Resynthesis of rhodopsin occurs slowly in the dark for continued photochemical reaction in the rods.

Rods are in greater concentration round the periphery of the retina and are absent in the fovea centralis. Their greater number in the retina tends to confirm their special value in dim light. In the retina of nocturnal animals, there are more rods than cones. This is because the rods are more sensitive to light of low intensity. The combination of rods and cones enables the eye to be efficient under all light conditions.
In the retina there is an area where the optic nerve enters the eyeball. This area is called the **blind spot.** This area has neither rods nor cones, so images from objects falling on the blind spot cannot be perceived.

Image Formation and Interpretation

Light from the object is refracted by cornea aqueous humour and the lens through the vitreous humour and focused onto the fovea centralis on the retina.

The image is recorded as real, inverted and small. See figure 1.15. The photoreceptor cells become stimulated and nerve impulse is generated and transmitted by the optic nerve to the cerebrum part of the brain for interpretation. In the brain the impulses are interpreted and the object appears real, upright and normal. The images from the left eye are interpreted by the right cerebral hemisphere and those from the right eye by the left cerebral hemisphere.

Binocular Vision and Stereoscopic Vision

Binocular vision occurs when the visual fields of both eyes overlap so that the fovea of both eyes are focused on the same object. It forms the basis of stereoscopic vision. Stereoscopic vision depends upon the eyes simultaneously producing slightly different retinal images which the brain resolves as an image. It has several advantages over monocular vision and these include a larger visual field, damage to one eye being compensated for by the other, for example,

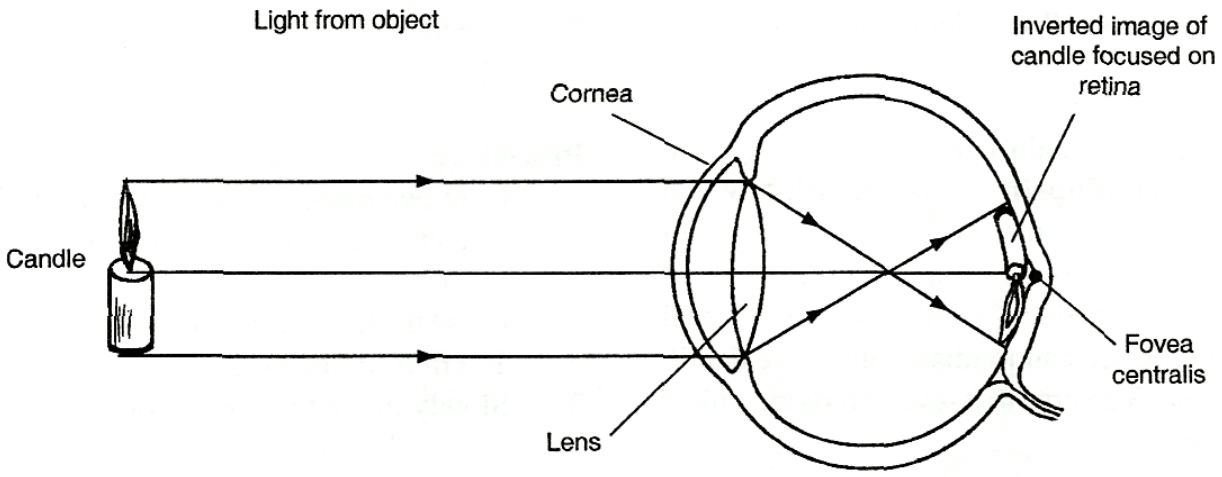


Figure: 1.15 Image formation in a human eye

it cancels the effects of the blind spot, provides much more accurate assessment of the distance, depth, height and width of an object.

Accommodation of the eye

This is the adjustment of the eye structures to bring an image from a near or far object into **sharp focus** on the retina. The lens' curvature is altered by the action of the ciliary muscles acting on the suspensory ligaments.

Accommodation of a Close Object

The ciliary muscles contract thereby relaxing the tension on suspensory ligaments. The curvature of the lens increases i.e. the close objects are greatly refracted by the lens focusing them on to the retina as shown in figure 1.16 (a).

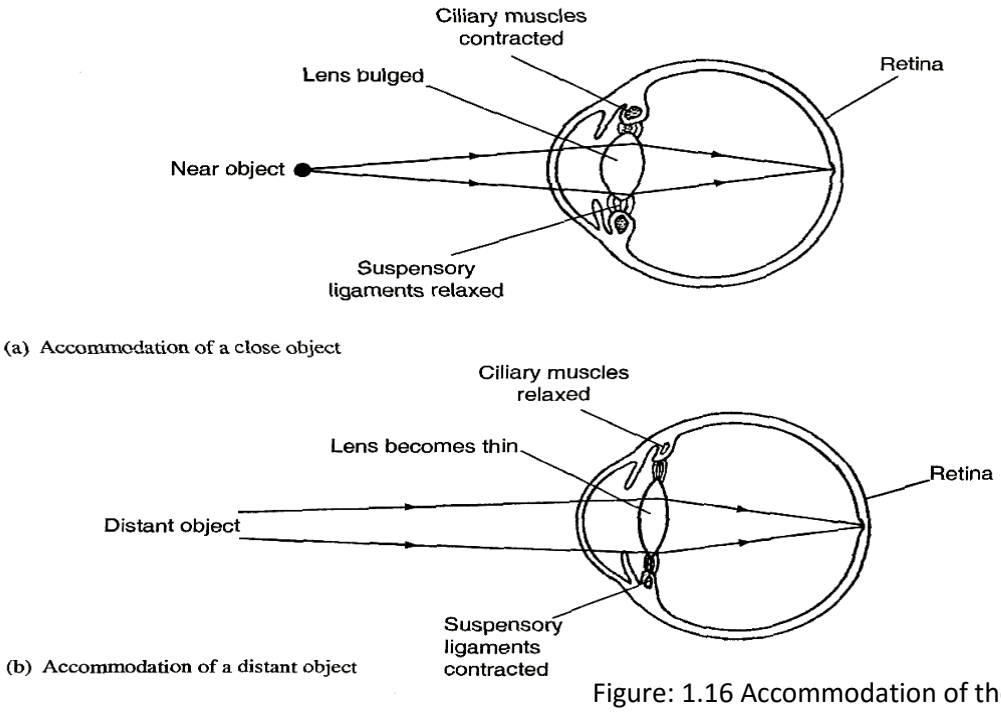


Figure: 1.16 Accommodation of the eye

Accommodation of a Distant Object

The ciliary muscles relax thereby increasing the tension of the suspensory ligaments. This stretches the lens decreasing its curvature i.e. the lens become thinner. Light rays from a far object are less refracted and hence focused onto the retina. Figure 3.28(b) illustrates this.

During accommodation, the iris regulates the amount of light entering the eye. In bright light the circular muscles of the iris contract, while the radial muscles relax, and the pupil becomes smaller. This prevents damage of the retina by excessive light. See figure 1.17(a),

In dim light, the radial muscles of the iris contract, and the circular muscle relax and the pupil enlarges. This allows in enough light to stimulate photoreceptors or the retina. See figure 1.17(b).

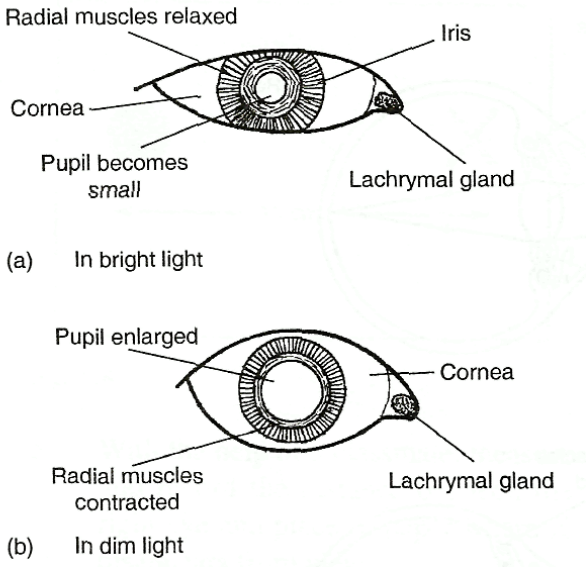


Figure: 1.17 How the iris regulates amount of light entering the eye

Defects of the Eye

These are structural changes in the eye which make the focusing mechanism of the eye difficult. Most eye defects can be corrected after careful diagnosis by an optician, as plate show an optician using modern detection equipment to diagnose an eye defect. See figure 3.30 (a). Common eye defects are discussed below.

(a) Short Sightedness (Myopia)

This is a condition in which light rays from a distant object are brought to focus in front of the retina while those from a near object are clearly focussed on it. This is caused by a long eyeball. It may also be due to too much refractive power of the eye lens.
Short sightedness is corrected by wearing concave or diverging lenses. The concave lenses diverges light rays before reaching the eye lens which then focuses the light rays on the retina as shown in figure 1.18 (b).

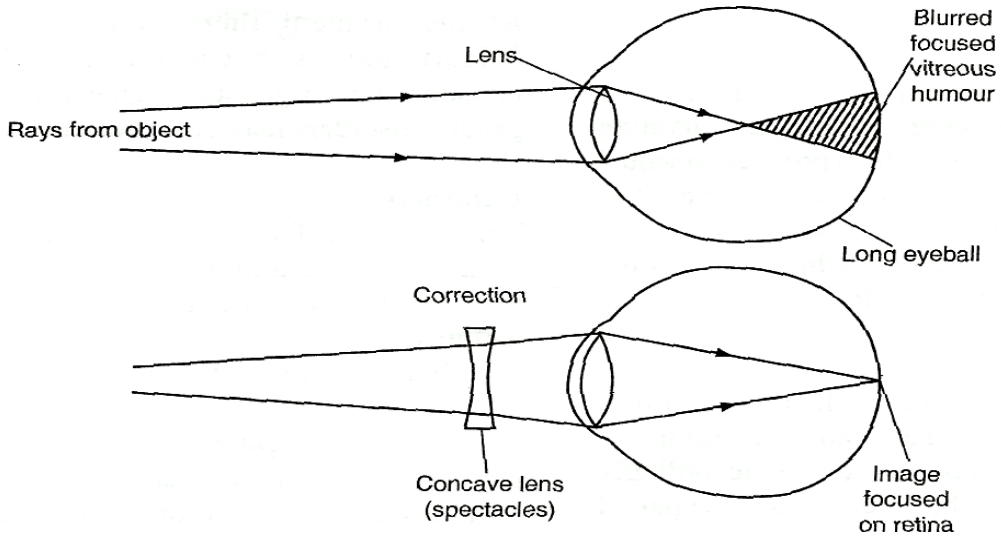


Figure: 1.18 (b) Short-sightedness and how it is corrected

(b) Long Sightedness (Hypermetropia)

This is a condition in which light rays from a near object are not brought to focus by the time they reach the retina, while those from a distant object are sharply focused. It is caused by too short an eyeball or a weak lens system. The disorder can be corrected by wearing a convex (converging) lens. This lens refracts light rays before reaching the eye lens thereby enhancing refraction in order to focus rays sharply on to the retina as shown in figure 1.19.

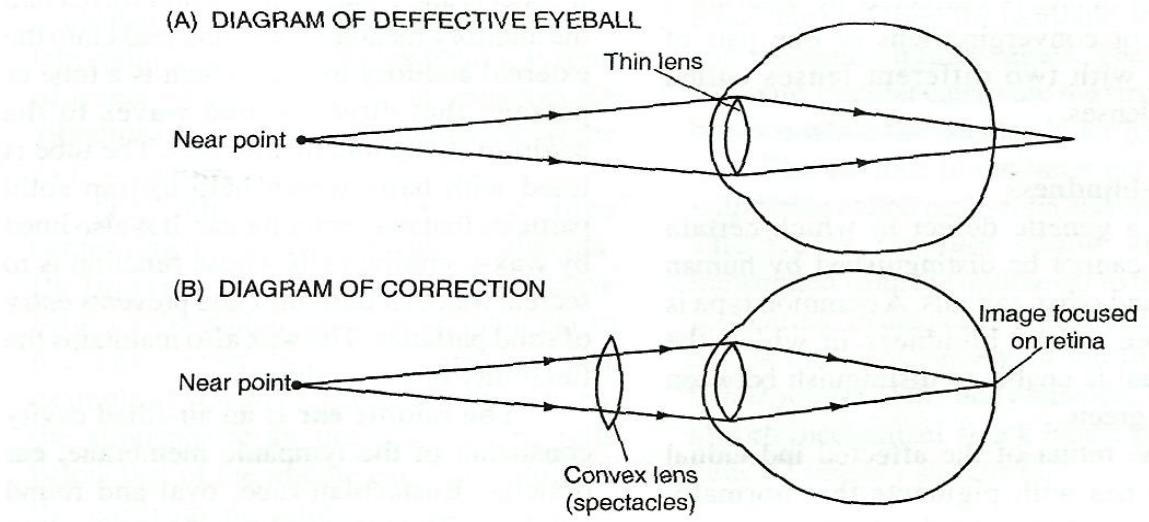


Figure: 1.19 Long-sightedness and how it is corrected

Astigmatism

This is a condition in which light rays from an object are brought to focus in different planes. This is caused by unequal curvature of the cornea or lens which produces unequal refraction of light entering the eye. It is corrected by wearing a special cylindrical lens in front of the eye, which corrects the focus in the defective planes.

Squintedness

This is an eye defect in which the extrinsic muscle of the eye that control the turning of the eyeball do not co-ordinate accordingly on stimulation. The defect affects the paired rectus muscle which turn the eye up and down and the lateral rectus muscles which move the eye left and right. In this condition, the eyeballs face different directions hence focusing and accommodation are achieved with difficulty. The defect is difficult to correct.

Old Sight (Presbyopia)

This is a condition in which the light rays from a near object is brought to focus behind the retina, while the rays from the distant object is sharply focussed. This is caused by hardening (loss of elasticity) of the lens and weakening of the ciliary muscles due to old age. The defect is corrected by wearing a convex or converging lens or one pair of glasses with two different lenses called bifocal lenses.

Colour- blindness

This is a genetic defect in which certain colours cannot be distinguished by human beings and other animals.
A common type is red-green colour blindness in which the individual is unable to distinguish between red and green.

The retina of the affected individual lacks cones with pigments that normally respond to green and red colours.

At the moment there is no cure for colourblindness, but in future, with the breakthrough in genetic engineering, such genetic disorders may be corrected.

Cataracts

This is an eye defect associated with old age. It may also be caused by eye injury due to a blow or by complications of diabetes mellitus.

In this condition the eye lens becomes cloudy or opaque hence blocking transmission of light rays. The transparent protein fibres in the lens are denatured and coagulated forming the opaqueness in the lens. The defect can be corrected surgically by replacing the defective lens with a good one from a donor or an artificial lens.

1.7: The Human Ear

The ear is a complex sense organ whose functions are to perceive sound and maintain balance. The structure of the ear consists of three parts; an outer, middle and inner ear. See figure 1.20.

The outer ear consists of the pinna and external auditory meatus. The pinna is a flap of skin and cartilage which partially covers the opening to the external auditory meatus. It collects and concentrates sound waves into the auditory meatus. The pinna leads into the external auditory meatus which is a tube or passage that directs sound waves to the eardrum (tympanic membrane). The tube is lined with hairs which help to trap solid particles that may enter the ear. It is also lined by wax-secreting cells whose function is to secrete wax that traps dust and prevents entry of solid particles. The wax also maintains the flexibility of the eardrum.

The middle ear is an air-filled cavity consisting of the tympanic membrane, ear ossicles, Eustachian tube, oval and round windows. The tympanic membrane is a thin tough membrane that covers the external opening of the middle ear. It consists of a double layer of epidermis, with connective tissue in between the layers. When it is hit by sound waves from outside, it vibrates and transforms sound waves into vibrations. It then transmits the vibrations to the ear ossicles. The ear ossicles are three bones namely malleus, incus and stapes.

The ossicles are suspended by muscles, tensor tympani and stapedius. These muscles also prevent excessive vibrations which could damage the inner delicate membranous labyrinth. The three ossicles form a system of levers which amplifies and transmits the vibrations from tympanic membrane to the oval window.

The eustachian tube is a tube connecting the middle ear with the pharynx. Its function is to equalise air pressure between the middle ear and the outer ear to prevent distortion of the eardrum. For example, if you go higher up in an aeroplane, the atmospheric air pressure outside falls below that of the middle ear. This results in the eardrum bulging outwards, and the condition can be rectified by yawning or swallowing which opens the eustachian tube to equalise the pressure on both sides of the eardrum. Although the eustachian tube is an important part of the ear, on the other hand it can provide a passage for entry of pathogenic microbes from the pharynx to the middle ear causing ear infection.

The inner ear is a fluid-filled cavity connected to the middle ear by the oval window. It consists of a series of chambers and canals embedded in the bone of the skull-It has three cavities: the vestibule, the cochlea and the semi-circular canals. The vestibule and semi-circular canals are the structures for balance while the cochlea is for hearing.

The cavities in the inner ear are filled with fluids called perilymph and endolymph. The fluids conduct sound vibrations transmitted from the middle ear to the cochlea for hearing. In the vestibule and semi-circular canals the displacement of the fluids leads to restoration of the body balance. The fluids absorb mechanical shock hence protect the delicate sensory structures.

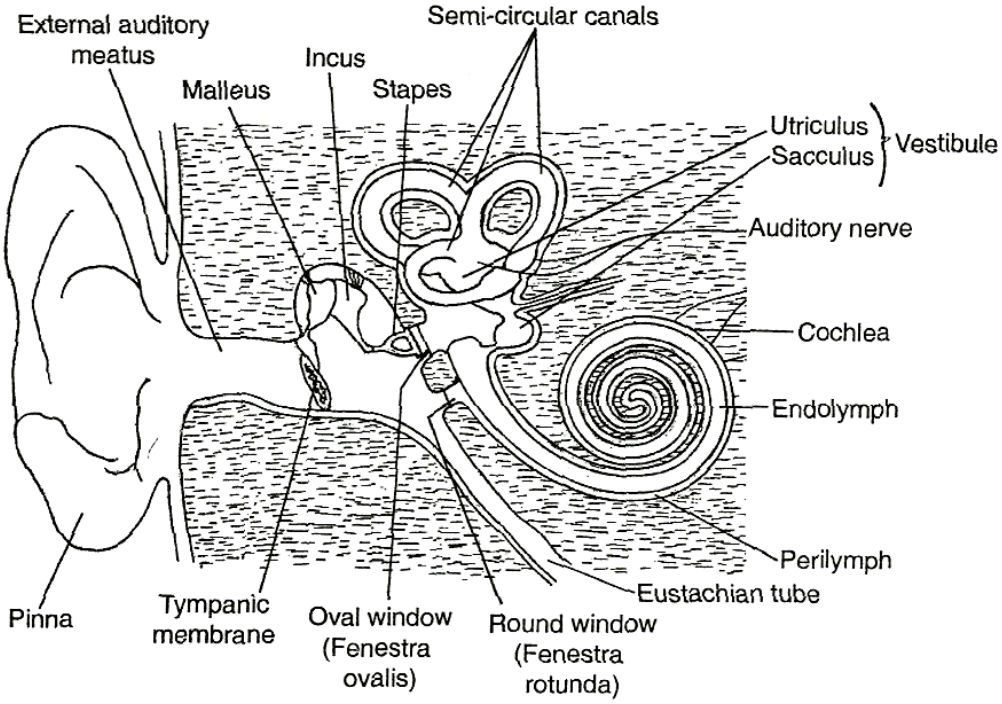


Figure: 1.20 Longitudinal section of the human ear

Hearing

The cochlea is the structure responsible for hearing. It is a spirally shaped tube consisting of a system of canals, membranes and sensory cells. The canals are filled with endolymph and perilymph. The coiling of the cochlea offers a large surface area for attachment of the sensory cells responsible for hearing. See figure 1.21.

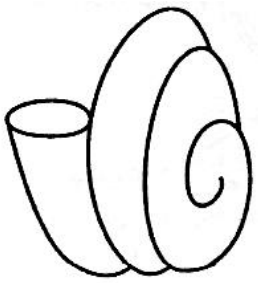


Figure: 1.21 External view of the cochlea

How do the ears perceive sound? Firstly, the pinna concentrates sound waves into the auditory meatus. The sound waves strike the eardrum and cause it to vibrate. The vibrations are transmitted to the ear ossicles in the middle ear.

From the eardrum the vibrations are picked by the first ear ossicle, the malleus, which transmits to the incus up to the stapes. The stapes passes the vibrations to the oval window from where the vibrations are transmitted to the perilymph of the cochlea.

The three ear ossicles are specially arranged to amplify the vibrations as they transmit them to the oval window. In the cochlea the vibrations stimulate the sensory cell hairs to generate nerve impulses which are transmitted to the brain via the auditory nerve for interpretation. The intensity of stimulus transmitted to the brain enables the brain to interpret the impulses as sound of specific pitch and loudness.

Meanwhile the vibrations in the fluid of the inner ear are dissipated back into the middle ear through the round window. The ear discriminates between frequencies in that certain frequencies stimulate only specific small parts of the cochlea. The direction of sound is detected accurately as a result of both ears functioning together. When sound waves come from the front, both ears pick the waves at the same time. The intensity of the impulses by the auditory nerve will be of equal strength. If sound is from the sides, one ear will pick the waves earlier than the other,, so that the intensity of the impulses, transmitted to the brain from one ear will be different from the other one. The time lapse of impulses to the brain allows for the determination of direction and distance.

Maintenance of Body Balance and Posture

Balance is brought about by the semi-circular canals and the vestibule shown in figure 1-22.

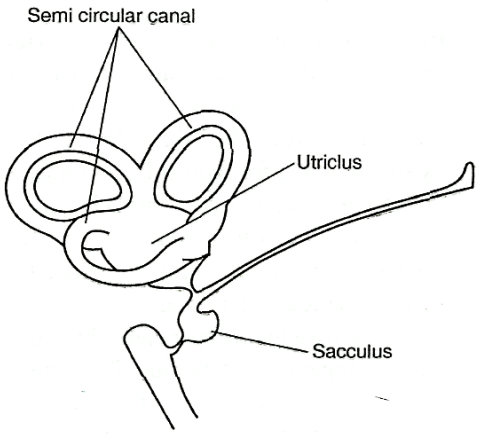


Figure: 1.22 Vestibular apparatus

Semi-Circular Canals

These are three tubular cavities containing endolymph. These canals lie mutually at right angles to each other and occupy the three planes of space. The two of these lie vertically and at right angles to one another while the third is horizontal. Each semicircular canal has a swelling called ampulla at one end containing sensory cells. The semi-circular canals maintain body balance and posture in relation to movement of the head. For example, when one spins and then stops suddenly one feels dizzy. This is because the fluid is still in

motion and stimulating sensory cells in the ampulla. The movement of the fluid stimulates the sensory cells which trigger off nerve impulses which are transmitted via the auditory nerve to the brain for interpretation. In the brain the information is relayed to the motor nerve which carries motor impulses to the muscles of the body which restore the body balance.

Vestibule

The vestibule consists of utriculus and sacculus which contain the sensory cells. They maintain body balance and posture in relation to gravity. When the body balance is shifted the fluid disturbs sensory cells. This triggers a nerve impulse to the brain via the auditory nerve. The brain interprets the impulse according to the position of the body in relation to gravity. The brain relays a nerve impulse through the motor neurone to the muscles of the body to restore the correct posture.

Defects of the Ear

Deafness is a hearing defect which makes an individual unable to perceive sound. There are two categories i.e. permanent and partial deafness.

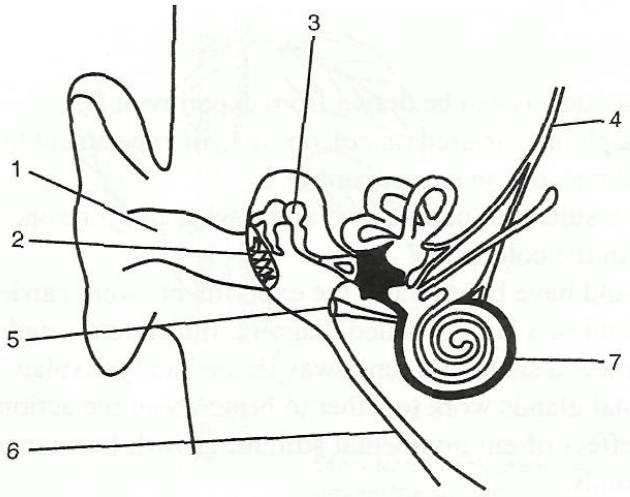
Permanent deafness is due to damage of the cochlea or auditory nerve. These may be damaged due to prolonged exposure to loud sounds. It may also result when the cochlea is sensitive to certain drugs e.g. some antibiotics, permanent deafness is difficult to correct.

Partial deafness is brought about by impairment of the structures that conduct vibrations to the cochlea e.g. the eardrum and ear ossicles. Ear ossicles can be impaired due to abnormal growth of connective tissue (fibrosis) in the middle ear or by calcification of ear canals. The eardrum can also be damaged by infection or physical blow. It may also be due to the production of too much wax which hardens hence blocking the external auditory meatus. This type of partial deafness can be corrected by surgery or by using a hearing aid.

Deaf persons can be assisted to learn by using the sign language. Hence they can be integrated in the normal learning institutions without the need of special schools.

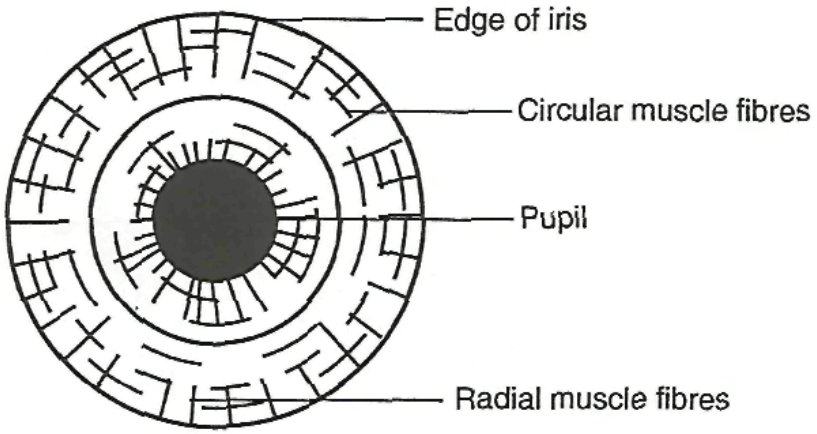
Revision Questions

1. This diagram shows the human ear



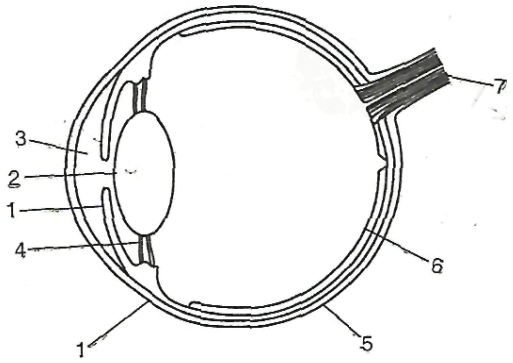
a. Name the structure labelled 1-7.
b. In which region of the ear is the velocity of the sound fastest?
c. What substance is produced by structure 1?
d. Give the function of structure 6.
e. From structure 7, how does hearing finally take place?
f. State the other functions of the ear apart from hearing.

2. When a person's hand accidentally touches a hot object it is quickly withdrawn. With the aid of a large labelled diagram explain what causes this response.
3. (a) State four differences between co-ordination of the human eye's internal response to light and that of tropic movement of the flowering plant in response to light,
   (b) Which structure in the ear detects: (i) Sound waves? (ii) Change in posture?
4. (a) With the aid of a large labelled diagram, illustrate a simple reflex arc.
   (b) Aperson sees a snake and runs away immediately. Explain how the nervous system and adrenal glands work together to bring about the action observed.
5. The following figure shows the internal arrangement of the muscle fibres in the iris of human eye.

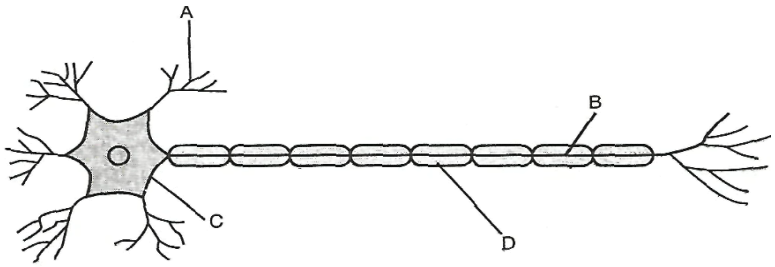


   (a) How is the pupil affected by the contraction of:
      (i) Circular muscle fibres?
      (ii) Radial muscle fibres?
   (b) Where are the light-sensitive cells located in the eye?
6. How is the fovea centralis adapted for Its function in the human eye?
7. What are the functions of the human ear? Explain how the structure of the human ear is suited to perform these functions.
8. (a) (i) At the resting potential the inside of an axon is_____charge while the outside is_____charged.
      (ii) Explain the difference in the charges in (a)(i) above.
   (b) What would be the effect of treating an axon with a metabolic poison?
   (c) How is resting potential attained?
9. Nocturnal animals such as the owl are capable of seeing fairly well at night. What two retinal adaptations have made this possible?

10. The following figure is a representation of a human eye.
    a) Name the parts labeled 1-7
    b) State two function of structure 3.



11. Study the following figure of the motor neuron:
    (a) Name the parts labelled A, B, C and D.
    (b) State the functions of the parts labelled A, B and D.



12. State the types of neurons and their functions.
13. Describe the parts of the brain.
14. What is the role of the peripheral of the nervous system?
15. What is an impulse? How impulse passes through the synapse?

CHAPTER TWO
REPRODUCTION IN ANIMALS AND PLANTS

2.1 Introduction

The process by which mature individuals produce offspring is called reproduction. Reproduction is an essential characteristic of all living organisms. Basically there are two types of reproduction which are based on the ability of the cell to divide and form new daughter cells: sexual and asexual reproduction. Sexual reproduction involves the fusion of the male and female gametes to form a zygote. The fusion of the nuclei of the male and female gametes is known as fertilization. Asexual reproduction does not involve gametes; instead, parts of the mature organisms may develop to new individuals. Figure 2.1(a) and (b) show both **sexual** and **asexual** reproduction.

Importance of Reproduction

1. **Procreation:** Reproduction sustains or perpetuates the species so that does not become extinct. Since no living organism lives for ever, every species must produce new individuals (offspring) in order for the species to continue.
2. **Quality improvement:** It improves the quality of the species. Reproduction allows for mixing of genetic materials which leads to variations among individuals in a species. This is observed in sexual reproduction. The variations form the basis for adaptability in their habitats.

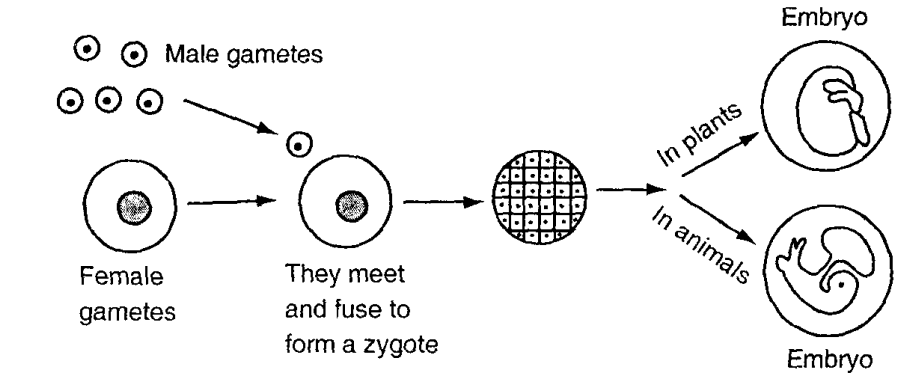


Figure: 2.1 (a) Generalized diagram of sexual reproduction

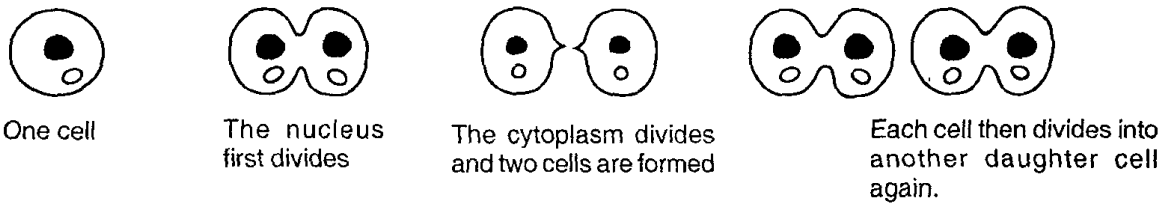


Figure: 2.1 (b) General representation of a sexual reproduction

2.2 Cell Division

Life in living organisms starts as a single cell, as a spore or as a zygote. In multicellular organisms, the cell divides into two and continues to divide in the same way. In unicellular organisms the cell divides into two separate daughter cells. The cell division starts with division of the nucleus i.e. the chromosomes and then the cytoplasm.

Chromosomes

In the nucleus there are a number of long thread-like structures called **chromosomes.** Each cell normally has a fixed number of chromosomes. Each chromosome is made of two parallel strands called **chromatids.** Each pair of chromatid is connected at one point by a structure called **centromere.** See figure 2.2.

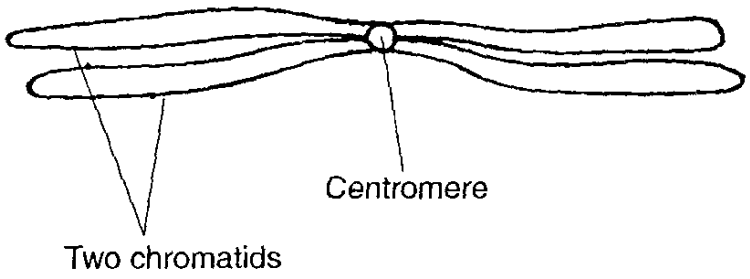


Figure: 2.2 A chromosome

Chromosomes are present in the nucleus all the time, but they only appear or become visible when viewed under a microscope during cell division. In body cells, chromosomes occur in pairs. Each pair of chromosomes has a characteristic length. The member of each pair is called a **homologous chromosome.** This means that the chromosomes are alike in appearance although their genetic composition may be different. During sexual reproduction each parent contributes one of the chromosomes from a homologous pair.

Along the length of the chromosome is a series of structures called genes. They are roo small to be seen even with a powerful ricroscope. They determine the characteristics of the cell and its progeny. Genes are made of a protein chemical substance called DNA (Deoxyribonucleic acid) which contains coded information of instructions that dictate the characteristics of the offspring. For example, whether male or female.

Young cells of an organism divide actively and grow before they differentiate into tissues and organs. The ability of cells to divide is located in specific areas where the cells are unspecialised. These include the meristematic cambium cells, meristematic apical cells in woody plants and in the malpighian layer in the mammalian skin.

The sequence of events leading to cell division in plant and animal cells is basically the same. There are two types of cell divisions namely mitosis and meiosis.

Mitosis

This is a type of cell division in which a cell divides into two daughter cells each having the same number of chromosomes as the parent cell. It ensures that every body cell contains the same number of genes as the parent cell.

The behaviour of chromosomes during mitosis is usually described as a series of stages, for the convenience of explaining the process involved in a logical manner. These stages are **interphase, prophase, metaphase, anapha.se and telophase.** The sequence of these stages occur in a smooth continuous manner so that one stage merges into the next stage without interfering with cellular activities. It is worth noting that mitosis takes place in somatic (body) cells. The stages of mitosis are summarised in figure 2.3 (a) to (e).

Interphase

During interphase the cell undergoes intense internal activities in preparation for the division. These activities include:

- ❖ Multiplication of genetic material so that daughter cells will have the same number of chromosomes as the parent cell.
- ❖ Synthesis of new cell organelles such as golgi apparatus, centrioles mitochondria and ribosomes.
- ❖ Build up of enough energy stores in form of Adenosine Triphosphate (ATP) (mitochondria) to drive the cell through the entire process of cell division. See figure 2.3 (a).

Prophase

1. A cell in prophase undergoes the following events:
2. The duplicated centrioles (in animal cells) separate and move to opposite poles of the cell. Spindle fibres begin to form.
3. The nuclear membrane begins to break down while the nucleolus disappears.
4. The chromosomes thicken and shorten. At this stage, they take up stains easily hence become visible. Each chromosome is now seen to consist of a pair of chromatids joined at the centromere as seen in figure 2.3(b).

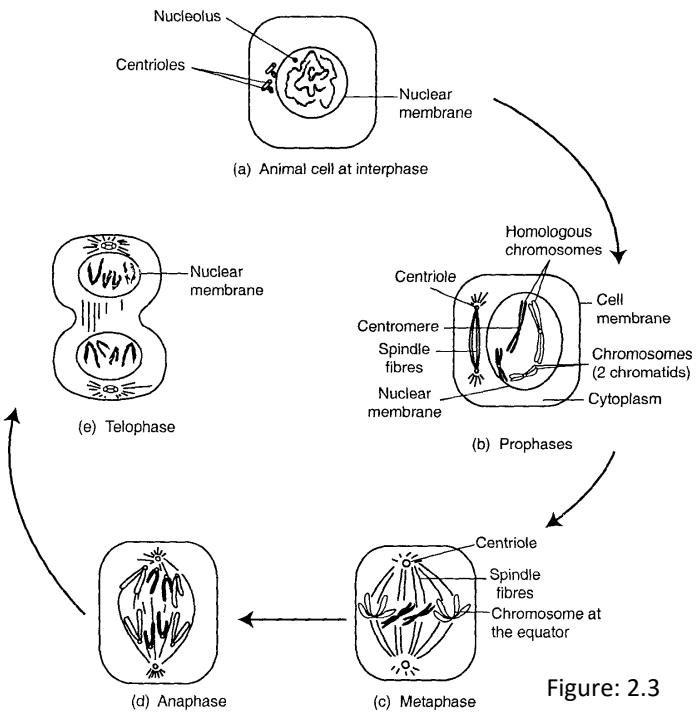


Figure: 2.3

Metaphase

1. The nuclear membrane disappears hence chromosomes are free in the cytoplasm.
2. The spindle fibres lengthen. In animal cells they attach to the centrioles at both poles.
3. The chromosomes align themselves at the equator of the spindle and are attached to the spindle fibres by their centromeres. See figure 2.3(c).

Anaphase

This is the phase of cell division during which the following events occur:

1. The chromatids separate at the centromere and migrate to the opposite poles. It is believed that the movement of these chromatids is brought about by the shortening of spindle fibres.
2. The spindle apparatus begins to disappear.
3. In animal cells the cell membrane begins to constrict towards the end of anaphase. See figure 2.3(d).

Telophase

This is the final phase of cell division.

1. The chromatids collect together at the two opposite ends of the spindle.
2. A nuclear membrane forms around each set of chromatids and are now referred to as chromosomes.
3. The cytoplasm divides into two leading to the formation of two daughter cells.
4. The chromosomes become less distinct. See figure 3.3(e).

Note: In animal cells the division of cytoplasm is by constriction of cell membrane. But in plant cells a cell plate forms within the cytoplasm and grows to separate the cell into two. See figure 2.4(a) and (b).

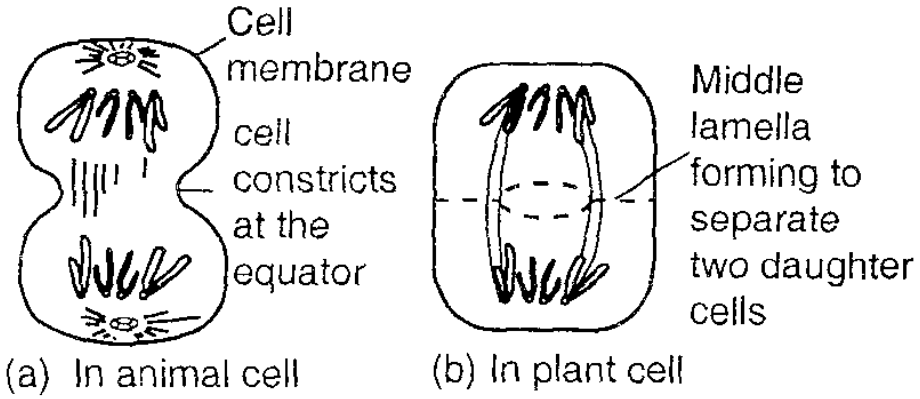


Figure: 2.4 Cytoplasmic division in animal cells and plant cells

Significance of Mitosis

Mitosis is the type of cell division that takes place during the growth of an organism, for example in the development of a fertilised egg into an adult human being. The fact that these divisions are mitotic means that all the cells of the body have the diploid (double number) of chromosome (also referred to as "2n" constitution), 23 pairs in the case of the human, 4 pairs in *Drosophila, 1* pairs in garden pen and 20 pairs in a mouse. Mitosis is also the basis of asexual reproduction. It is the process that occurs when amoeba undergoes binary or multiple fission or when a bud develops in yeast.

Mitosis ensures that the chromosomal constitution and hence the genetic constitution of the offspring is the same as the parents.

Meiosis

We have seen that a built-in feature of mitosis is the preservation of the parental chromosome constitution. Meiosis however involves two divisions of the parental cell resulting into four daughter cells. Each daughter cell has half the number of chromosomes (haploid-n) as the parental cell. This type of cell division takes place in reproductive organs during gamete formation in organisms.

Principle underlying Meiosis

Meiosis consists of two successive divisions. The parent cell splits into two (first meiotic division) and the products then divide again (second meiotic division), giving a total of four daughter cells. In the first meiotic division, homologous chromosomes get separated from each other and go into different cells. In the second meiotic division the chromatids separate. As in mitosis, meiosis is divided for convenience into a series of stages. These are given the same names as in mitosis but each is followed by I or II indicating whether it belongs to the first or second meiotic division. These are summarised in figures 2.5

First Meiotic Division Interphase I

As already stated under mitosis the cell prepares for division during interphase. This involves replication of chromosomes, synthesis of organelles and build up of energy to be used during the meiotic division. See figure 2.6 (a).

Prophase I

The first prophase of meiosis is characterised by the following activities:

1. The nucleolus disappears.
2. Centrioles, if present become arranged at opposite sides of the nucleus.
3. Chromosomes condense by shortening and thickening hence become more visible.
4. The Homologous chromosomes lie side by side in the process of **synapsis** forming pairs called **bivalents.**
5. As prophase proceeds the chromosomes may become coiled around each other and later their chromatids may remain in contact at points called **chiasmata** (singular-chiasma). Important genetic exchanges usually take place at these points. Chiasma formation is common in most cells during meiosis. However it is easier to understand the division where no chiasma formation takes place (achiasmate division) though they are uncommon. Prophase I is summarised in figure 2.6(b).

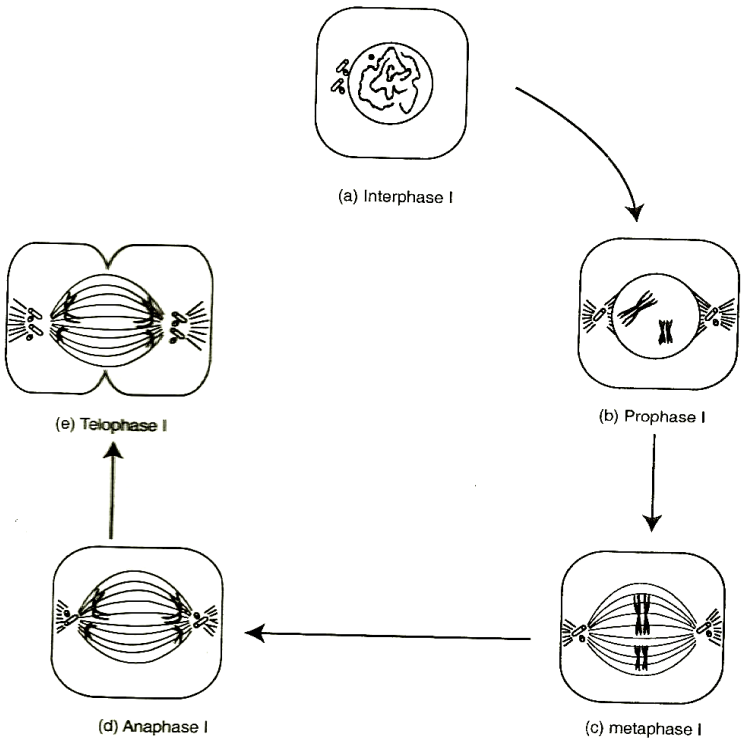


Figure: 2.5 Stages of the first meiotic division

Meta phase I

1. The nuclear membrane has disappeared hence chromosomes are free in the cytoplasm.
2. Spindle fibres are fully formed.
3. The homologous chromosomes still associated as bivalents move to the equator of the spindles. They attach to the spindles by their centromeres such that the two homologous chromosomes orientate towards opposite poles. The cell is now ready for separation of homologous chromosomes. See figure 2.6(c).

Anaphase I

During the first anaphase of meiosis **homologous chromosomes separate** and migrate to the opposite poles with their centromeres leading. This would be as a result of shortening of the spindle fibres hence pulling the chromosomes. See figure 2.6 (d).

Telophase I

When the chromosomes reach their respective poles the cell generally divides across the middle as in mitosis (figure 2.6 (e). Usually the daughter cells go into a short resting stage (interphase), but sometimes the chromosomes remain condensed and the daughter cells go straight into prophase of the second meiotic division.

At the end of meiosis I separation of homologous chromosomes has now been achieved.

Second Meiotic Division

The purpose of the second meiotic division is to separate the chromatids from one another. It also occurs in similar phases as in the final meiotic division.

Interphase II

As already stated the resultant cells of meiosis I usually go into a short interphase. See figure 2.7(a).

Prophase II: New spindle fibres are formed. See figure 2.7(b).

Metaphase II: The chromosomes move to the equator of the spindle and attach to the spindle fibres at their centromeres. The chromosomes orientate themselves towards the opposite poles. See figure 2.7(c).

Anaphase II: The sister **chromatids separate** from each other and move to the opposite poles pulled by the shortening of the spindle fibres. See figure 2.7(d).

Telophase II

1. The spindle apparatus disappears.
2. The nucleolus reappears and a nuclear membrane is formed around each set of chromatids.
3. The chromatids now at their destinations become the chromosomes of the daughter cells. They uncoil and regain their thread-like form.
4. The cytoplasm divides across the middle in the usual way. Four cells (sometimes referred to as a tetrad) are formed. Each cell has the haploid number of chromosomes (n). See figure 2.7(e). Meiosis is complete at this stage.

From the brief description of meiosis it is clear that there are two successive divisions. The first meiotic division is responsible for separating the homologous chromosomes and halving the chromosome number. For this reason the first meiotic division is described as **reduction division.** The function of the second meiotic division is to separate the chromatids from each other.

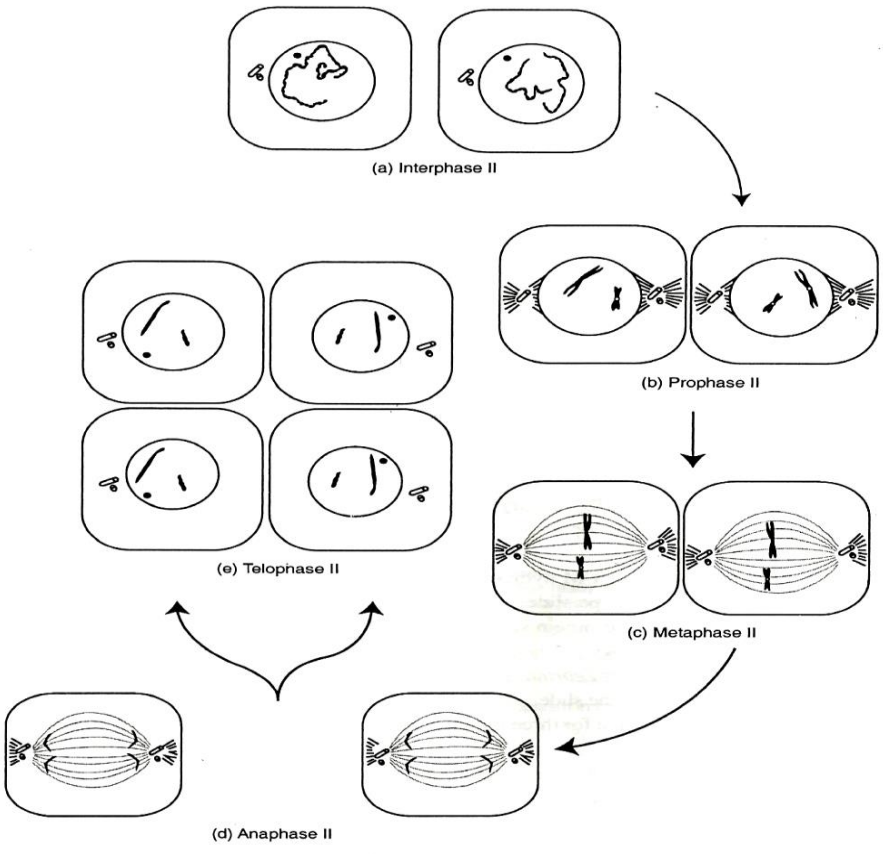


Figure: 2.7: Stages of the second meiotic division

Significance of Meiosis

Meiosis occurs during the formation of gametes (the sex cells) such as eggs and sperms. These contain half the number of chromosomes as the parent cells in those organisms which carry out sexual reproduction. Meiosis helps to restore a constant diploid chromosomal constitution in a species at fertilisation.

During fertilisation the nuclei of the two gametes fuse and produce a zygote which has a fixed number of chromosomes for each species. This represents the diploid condition (2n). If meiosis never occurred, fusion of gametes would result in doubling of the chromosomes for each successive sexually reproduced generation.

Meiosis also provides opportunities for new combinations of genes to occur in the gamete cells. This leads to genetic variation in the offspring produced by the fusion of gametes.

Similarities between Mitosis and Meiosis

1. Both take place in plant and animal cells
2. Both involve the division (multiplication) of cells. See table 2.1.

Table 2.1: Differences between Meiosis and Mitosis

Meiosis	*Mitosis*
1. Homologous chromosomes associate with one another.	1. Homologous chromosomes do not associate with one another.
2. Takes place in two nuclear divisions each having four stages.	2. Takes place in one nuclear division of four stages.
3. Produces four daughter cells, each haploid.	3. Produces two daughter cells, each diploid.
4. Occurs in reproductive organs leading to formation of gametes.	4. Occurs in somatic cells leading to growth.
5. Chiasma formation takes place and may Lead to crossing-over hence variation.	5. No chiasma formation therefore no crossing-over hence no variation.

Sexual Reproduction in Animals

Sexual reproduction involves the fusion of gametes. In animals two individuals are involved, a male and a female. The males produce gametes known as sperms and the females produce gametes known as ova (singular ovum). These gametes are produced by special organs known as **gonads** - the testes which produce sperms and ovaries which produce ova.

The sperm fuses with the ovum to form a **zygote**. This process is called **fertilisation**. The gametes are **haploid** and the zygote is **diploid**. Fertilisation may occur externally or internally.

External Fertilisation in Amphibians

External fertilisation occurs in animals such as amphibians and fish. This is only possible in water. During this time, the female lays eggs in water and the male sheds sperms over these eggs to fertilise them, resulting in fertilisation outside the body.

In this kind of fertilisation many eggs are released to increase the chances of survival, since the fertilised eggs could be attacked by bacteria or eaten by some animals.

During the mating season the males croak, mainly at night to attract females. While mating, the male mounts the female and shed sperms as the female lays the eggs. These activities increase the chances of fertilisation.

Eggs are laid in long strands of slippery jelly-like substance which provides protection to the eggs. At the same time the jelly prevents predators from feeding on the eggs. This substance separates the eggs from each other allowing for good aeration. It also attaches the eggs to the water plants and also makes the eggs to be buoyant.

Internal Fertilisation

Internal fertilisation occurs in reptiles, birds and mammals. Fertilisation occurs within the body of the female. Generally, the number of eggs produced by the females is fewer than those produced by animals where external fertilisation occurs. This is because there are higher chances of fertilisation since the sperms are deposited into the female's body. Furthermore, protection of the gametes and fertilised eggs is higher.

In most mammals, some chameleons and some snakes, the fertilised eggs develop into young ones within the body of the female. After the gestation period the females give birth to young ones.

Reproduction in Mammals

Fertilisation in mammals occurs internally. After fertilisation the fertilised egg is laid or develops within the female's body in a special structure, the uterus. The egg-laying mammals (monotremes) are said to be **oviparous.** An example of an oviparous mammal is the platypus. In some mammals, the zygote does not develop fully within the uterus but completes development within a special structure called pouch as in the **marsupials** e.g. kangaroo. In most mammals however, the zygote develops fully into a young mammal which resembles the adult.

The ability to give birth to young one's as in **placental mammals** is referred to as **viviparity.** Mammals whose zygotes develop within the uterus have mammary glands. These glands produce milk on which the young mammals feed until they are able to feed on the same food as the adults. In these mammals, parental care is highly developed.

2.5: Reproduction in Human beings

Structure and Functions of the Male Reproductive System

Figure 2.8(a) and (b) show the structures of the human male reproductive system. The testes lie outside the abdominal cavity in the **scrotal sac.** The position of the testes

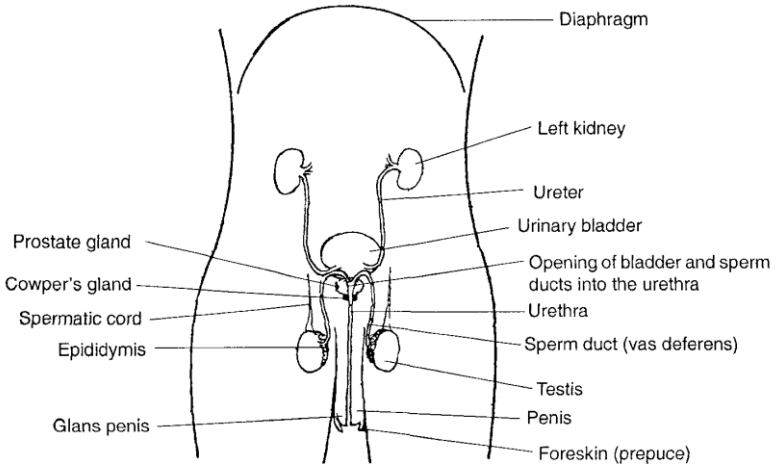


Figure: 2.8 (a) Male reproductive system (front view)

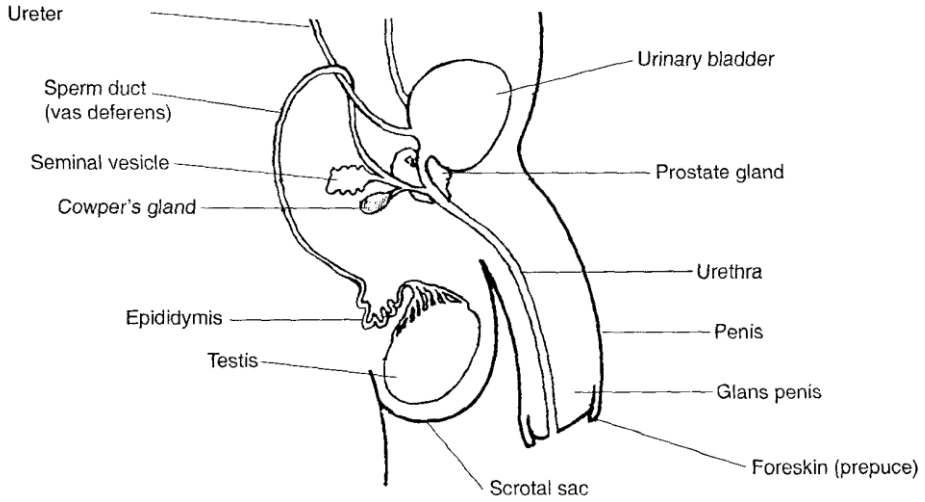


Figure: 2.8 (b) Male reproductive system (side view)

outside the body is significant as it provides a cooler environment for sperm production. Sperms develop best at a lower temperature than that of the body. The testes originate in the abdomen from the embryonic tissue, but in mammals they later move down into the scrotal sac. The testis is made up of several highly coiled tubes known as the **seminiferous tubules.** The lining of these tubules consists of actively dividing cells which give rise ultimately to sperms. Between the seminiferous tubules are interstitial cells which produce the male hormones called **androgens.**

The seminiferous tubules finally unite to form the **epididymis,** a much coiled tube about 6 metres long when stretched. The epididymis lies on the outside of each testis and its function is to store the sperms. It is connected to the **sperm duct, or vas deferens.** This is a narrow tube connecting the epididymis to the urethra which is the ejaculatory duct.

The urethra is continuous with the urinary bladder. The two vasa eferentia come together and open into the origin of the urethra i.e. at the junction of the urethra and the urinary bladder.

The seminal vescicle is a blindly ending sac which also opens into the urethra at this region. It provides an alkaline fluid which contains nutrients for the spermatozoa. Near this point is situated the **prostate gland** whose secretion is alkaline to neutralise the vaginal fluids. It also activates the sperms. Just below the prostate gland on either side of the urethra, lies the **cowpers' gland** which secretes an alkaline fluid that neutralises the acidity along the urethra. The acidity of the urethra caused by the pH variation of the urine. All the fluids combine with the spermatozoa from the vasa eferentia to form the semen.

The urethra is a long tube ordinarily used for the expulsion of urine to the exterior. It traverses an erectile intromittent organ, the penis, which projects from the body. The penis has a retractable skin (prepuce) covering the end region which is known as the glans penis. Since the urethra also serves as the duct for the passage of sperms during copulation, it is said to be urinogenital in function. The **penis** is made up of spongy tissue, muscle and blood vessels. At the time of sexual activity, the penis erects by having the spaces in its spongy -tissue filled with blood. This enables it to penetrate the vagina during coitus in order to deposit sperms in the female reproductive tract.

Structure and Function of the Female Reproductive System

Figure 2.9 shows the major structures of the female reproductive system. There are two **ovaries** which are cream coloured oval bodies measuring 3-4 cm long. They are found in the lower part of the abdomen below the kidneys. Ovaries are held in position by membranes and blood is supplied to them by the ovarian artery and removed by the ovarian vein. The ovary produces the egg and female hormones.

An **oviduct** is a tube with an expanded funnel shaped opening which conducts ova released by the ovary to the uterus. It is lined with cilia which waft the ovum towards the uterus. The movement of the ovum is also aided by contractions of the smooth muscles of the tubal wall. Fertilisation occurs in the oviducts.

The **uterus** is found in the lower abdomen. It is in this structure where the embryo develops. The uterus is capable of expanding as the embryo grows and can return to original size of about 8 cm in length after birth. This is possible because its walls are muscular. These muscles are also important at the time of birth as they aid in the expulsion of the fully developed foetus.

The uterine wall is lined by an endometrium for implantation and nourishing of the embryo at its initial stages. The uterus is kept in position by ligaments and is supported by the bladder and the

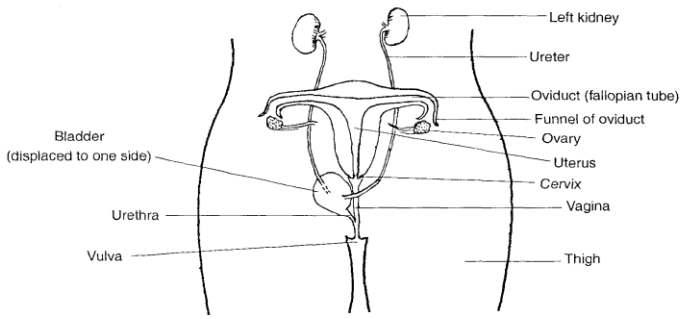


Figure 2.8(a) Female reproductive system (front view)

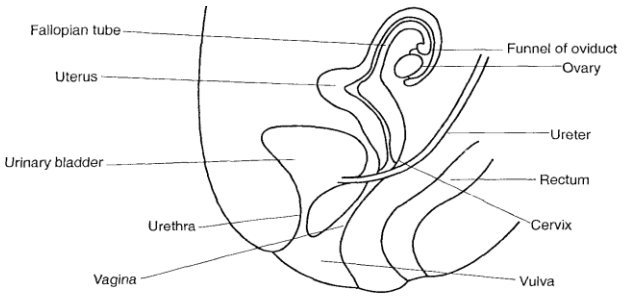


Fig. 2.9(b): Female reproductive system (vertical section)

muscular floor of the pelvis. At the lower narrow end of the uterus which leads into the vagina is the cervix. The cervix has a ring of muscles that separates the uterus from the vagina. It secretes a plug of mucus which prevents entry of pathogens into the uterus during pregnancy.

The vagina is the copulatory canal. It is also called the birth canal. The vagina together with the urethra opens to the outside at the vulva. Within the walls of the vulva are the vestibular glands which release mucus when the female is sexually aroused which helps to lubricate the vagina during intercourse.

Fertilisation

For proper discussion of fertilisation it is necessary to understand the structure of the male and female gametes. The male gametes are formed in the seminiferous tubules of the testes by meiosis. The final products of meiosis enter the sertoli cells where they are nourished and undergo differentiation into the mature sperms. The mature sperms such as the one shown in figure 2.10, leave the seminiferous tubules and are stored in the epididymis.

The Human Sperm

A sperm consists of an ovoid head, short neck, middle peace and tail as seen in figure 2.11 The head contains a large nucleus. The nucleus carries genetic material which is haploid in number (n). At the tip of the head is an acrosome which contains lytic enzymes. These enzymes digest the membrane of the egg for the sperm to penetrate and affect fertilisation.

The short neck contains centrioles. The middle piece is packed with a large number of mitochondria. These mitochondria produce energy necessary for propulsion of sperm to reach the egg. The tail propels the sperm forward by its side to side lashing action.

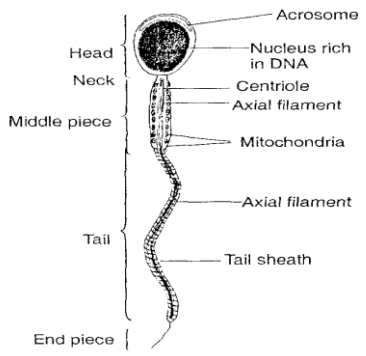


Fig. 2.11: Unman spermatozoon

Formation of Ova

Unlike the production of sperms 'in males which only begins at puberty, the process of egg formation begins in the ovary of the foetus before birth.

At birth there are about 70,000 **potential** egg cells in the ovaries of a baby girl. They are enclosed by a layer of ovary cells known as **primary follicles** which provide nourishment. Of these about 500 of them may develop into ova during puberty. This involves the process of meiosis.

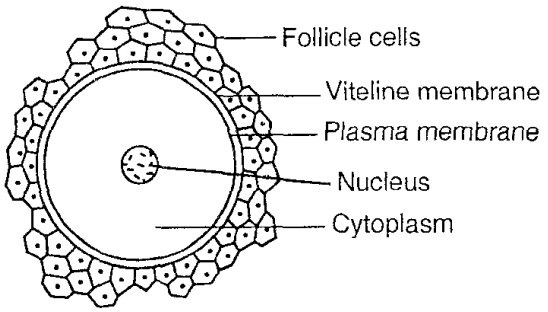


Figure: 2.12 Mature human ovum

During puberty the primary follicles undergo growth to become the mature **Graafian follicle.** At ovulation the Graafian follicle bursts open to release a mature ovum surrounded by layers of follicle cells. See figure 2.12.

Mature Human Ovum

A mature human ovum is spherical in shape with a diameter of about 0.2 mm. It contains a large haploid nucleus surrounded by a nuclear membrane. The nucleus is within the cytoplasm enclosed by a plasma membrane. Another membrane the vitelline membrane surrounds the plasma membrane.

The Process of Fertilisation

Fertilisation is a process whereby the nucleus of a male gamete fuses with the nucleus of a female gamete to form a zygote. This occurs in the upper part of the oviduct after copulation. The sperms are drawn up by suction through the cervix into the uterus from where they swim up to the oviduct using their tails. See figure 2.13(a). Although a single ejaculation contains millions of sperms, only one will fertilise the ovum.

As the ovum moves down the oviduct, it releases chemical substances which have to be neutralised by those produced by the acrosome before the sperm penetrates the ovum.

When the sperm comes into contact with the egg the acrosome bursts open and releases the lytic enzymes which dissolve the egg membranes. See figure 2.13(b). The acrosome then turns inside-out forming a fine filament that is used to penetrate the egg. See figure 1.24. Hence the head of the sperm enters the ovum, the tail is left outside the ovum. See figure 2.13(c).

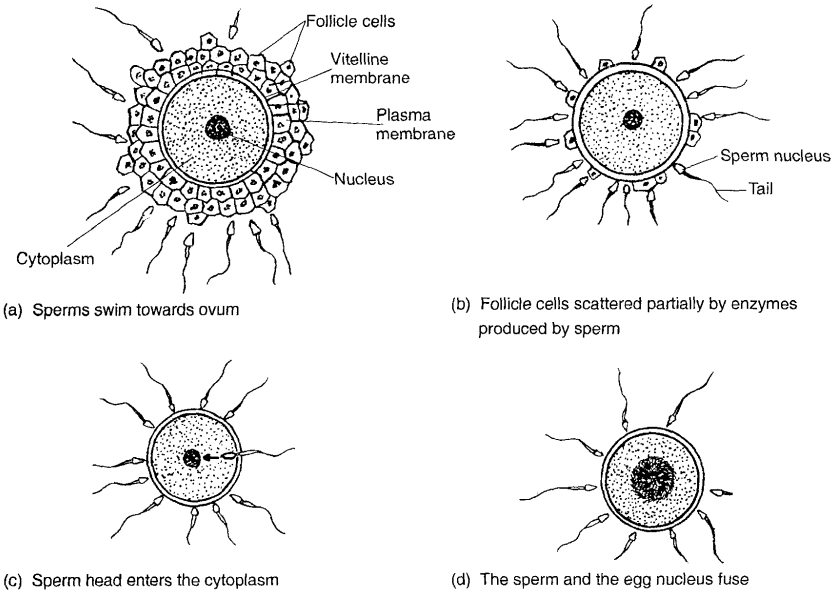


Figure 2.13: The process of fertilization

The vitelline membrane undergoes a change which stops any other sperm from entering the ovum. Once in the cytoplasm the head bursts to release the male nucleus. The male nucleus then fuses with the female nucleus to form a diploid zygote. See fig. 2.14(d). After ovulation the ovum can remain viable for 8-24 hours before it dies. On the other hand the sperms can remain viable for 2-3 days within the female reproductive tract.

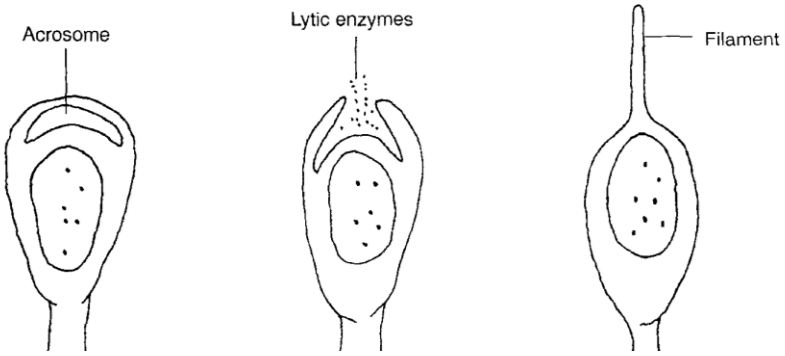


Figure 2.14: Release of acrosome enzymes and formation of filament that help sperms penetrate the egg

Implantation

The attachment of the blastocyst as seen in figure 2.14 to the wall of the uterus by the villi is called **implantation.** Normally implantation takes place in the uterus.

After fertilisation the zygote undergoes several mitotic division as it moves down the oviduct. Its movement is aided by the cilia movements and the contractions of the smooth muscle along the oviduct. By the time it reaches the uterus, it has formed a hollow structure of several cells called a blastocyst. The movement of the zygote from the oviduct to the time it gets implanted last for about seven days.

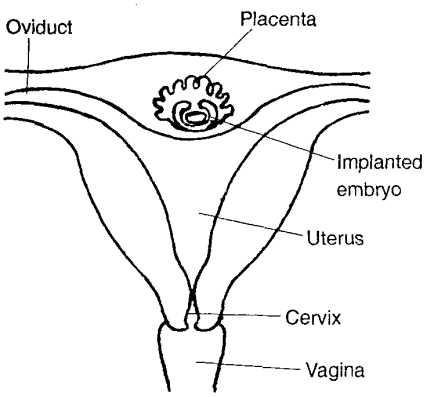


Figure 2.14: Embryo implants into uterus

In the uterus the blastocyst develops finger-like projections called villi which grow into the wall of the uterus (endometrium). The villi together with endometrium develop into a special organ called the placenta. Upon implantation the blastocyst becomes an embryo. Occasionally the zygote fails to move down the oviduct to the uterus but instead gets implanted into the walls of the oviduct where it develops. This condition is referred to as **ectopic pregnancy** which is fatal if carried to term in most cases.

Formation of Placenta

During implantation the blastocyst differentiates into three layers namely the chorion, amnion and allantois as shown in figure 2.15.

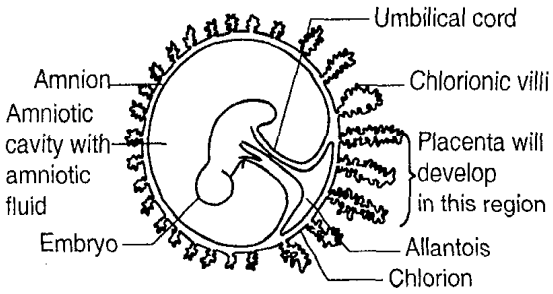


Figure 2.15: Diagram illustrating relationship between the human embryo and its embyanic membranes

The chorion, which is the outermost, develops finger-like projections called chorionic villi. These villi grow into the endometrium. During the early stages of embryo development, the villi form the sites for material exchange, between the embryo and maternal blood vessels in the uterine wall.

The amnion surrounds the embryo forming an amniotic cavity within which the embryo lies. The amniotic cavity is then filled by a fluid secreted by the amnion called the amniotic fluid. This fluid provides a fluid environment which later suspends the foetus providing it with support. It also acts as a shock absorber hence protecting the foetus against mechanical injury.

The chorionic villi, allantois together with the endometrium form the placenta. The embryo is attached to the placenta by a tube called the umbilical cord which increases in length as the embryo develops. When the placenta is fully formed, the embryo becomes a foetus, this is at about 3 months of pregnancy.

Table 2.2: Placental exchanges

What is allowed to pass through the Placenta	*What is not allowed to pass through the Placenta*
(a) From the mother to the foetus. (i) Oxygen. (ii) Digested food substances like; glucose, amino acids, fatty acids, glycerol. (iii) Vitamins. (iv) Mineral salts. (v) Mineral hormones. (vi) Water. (vii) Antibodies and antigens. (b) From the foetus to mother. (i) Carbon (IV) oxide. (ii) Nitrogenous waste products.	(i) All the blood cells. (ii) Plasma proteins. (iii) Most bacteria.

The Role of the Placenta

The placenta is a temporary organ found only in placenta! mammals and is the only organ in animals composed of cells derived from two different organisms, the foetus and the mother. It is a point of close association between the maternal and foetal circulations and facilitates the transfer of nutrients, and metabolic waste products between the foetus and mother. The placenta, is a discrete disc-shaped structure localised in one region of the uterus wall and as it develops it takes over from the trophoblastic villi as the principle site of exchange of materials after 12 weeks. The placenta selectively allows some substances to pass through and not others. See table 2.2.

Drugs, alcohol and some chemicals from cigarette smoke pass through the placenta hence pregnant mothers are advised not to take alcohol or smoke excessively. If she has to take any drug like asprin, it has to be under the instructions of a doctor.

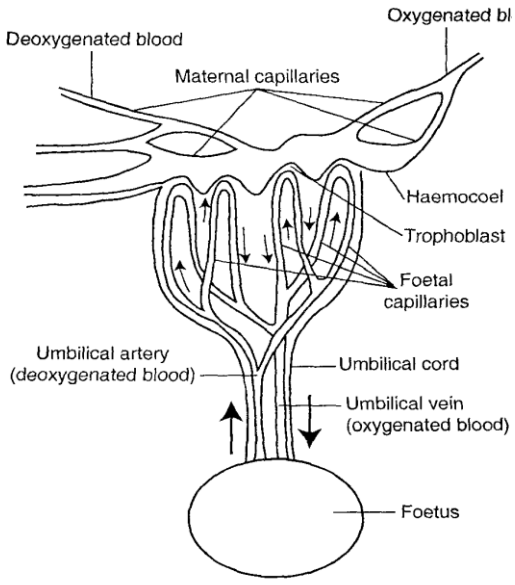


Figure 2.16: (a) diagram showing the relationship between blood supplies of the embryo, the placenta and the uterus.

The foetal blood does not mix with maternal blood in the placenta. The exchange of materials occur across the **sinus** in the uterine wall and the capillary systems of foetus across intercellular space by diffusion. See figure 2.16(a) and (b).

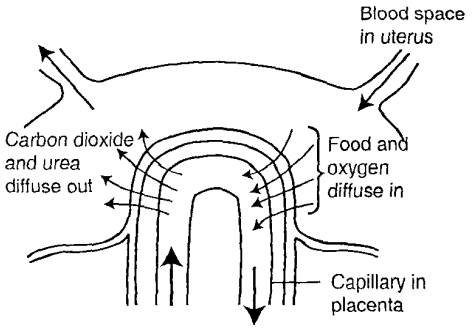


Fig. 2.16(b): Diffusion across the placenta

This is because there is no direct connection between the foetal blood system and that of the mother. If the two systems were directly connected, the delicate blood vessels of the foetus would burst due to the Higher blood pressure in the maternal circulatory system. During pregnancy, the placenta takes over the role of producing hormones, oestrogen and progesterone whose role is summarised in table 2.3.

Table 2.3: Summary of major functions of human oestrogen and progesterone during pregnancy

Oestrogen	*Progesterone*
Growth of mammary glands Inhibits Folical Stimulating Hormone release Inhibits prolactin release Prevents infection in uterus Increases size of uterine muscle cells Increases ATP and creatine phosphate formation Increase sensitivity of myometrium to oxytocin	Growth of mammary glands Inhibits Folical Stimulating Hormone release Inhibits prolactin release Inhibits contraction of myometrium

Gestation Period

The period between conception (implantation) and birth is termed as gestation. The gestation period varies in different mammals. In mice the period is about 22 days, in rabbits it is about 30 days and in man it is 9 months. In a large mammal like an elephant it is about eighteen months.

By the time the human embryo is two weeks old the three embryonic membranes aliantois, amnion and chorion have already formed. The embryo now appears as a bump in the uterine wall.

The embryo then differentiates into tissues and organs. By the end of the third month, the heart and blood vessels forming the foetal circulatory system are fully developed. The head region which includes the nose and eyes is also well developed. The other regions which are formed by this time are the spinal cord and the tail. The limbs also show early signs of development. Within the next three months the limbs, alveoli and the nostrils are well developed and the foetaJ movements can be felt.

By the end of the nine-month period the foetus's head is directly above the cervix and all the organs and systems are fully developed such that they are functional at birth as in figure 2.16(a), (b) and (c). Normally birth occurs after the nine-month period. If birth occurs before the completion of six months the baby will not survive and this is referred to as **miscarriage.**

In the case where foetal development is interfered with either chemically or physically such that the foetus is expelled the condition is called **abortion.** However, if birth occurs after the seven month but before full term, such is referred to as a **premature birth.** A premature baby can survive if it has attained a certain weight or else it will require specialised medical care. In hospitals, premature babies are cared for in incubators.

A pregnant mother must have a balanced diet to keep her healthy. In her diet there should be plenty of proteins, calcium, phosphates and iron which are required by the developing embryo. The embryo requires protein for growth and development.

Calcium and phosphorus are required for bone formation while iron is for formation of haemoglobin. Since the foetus gets these nutrients from the mother's circulatory system, she has to take them in plenty so that they are sufficient to her and the foetus.

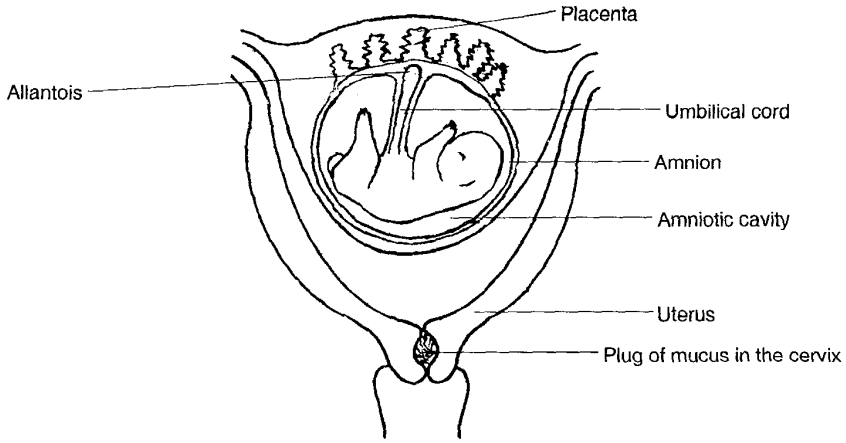
The expectant mother is advised to visit antenatal clinic or her doctor regularly for examination. During the examination urine test is carried out, changes in blood pressure, heartbeat, weight, sugar and albumen level are recorded to monitor the health of both mother and foetus.

Birth (Parturition)

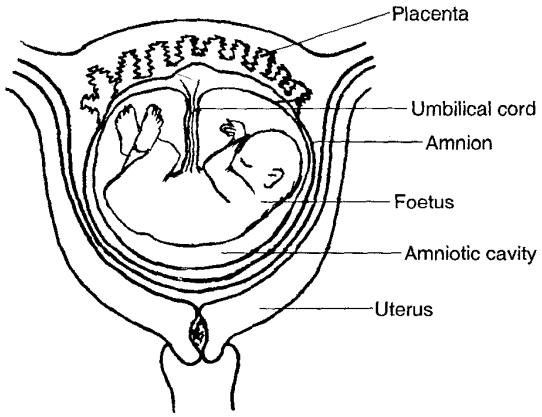
The onset of birth is signalled by the reduction in progesterone level in the mother's blood which allows the maternal **posterior puitary** gland to release hormone **oxytocin.** Oxytocin removes the inhibitory effect on contractions of the myometrium whose muscles start contracting. The release of oxytocin occurs in "waves" during "labour" and provides the force to expel the foetus from the uterus. The onset of contractions of the myometrium, called "labour pains" are accompanied by the dilation of the cervix, the rupture of the amnion and chorion releasing the amniotic fluid through the cervix, and the stimulation of stretch receptors in the walls of the uterus and cervix. The contraction of the uterus wall follows. Uterine contraction spreads down over the uterus thus pushing the foetus

downwards, head first through the widened cervix and birth canal and the baby is born. After birth the umbilical cord is ligatured and cut in order to separate the baby from the placenta. The placenta is expelled later as after-birth.

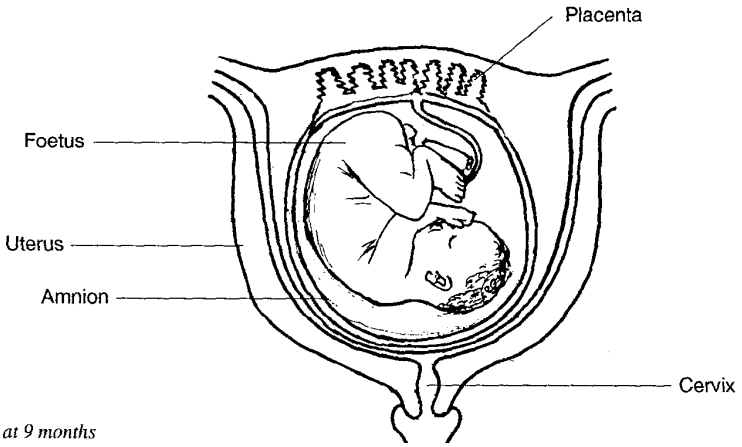
After birth and expulsion of the placenta, important changes take place in the baby's circulation associated with the fact that respiratory function of the placenta is taken over by the lungs. The newborn takes the first breath and the lungs expand and become functional.



(a) Foetus at 3 months



(b) Foetus at 6 months



(c) Foetus at 9 months

Figure: 2.16 Development of the human foetus.

Caesarean Delivery

Caesarean deliver is a surgical incision of the abdominal and uterine walls for the delivery of the offspring. This is done when there are complications such that the foetus cannot pass through the birth canal.

Abortion

This the premature termination of pregnancy before the foetus is capable of surviving. It may be brought about artificially through use of suction or hormones. In Somalia, abortion is illegal. It is not available on demand. However, it is permitted only in circumstances where doctors agree that continuing a pregnancy would endanger a woman's mental or physical health. Only then, can the abortion be allowed. Any other way, abortion is illegal and undesirable and may be fatal.

Parental Care

It is the attention given to the new born by providing food and protection. In human beings the attention is prolonged to cover even the maturity stage. In placenta! mammals the newborn is first fed on milk. In mammals, the milk is produced by the mammary glands under the influence of lactogenic hormones e.g. prolactin.

Mother's milk is the best food for the offspring because it contains all the nutrients needed for the growth and development of the body. From the first to the third day the mammary glands produce colostrum, a yellowish fluid which contains proteins and lactose. It also contains a high percentage of antibodies which provide natural defence against some diseases. Colostrum is then replaced by milk which contains protein, fat, lactose, vitamin and mineral salts including calcium. It should be noted that milk is deficient in iron and the new born, therefore, relies on iron that had been stored in the liver during gestation.

The releasing of milk or milk let-down is an example of a reflex action. This is influenced by the prevailing environmental conditions which could be either positive or negative. This is summarised in table 2.4. Figure 2.17(a) and (b) show mammary glands and neuro-endocrinal action during breast-feeding. Note that when the baby begins to touch the breast and suck impulses go to the brain.

In the brain, the hypothalamus sends an impulse to the pituitary gland which in turn signals the breast to let down the milk. In a positive environment, the milk let-down reflex is triggered by sucking at the breast or in some cases the crying of the baby or smell of the baby. When this happens the hypothalamus relays impulses to the pituitary gland which in turn releases the hormone **oxytocin** which reaches the breast and causes the alveoli to contract forcing milk into the ducts. The ducts conduct milk into the reservoirs behind the areola (see figure 3.48(a). The baby then sucks the milk from this reservoir into its mouth.

The milk let-down reflex may be inhibited or blocked if the breast-feeding mother experiences distraction, embarrassment, anxiety or fatigue. This is a negative environment. Lactating mothers should therefore be provided with a positive environment so that their babies are assured of a good milk supply before the weaning period. This is a negative environment.

Table 2.4: Milk production in various environments

Positive environment	***Negative environment***
The milk let-down reflex is triggered by sucking at the breast or in some cases the crying of the baby or smell of the baby. When this happens the hypothalamus relays impulses to the pituitary gland which in turn releases the hormone, oxytocin which reaches the breast and causes the alveoli to contract forcing milk into the ducts. The ducts conduct milk into the reservoirs behind the areola (see fig. 3.48 (a). The baby then sucks the milk from this reservoir into its mouth.	The milk let-down reflex may be inhibited or blocked if the breast-feeding mother experiences distraction, embarrassment, anxiety or fatigue.

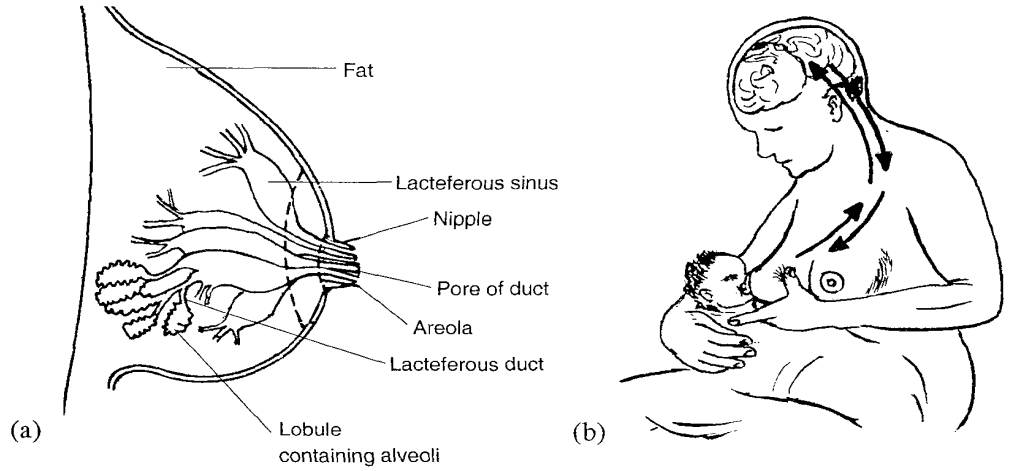


Fig. 2.17: Mammary gland read\ for milk production

Child Labour

During infancy among human beings, babies require considerable care. In urban centres, where both parents are in employment, a hired domestic helper is often engaged to take care of the infant. Many employers are tempted to go for cheap labour and may occassionally go for under-age workers. In Somalia, the government has outlawed child-labour. Employers, however humble their earnings are, should not employ under-age domestic workers because this denies the young a chance to be in school and acquire self-supporting skills.

Role of Hormones in the Human Reproduction

Secondary Sexual Characteristics

Secondary sexual characteristics are physiological, structural and mental changes which are associated with femininity and masculinity. These are controlled by oestrogen in females and androgens in males. The period during which these changes occur is referred to as puberty.

Secondary Sexual Characteristics in Males

The hypothalamus stimulates the pituitary gland to release follicle stimulating hormone (FSH) and luteinising hormone (LH). These are also known as gonadotrophic hormones. The FSH stimulates the synthesis of sperms. The LH also known as Interstitial Cell Stimulating Hormone (ICSH) stimulates interstitial cells to release the male hormones known as **androgens.** Testosterone is the main androgen. It stimulates the development of the secondary sexual characteristics. In males these characteristics begin to show up mostly at the age of fourteen. These include the deepening of the voice, growth of the hair in pubic region and armpit regions and sometimes on the chin. The body becomes more masculine, the testes enlarge and begin to produce sperms. The production and maturation of sperms is stimulated by FSH.

Secondary Sexual Characteristics in females

In females the secondary sexual characteristics begin to show as early as the age of ten in some girls. These include development of the mammary glands, enlargement of the pelvic girdle and widening of the hip. Also, hair grows in the pubic and armpit regions and the entire body becomes feminine. Internally the ovaries mature and start releasing eggs and the girl begins to menstruate. As in the males, the hypothalamus stimulates the pituitary gland to release gonadotrophic hormones - follicle stimulating hormone (FSH) and luteinising hormone (LH).

The FSH stimulates the ovary to release hormone oestrogen and triggers the development of the Graafian follicles in the ovary. As the level of oestrogen increases, it triggers the onset of the secondary sexual characteristics. At a certain level, oestrogen will stimulate the pituitary gland to release luteinising hormone. The LH triggers the mature Graafian follicles to burst open to release a mature ovum (ovulation). After ovulation, hormone progesterone starts being produced. Unlike in males the production of the gonadotrophic hormones is not continuous i.e. it is produced periodically in cycles.

Menstrual Cycle

In females, gamete production is a cyclical activity with a periodicity of approximately 28 days. It is called the menstrual cycle and can be divided into four phases as shown in figure 2.18. The events of the menstrual cycle involve the ovaries (the ovarian cycle) and the uterus (the uterine cycle) and these are regulated by hormones secreted by the ovary which in turn is regulated by the pituitary gonadotrophins.

The cycle begins with the discharge of the blood and tissue debris from the uterus. This flow is called menses. Before menses the women experiences nausea, abdominal pains and back pains. Just after menstruation, the anterior lobe of pituitary gland starts secreting the follicle stimulating hormone (FSH) which has two effects. It causes Graafian follicles to develop in the ovary and stimulates the tissues of the ovary to secrete another hormone called the oestrogen.

Oestrogen brings about repair and healing of the endometrium (inner lining of uterine wall) which is destroyed during menstruation. Oestrogen accumulates to a level which stimulates the anterior pituitary gland to produce luteinising hormone (LH). This hormone stimulates the maturity of Graafian follicle. The mature Graafian follicle releases an ovum into the funnel of the fallopian tube. This process is called **ovulation.** After releasing the ovum, the Graafian follicle changes into a yellow body called the **corpus luteum.** The luteinising hormone stimulates the corpus luteum to secrete a hormone called **progesterone;** see figure 3.50. This hormone stimulates the thickening and increased blood supply to the endometrium. This prepares the uterus for **implantation** of the blastocyct.

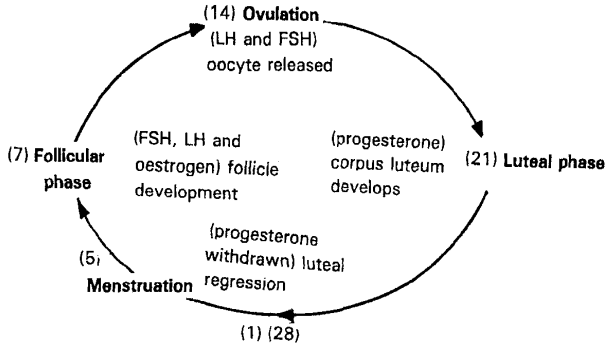


Figure: 2.18 Summary of the main phases of the human menstrual cycle

If fertilisation takes place, the level of progesterone increases and thus inhibits FSH from stimulating the maturation of another Graafian follicle.

On the other hand, if fertilisation does not occur, the corpus luteum disintegrates and no more progesterone is produced. Hence the endometrium sloughs off and menstruation occurs. This completes the cycle. The whole cycle lasts for about 28 days in human beings.

Key: Numbers represent the days of the cycle

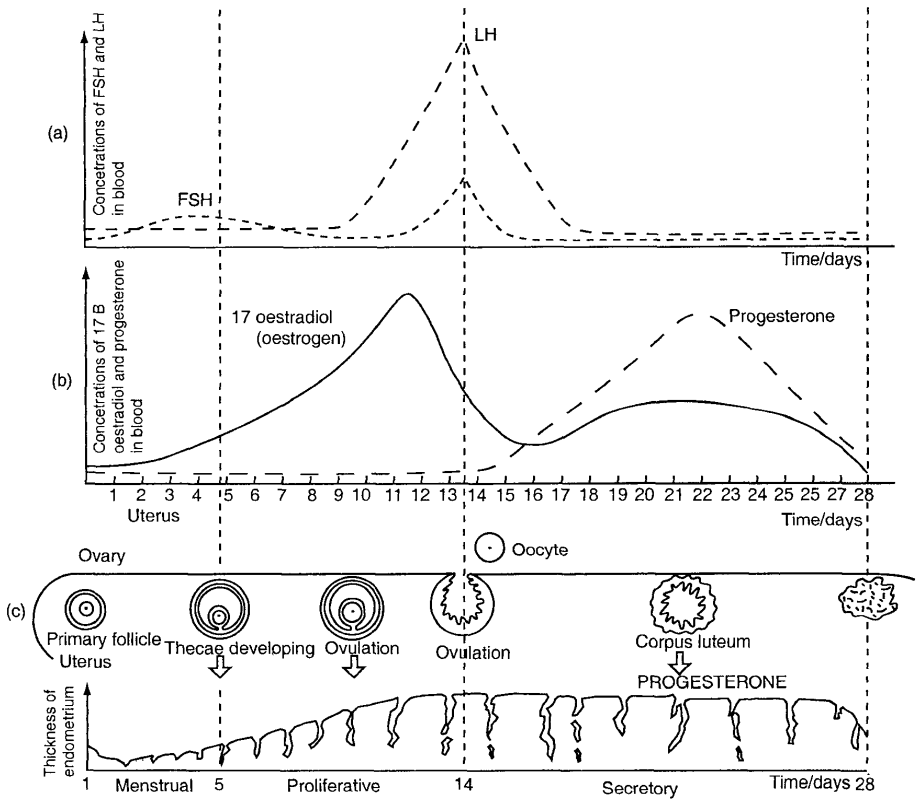


Fig. 2.18: the relationship between (a) pituitary gonadotrophins, (b) ovarian steroids, (c) follicle and (d) corpus luteal development.

Menopause

Majority of women stop to ovulate at the age of 45. This is described as **menopause.** Men do not stop producing spermatozoa. They can produce viable spermatozoa even at the age of 75. Knowledge of hormones of the menstrual cycle has been used in the manufacture of contraceptive pills. These include oral pills while others are in form of injections or inserted under the skin.

This account on sexual reproduction in human beings has been based on natural methods of reproduction. It should however be noted that about 10% of the population suffer from some form of **infertility** hence unable to reproduce naturally.

The major cause of male infertility is low sperm count. This problem is being solved by **'in vitro'** fertilisation i.e. fertilisation is done in a test-tube and the fertilised ovum transferred to the mother's uterus.

Today it is possible to store one's' sperms in a sperm bank for many years until the person is ready to give children. However these issues are still controversial.
Other emerging issues in reproduction relate to the place of test-tube babies, and surrogate mothers.

2.6 Sexually Transmitted Infections (STIs)

Sexually Transmitted Infections are diseases transmitted through sexual intercourse. These include gonorrhea, herpes, syphilis, trichomoniasis, hepatitis, candidiasis and Acquired Immune Deficiency Syndrome (HIV/AIDS).

1. Gonorrhea

This is a disease of the genital organs caused by a bacterial infection. The infection is caused by gonococcus bacteria called *Neisseria gonorrhea* which infect the urethra in males and the vaginal tract in the females.

Mode of transmission

Gonorrhea is transmitted in various ways. The most common mode of transmission is through sexual intercourse. In infants the infection occurs during birth if the mother is suffering from the disease.

Incubation Period

Incubation period of *Neisseria gonorrhea* is from 2-14 days. After this period the symptoms manifest in form of itching of the urethra, a yellowish discharge and pain when urinating in males. In females these symptoms are not clear but unusually vaginal odour should alert the person of the infection.

Control and Treatment

Gonorrhea is a social disease that involves two people and therefore if one of the partners is infected both must be treated. Control should also involve public education on dangers of indiscriminate sexual contacts and regular screening and treating of people who might be having the disease and are not seeking medical attention. Condoms can be used for prevention.
Gonorrhea infection can be treated completely in our health clinics. The drugs used usually are antibiotics which must be administered by a qualified doctor. If properly treated the patient is fully cured and gains normal sexual life. If left untreated, it becomes a systemic disease, thus affects other related organs such as the spinal cord and urinary bladder, and can result in sterility in both sexes.

2. Syphilis

Syphilis is an acute disease which affects the genital organs of both females and males. Syphilis is caused by a spiral shaped bacterium (spirochaetes) called *Treponema pallidum.* It is a contagious disease spread through sexual intercourse. It could also be transmitted through blood transfusion. Infants may contract the disease during birth or through the placenta if the mother has the disease and has not been treated before the seventh month of pregnancy.

Incubation period for *Treponema pallidum* is from 7-90 days or usually three weeks. The acute phase of the disease is called primary stage and manifests itself by the presence of a chancre or a solitary painless ulcer on genital or mucous membranes. The secondary stage occurs after six months and manifests itself as rashes or mucous patches. Macules (discoloured spots) and papules (pimples on skin) may appear on hands, feet, oral cavity, lips and genital areas. The last stage is the tertiary phase. At this stage the disease becomes systemic affecting the whole body. When the meninges are attacked the victims show signs of insanity. The tertiary phase could occur after several years.

Control and Treatment

It is easier to treat syphilis if the infection is detected in the primary phase. This treatment is by use of any broad spectrum antibiotics. Re-examination after every six months to a year is done to confirm total cure. Secondary and tertiary phases are very difficult to treat and need specialised medical care. **Control involves:** avoiding indiscriminate sex. Use of condoms and encouraging positive behaviourial change at individual level may help in steming the spread of the disease.

3. Trichonioniasis

Trichomoniasis is a disease that infects genital organs of both males and females. Trichomoniasis is caused by a protozoa called *Trichomonas vaginalis.* The protozoon thrives well in a vaginal canal which is less acidic. Trichomoniasis is a contagious disease which spreads by sexual intercourse and through contaminated linen.

The infection causes itching of the urethra in males and vaginal itch in females. There is also discharge in the males which is not easily noticeable. In females there is a yellow smelly discharge.

Treatment

Trichomoniasis can be treated and cured if the infected couple are properly diagnosed and the correct antibiotics administered. Control involves avoiding sharing of linen, avoiding indiscriminate sex and high personal hygiene in the genitals.

4. Candidiasis

This is an infection caused by yeast-like fungus called *Candida albicans.* It is also known as 'thrush'. It mainly affects genital organs of women and men.

Vaginal Candidiasis causes itching and burning sensation of the genital organs. This may be accompanied by a white discharge from the vagina which does not smell. The fungus may be present in the vaginal canal of an individual and cause no harm to the individual. The problem arises only when its population increases due to factors such as change of pH in the vaginal canal or use of antibiotics which kill bacteria that keep *Candida* population in control. The fungus is usually transmitted through sexual contact.

Treatment is administered by use of anti-fungal drugs. Once infected control includes avoiding use of strongly scented medicated soaps or disinfectants that might alter the pH medium of the birth canal, wiping oneself from front to back after going to the toilet to prevent thrush being transferred from the bowel and keeping proper aeration of the genital region by use of pure cotton and loose pants.

Candidiasis can also be an opportunistic infection in women with diabetes mellitus and so it is necessary to go for a medical check up to rule out that possibility.

5. Hepatitis

Hepatitis is a condition that describes the inflammation of the liver. It is caused by a virus which attacks liver cells eventually causing damage in the liver. There are two main types depending on the causative virus, that is, viral hepatitis type A and type B. In this book we will discuss hepatitis type B. Hepatitis type B is caused by a DNA containing virus. Symptoms include nausea, severe loss of appetite, jaundice and flu-like symptoms, but fever is rare. It has a high rate of mortality and is more common in adults. This type is highly infectious and is usually transmitted through sexual contacts, blood transfusion, sharing contaminated razors and unsterilised syringes used mainly by drug addicts; kissing and contaminated instruments used by dentists and barbers.

Hepatitis virus type B is present in body fluids such as urine, saliva, semen, milk and even transplacental transmission is possible. Incubation period is between 2-6 months.
Both the hepatitis types are best controlled by use of vaccines especially in children because once infected the viruses are **not easily** cleared by use of antibiotics. It is also necessary to observe high standards of hygiene, avoiding sexual contacts with infected persons and other causative agents.

6. Herpes

The causative agent to herpes is a virus called *Herpes simplex.* Herpes is a contagious disease which is spread by sexual intercourse, kissing and contaminated needles and syringes. *Herpes simplex* is a disease that manifests itself by lesions on the skin and mucous membrane of buccal cavity, vagina canal and conjuctiva. In males the lesions are found on the head of the penis. These lesions are painless.

Control and Treatment

There is no known treatment for herpes, but exposure to the disease can stimulate the body immune system to acquire partial resistance to the disease. *Herpes simplex* (being a viral disease) does not respond to antibiotics. Avoid indiscriminate sex and contaminated needles and syringes.

7. HIV and AIDS

AIDS is an abbreviation for Acquired Immune Deficiency Syndrome. This is a condition caused by a virus known as human immunodeficiency virus (HIV).

The disease was first identified among homosexuals and drug users in the United States of America. Later it was discovered in Europe and the causative agent was isolated in a patient at Pasteur Institute in Paris, France. Since then, the syndrome has been found in other parts of the world.

In Africa it is prominent among the heterosexuals. It is a serious contagious disease which has no known cure or vaccine for control at the moment.

Mode of Transmission

The major way of transmitting HIV/AIDS is through sexual intercourse although it can also be spread through blood transfusion, transplant and by use of contaminated surgical instruments. Infected mothers can transmit HIV/AIDS to babies during birth and through breast milk.

This disease is not spread by casual contact (shaking hands, staying together and second-hand clothing), airborne means, ingestion and faecal matter. This is because the virus always occurs within the lymphatic system and only in small quantities in the blood. This makes it difficult to be detected by normal serological tests and therefore there are special HIV/AIDS kits which have been installed in every District and Provincial Medical Centres for the detection of the HIV/ AIDS virus.

Once the HIV/AIDS virus enters the lymphocytes it binds itself to the chromosomes and integrates into the genetic material. The virus now replicates very fast using the contents of the lymphocytes. The daughter viruses invade more lymphocytes destroying them. The immune system of the body produces antibody against the virus but due to high rate of mutation of the virus the antibody fails to act against it.

HIV/AIDS manifests itself in adults by major and minor signs. The major signs include chronic diarrhoea for more than one month and eventual loss of more than 10% of the body weight. The minor signs include constant and persistent cough for more than four weeks, generalised skin infections, herpes zoster and herpes simplex characterised with generalised inflamed lymph nodes.

In children HIV/AIDS manifests itself by the above signs but it has to be ruled out that the signs are not due to cancer or severe malnutrition.

Prevention and Cure

HIV/AIDS is a major killer disease with no treatment. So the only way to avoid infection by the HIV/AIDS virus is through positive behaviour change in the following ways:

- Avoidance of indiscriminate sex.
- Avoidance of situations that expose you to high risk of infection, such as excessive intake of alcohol, drug addiction, some cultural practices like wife inheritance, female genital mutilation and traditional circumcision. See figure 1.32.

Other ways of controlling the spread is by avoiding blood transfusion unless the blood has been screened for HIV virus. There should be no sharing of tooth brushes, razors or other implements contaminated with blood and fresh body fluids.

At the moment attempts are being made to develop a vaccine against HIV virus and when this is accomplished it will be a breakthrough in the prevention and control of HIV/AIDS. Otherwise there are drugs that can be taken by HIV/AIDS sufferers to alleviate the conditions. These are the **anti-retrovirals.** It should be noted that these are only used to prolong the life of the infected individuals. Anti-retroviral drugs are not a cure for HIV/AIDS!

2.7 Advantages of Asexual Reproduction

Good qualities from the parents are retained in the offspring without any variation. Thus it is possible to obtain several generations of a particular kind of organism with some special desired quality. The new plants produced by asexual means **mature faster** than those produced by sexual means.

Asexual reproduction does not depend on processes such as pollination, fertilisation and the dispersal of fruits and seeds. These processes occur only by the intervention of external agents which are not bound to be available when needed. Hence the plant **depends on its own** activity to reproduce asexually. The new plants are able to obtain nourishment from their parent plants and so are **able to survive** temporarily under unsuitable conditions. Asexual reproduction, unlike reproduction from seeds, does not result in the indiscriminate and widespread distribution of new plants, a process which is often accompanied by the wastage of a large number of offspring. On the other hand, it often gives rise to dense clumps of plants which **do not encourage competitors.** However, these clumps are very persistent and difficult to eradicate should the plants in question be "weeds".

Disadvantages of ASexual Reproduction

The new offspring being exactly similar to the parent, would carry even **undesired qualities** from the parents. Since there are no variations, the offspring may not be able to withstand **changing environmental** conditions. Plants produced through asexual reproduction usually **mature faster** than those from seeds. This could possibly bring about **over-crowding** and stiff competition whereby only a few members will survive. Asexual reproduction gradually reduces the strength and vigour of the succeeding generation.

Advantages of Sexual Reproduction

In sexual reproduction fertilisation brings about mixing of different genetic material. This mixing leads to formation of new combination of characteristics. These combinations often lead to **desirable variations.** The variants often show **hybrid vigour** and also high **adaptability** to environmental conditions. Furthermore variations provide the basis for **evolutionary** changes.

Disadvantages of Sexual Reproduction

The method involves the union of two different gametes from two separate organisms, therefore it is necessary for the two gametes to be brought together before fertilisation can occur. This becomes difficult in cases where certain organisms are **isolated** from one another. This method may produce individuals exhibiting **undesirable qualities** which may sooner or later become eliminated.

2.3 Sexual and Asexual Reproduction in plants

Asexual Reproduction in plants

Asexual reproduction is the production of offspring from a single organism without the fusion of gametes. Meiosis is not involved and the offsprings are identical to the parents.

Types of a sexual Reproduction

The following are the three types of asexual reproduction that will be discussed in this book.

- Binary fission in amoeba.
- Spore formation in *Rhizopus* sp.
- Budding in yeast.

Binary Fission

Binary fission is the simplest form of asexual reproduction. This method involves the splitting (fission means splitting) of the original cell into two similar daughter cells. The fission occurs when the organism attains the maximum size.

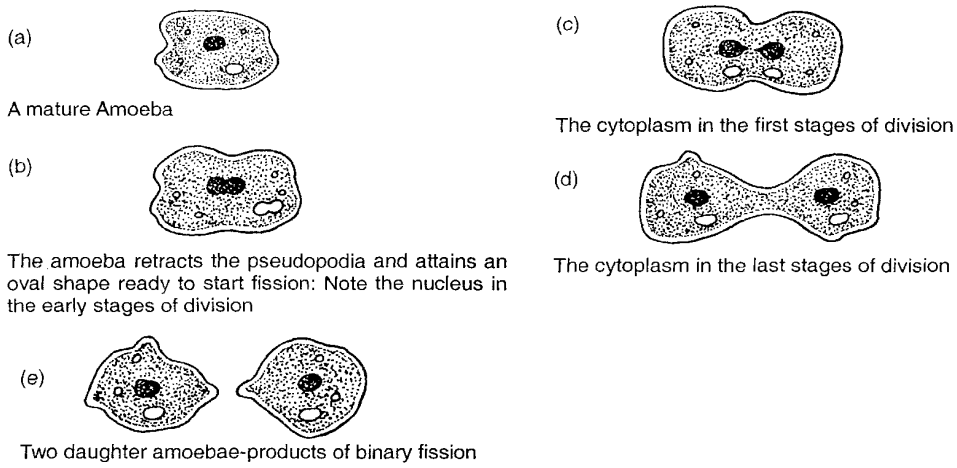


Figure: 2.19 Binary fission in amoeba

Binary fission is a complex process that includes internal re-organisation, division of the nucleus **(karyogamy)** and cytopolasmic division **(cytogamy).** Briefly, the nucleus divides into two, then the cytoplasm divides to form two daughter cells. Binary fission is common in amoeba, plasmodium and bacteria.

Binary Fission in Amoeba

When conditions are favourable, that is there is enough food, favourable temperature and pH is within the tolerable limits, a mature amoeba adult divides into two. This type of reproduction is referred to as **binary fission.** See figure 2.8(a) to (e).

The first step in binary fission in amoeba is molecular division. Here, there is internal re-organisation of the molecules necessary for structural construction. The molecules are re-aggregated and utilised in the formation of the new cell.

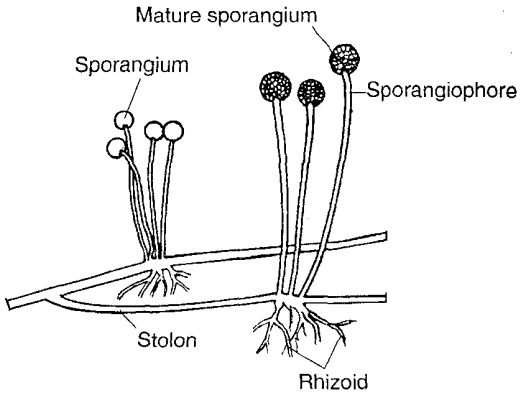


Figure: 2.19 (a) Parts of mycelium of Rhizopus

The next stage is division of the nucleus. In this case, the nucleus undergoes mitotic division to give rise to two nuclei with the same number of chromosomes.

The cytoplasm then starts dividing into two daughter cells which separate from each other.

Spore formation (Sporulation)

A spore is a small reproductive unit which is usually microscopic and unicellular containing a small amount of cytoplasm and a nucleus. Spores are produced by bacteria, most fungi and some groups of green plants such as mosses and ferns.

Spore Formation in *Rhizopus*

Rhizopus is a saprophytic fungus which grows on substrate like bread, rotting fruits and other decaying organic matter. The vegetative body is called **mycelium** which consists of many branched threads called hyphae. The horizontal hyphae are called **stolons.**

The hyphae which grow vertically are called the **sporangiophore.** The tips of these upright hyphae swell up to form the **sporangia (spore bearing structures)** as seen in figure 2.19 (a).

Inside the sporangium the nuclei divide meiotically producing daughter nuclei that contain a haploid number of chromosomes (n). The daughter nuclei develop into spores by the incorporation cytoplasm around each nucleus and a wall around the cytoplasm. The sporangium contains many spores, as it matures and ripens, it turns black in colour. When fully mature, the sporangium wall burst and release the spores which are dispersed to restart a fresh generation of growth and development. Spore dispersal may be by wind, by an insect or mechanically being scattered by animals. See figure 2.9(b).

Budding in Yeast

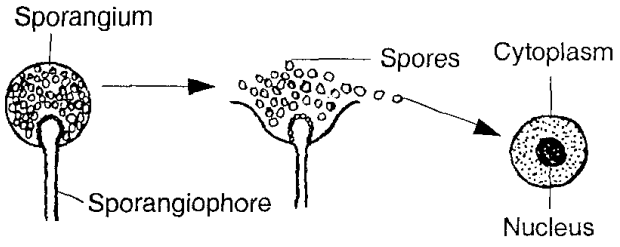


Figure: 2.19 (b): Spore formation

Budding is a form of asexual reproduction in which a new individual is produced as an outgrowth (bud) of the parent, and is later released as a self-supporting, identical copy of the parent. It takes place in the unicellular fungi such as yeast.

Yeast is a single celled organism in the kingdom Fungi. The cell is made up of a thin cell wall which encloses the cytoplasm containing a vacuole and a nucleus. In the cytoplasm are glycogen granules and other food reserves. See figure 2.19(a).

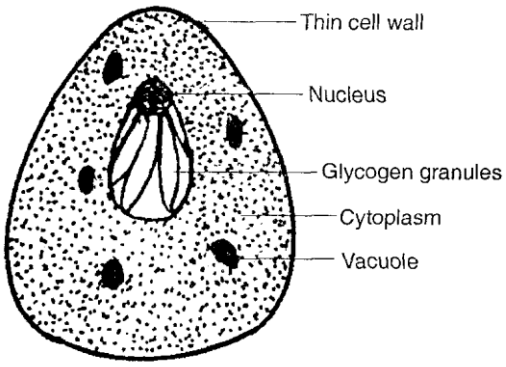


Figure: 2.19 (a)

The yeast cell under favourable conditions (i.e. plenty of sugar, moisture, oxygen and optimum temperature) reproduces asexually by budding. In budding a small area of the cell wall of a parent cell softens and forms a projection of bud, which bulges outwardly. This is followed by the division of the nucleus into two. One of the nuclei moves into the new bud. The bud then grows in size and forms new cell organelles. At this stage, the bud separates off, but since the budding process is so fast, the first bud starts to form another before it separates off from the parent, thus forming a short chain of cells. See figure 2.19(b).

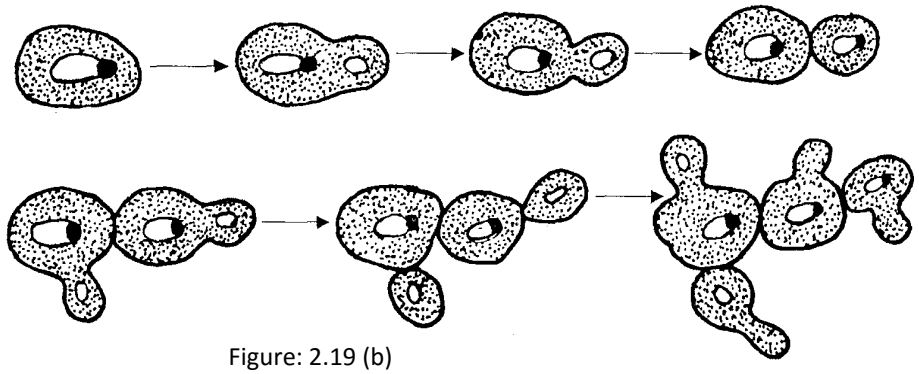


Figure: 2.19 (b)

2.4 Sexual Reproduction in Plants

Sexual reproduction is as significant in plants as it is in mammals, where asexual methods are virtually unknown. In flowering plants the flower is the reproductive organ which is a specialised shoot consisting of a modified Stem and modified leaves. Typically the stem portion consists of a pedicel (the flower stalk) and a receptacle, to which are attached the modified leaves. After pollination followed by fertilisation the ovary of the flower forms the fruit which encloses the seeds which can later germinate to form a new plant.

Note: Other appropriate flowers may be used.

Structure and Function of a Flower

A flower is made up of a flower stalk **(pedicel),** the apex of the flower stalk **(receptacle)** to which are attached the four groups of floral structures, namely the calyx on the outside, corolla (the coloured parts), the male parts **(androecium)** and the female parts (the **gynoecium** or the **pistil).** See figure 2.20.

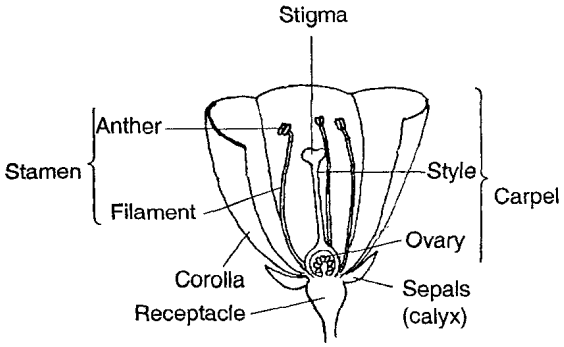


Fig. 2.20: Longitudinal section of a generalised flower

The calyx is made up of sepals, which are usually green. Where the sepals are free, they form a **polysepalous** calyx and when fused they form a **gamosepalous** calyx.

The calyx protects the inner parts of the flower especially during bud development. In some flowers, there may be another ring of sepal-like structures just beneath the calyx called **epicalyx.**

Corolla: The corolla is made of petals which are brightly coloured, large and conspicuous especially in insect pollinated flowers where they attract insects for pollination. If the petals are fused, the corolla is said to be gamopetalous, and if they are free the term **polypetalous.**

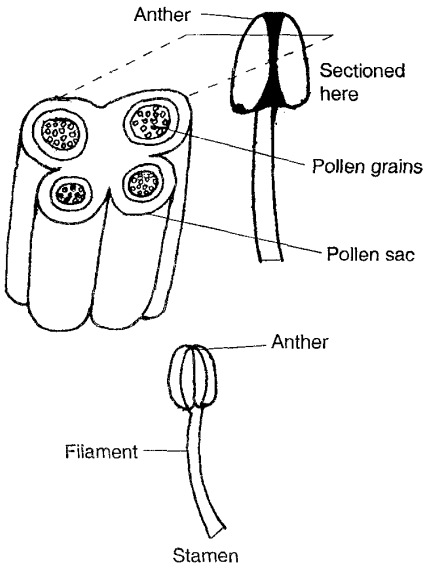


Figure: 2.21 (a) Stamen of a flower

Androecium: This is the male part of the flower and is made up of one or more **stamens.** The stamen consists of two parts, the long stalk-like structure, the **filament,** which bears the **anther** at its tip. The anther consists of four pollen sacs, which contain pollen grains. These contain the male gametes. The stamen may be either fused forming a staminal tube, as in the *Hibiscus*, or they may be free, as in a crotalaria flower. See figure 2.21(a) and (b).

Gynoecium (pistil): This consists of carpels that form the female reproductive organ of the flower. It may consist of one, a few or many carpels. A carpel consists of the ovary. the style and the stigma. Refer to figure 2.21.

The ovary contains ovules. If the position of the ovary on the receptacle is such that the other floral parts occur above it, it is said to be inferior or epigynous ovary, as seen in the apple flowers. See figure 2.13.

If it is above the other floral parts it is said to be superior or **hypogynous** ovary as in the hibiscus flowers and when the receptacle sorrounds the carpel, with other floral parts arising around the ovary, it is said to be **perigynous** as in the rose flower.

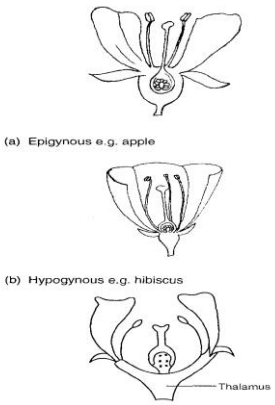


Figure: 2.21

The gynoecium can be of different types depending on the number of carpels. **Monocarpous** gynoecium has one carpel e.g. beans, while a polycarpous gynoecium is one with two or more carpels. The **polycarpous** gynoecium with free carpels is termed as **apocarpous** e.g. in rose and *Bryophylum.* When the carpels are fused together the gynoecium is termed as **syncarpous** e.g. *Hibiscus.* See figure 2.14.

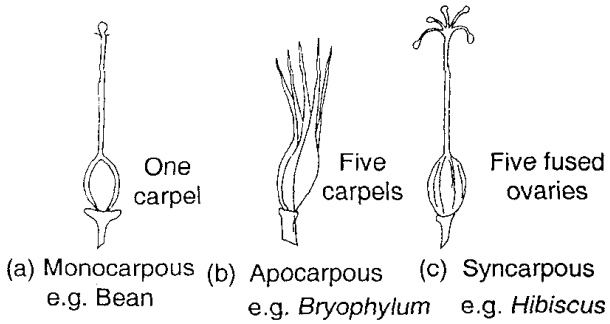


Figure: 2.14 Type of carpels

Other Terms Used in Describing a Flower

1. **Complete flower** - one with all the four floral parts present, namely calyx, corolla, androecium and gynoecium. When one part or more of these are absent, the flower is said to be incomplete.
2. **Unisexual flower** - one with only one of the reproductive parts. It may be either a male or female flower. **Staminate flower** - a male flower. **Pistillate flower** - a female flower.
3. **Monoecius plant** - when both male and female flowers are borne on the same plant, the plant is said to be **monoecius** e.g. maize, oil palm. However, there are cases when plants bear either male or female flowers. These plants are also known as male or female plants and are described as **dioecious** e.g. pawpaw.
4. **Hermaphrodite (bisexual) flower** -has both the male and female reproductive organs e.g. Hibiscus.
5. **The calyx and corolla** - are known as the **non-essential parts** of a flower while androecium and gynoecium are essential parts.

6. **Regular (actinomorphic) flower -**those that can be divided into two similar halves by any vertical section passing through the centre e.g. morning glory. These types of flowers are radially symmetrical. 7.
7. **Irregular (zygomorphic) flower -** can be divided into two equal halves in one particular plane only e.g. crotalaria. Such are bilaterally symmetrical.
8. **Pedicillate flower** - flower with a stalk.
9. **Solitary flower** - those that occur singly while those that grow in clusters make an inflorescence.

Pollination

The transfer of pollen grains from the anther to the stigma is referred to as pollination. When the transfer is from the anther of one flower to the stigma of another flower but of the same species it is called **cross-pollination.** If the transfer of the pollen grains is from the anther to the stigma of the same flower, it is referred to as **self-pollination.**

Agents of Pollination

The structural arrangements and the differences in time of ripening of male or female parts of the flower may necessitate the intervention of some agents to aid in the transfer of pollen grains to the stigma for fertilisation. Agents of pollination include wind and insects. For pollination to occur, flowers are structured in such a manner as to enable the appropriate agent to carry out pollination without hindrance. Insect pollinators include bees, butterflies, and mosquitoes which usually visit such flowers for the purpose of getting nectar. Wind pollination occurs mostly in plants of the grass family like maize, wheat and oat.

The process of Fertilisation in flowering Plants

Before we discuss fertilisation in flowering plants, it is important to understand the structure of the gametes.

The male gamete is contained in the pollen grain produced in the anther. The female gamete (egg cell) is found in ovules within a structure called embryo sac. See figure 2.15.

Study Question 4

a) Name the cell division that produces the gametes.
b) From your knowledge of the cell division you have named in (a) above, state the chromosome constitution of the gametes.

Fertilisation is the fusion of the male and female nuclei in the embryo sac. After pollination the pollen grain absorbs nutrients from the stigma and develops an outgrowth called the pollen tube. The pollen tube grows down the style, to the embryo sac, taking along the male gametes with it. The pollen grains usually adhere to the stigma as a result of the stigma cells secreting a sticky substance, which also stimulates the pollen grain to germinate sending down its pollen tube. The growth of the pollen tube into the stigma, through the style, to the ovary, is by pushing its way between the cells where it gets its nourishment from the surrounding tissues. The process is quite rapid and takes place in a matter of minutes.

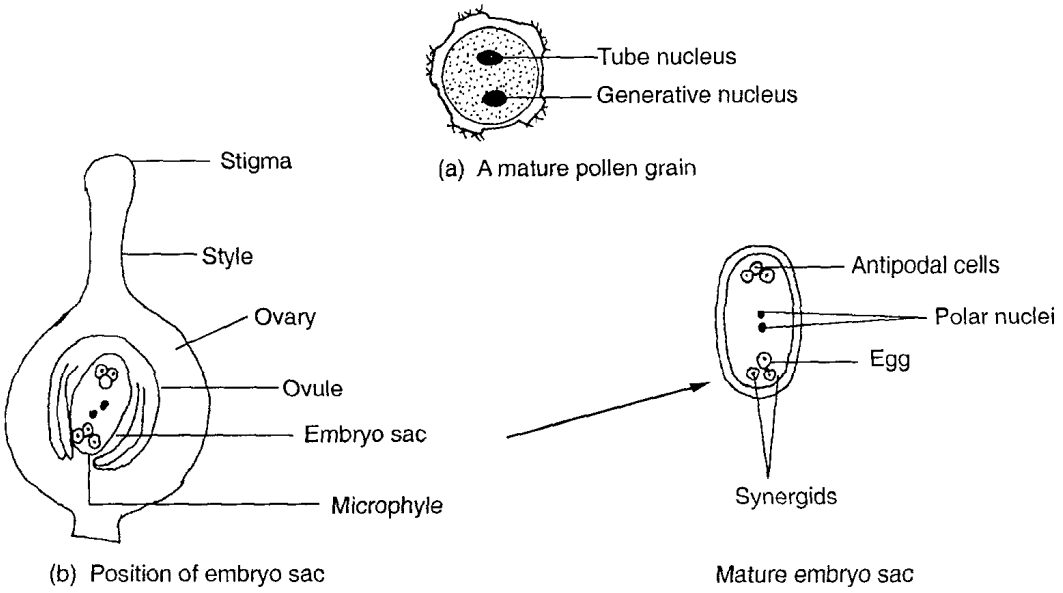


Figure: 2.22 Structures containing male and female gametes

As the pollen grain germinates, the tube nucleus occupies a position at the tip of the growing pollen tube. The generative nucleus divides by mitosis into two male gamete nuclei, which follow behind the tube nucleus as the pollen tube grows down the style as shown in figure 2.22.

The pollen tube enters an ovule through the **micropyle,** and when it reaches the centre of the ovule it penetrates the wall of the embryo sac and burst open; meanwhile the tube nucleus disintegrates leaving a clear way for the entry of the male nuclei. One of the male nuclei fuses with the egg cell nucleus, to form a diploid zygote which develops into an embryo, while the other male nucleus fuses with the polar nucleus to form a triploid nucleus. This is the primary endosperm nucleus. See figure 2.23. This gives the **double fertilisation** that is unique in flowering plants.

Seed and Fruit Development

After fertilisation some changes occur to the ovary, the fertilised ovule and to the entire flower. The external protective calyx dries and falls off or persists. The petals and stamens wither and fall off. (a) **Development of the Seed** The zygote undergoes mitotic division and develops to become an embryo. The embryo has a plumule (young shoot), the radicle (young root) and one or two cotyledons.

The primary endosperm nucleus develops into the endosperm. The ovule forms the seed while the ovary develops into a fruit. The cotyledons are surrounded by a seed coat (testa). The testa has got a scar (hilum) which is the point of attachment to the placenta.

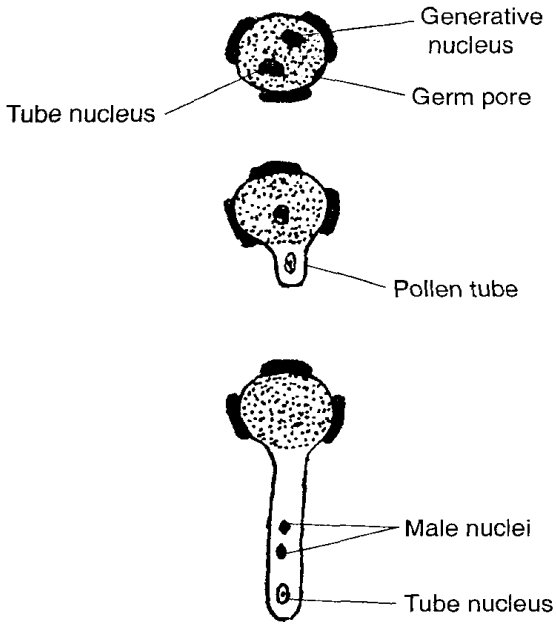


Figure: 2.23 Germination of pollen grain and growth of pollen

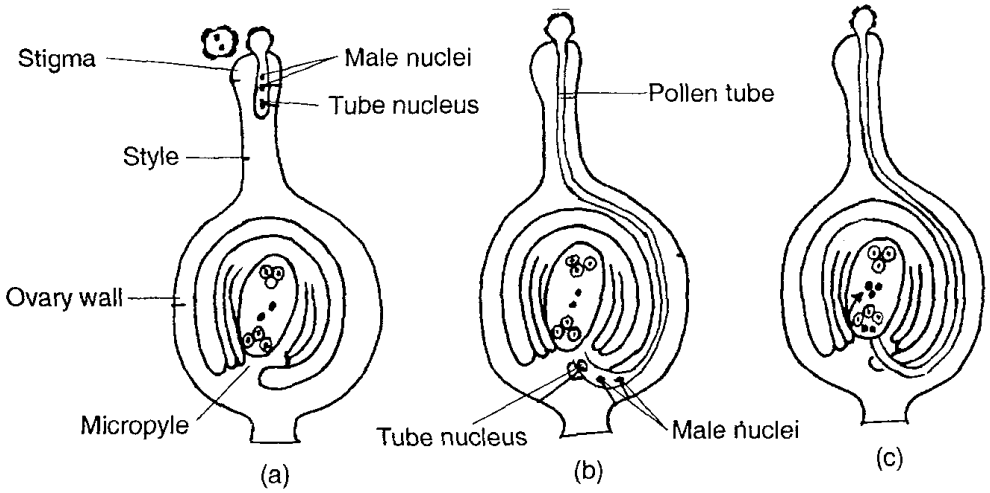


Figure: 2.24 Stages of fertilization

The embryo then completely separates from the endosperm and a membrane, leaving an opening (micropyle) which allows in water into the seed.

As the seed matures the endosperm or cotyledons harden by losing water from 80% to 15% by mass, then it dries and becomes dormant. The seed is usually dispersed in this condition while being protected by other fruit structures. More details on seed structure, will be found in Chapter four of this book. **(b) Development of fruits:** The fruit begins its development immediately after fertilisation, and is usually brought about by **gibberellins** which are hormones released and cause its increase in size.

During fruit formation, the wall of the ovary becomes the **pericarp** or fruit wall. The pericarp is usually made up of three layers, an outer epicarp, a middle layer, the mesocarp and an inner endocarp. A fruit is described as a fully grown fertilised ovary containing fully developed seeds. However in certain plants such as pineapples and bananas, fruit development takes place without fertilisation. No seed development is therefore noticed. This is known as **parthenocarpy.**

It is sometimes difficult to decide whether a structure is a seed or a fruit. In such cases, the number of scars on the structure should be counted. A seed will only have one scar, the point at which it was attached to the receptacle. The fruit, however, usually has two scars, the points at which it was attached to the receptacle and the other represents the remains of the style.

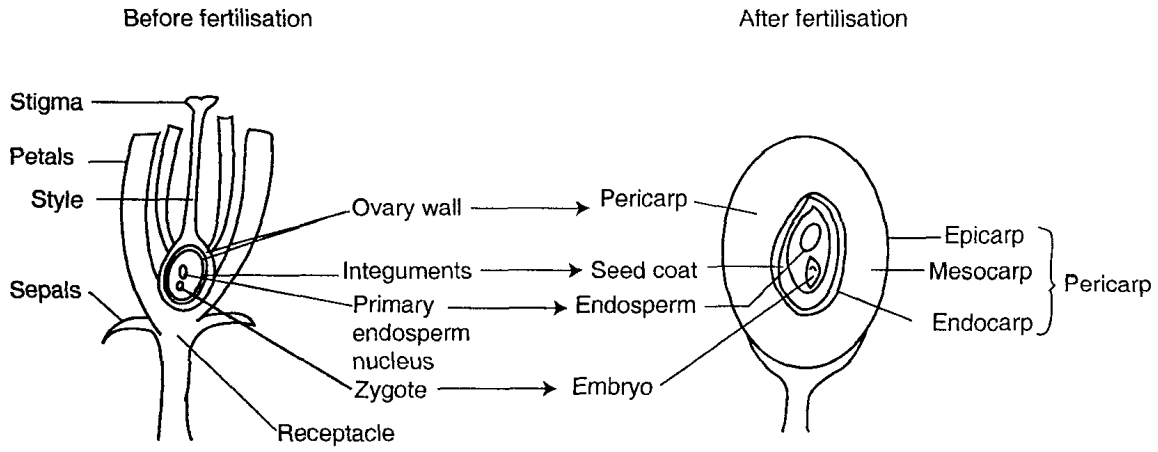


Figure: 2.25 Changes in a flower after fertilization

Fruit and Seed Dispersal

If all the seeds and fruits produced by a plant germinated and grew into plants around the parent plant, this could lead to competition for light and nutrients. To prevent over-crowding, fruits and seeds have developed adaptive features which enable them to be spread or dispersed to new environments by various agents such as wind, water, animals as well as self-dispersal mechanism.

Adaptations of Fruits and Seeds to their Agents of dispersal

1. Animal Dispersal

Some plants have developed hooks on the ovary walls or on the calyx. These hooks stick on the fur of passing animals. In some cases the fruits are succulent, brightly coloured and scented to attract animals and birds, which eat or carry them away from the parent plant. At times the fruit is eaten together with seeds. The seed coats of some such seeds are hard and resistant to the digestive enzymes so that they pass through the gut undigested, and are passed out in faeces some distance away from the parent plant e.g. guava, passion and tomato.

2. Water Dispersal

Fruits and seeds dispersed by water need to be light so as to float on water and their coats have to be waterproof.

In fruits like the coconut, their mesocarps is fibrous and spongy to trap air. The trapped air makes the fruit light and buoyant to float on water which then carries it away from the parent plant.

Plants like the water lily produce seeds whose seed coats trap air bubbles. The air bubbles make the seeds float on water and be carried away from the parent plant when released from the fruit.

The fruit pericarp and seed testa are waterproof. This way, the fruits and seeds can remain afloat without soaking and sinking immediately they are released from the parent plant.

3. Wind dispersal

Wind dispersed fruits and seeds are generally light and small in order to be carried by air currents. Dispersal is achieved by the following methods:

(a) Censor mechanism

The fruit which is capsule-shaped, is either split as in simsim and tobacco *(Nicotina spp)* or has pores at the top e.g. in mexican poppy *(Argemone spp)* See figure 2.26)
The capsule is usually attached to a long stalk. When swayed by wind. The seeds are released and scattered.

(b) Extended Pericarp and seedcoats

Some seeds and fruits have developed hairy and feather-like projections which increase their surface area so that they can be blown about by wind and dropped some distance away from the parent plant. This can be observed in cotton and *Sonchus* spp.
Some other fruits and seeds have wing-like structures, for example seeds of Jacaranda, Nandi flame *(Spathodea* spp), *Tecoma* and fruits of *Tridax* and sycamore plant. These extensions increase the surface area of these fruits and seeds so that they are easily carried away by air currents and scattered, See figure 2.26.

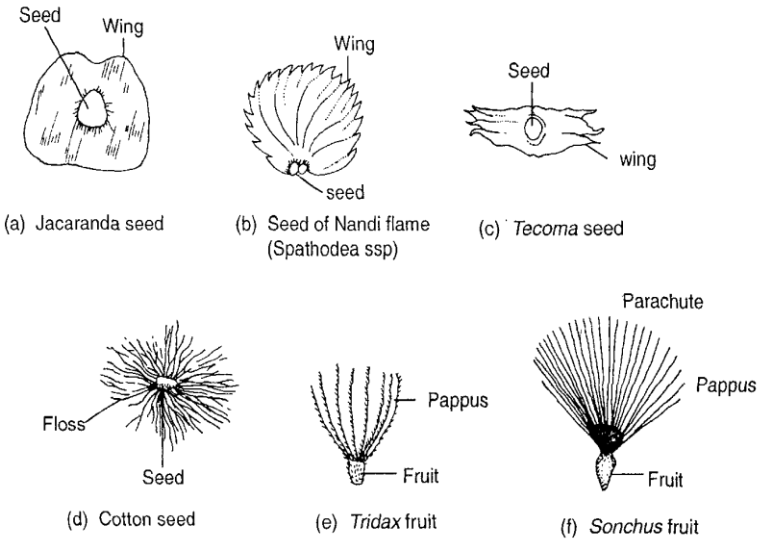


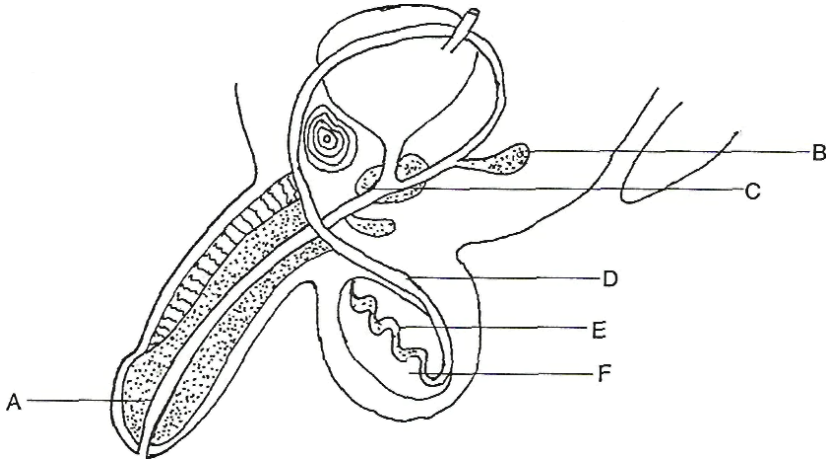
Figure: 2.26 Examples of fruits dispersed by wind

1. Self-dispersal mechanism (explosive mechanism)

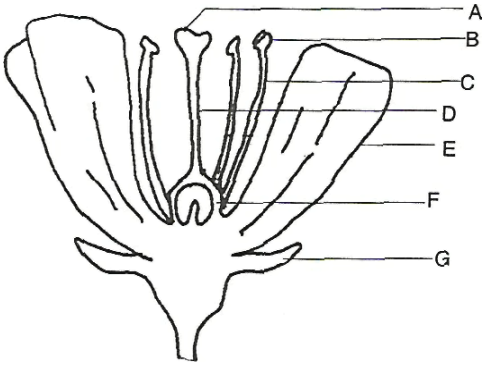
This method of dispersal occurs in fruits with dry pods, such as legumes. After the pod dries, the seeds break off from the placenta and are placed inside the pod. Due to the loss of water from the pod and the pressure from within, the pod opens violently along the lines of weakness (sutures). In the process the seeds are thrown away from the parent plant. Such plants include beans, peas and castor oil.

Revision Questions

1. Describe how budding occurs in yeast.
2. List ways in which asexual reproduction occurs giving suitable examples in each case.
3. What are the advantages of asexual reproduction?
4. Use a well labelled diagram to explain how asexual reproduction occurs in:
   (a) Bread mould
   (b) Amoeba
5. What are the differences between asexual and sexual reproduction?
6. Figure 3.52 is a section through a male urinogenital system:
   (a) Name the structures labelled A to F.
   (b) State the functions of each of the named parts in (a) above.
   (c) What are the functions of the fluid produced by structure labelled C.
   (d) What are the advantages of internal fertilisation.
7. List ways in which asexual reproduction occurs giving suitable examples in each case.
8. What are the differences between asexual and sexual reproduction?
9. Figure 3.52 is a section through a male urinogenital system:
   (a) Name the structures labelled A to F.
   (b) State the functions of each of the named parts in (a) above.
   (c) What are the functions of the fluid produced by structure labeled.
   (d) What are the advantages of internal fertilisation.



10. (a) Describe how fertilization occurs in a named flower.
    (b) How is a seed formed?
    (c) What are the differences between a seed and a fruit?
11. (a) What are the characteristics of an insect-pollinated flower?
    (b) Define cross-pollination.
12. Describe the part played by each of the following in reproduction:
    (a) Androecium. (b) Gynoecium. (c) Corolla.
13. Why is sexual reproduction considered to be better than asexual reproduction in some flowering plants.
14. What is the physiological significance of having testes outside the body of the human male?
15. Look the following figure of a flower section and answer the questions that follow.



(a) Name the parts labelled above.
(b) Which of the labelled parts constitute the gynoecium of the flower?
(c) This flower has both stamen and carpels. What term is used to describe such a flower.

16. Complete the table below.

Disease	*Cause*	*Curative/preventive control measures*
Herpes simplex		
Gonorrhea		
Trichomoniasis		

17. (a) Where do the following processes occur in the human body:
(i) Spermatogenesis.
(ii) Oogenesis.
(b) What is the main difference between the two processes in (a) above.

18. Explain the meaning of the following terms in human reproduction:
(a) Implantation.
(b) Ovulation.
(c) Parturition.

19. Discuss the dispersal of fruits and seeds under the following headings:
(a) Water dispersal.
(b) Animal dispersal.
(c) Wind dispersal.
(d) Self dispersal.

20. State the functions of each of the following structures:
(a) Placenta.
(b) Fallopian tube.
(c) Amniotic fluid.
(d) Umbilical cord.

21. Name the hormones which control the following processes in the human body:
(a) Development of female secondary sexual characteristics.
(b) Contraction of uterus wall during parturition.

22. What are the similarities and differences in the processes leading up to fertilization in a mammal and a flowering plant?

23. Describe mitosis. What are the essential differences between mitosis and meiosis?
24. Describe the main differences between entomophilous flowers and anemophilous flowers.
25. Describe the hormonal control of the production of gametes and the development of secondary sexual characteristics.
26. Compare the advantages and disadvantages of asexual reproduction.
27. What is the importance of the pollen tube in fertilisation in plants?
28. What do you understand by the term double fertilisation in plants?
29. Figure 3.54 represents stages in cell division.



Fig 3.54

(a) Identify the type of cell division represented.
(b) Name the stage s_represen ted in the diagrams Q and S.
(c) Name regions in plants where the division actively takes place.

30. Identify four ways through which the HIV/AIDS virus is transmitted.
31. The ovaries of an expectant woman can be removed after the first four months of pregnancy without terminating pregnancy. Explain.
32. Describe the following diseases under the following headings. Candidiasis, Gonorrhea, Syphilis.
    (a) Causative agent.
    (b) Mode of transmission.
    (c) Symptoms.
    (d) Control measures.

CHAPTER THREE
GENETICS

3.1 Introduction

The most striking feature about the living world is the great **variation** observed among organisms. Even organisms which are closely related vary in size, shape and form. In the survey of living organisms in Form 3 Book, variability was used to classify organisms into different taxonomic groups. The study of these **variations** and how they are **inherited** is the branch of biology called **Genetics.**

The science of genetics attempts to explain why organisms differ from one another and at the same time show similarities within the same species.

When organisms reproduce, the offspring resemble the parental forms. This is as a result of inheritance of characteristics from the parents. In certain cases, however, the offspring may show slight differences from their parents. For example, among human beings, members of the same family may differ in the appearance of the face, shape of the nose, skin colour and other features. This is due to the variety of hereditary factors that each of them acquires from the parents. Inheritance of these factors in many different combinations is responsible for the variations within a species. The environment also affects the characteristics that are expressed in the organisms.

3.2 Concepts of Variation

Variation refers to observable differences among living organisms. Some of the variations in human beings are shown in tongue rolling, fingerprints, height, type of ear lobes (free or attached), sex, blood groups, skin colour and weight. In plants, variations are observed in the length of leaves and internodes and size of fruits. These variations can be categorised into two types: **discontinuous and continuous** variations.

Discontinuous Variation

In discontinuous variation there are either tongue rollers or non-rollers. Within this type of variation there are definite distinct groups of individuals with no intermediate forms.
Other examples of humans include sex, where an individual is either male or female. The ABO blood group system is another example of discontinuous variation. An individual can only belong to one of the groups A, B, AB or O. Some people have a free ear lobe while in others it is attached. Similarly the presence of long hair in the nose and on the ear pinna are also discontinuous variations. Discontinuous variation is also observed in plants. For example, a pawpaw tree is either male or female.
Characteristics exhibiting discontinuous variations are controlled by one or two major genes. The physical expression of these genes is not influenced by environmental conditions.

Continuous Variation

This type of variation exhibits a wide range of differences for the same characteristic from one extreme end to the other. For example, from Practical Activity 1(C) you realised that within a group of people, height ranges from shortest to tallest with several intermediates. When plotted on a graph it produces a normal distribution curve, see figure 3.1.

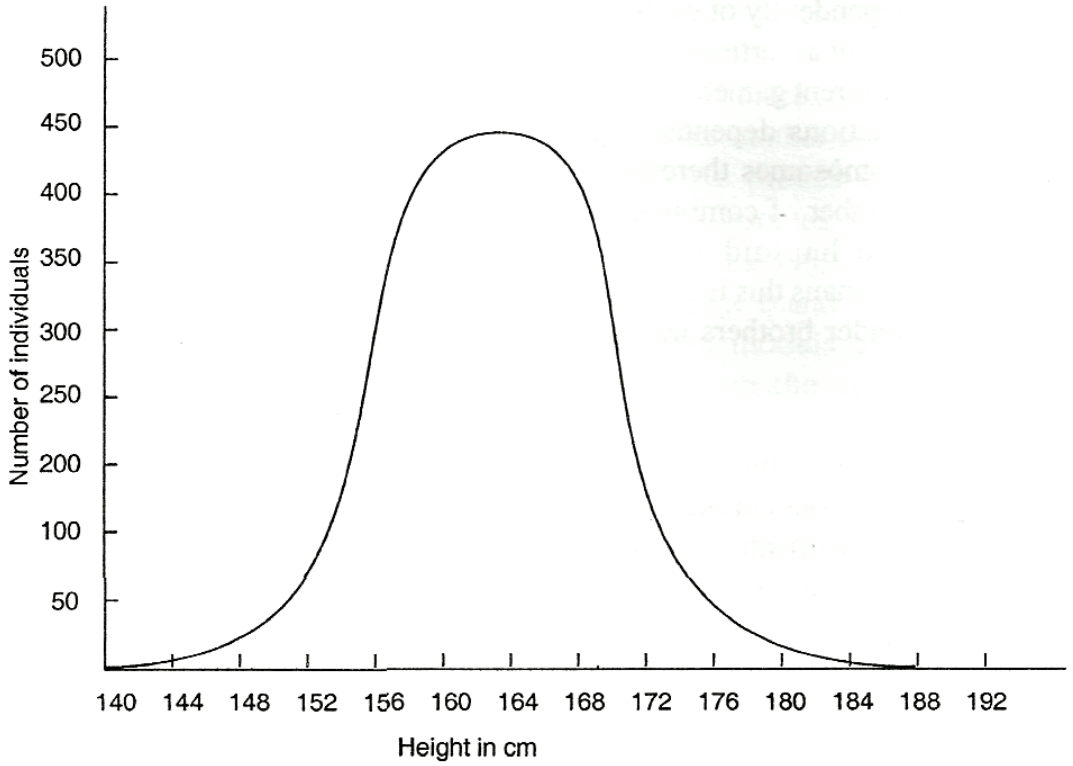


Figure: 3.1 A normal distribution curve of heights.

Other variations of continuous variations in human beings are fingerprint types, skin colour (pigmentation) and body weight. In plants the length of internodes, number of branches, leaves or fruits on a tree and size of fruits at maturity are also continuous variations. Characteristics that show continuous variations are controlled by many genes. The physical expression of these genes is influenced by interaction of the genes and environmental factors. For example, a plant possessing the genetic factors for tallness may fail to grow tall due to unsuitable soil and climate.

Causes of Variations

1. Gamete Formation

During gamete formation two processes contribute to variations:

(a) Independent Assortment

During metaphase of first meiotic division (as seen earlier in Form 3 Students' Book), homologous chromosomes come together in pairs and subsequently segregate into daughter cells independently of each other. This independent assortment produces a wide variety of different gametes. The total number of combinations depends on how many pairs of chromosomes there are in a parent cell. The number of combinations is 2^n where n is the haploid number of chromosomes. In humans this is 2^{23} which is 8,388,608. No wonder brothers never look exactly alike!

(b) Crossing Over

During the prophase of the first meiotic division when homologous chromosomes are in intimate contact with one another, the chromatids of homologous chromosomes break and rejoin at certain points called chiasmata. This is called crossing over. During crossing over, important genetic exchanges take place at the chiasma hence resulting in more variations.

2. Fertilisation

Fertilisation permits parental genes to be brought together in different combinations. This way, different qualities of the parents can be combined in the offspring.

3. Mutations

These are spontaneous changes in the genetic make-up of an organism. Other great changes brought about by mutations will be considered later in the chapter,

3.3 The Chromosome

As you learnt in the Form 3 Students' Book the nucleus of a cell has a number of long threadlike structures called chromosomes. Each chromosome is made of two parallel strands called **chromatids.** Each pair of chromatids is connected at one point by a structure called centromere as shown in figure 3.2.

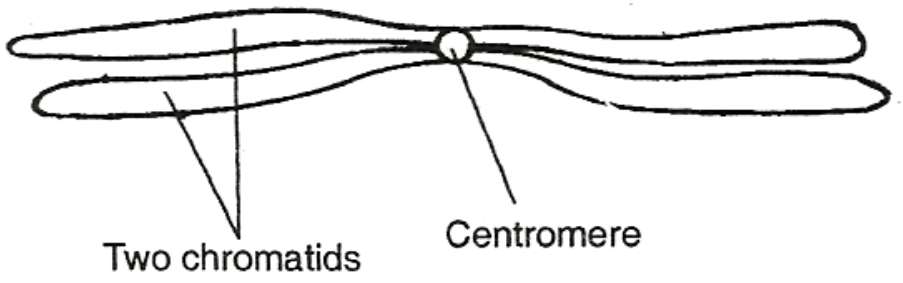


Figure: 3.2 A chromosome

In body cells, otherwise referred to as somatic cells, chromosomes occur in pairs. Each pair of chromosomes has a characteristic length. The member of each pair is called a homologous chromosome. This means that the chromosomes are alike in appearance although their genetic composition may be different.

During sexual reproduction each parent contributes one of the chromosomes of a homologous pair. Along the length of the chromosome is a series of structures called genes. They are too small to be seen even with a powerful microscope. It is genes that determine the characteristics of the cell and its progeny.

Table 3.1: Chromosomal numbers in organisms

Organism	*Number of chromosomes*	
	Somatic cells (Diploid - 2n)	*Gametes (Haploid - n)*
Sheep *(Ovis auries)*	56	28
Cow *(Bos taunts')*	60	30
Fruit-fly *(Drosophila melanogaster)*	8	4
Maize *(Zea mays)*	20	10
Wheat *(Triticum vulgare*)	14	7
Tobacco *(Nicotiana tabacuni)*	12	6

All cells including the gametes (sperms and ova) contain chromosomes. Counts of the chiOTKKAima wimis&x sfeam <fe& Vta^, tss, definite constant number of chromosomes in each cell for every species of animal orplant. For instance, in humans each somatic cell contains 46 chromosomes, while each gamete contains 23 chromosomes. On fertilisation, the number 46 (diploid number) is restored in the zygote. Other examples of this constancy in the chromosome numbers are given in table 3.1.

Chromosomes are present in the nucleus all the time, but they only appear or become visible when viewed under a microscope during cell division, that is, mitosis and meiosis. Chromosomes exhibit certain characteristic behaviour during the stages of cell division. The stages of cell division are interphase, prophase, metaphase, anaphase and telophase.

Genes and DNA

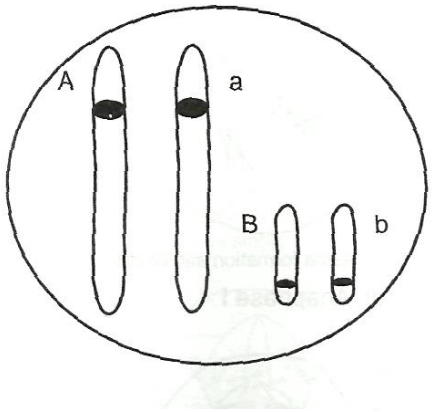


Figure: 3.3 Two gene loci

It has been conclusively established that chromosomes contain the hereditary material or factors that are transmitted from parent to offspring. These factors are what are known as genes.

Experiments have shown that genes occupy definite positions on the chromosomes known as the **gene loci** (a gene locus). See figure 3.3.

It has further been shown that the gene is chemical in nature. In 1944, Oswald Avery established that the gene was in the form of a nucleic acid molecule called **Deoxyribonucleic acid** (DNA). The chemical nature of this molecule was not fully understood until 1953 when two biologists, Francis Crick and James Watson, worked out its structure. They found that DNA is a complex molecule composed of three different components. These are; a five-carbon sugar, a phosphate molecule and a nitrogenous base of which there are four types; Adenine (A), Guanine (G), Thymine (T) and Cytosine (C). A combination of the three components above, form a **nucleotide,** Watson and Crick suggested that the DNA structure consists of several nucleotides joined together to form long chains that they called the DNA strands. Two parallel DNA strands twist on one another forming a double helix. It was observed that the quantities of Adenine and Thymine were always equal while those of Cytosine and Guanine were also equal. This suggests that Adenine always combine with Thymine while Cytosine combines with Guanine when forming the double helix structure of DNA.

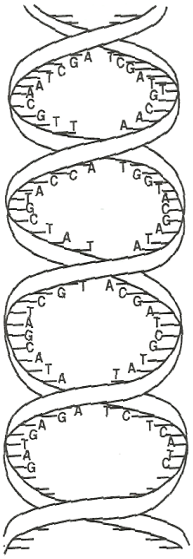


Figure: 3.4 (a) The double helix structure of the DNA molecule

The DNA is therefore like a twisted ladder with the nitrogen bases forming the steps or rungs as shown in figure 1.7(a).

A short section of the DNA molecule with two strands untwisted to show the positions of the bases, sugars and the phosphate molecules is shown in figure 3.5.

In general we can say that a gene is a section of the DNA on the chromosome made of chains of bases along the DNA strand.

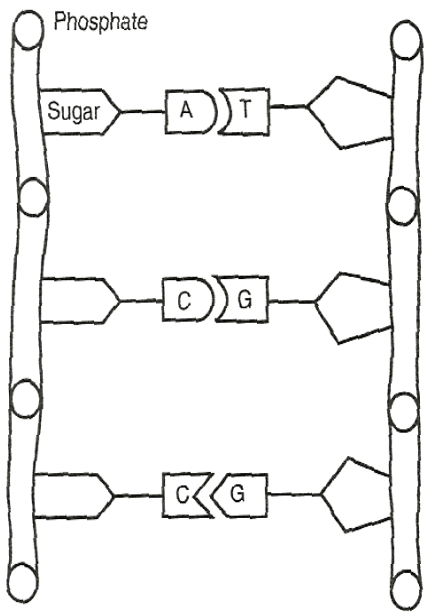


Figure: 3.5(b) The untwisted DNA strand

The Role of DNA

The DNA is an important molecule because it:

- ❖ Stores genetic information in a coded form.
- ❖ Enables transfer of genetic information unchanged to daughter cells through replication.
- ❖ Translates the genetic information into the characteristics of an organism through protein synthesis.

DNA Replication

Hereditary material must be passed on to the next generation. The ability of the DNA to replicate itself clearly explains how inherited characteristics are passed on. The DNA double helix consists of two long separate strands joined together by the base pairs. When the molecule is due to replicate the double helix unwinds and the two strands unzip themselves.

This is made possible by the presence of the weak hydrogen bonds that link the bases of the two strands. Unzipping is therefore as a result of the breaking of the hydrogen bonds thus setting each strand free from the other. After unzipping, the information on the DNA strands, that is the base sequence, is copied out onto a new DNA structure using the parent DNA as the template and thus, the parent DNA molecule is said to have replicated itself. The replication makes it possible to pass on the DNA molecule together with its exact genetic information to daughter cells during cell divisions in the organism. See figure 3.6.

As the cell prepares for division during interphase; genetic material (DNA) replicates i.e. doubles itself so that sufficient DNA is made available for each of the daughter strands.

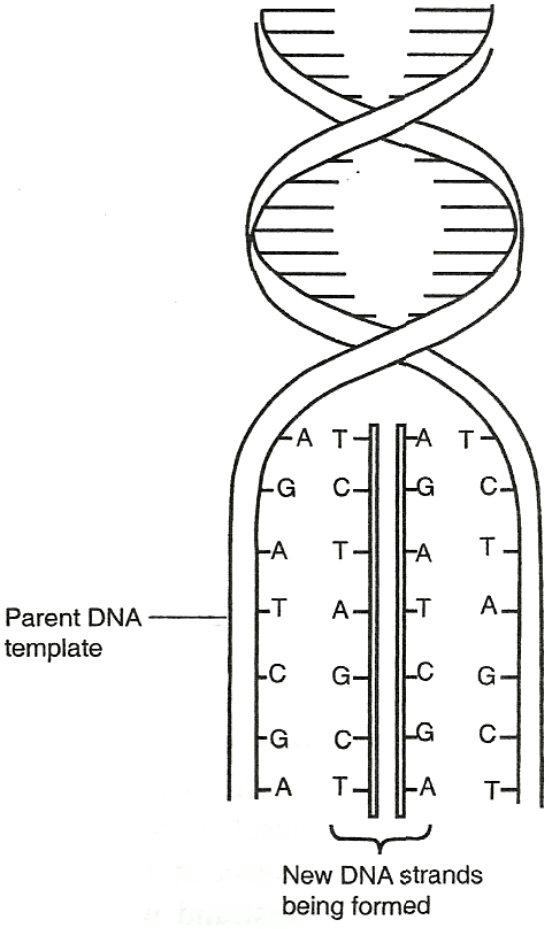


Figure: 3.6 Diagrammatic representation of DNA replication

Role of DNA in Protein Synthesis

The DNA molecule is basically responsible for protein synthesis in the cells. This bears a lot of significance since proteins control nearly every aspect of life of a cell. Structural protein molecules determine the structure of the cell and therefore the organism, while functional protein molecules such as enzymes and hormones control the functioning of the cell.

The sequence of the bases along the DNA strands act as the **alphabet or code** that spells out the sequence of amino acids. Every set of three bases along the DNA strands is responsible for bringing into position a particular amino acid of a polypeptide chain. The set of a base triplet is known as a **codon,** and is said to **code** for a particular amino acid of a protein molecule. Examples of such DNA codons are AAA coding for amino acid phenylalanine; TTT for lysine; CAA for valine; CTA for aspartic acid; and many other codons for different amino acids.

Protein synthesis takes place in ribosomes found in the cytoplasm. Since DNA molecules are confined to the cell nucleus, there has to be means of communicating the DNA information to the ribosomes where protein synthesis occurs.

The cell has got a special molecule that mediates between the DNA in the nucleus and the cytoplasm. This molecule is also a nucleic acid molecule and is known as Ribonucleic acid (RNA). Since its role is to carry genetic information from DNA to the site of protein synthesis in the cytoplasm, it is referred to a messenger RNA (m-RNA) and is formed from the DNA strands. In the formation of m-RNA, an appropriate section of the DNA strand serves as a template. The double helix of the DNA unzips and free nucleotides align themselves opposite the template. The base sequence of the template is copied onto a new strand which then becomes an RNA strand. In the RNA,Thymine (T) is replaced by the base Uracil (U). The transfer of DNA base sequence on to the m-RNA leaves the nucleus with the full instructions from the DNA about the kind of protein to be synthesised by the cell. See figure 1.9. This instruction is in the form of the base triplets or codons; which are then practically used to assemble the amino acids on the protein polypeptide chains.

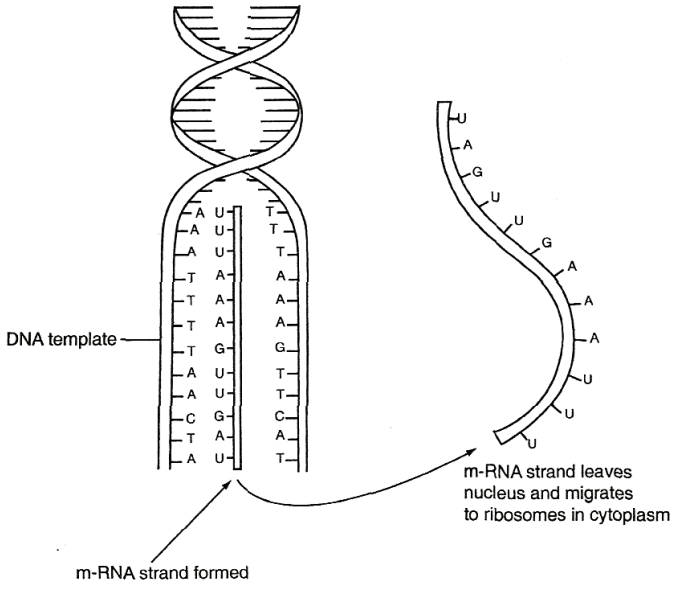


Figure: 3.7 Diagrammatic representation of DNA synthesis

Information on m-RNA is translated by the ribosomes and is used to assemble amino acids into specific protein molecules. Protein molecules determine the inherited characteristics in organisms.

3.4 The First Law of Heredity

Mendel's Experiments

An Austrian monk known as Gregor Mendel is considered to be the father of Genetics because of his pioneering work on inheritance. He carried out various breeding experiments and observed the variations in different characteristics of the garden pea. The characteristics include:

- Height of the sterns - tall or dwarf
- Texture of seed coat - yellow or green
- Colour of seeds - purple or white
- Texture of pods - smooth or wrinkled
- Colour of pods - green or yellow
- Position of flower - axial or terminal

In one of his experiments, Mendel selected a group of dwarf plants and self-pollinated them by dusting mature pollen grains on to stigmas of the same plant. He then collected the resulting seeds and planted them. Mendel noted that these seeds germinated and grew into dwarf plants only. He repeated the experiment for several generations and obtained the same results. This showed that dwarf garden pea plants could produce only their own type, that is, they were **pure breeds.** See figure 1.10(a).

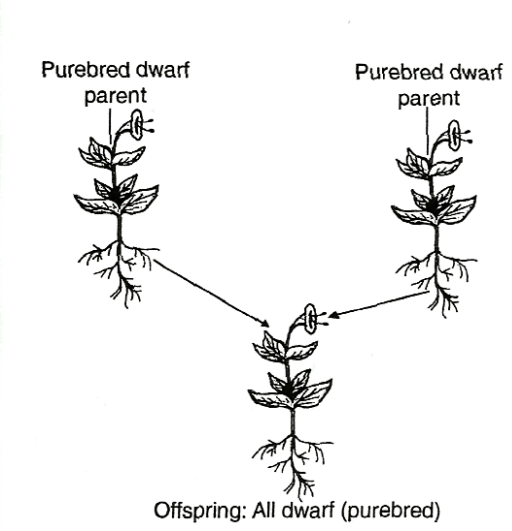


Figure: 3.8 (a) Cross between purebred dwarf plants

He also selected tall plants and serf-pollinated them. He then planted the resulting seeds and observed that they grew into a mixture of taller and dwarf plants. He took seeds from the tall offspring only and repeated the experiment for many generations until he obtained only tall plants. This way Mendel established a **pure breed** of tall plants.

He then cross-pollinated purebred tall garden pea plants with the purebred dwarf variety. He planted the resulting seeds and observed that the offspring were all tall plants. See figure 3.8 (b).

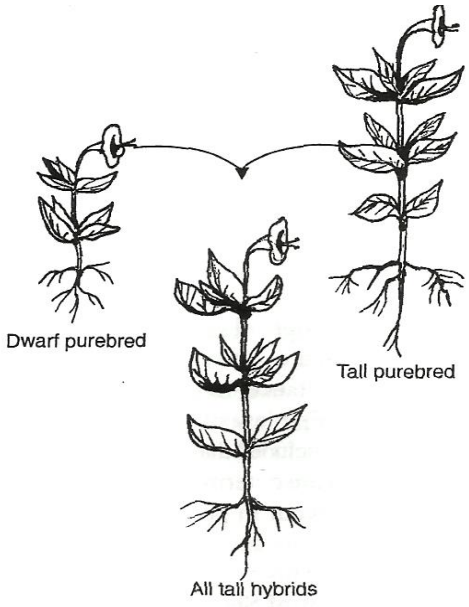


Figure: 3.8 (b) Cross between purebred tall plants and purebred dwarf plants

He crossed two of these tall offspring and planted the resulting seeds. Mendel observed that second generation consisted of a mixture of tall and dwarf. He counted these plants and noted that the ratio of the tall to dwarf plants was approximately 3:1 respectively. Mendel observed that the ratio was always obtained when a cross was made between non-purebreeds of the tall plants. See figure 1.10(c)

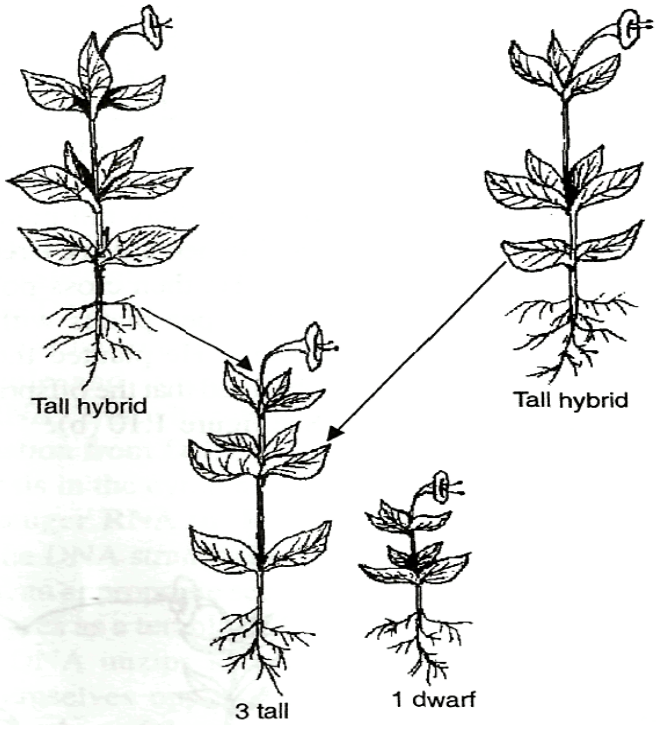


Figure: 3.9 (c) Results of self pollinating tall hybrid

From his work, Mendel was able to postulate hypotheses that are now considered as laws governing inheritance. In this book we shall emphasise the first law of inheritance.
Mendel concluded that the characteristics of an organism are determined by hereditary factors which occur in pairs. Only one of a pair of such factors can be represented in a single gamete. This is known as **Mendel's first law, the Law of Segregation.**

At his time, Mendel had no idea of genes and so he called them factors. He postulated that these factors are located on chromosomes and they are transmitted from parents to offspring via gametes. Adult jplants contain a pair of factors controlling their size but the gamete contains only one of the factors.

Mendel's success can be attributed to the following:

1. He used favourable materials, i.e. the pea plant which is normally self- fertilised. This made it easy for him to employ cross-fertilisation at will.
2. The pea plant he used had several observable contrasting characteristics (traits).
3. His study focused on particular traits while those before him had been attempting to determine wholesome heredity of each organism.
4. He kept accurate data on all his experiments and from the analysis of his data he was able to formulate definite hypotheses.

Monohybrid Inheritance

In his experiments, Mendel postulated that the inheritance of one characteristic like height in the garden pea plant is controlled by a single pair of hereditary factors contributed by both parents. This type of inheritance is known as **monohybrid inheritance.** It involves the transmission of just one pair of contrasting characteristics (traits) such as tallness and dwarfness for height, or smooth and wrinkled for shape of seed coat. A single pair of hereditary factors known as genes controls such a trait. Genes occur in pairs on chromosomes and such gene pairs are known as **alleles.** The genetic constitution of an organism is known as its **genotype** while the outward appearance of the organism is called **phenotype.**

The genotype of an organism is represented using paired letter symbols, where the capital letter represents the dominant gene while the small letter represents the recessive gene.
In the following illustration t represents the gene for dwarfness while T represents the gene for tallness. The conventional symbol for male is **Cr**while that of female is p.
During gamete formation (gametogenesis) in the dwarf plant, each gene in the pair segregates into different gametes. When the male and female gametes fuse during fertilisation, the offspring produced contain the same number of genes as in each parent.
The inheritance of dwarfhess in the pea plant can be illustrated diagrammaticaUy by a **genetic cross** as shown in figure 3.10(a).

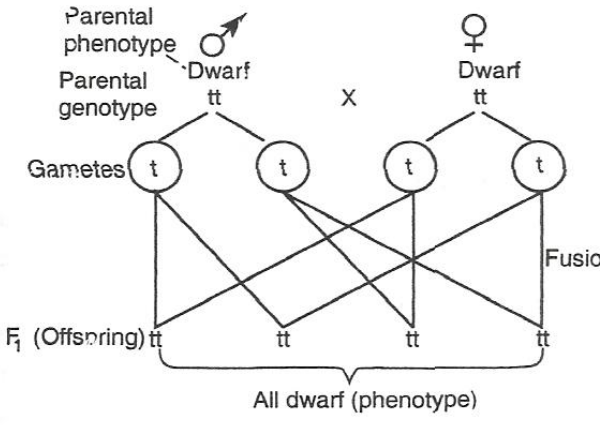


Figure: 3.10 (a) All dwarf (phenotype)

Similarly the pair of genes in the pure breed tall pea plants will segregate into different gametes during gametogenesis. Thus when self-fertilised, the resulting seeds will have half the number of genes from each parent. This is shown in the genetic cross in figure 3.10(b).

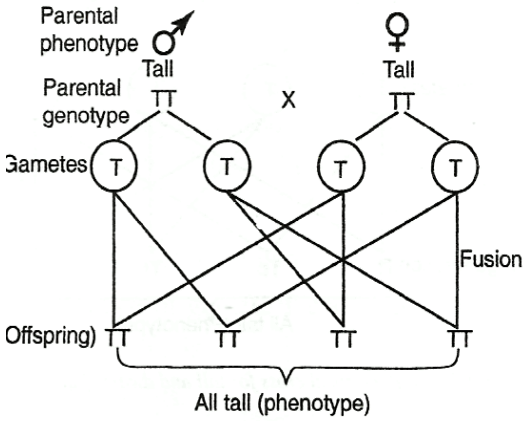


Figure: 3.10 (b) Inheritance of tallness trait

In the genetic cross above, the male plant is tall and the female plant is dwarf. If the cross is reversed so that the female is tall and male

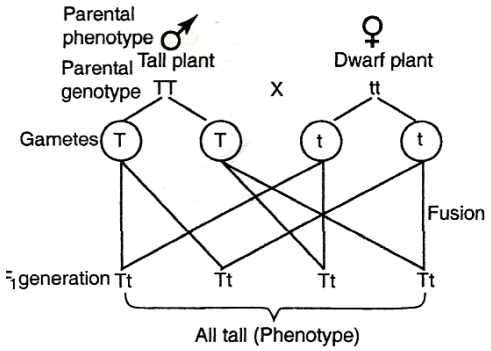


Figure: 3.11 (a) Cross between pure breeds

a dwarf, this is referred to as **a reciprocal** cross. The F_1 results will be the same for either cross. The reciprocal cross is shown in figure 3.11(b).

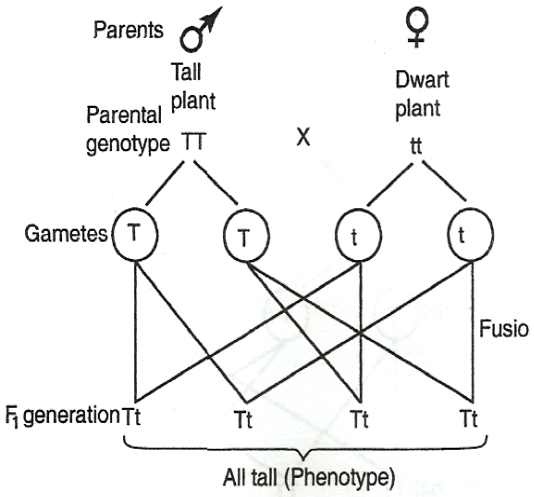


Figure: 3.11 (b) Reciprocal cross for tall and dwarf plants

However when these F, offspring are self-pollinated they produce offspring that grow into a mixture of tall and dwarf plants. These offspring are known as the second filial generation (F_2 generation). Thus, there are no intermediates between tall and dwarf plants. See figure 3.11(c).

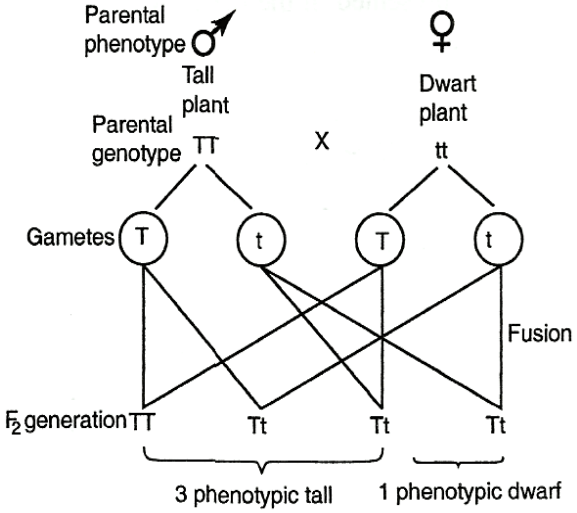
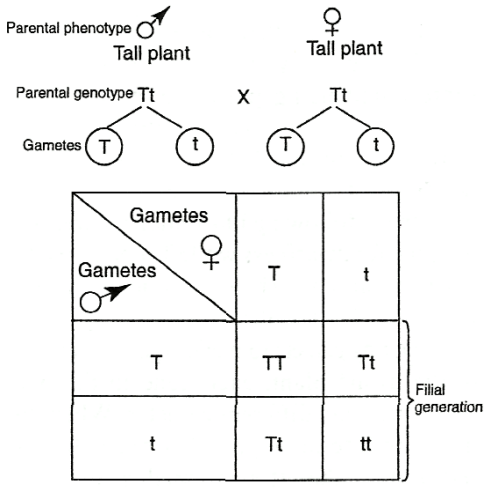


Figure: 3.11 (c) Results of F, selfing cross

From the genetic cross studied in figure 3.11(c), you notice that the following are components of a genetic cross:

- The parental phenotypes
- The parental genotypes (the crossing x) should be shown here.
- The gametes (conventionally circled).
- The fusion process (fertilisation).
- The filial generation genotypes.

A punnet square shown in figure 3.12 is an alternative method of making genetic crosses.



When the aSlelic genes are identical as **in** TT and tt, the condition is known as **homozygous.** An individual with such a condition is referred to as a **homozygote.** However, when allelic genes are not identical as in Tt, the condition is referred to as **heterozygous.** An individual with such a genotypic condition is referred to as a **heterozygote.** An individual with genotype Tt will be phenotypic ally tall because the gene T is **dominant** over the gene t. The allele t is **recessive.** A dominant gene is that

which can express itself in both its homozygous (TT) and heterozygous (Tt) state. While a recessive gene is that which can only express itself in its homozygous state (tt). Therefore the, genotypic condition TT is referred to as homozygous dominant while tt is hornozygous recessive.

The ratio 3 tall: 1 dwarf in the F_2 generation is characteristic of monohybrid inheritance where one gene is completely dominant over the other. This is **complete dominance.** The monohybrid crosses are based on Mendel's first law, which states **that the characteristics of an organism are determined by internal factors which occur in pairs.** Only one of a pair of such factors can be represented in a single gamete.

It is now known that Mendel's "factors" are specific portions of a chromosome called **genes.** It is also known that the process which produces gametes with only one of each pair of factors is meiosis.
The process of segregation is accomplished during meiosis as illustrated in figure 3.13 below.

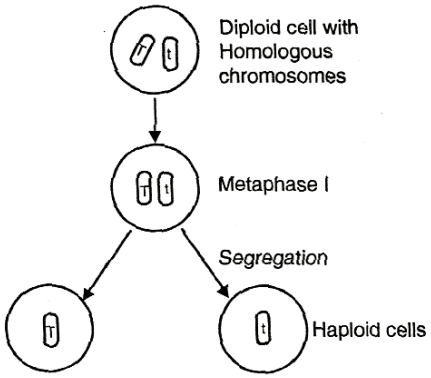


Figure: 3.13 Process of segregation

Study these Questions

Distinguish between:

(a) Homozygous and.homozygote.
(b) Dominant and recessive gene.
(c) Diploidy and haploidy.
(d) Fj generation and F_2 generation.
(e) Genotype and phenotype.

Ratios and Probability

The 3:1 ratio in monohybrid inheritance can be presented in the form of probability. When a large number of heterozygous tall pea plants were self-pollinated, the offspring phenotypes were in ratio of 3 tall: 1 dwarf. Another way of stating this is 1 or 75% of the offspring are tall while 1 or 25% are dwarf.

These ratios therefore are an expression of probability i.e. chance. In the heterozygous plants Tt, the chance of producing T gamete from both parents is ± each. Similarly the chance of forming t gamete is 1. Therefore the chance of gamete T and t fusing to get genotype Tt is i x i = i. Figure 3.14 illustrates this.

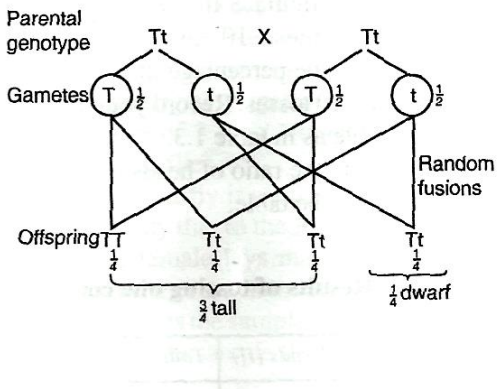


Figure: 3.14 Ratios of phenotypes and genotypes

The inheritance of characteristics involves probability. The chance that a particular gamete will fuse with another is a random occurrence. In genetic crosses this is done by showing all possible fusions. We can illustrate the role of chance by tossing a coin/die or by picking different coloured beads to represent gametes.

Study these questions

In a breeding experiment, garden;peas with axial flowers were crossed with plants with terminal flowers. All the F, plants had axial flowers. When the F, plants were self-pollinated, a total of 858 seeds were ^produced in the F_2 generation. Out of the 'total, 65 1 seeds gave rise to plants with axial flowers.

(a) Using the figures given, work out the ratio, of F_2 plants with axial flowers to that of plants with terminal flowers,
(b) Use a punnet square to show the genotypes of the F,, offspring.
Work out the phenotypic ratio of the F_2 offspring.
(c) Name the recessive characteristic in this cross and give a reason for yoar answer.

Similar monohybrid results as those of Mendel have been obtained by using a common insect the fruit fly *(Drosophila melanogaster}.* The insect has many observable characteristics that show discontinuous variations. These include:

- Wing length (long wing dominant over vestigial wing).
- Eye colour (red eyes dominant over white eye).
- Size of abdomen (broad abdomen dominant over narrow abdomen).
- Body colour (grey body colour dominant over black body colour).

For example, a cross between a purebred long winged and vestigial winged flies results produced all offspring in F, generation being long winged. However, when F_s offspring are selfed they produce a mixture of long winged flies and vestigial winged in the F_2 generation in the ratio of 3 long winged : 1 vestigial winged fruit flies.

The fruit fly is a suitable organism for genetic study due to the following reasons:

1. The female lays many eggs resulting in a large number of offspring. This increases the sample size for study. The larger the sample the more reliable the result.
2. Have many observable characteristics that are distinct and contrasting.
3. It is easily bred in the laboratory with minimum requirements.

4. It has a short generation time, that is, 10 -14 days. Therefore many generations can be studied in a short period.
5. Offspring can be crossed with their parents at will (backcrossing).
6. The flies are safe to handle because they do not transmit any known human diseases.

Incomplete Dominance

In the experiments discussed so far one allele has always been dominant over the other. For instance, in the garden pea, the tall plant with genotype TT (homozygous) could not be distinguished from an individual with the genotype Tt (heterozygous). Thus although the genotypes were different, the phenotypes were identical, indicating that the gene determining tallness is completely dominant over that determining dwarfhess.

However, in some plants such as *Mirabilis jalapa* (4 o'clock plant) a cross between red and white flowered plants results in F, generation with all the offspring bearing **pink** flowers thus showing blending of colour. Self pollinating the F, individuals gives phenotypic ratio of 1 red:2 pink: 1 white. This shows that there is no allele which completely dominates the other, that is both alleles express themselves equally. This is an example of **incomplete dominance or co-dominance** as illustrated in figure 3.17.

Incomplete dominance can also be observed in animals. For example in short homed cattle, the gene for the red coat colour is co-dominant to white coat colour. A cross between them produces a mixture of red and white coat colour referred to as roan. In genetic crosses involving incomplete dominance, two different capital letters are used to represent the two genes. Let R represent the gene for red flower colour. Let W represent the gene for white flower colour.

Study this question

In a particular species of tropical beetle, the wings had either red or orange marks. A cross between red marked beetles with orange marked beetles produces offspring with yellow marks only. When Fj offspring were selfed, they produced F_2 generation in the ratio of 1 red: 2 yellow: 1 ora- - -

(a) Explain the al
(b) Using a geneti

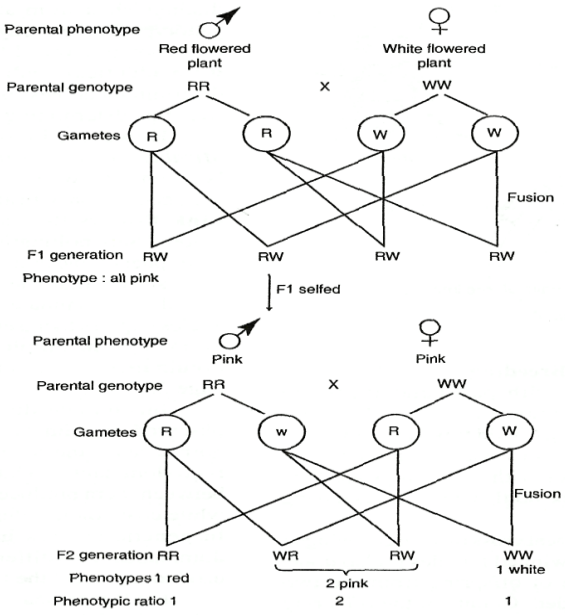


Figure: 3.17 Incomplete dominance

Inheritance of ABO Blood Groups

In human beings, the ABO blood group system is an inheritable characteristic that is transmitted from parents to offspring. Unlike other genetic traits determined by a pair of alleles, the ABO blood groups have three genes involved, a case of multiple allefes and they are responsible for the presence of antigen types on the red blood cells. These are gene A responsible for the presence of antigen A, gene B responsible for presence of antigen B and gene O responsible for no (zero) antigen on the red blood cells. Gene A and gene B have equal degrees of dominance, that is they are **co-dominant,** and will both express themselves when present together as in the AB blood group. Gene O is recessive and will only express itself in the homozygous condition.

The genotypes for the four blood groups in the ABO system are thus formed by allelic pairs of genes as shown in table 3.4.

Table 3.4: Human blood groups and their genotypes

Blood group (phenotype)	*Genotype*	*Antigens*
A	AA, AO	A
B	BB, BO	B
AB	AB	A and B
O	00	0 (Zero)

These alleles are transmitted from parent to offspring in the usual Mendelian fashion. Thus a marriage between a man of blood group A and a woman of blood group B will produce children of all four blood groups as shown below if both parents are heterozygous. See figure 1.19(a).

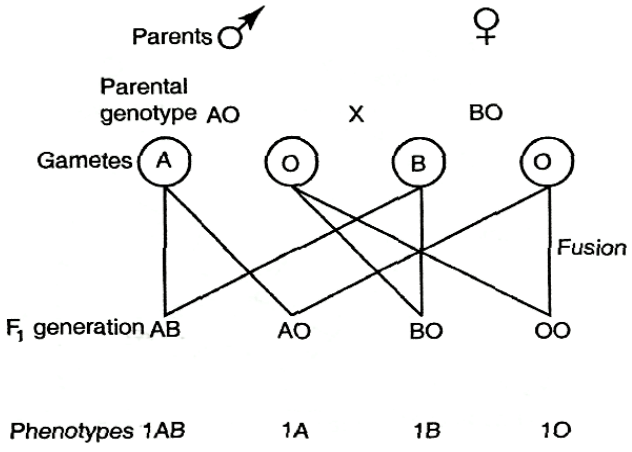
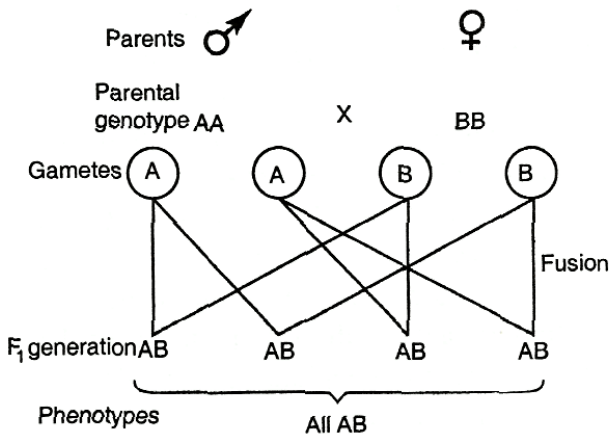


Figure: 3.18 Inheritance of groups in the ABO system

A man who is homozygous for blood group A married to a woman who is homozygous for blood group B would produce children who would only be AB as shown in figure.



However, a marriage between a man of blood group A and a woman of the same blood group cannot produce children of blood group B. Likewise, a man of blood group B and a woman of the same blood group cannot produce children of blood group A. Parents who belong to blood group O cannot produce children with blood group A or B.

Knowledge of blood group inheritance has been used as supportive evidence in court cases where parentage is disputed. It is also useful in blood transfusion. This is discussed later in the chapter.

Study this question

A Mrs Romanas claims that her child was wrongly identified at hospital, so that she took away the wrong baby, BothRomanas and her husband are blood group A. The child's blood group is O. Is Romaaas justified in her claim? Make a genetic cross using a punnet square to explain your answer.

Inheritance of the Rhesus factor

In human beings, possession of Rhesus antigen makes one Rh+ (Rhesus positive) while absence of Rhesus antigen makes one Rh- (Rhesus negative). The presence of Rh antigen is due to a dominant gene which is dominant over the gene for its absence.

If one of the parents is Rh+ then all the children will be Rh+. Rh- children will only result if both parents are Rh-If blood from a Rhesus positive (Rh+) person is transfused into a person without the Rhesus factor, the recipient produces antibodies against the Rhesus factor of the donor. This causes agglutination of red blood cells of the recipient.

If a woman who is Rhesus negative is married to a Rhesus positive man, when she becomes pregnant the child will be Rhesus positive. Rhesus antigen can cross the placenta into the mother's bloodstream prompting the mother's immune system to produce Rhesus antibodies. When antibodies get into the foetal circulation, an antigen-antibody reaction takes place and the red blood cells of the foetus are destroyed (haemolysed). In the second pregnancy the amount of antibodies are more and cause a lot of damage to the foetal red blood cells resulting in death. This is called Haemolytic **disease** of the new born *(Erythroblastosis foetalis).*

Determining Unknown Genotypes

In the garden pea, the gene that determines red flowers is dominant over that which determines white flowers. A plant with red flowers may either be homozygous or heterozygous for this characteristic. To establish its correct genotype it is crossed with a homozygous recessive plant. If their offspring bear red flowers, then this indicates that the red flowered plant is homozygous, that is, it is from a pure line, as shown in figure 3.19 (a).

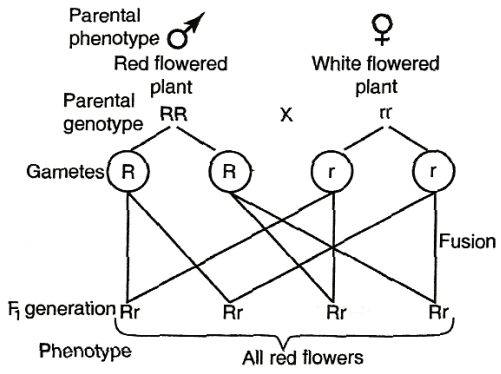


Figure: 3.19 (a) Test cross for the homozygous dominant trait

If on the other hand their offspring bear a mixture of white and red flowers in equal proportions giving the ratio of 1:1, this indicates that the red flowered plant was heterozygous as shown in figure 1.20(b).

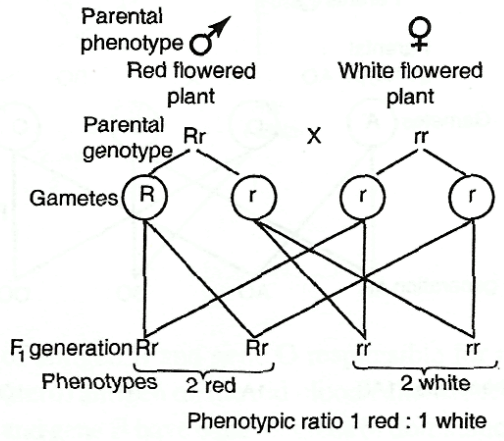


Figure: 3.19 (b) Test cross for heterozygous

A cross between an individual of unknown genotype with an individual of recessive genotype is known as a test cross. Atest cross where an offspring is crossed with one of its parents is known as **back cross**.

Unknown genotypes can also be determined by carrying out setting experiments. For example a phenotypically tall plant is either genotypically homozygous or heterozygous for this trait. If selfed and all its offspring are phenotypically tall then the parental genotype is XT, that is, homozygous dominant. However, if after selling both tall and dwarf offspring are produced in the 3:1 ratio, then the parental genotype is Tt, that is, heterozygous. This is illustrated in figure 3.19(c).

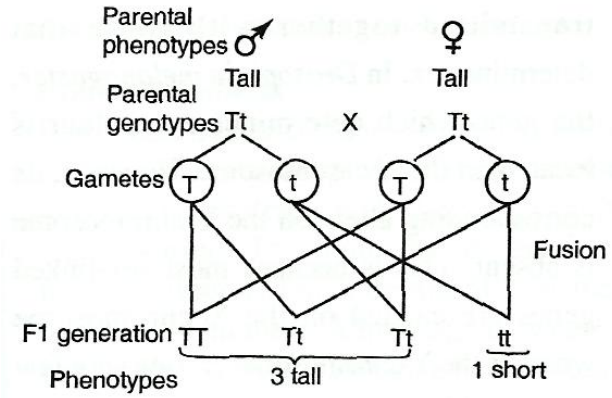


Figure: 3.19 (c) Selfing cross

3.5 Sex Determination

Sex determination in higher animals is controlled by a specific pair of chromosomes. For instance in human beings, there are 46 chromosomes (23 pairs of homologous chromosomes) in every body cell. The genes that determine whether a child becomes a male or female are located on the specific pair of chromosomes called sex chromosomes which are of two types, X and Y chromosomes (named after their shape). The remaining 22 pairs of chromosomes are called autosomes and are responsible for other inheritable characteristics. A male human being carries the XY (heterogametic) while a female carries XX (homogametic) combination. After meiosis in a male, the spermatozoa can either contain the X or Y chromosome while the female ova will contain only X chromosome. The sex of a child is a matter of chance and depends only on whether a spermatozoon that fertilises the ovum carries X or Y chromosome.

During fertilisation there are four possible genotypic combinations. Two out of these four combinations (XX) result in a girl while the other two combinations (XY) result in a boy. There is therefore a 50% chance that fertilisation can result in either XX (girl) of XY (boy). Diagramatical representation of human sex determination is shown in figure 3.20.

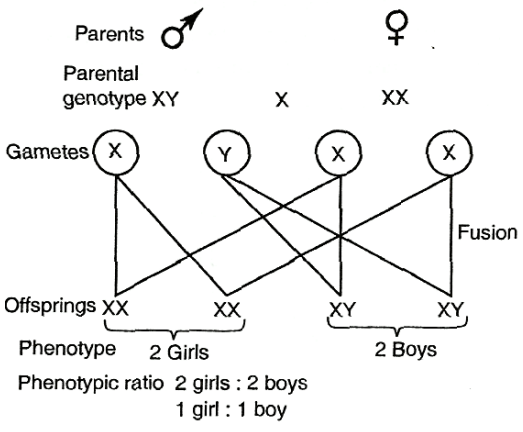


Figure: 3.20 Sex determination in man

In terms of probability, the chance that a boy or girl is produced in a family is a half (±). This means that chances are equally likely that a boy or girl is born in a family.

In other animals, the male is homogametic, while the female is heterogametic. In birds, the male is XX and the female is XY. In some insects, the female is XX and the male is XO; the Y chromosome is missing altogether. In the fruit fly, *Drosophila melanogaster,* sex determination is exactly as in human beings, that is males are XY and females are XX.

Linkage

An organism has a large number of characteristics controlled by many different genes. Due to the limited number of chromosomes, each gene cannot be located on its own chromosome. Therefore a chromosome must accommodate many different genes each controlling particular characteristics. For example, genes located on only 23 pairs of chromosomes control all the thousands of characteristics in human beings. Those genes found on the same chromosome are called **linked genes.** All the linked genes constitute a **linkage group.** Linked genes are inherited together and therefore do not segregate during meiosis. They are therefore transmitted into the same gamete. See figure 3.21.

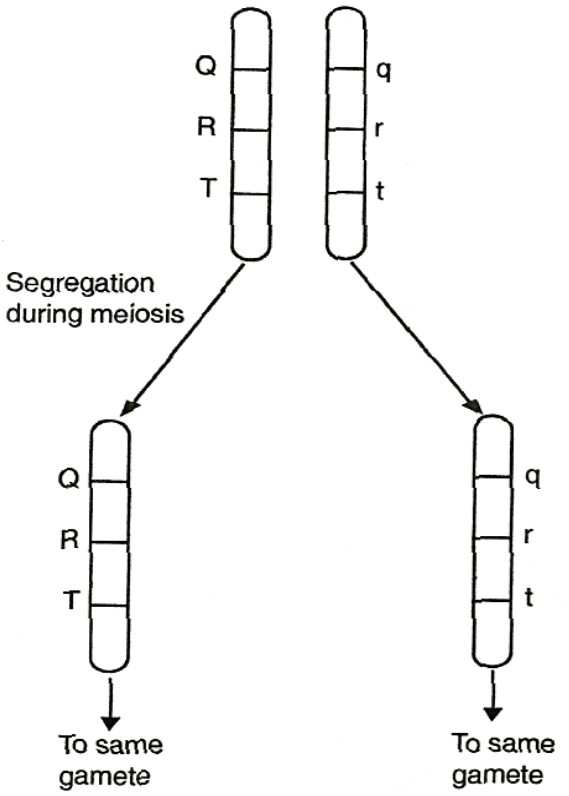


Figure: 3.21 Transmission of linked genes

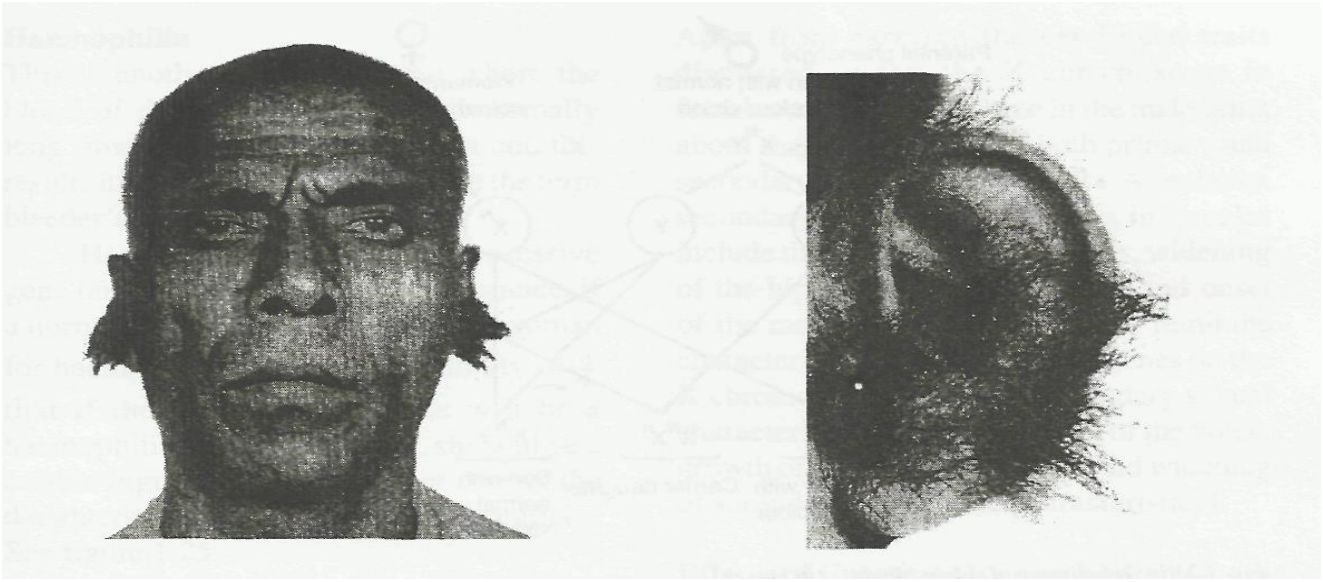
If genes Q, R and T are linked, then all the three pairs of genes are accommodated on a homologous pair of chromosomes.

Cases of linked genes have been studied in *Drosophila sp.* It has been found that the genes for wing length, abdomen size and body colour are located on the same chromosome. Therefore these characteristics are usually inherited together.

Sex-linked Genes

All genes located on the sex chromosomes are said to be **sex-linked** and therefore are transmitted together with those that determine sex. In *Drosophila melanogaster,* the gene which determines eye colour is located on the X chromosome. However, its corresponding allele on the Y chromosome is absent. This is because most sex-linked genes are carried on the X chromosome whereas the Y chromosome carries very few genes and is almost empty. The principle of inheritance of sex-linked characteristics in *Drosophila* is similar to that in humans.

In humans there are a few genes located on the Y chromosome which control characteristics that are exclusively male. These are premature baldness and tuft of hair in the ear pinna and in the nose. See plate 2. Characteristics controlled by genes located on the X chromosome include colour blindness and haemophilia. These characteristics can arise in either males or females.



***Inheritance of human** sex-linked characteristics*

Colour Blindness

Red-green colour-blindness is the inability to distinguish red and green colours by some people. This trait is linked to the X chromosome. The gene that determines normal colour vision is dominant over that for colour-blindness. A marriage between a colour-blind man and a woman homozygous for normal colour vision results in their daughters being carriers but with normal colour vision. The daughters are described as carriers because they are heterozygous and colour blindness is suppressed by the dominant gene for normal colour vision. All the sons of the two parents however, are normal. Figure 3.22 (a) illustrates this. Let N represent the gene for normal colour vision. Let n represent the gene for colour-blindness. Since the gene is linked to X chromosome its alleles are represented as X^N and X^n.

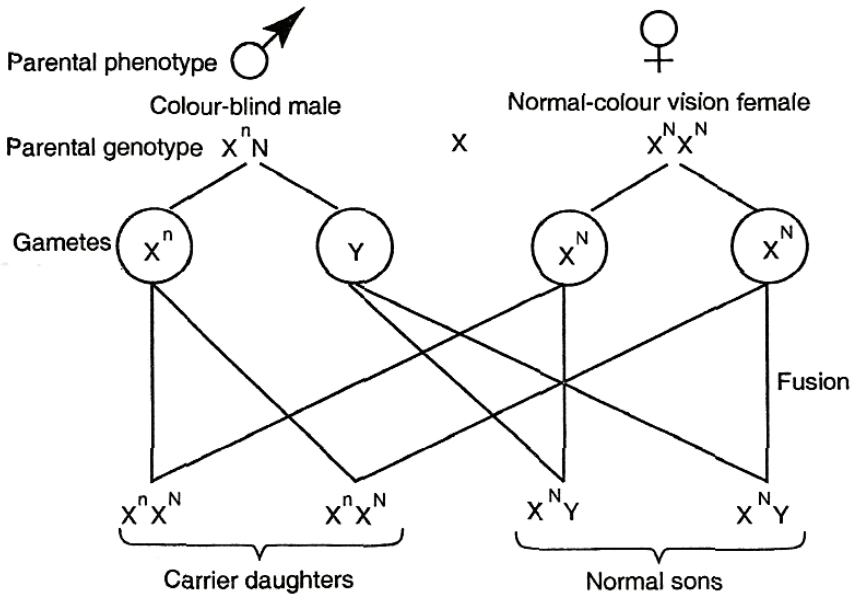


Figure: 3.22 (a) Inheritance of colour blindness

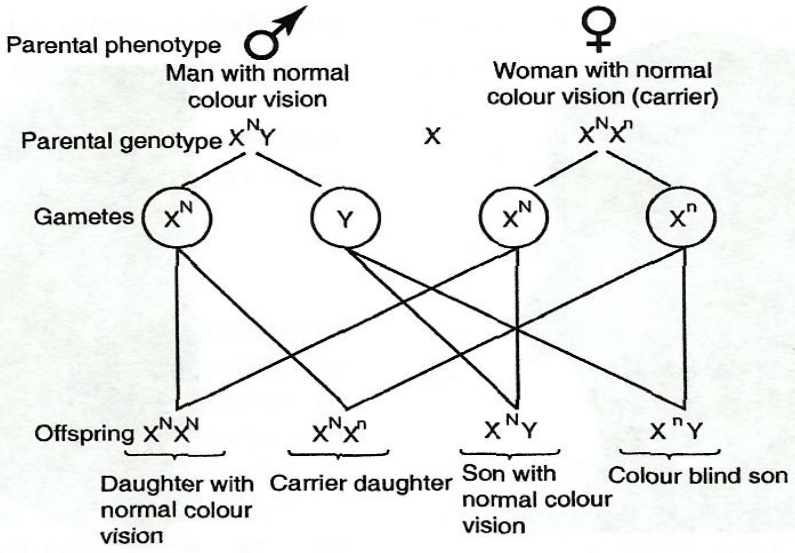


Figure: 3.22 (a) Inheritance of colour blindness in humans

If a carrier daughter from the above parents married a normal man, some of their sons will suffer from colour-blindness while the daughters will be either carriers or homozygous for normal colour vision as shown in figure 3.22(b).

The above example shows that the gene for colour-blindness is passed from mother to sons. This is because the only X chromosome the male offspring inherits is from the mother.

Consequently there are more male sufferers in a population compared to females. Females only suffer when in homozygous condition of the recessive gene. If the X chromosome carries the gene for the trait then this gene will be expressed since allele on the Y chromosome is absent.

The pedigree given in figure 3.25 illustrates the inheritance of colour-blindness in two generations above.

Inheritance of colour-blindness through several generations can be clearly illustrated using a pedigree. Apedigree is a record, in table form showing the distribution of one or more traits in different generations of related individuals. Figure 3.23 illustrates the inheritance of colour-blindness through two generations.

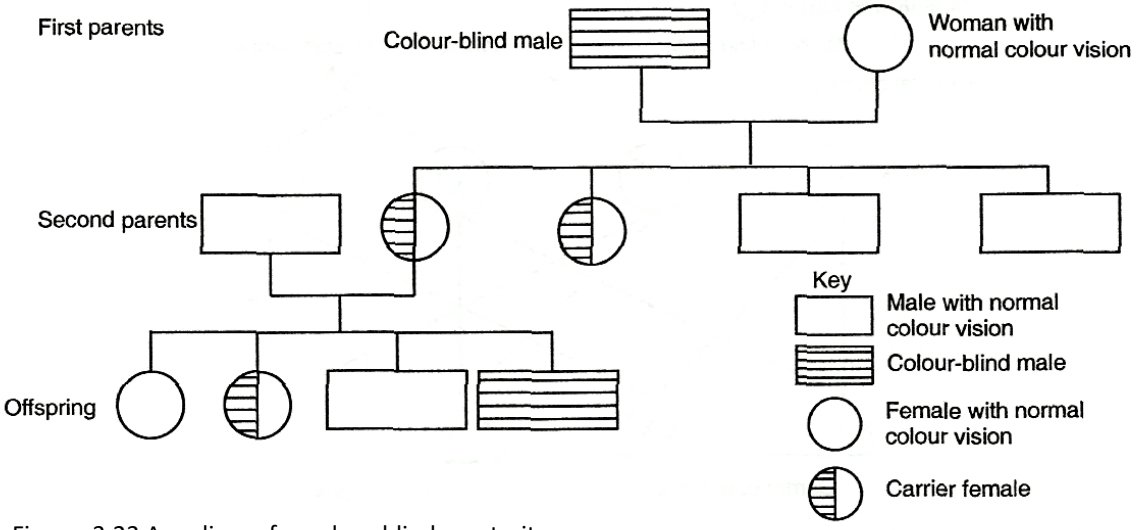


Figure: 3.23 A pedigree for colour blindness trait

Haemophilia

This is another sex-linked trait where the blood of the sufferer takes an abnormally long time to clot. In the event of a cut, this results in prolonged bleeding, hence the term bleeder's disease.

Haemophilia is caused by a recessive gene on the X chromosome. For instance, if a normal man is married to a carrier woman for haemophilia, there is a probability of | that if their child is a boy he will be a haemophiliac and if a daughter, she will be a carrier. Figure 1.25 indicates that none of the daughters of the couple are haemophiliacs. See figure 3.24.

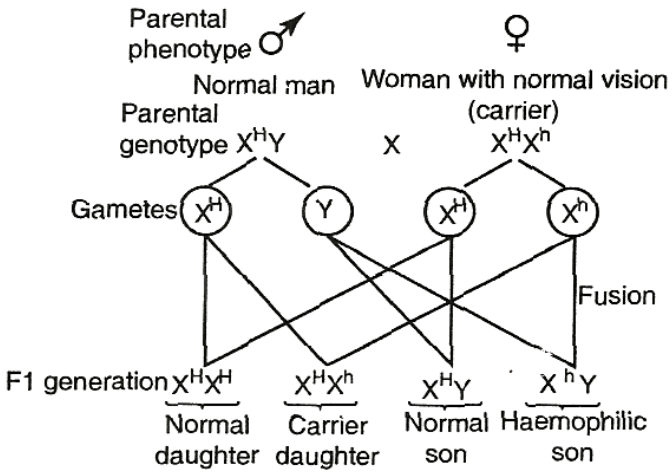


Figure: 3.24 Inheritance of heamophilia in man

Let H represent the gene for normal blood clotting condition. Let h represent the gene for haemophilia. Both genes are located on the X chromosome e.g. X^H or X^h.

Study this question

If a haemophiliac man marries a carrier woman:

(a) Use a genetic cross to work out the product of the above marriage.
(b) What is the probability that their daughter will be haemophiliac.
(c) The above disorder is more common in males than females. Explain.

Apart from carrying the sex-linked traits discussed so far, the X chromosome in females and Y chromosome in the male bring about the development of both primary and secondary sexual characteristics. At puberty, secondary sexual characteristics in females include the enlargement of breasts, widening of the hips, growth of pubic hair and onset of the menstrual cycle. These are feminine characteristics all controlled by genes on the X chromosome. In males, secondary sexual characteristics include breaking of the voice, growth of pubic hair and beard, and widening of shoulders (masculine characteristics).

Effects of Crossing Over on Linked Genes

Linked genes are carried on the same chromosome and it is expected that these genes would always stay together and never get separated during their transmission. It has been observed, however, that this is not always the case. Experimental evidence shows that it is unusual to find complete gene linkage. Usually it is common to find that a certain small proportion of the offspring show new combinations.

This indicates that some of the linked genes separate and are transmitted on different chromosomes. This happens during crossing over when sections of chromatids of a bivalent intertwine and may break off. Some of these sections get rejoined to different chromatids thus separating genes that were previously linked. Fusion of the few gametes containing chromatids whose genes have changed places in this way will produce new combinations (re-combinants).

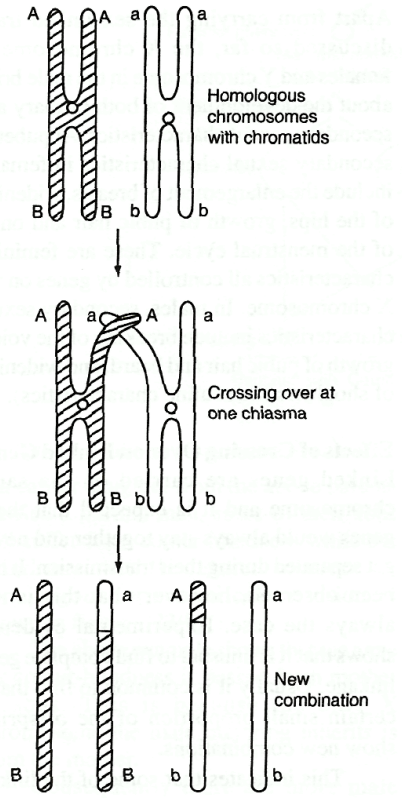


Figure: 3.25 A pair of linked genes separated

However, the majority of the gametes that fuse contain chromatids whose gene linkage has not been interfered with by crossing over. Crossing over results in chromosomal mutations which in turn cause variations. See figure 3.25

3.6 Mutations

In a natural population of animals or plants, an individual with some unusual characteristics, or a **mutant,** may be produced as a result of a **spontaneous change in the individual's** genetic **makeup.** The change is then described as **mutation.** For instance, in human beings, a haemophiliac might suddenly be produced from quite normal parents. In *Drosophila* vestigial wings may crop up in offspring of parents with genes for normal long wings. Resistance to DDT by insects (e.g. mosquitoes) or resistance to penicillin by bacteria are further examples of mutation.

Mutations are normally due to recessive genes most of which are transmitted in the usual Mendelian fashion. As such, mutations, occur naturally but are extremely rare. However, they can be induced by certain factors of the environment. Such factors are described as mutagens and include exposure to gamma rays, ultraviolet light and a variety of chemicals such as colchicine and mustard gas. Mutations occurring in gametes are more 'important than those occurring in somatic cells, since these mutations are inherited.

Mutational changes are the basis of discontinuous variation in populations.

Types of Mutations

There are two types of mutations. **chromosomal mutations** and **gene mutations**:

Chromosomal Mutations

Chromosomal mutations involve changes in the structure or number of the chromosomes. During crossing over in meiosis chromatids of homologous chromosomes intertwine at several points, the chiasmata. Breaking of chromosomes at the chiasmata creates plenty of opportunity for various changes on the chromatids leading to chromosome mutations. There are five types of chromosome mutations sometimes called chromosome aberrations. They are: deletion, duplication, inversion, translocation and non-disjunction. These are discussed below.

Deletion

This occurs when some sections of the chromatids break off and fail to reconnect to any of the chromatids. In this case these sections are completely lost and genetic material they contain is said to be deleted out. as seen in figure 3.26(a).

Deletion can produce great effects on an individual since it involves loss of genes. Both the structure and the development of the individual can be grossly interfered with. Indeed most deletions are lethal since the offspring may lose genes responsible for the synthesis of some vital protein molecule.

Duplication

In this case a section of a chromatid replicates and adds an extra length to itself and in so doing sets off genes is repeated as shown in figure 3:26 (b).

Duplication can produce serious effects depending on the chromosome sections involved. For instance, if the gene duplicated were responsible for certain traits, these traits may be over-emphasised in the organism.

Inversion

This is the type of chromosome mutation which occurs when a chromatid breaks at two places. When rejoining, the middle piece rotates and rejoins in an inverted position. This has the effect of **reversing the gene sequence** along the chromatid. The consequence depends on the group of genes affected. It might bring closer together genes whose combined effects are advantageous or disadvantageous.

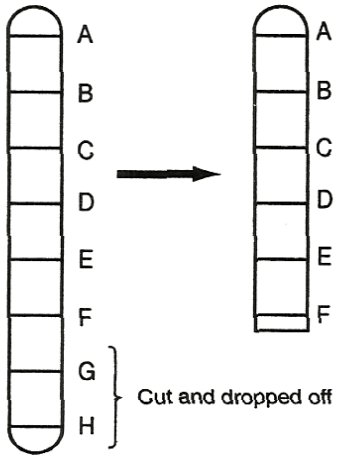


Fig. 3.26(a): Chromosomal deletion

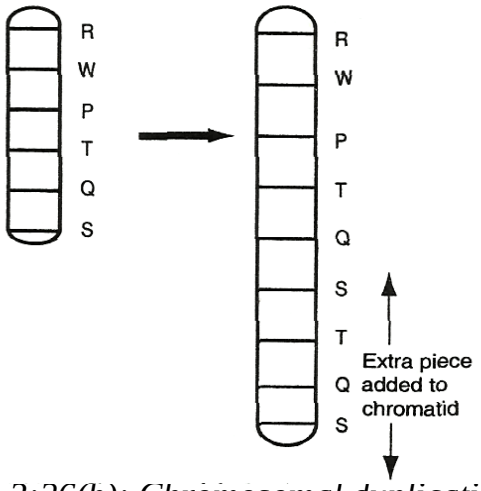


Fig. 3:26(b): Chromosomal duplication

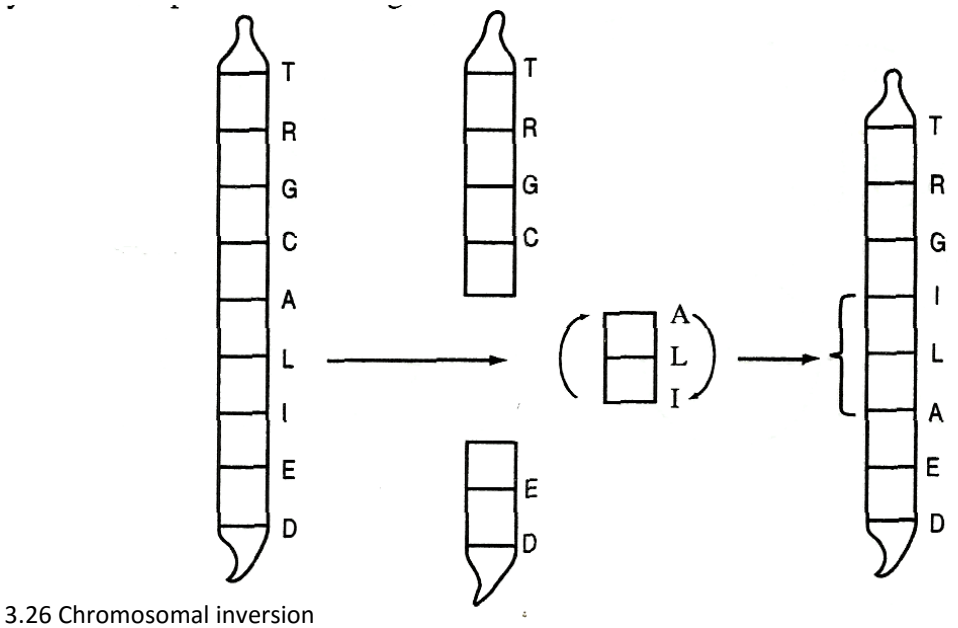


Figure: 3.26 Chromosomal inversion

Translocation

This occurs when a section of one chromatid breaks off and becomes attached to another chromatid but of the non-homologous pair. Translocation therefore involves the movement of genes from one non-homologous chromosome to another. See figure 3.26(d).

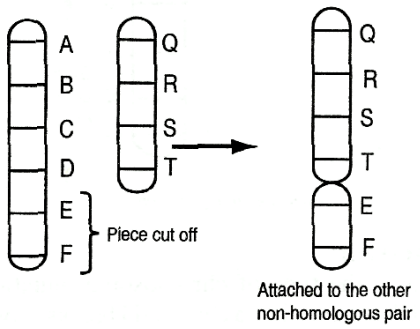


Figure: 3.26 (d) Chromosomal translocation

Non-disjunction

This is the kind of chromosome abnormality that leads to addition or loss of one or more whole chromosomes. If it occurs during the anaphase of the first meiotic division, two homologous chromosomes fail to segregate and so move on into the same gamete cell. And if it happens at anaphase of the second meiotic division, sister chromatids fail to segregate.

This results in half of the gametes containing two of the same chromosome whilst the others have none. The fusion of the first type of gamete with a normal gamete of the opposite sex will result in an individual with three such chromosomes, that is the normal homologous pair plus one extra chromosome. See figure 3.27(a), (b) and (c).

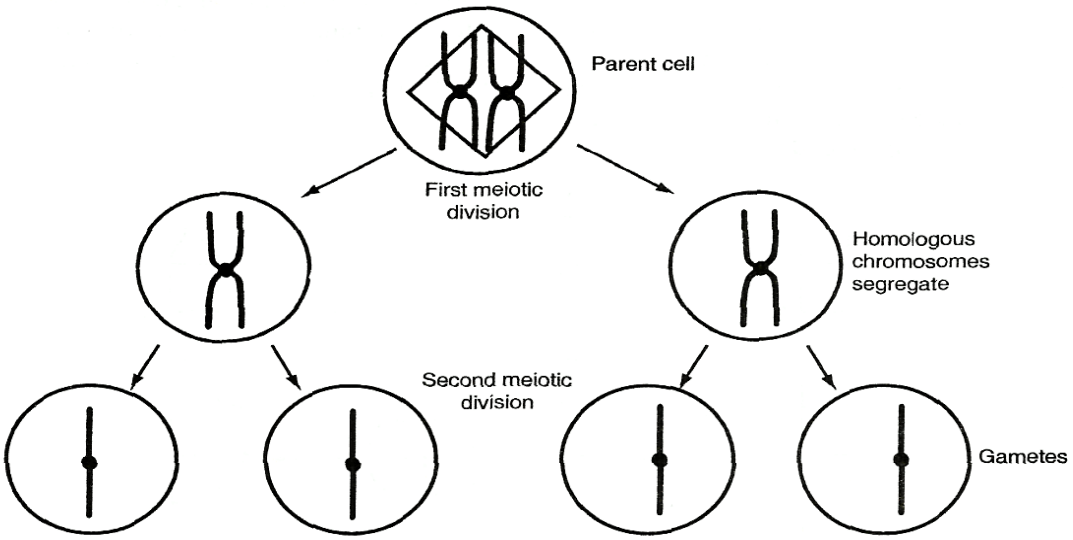


Figure: 3.27 (a) Normal meiosis

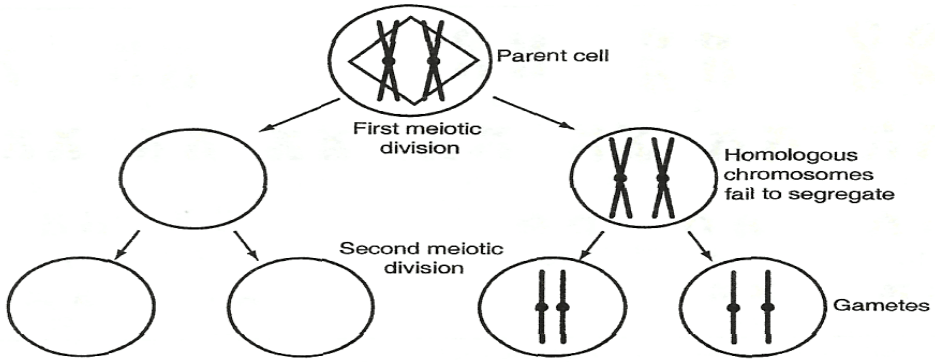


Figure: 3.27 (b) Non-disjunction at first meiotic division

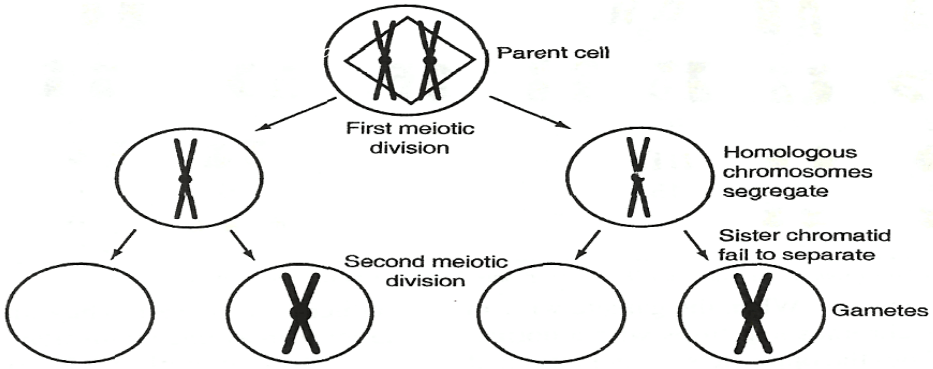


Fig. 3:27(c): Non-disjunction at second meiotic division

Non-disjunction causes Downs's syndrome where there is an extra somatic chromosome number 21.

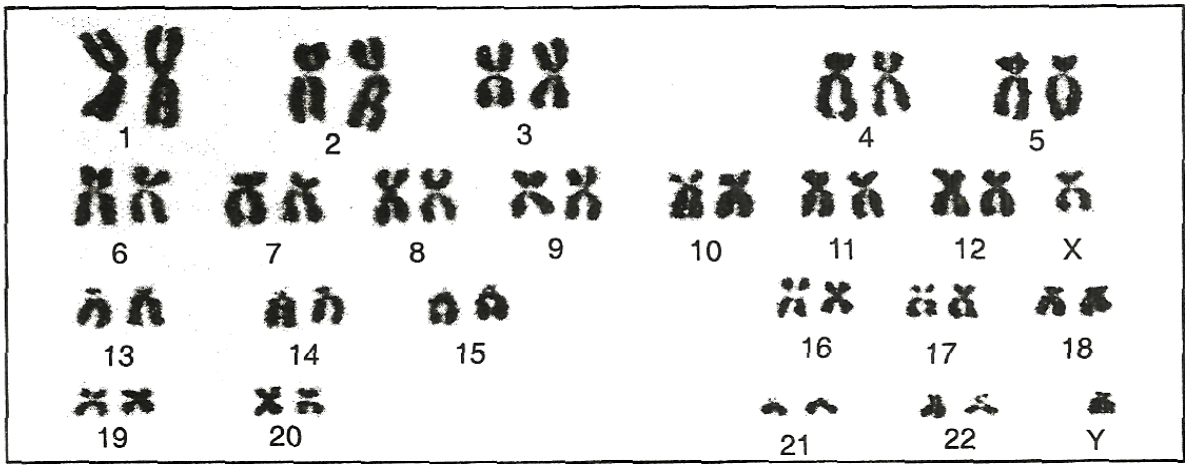
Such individuals have slit-eye appearance, reduced resistance to infection, always mentally deficient, thick tongue, cardiac malfunctions and short body with stubby fingers. Higher incidence is among children of older mothers about 40 years old and may be due to depletion of nutrients in eggs. Fathers aged 55 years and above also have increased risk of producing offspring with Downs's syndrome.

Other examples of non-disjunction in human beings include KHnefelter's and Turner's syndrome. Polyploidy is another case resulting from non-disjunction.

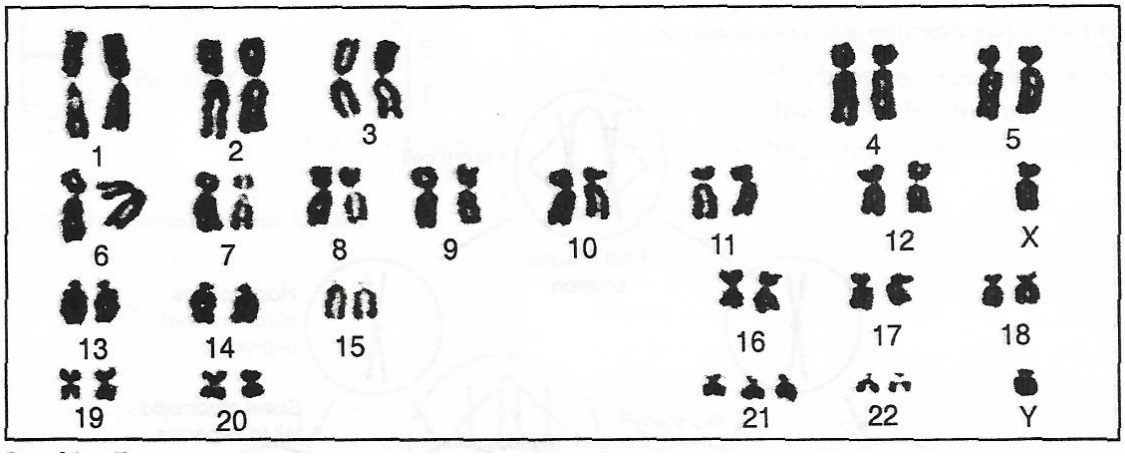
Klinefelter's syndrome individuals have an extra sex chromosome. Hence they have a total of 47 chromosomes in their cells i.e. XXY (male) and XXX (female).

Non-disjunction leading to Klinefelter's syndrome can occur either during spermatogenesis or oogenesis. It results in half of the gametes containing an extra sex chromosome and half having no sex chromosome. When the gamete with an extra sex chromosome fuses with a normal gamete from the opposite sex, an individual with Klinefelter's syndrome is produced. This is illustrated in figure 1.29 (a) and (b). Symptoms of Klinefelter's syndrome in males include infertility due to lack of sperm production, underdeveloped testes and reduced facial hair. They are also usually taller than average with signs of obesity.
Persons with XXX constitution are females who appear relatively normal in most characteristics.

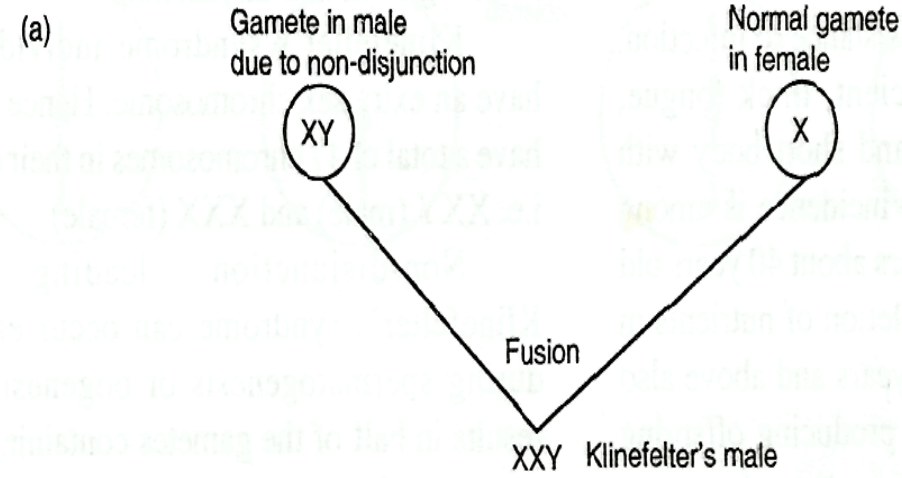
Turner's syndrome is where an individual lacks one sex chromosome, hence there are only 45 chromosomes (XO or YO) in the cells instead of the normal 46 chromosomes. YO zygotes do not develop due to the absence of many vital genes. Individuals with this syndrome are females that show underdeveloped female characteristics. For example, they are infertile due to lack of ovaries and small uterus, no breast development and are short in stature.

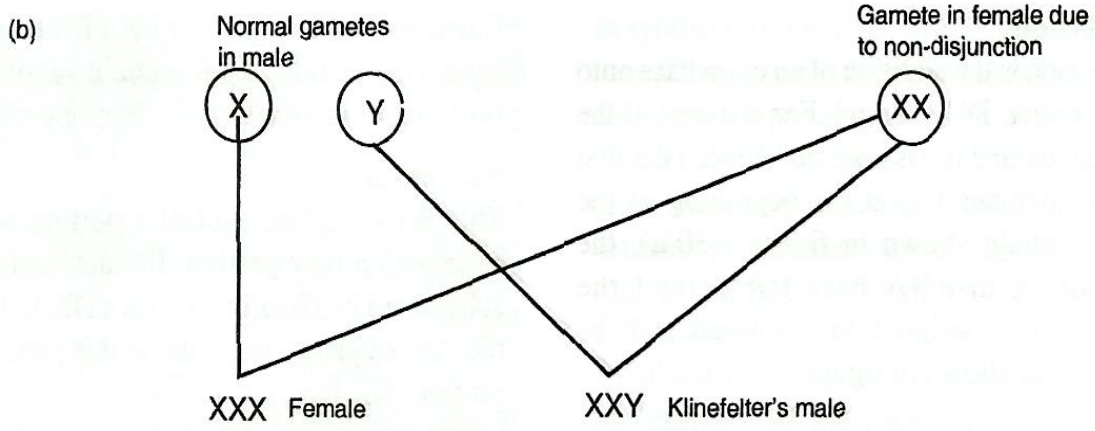


a): A full set of chromosomes in a normal human male



(b): Chromosomes of a male with Down's syndrome. There is an extra chromosome 21





Polyploidy

Occasionally, during meiosis, chromosome pairs might undergo non-disjunction simultaneously. This results in half the gametes having two of each type of chromosome (i.e. diploid), the rest having none. If the resulting diploid gamete fuses with a normal haploid gamete, the zygote so formed is triploid. If two **diploid** gametes fuse, a **tetraploid** individual results. This is what is called polyploidy, where it is possible for an organism to acquire one or more complete extra sets of chromosomes. Polyploidy can also occur if the whole set of chromosomes doubles after fertilisation. Polyploidy is rare in animals, but common in plants where it is often associated with advantageous characteristics as has been shown in species of wheat and rice. Such characteristics include increased yields, early maturity, and resistance to drought, pests and diseases. Polyploidy can artificially be induced by using a chemical called colchicine which prevents spindle formation during mitosis thus leading to a cell with double the number of chromosomes (4n).

Gene Mutation

A gene mutation involves a change in the structure of a gene. Gene mutations are also referred to as point mutations.

A gene mutation arises as a result of a change in the chemical nature of the gene. The change may involve some alteration in the DNA molecule. For instance, the sequence of nucleotides in a certain section of DNA molecule corresponding to a particular gene may change. Such a change will result in an alteration of the amino acid sequence required in the synthesis of the protein formed will also change and this will produce very great effects on both the structure and development of the organism. When such a change is drastic, a completely abnormal protein molecule may result. Such a protein will function properly.
A change in the DNA molecule is passed onto the m-RNA. Consequently this alters the sequence of amino acids during protein synthesis. This results in unintended protein molecules which may bring confusion or may be lethal.

There are four main types of gene mutations namely insertion, substitution, inversion and deletion. These are summarised in figure 3.29(a) to (d).

Insertion

Insertion is the addition of an extra base onto an existing DNA strand. For instance, if the base Guanine (G) is inserted between the first two Adenines (A) at the beginning of the DNA chain shown in figure 1.30(a), the resulting m-RNA base triplet and the subsequent amino acid alignment will be altered as shown in figure 2.29(a),

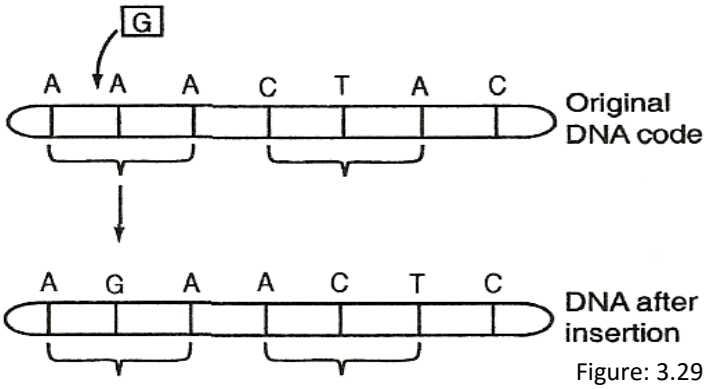


Figure: 3.29 (a) Insertion

By the mere insertion of Guanine at the position indicated, no polypeptide chain is formed because none of the intended amino acids have been linked.

Deletion

Deletion is the removal of a gene portion. If the base Thymine (T) is deleted from its position at the indicated section of the DNA strand as shown in figure 1.30 (b), the base sequence becomes altered at this point.

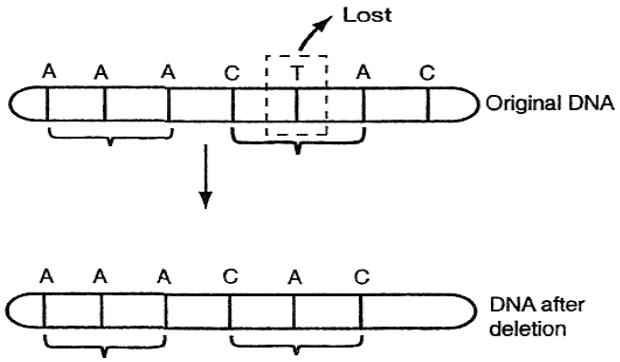


Figure: 3.29 (b) Deletion

Consequently the sequencing of the amino acids on the polypeptide chain is altered, resulting in production of a wrong protein.

Substitution

This is the replacement of a portion of the gene with a new portion. If Adenine (A) is substituted by Guanine (G) on a DNA strand the base sequence is altered at this particular portion. See figure 1.30 (c).

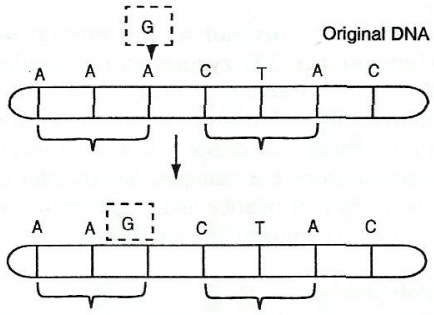


Figure: 3.29 (c) Substitution

Inversion

If a portion of the DNA strand carrying AC rotates through 180°, that portion is said to be inverted, see figure 3:29 (d). The inversion results in alteration of the base sequence at this point.

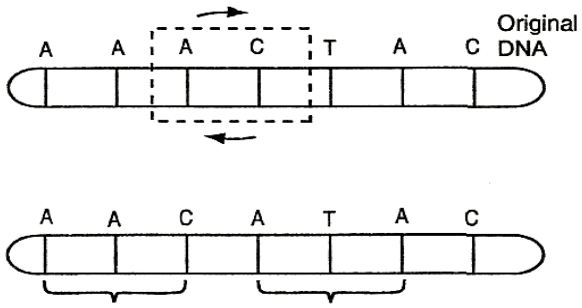


Figure: 3.29 (d) Inversion

Disorders Due to Gene Mutations

In human beings examples of such disorders include albinism, sickle-cell anaemia, haemophilia, colour-blindness and chondrodystrophic dwarfism.

Albinism

This is a condition where the synthesis of the skin pigment, melanin, fails and is characterised by a light skin, white hair and pink eyes. Such an individual is described as an albino. Melanin is a derivative of the amino acids phenylalanine and tyrosine, and is synthesised through a series of reactions. Each of these reactions is controlled by a specific gene. In albinism one of these genes (designated by letter A) is **substituted** by a recessive gene (designated by a). Gene a in the homozygous condition **aa** blocks in one or two places of the chain reactions involved in synthesis of melanin. This is as a result of one of the enzymes (tyrosinase) failing to be formed in the presence of the recessive gene. Consequently melanin is not formed and albinism results. The genotype of an albino is homozygous recessive aa. A carrier for the trait is heterozygous with the genotype Aa and has normal skin pigmentation. In a family an albino child can be bom if both parents are carriers of the recessive gene. This possibility is shown in figure 3.30.

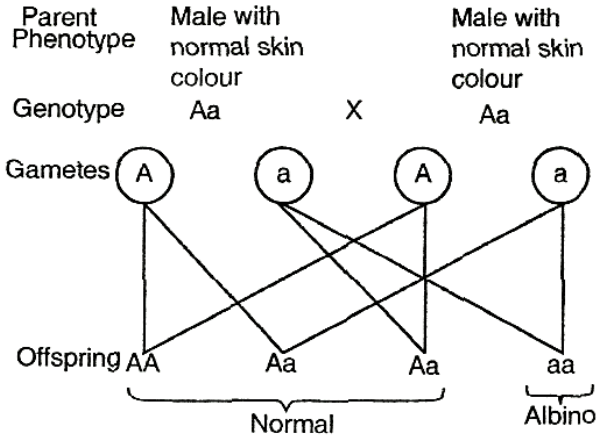


Fig. 3.30: Inheritance of albinism

Therefore, the probability that any child born to carrier parents will be an albino is i. The probability that any of their children is a carrier is 1.

The skin of an albino person is susceptible to sunburn and the eyes are sensitive to bright light. Use of sunglasses and sunscreen lotions helps them to lead a normal life.

Sickle-cell Anaemia

Another known example of gene mutation through substitution is the sick-cell condition. Normal haemoglobin type A consists of two polypeptide chains. In the sickle-cell condition one amino acid, glutamic acid, is replaced by another acid valine, in each of the two polypeptide chains of the haemoglobin molecule. The resulting haemoglobin, known as haemoglobin type S is defective and has a marked difference from the normal one as a result of this seemingly minor substitution. These differences are given in table 1.7,

Sickle-cell anaemia is thus the condition where the individual is homozygous for the defective gene that direct the synthesis of haemoglobin S. Most of the individual's red blood cells are therefore sickle-shaped and the person frequently experiences oxygen shortage to the body tissues hence cannot carry out strenuous physical exercises.

The sickle-shaped cells are not able to squeeze through capillaries.

Thus they end up clogging blood vessels preventing normal blood flow. This blockage results into severe pain in the joints, arms, legs, and the stomach. With close medical attention, sickle cell persons lead a relatively normal life. However, most deaths are due to infections from other diseases or damage to tissue.

A less serious condition is the **sickle-cell trait.** This is a heterozygous condition where less than half the number of red blood cells are sickle-shaped. The rest of these cells are normal and are efficient in oxygen loading.

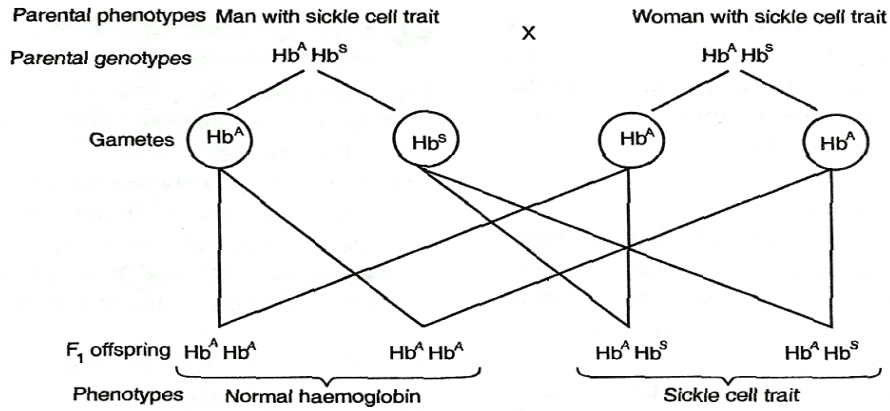


Figure: 3.31 (a) Inheritance of sickle cell trait

An individual with the sickle-cell trait experiences a mild case of anaemia but leads a normal life. Such individuals have an adoptive advantage in surviving malarial attacks as compared to those who have normal haemoglobin.

Inheritance of sickle cell condition is a case of incomplete dominance. If a man with sickle-cell trait (carrier) marries a normal woman, the probability that any of the offspring will carry the sickle-cell trait is $\frac{1}{2}$. This is shown in figure 3.31 (a).
However in a marriage between two sickle-cell carriers the probability of obtaining a sickle-cell child is 1 while the probability of getting a child carrying the trait is, see figure 1.32(b).

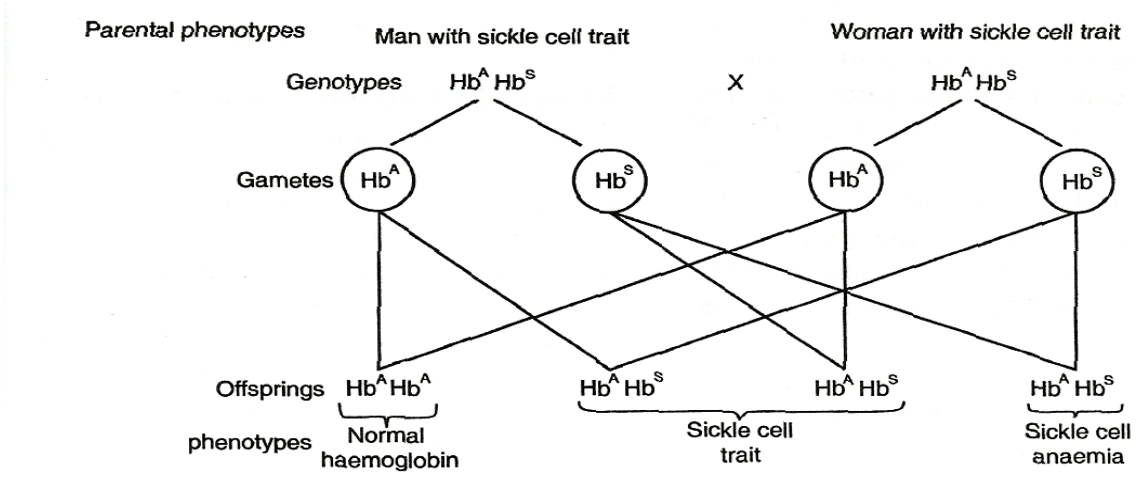
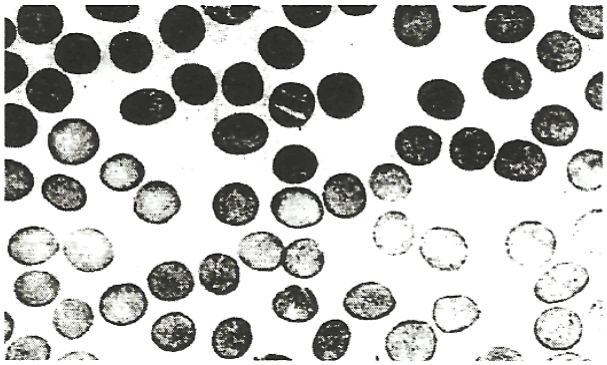
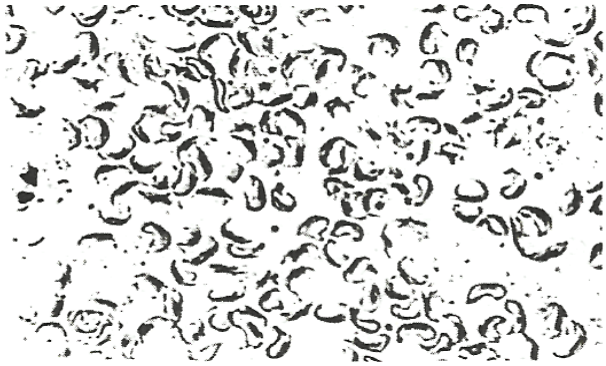


Figure: 3.31 (b): First generation in a cross between Sickle-cell carriers

Table 1.7: Comparison between Normal Haemoglobin and Haemoglobin HbS

Normal Haemoglobin (Hb A)	*Defective Haemoglobin (fib S)*
I. A position in each polypeptide chain is occupied by glutamic acid.	1. The same position in each polypeptide is occupied by valine.
2, Does not easily crystalise in low oxygen concentration such as in the capillaries.	2. Easily crystalises in low oxygen concentration.
3. The haemoglobin is efficient in oxygen loading and transportation.	3. Is not efficient in oxygen loading and transportation.
4. The red blood cells carrying them have the normal biconcave shape.	4. The red blood cells carrying them are crescent or sickle-shaped.





Haemophilia

The inheritance of this condition haemophilia has already been discussed due to a recessive gene on the X chromosome produced by gene substitution. The haemophilic blood lacks the ability to clot. The condition is caused by a haemophilic gene that prevents the production of the necessary clotting factors (especially clotting factor VIII called antihaemophiliac globulin, AHG). Haemophiliacs lose a lot of blood even from minor cuts. Persistent bleeding results into anaemia, which when not checked is potentially lethal.

Remedies include introduction of clotting factors e.g. factor VIII and IX from blood donated by normal persons into haemophiliacs. Meanwhile, couples are advised to undergo screening and get genetic counselling to enable them make informed decisions on the chances of bearing haemophiliac children.

Colour-blindness

There are different forms of colour blindness. The most common form is the red-green colour-blindness. In this form, the individual is not able to distinguish between red and green colours. Colour perception is due to presence of specific cones on the retina for specific colour. Colour-blindness is brought about by the presence of a gene in its recessive form causing total absence or shortage of the respective cones for colour perception. The gene for colour vision is located on the X chromosome and it is inherited in the Mendelian fashion as already discussed. Due to this occurrence of the gene on X chromosome, there are more male sufferers compared to females. Sufferers usually need assistance in situations where colour perception is essential e.g. streetlights and practical experiments where specific colour changes are observed.

Older parents transmit a slightly greater number of mutations to their offspring than younger parents. This elevated chance may be a result of X-rays or other radiation used in medical diagnosis and treatment.

Most disadvantageous genes are recessive to theirnormal alleles. For instance, the genes for albinism, colour-blindness and haemophilia are recessive to their normal alleles. Very few disadvantageous alleles are dominant. One such allele is the gene for chondrodystrophic dwarfness. The gene can express itself phenotypically in both the homozygous and the heterozygous conditions.

Study these questions

(a) Name the type of disorders -that arise; due t6 chromosomal mutation in human beings.
(b) In a marriage between normal skin colour man and an albino woman, all the children had normal skin colour Using letters 'A' and ‘a’ appropriately:

(i) State the genotypes of the parents.
(ii) Work out the genotypes of the children.
(iii) What is the explanation for the absence of an albino child in this marriage?

Effect of Environment on Heredity

The development of an organism depends on its genetic make-up or genotype and the environment. The interaction between the genotype of an organism and the environment will modify the phenotype of the organism. The genotype of an organism may be such that the organism would grow tall if the environment would provide suitable conditions. If this provision is not met the organism will not grow tall.

In plants and animals, genetically identical individuals reared in different sets of environment will appear more different than those reared in the same environment. For example, in human beings, there are cases of identical twins who have been, separated early in life and brought up in different environments until they are mature. A comparison between these individuals has revealed that they exhibit some observable differences. Such studies indicate that diet, disease and climate, which are factors of environment, influence the phenotype of an individual.

The degree of modification or influence of gene expression by the environmental factors such as disease and food can be observed and measured. During the study of nutrition in plants, it is observed that the effect of mineral deficiency on the development of seedlings could be serious. The effect of drought, pests and disease on otherwise good varieties of plants can be easily observed. Similarly, the effects of protein and vitamins in the development of young children have been observed.

The basic substance from which chlorophyll in the plants develop are found in the chloroplasts. But for plants to develop chlorophyll to the full, light is necessary. Plants grown in the dark do not get their chlorophyll properly developed. Such plants will not carry out photosynthesis efficiently. Thus, although the gene that determines chlorophyll synthesis is present, light must be available for this synthesis to occur. Equally important plant cells which do not have the gene for chlorophyll will not develop chlorophyll even if placed in sunlight.

Mental development and performance depends on both the inherited patterns and the total effect of the environmental influences. This is partly the reason why children go to school, in order to learn and develop. However, this is an area that has remained controversial, since it has often been misused. Measurement and estimation of the amount of influence the environment has on the development of inherited intelligence has not been easy. One approach to measure intelligence is to compare identical twins that are separated and raised in different environments, and compare identical twins raised in the same environment. If heredity is prominent in the determination of IQ (intelligence quotient), separated twins should be similar to twins raised together. Results have shown that separating twins into different environments increases the differences between them. This shows that the determination of IQ is partly environmental with a strong suggestion that the two are of equal importance.

Another way of measuring the relative importance of heredity and environment is to compare the IQ for adopted children with those of children with that adopting parents. The assumption is that the "biological" children should exhibit an IQ which is closer to that of the parents than the adopted children. The results indicate that the adopted children do not differ greatly from the biological children. They show similarity. The children are different genetically but are brought up under similar environmental conditions which makes their IQ close. Much as the environment is important in shaping the expression of the genotypes, those genotypes controlling discontinuous variations **cannot** be influenced by environmental conditions.

3.7: Practical Applications of Genetics

Knowledge of genetics has been put to practical use in areas ranging from plants and animal breeding, blood transfusion, genetic counselling.

Plant and Animal Breeding

Over time human beings have been breeding plants and animals by selectively choosing those with desirable qualities. This process is referred to as **artificial selection.**

Artificial selection is done either by inbreeding or crossbreeding. Inbreeding is useful for retaining desirable qualities between closely related individuals. However, inbreeding increases the chances of undesirable or harmful recessi[1]. £ zrr.es expressing themselves in the **phenotype-** For this reason crossbreeding has been preferred for purposes of increasing **heterozygosity.** It has been observed that offspring resulting from a cross between two genetically dissimilar lines often possess beneficial characteristics not shown by either of the parents. This principle is known as **hybrid vigour** and has been put to good use in plant and animal breeding.

An example of cross-breeding in oil palm shows that *Dura* variety oil palm has a narrow mesocarp yielding little oil, thick endocarp making oil extraction difficult but has a large kernel for kernel oil production. *Pisifera* variety of oil palm has wide mesocarp yielding high quantities of oil, thin endocarp allowing easier oil extraction and small kernel yielding low quantities of kernel oil. When *Dura* and *Pisifera* varieties are crossed, *Tenera* variety is produced, It has the good qualities of both the varieties. It has thick mesocarp yielding high quantities of oil, relatively thin endocarp for ease of oil extraction, large kernel yielding large quantities of kernel oil.

Another example is in cattle. Hereford, an English breed contributes high beef production and quick maturation. The Boran from Kenya contributes disease resistance and the ability to feed and grow on dry pasture. A cross between a Hereford bull and a Boran cow yields a suitable hybrid with all these qualities. See figure 3.32.

Polyploidy has been quite useful in plant breeding. Hybrid polyploids are now quite common among the plants that are grown. For instance, the original wheat had a diploid number of 4 chromosomes but the commercial wheat has either 28 or 42 (tetraploid -4n or hexaploid-6n).

It is believed that the tetraploid wheats arose from a cross between the original diploid wheat and a wild grass, followed by doubling of the chromosome number to form a fertile hybrid. These hybrids were selected for their high yields. A similar technique has been used in the production of new varieties of rice. Other phenotypic characteristics which have been selected for modern agricultural purpose include:

1. Early maturity in both animals and plants.
2. Resistance to disease e.g. cassava resistant to cassava mosaic, coffee variety *Ruiru* eleven (11) resistant to leaf rust and coffee berrv disease.

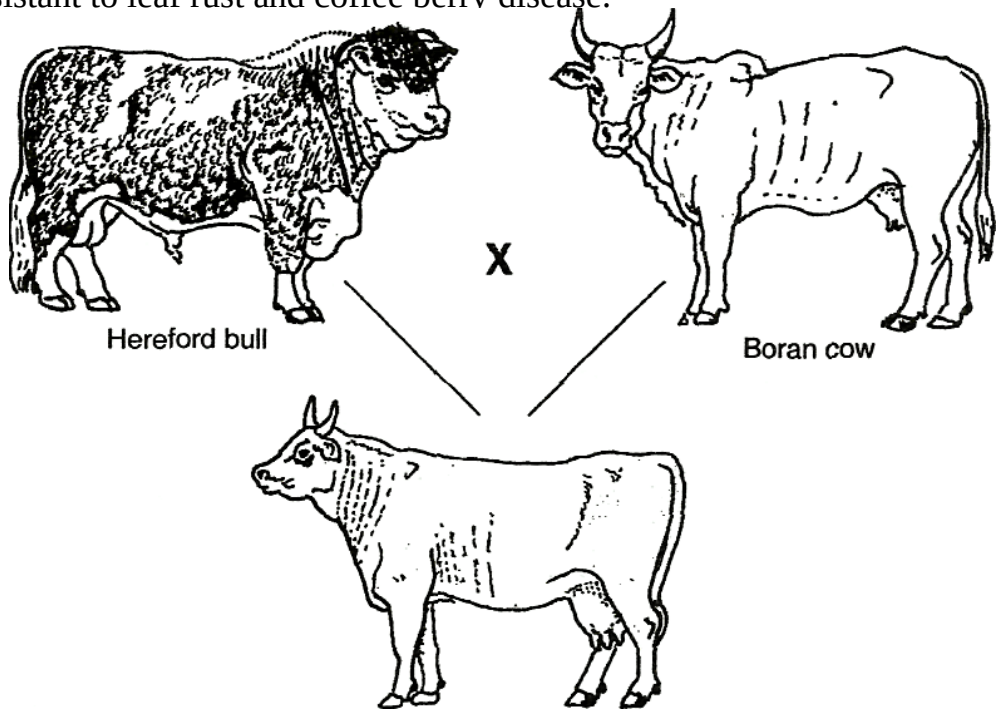


Fig. 3.32: A cross between a Hereford bull and boron

3. Increased length of productive season. Examples of these include chicken varieties with long egg laying durations and *sukumawiki* (kales) which can be harvested over a long period.
4. Adaptations to local conditions such as amount of rainfall, soil type and temperature. For example the maize varieties for various ecological zones.
5. Flowers such as roses, orchids, etc. are selectively bred for their colour, shape and aroma.
6. Higher yields in terms of meat, milk, egg and fruit production.
7. Ease of harvesting as in case of coconut palm, coffee, mango and banana where dwarf varieties have been produced.

In many cases it has been found profitable to improve the stock by crossing locally bred animals and plants with strains adapted to similar environments in different parts of the world.

Blood Transfusion

Knowledge of blood groups finds great application during blood transfusion. To ensure compatibility of donor and recipient blood groups, blood typing is done before the transfusion.

During blood typing a **qualified person** tests for both ABO and Rh antigens. For blood transfusion we consider the effect that the recipient's antibodies will have on the donor's antigens. Antibodies from the donor will be so diluted that they will not have much effect on the red blood cells of the recipient. For example, Ali who is blood group O+ can donate to Omar of blood group A+ but Ali cannot donate to Hussein who is blood group A-. This shows that the Rh factor must also be considered before transfusion. Knowledge of human blood typing and matching has also been used in solving disputed parentage. For example if an unmarried girl gives birth to a child and accuses a well known politician of being the biological father. The girl has blood group A, genotype AO and the baby is blood group O. The accused man however has blood group AB, this clearly shows that he cannot be the biological father. The biological father must be of genotype AO, BO or OO.

However, paternity cases are not normally that simple, other factors must be used. The most recent technique in establishing parentage is the **DNA matching.**

Genetic Counselling

This is the provision of information and advice on genetically inherited disorders, their risks and outcpmes. This is offered by specialists with knowledge of medical genetics and proper counselling techniques i.e. a medical doctor. The individual (counsellee) is given information and advice to enable him/her arrive at an informed decision.

Examples of disorders for which genetic counselling may be required include sickle-cell anaemia, albinism, haemophilia, *erythroblastosis foetalis,* Klinefelter's syndrome and colour-blindness.

The first step in genetic counselling is making a diagnosis to establish the nature of the disorder. This may include:

- Physical examination e.g. lack of breasts in Turner's syndrome.
- Laboratory tests e.g. Blood test for sickle-cell anaemia.
- Amniocentesis for chromosomal abnormalities in foetus.
- Family history may be used to determine possible inheritance of the disorder e.g. haemophilia condition.
- Genetic screening of the defective gene in the population.

Case Study

A 22-year-old girl comes to a doctor worrying that she has not yet had her first menstruation. Could this be a case of delayed puberty, hormonal imbalance or Turner's syndrome? Initial physical examination reveals that her breasts were underdeveloped. Laboratory chromosomal analysis showed normal chromosome, constitution thereby ruling out Turner's syndrome.

The information obtained from the diagnosis is used by the counsellor to:

- Explain the cause of the condition.
- Analyse the risks involved.

For example, a couple is worried that then-child will turn out to be a haemophiliac. The woman is a carrier for the trait while the man is normal. What is the chance of conceiving a haemophiliac child?

In the final step of counselling the counsellor:

- Gives advice on the quality and likely length of life.
- Explains the options available e.g.: contraception, adoption, artificial insemination.
- Genetic counselling encounters limitations e.g.
- If gene screening shows low prevalence for a certain disorder the affected few may develop stigmatisation.
- Children suing their parents for disorders inherited.
- Some of the options available to the individual have serious ethical and socio-cultural implications.

Genetic Engineering

This deals with identification of a desirable gene, altering, isolating and transferring it from one living organism to another. Through genetic engineering it is now possible to make use of rapidly reproducing living organisms such as bacteria and fungi in the production of useful life saving substances. These substances include hormones like insulin, and somatotrophin, antibiotics, interferons, vaccines and vitamins.

Genetic engineering has also made it possible to produce genetically modified organisms (transgenics), which have resulted in increased production in crops and domestic animals.
Genetic engineering has been applied in the following fields:

Farming

The genetic material of the organism is altered to achieve desired characteristics in a shorter time than it would be possible through the normal crossing.

a. Genetically modified maize and soya beans have been produced which have resistance against insect pests. This has been achieved by inserting the genes that confer the resistance from a bacterium *Baccillus thuringensis* into these crops. The gene enables the crops to produce toxins which kill the insects that feed on the plant.
b. Normally, tomatoes are harvested green, treated with ethylene gas for ripening. This has the disadvantage that the tomatoes lose their flavour.

In the genetically modified tomatoes there is deletion of the gene responsible of enzyme production that leads to fruit softening, hence the tomatoes stay on the plant to ripen and realising fuller development of the flavour without softening.

c. Attempts are being made to transfer the gene for nitrogen fixation from bacteria into cereal crops to increase yields without use of fertilisers.
d. Bovine somatotrophin is a hormone that increase milk production in cows. The gene that controls production of this hormone, when transferred into bacteria it makes the bacteria to produce the hormone in large quantities in a fermentation process. When this hormone is extracted from the bacteria and injected into a cow it leads to increased number of cells in the mammary glands. The hormone has also been found to increase weight of beef cattle by 10-15%.

Agricultural biotechnology can assist farmers improve their yields and overall quality of their produce. Through genetic modification (GM) or engineering, desirable genes can be transferred to crops while plants can be made to be more resistant to diseases, insect pests and other stresses. Genetic modification can also facilitate the development of crops with improved storage properties and quality characteristics. An example of this is the insect. Resistant Maize for Africa (IRMA) project launched in march 2000 which aims to develop stem borer resistant and locally adapted maize for Somalia's various agro-ecology zones, by using both conventional and biotechnology-mediated methods, especially biotechnology. Transgenic maize containing *Bacillus thuringiensis* (Bt) is a focal point of the project.

Essentially, what IRMA aims to do is to increase maize production and overall food security through the development of insect resistant maize varieties.

Medicine

(a) **Various hormones are being produced by genetically modified organisms**

(i) A strain of *Escherichia coli* has been made which synthesise human insulin. The human gene that codes for insulin is transferred into the bacteria thereby producing insulin that is purer and in larger quantities. Previously insulin was extracted from cows' and pigs' pancrease and was not pure. Such impurities have been the cause of many allergies and other disorders. (U) Human somatotrophic hormone for treatment of dwarfism is now extracted from genetically modified strain of *Escherichia coli.*

(b) **Medicinal Proteins in Milk**

Sheep have been genetically modified to" produce milk which contains medicinal proteins used to relieve haemophilia and emphysema patients.

(i) For haemophilia, the gene for blood clotting factor is transferred into sheep embryos to interact with milk production genes. When born, the sheep's female offspring has the ability to produce milk containing the blood-clotting factor. This factor is isolated and used for relieving haemophiliacs, (ii) Hereditary emphysema is due to presence of uninhibited activity of enzyme elastase in the lungs. This enzyme dissolves the elastic tissue in the lungs leading to the collapse of alveoli.

In normal persons the activity of enzyme elastase is inhibited by a protein called alpha-anti-trypsin (AAT) normally circulating in the blood. Emphysema patients lack AAT. The AAT is now also being produced in sheep milk in a manner similar to that of the blood-clotting factor (IX).

(c) Production of Vaccines

(i) In the production of a vaccine for hepatitis B virus, the gene for the protein coat of the hepatitis B virus is isolated and transferred into a fungus (yeast) the yeast is cultured to produce the protein. The protein is isolated and purified. When this protein is injected into the human body it acts as an antigen and stimulates the production of antibodies against the hepatitis virus. This way immunity against infection is conferred.

(ii) Some genetically modified plants e.g. banana are being targeted for the production of orally administered vaccines against rabies and cholera.

(d) Gene Therapy

Gene therapy is the replacement of faulty genes with normal ones aimed at correcting genetic disorders.
In somatical gene therapy, genetically modified organisms e.g. viruses are used to carry the normal gene and introduce it into the affected tissue cells. The defective gene in the tissue cell is thereby corrected by the genes in the carrier. This is being used in the treatment of lung cystic fibrosis and the Duchem muscular dystrophy. Current research called *germ-line gene therapy* is targeting correction of defective genes in cells of embryos.

Environment

Genetically modified *Pseudonomonas* bacteria are capable of decomposing hydrocarbons in petroleum and are therefore used in controlling pollution due to oil spillage in water bodies and soil.

Crime Detection

The DNA is unique to each individual. Through a series of genetic techniques the pattern of DNA base sequence is prepared and produced on film. The pattern for each individual is very specific and therefore a "DNA fingerprint".
At the scene of crime, a specimen from the suspect e.g. hair, blood, semen in the case of rape is obtained and DNA extracted from the developed hairs or blood cells.
By comparing this DNA pattern, it is possible to isolate the culprit from several suspects. See figure 3.33.



Fig. 3.33: Photomicrograph of DNA fingerprints from three suspects in a crime

By comparing the three samples from the suspect, which sample is closest to the culprit's specimen?
DNA fingerprinting can also be conclusively used in solving disputed parentage. A child inherits one set of DNA from the mother and the other from the father. DNA is extracted

from the child, mother and suspected father and matching done. If portions of DNA in father match the one in the child then it confirms paternity.

Cloning

This is a type of reproduction where a group of cells arise from a single individual cell without fertilisation. It is therefore a form of asexual reproduction. The offspring are called clones and are genetically identical. In the recent past, cloning has been carried out in sheep producing the celebrated sheep called "Dolly". In this process a nucleus from a fertilised ovum was removed and replaced. with a diploid nucleus of a cell from the mammary glands of another sheep. The ovum was implanted into the sheep's uterus. See figure 1.35.

The lamb, Dolly, was a clone from the sheep which donated mammary gland cell. However, Dolly died before her tenth birthday.

As early as 1993 human cloning was attempted. Recently pigs and cows have also been cloned with varying degrees of success. Cloning of plants is more common and successful. It has resulted in tissue culture techniques through which new varieties of crops such as pyrethrum and bananas have been produced.

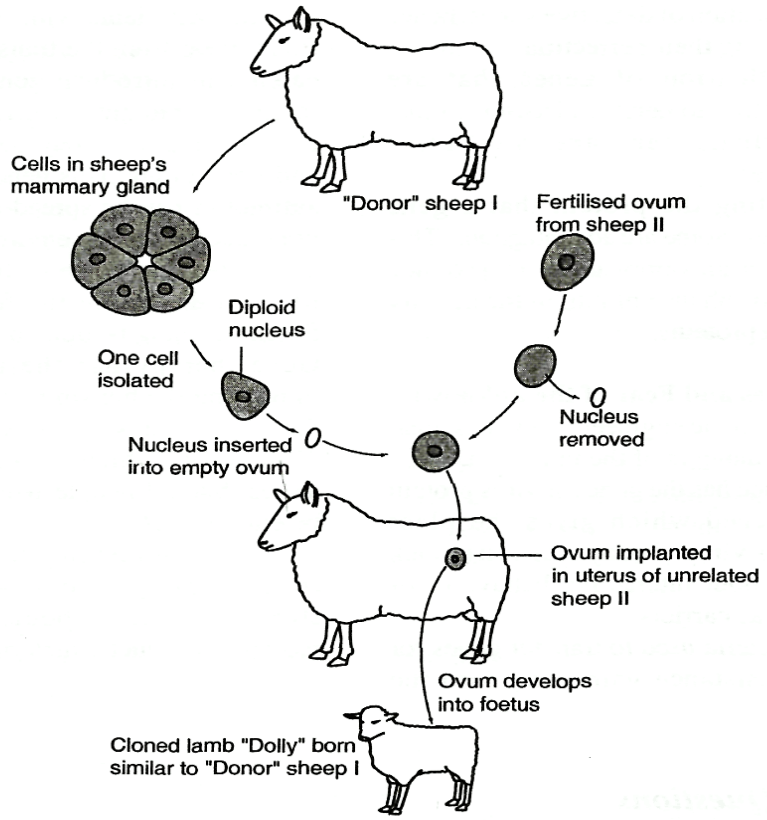


***Fig.** 3.34: **Cloning** of sheep*

Human Genome

Genome is the total genetic content of any cell in an organism. It comprises of all genes on all the chromosomes. In humans, there are up to 100,000 genes. The human genome projects aim at:

Gene Mapping

This is identifying specific positions occupied by specific genes on a chromosome e.g. cystic fibrosis is located on chromosome 7, sickle-cell gene on chromosome 11 and haemophilia on the X chromosome.

Sequencing of Gene

The process involves analysing DNA to reveal the order of bases in all chromosomes. The human genome project is important in:

(i) Identification of defective genes, hence facilitating their correction.
(ii) Identification of genes that are susceptible to certain diseases so that individuals can take preventive measures.
(iii) Predicting the protein that a gene produces. Some are advantageous. This provides an opportunity to produce drugs to enhance or inhibit the activity of such proteins.

Issues and Fear of the unknown

The field of genetic engineering evokes great dread on the dangers of the unknown. Transgenic rice has the gene for virus protein coat introduced which gives the plant resistance to virus. Today, scientists lack knowledge about interactive behaviour of viruses used as carriers.

The bacteria used to transfer genes for antibiotic resistance gain entry into the transformed plants with the desired genes. Food made from the transgenic plant when eaten will introduce genes for antibiotic resistance into gut bacteria e.g. *Escherichia coli.* Such *E, coli* may become resistant to antibiotic drugs. This gene for resistance to antibiotics can be spread through faeces to other bacteria in the environment.

The early death of the sheep "Dolly" has cast doubts on the future of cloning. Should cloning be done on human beings? Gene therapy has the ultimate aim of improving the human race by replacing the defective genes. This is the field called **"Eugenics"** which evokes strong ethical issues. Should people with defective genes be eliminated?
In conclusion, despite the many advantages of genetic knowledge, it calls for strong regulatory bodies to control all research on genetic material.

Revision Questions

1. Explain what you understand by the following terms:
   (a) Genotype (b) Phenotype (c) Test cross
   (d) Linkage (e) Cross-over (f) Polyploidy

2. Why is *Drosophila* considered a suitable organism for use in genetic experiments?

3. What are the causes of genetic variations in living organisms?

4. In human beings, the ability to roll the tongue depends upon the presence of a dominant gene. Construct diagrams to show the genotype and phenotype of the parental generation, the F_t generation and the gametes of the cross between homozygous tongue roller and a homozygous non-roller.

5. On the basis of Mendel's hypothesis and observations, predict the results from the following crosses in garden peas:
   (a) A tall homozygous dominant variety crossed with a dwarf variety.
   (b) Selfing the offspring (progeny) from the cross (a) above.
   (c) The progeny from the cross in (a) crossed with the original dwarf parent variety.

6. (a) State Mendel's first law of inheritance, (c) How would you explain this law?

7. A tall garden pea plant crossed with a dwarf one produces offspring of which about half are tall and the other half are dwarf. What are the genotypes of the parents?

8. In an experiment, a variety of garden peas having a smooth seed coat was crossed with a variety having a wrinkled seed coat. All the seeds obtained in the F, generation had a smooth seed coat. The F, generation was selfed. The total number of F_t generation was 7324.
(a) Using appropriate letter symbols work out the genotypes of the F, generation.
(b) From the information above, work out the following for the F_3 generation:
   (i) Genotypic ratio.
   (ii) The total number of wrinkled seeds.
   (iii) Phenotypic ratio.

9. In the 'four o'clock' plant, red flower colour (gene represented by R) shares equal dominance (co-dominant) with white flower (gene represented by W), the heterozygous plants being pink flowered. If a red flowered plant is crossed with a white flowered one, what will be the flower colour of:
   (a) The F, generation?
   (b) The F_2 generation after selfing Fj?
   (c) The offspring of a cross between the F, and their red flowered parents?
   (d) The offspring of a cross between the F, and their white flowered parents?

10. Construct a diagram to show the possible phenotypes arising in the children of a marriage between a woman with blood group A and a man with blood group B, where both parents are heterozygous.

11. (a) What are gene mutations?
    (b) What are chromosomal mutations (aberrations)?
    (c) What are the causes of mutations?

12. (a) How is sex determined in human beings?
    (b) What is the importance of crossing over?

13. (a) What is meant by the term sex-linkage?
(b) Each human somatic (body) cell has 46 chromosomes in its nucleus. How many of these are sex chromosomes?

14. Sickle-cell anaemia is a hereditary disease due to a recessive gene which changes normai haemoglobin (Hb-A) to abnormal haemoglobin (Hb-S). The red blood cells of people with sickle-cell anaemia are sickle-shaped.
(a) What are the possible phenotypes of the offspring of a man who is heterozygous and a woman who is also heterozygous?
(b) What proportion of the offspring would have:
(i) Sickle-cell anaemia?
(ii) Sickle-cell trait?

15. Acouple with normal colour vision had a colour-blind sonAli, and two normal daughters Edith and Grace. Ali had a daughter with normal colour vision. Edith had two sons, one colour-blind and the other had normal vision. What are the probable genotypes of the parents, their children and their grandchildren? Explain how you arrived at your conclusions. Use a pedigree diagram to present these genotypes.

16. A man with normal skin colour got married to a woman with normal skin colour. They gave birth to three children, one of them an albino.
(a) Identify the probable genotype of the parents and the children.
(b) If one of the boys with normal skin colour married a girl who happens to be a carrier for the albino gene, what is the probability that their first child will have normal skin colour?

17. (a) What are the characteristics of an individual who has Down's syndrome?
(b) Pan of one strand of DNA molecule was found to have the following sequences; G-C-C-T-A-G-A-T-C-A-C. What is the sequence: (i) of the complimentary DNA strand? (ii) on a m-RNA strand copied from this DNA portion?

18. List down phenotypic characters that have been selected for the production of strains suitable for modem agricultural purposes.

19. A recessive mutant of the gene which is responsible for chlorophyll synthesis in the tomato plant causes the plant to be colourless when present in homozygous condition. Such a plant dies as a seedling after it has used up its reserve supplies of food. In the heterozygous state, the mutant produces a pale plant which survives.
(a) Why does the homozygous plant die?
(b) Let the gene for normal chlorophyll be R, while the mutant recessive gene be r. Two pale green heterozygous plants were crossed. What types of offspring are produced?

20- Assume that you had two bacteria each carrying a different drug resistant gene. What procedure would you follow to obtain bacteria that possess both drug resistance genes?

21. (a) What is meant by the terms:
(i) inbreeding?
(ii) cross breeding?
(b) State the advantages of crossbreeding over inbreeding.

22. (a) What is meant by the term genetically modified organisms?
(b) How has genetic engineering helped in the field of:
(i) Medicine? (ii) Farming?

CHAPTER FOUR
ECOLOGY

4.1Introduction

Ecology is the study of the interrelationships of organisms to each other and to their environment. The environment constitutes the surroundings of an organism both living (biotic) and non-living (abiotic or physical). Therefore the environment constitutes all the factors that act on an organism. If the study involves a single species it is referred to as **Autecology** while the study of many species is called **Synecology.**

Autecology is the study of an individual species within a community. It involves studying the relationship of the species with both biotic and abiotic components of the ecosystem, its life cycle and adaptation for survival.

Synecology is the study **of different** species of organisms interacting among themselves within an ecosystem.

The knowledge gained from ecology is applied in many spheres of life such as:

- Sustainable food production.
- Conservation of natural resources, pollution control
- Control of diseases and pests.
- Prediction of adverse weather patterns.
- Population control.
- Ecotourism.

4.2 Concepts of Ecology

Before getting very far, it is important for every student of ecology to familiarise themselves with the terms used in ecology. Some of these are described below.

Biosphere is the part of earth and atmosphere inhabited by living organisms. It is also called **ecosphere.**

The habitat is a specific locality with a particular set of conditions where an organism lives. Habitats are categorised into terrestrial (land) habitats and aquatic (water) habitats.

An **ecological niche** is the position that an organism occupies in a habitat. It includes the physical **space** where an organism is found and its **role** in that habitat in terms of feeding relationships and other interactions with other species.

The term **population** refers to all members of a given species in a particular habitat, at a particular time.

A community refers to all organisms belonging to different species that interact in the same habitat. A community therefore, is made up of populations. A community is not static but undergoes changes progressively starting from a simple form to a more complex form.

An ecosystem is a natural unit composed of abiotic and biotic factors whose interactions lead to a **self-sustaining** system e.g. a small pond or a large ecosystem such as a tropical forest.

Biomass is the total dry weight of living organisms at a particular trophic level (feeding level) or per unit area e.g. total weight of a maize crop per hectare or weight of zebras in a park. On the other hand, **carrying capacity** refers to the maximum number of organisms an area can comfortably support without depletion of the available resources e.g. the maximum number of cattle a paddock can hold without overgrazing.

Study this question

Differentiate between environment and Habitat.

4.3 Factors in an Ecosystem

Factors in an ecosystem are divided into two groups namely **abiotic and biotic** factors. Abiotic factors are the non-living environmental factors which affect the distribution of organisms like light, temperature, atmospheric pressure, salinity, humidity, soil texture, pH and wind.

Light

The sun is the main source of energy for all life on earth. Green plants and photosynthetic bacteria need light energy to manufacture food. Animals depend on plants for food. Light affects living organisms in terms of intensity, quality (wavelength/colour) and duration. Light intensity and quality affects rate of photosynthesis, flowering and germination of plants while in animals it affects migration, hibernation and reproduction.
A photographic light meter is used to measure light intensity while the **Seechi disc** measures light penetration in water.

Temperature

Biochemical processes of most organisms function efficiently within a narrow range of temperature. Temperatures vary due to seasons, altitude, latitude and also diurnally especially in hot deserts.
This therefore affects the distribution of organisms in a habitat. Temperature variations influence the distribution of organisms more in terrestrial habitats than in aquatic ones. High heat capacity of water helps to keep the temperature of aquatic habitats relatively constant.
Living organisms must develop necessary physiological and behavioural adaptations to cope with extremes of temperature. Very low temperatures may inactivate enzymes or kill their protoplasm while very high temperatures denature enzymes.
Air temperature is measured by a thermometer while air temperature range is measured by the maximum and minimum thermometer. See figure 4.1.

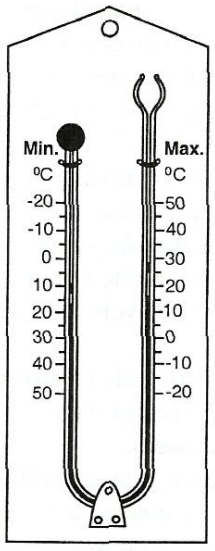


Fig. 4.1: The maximum and minimum thermometer

Atmospheric Pressure

The atmosphere has a definite weight and so it exerts pressure upon the earth. On the surface of the earth, atmospheric pressure varies with altitude. Variation in atmospheric pressure affects the amount of oxygen available for respiration and of carbon (IV) oxide for photosynthesis. These two gases affect the distribution of organisms.

Decreased atmospheric pressure increases the rate of transpiration and therefore the need to conserve water by plants. Atmospheric pressure is measured using a barometer.

Humidity

Humidity refers to the amount of water vapour in the atmosphere. When humidity is high there is much water vapour in the atmosphere, but when it is low there is less water vapour in the atmosphere. Humidity affects the rate at which water evaporates from the surface of organisms such as in transpiration or sweating. This in turn affects their distribution on earth.

The instrument used to measure humidity is the wet and dry bulb hygrometer shown in figure 4.2 or a **paper hygrometer.** A simple method is by using blue anhydrous cobalt chloride (II) paper, which turns pink when hydrated. The rate at which the paper turns pink is an indication of amount of water vapour in the atmosphere. The paper turns pink faster in a humid atmosphere than in a relatively dry atmosphere.

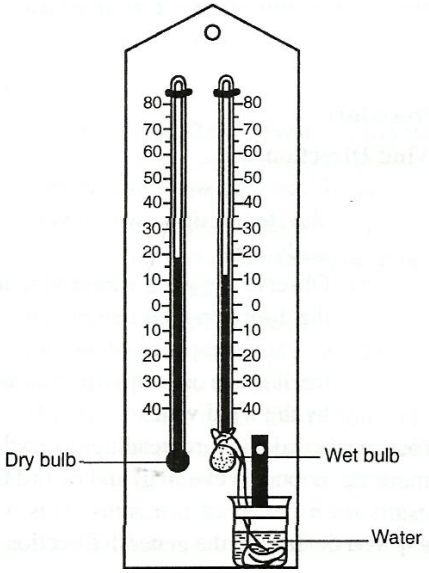


Fig. 4.2: The wet and dry bulb hygrometer

Wind

Wind is moving air. It increases the rate of water loss from organisms, therefore affecting their distribution.

Wind is also important in rain formation. In desert areas wind aids in formation of sand dunes. Stable sand dunes may become habitats for growth of desert plants.

Wind causes wave formation in lakes and oceans, which enhances aeration of water in these water bodies. Trees in areas experiencing strong winds may have stunted and distorted growth. Wind also disperses spores and seeds and influences dispersal and migration of flying animals. Wind wafts scent hence determines the positioning of hunting animals with respect to their prey in a habitat.

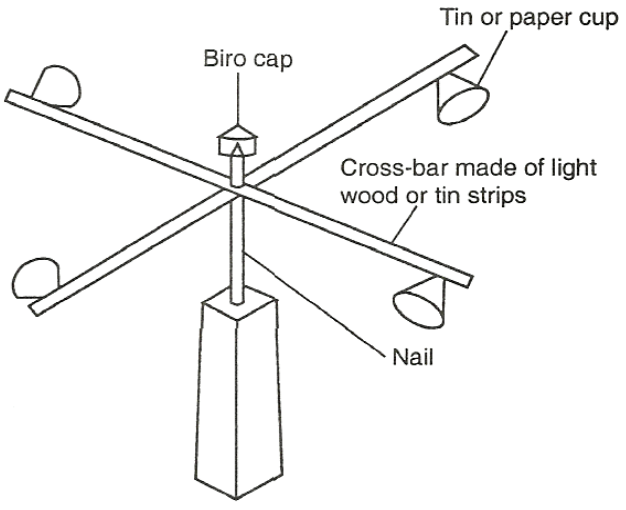


Fig. 4.3: An anemometer

A wind vane or a windsock is used to determine direction of prevailing wind. The speed of wind is measured by **anemometer.** See figure 4.3.

Salinity

This term refers to the salt concentration of water, causing a division of the aquatic environment into marine, estuarine and fresh water.

Saline conditions immediately outside the body of an organism poses the problem of water loss from the body to the environment. Only organisms with suitable osmoregulatory adaptations can occupy such habitats. More crucial, however, is the effect of salinity on organisms of estuarine habitats.

In estuaries, there are fluctuations of salt concentration at varying times. When sea-tide is low, the fresh water discharged by the river has a greater diluting effect on the estuarine water while high tide raises the salt level. The estuarine organisms must have adaptations to cope with these wide ranges of salinity. This affects the distribution of organisms markedly.

Salinity can be determined by calculating percentage of salts in water or by the acid-base titration method.

pH (hydrogen ion concentration) pH is the measure of how acidic or alkaline water is in aquatic habitat or soil solution. It influences the distribution of plants and animals in soil and fresh water ponds. Some plants thrive well in acidic conditions while others thrive in neutral or alkaline conditions. The pH of a soil can be altered by leaching fertilisers applied or soil exhaustion. pH is expressed in terms of pH scale by use of BDH universal indicator solution or paper and pH meter.

Study this question

* Of what value are the following practices to a farmer:
    (i) Liming of soil?
    (ii) Organic fanning?
    (iii) Mulching?
    (iv) Keeping transplanted seedlings in shade?

Biotic Inter-Relationships

Competition

If two different species require a common resource whose availability is limited, they are said to be in competition for it. These resources include nutrients, space, light or mates. Under such conditions, they may exist together in competition, or one may displace the other.

Competition between individuals of the same species is known as **intraspecific** while that between individuals of different species is known as **interspecific competition.** In such competition for a limited resource, organisms with suitable structural and behavioural adaptations survive while others without such adaptations may die out or migrate. Competition is severe if the ecological niches of competing organisms are close. In one of the studies on the interaction between populations, experiments have been carried out on two closely related species of Paramecia - *Paramecium caudatum* and *Paramecium aurelia.* It was observed that when each species is grown separately in controlled cultures with constant food supply, they show normal population growth. However, when they are grown together in

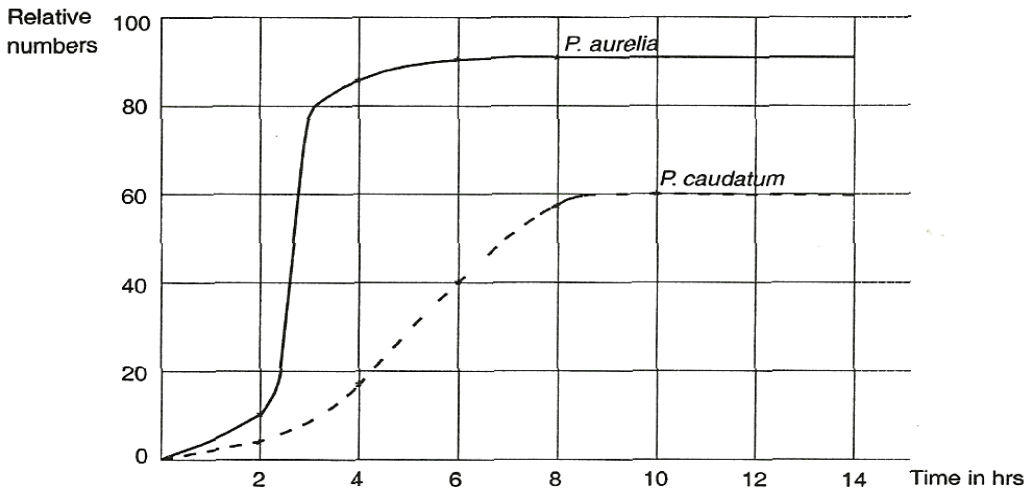


Fig. 4.4 (a): The population growth of the species Paramecium caudatum and Paramecium Aurelia

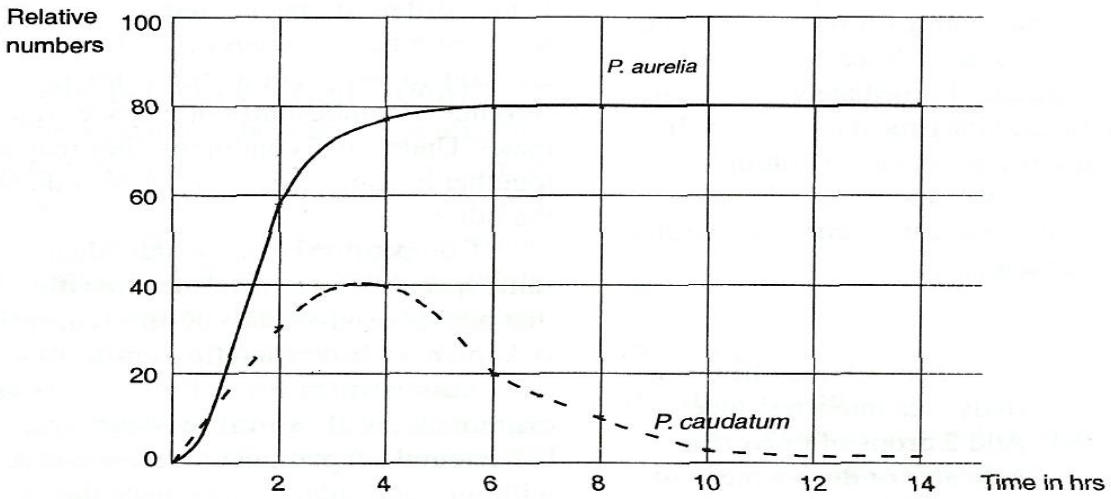


Fig. 4.4 (b): The population of Paramecium caudatum and Paramecium aurelia when they compete in the same culture the same culture, competition occurs and one species is eliminated. The graphs in figures 4.4 (a) and (b) represent this relationship.

Closely related species can live together without competition. For example, when *Paramecium caudatum* and *Paramecium bursoria* are grown in the same culture, each occupies a different part of the culture where it can feed on bacteria without competing with the other species.

Similar examples, include browsers and grazers in the same habitat. Among grazers living in the same habitat competition is avoided by feeding at different levels of the same plants. For example, the zebra eats the softer shoots, followed by wildebeest and later on, the gazelle which eat the more fibrous remnants of the same grass. Thus, although the food of these species of animals is identical, none eliminates the other because they occupy different niches.

Predation

This is the food relationship in which one organism kills another for food and feeds on it either wholly or in part. The organisms which kills another for food is referred to as the **predator** while the one killed is the **prey.**

Predators have various adaptive characteristics which make them efficient in capturing the prey. The praying mantis has enlarged forelimbs with spikes for capturing its prey. It feeds on small insects such as grasshoppers.

Birds such as hawks, kites and eagles have sharp eyesight, fast flight, modified beaks and talons; while the lion which preys on antelopes has strong jaws with carnassial teeth, large claws on strong forelimbs and is fast in movement. In addition, predators have behavioural adaptations e.g. a lion moves against the wind while stalking the prey. Colour camouflage is a common adaptive feature. This involves the body colour of the organism blending well with the background environment to conceal the organism to a great extent. For example, the spotted pattern of the leopard blends well with the background colour of the bushes and trees concealing the leopard from its prey that may not be keen.

On the other hand, the prey also have structural and behavioural adaptations that minimise predation e.g. a stick insect mimics a dry stick and the confrontational display in porcupine. The antelopes and gazelles have swift movement to escape predators. Camouflage is observed in the stripes of zebra and the spotted pattern of the giraffe.
Herbivores such as zebra have large eyes on the sides of the head which gives them a wide field of vision. This enables them to keep track of their enemies from far and therefore take precautions.

The distribution of prey and predators are related e.g a herbivore will be found where its food is readily available. The relationship between prey and predator may be illustrated using the numbers of gazelles and lions in a section of a park.

An increase in number of gazelles leads to an increase in number of lions. As the lion numbers increase they feed on the gazelles, whose members will decrease to such a low number that the lions themselves will start to starve and die or migrate. With a decline in number of lions, the gazelles have a chance of increasing their numbers. This helps to maintain the population of the gazelles and lions at the carrying capacity of the habitat. This is the basis of biological control.

Parasitism

Parasitism is the relationship in which an organism obtains nutrients from another live organism without killing it. This organism which lives on or in another live organism is called a **parasite** while the one from which nutrients are obtained is called the **host.**

A parasite benefits in terms of food and shelter from the host while causing the host surface of a host are known as **ectoparasites** e.g ticks while those found inside the body of the host are known as **endoparasites** e.g. plasmodium.

Parasites weaken their hosts, cause or transmit diseases which may kill their hosts thus reducing their numbers and distribution.

Study this question

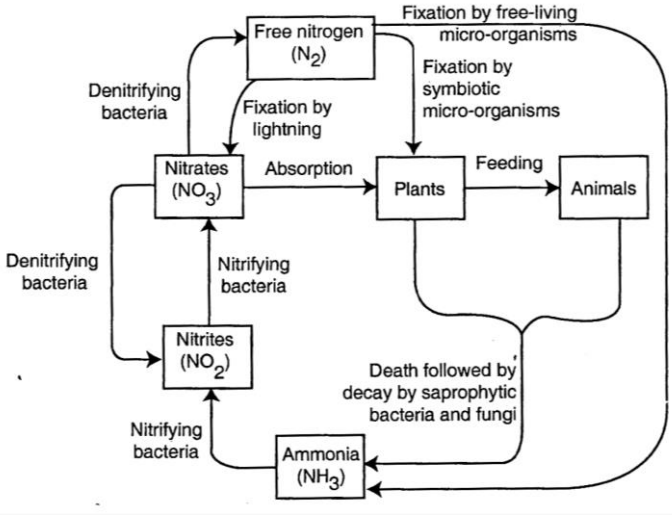
State the differences and similarities between predation and parasitism.
Symbiosis

This is an association between organisms of different species in which both organisms benefit e.g. *Rhizobium* bacteria which live in the root nodules of leguminous plants. The plants benefit from the nitrates fixed by *Rhizobium* bacteria while the bacteria benefit from shelter and carbohydrates provided by the plants. This relationship enables such plants to thrive on nitrogen deficient soils. See figure 4.6.

Saprophytism

This is a type of nutrition where organisms obtain nutrients from dead organic matter hence causing decomposition. Organisms which feed in this manner are known as saprophytes and include fungi and bacteria. Decomposition releases nutrients into the ecosystem which are then made available to other living organisms.

Nitrogen Cycle



Nitrogen cycle refers to the cycling of nitrogen and its compounds in nature. See figure 4.6. Nitrogen is essential in the manufacture of proteins by organisms. However, organisms cannot utilise the free nitrogen in the atmosphere. Instead, plants absorb nitrogen in form of nitrates and assimilate it into plant proteins. Animals then obtain the nitrogen in form of proteins either by eating plants or other animals.

It is therefore necessary that the free atmospheric nitrogen is converted into a form that can be utilised by plants through the process called **nitrogen fixation.** Biological nitrogen fixation is done by nitrogen-fixing micro-organisms. These include symbiotic bacteria like *Rhizobhim* of the root nodules of legumes. They convert nitrogen gas into ammonia which is then utilised by the plants to make proteins. Biological fixation is also done by free-living bacteria *e.gAzotobacter* and *Clostridium,* and some algae e.g *Anabaena, Chlorella* and *Nostoc.* These organisms fix nitrogen into ammonia which is then converted to nitrates.

Non-biological nitrogen fixation is achieved by lightning. During thunderstorms, the lightning energy combines atmospheric nitrogen with oxygen to form nitrous acid and nitric acid. These are then chemically converted into nitrates.

Plants absorb nitrates from the soil and convert them into plant proteins. Thus animals obtain the nitrogen in form of proteins directly or indirectly from plants. The proteins are digested into amino acids and assimilated into animal proteins.

When organisms die (or their waste and droppings), saprophytic bacteria and fungi break down the protein material in their bodies into ammonia. In the process of nitrification, ammonia is eventually converted into nitrates. This is done by several **nitrifying bacteria** e.g *Nitrosomonas* and *Nitrococcus* which oxidise ammonia into nitrites and *Nitrobacter* bacteria which convert the nitrites into nitrates. The process of nitrification enriches the soil with nitrates.

Some soil micro-organisms reduce nitrates to nitrates, ammonia and even nitrogen gas which are not useful to plants, the process called **denitrification.** Examples of such bacteria are *Pseudomonas denitrif(cations* and *Thiobacillus denitrifleans.* They utilise the oxygen released in the process for their respiration. The process of denitrification deprives the soil of fixed nitrogen gas. However, it is important in releasing free nitrogen into the air, hence the nitrogen is again available for cycling as seen in figure 4.6.

4.4 Energy Flow in an Ecosystem

The sun is the natural source of energy. It is this energy that is trapped by the green plants for photosynthesis. This process produces food which is potential energy in chemical form e.g. glucose. Therefore, green plants are known as **producers** in any ecosystem.
Green plants are eaten by animals e.g. herbivores. Herbivores are usually referred to as **primary consumers.** They in turn are eaten by carnivores, usually referred to as **secondary consumers** e.g. dogs. The secondary consumer is eaten by a **tertiary** consumer e.g. leopard. When the leopard dies it is eaten by a vulture which is referred to as a **quaternary consumer,** These feeding levels, that is, producers and the consumer levels are referred to as **trophic levels.** When living organisms die, they are decomposed by bacteria and fungi which are referred to as **decomposers.**

The energy moves from one trophic level to the next e.g. from producers to the primary consumers.This passage of energy from one trophic level to the next results in loss of some energy in form of heat. During respiration, excretion or defecation, some energy is also lost. When organic materials are fully decomposed, all the energy is lost from the ecosystem. Thus **energy flows** through an ecosystem and it is not recycled.

Decomposers

Dead bodies of organisms and waste materials from bodies of living organisms form a source of energy and nutrients for many other organisms known as decomposers. Most decomposers are bacteria and fungi. The decomposers break down organic materials into simple substances which are made available for re-use by other organisms. Thus the materials are recycled in the ecosystem. The rate at which decomposers work on substrate differs depending on climate and type of substrate. For example a dead animal takes a matter of weeks whereas a fallen tree and branches may take many years to decompose. See figure 4.7.

Food Chains

The flow of energy from a producer to other organisms is represented linearly as a **food chain.** A food chain is composed of producers, consumers and decomposers; for example: Green plants are eaten by a herbivore and the herbivore is eaten by a carnivore. When these organisms die they are broken down by decomposers. An illustration of a general food chain is shown below: Producer -> Primary -> Secondary consumer consumer Specific examples of food chains are given below:

1. Grass ⟶ Grasshopper ⟶ Bird
2. Napier grass → Goat ⟶ Human
3. Kikuyugrass ⟶ Mouse → Snake → Hawk
4. Algae → Mosquito ⟶ Tilapia → NiIe → Human

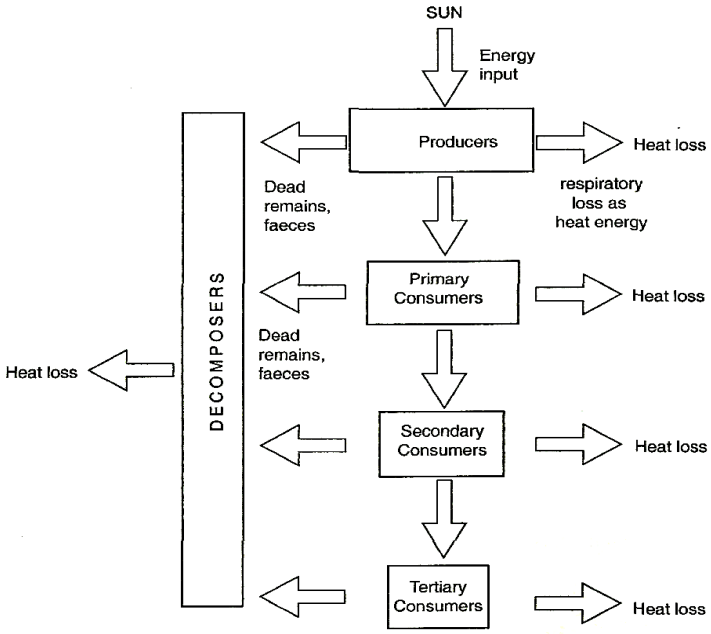


Figure: 4.7 Diagrammatic illustration to show energy flow through an ecosystem

When the decomposers are included in a food chain they are usually placed at the end as shown below.

Litter—> Earth worm—>Frog —>Snake ⟶ Bacteria and Fungi

Note: The arrow is a food chain and food web always shows the direction of energy flow.

Study Question 7

(a) In example 4 given above, identify the trophic level occupied by the:

(i) Nile perch (ii) algae.

(b) Suggest what is likely to happen should tilapia be removed from the food chain in example 4 of the food chain.

Food Webs

In a community where populations live and interact, simple food chains rarely exist. Most associations concerned with energy flow are made of several interconnecting food chains forming **food webs**

An example of a food web: The African savannah grass ***Cynibopogon afronardus*** is eaten by termites which are in turn eaten by chicken. The chicken are then consumed by human beings. This so far, constitutes a simple food chain. The relationship between this grass and other organisms, however, is not as simple. The.same grass is also eaten by grasshopper and sheep. At various stages other consumers are involved forming a food web as in figure 4.8.

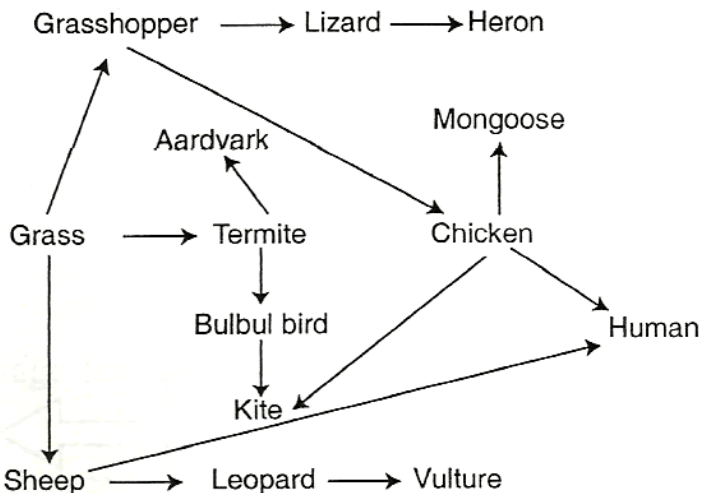


Figure: 4.8 Food web in a terrestrial habitat flow

Study these questions

(a) In figure 4.8, isolate any two food chains in which the human is a tertiary consumer.
(b) Identify the organism with the highest number of predators.
(c) Suggest the possible short term effects on this ecosystem if all the kites migrated away.

Ecological Pyramids

The efficiency of energy transfer from one trophic level to the next can be summarised diagrammatically in form of pyramids. These pyramids give a simplified pictorial representation of feeding relationships and energy flow in an ecosystem. They are useful in comparing different ecosystems, showing seasonal variations in an ecosystem or a change in the components of an ecosystem. There are three types of ecological pyramids namely pyramid of numbers, pyramid of biomass and pyramid of energy. In this book we shall deal with only pyramid of numbers and pyramid of biomass.

Pyramid of Numbers

In natural ecosystem there is a progressive decrease in the numbers of organisms constituting any trophic or feeding level in a food chain. The greatest in number are the producers followed in decreasing order by primary consumers, secondary consumers, tertiary consumers and least of all quaternary consumers.

When these numbers are drawn to scale the above food relationships produce a pyramid-shaped histogram or pictogramcalled pyramid of numbers shown in figure 4.9.

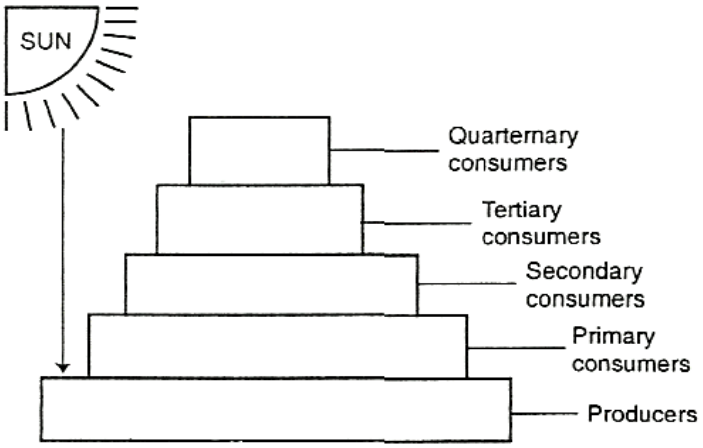


Fig. 4.9: Pyramid of numbers

Construction of Pyramid of Numbers

1. Use data collected or provided.
2. From the data identify and draw the most suitable food chain.
3. Indicate the numbers at each trophic level in the food chain.
4. Choose a suitable scale for the data.
5. Using the chosen scale draw a horizontal rectangular bar to represent the number of producers as the base of the pyramid.
6. Progressively draw horizontal bars of the other trophic levels in their ascending order.

Note: Ensure that the width of the bars is uniform.

Study this question:
The following table shows the estimated number of organisms recorded in a dam.

Organism	*Number*
Small fish	3,500
Microscopic algae Crocodiles	12,000 100
Large fish Mosquito larvae	950 8,900

(a) Construct a possible food chain for the dam.
(b) Construct a pyramid of numbers from the given data.
(c) Explain the shape of the pyramid . obtained.

Interpretation of Pyramid of Numbers
As a general principle, the body size of organisms increases at each trophic level from the base to the apex of the pyramid as their number decreases.
At each trophic level much of the energy obtained is lost in respiration and thus fewer organisms can be supported at the succeeding level.
However, there are cases in which the number of organisms will not decrease at each succeeding level. For example, many caterpillars feeding on one cabbage. Such gives an inverted pyramid of numbers. See figure 4.10.

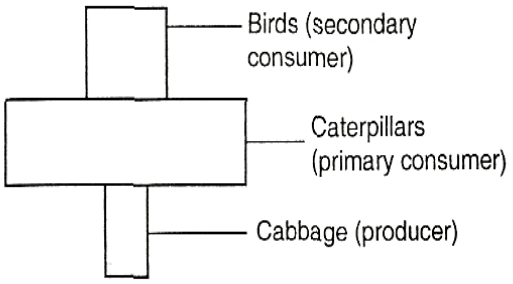


Fig. 4. 10: inverted pyramid of number

Pyramid of Biomass
The biomass of an organism is its constant dry weight. When biomass measurements are carried out in a given ecosystem of known dimensions and components, the statistical representation also produces a pyramid-shaped histogram as in figure 4.11. The producers have the highest biomass per unit area and in decreasing order are followed by primary consumers, secondary consumers, tertiary consumers and quaternary consumers.

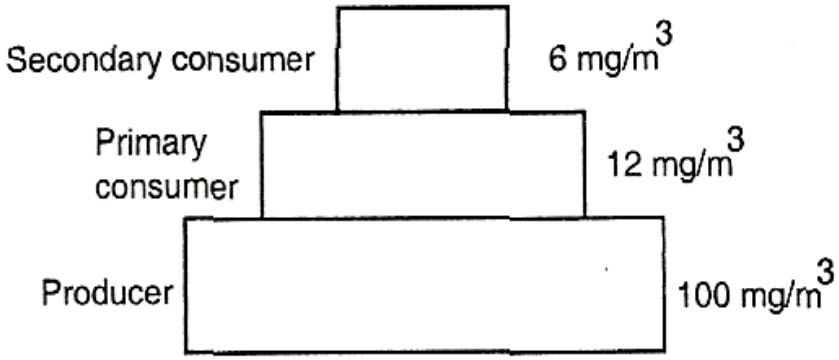


Fig. 4. 11: Pyramid of biomass

4.5 Population

A population is a group of organisms belonging to the same species in a particular habitat e.g. a population of buffaloes in Nakuru National Park. Populations are not static but change in size, structure and organisation. The following are some of the characteristics of populations:

(1) **Density:** Refers to the number of individuals per unit area. For example fifty antelopes per square kilometre.

(2) **Dispersion:** This is the spread or distribution of organisms in a habitat.

(3) **Population growth:** Refers to the rate of increase in numbers.

Population growth rate may be influenced by such factors as food availability, space, diseases and pests and predators.

Population Estimation Methods

In natural populations, the density of organisms in a habitat can be determined by actual body counts. If the area of the habitat is known, the average per unit area (or volume) can be calculated. It should be appreciated that in the real situation animals (bees, locusts, mammals, birds, reptiles, fish and amphibians) are not uniformly distributed in the habitats. They in fact occur in groups or clusters.

As for plants, counting may be easy for large trees like the baobab or for rare trees like Meru Oak. In field studies, if we wanted to know the kinds of plants and animals present in a particular habitat and how many of each species, it is usually impossible to count each and every one present. This problem is usually solved by taking representative **samples** from within the habitat.

A sample is a small number of individuals taken from a habitat that is representative of the whole population. Samples are used where the area to be studied is too big to enable all the organisms living there to be studied. Therefore, only certain areas or position can be investigated, e.g. the distribution of water fleas along the length of a river. In this case, at least 10 samples of water need to be taken where a plankton net has been placed at the fixed points equidistant along the river. The samples are examined microscopically and organisms caught counted. The average number of water fleas in a given amount of water is recorded for each station. Sampling can be carried out using the following methods:

- ***** Quadrat method.
- ***** Line transect.
- ***** Belt transect.
- ***** Capture - recapture method.

Quadrat Method

A quadrat is a square frame of known area made of wood or metal. The standard quadrat is one square metre, but small quadrats can be used if only a small area is being studied. The quadrat can further be sub-divided into smaller squares by lengths of string or wire as shown in figure 2.12. The choice of the quadrat size to be used depends on the area, nature of habitat and the objective of the study. The quadrat method is suitable for small plants like grass, herbs and small slow moving animals.

Line Transect method

A line transect method may be used to find out the distribution of species of plants in an area. A line transect is taken by running a rope across the plot and marking off equidistant points. Counts are made at each point (stations). Only those plants along the line are identified, counted and recorded. Usually a large number of transects are required to obtain more accurate results. A line transect is particularly useful when studying **transition** in habitats and population though an area.

Belt Transect Method

A belt transect is taken by running two ropes parallel to each other and about one metre apart along the length of a plot. Counts are made between the two ropes at marked points. Fewer belt transects are required to build up a realistic picture of the distribution and abundance of plant species in an ecosystem compared to the line transect. Quadrats may be used together with the belt transect.

A belt transect is most suitable in the estimation of plant populations. This can equally be used to estimate the populations of animals.

Capture-Recapture Method

It is possible to estimate the total number of individuals in a population by repeated sampling. After selecting the study area determine its size and choose the organism to be studied. Select an appropriate technique for the organism's capture. Catch the organism, count, mark and release them back into the habitat.

Catch and mark as many organisms under study, recording the first number marked and released (FM).

After twenty-four hours, re-examine the experimental area and collect as many organisms as possible including those that show the paint marks. Record the number of organisms collected, second capture (SC) and the number of those that were marked with paint, i.e. marked recaptured (MR). Then, if P represents the total population,

$$\frac{FM}{P} = \frac{MR}{SC}$$

Or

$$P = \frac{MM \times SC}{MR}$$

Key

FM = First number marked SC = Second capture MR = Marked recaptured P = Total population It is important that the marking technique does not harm the animal or alter its behaviour. Marking techniques include light coloured paint that is quick drying e.g. cellulose paint or coloured nail vanish. For water animals the paint should be waterproof. Other methods include use of tags. This method assumes that:

- No organism moves in or out of the area between the two counts.
- The released animals mix freely with the remaining population.
- The mark does not alter the animal's behaviour.
- The marked animals will have enough time to mix with the rest.
- The population number does not vary during the study period.

This method is suitable for highly mobile animals like insects, birds, small mammals and fish.

Study this question

To estimate the population size **of,** mosquitoes in Jowhar town, Somali Medical Researchers, caught 400 mosquitoes which they marked and released. After 24 hours 200J mosquitoes were caught out of which 80: had the-marks:

(a) Suggest the possible instrument that may have been used for capturing and| marking the insects.

(b) Estimate the population size of the mosquitoes in the village,

4.6 Adaptations of Plants to Various Habitats

An adaptation is a change in an organism that increases its chances of survival in a specific environment. These changes may be structural, behavioural or physiological.
Plants possess different adaptations based on their habitats, hence there are four main groups of plants namely:

- Xerophytes
- Mesophytes
- Hydrophytes Halophytes

Xerophytes

Xerophytes are plants adapted to withstand a dry habitat, or to endure conditions of prolonged drought as in arid and semi-arid areas.
These habitats are characterised by the following conditions:

a. Unpredictable and poorly distributed rainfall which is usually less than 250 mm but hardly exceeds 350 mm per year.
b. Very high day temperatures but very low night temperatures which result in high diurnal temperature ranges.
c. They are windy.
d. Low humidity.

Adaptation of Xerophytes to their Habitats

1. Leaves are **reduced in size** such as the scale like leaves of whistling pine *(Casuarina sp.)* or modified to spines as in the cactus. This reduces the surface area over which transpiration occurs.
2. Shedding of leaves during drought to reduce surface exposed to transpiration.

Leaves have **thick waxy cuticle to** minimise the rate of cuticular transpiration. Some leaves are **folded** to reduce rate of transpiration by not exposing stomata to environmental factors. Some have **sunken stomata** which accumulate moisture in substomatal air spaces leading to low diffusion gradient thus reducing transpiration rate. Most Xerophytes show **reduced number of stomata** that lowers the rate of transpiration.



Fig. 4.12: Note the succulent stem and spines on cactus

Some xerophytes experience **reversed stomatal rhythm** (opening the stomata at night and closing them by day) to prevent excessive loss of water by transpiration.
Some plants have **deep roots** to absorb water from deep in the soil e.g. Acacia tree. Other plants have **superficial roots** which grow horizontally close to the soil surface to absorb water after a short or light shower of rain. Some plants store water in large parenchyma cells contained in **succulent** stems and leaves e.g. cactus which has a swollen stem.

10. Some xerophytes have a very short life cycle to evade drought, hence some survive as seeds or as underground penetrating organs e.g. corns and bulbs.

Mesophytes

A plant living under normal conditions of water supply or in well-watered soils is described as a mesophyte. Mesophytes are predominantly found in such ecosystems as savannah, rain forests and reserve forests. The habitats of mesophytes have the following general characteristics:

a. Adequate rainfall ranging from 950 mm-1800 mm that is distributed throughout the year.
b. Humidity is relatively high.
c. Thick clouds are common.
d. Moderate to high temperatures, with low diurnal range.
e. Less windy.
f. Shallow water table.

Adaptations of Mesophytes to their Habitats

Depending on where they grow in these habitats, they show various adaptations. Some of these adaptations are for reduction of water loss while others are for increase of water loss. They are also adapted to light conditions.

In a forest ecosystem the vegetation grows very fast and forms dense vegetation in which there is competition for light amongst various plants. Trees grow tall due to competition for light. Climbers such as lianas support themselves on the stems of larger trees in an attempt to reach the light, while epiphytes support themselves on the branches of taller trees. Others that cannot compete for light are adapted to photosynthesise under low light intensities by having numerous chloroplasts. They form the undergrowth. Majority of mesophytes show leaf mosaic that minimise overlapping and overshadowing of leaves so that all leaves are exposed to light for photosynthesis.

Mesophytes in areas with ample water supply possess broad leaves with thin cuticle and many stomata on both leaf surfaces to encourage high rate of transpiration. However, those in relatively drier areas have more stomata on the lower surface than on the upper surface which is more exposed to wind and direct sunlight.

Some mesophytes are shallow rooted and thus develop buttress roots or prop roots for extra support e.g. *Ficus natalensis.* Others in relatively drier areas are deep-rooted in an attempt to absorb enough water.

Some mesophytes have waxy and glossy surfaces to reflect the strong light rays and drip off rain water. Examples of mesophytes are majority of the common terrestrial plants.

Hydrophytes

Plants which normally grow wholly or partly in fresh water are referred to as **hydrophytes.** Their habitats are characterised by the following conditions:

1. They have low concentration of dissolved gases such as oxygen and the water medium is of low density.
2. Waves and currents are usually common.
3. Light is less abundant under water.

Adaptations of Hydrophytes to their Habitats

1. Most emergent and floating types have broad leaves with maximum number of stomata on the upper surface. This provides a large surface area for gaseous exchange. The exposed stomata allow for quick loss of excess water through transpiration.
2. Some submerged hydrophytes have leaves which are deeply dissected into threadlike straws in order to provide large surface area for absorption of maximum light for photosynthesis. Their leaves have numerous and sensitive chloroplasts that photosynthesise under low light intensities.
3. Hydrophytes have large air-filled tissues (aerenchyma). The air in the aerenchyma reduces the density giving buoyancy to the plants and also assist in gaseous exchange. See figure 4.13(a) and (b).
4. They have poorly developed roots that lack root hairs to reduce absorption of water.
5. Flowers are raised above the water t o allow for pollination.

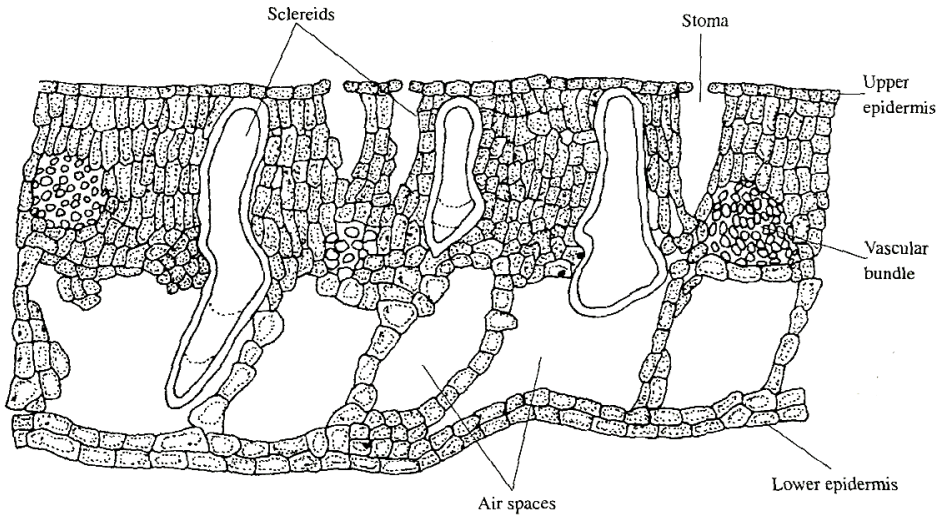


Fig. 4.13 (a): A transverse section of water lily leaf showing the large airspaces characteristic to hydrophytes

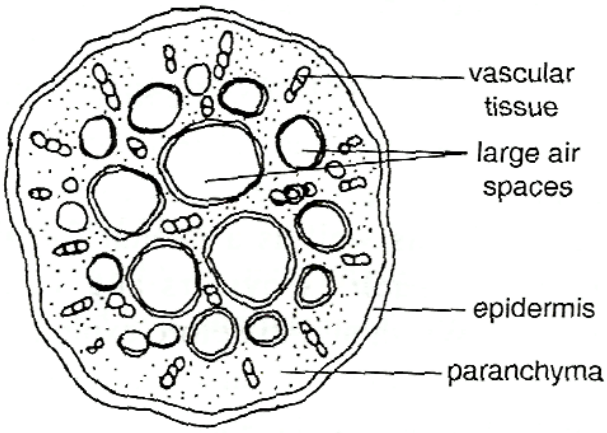
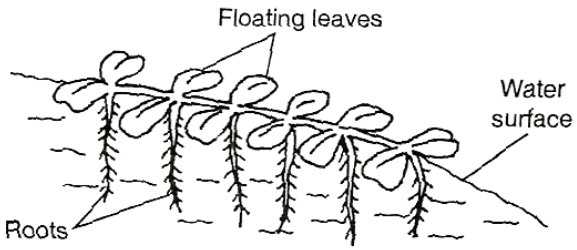


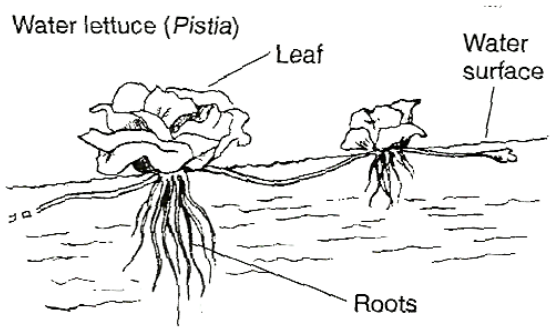
Fig. 4.13 (b): A transverse section through the stem of a hydrophyte to show ilit ***aerenchyma***

Examples include members in figure 4.14(a), (b) and (c).

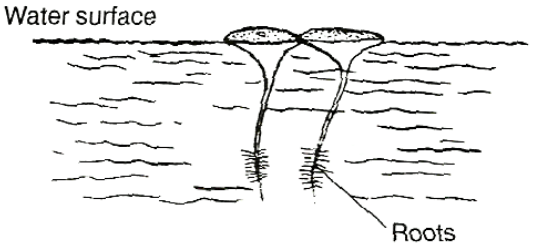
1. *Salvinia*



2. Water lettuce (*Pistia*)



3. Duckweed (*Lemna*)



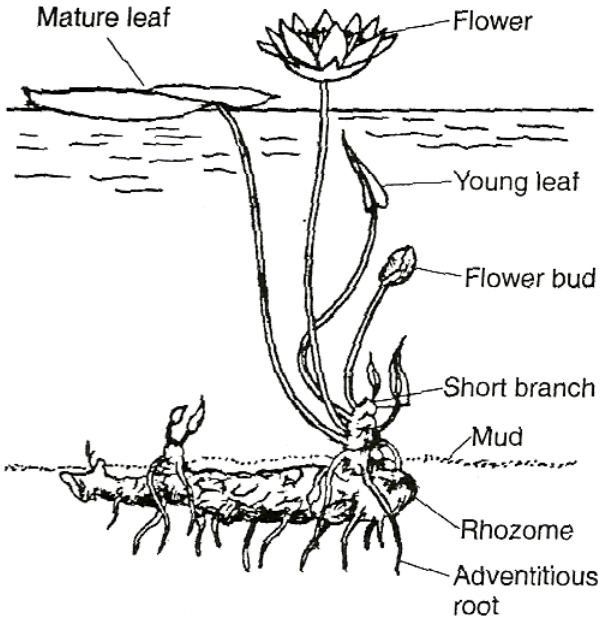


Fig. 4.14(b); Water lily ix an emergent and rooted type

Note the papyrus in the background and the sedges in the middle.

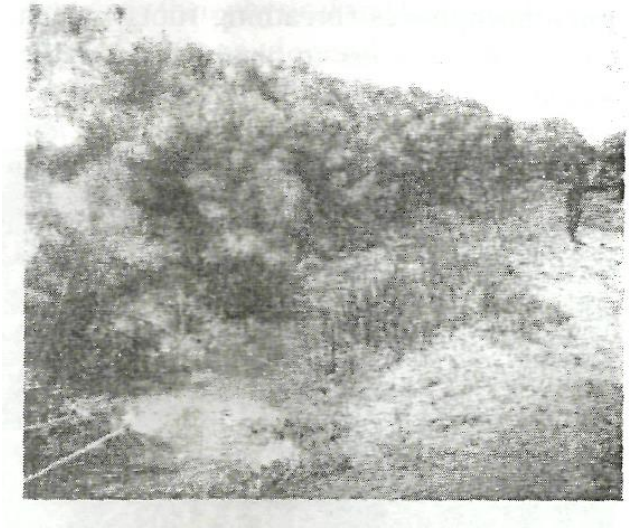


Fig. 4.14(c): Part of Yaia swamp

Halophytes

These are plants which are able to tolerate very salty conditions in soil and marine water. These habitats are characterised by the following conditions:

1. They have high concentration of mineral salts.
2. They have low concentration of dissolved gases especially in marine water.
3. Light intensity is low in marine water.
4. Currents and waves are common in seas. Note:Temperatures in marine environment are generally stable.

Adaptation of halophytes to their habitats

Halophytes are faced with a problem of absorbing water from a medium which has a very high salt concentration. The water is thus not easily available to the plant, making the plant experience a physiological drought.

They overcome this problem in several ways. They have root cells which concentrate a lot of salts in them and this enables them to take in water by osmosis in the normal way. Some plants have salt glands that secrete excess salts. Also many of them have water storage tissues.

Some plants like the mangrove have pneumatophores (breathing roots) which emerge above water to obtain atmospheric oxygen for respiration. Mangroves growing on mudflats have buttress roots for support and anchorage. See figure 4.15.

Mangrove forests on the Kenyan South Coast are a vital natural resource for the country. They provide wood to the local community as well as a habitat for other organisms such as oysters and various moluscs. We should therefore exploit them in a responsible and sustainable way to maintain ecological balance.

Most of the submerged halophytes are found close to the surface where there is sufficient light energy for photosynthesis. Those in deeper waters are capable of photosynthesising in low light intensities.

The reproductive adaptations include floating fruits. The fruits have got large aerenchymatous tissue for air storage that makes them buoyant. See details in chapter three of this book.



Fig. 4.15: Mangrove trees: Note: the pneumatophores in the foreground and buttress roots

4.7 Effects of pollution on Human beings and other organisms

Living organisms depend on the non-living environment for their oxygen, carbon (IV) oxide, water and minerals. They also depend on each other and cannot live in complete isolation. Organisms have formed different types of communities, which interact with the physical environment of an ecosystem. Each animal and plant influences its own ecosystem. An organism in a community may become numerous, or a pest may invade the area and upset the balance of the ecosystem which is usually restored naturally.

Human beings influence almost all ecological systems on earth. They have an advantage over other organisms since they can change the ecosystem for their own use. To satisfy their physical and biological needs, human beings depend on what their environment can offer. They grow their crops but also depend on other natural resources like water, air, other plants and animals which all form part of their environment. The natural resources are limited, for example it is difficult to increase the amount of land.

While interacting with the environment, human beings often misuse the natural resources. Some of the negative effects of human activities include deforestation, soil erosion, overgrazing and pollution.

The human being has also misused plants and animals exterminating many of them. If human beings are to continue to survive, they must understand the environment and use the natural resources in it in a responsible way, not only for themselves but also for future generations.

It is such realisation that have dawned on many nations, which have formed International Committees to regulate various environmental issues. Such include the United Nations Environmental Programme (UNEP) whose headquarters are in Nairobi. Since most environmental issues affect large areas, they are better therefore addressed on a global scale. UNEP helps in mobilisation of nations worldwide to support various initiatives that are ecologically beneficial.

There are therefore several **emerging environmental issues** that can be addressed. However in this book we shall highlight pollution.

Pollution

Pollution may be defined as the release of substances or forms of energy into the environment by human activities in such quantities whose effects are either harmful or unpleasant to humans or other living organisms.

There are three main categories of pollution namely air, water and soil pollution. A **pollutant** is a substance mainly waste that contaminates air, water or soil.

Air Pollution

What do you understand by the-term air pollution?

Causes of Air pollution

(a) Sulphur based chemicals e.g. sulphur (IV) **oxide** (SO_2) **and Hydrogen Sulphide** (H_2S). They are produced by food preserving industries, manufacture of sulphuric acid and burning of sulphur based petroleum fuels. Hydrogen sulphide is produced from mineral extraction mines and also from geotherrnal power stations like Olkaria in Kenya. Volcanic activities also release hydrogen sulphide, carbon (IV) oxide and carbon (II) oxide into the atmosphere.

Effects

High concentrations of sulphur (IV) oxide are harmful to organisms in that they lead to bronchitis, pneumonia and heart failure. It slows down the ciliary activities in the respiratory tract hence solid particles reach the alveoli where they cause irritation and interfere with gaseous exchange. Once absorbed through the stomata, sulphur (IV) oxide becomes toxic to plants.

Sulphur (IV) oxide dissolves in rain water and falls as **acid rain** which tends to lower the soil pH leading to a fall in crop production. It also corrodes metals such as iron and aluminium in buildings and monuments. The products of corrosion are poisonous to living organisms and contaminate drinking water supplies. Acid rain also causes leaching of magnesium and calcium ions from soils. Hydrogen sulphide also poisons organisms. It contaminates blood and suffocates victims when inhaled.

(b) Oxides of Nitrogen e.g. nitrogen (II) oxide (NO) **and nitrogen** (IV) **oxide** ($N0_2$)

These are produced from burning of petroleum fuels in industries and emissions of exhaust fumes in motor vehicles. They are also released during industrial manufacture of nitric acid.

Effects

The nitrogen oxides dissolve in rain water forming acid rain (with similar effects as for sulphur (IV) oxide). They are also poisonous to animals affecting respiratory systems

when inhaled. Nitrogen (IV) oxide is **carcinogenic.** When trapped near the ground due to thermal inversion these gases seriously diminish visibility on roads.

(c) Smoke and Fumes

There contain carbon (II) oxide (CO), carbon (IV) oxide (CO,) and carbon particles.
These are produced from industries which bum coal and petroleum fuels and also from motor vehicles exhaust. They are also produced from the burning of natural gases and charcoal.

Effects

Smoke and fumes affect the visibility due to "smog" on roads. When they settle on leaves they block stomata hence hinder photosynthesis. Smog also causes intense eye irritation, headaches and breathing difficulties. Carbon (II) dioxide causes respiratory poisoning since it readily combines with haemoglobin forming carboxyhaemoglobin leading to oxygen deficiency. (Refer to Chapter One. Book Two). Carbon (IV) oxide prevents layers of warm air from escaping into the upper atmosphere causing green house effect that leads to global warming. On a global scale, this may bring about melting of the polar ice caps thus raising the level of oceans hence flooding of lowland areas.

(d) Dust

It is composed of small particles emitted from cement and lime producing industries such as cement works, and also from quarries, road constructions and dusty dry weather roads.
Environmental concerns have led many cement manufacturing industries to adopt the "wet method" of cement manufacture which does not result into the release of dust in the environment.

This method has beed adopted by East Africa Portland Cement and Bamburi Cement Ltd, in Kenya.

Effects

Dust settles on plant leaves hence limiting photosynthesis. It clogs the respiratory surfaces of organisms resulting in breathing difficulties and respiratory diseases. Dust also reduces visibility and irritates the eyes.

(e) Lead (Pb)

This is mainly from combustion of leaded petrol by motor vehicles. Lead is normally added to petrol to serve as an anti-knock compound in vehicle engines so as to improve the efficiency of the engine combustion.

Increased environmental awareness has led to phasing out of the use of lead antiknock addictive. In Kenya this will be fully implemented by 2005 as per the Clean Air Convention.

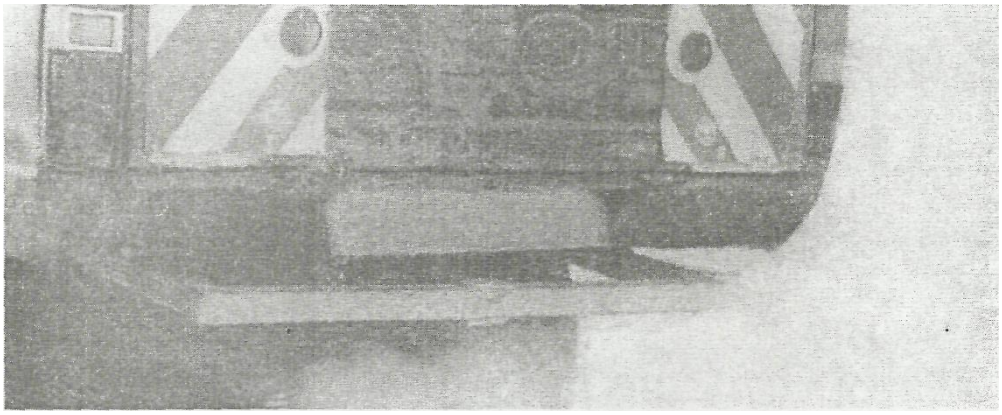


*Fig. **4.16 (a): Air pollution from** a motor vehicle*

Effects

When inhaled, it is absorbed into the blood stream and accumulates in the liver, kidneys and bones of animals affecting physiological functioning of these organs. Lead is also thought to interfere with mental development of children.
In plants, it leads to the blocking of stomatal pores making it difficult for the plant to carry out gaseous exchange and hence no photosynthesis leading to death.

(f) **Aerosols**

An aerosol is a substance that consists of very fine particles of liquid or solid suspended in a gas. These include pesticides, insecticides, fungicides, perfumes, air fresheners and spray paints.

The main pollutant in these aerosols are copper, lead and chlorofluorocarbon (CFC) compounds.

Effects

When copper based aerosols are inhaled, they cause irritation of respiratory organs of animals. Copper also causes poisoning of water plants and fish. Furthermore the copper based chemicals are non-biodegradable hence tend to accumulate in the ecosystems. Chlorofluorocarbons are used in refrigerators and as propellants in aerosol cans such as perfumes. The main effect of Chlorofluorocarbons is **depletion of the ozone layer** leading to increased penetration of ultra (UV) radiation. The UV radiation causes skin cancer and affects crops.

Noise

Noise is the presence of undesirable sound in the atmosphere. It is produced by machines in factories, heavy vehicles, aeroplanes, music players, loud speakers and *'jua kali'* workshops.

Effects

Noise affects hearing in animals. Human beings become insensitive to low pitched sounds. It is an irritant and causes stress in animals. Figure 4.16(a), (b) and (c) show some sources of air pollution.

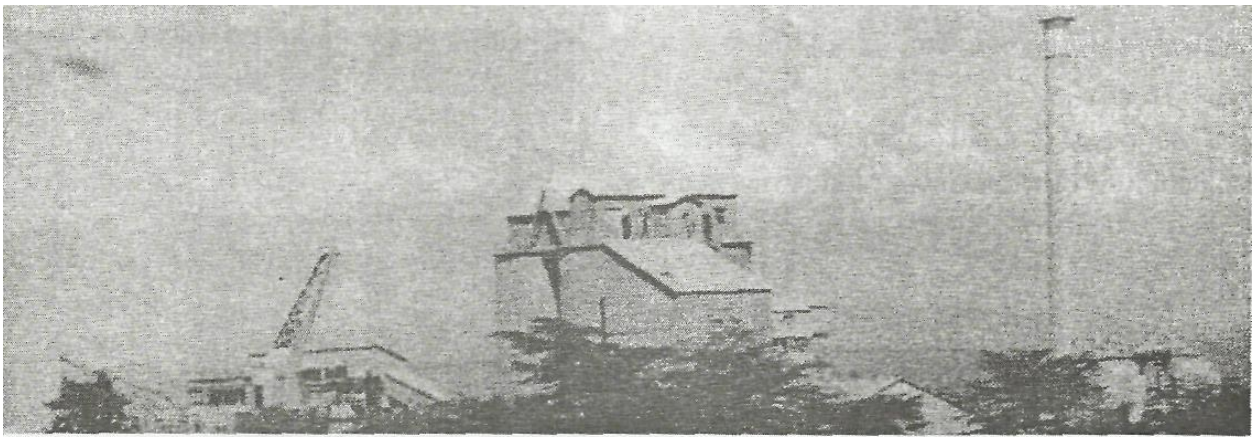


Fig. 4.16 (b): Air pollution from factories

Control of Air Pollution

1. Legislation

Governments need to enforce the relevant legislative acts on environmental pollution.
Automobiles should be fitted with filters and catalytic converters in their exhaust pipes to reduce emission of oxides of nitrogen, sulphur and carbon.

Industries manufacturing sulphuric and nitric acids should have long chimneys fitted with scrubbers to remove the acid gases.

1. Encourage the use of lead free fuels in motor vehicles.
2. Develop and encourage use of **renewable energy sources** e.g. solar and wind energy. See Figure 2.20 (a) and (b).
3. Use CFC free aerosols and appliances.
4. Use of biological control methods to control pests, diseases and weeds. This reduces reliance on non-biodegradable chemicals.
5. Encourage use of public means of transport as much as possible other than private cars. This minimises consumption of fossil fuels and emission of gas pollutants.
6. Smoking in public should be banned.
7. Ear muffs should be used in factories and *'jua kali'* workshops that generate loud noises.
8. The masses should be educated on the need for sustainable environmental management.
9. The government should be a signatory to global treaties on environmental conservation.

Study this question

From your own environment, identify main air pollutants. State their causes, effects and suggest their possible control measures.

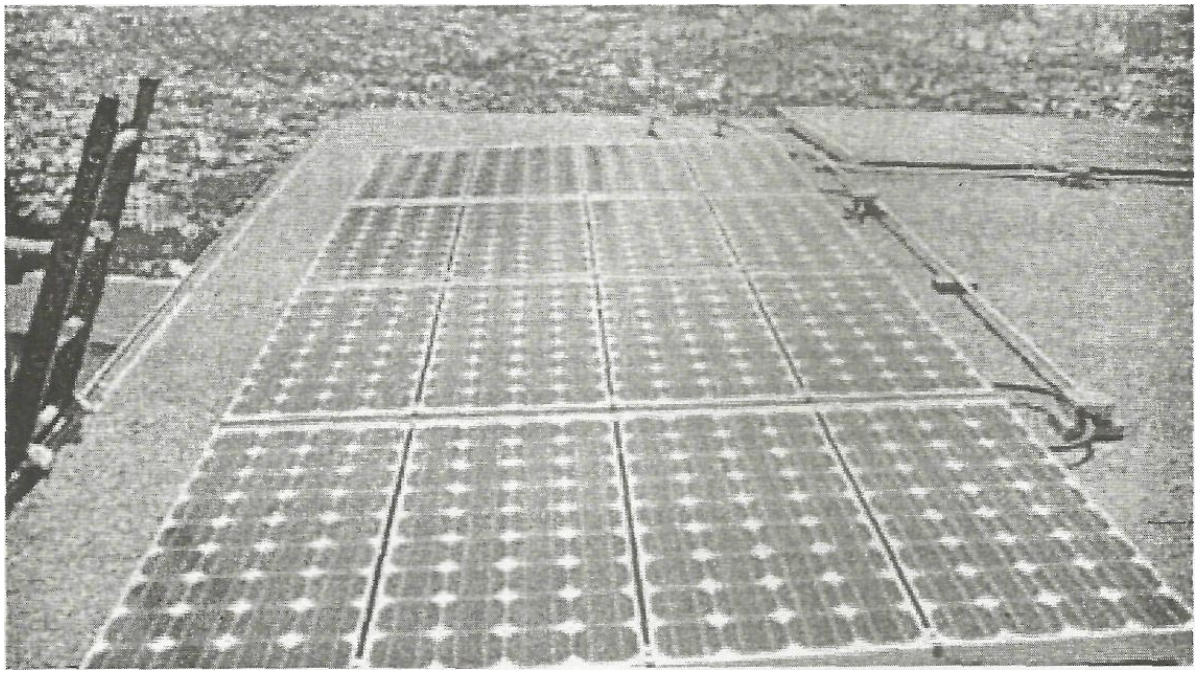


Fig. 4 17(a): Electrical solar cells on a roof

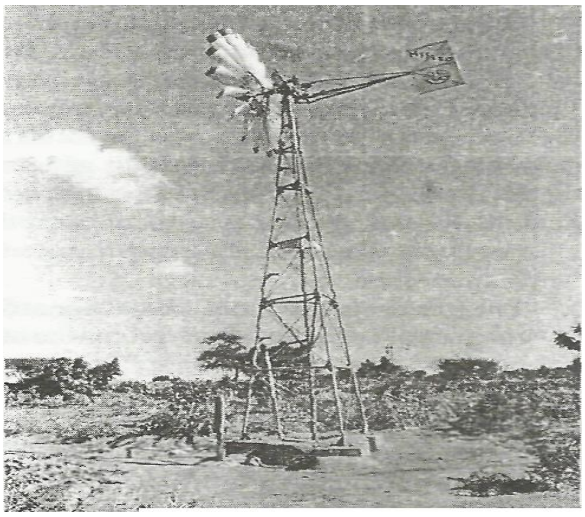


Fig. 4.17 (b): A wind mill

Water Pollution

As indicated in the definition of pollution, the pollution of water involves addition of substances or energy forms into water bodies in quantities that are harmful to the living organisms dependent on that water.

Sources of Water Pollution

(a) Domestic Effluents

Untreated sewage from urban centres gets discharged into rivers used for water supplies for domestic purposes. This sewage contains disease causing micro-organisms such as bacteria, viruses and protozoa. It is also full of faecal material and urine which encourage bacterial growth. Kitchen waste also contain detergents that have a lot of phosphates.

Effects

Water pollution may cause epidemics of water borne diseases e.g. cholera, typhoid and amoebic dysentery. The faecal material is broken down by saprophytic bacteria and fungi which leads to depletion of dissolved oxygen in water. This in turn affects the aquatic organisms such as fish and aquatic plants.

The breakdown of these organic matter releases nutrients such as nitrates, phosphates and sulphates which enrich the water body resulting in **eutrophication** as happened with excessive growth of water hyacinth on Lake Victoria and other water bodies in the year 2000. This plant is causing serious environmental problems on Lake Victoria. See figure 4.18.

(b) **Industrial Effluents**

Industries discharge various effluents into rivers, dams, marshes, fresh water lakes, seas and oceans. The effluents contain toxic metallic compounds of mercury, arsenic and cadmium in addition to acids and other chemicals.

Effects

The poisonous compounds directly kill aquatic organisms such as fish. Death can also be caused indirectly through eutrophication. These compounds also enter the food chain and accumulate to lethal levels in organisms higher up the trophic levels.

(c) **Heat**

Industries discharge hot water directly into water bodies. This may be from the cooling process or for discharging industrial effluents. Some of the effluents may react among themselves releasing heat into the water.

Effects

Heat reduces the amount of dissolved gases in water e.g. oxygen and carbon (IV) oxide. Thus organisms may die from oxygen deficiency or from lack of photosynthesis. Heat raises respiratory rate to abnormal levels causing malfunctioning in the organisms. The hot water may even kill the living organisms directly due to the high temperatures.

(d) **Oil Spillage**

Oil is an important pollutant. Oil spillages occur in oceans from oil tanker accidents, offshore oil wells and refineries and also from damaged warships.

Effects

Oil layer on water reduces oxygen supply to the water and this may lead to death of aquatic life forms. Marine organisms such as fish are killed by clogging of their respiratory surfaces. Marine birds get their feathers clogged hence have difficulty in flight. Oil coats photosynthetic phytoplanktons till they die. There is reduced light penetration into the water hence photosynthesis of submerged plants is hindered.

(e) **Agro-chemicals**

Agricultural chemicals include inorganic fertilisers, herbicides and pesticides. The inorganic fertilisers contain phosphates and nitrates. Pesticides may contain heavy metals such as mercury and copper. Other pesticides such as DDT contain chlorofluorocarbon which are not easily broken down biologically (non-biodegradable).

These chemicals and fertilisers percolate through soil and after underground seepage they join streams and rivers eventually into lakes and oceans.

Effects

Since most of these chemicals contain the heavy metals such as copper and mercury, they affect the respiratory activities of aquatic organisms. These chemicals find their way into the organisms' bodies in small amounts. However they accumulate over a long time and reach toxic levels leading to death. Furthermore they accumulate along food chains becoming lethal at higher trophic levels. Nitrates and phosphates in fertilisers cause eutrophication.

(f) Lead

This is a water pollutant mainly from pipes and tanks in domestic water supply systems. Through run-off it finds its way into water bodies like rivers, lakes and oceans.

The effects of lead whether inhaled or ingested are similar as discussed under air pollution.

(g) Mercury

Mercury as a pollutant is released by industries that manufacture chlorine, sodium hydroxide, ores and vinyl plastics. It is also released during combustion of coal and petroleum oils. Fungicides and some cosmetics also contain mercury.

The mud in some rivers contains mercury which is converted to methyl mercury by methane producing bacteria.

Effects

Methyl mercury is volatile and very toxic. It is absorbed by aquatic organisms or through leaves and roots of plants hence entering the food web involving human beings.
Animals eating plants with mercury are poisoned and killed as observed in wood-pigeons.
Mercury poisoning in people results in accumulation of mercury in liver, kidneys and brain affecting the physiological functioning and eventually causes death.

Mercury also interferes with the process of melanin formation leading to skin lightening, blindness paralysis and even death.

(h) Soil Erosion

Through soil erosion, silt is transported into water bodies.

Effects

This makes water unclean and unfit for human consumption. The silt particularly reduces light penetration hence hindering photosynthetic activity. It also clogs the respiratory surfaces of aquatic organisms e.g. gills in fish and stomata in plants. This interferes with gaseous exchange.

Control of Water Pollution

1. Legislation: The relevant legislation should be enforced and provide for heavy penalties. In addition, international treaties on environmental conservation should be adhered to.
2. Industries should control or treat the industrial effluents before discharge into water bodies.
3. Proper treatment and disposal of sewage: There should be separate systems for disposal of sewage and drinking water. Latrines should be constructed and properly used in addition to proper personal hygiene to control disease causing agents.
4. Encourage the use of unleaded petrol.
5. The public should be educated on correct amounts of inorganic fertilisers and pesticides to be used. They should be encouraged to use organic farming and biological control of pests.
6. Appropriate soil erosion control methods to be put in place such as building of gabions, terraces, mulching and growing of soil cover crops.

Study these questions

(a) Give the various sources of water pollution.
(b) For each source given state the appropriate control measures.
(c) Industrial wastes may contain metallic-.* pollutants. State how such pollutants "" may indirectly reach and accumulate ' in the human body if the wastes were dumped in rivers.

Sources of Soil Pollution

Either intentionally or accidentally human beings discharge chemicals into the soil which accumulate to levels that cause harm to soil organisms.
(a) **Oxides of sulphur** e.g. sulphur (IV) oxide enter the soil through precipitation as acid rain.
Acid rain alters the soil pH therefore affecting the plants and animals that cannot tolerate acid soil. However, acid rain may promote the growth of plants that tolerate acidic conditions. Acid rain also causes leaching of minerals leading to loss of soil fertility.

(b) **Aerosols**

Most aerosols sprayed to control pests and diseases in plants and animals contain heavy metals e.g. copper and mercury.

The chemicals fall on the soil and are taken up by plants where their concentration increases. As animals eat these plants, toxicity increases and leads to death of animals. These chemicals kill nitrogen fixing soil micro-organisms hence lowering soil fertility with consequent reduction of plant growth.

(c) **Petroleum products**

Petroleum products spilled on land e.g. oil tankers. Soil organisms fail to obtain oxygen in oil saturated soils and therefore die. Coating of plant leaves or respiratory surfaces of animals also leads to their death.

(d) **Inorganic fertilisers** Agricultural inorganic fertilisers contain phosphates and nitrates.

These increase soil acidity so that soil micro-organisms cannot inhabit such soils. Formation of soil organic matter slows down and then stops. Soils become exhausted hence plant and animal life ceases. In addition soil structure is changed hence encouraging soil erosion.

(e) **Solid Waste**

Community household wastes and industrial wastes. Some are biodegradable e.g. food residues, old clothing and papers. Others are non-biodegradable e.g. rubber, plastic containers, scrap metals and glass bottles. See figure 2.22.

Solid wastes are a nuisance and may also be injurious e.g. glass bottles.

They destroy the aesthetic state of the environment. They offer breeding grounds for pests, rodents and insect vectors which in turn pose health hazards to human beings. The non-biodegradable solid wastes limit soil aeration thus inhibiting micro-organism activity.

Control of Soil Pollution

All solid wastes should be sorted out according to manufacturer specifications, then appropriate disposal methods applied.

1. Recycle solid wastes e.g. polythene paper and plastic containers, glass bottles, paper, and scrap metal.
2. Household wastes that are biodegradable can be disposed in a compost pit to form compost manure for organic farming.
3. Combustible solid wastes e.g. old clothes, sanitary towels, hair should be burned in incinerators.
4. Discourage excessive use of agro-chemicals.
5. Biological control of pests and diseases to be encouraged.
6. Encourage pipeline transportation of petrol and petroleum products to minimise risk of spillage.
7. Enforce appropriate legislation on proper solid waste management.

Radioactive Emissions

Nuclear emissions can also cause soil, air and water pollution.

Although nuclear energy is available in limitless quantity, its harnessing, management and risks of damage to life are very high. It is based on the destruction of the atom of matter to release energy that holds the constituents of the atom. The form in which this energy is released when atoms are broken down are generally called **radiations.** Such radiation has very great power and is very destructive if it leaks accidentally. The industries in which

this energy is produced are called radioactive or nuclear reactors. Some of the common substances broken down to release nuclear energy are uranium, radium, germanium, plutonium and hydrosonium (heavy water).

Use of Nuclear Energy

Nuclear energy is used in the generation of electricity and propelling of nuclear war planes, nuclear propelled ocean vessels, space ships and submarines.

Effects of Radioactive Emissions

1. Increased mutation rates with increased abnormalities some of which are inheritable.
2. It causes cancer such as bone tumours and leukaemia.
3. Excess doses of radioactive emissions cause so much damage leading to death.

Control

Due to potential dangers of nuclear waste disposal and energy management, the control is only by dialogue between nations with the nuclear technology.

4.8 Human Diseases

A disease is a disordered state of a tissue, organ, system or organism, during which its functions are not carried out normally.

In human beings, disease results from genetic disorders, nutritional deficiencies or infections by other organisms and viruses.

In this text we shall discuss a few diseases caused by bacteria, protozoa and parasitic worms.

Bacterial Diseases

Cholera

This is a disease by a bacterium known as *Vibrio cholerae.* Figure 4.18 shows the shape of these bacteria. It is a killer disease in the tropics. The bacteria are normally found in **infected water** and are passed on by flies to food, thereby contaminating the **food.** People leaving in unhygienic conditions, i.e. where sanitation is poor and the domestic water supply is contaminated, can easily contract the disease. Once there is an outbreak of the disease, it spreads rapidly and can cause an epidemic.

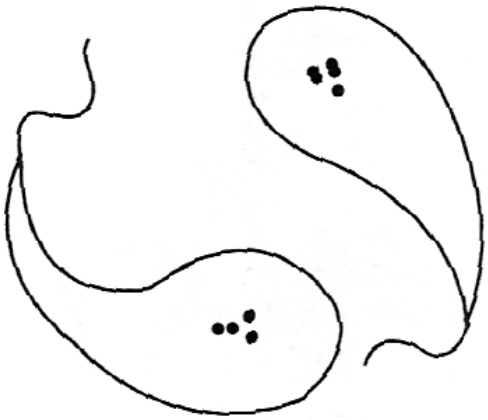


Fig. 4.18: Vibrio cholerae bacteria

Symptoms

The incubation period varies between one to six days depending on the magnitude of the infection and state of health of the individual. The bacteria reach the intestines and multiply rapidly. They secrete an enzyme called mucinase which digests the inner lining of the intestines. The exposed intestinal wall then becomes irritated and damaged by the toxins produced by the bacteria, and this causes violent diarrhoea and vomiting. This is accompanied by severe abdominal pains. The disease develops rapidly and leads to general body dehydration owing to the high frequency of defecation, accompanied by loss of large quantities of water. Death by cholera can be rapid - within 24 hours of infection in extreme cases.

Prevention and Treatment

Sanitary disposal of faeces and refuse is needed to prevent the contamination of water and food, The pit-latrines in rural areas should be deep. They should be kept clean to keep away flies. Personal hygiene should be maintained. Domestic water should be boiled and filtered, or chlorinated before use so as to kill bacteria and their spores.

The infected persons are infectious and so should be isolated and treated as soon as possible. Treatment involves administering of antibiotic drugs in order to kill the bacteria. Oral rehydration salts should be administered before treatment.

Typhoid

This is also a disease caused by a bacterium called *Salmonella typhi.* See figure 4.19. The bacteria are passed out in either urine or faeces. Poor disposal of urine and faeces may cause contamination of the water supply from rivers, dams and lakes. Healthy individuals can be infected by taking **contaminated water or food.** Sometimes the bacteria can be present in sweat and saliva and so the clothes and beddings of the patient can be sources of infection to others.

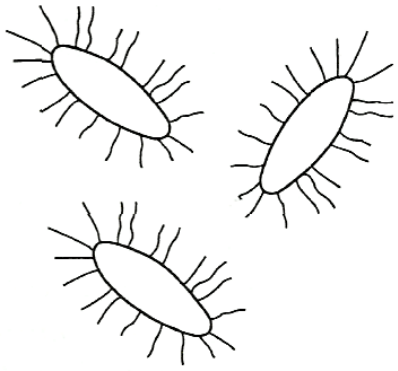


Fig. 4.19*: Salmonella typhi bacteria*

Symptoms

Its incubation period lasts for about two weeks after which a fever and rush develop, followed by severe diarrhoea. The bacteria attack the walls of the intestines and cause patches of sores. Patients are advised not to eat solid food as this might irritate the intestinal sores and cause bleeding.

In severe attacks the sores may burst and cause perforation in the intestines. This may result in death if the patient is not treated early enough. The bacteria invade the lyrnph glands around the intestines and then pass into the blood stream.
Patients do not develop immunity to this disease and therefore one can be attacked again and again.

Prevention and Treatment

There should be proper disposal of faeces and urine to prevent spread of the bacteria. Domestic water should be boiled or chlorinated before drinking to kill the bacteria. Hands and cutlery should be washed clean before eating. Fruits should be washed with clean water before being eaten. Food handlers should be clean, and should- be subjected to regular medical check-ups. Healthy people may be vaccinated with **attenuated (weakened) typhoid bacteria** in order to provide immunity for at least two years. Treatment involves administering antibiotics.

Protozoan Diseases

Amoebic Dysentery

Amoebic dysentery is a disease caused by a protozoan called ***Entamoeba*** *histolytica.* When the amoebae **cysts** are ingested, the cyst's membrane is digested and the protozoa are released. When they reach the large intestines and the colon, the *E. histolytica* multiply.

Symptoms

Normally *E. histolytica* live within the lumen of the colon and feed on bacteria without harming the host. At certain times, they invade the mucosal wall of the colon and produce a tissue-dissolving enzyme called histolysin (hence the name histolytica). This results in formation of ulcers on the colon wall and the parasites then feed on red blood cells at the site of the ulcers. This condition usually leads to diarrhoea or amoebic dy sentry and the faeces contain blood.

The disease is usually characterised by diarrhoea, dehydration, fever and abdominal pains and severe pains when passing stool. The infection may also become systemic ("i.e. invade the blood stream), and the parasites may reach other tissues or organs of the body such as liver, lungs and brain where they produce abscesses which may be fatal.

Prevention and Treatment

Prevention of the infection aims at avoiding contamination of food or water with cysts. Control measures include boiling water for drinking, proper food storage and proper faecal disposal. For treatment, a number of amoebicides can be used.

Malaria

Malaria is a disease caused by a protozoan parasite called Plasmodium.
There are four different species of plasmodium namely *P. vivax, P. ovale, P. falcipamm* and *P. malariae.*
The *Plasmodium* is transmitted from an infected person to a healthy person by a female *Anopheles* mosquito (vector). When the mosquito bites an infected person it sucks blood containing the parasites. Inside the mosquito, the plasmodia develop into infective stages. When the same mosquito next bites a healthy person it passes on the infective plasmodia from its salivary glands into the blood system of the healthy person.

The incubation period lasts between seven to ten days. During this period the parasites invade the liver cells where they multiply. They are then released into the bloodstream where they now attack and destroy the red blood cells.

Symptoms

The symptoms of malaria include high regular fevers accompanied by profuse sweating punctuated by chills and shivers. Headaches, muscle and joint pains are felt most of the time. The patient lacks appetite and vomits from time to time. There is enlargement of liver and spleen. Anaemia results because of the destruction of red blood cells. In severe attacks, convulsions in children are observed.

Malaria is a killer disease especially in children in the tropics.

Prevention and Treatment

Various methods of prevention are available in the management of malaria. The most recent method is the development of vaccines against the *Plasmodium.* These target various stages in the life cycle of the parasite hence developing some immunity. Traditionally malaria has been controlled by use of nets to prevent mosquito bites. Similarly mosquito repellents such as creams and mosquito coils have been used. Insecticides are sprayed in dwelling places and also use of treated mosquito nets.

Drainage of stagnant water and clearance of vegetation around houses destroys the breeding and resting sites of mosquitoes hence reduction in their numbers. Tins, plastic containers and polyethene papers that hold water should also be destroyed. The use of oil on stagnant water has been useful but is being replaced by powdery treatment of water surfaces.

Biological control involves use offish in ponds to feed on the mosquito larvae. A more recent method involves release of genetically sterilised male mosquitoes to mate hence reducing the numbers of mosquitoes.

People travelling into malaria prone areas are advised to take antimalarial drugs for prevention. Treatment should be preceded by proper diagnosis and the full dosage administered for full cure. Under dose often leads to development of resistance.

Study these questions

(a) From the information given on prevention and treatment of malaria, identify those measures that are directed towards eradication of the:

(i) *Plasmodium* parasite.

(ii) Adult mosquito.

(iii) Mosquito larvae.

(b) Whyistheuseofoilonstaghantwaters as a control measure for **mosquitoes** being discouraged.

Parasitic worms

Ascaris Lumbricoides

Ascaris lumbricoides is a parasitic roundworm which belongs to the phylum Nematoda. *Ascaris lumbricoides* is widespread in distribution and infects small intestines of pigs and human beings. It may also occur in other organs of the body. The genus *Ascaris* is the largest nematode parasitic to humans. It is characterised by a brownish yellow colour with mouth parts having three lips. The male is about 25 cm long and 0.4 cm in diameter, while the female is about 35 cm long and 0.5 cm in diameter.

Mode of Transmission

The adult female lays eggs in the small intestine of the host. The eggs are passed out with the faeces and may be swallowed by a new host through contaminated food and water. Contaminated vegetables or fruits which are not washed well before being eaten are also a source of infection. There is also direct infection from faeces to mouth by hands especially in children.

When they are swallowed by a host, the egg shells are dissolved, releasing the larvae. These penetrate the intestinal wall and enter the blood stream. They move to the liver and then to the heart and lungs. Jn the alveoli they grow and moult twice. The larvae then migrate up to the trachea where they cause irritation and so are coughed out and may be swallowed down into the aesophagus, stomach and small intestines where they finally mature in adults.

Effects of the Parasite on the Host

During the migration of the larvae they cause irritation in the trachea that lead to lung damage and infection with other diseases.

If the infection is heavy, a lot of digested food is consumed by the parasite in the intestine and this leads to malnutrition in the host, especially in children. During their cycle in the human host, the parasites feed on blood and therefore can cause anaemia to the host. Very heavy infection can also lead to intestinal blockage where victims develop large round stomachs. The worms may also enter the bile duct, pancreatic duct and appendix, causing further complications.

Adaptative Characteristics of Ascaris lumbricoides to its Parasitic Mode of Life

1. *Ascaris lumbricoides* has two hosts, human beings and pigs. This ensures that it always has a ready host for survival.
2. It lays many eggs to increase the chances of survival even when some are destroyed.
3. The eggs have a protective shell to survive harsh environmental conditions. See figure 4.25. The egg is well protected and can remain infective up to a year.

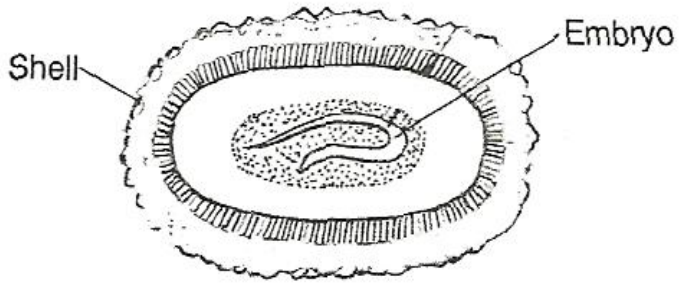


Fig. 2.20: Infective egg 60 - 70 ***fun-diameter***

4. *Ascaris lumbricoides* has a thick elastic cuticle which protects it against the digestive enzymes of the host enabling it to survive in the alimentary canal.
5. It has tissues tolerant to low oxygen concentration characteristic of the gut.
6. It has a muscular pharynx through which it sucks digested food from the host's intestine into its own gut.

Prevention and Treatment

Proper sanitary disposal methods are required especially the availability and proper use of toilet facilities. High standards of personal hygiene should be observed such as washing hands after a visit to the toilet.
Hygienic handling and cleaning of fruits and vegetables is necessary. Drinking water should be boiled.
Treatment involves use of drugs to kill the worms or inactivate the eggs.

Study this question

The table below gives information about some diseases. Complete the table.

Disease	Type of organism causing the disease	Mode of transmission	Symptoms of the disease
1. Malaria	……	…….	…….
2. Amoebiosis	……	…….	…….
3. Cholera	……	…….	…….
4. Typhoid	……	…….	…….

Schistosomiasis (Bilharzia)

This is a parasitic disease of the blood. It is caused by a flatworm of the phylum platyhelminthes of the genus *Schistosoma.* See figure 4.21(a). There are three different species of schistosoma that infect human beings. These include *Schistosoma mansoni, Schistosoma haematobium* and *Schistosoma japonicum.*

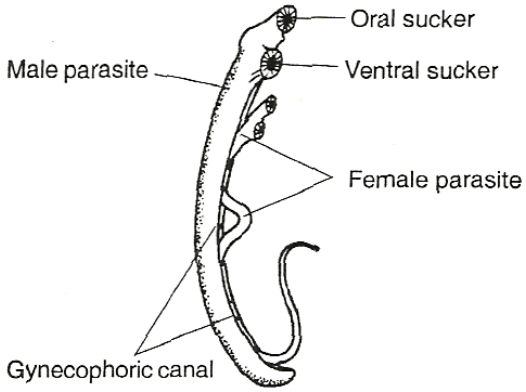


Fig. 4.21(a) A male and female Schistosoma parasite

The parasite is found in fresh water canals, lakes, rivers, dams, rice-growing fields and other similar habitats.

Modes of Transmission

The parasite is spread when people drink water contaminated by a larval form called **cercariae.** See figure 2.21(b). Also the parasite can penetrate the skin when bathing **or** wading through water containing the larvae. Once in the body they get into the blood streams and migrate to the liver where they mature into adults. After coupling of the adult worms, eggs are shed into the blood vessels or alimentary tract.

When the faeces or urine containing eggs are disposed of into water. The eggs hatch into larvae called **miracidia.** The *miracidia* find and penetrate the water snails such as *Biomphalaria* and *Bulinus.* See figure 4.21(c).

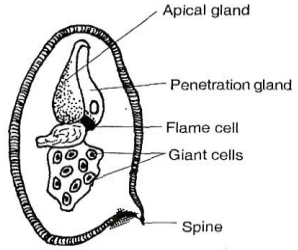


Fig. 4.21(b): ***Mature eggs of s.mansoni***

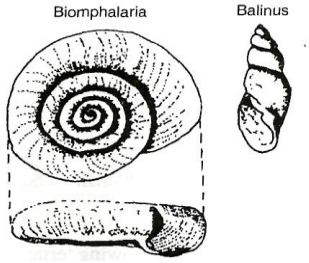


Fig. 4.21(c): ***Snail vectors for Schistosoma***

It is from the snails that the infective stage cercariae emerge and can now infect human beings who stand, bath or drink in such water.

Effects of Parasite on its Host

The parasite damages the host's skin when penetrating and this causes itching. Once in the blood the adult *schistosoma* releases chemical substances which cause fever.

The adult worms have sharp spines which they use to tear through the veins and enter into the intestines or the urinary bladder. This causes blood to appear in urine or stool. This can eventually lead to anaemia. The person also experiences abdominal pains and diarrhoea.

If untreated the disease can result in death due to exhaustion or by infection from other diseases due to reduced body immunity.

Adaptive Characteristics of *Schistosoma*

The parasite has suckers for attachment so that they are not dislodged. The parasite has two hosts, that is the secondary host, the snail and the primary host, the human being. This increases its chances of transfer to several hosts and from one place to another.

The cercariae larvae and eggs of the parasite have glands that secrete lytic enzymes which soften tissue to allow for penetration into the hosts. Some larval forms e.g. cercariae are encysted and can remain dormant and viable until they come into contact with a human being.

The parasite reproduces through larval forms e.g. miracidia, cercariae, and redia in snails. This makes it very difficult to eradicate the parasite and also increases its chances of transmission and survival.

The adult worm in blood produces chemical substances which protect it against the host's defence mechanism. The worms are of separate sexes. The male forms a gynecophoric canal in which it carries the female. This ensures that the eggs produced by the female are fertilised before they are shed into the blood vessels.

Prevention and Treatment

Schistosomiasis (Bilharzia) can be prevented by proper sanitary disposal of both faeces and urine. Deep pit latrines or flush toilets should be used. Urine and faeces should not be disposed of into rivers, dams and other water bodies. All drinking water should be chemically treated or boiled in order to kill the eggs, miracidia and cercariae that may be present. People should not bathe or swim in water infested with snails. People should wear protective shoes and clothes and avoid walking bare feet in swampy areas. The snails should be killed by spraying the water with molluscicides. Infected persons should receive proper medical treatment.

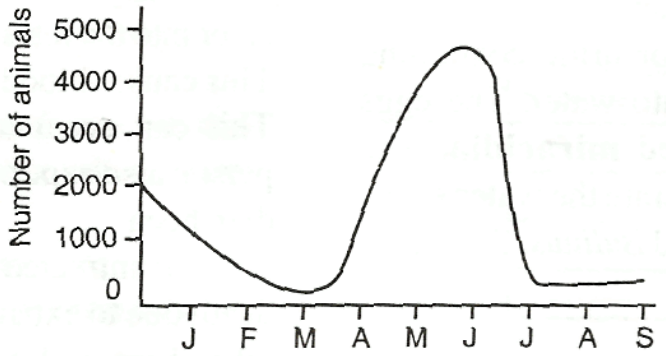
Revision Questions

(a) Define the following terms used in ecology:
- (i) Biosphere,
- (ii) Habitat
- (iii) Population
- (iv) Synecology.
- (v) Carrying capacity,

(b) What are the two main components of an ecosystem?

Name two organisms which form the biological environment of each of the following:
- (a) Roundworm *(Ascaris lumbricoides).*
- (b) Malaria parasite *(plasmodium spp).*
- *(c) Schistosoma spp.*

The following figure represents the populations of animals in a pond over a period of 9 months. The pond is situated in a country with evenly distributed rainfall throughout the year.



1. (a) Define the following terms used in ecology:
   - (i) Biosphere
   - (ii) Habitat
   - (iii) Population.
   - (iv) Synecology.
   - (v) Carrying capacity,
   - (b) What are the two main components of an ecosystem?
2. Name two organisms which form the biological environment of each of the following:
   - (a) Roundworm *(Ascaris lumbricoides).*
   - (b) Malaria parasite *(plasmodium spp).*
   - *(c) Schistosoma spp.*
3. (a) What is a food chain?
   - (b) Construct a food chain where all the consumers are chordates.
   - (c) Construct a food chain where all consumers are arthropods.
   - (d) Construct food chains where a human being is a:
     - (i) primary consumer.
     - (ii) secondary consumer.
     - (iii) tertiary consumer.
     - (iv) quaternary consumer.

4. The following table shows the estimated number of organisms recorded in a dam.

Organism	*Number*
Small fish	3,500
Microscopic algae	120,000
Crocodiles	95
Large fish	950
Mosquito larvae	8,900

(a) Draw a possible food web for the dam.

(b) Which organism would be depleted first in this ecosystem? Give a reason for the answer.

5. Supposing you are asked to study the population offish in a school pond.

(a) List down the apparatus that you would need for this investigation.

(b) State the method of sampling.

(c) What precautions should be taken when performing this investigation?

(d) Name the apparatus you would use to measure each of the following environmental factors that would determine the number offish in the pond:

(i) Temperature. (ii) Oxygen concentration.

(iii) PH. (iv) Light intensity.

(e) State two methods that you would use to determine what the fish in the pond feed on.

6. Give reasons as to why biological control is preferred to chemical control in the control of pests and parasites.

7. (a) The following living organisms have been observed in an isolated island: rats, lizards,insects, tortoise, snakes, grasses and birds. Construct four possible food chains each consisting of four organisms.

(b) Outline the dangers that are brought about by stagnant water, bush and exposed rotting rubbish near a home.

8. A farmer noted that every season, several of the seeds he had planted did not germinate, and those that germinated were heavily attacked by insects. He decided to pre-treat the seed with different chemicals before planting, hoping to find a chemical that would eliminate the losses. He selected 200,000 seeds for each investigation. The table below shows the different treatments and their results.

Treatment	*Chemical*	*Number of seedlings lost due to:*	
		Rotting	*Insects*
A	I	17 900	3 200
B	II	900	3 100
C	III	9 100	3 000
D	I + II	2 000	3 100
E	I + III	3 400	3 300
F	None	18 400	3 300

Which treatment was the most effective? Give a reason for your answer.

(a) Explain the reason why the loss of seedlings due to insect attack did not change much with various chemical treatments.

(b) Name two organisms that might have caused rotting in the seeds.

(c) Referring to treatments A, B, F, comment on the effect of mixing chemical I and II.

9. List the four modes of expressing food relationships in an ecological system, then describe the nature and importance of energy in such relationships:

(i) Prepare a food web of a known natural ecosystem and from it construct a pyramid of numbers.

(ii) State two characteristics of pyramid of numbers you have constructed in (i) above.

(iii) Differentiate between the pyramid of numbers and pyramid of biomass.

10. A biologist carried out a study to investigate the growth of a certain species of herbivorous bony fish and the factors influencing plant and animal life in four lakes A, B, C and D. The lakes were located in the same geographical area. Two of the lakes, A and B, were found to contain hard water due to presence of high content of calcium salts. Lakes C and D were found to have soft water with low content of calcium salts.

The mean body length of two years old fish, amount of plant life and invertebrate biomass in each lake were determined. The data was as shown in the table below.

Lakes	Mean body length of 2-year old fish (cm)	Type of water	Amount of plant life (g/cm^3 of water)	Invertebrate biomass (g/m^3 of water)			
				Insects	Snails	Crabs	Worms
A	31.2	Hard	1 050	11	300	10	180
B	28.6	Hard	950	72	100	9	90
C	18.4	Soft	1.2	97	0	2	20
D	16.3	Soft	0.5	99	0	1	10

a. Describe the procedure that may have been used to determine the mean body length of the fish.

b. What are likely reasons for the difference in the mean body length of the fish living in lakes A and D?

c. Suggest one reason for the absence of snails in lakes C and D.

d. (i) Name any **six** abiotic factors that are likely to influence the plant and animal life in Lake A

(ii) Explain how each of the factors named in (d) (i) may influence the plant and animal life in Lake A.

12. During an ecological study of a lake, a group of students recorded the following observations:

(i) Planktonic crustaceans feed on planktonic algae.

(ii) Small fish feed on planktonic crustacean, worms and insect larvae.

(iii) Worms feed on insect larvae.

(iv) A bird species feeds on small fish, planktonic crustaceans and worms.

(v) Insect larvae feed on planktonic algae.

(vi) Large fish feed on small fish.

(a) From this record of observations, construct a food web,

(b) From the food web you have constructed in (a) above, isolate and write down a food chain that ends with:

(i) Bird species as secondary consumer,

(ii) Large fish as tertiary consumer.

(c) The biomass of the producers in the lake was found to be greater than that of primary consumers. Give an explanation for this observation.

(d) Using either the observations recorded by the students, or the food web you have constructed, name:

(i) Two organisms that compete for food in the lake.

(ii) The source of food the organisms in (d) (i) above compete for.

(e) (i) State three ways by which humans may interfere with this lake ecosystem,

(ii) Explain how each of the ways you have stated may affect life in the lake.

13. An investigation was carried out between 1994 and 2003 to study the changes of fish population in a certain small lake. Four species offish, A, B, C and D were found to live in this lake.

In 1995, a factory was built near the lake raising the average temperature from 25°C to 30°C. In 1997, sewage and industrial waste from a nearby town was diverted into the lake. 1999, discharge of hot water, sewage and industrial waste into the lake was stopped.

The fish population during the period of investigation are shown in the table below.

Fish Species	1994	1996	1998	2000	2001	2002	2003
A	6 102	223	20	106	660	4 071	7 512
B	208	30	11	22	63	311	405
C	36	100	0	0	0	0	0
D	4 521	272	23	27	29	400	617

(a) (i) In which year were the fish population lowest?

(ii) State the factors that might have caused the lowest fish populations during the year you have stated in (a)(i) above.

(iii) Explain how each factor you have stated in (a)(ii) above could have brought about the changes in fish populations.

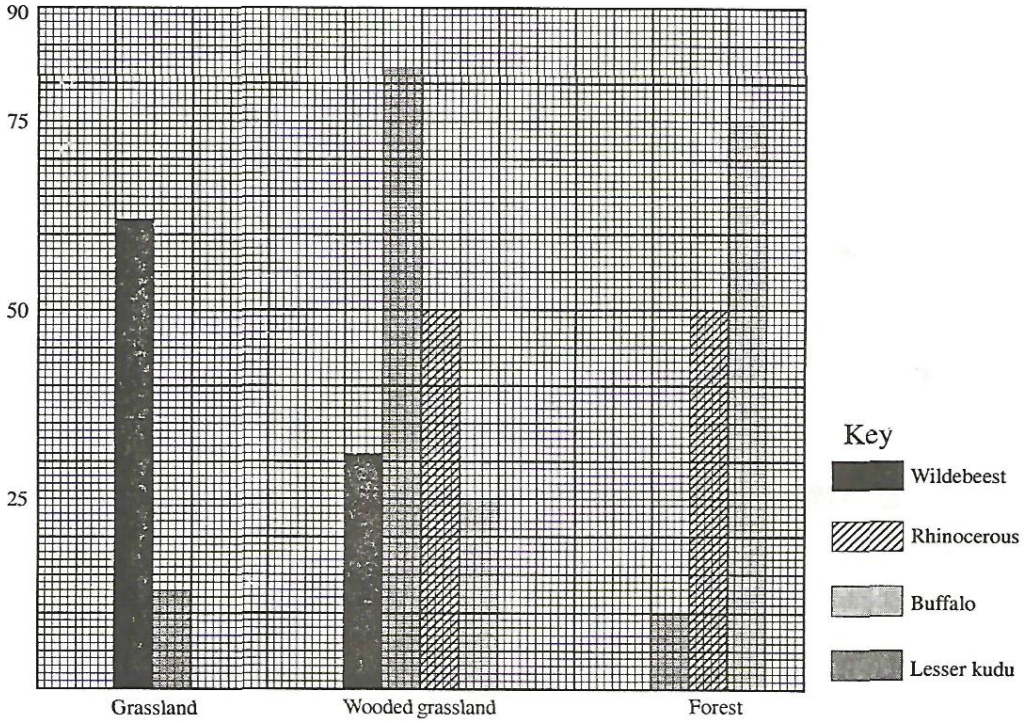
(b) (i) What is the difference in the rate of population recovery of species A and D?

(ii) Suggest **two** biological factors that could have led to this difference.

(c) (i) State a method that might have been used in estimating the fish populations in the lake,

(ii) State **one** advantage of the method you have stated in (c)(i) above.

14. A study was carried out to investigate the distribution of certain mammals in a game reserve with three distinct habitats. The results were as shown in the graph that follows.



Suggest a suitable method that could have been used to obtain the data from the three habitats

(b) Suggest **three** reasons why all mammalian species were found in the wooded grassland.

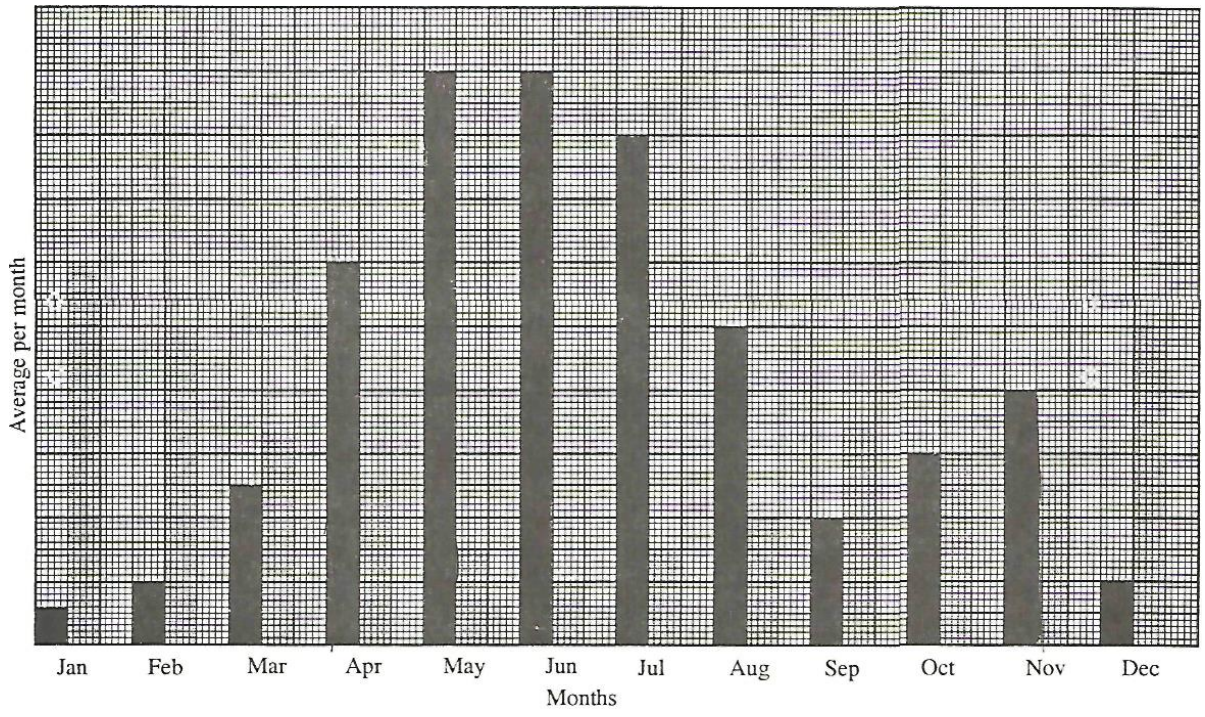
(c) From the data, deduce the feeding habits of:

(i) Wildebeest.
(ii) Lesser kudu.

(d) The vegetation in this game reserve was destroyed by fire. Two weeks after the onset of rains, most of the animals were found in the grassland. Explain.

15. A group of students investigated the relationship between the rainfall pattern and the number of plant species eaten by a certain herbivorous mammal through the year. The results were as shown in the graph that follows.

(a) Giving reasons, name the month when the mammal was most selective in its feeding.
(b) Account for the change in the number of plant species eaten during the month of December, January and February.
(c) What is the advantage of the type of feeding behaviour exhibited by the mammal?
(d) Suggest two methods that may have been used to determine the plant species eaten by this mammal.



Kev Rainfall Number of plant species eaten

16. Which diseases could be prevented by:

(a) Personal hygiene?
(b) Efficient sewage disposal?
(c) Purification of drinking water?

17. It is possible to contract amoebic dysentery as a result of close contact with an infected person. Similar contact with malaria victim cannot produce infection. Explain why the transmission of these two diseases is so different.

23. Describe the various methods used to reduce the incidence of water-borne diseases.