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BIOLOGY

Standard 12

(Semester IV)

PLEDGE

India is my country.
All Indians are my brothers and sisters.
I love my country and I am proud of its rich and varied heritage.
I shall always strive to be worthy of it.
I shall respect my parents, teachers and all my elders and treat everyone with courtesy.
I pledge my devotion to my country and its people.
My happiness lies in their well-being and prosperity.

રાજ્ય સરકારની વિનામૂલ્યે યોજના હેઠળનું પુસ્તક

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PREFACE

In compliance with the new national syllabi designed by N.C.E.R.T. according to NCF-2005 and core-curriculum the Secondary and Higher Secondary Board of Education, Gujarat State, has prepared the new syllabi of various subjects with the approval of the State Government.

The State Textbook Board delightfully introduces the new edition of **Biology** for **Semester IV** for the students which has been prepared according to the new syllabus of Biology approved by the State Government for **Semester IV of XII standard**.

It has been reviewed and revised thoroughly by the subject experts.

The Textbook Board has taken all precautions to make it interesting, advantageous and inerroreous. However, the Board welcomes suggestions from the concerned intellectuals for the qualitative enrichment of this book.

Dr. Bharat Pandit
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FUNDAMENTAL DUTIES

It shall be the duty of every citizen of India :

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers and wide life, and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;

(k) to provide opportunities for education by the parent or the guardian, to his child, or a ward between the age of 6-14 years as the case may be.

* Constitution of India : Section 51-C

INDEX

1

Neural Control and Coordination in Animals

We have studied different physiological processes in animals. Each physiological process requires control and coordination. All functional components are necessary to be controlled are put together so that they work consistently. Thus, coordination is the process through which two or more organs interact and complement the functions of each other. For example, when we do physical exercise, we notice an increase in the rate of breathing, heart beat, flow of blood etc. When we stop physical exercise, we observe that breathing, heart beat, blood flow etc. gradually return to normal. Thus during physical exercise, the activity of various organs of body are coordinated, controlled and integrated jointly by two systems : the nervous system and the endocrine system. In humans all the physiological activities are controlled and coordinated by nervous and endocrine systems. The nervous system provides an organised network of nerves for fast coordination and the endocrine system provides chemical integration through hormones. In this chapter, you will learn about the nervous system of humans the nerve cell, which is the structural and functional unit of the nervous system; generation and conduction of nerve impulse, central nervous system and the physiology of reflex action.

Nervous System

The nervous system is composed of highly specialized cells called neurons (Nerve Cells). Neuron's function is to control various kinds of stimuli by sending nerve impulses which detect, receive and transmit stimuli. In higher organisms, the nervous system performs three basic functions. (1) Receiving sensory stimuli from external and internal environment by nerves to the brain. (2) Processing the stimuli information by brain. (3) Responding to stimuli transmitting impulses from brain to body parts or cells.

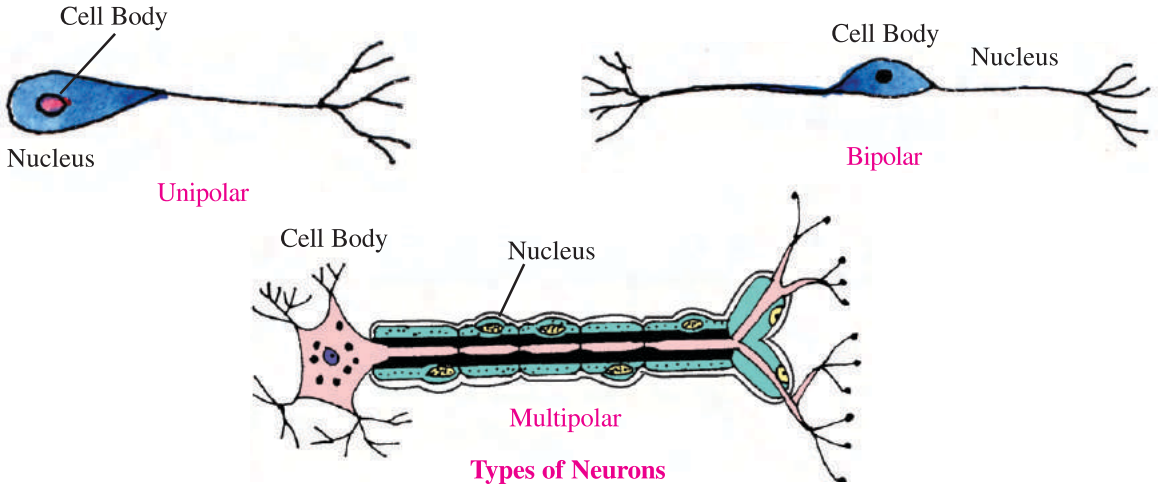
The nervous system of hydra is composed of network of nerve cells. The nervous system is well developed in insects, which consists of brain, ganglia and nervous system. Vertebrates have a highly developed nervous system.

Nerve Cells : Structural and Functional Unit of Nervous System

Structure of Nerve Cells : Nerve cells are the functional units of nervous system. Nerve cells differ in size and shape to a large extent. A microscopic structure of the nerve cell consists of three major parts, namely (1) cell body (2) dendrites and (3) axon. The cell body of nerve cell is called cyton. The cyton may be oval, rounded or star shaped. The cytoplasm of nerve cell is known as neuroplasm, and has a relatively large and spherical nucleus. The neuroplasm has mitochondria, golgibody and small variously shaped basophillic granules, which are known as Nissl's granules. The neurofibrils form a complicated network. Dendrites and axon are two types of processes of nerve cells; cyton contains neurofibrils which arise from peripheral region of neuroplasm and Nissl's granules which surround the nucleus.

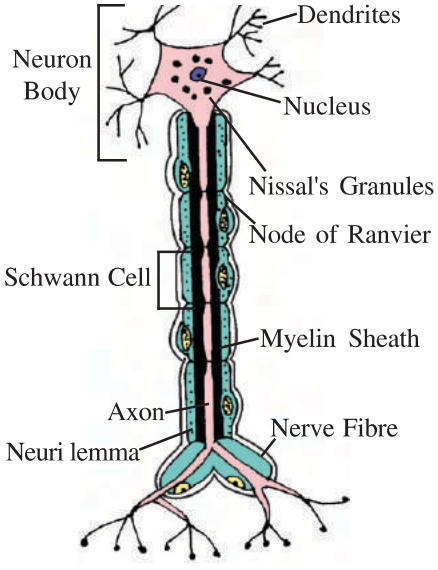
Dendrites are several short, branched and tapering processes. They carry nerve impulses towards the cyton. Axon is a single, cylindrical and very long process of uniform diameter, the distal end of which is branched. Each branch terminates in slight swelling structure called synaptic knob. There is no direct physical contact between terminal branches of an axon of a neuron and the dendrites of the following neuron. This physical gap is called 'synapse'. Synaptic knob which possesses synaptic vesicles produces chemical called neurotransmitters, such as acetylcholine.

On the basis of the number of axon and dendrites, the neurons are divided into three types**.** (1) Unipolar neurons a cell body with one axon only, e.g. found in embryonic stage. (2) Bipolar neurons a neuron with one axon and one dendrites e.g found in retina of eye. (3) Multipolar neurons a neuron with one axon and two or more dendrites, present in the cerebral cortex.



Types of Neurons

Axons are of two types, namely myelinated and non myelinated. The myelinated nerve fibres are surrounded by two sheaths, inner thick medullary sheath and outer neurilemma (sheath of Schwann cells). Medullary sheath is composed of a white, shining, fatty substance called myelin, which may serve as an insulating layer. But in the fibres of the peripheral nerve, myelin is absent at a certain points which are known as nodes of Ranvier. Non myelinated nerve fibers consist of an axis cylinder which has a single sheath, the neurilemma, while medullary sheath is absent. They do not show Ranvier nodes, found in autonomic nerve.



Structure of Nerve Cell

Initiation of the Impulse or Action Potential

Action potential is another name of a nerve impulse, that transmits along membrane. Nerve fibre can become excited in different ways. Touch, smell, chemical changes and pressure etc can induce this. A change in the polarity of nerve fibre is known as action potential. When the Nerve becomes excited, Na^+ channels open up and the electrical excitation generated in plasma membrane. Na^+ ions are actively transported inside through ion channels in plasma membrane. The lower concentration of Na^+ ion inside is responsible for this. Due to a sudden influx of a large amount of Na^+ towards inside, the plasma membrane becomes positively charged on its inner side; it is said to be depolarized. It lasts for a very short period only, of about 0.5 milli second. To be more definite, a nerve impluse is physico-chemical electrical change in the nerve fibre membrane produced by a stimulus at one end and transmitted along the nerve fibre to its termination without any change in abundance. Important features of action potential is that a stimulus must be of a certain minimum intensity, which can produce an action potential.

Conduction of Nerve Impulse throgh Nervefiber

Various sensations are conducted through nerve fibre. The conduction of nerve impulse is an electro-chemical process. Before understanding the process of generation of nerve impulse and its conduction, it is necessary to know the structure of the nerve fibre.

Structure of Nervefiber : As is the case in other cells of the body, the neuroplasm possesses a higher negative charge. Compared to it, there is a higher positive charge on the outer side of plasma membrane. The distribution of positive and negative ions is responsible for this difference in electrical charges. This difference in electrical charges between the inside and the outside of plasma membrane is called the 'membrane potential'. In an unexcited state of nerve fibre, it is called 'resting potential'. It can be measured using electrodes and voltmeter.

For maintenance of this electrical potential and induction of changes in it the structure of plasma membrane is responsible.

Like all plasma membranes, this plasma membrane is also made up of a lipid bilayer. Lipid is impermeable to ions. Special proteins occur in this layer at various places. These act as ion channels and ion pumps. Ion pumps and ion channels play an important role in maintenance and in changing of the electrical potential. Ion pumps are utilized in transport of ions against their concentration gradient. Energy of ATP is used in it. Main ion pump is sodium-potassium pump with this pump Na^+ are expelled out from the cytoplasm and K^+ are drawn into it. For every two Na^+ expelled three K^+ are drawn within. The concentration of K^+ remains high in cytoplasm. Concentration of Na^+ remains high on the outside of cytoplasm. Ion channels are aqueous and made up of protein. They carry out two-way transport of ions selectively. They are permeable to any one kind of ion only. Thus there are sodium channels, potassium channels, chlorine channels and calcium channels. Ion channels can be opened and closed. Chemical and electrical changes are responsible for this.

Resting Potential

When the nerve fibre is at rest, a negative electrical charge occurs on its inner side and a positive electrical charge occurs on its outerside. Such a nerve fibre is called polarized. For this, ions are responsible. Na^+ are concentrated on the outside of plasma membrane whereas K^+ are concentrated on its inside. Sodium-potassium pump is responsible for this. Moreover protien molecules having negative charges on them also occur. They cannot move out of plasma membrane.

This condition is called-resting potential.

Active Potential or Initiation of the Impulse

Nerve fibre can become excited in various ways. Touch, smell, pressure, chemical changes etc can induce this. A change in the polarity of nerve fibre is called active potential.

In the excited region Na^+ channels open up; the electrical excitation generated in plasma membrane in this region is responsible for this. Na^+ ions are poured inside through its ion channels in plasma membrane. The lower concentration of Na^+ on the inside is responsible for this. Moreover, negatively charged proteins are also responsible. Thus, due to a sudden influx of a large number of Na^+ towards the inside, the plasma membrane in this region becomes positively charged on its inner side. This phenomenon is called-depolarization. It is called active potential. It lasts for a very short period i.e. a millionth part of a second. The excited region immediately becomes repolarised.

For repolarization, the process of closure of Na^+ ion channels is responsible. Simultaneously, K^+ ion channels open up and K^+ ions go out of the plasma membrane.

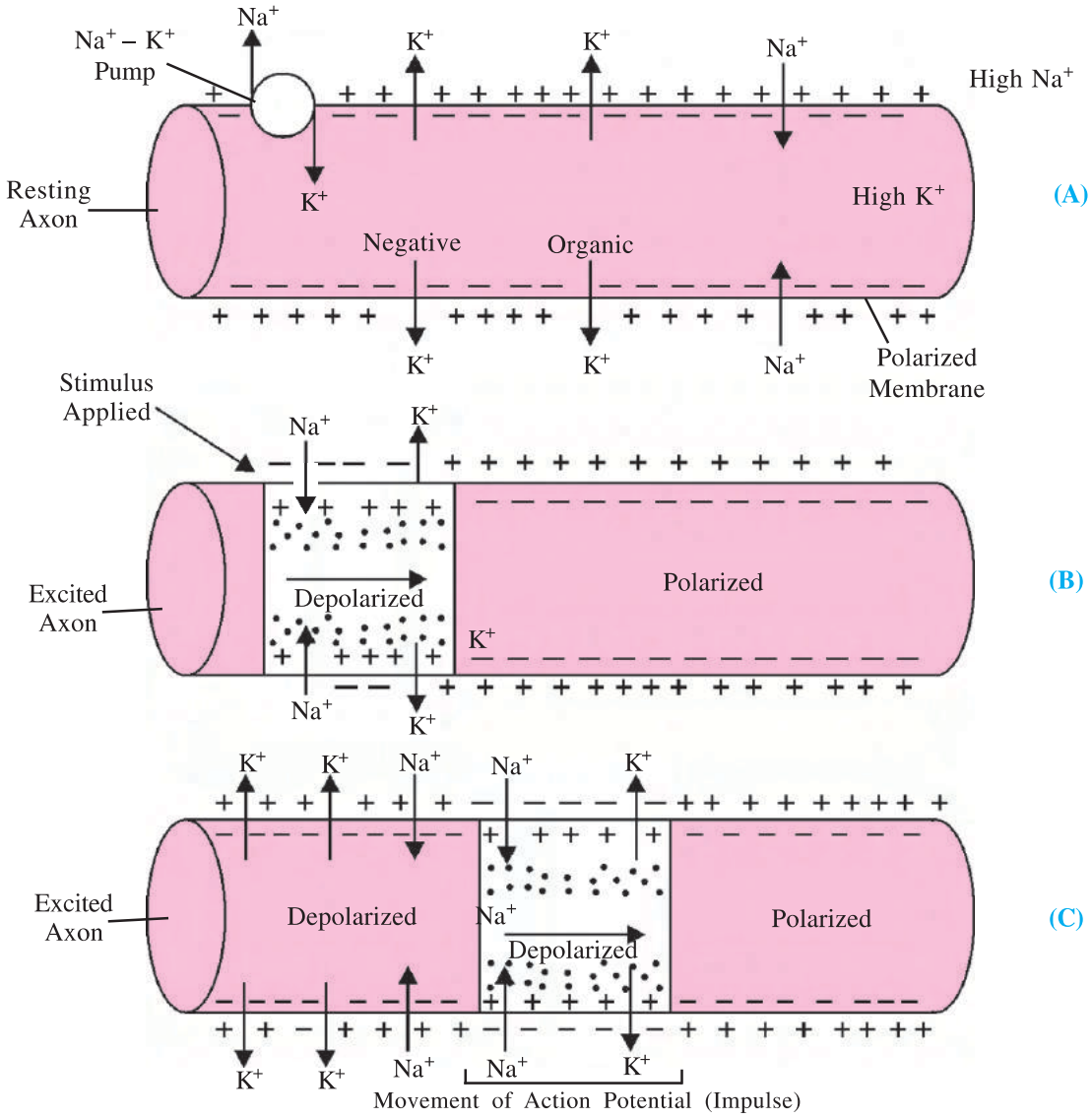
At the end of this phase, a difference in concentration of positive ions on two sides of plasma membrane is generated. Concentration of Na^+ increases on inside and that of K^+ increases on the outside. The activity of sodium-potassium pump removes this imbalance.

Conduction of Nerve Impulse

The nerve impulse generated as described above is now conducted along one direction. This process is self-induced because when the membrane electric potential is reduced in the nearby region, the ion-channels in the region automatically open up. Thus sequential depolarization and

repolarization progress and the nerve impulse moves along in that direction. To protect the impulse weakening through diffusion all around, nerve fibre is surrounded by a medullary layer. This conduction is very swift (100 meters per second).

In vertebrate animals, the medullary layer is discontinuous in the medullated nerve fibre. The regions with lesser medullary layer are known as node of Ranvier. In these nerve fibres, active potential, after it is generated, does not move in cyclic waves gradually. It moves directly from one Ranvier's node to the next node. Such a conduction in known as 'Saltatory Conduction'.

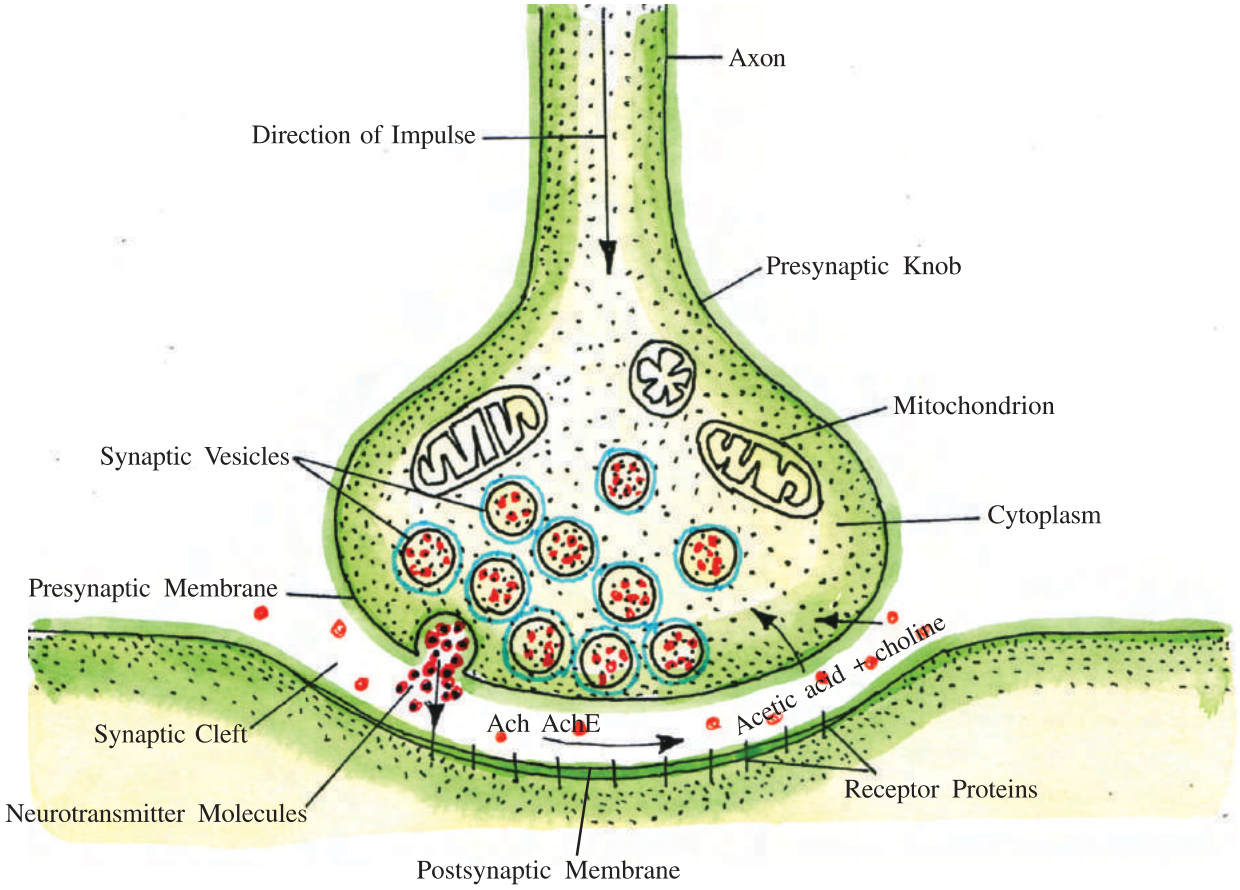


Conduction of Impulse through Nerve

Transmission of Impulse at a Synapse

Synapse is the close functional contact between axon of one neuron and cyton or dendrites of successive neuron with a cleft of about 200A° length. When a nerve impulse reaches the synapse, a chemical substance Acetylcholine (Ach) is liberated. This substance is responsible for the conduction of impulse through synpase. When impulse reaches the synaptic knob of the axon, it depolarises the presynaptic membrane, and thus calcium ions permeability increases. These calcium ions from the synaptic cleft enter into synaptic knob; this rise of calcium in cytoplasm releases a neurotransmitter, acetylcholine. This substance diffuses into the cleft and binds with protein receptor molecules which acts as the acetylcholine receptors, on the post synaptic membrane; now the post synaptic membrane allows sodium ions to enter the cell. This will cause the depolarization and generate new action potential in the post synaptic membrane. Now the nerve impulse passes to next neuron.

Acetylcholine is inactivated by acetycholine esterase (AchE) enzyme present in cleft and post synaptic membrane. Now, acetylcholine is hydrolysed in the presence of above mentioned enzyme into choline and acetic acid, which are reabsorbed into the synaptic knob where they are resynthesised into acetylcholine in presence of ATP. In synapse, transmission of impulse, arises in nerve direction, is not fixed because dendrite cannot secrete neurotransmitter.



Ach = Acetylcholine, AchE = Acetylcholine esterase
Transmission of Nerve Impulse at a Synapse

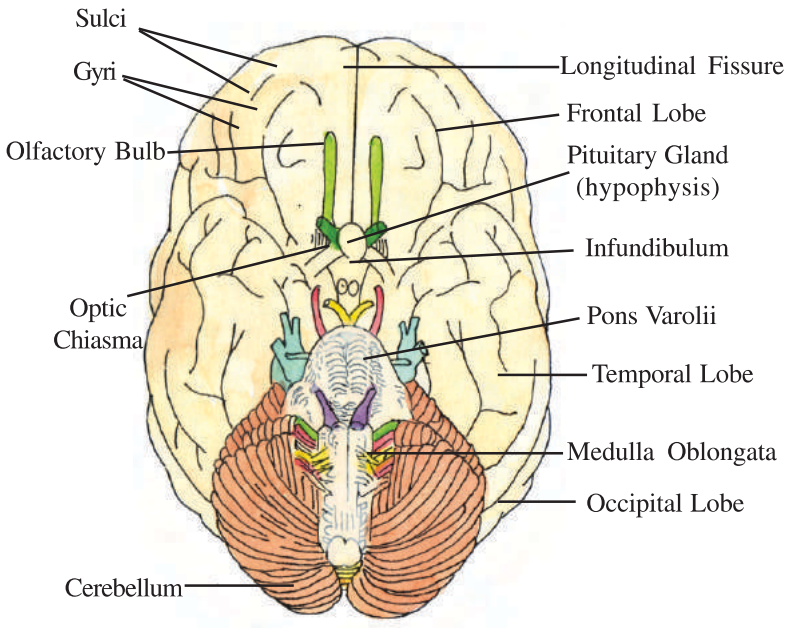
Human Nervous System : The human nervous system is divided into two parts (i) the central nervous system (CNS) (ii) the peripheral nervous system (PNS). Central nervous system consists of brain and spinal cord and it is the centre of information processing and control. The PNS comprises of cranial nerves which arise from brain and spinal nerves which arise from the spinal cord.

The nerve fibers of the PNS are of two types (1) afferent or sensory nerve fibres : These fibres transmit nerve impulse from the tissue/organs to central nervous system (CNS) (2) efferent or motor nerve fibres : These fibres conduct regulatory impulses from the CNS to the effector organs such as peripheral glands and muscles.

The PNS is divided into two divisions known as somatic nervous system and autonomic nervous system. The somatic nervous system transmits impulses from CNS to skeletal muscles. The autonomic nervous system relays impulses from the CNS to the involuntary organs and nonstriated muscles of the body. The autonomic nervous system is further divided into sympathetic nervous system and parasympathetic nervous system.

Central Nervous System (CNS)

The central nervous system consists of the brain and the spinal cord. These structures are covered by three membranes which are known as meninges. The inner membrane is pia matter which is a thin highly vascular membrane. The middle membrane, arachnoid matter, which is a thin transparent membrane, but non vascular. The outer membrane, dura matter is the thickest and toughest membrane, which covers the brain. It is also adherent to the inner surface of cranial bones by fibrous and vascular processes. The CNS has two distinct regions (1) white matter is white in colour and consists of myelinated fibres (2) gray matter consists of cyton bodies along with their dendrites and axon.



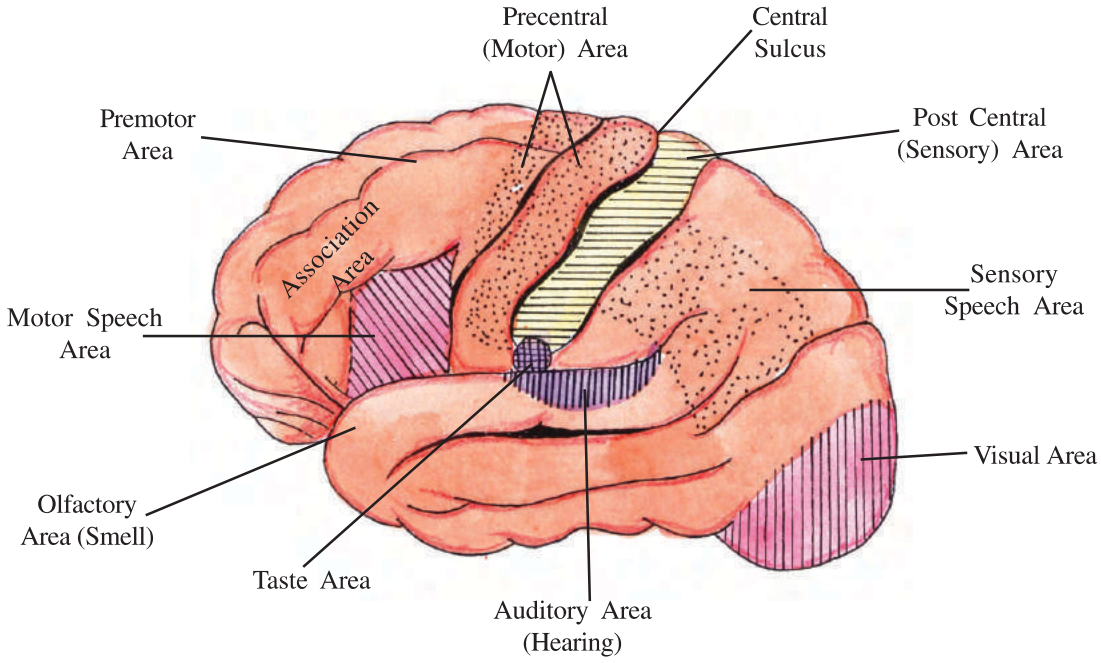
Ventral View of Human Brain

The brain is the central information analysing organ of body. It acts as the command and controlling system and functions as an integrated unit. It controls the voluntary movements and function of involuntary organs like heart, lungs, and kidneys as well as balance of the body, hunger and thirst and thermoregulation and activities of many endocrine glands. It is the site for processing of hearing, vision, memory, emotion, thoughts and finally intelligence. The brain can be divided into three major parts (1) fore brain (2) mid brain and (3) hind brain.

The weight of brain is about 1200 to 1400 grams, and number of neurons is about 100 billion. Fore brain forms greater part of the brain. It is formed of three regions, olfactory lobes, cerebral hemispheres or cerebrum and diencephalon.

Fore brain : The olfactory lobes present in a pair are small, club shaped, solid and separated from each other. They are visible only in the ventral view of the brain because they are fully covered by cerebral hemisphere. Cerebral hemispheres (cerebrum) are the largest parts of the brain and they are separated from each other by a longitudinal cerebral fissure. The hemispheres are connected by a large bundle of myelinated fibres, known as corpus callosum.

The outer surface of cerebrum is known as the cerebral cortex. The surface of the cortex is highly folded to increase the area for accommodating more nerve cells. The folds are called gyri and the depression between them are known as sulci. Three wide and deep sulci are termed as fissures, which divide each hemisphere into four lobes. Anterior frontal lobe controls voluntary movements The premotor area frontal lobe controls involuntary movements and autonomic nervous system. The associated area of the frontal lobe is concerned with memory, reasoning, learning and creative ability. Middle parietal lobe is associated touch, cold, temperature and pain. The posterior occipital lobe has visual and auditory areas which are centres for hearing and sight. The lateral temporal lobe is concerned with sound, smell, emotion and memory. Each cerebral hemisphere encloses a cavity called lateral ventricle, which is closed in front but open behind into third ventricle of diencephalon by a aperture known as foramen of monro.

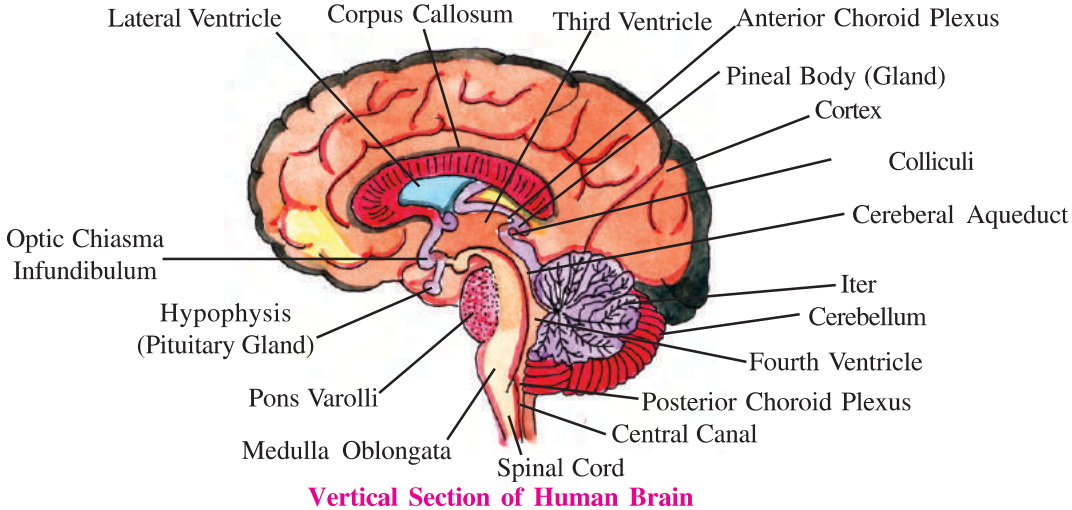


A Cerebral Hemisphere showing the Functional Areas

Diencephalon

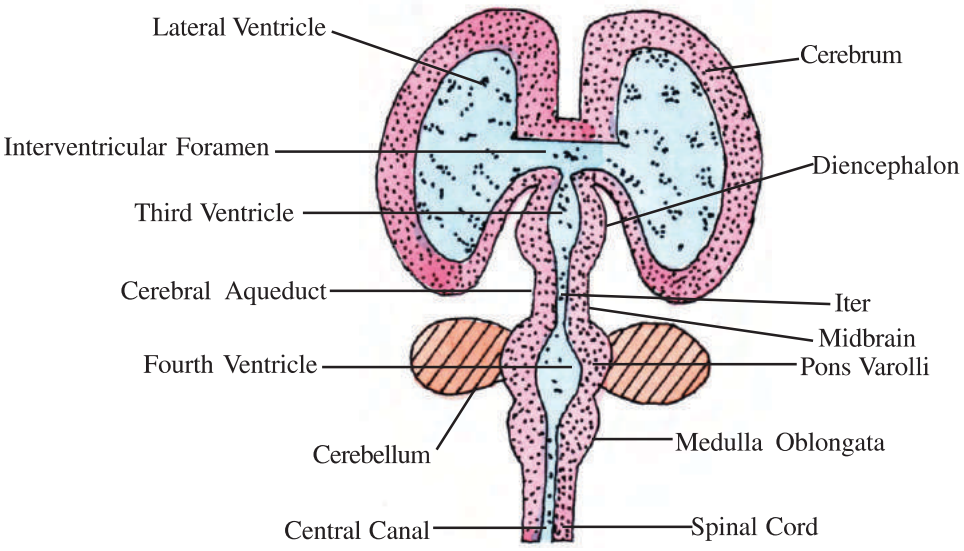
Diencephalon encloses a cavity of the third ventricle, the roof of the cavity is known as the epithalamus, the right and left sides are known as thalamus and floor as the hypothalamus. Epithalamus is not formed of nervous tissues, but it is mode up of blood vessels possessing folds. Which form anterior choroid plexus. Just behind this the epithalamus forms a short stalk, the pineal stalk, and at its tip is a rounded body, known as pineal body is present. Pineal body secretes hormone melatonin. The hypothalamus is visible in the ventral view of the brain. The optic nerve orginating from the eyes forms a crossing, the optic chiasma in front of the hypothalamus. The hypothalamus is small, possessing 4 grams weight. The pituitary is attached to the hypothalamus by a stalk called the infundibulum. The diencephalon encloses a cavity termed as third ventricle which communicates anteriorly with the lateral ventricle of cerebrum by the foramen of monro and posteriorly with the fourth ventricle of medulla oblongata by a narrow passage called the iter, which is present in mid brain.

Mid Brain : The mid brain is very small and it consists of four small lobes, the coropora quadrigemina. The superior pair is called superior colliculi which receives impulses from the eyes and muscles of head and controls visual reflexes. The inferior pair is termed as inferior colliculi, which receives impulses from the ears and the muscles of the head and controls the auditory reflexes.



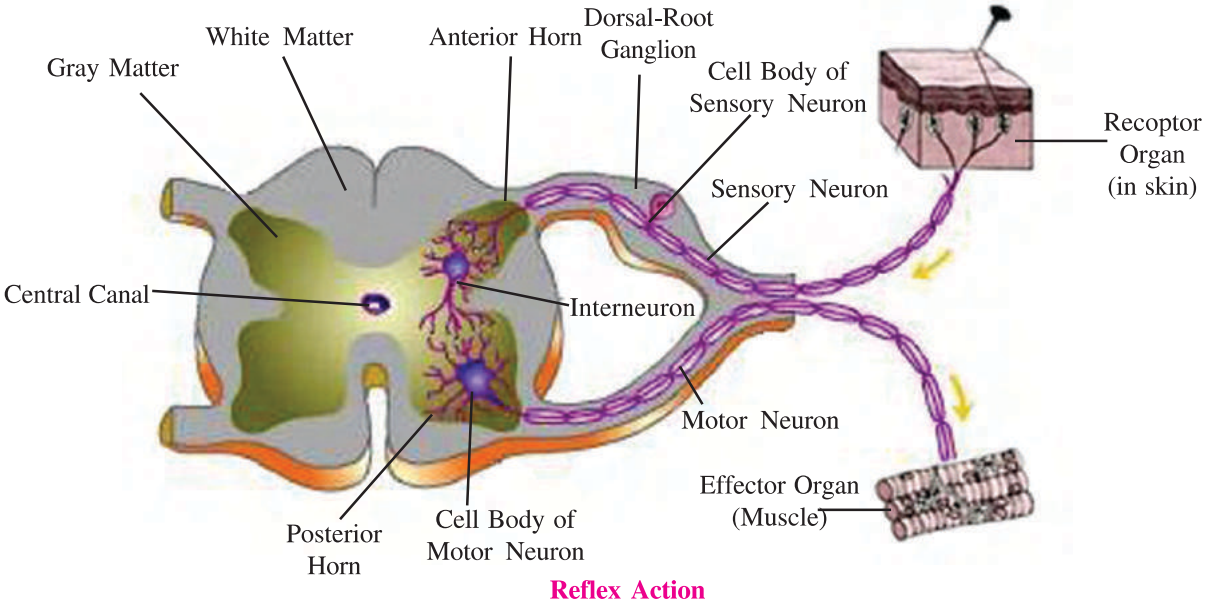
Vertical Section of Human Brain

Hind Brain : It consists of cerebellum, pons varolli and medulla oblongata. The cerebellum is very large and well developed. It consists of two large lateral parts, the cerebral hemispheres, and a small vermis. The cerebellum is solid, and has a branching tree like structure of white matter surrounded by a shealth of greatly folded grey matter. The cerebellum controls muscular activities like running, talking and typing. Pons varolii is an oval mass which consists of mainly nerve fibres, and bridges the cerebellar hemispheres and medulla oblongata; it relays impulses between medulla oblongata, cerebellar hemi-spheres and between the cerebrum and cerebellum. Medulla oblongata is pyramid shapedif is the posterior most part of the brain that connects the spinal cords. It encloses a cavity, the fourth ventricle. This ventricle has a very thin non nervous, epithelial, folded roof known as posterior choroid plexus. The medulla oblongata contains centres for cardiac activities, respiration and vasoconstrictor that control heart beat, breathing, blood pressure, salivation, swallowing, vomiting, sneezing and coughing and other involuntary functions



Schematic Representation of the Ventricles of Human Brain

Reflex Action : Reflex action is a monotonous or unchangeable response to a stimulus. An involuntry response to stimulus given by reflex center of brain/spinal cord without knowledge of the voluntary centers of brain is called reflex action. Animals show two types of actions, voluntary and involuntary. Voluntary action is performed by the animal according its will. In this action, the animal uses its own choice, for example, on seeing a leopard on the way, one may run away or call for help to save one self. An involuntary action is performed by the animal very quickly and the it takes place without any choice and willingness of animal. For example, the foot or hand is withdrawn when it suddenly touch a hot plate. These involuntary actions are known as reflex actions. The other common examples of reflex action in man are blinking of eyes, coughing, sneezing, yawning, knee-jerk, movement of diaphragm during respiration. In reflex, action the spinal cord is also involved for quick response to stimulus, such reflexes are known as spinal reflexes. Some reflexes which involve the brain, are termed as cerebral reflexes, for secretion excitement of the saliva after seeing palatable tasty food. These reflex actions are in our knowledge but there are some reflex as which go on without our knowledge, for example heart beating and paristalsis of the alimentary canal . These reflex actions are controlled by autonomic nervous system.



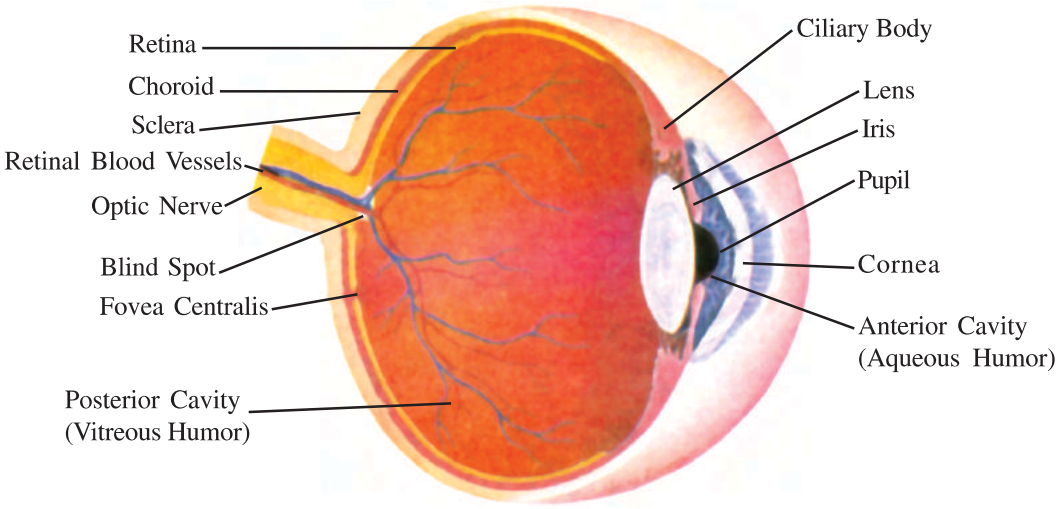
Reflex Action

Reflex Arc : The reflex arc is the nerve chain between a receptor and an effector organ a receptor of the neurons receives a stimulus. An afferent nerve brings the sensory impulse from the receptor to the CNS. The neuron of the spinal cord or brain analyses and interprets the sensory impulse and set up motor impulse. Spinal cord and brain act as modulators. The motor nerve carries the impulse from the brain or spinal cord to the effector organs. An effector organs may be a muscle or gland which responds to impulse instruction received from the modulator. In reflex arc, nerve impulse can travel only in a single direction. Importance of reflex action is that it enables the animal to respond quickly to harmful stimuli and saves the animal from harmful effect.

Conditioned Acquired Reflexes : The reflexes described above are unconditional reflexes and are inborn (inherited), while conditioned reflexes are acquired during life. They are behaviour of an animal gradually developed by training and experience. This reflexes are shown only by trained animals. The conditioned reflexes can be discontinued if the specific stimulus is lost it not transmitted through heredity. Thus conditioned reflexes play a significant role in learning. Examples of condition reflexes are habits, likes and dislikes, prejudices and interests, typing, riding a bicycle, knitting etc.

Sensory Reception and Processing : There are climatic changes in the environment. Have you ever thought how you feel ? How you see an object with its colour ? How you hear a sound ? The sensory organs detect changes in the environment and send impulses to the CNS, where all the impulses are processed and analysed. How can you understand the environment ? In this section, you will learn about the structure and functions of eye and ear.

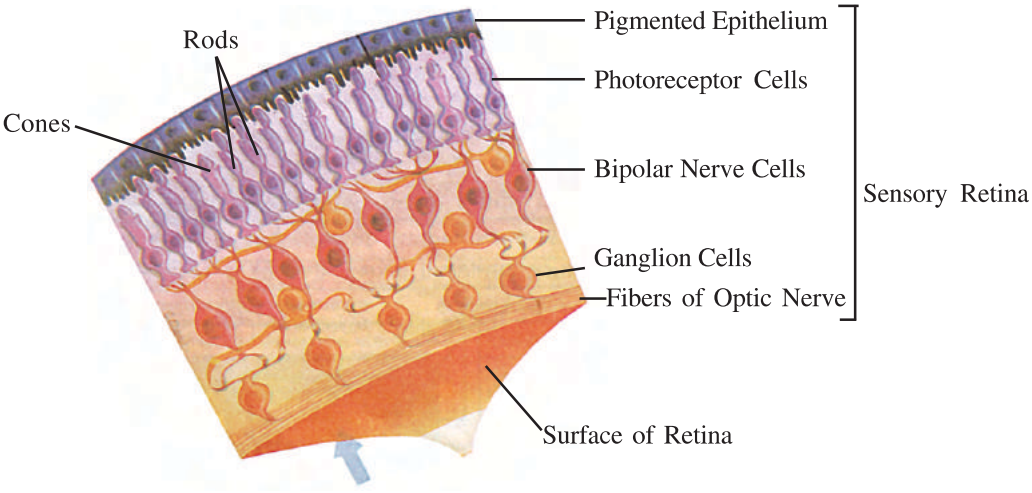
Eye Structure and Mechanism : The eyes are located in a deep protective bony cavities, known as orbits. The eye is hollow spherical in shape, about 2.5 cm in diameter and its weight is about 6 to 8 gms. The eye has two parts wall and contents. The wall of the eye is composed of three layers, outer fibrous sclera middle choroid and inner retina. The fibrous layer consists of sclera and cornea. Sclera forms the posterior 5/6th part of the collagen fibres while cornea forms, while 1/6th part made up of connective tissue and lacks blood vessels. Conjunctiva is thin, transparent and composed of stratified epithelium, which cornea externally covers and the exposed part of sclera. The choroid is made up of iris and ciliary body of two regions. Choroid is composed of connective tissue and blood vessels. Blood vessels of the choroid nourish the retina. Iris is a circular shelf like diaphragm and perforated in the centre by an aperture termed as pupil. The iris works like the diaphragm of a camera. Just behind the iris, the choroid is thickened to form ciliary body, which contains circular and radial muscle fibres. Retina is a delicate layer of optic part. It composed of four layers. (1) Pigmented epithelium. (2) Layer of photoreceptor cell. (3) Layer of dipolar nerve cells. (4) Layer of ganglion cells. Pigmented epithelium– It contain pigmented cells. Layer of photoreceptor cells, it contain rod cells and cone cells. Name given of these cell by their shape. Rod cells consist of purplish pigments termed as rhodopsin.



Structure of Eye

Rod cells function at night and in dimlight. In bright light rhodopsin splits in to scotopsin and retinal through a process called bleaching. Splitting of rhodopsin depolarizes the rod cells, and that releases a neurotransmitter which sends the nerve impulse to the optic nerve via bipolar and ganglion cells. In the dark, rhodopsin is resynthesized from retinal and scotopsin. Now rhodopsin becomes functional.

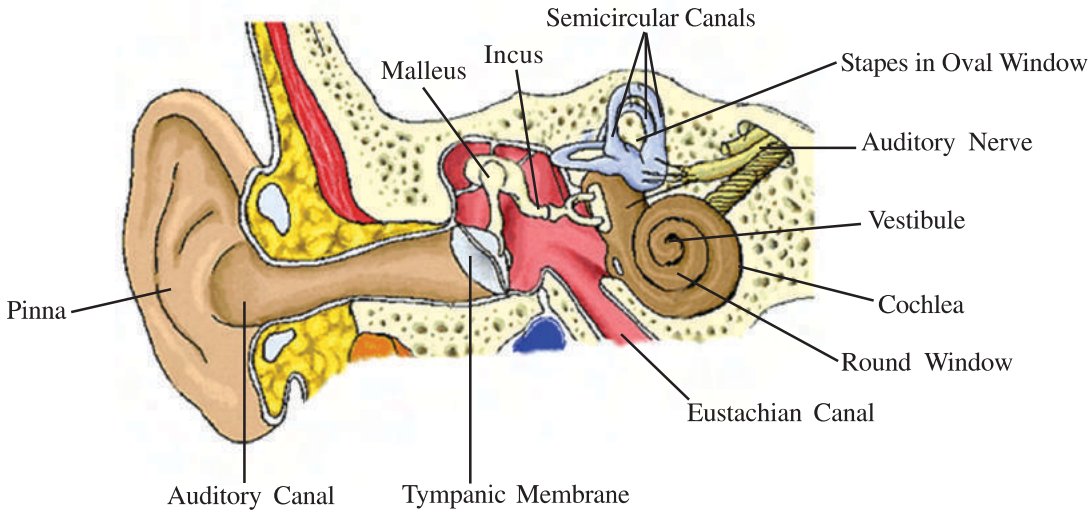
Cone cells contains iodopsin pigments. Cone cells function in day light and produce complete images and give colour vision. The cone cells are less sensitive as compared to rod cells. In the human eye, three types of cones are found which possess their own photopigment, each absorbing light rays of different wave-lengths. Erythrolabe pigment is sensitive to red light, chlorolabe pigment to green and cynolabe pigment to blue light. Lack of one or more types of cone cells causes colour blindness. Under the layer of rod cells and cone cells, a layer of bipolar nerve cells and a layer of ganglion cells are arranged. On the retina there is a small depression known as fovea, which has only cone cells. The retina from where optic nerves starts is known as blind spot. It lacks the receptor cells and is insensitive to light. The Lens is solid, elastic, transparent, biconvex, and consists of laminated fibrous tissue which is enclosed in thin elastic membrane known as lens capsule. The lens focuses light on retina. The lens divides eyeball cavity into two chambers. The anterior small aqueous chamber and the posterior large vitreous chamber. Aqueous chamber is filled with a watery clear fluid, the aqueous humor, which is secreted by ciliary processes of ciliary body. The vitreous chamber is full of transparent fluid thick the vitreous humour which is secreted by retina during development of the eye.



Ultra Structure of Retina

Mechanism of Vision : The light rays focused on the retina generate impulses on rods and cones. In the eyes scotopsin and retinal photopigments are present. Light influences dissociation of retinal and scotopsin, effecting changes in the structure of scotopsin. It produces membrane permeability changes. Due to this, potential differences are generated in the photoreceptor cells. This produces a signal that generates impulses in the ganglion cells through the bipolar cells. These impulses are carried by the optic nerve to visual area of the brain, where the impulses are analysed and the image formed on the retina is identified based on earlier memory and knowledge.

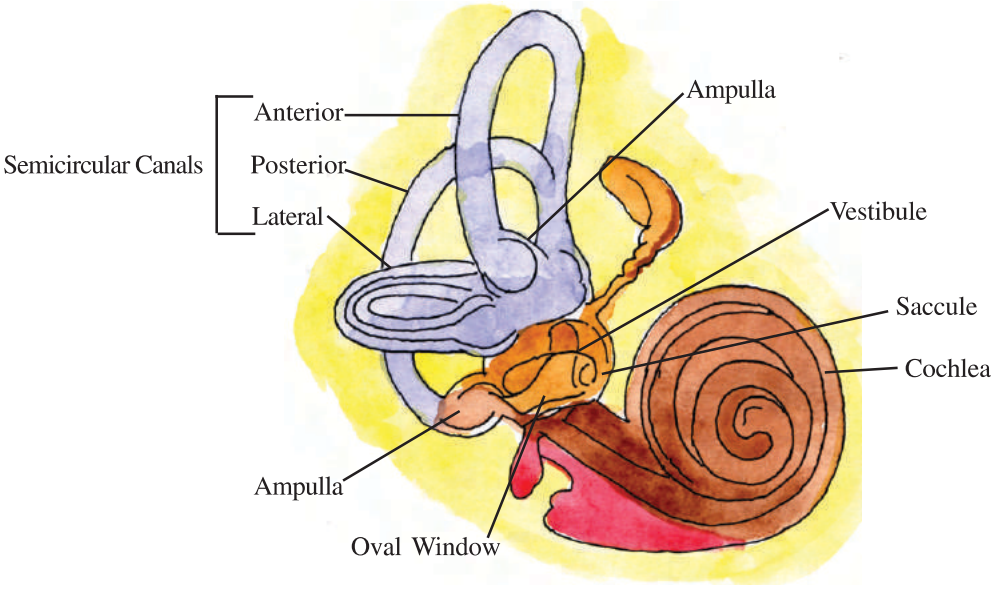
Structure of Ear : The human ear is made up of three major parts, external ear, middle ear and internal ear. The external ear consists of pinna and external auditory meatus (canal). Pinna is an oval, some what funnel-shaped, and the stiff outer ridge is known as helix, while its flexible lower lobe is known as lobule. The external auditory meatus is am S-shaped tube which spreads inwards up to the tympanic membrane. The upper part of meatus bears hairs which prevents entry of dust particles. Its inner parts have wax glands. It secretes a brownish fatty substance known as earwax. It protects and lubricates the lining of canal. Tympanic membrane is a thin, oval membrane made up of connective tissue with fibres, covered with skin outside and muscle membrane inside. Inner wall of the tympanic cavity has two apertures. The upper aperture is known as fenestra ovalis and the lower is called the fenestra rotunda. Both these apertures are covered by membrane. Middle ear contains three small, movable articulated bones, the ear ossicles. Hammer shaped ossicle is called the malleus, which is attached to tympanic membrane. Inner ossicle known as stapes, is stirrup-shaped. The middle anvil-shaped ossicle is known as incus, It is externally joined to the malleus and internally to the stapes. The function of ear ossicles is to transmit the vibration from the tympanic membrane to the internal ear and amplify vibration 20 times.



Structure of Ear

Internal ear is an irregular, delicate and complicated organ, he the know as membranous labyrinth which is enclosed in a bony labyrinth. The space between these two is filled with fluid called perilymph. The membranous labyrinth is also filled by another fluid, the endolymph. The membranous labyrinth consists of 3 parts (1) Vestibule, (2) semicircular ducts and (3) cochlear duct.

(1) Vestibule : is a sac like part and consists of 2 chambers, the larger utricle and smaller saccule, which leads into cochlear duct.

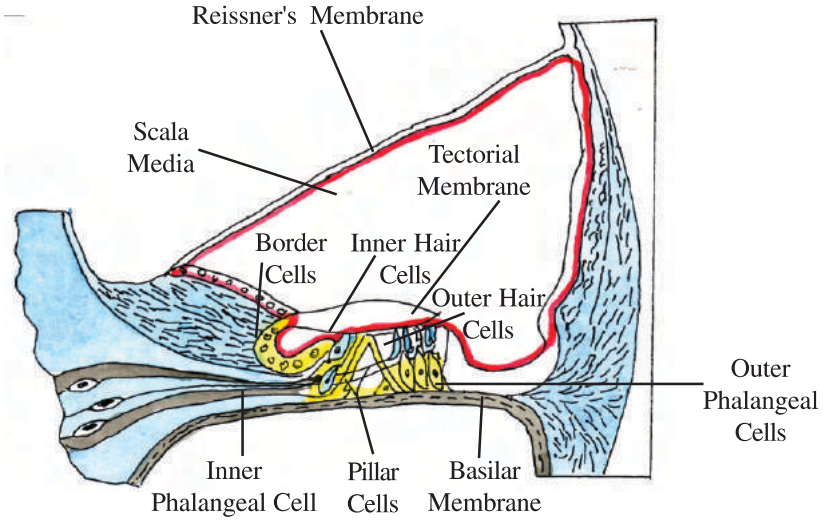


Inner Ear

Two sensory spots are present in macula of utricle and macula of saccule They are located in the wall of utricle and saccule. A macula consists of hair cells and supporting cells. The supporting cells contain many minute particles known as earstones or otoliths, composed of calcium carbonate and protein.

(2) Semicircular Ducts : Three semi circular ducts are aranged on outerior, posterior and lateral sides. Each duct opens in to the utricle on both ends. One end of each duct is swollen to form ampulla. Sensory spot is found on each ampulla and is known as crista its function is to maintain equilibrium.

(3) Cochlear Duct : It is a spirally coiled tube, resembling a shell of snail. It is a part of the bony labyrinth. Which encloses the cochlear duct together termed as the cochlea. Cochlea has three longitudinal chambers, known as scalae, which are separated from one another by a thin membrane. The middle chamber is termed as scala media, which consists of organ of corti. The roof of scala media is called as Reissner's membrane and floor is term as basilar membrane. Organ of corti is an organ of hearing which consists of receptor cells hair cells and supporting cells. The hair cells bear hair at their free surface and at the basal region synaps has contact with dendrites of nerve cells. The tips of hair are embedded in a tectorial membrane. supporting cells are of two types, longer pillar cells and shorter phalangeal cells.



T. S. Organ of Corti

Mechanism of Hearing

The sound waves reach to the tympanic membrane through the way of external ear. The vibrations of the tympanic membrane pass through ear ossicles to fenestra ovalis present in the bony labyrinth. From here the vibration pass to the basilar membrane of cochlear canal, and then travel on the other side of the canal to Reissner's membrane. These vibrations cause a movement of the endolymph. These movements are recognised by the sensory cells found in the organ of corti. These vibratory movements are converted into nerve impulses. These impulses are transmitted by nerve fibers via auditory nerves to the auditory area of cerebrum, where the impulses are analysed and sound is recognised.

Disorders of the Nervous System

Multiple sclerosis : A chronic disease of the nervous system that affects young and middle aged person. The mylin sheaths surrounding the nerves in the brain and spinal cord are damaged, which affects the function of the nerves. Symptoms include shaky movement of the limbs rapid involuntary movements of the eyes, defects in speech, paralysis in greater or less a degree, finally causing death.

Parkinson's disease : This disease is associated with deficiency of the neurotransmitter dopamine and aging. Symptoms include tremor, rigidity and lack of spontaneous movements.

Sciatica : Usually caused by degeneration of intervertebral disc. Main cause of sciatica is 'slipped' out of intervertebral disc. There is a continuous pain in back, thigh and leg.

SUMMARY

In human all the Physiological activities are controlled and coordinated by nervous and endocrine systems. The nerous system is composed of highly specialised nerve cells, which exercise body control by transmitting nervous impulses. The nervous system of Hydra is composed of a network of nerve cells. The nerve cell consists of cellbody, dendrites and axon. On the basis of the number of axon and dendrite, the neurons are divided into three types, multipolar, bipolar and unipolar. Axons are of two types, myelinated and non myelinated. Action potential is another name of nerve impluse. A change in the polarity of nerve fibers is known as action potential. Active transport of sodium ions from axoplasm into the interstitial fluid is known as sodium pump. When stimulus applied on membrane of nerve fibre. Then it becomes depolarised, the spread of electric current along membrane is known as depolarization wave or nerve impluse. When a nerve impluse reaches the synapse a chemical substace Ach is liberated which is responsible for the conduction of impulse. Human nervous system is divided into CNS and PNS.

The CNS consists of the brain and spinal cord. The brain is divided into fore brain, midbrain and hind brain. Forebrain consists of olfactory lobes, cerebral hemispheres and diencephalon The cerebral hemispheres are the largest parts of brain and are separated from each other by a longitudinal cerebral fissure and connected by the corpus callosum. Hypothalamus is a very important part of fore brain. The mid brain is a very small part, and consists of four small lobes, the corpora quadrigemina Hind brain consists of cerebellum, pons varoli and medulla oblongata.

Reflex action is a monotonous response to a stimulus. Reflex actions are of two types, voluntary and involuntary. Reflex arc is the nerve chain between a receptor and an effector organ. Reflexes are of two type conditional and unconditional.

The wall of the eye is composed of three layers. They are sclera, choroid and retina. Retina contains two types of photoreceptor cells, namely rods and cones. The light enters through cornea, the lens and images are formed on the retina. The ear is divided into external ear, the middle ear and internal ear. The middle ear contains three small ear ossicles are called malleus incus and stapes. Internal ear is a irregular, delicate and complicated organ. Membranous labyrinth is enclosed in bony labyrinth. Membranous labyrinth is filled with fluid, the endolymph. The membranous labyrinth is formed of 3 parts, vestibule, semicircular duct and cochlear duct. In the structure of organ of cortia group of hair cells is present which acts as auditory receptor and found on the basilar membrane. The vibratory movements are converted into nerve impulses, which are transmitted via auditory nerve to the auditory area of cerebrum, where the impulse are analysed and sound is recognised.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

(1) From which the nerve impulses for hearing originate.

(a) Ear Ossicles ◯ (b) Cochlea ◯

(c) Auditory Nerve ◯ (d) Tympanic Membrane ◯

(2) In the resting stage of nerve, which is ture?

(a) Na^+ are pumped in and K^+ pumped out ◯

(b) Na^+ are pumped out and K^+ pumped in ◯

(c) There is no Na^+ or K^+ pump ◯

(d) None of these ◯

(3) Acetylcholine helps in

(a) Synaptic Transmission ◯ (b) Synaptic Delay ◯

(c) Membrane Permeability ◯ (d) None of these ◯

(4) Which ion produces action potential in a nerve fibre ?

(a) K^+ ◯ (b) Cl^- ◯ (c) Na^+ ◯ (d) Ca^{++} ◯

(5) Process of transmission of nerve impulse is

(a) Chemical ◯ (b) Physical ◯ (c) Biological ◯ (d) Mechanical ◯

(6) Which of the following pairs of elements/ions are required for conduction of nerve impulse?

(a) Na^+ and K^+ ◯ (b) Mg^{2+} and K^+ ◯

(c) Na^+ and Mg^{2+} ◯ (d) Ca^{2+} and Mg^{2+} ◯

(7) Organ of corti is found in

(a) Internal Ear ◯ (b) External Ear ◯

(c) Middle Ear ◯ (d) None these ◯

(8) Cerebellum is important in controlling

(a) Muscle Strength ◯ (b) Stretch Reflexes ◯

(c) Middle Ear ◯ (d) None of these ◯

(9) What is the location of structure which maintains the balance in human ?

(a) Outer Ear ◯ (b) Middle Ear ◯

(c) Inner Ear ◯ (d) Eustachian Tube ◯

(11) Node of Ranvier is seen in.....

(a) Cyton ◯ (b) Axon ◯ (c) Dendrite ◯ (d) Synape ◯

2. Answer the following questions in shorts :

(1) Name the fluid which is found in the space between pia mater and arachoid mater.

(2) Name the parts which constitute central nervous system (CNS).

(3) What is the origin of acetylcholine ?

(4) Where are the bipolar cells present in the human body ?

(5) Which is the principle mineral cation in the extracellular fluid ?

(6) Name the part of the brain which functions as endocrine gland.

(7) What is reflex action ?

3. Answer the following questions in detail :

(1) What is an impulse ? describe the physiology of impulse conduction.

(2) Describe the mechanism of hearing

(3) Describe the structure of internal ear.

(4) Describe the structure of forebrain of human.

(5) Write a brief note on synapse.

(6) How a nerve impulse is transmitted across a synaptic cleft ?

2

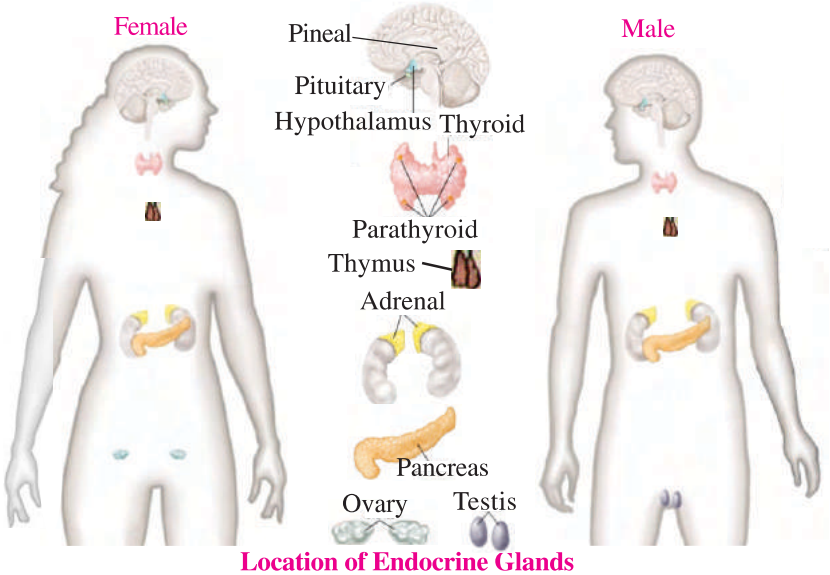
Chemical Coordination and Control

In the previous chapter, we have studied that the nervous system provides rapid coordination among organs. The nervous system controls speedily but its effects are very short lived. For example the nerve impulse transmits rapidly in milliseconds along the nerves to skeletal muscles, which respond immediately. But for the regulation of continuous cellular functions, control and coordination are done by endocrine system. Endocrine system is meant for internal regulation and communication of the human body. In this chapter we will study about human endocrine glands and their hormones and mechanism of hormones.

Endocrine Glands and Hormones

Endocrine glands are ductless and secrete the chemicals termed as hormones into the surrounding blood, which are then transported to the site of action, located away from the site of secretion. Hormones are special types of chemical messengers secreted by endocrine cells in one part of the body and influence the activity of various organs of another part of the body. They are effective in minute quantities to stimulate or inhibit specific physiological processes of the body. Hypothalamus, pituitary, pineal, thyroid, parathyroid, thymus, adrenal, pancreas, testis and ovary are the organised endocrine glands. In addition to these, hormones are secreted by some other organs, like heart, kidney and gastrointestinal tract.

Hypothalamus is the base of the diencephalon, a part of the forebrain. The hypothalamus is composed of nervous tissue and it regulates a wide range of body functions. Hypothalamus is connected with the anterior lobe of the pituitary gland by hypophysial portal vessels and with the posterior lobe of the gland by axon of its neurons. It contains several groups of neurosecretory cells which when stimulated, release hormones termed as neurohormones. These hormones regulate the synthesis and secretion of the pituitary hormones. Hypothalamus produces two types of hormones.

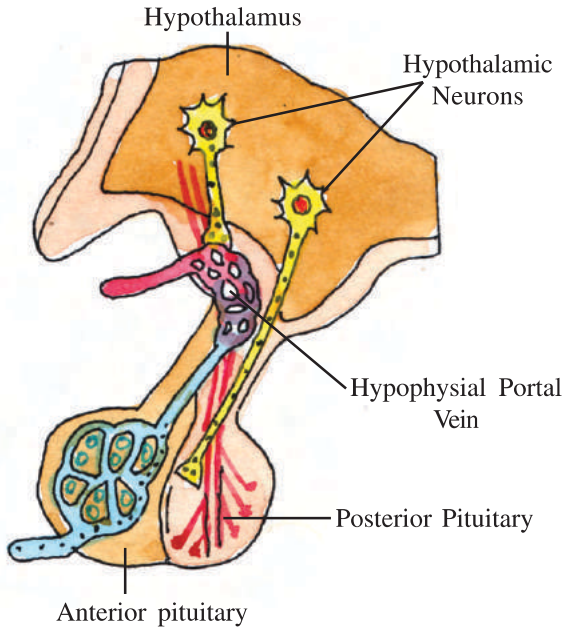


Location of Endocrine Glands

The releasing hormones (RH) stimulate secretion of pituitary hormones and the inhibiting hormones (IH) inhibit secretion of pituitary hormones. Growth hormones releasing hormone or somatotropic releasing hormone (GH.RH or STH.RH), stimulate the anterior pituitary to release growth hormone (GH) or somatotropin. Growth hormone releasing inhibiting hormone (GH-RIH), inhibits the secretion of growth hormone from the anterior pituitary.

Pituitary Gland

The pituitary gland is located just below the hypothalamus. It is situated in a depression of the sphenoid bone of the skull called sella turcica and attached to hypothalamus by stalk or infundibulum. Pituitary gland is divided anatomically into adenohypophysis and neurohypophysis (posterior lobe). Adenohypophysis consists of two parts, commonly known as anterior pituitary and pars intermedia. The anterior pituitary gland produces following hormones. (1) Growth Hormone (GH) or somatotropic hormone (STH) stimulates growth and development of all tissues by increasing cell division and protein synthesis. Dwarfism is caused by low secretion of GH. While Gigantism caused by over secretion of GH. It stimulates excess growth and abnormal height in childhood. In adult stage due of excess secretion of growth hormone, bones of lower jaw and libs becomes abnormally large which develops Acromegaly.



Pituitary and its Relationship with Hypothalamus

(2) Prolactin (PH) stimulates the growth of mammary gland and the secretion of milk after delivery. (3) Thyroid Stimulating Hormone (TSH) stimulates the thyroid and production of thyroid hormones. (4) Adrenocortico Trophic Hormone (ACTH) stimulates adrenal cortex to secrete glucocorticoid and mineralocorticoid hormones. (5) Leuteinising Hormone (LH) in male induces sex hormones-androgens (testosterone) which make the male reproductive system fully grown and functional. The (6) Follicle Stimulating Hormone (FSH) and androgen in male regulate spermatogenesis. In female LH causes ovulation of fully mature follicle (grafin follicles) and forms corpus luteum in the empty ovarian follicle.

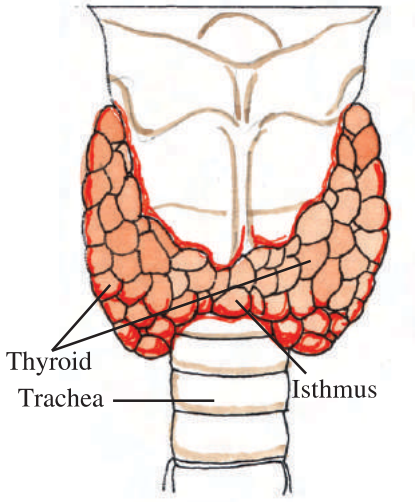
Follicle stimulating hormone (FSH) and Luteinising hormone are together termed as Gonadotrophic Hormones (GTHs). Intermediate lobe of pituitary secretes a hormones named Melanocyte Stimulating Hormone (MSH) which stimulates the melanocytes (black pigments in skin) and regulates pigmentation in skin. Posterior lobe of pituitary releases oxytocin and vasopressin. Oxytocin stimulates the contraction of smooth muscles of our body. In females, it stimulates a widening of uterus at the time of child birth and milk secretion from the mammary glands. Vasopressin stimulates the reabsorption of water and electrolytes by the distal tubules of kidney and reduces loss of water through urine (diuresis). It is also called anti-diuretic hormone (ADH). The deficiency of ADH reduces reabsorption of water and increases urine output. This disorder is known as diabetes incipidus.

Pineal Gland

The pineal gland is located under the corpus callosum between the two cerebral hemispheres of the brain. It is a very small, solid, vascular, reddish grey and conical body. Pineal secretes a hormone called melatonin, which plays a very important role in the regulation of a 24-hour rhythm of our body. Hence it functions as a biological clock. Pineal gland helps in maintaining the normal rhythm of body temperature, and sleep-wake cycle. The melatonin regulates metabolism, menstrual cycle, pigmentation and self defense capability.

Thyroid Gland

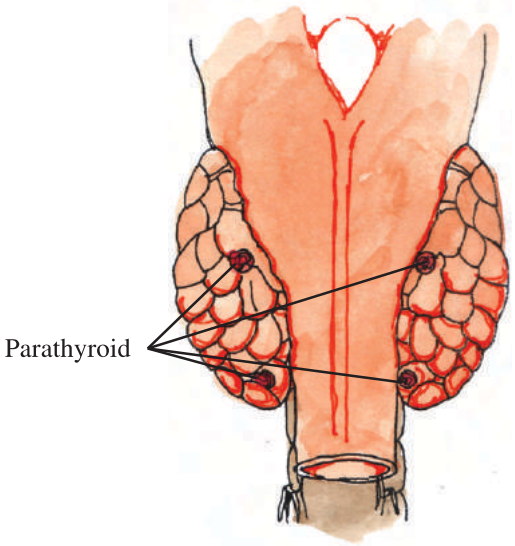
The Thyroid gland is bilobed, and located on either side of the upper part of the trachea. The two lobes are connected by a narrow connective tissue band called isthmus. The thyroid gland is composed of rounded follicles, which has a wall of cuboidal epithelium, and is filled with a gelatinous colloid secreted by epithelium. The thyroid gland secretes three hormones : Thyroxine (T4), Triiodothyronine (T3) and Thyrocalcitonin. Iodine is essential for the hormone of thyroid gland. Deficiency of iodine in our diet causes the enlargement of the thyroid gland, commonly known as Goiter. Hypothyroidism is caused by under secretion of thyroid gland. During pregnancy, it causes defective development and maturation of the infants leading to cretinism. A person with cretinism has stunted growth, mental retardation, abnormal skin and deaf-mutism. Hyperthyroidism in adult women may cause irregular menstrual cycle. In adult women the deficiency of hormone causes myxodema characterized by puffy appearance due to accumulation of fat in the subcutaneous tissue. Over secretion of Thyroxine hormone causes Exophthalmic Goitre, in which bulging of eyeballs, quick heart beat, rise in blood pressure and body temperature occur. Thyroid hormone plays an important role to control the general metabolism of carbohydrate by regulating the oxidation and ATP production. It maintains the basal metabolic rate (BMR) of the body. Thyroid hormone stimulates the process of RBC formation. Thyroid hormone also maintains water and electrolyte balance. Thyroid gland secretes hormone Thyrocalcitonin (TCT) which acts upon osteoblast of bones and decreases the calcium level in blood.



Thyroid Gland (Dorsal Side)

Parathyroid

The four lobes of parathyroid glands are located on the ventral surface of the thyroid gland. The parathyroid secretes only one hormone called Parathyroid hormone or Parethormone (PTH). PTH increasesthe Ca^{2+} level in blood. PTH acts on bone and activates the process of bone resorption. PTH increases Ca^{2+} absorption from the digested food and also activates reabsorption of Ca^{2+} by renal tubules. PTH along with TCT plays a significant role in maintenance of calcium balance in the body.



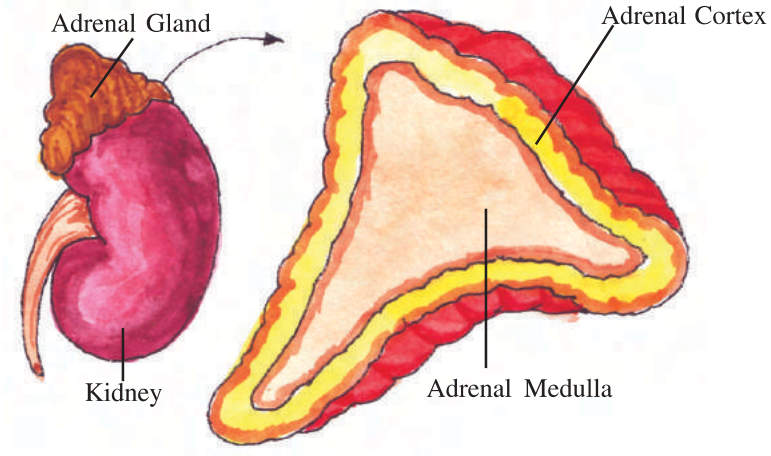
Diagrammatic View of the Position of Thyroid and Parathyroid Ventral Side

Thymus

It is located in upper dorsal side of the heart and aorta. The thymus is a soft, bilobed mass of lymphoid tissue. Thymus secretes hormone Thymosin. The thymus plays a major role in the development of the immune system. Thymosin stimulates the development and differentiation of T - lymphocytes which provide cell-mediated immunity. Beside this, thymosin stimulates the production of antibodies to provide humoral immunity. In children it is a prominent gland, but it gradually degenerates in the adult, resulting in a decreased secretion of thymosin. Due to this, the immune responses of old persons become weak.

Adrenal Gland

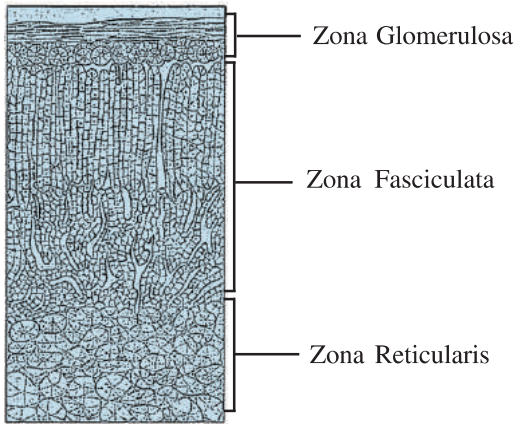
A pair of adrenal glands is present, one on the anterior part of each kidney. The adrenal gland is yellowish and conical in shape. Each gland has two distinct regions known as outer adrenal cortex and inner adrenal medulla. The adrenal medulla is a soft, dark reddish brown part. The adrenal medulla secretes two hormones known as adrenaline or epinephrine and noradrenaline or norepinephrine. They are placed in group called catecholamines. At the time of danger or stress or emergency, the CNS stimulates the medulla to secrete adrenaline and nor adrenaline. These hormones play an important role to over come 'flight or fight' situation hence they are called emergency hormones. Due to these hormones increase alertness and warm red face, pupilary dilation, raising of hairs, faster heart beats and sweating like symptoms are often noticeable. Catecholamine also activates the breakdown of glycogen resulting in an increased level of glucose in blood. They also stimulate the breakdown of protein and lipid.



Adrenal Gland and Kidney

Two Regions of Adrenal Gland

The adrenal cortex is divided into three layers : the inner layer Zona reticularis, middle layer, Zona fasciculata and the outer layer Zona glomerulosa. Each layer produces its own set of steroid hormones called corticoids. The adrenal cortex is important for life, because its destruction or removal causes death. Mineralocorticoids are secreted by outer layer. They regulate mineral metabolism and the balance of water and Na^+. Glucocorticoids hormones are secreted by middle region of adernal cortex. They regulate carbohydrate, protein and fat metabolism. They have antiallergic and anti-inflamatory effects and suppress the immune responses. The main glucocorticoid is cortisol. Sexcorticoids are hormones secreted by both, middle and inner parts of the cortex, which include male and female sex hormones. The male sex hormone, testosterone, stimulates the development of male secondary sexual characters such deepening of voice and distribution of hairs on body. The female sex hormones are estrogen and progesterone. The estrogen stimulates secondary sexual characters such as enlargement of breast and menstruation.



Adrenal L.S.

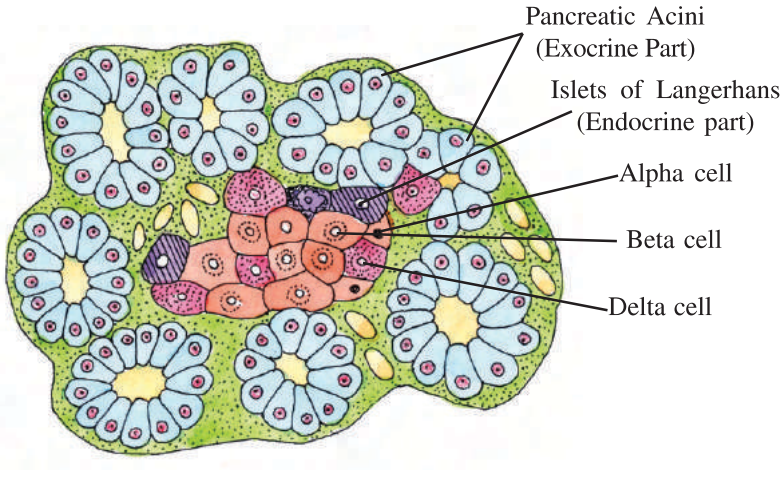
Disorders of Adrenal Gland

Addision Disease : It is caused by deficiency of mineralocorticoid, characterizid by ion imbalance. The symptoms include weakness, weight loss, vomitting, nausea and diarrhoea.

Cushing's syndrome is caused by excess secretion of cortisol. The symptoms include high blood sugar, obesity and rise in blood pressure and blood volume.

Pancreas

The pancreas is an elongated yellowish and lobulated gland. Pancreas acts as both exocrine as well as endocrine gland. The endocrine part of pancreas consists of about 1 to 2 million islets of Langerhans.



A Part of T.S. of Pancreas

The three main types of cells present in the islets of Langerhans are α-cells, -cells and delta cells. The β-cells secrete a hormone called glucagon which increases blood glucose level. Glucagon is a peptide hormone and is secreted in response to a fall in the blood glucose level. Glucagon acts mainly on liver cells and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia). Glucagon also stimulates the process of gluconeogenesis which results in rise of blood glucose level. Thus Glucagon is a hyperglycemic hormone. Secretion of insulin from β-cells is stimulated by increased blood glucose level. Insulin acts mainly on liver cells and adipose tissue and increases cellular glucose uptake and utilisation. As a result there is a transfer of glucose from blood to liver cells and adipose tissue resulting in decreased blood glucose level(hypoglycemia). Insulin stimulates conversion of glucose to glycogen (glycogenesis). The glucose level is thus maintained by opposite effect of above both the hormones. Deficiency of insulin causes diabetes mellitus. Diabetes can cause damage to kidney, blood circulation and vision. The symptoms of diabetes are excessive urination, excessive thirst, greater hunger etc. This disease can be controlled by proper diet-control, physical excercise and external introduction of insulin. Delta cells are about 5% and secrete somatostatin, which inhibits growth hormone (GH).

Testis

Testis are situated in the scrotum (outside abdomen) of male. They secrete male sex hormones known as androgens, mainly testosterone is secreted from the group of Leydig's cells. Testosterone stimulates the development, maturation and functions of the male accessory sex organs like epididymis, vas deference, seminal vesicle, prostate gland and urethra. These hormones stimulate the development of male accessory sex characters like beard and moustaches, muscular growth, axillary hair, low pitch of voice, aggressiveness and broadening of shoulders. Androgens play a main stimulatory role in the process of maturation spermatogenesis. It also acts on the CNS and influences the male sexual behaviour and sex urge.

Ovary

A pair of ovary lie in the abdomen. Ovary secretes three steroid female sex hormones **:** estrogen, progesterone and relaxin. Ovary is composed of ovarian follicle and stromal tissues. Growing ovarian follicles secrete estrogen and after ovulation, the ruptured follicle is converted to corpus luteum which secretes progesterone.

Estrogen stimulates the female reproductive system to grow to full size and becomes functional. It also stimulates the secondary sex characters (e. g. enlargement of breast, broadening of pelvis, growing axillary hair). It also stimulates development of ovarian follicles in the ovary.

Progesterone supports embryo and foetal development and suspends ovulation, implantation of the foetus in the uterine wall, and helps in placental formation. Progesterone also acts on the mammary glands to stimulate milk secretion and storage of milk. Relaxin is secreted by corpus luteum at the end of the gestation period. It relax the cervix of the uterus for easy birth of the young one.

Hormones of Heart, Kidney and Gastrointestinal Tract

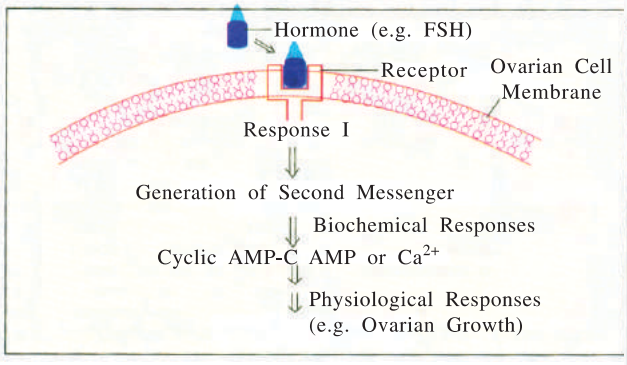
Hormones are also secreted by some tissues which are not endocrine glands. The atrial wall of heart secretes peptide hormone known as Atrial Natriuretic Factor (ANF) which decreases blood pressure, when blood pressure is increased. ANF causes dilation of the blood vessels, which reduces the blood pressure. The juxtaglomerular cells of kidney secrete erythropoietin which stimulates formation of RBCs (erythropoiesis). In different parts of gastro intestinal tract endocrine cells are present which secrete peptide hormones namely gastrin, secretin, cholecystokinin (CCK) and Gastric Inhibitory Peptide (GIP). Gastrin stimulates gastric glands to secrete pepsinogen and HCl. Secretin acts on the exocrine gland of pancreas and stimulates the secretion of bicarbonate ions and water. CCK acts on pancreas and gall bladder and stimulates them to secrete pancreatic enzyme and bile respectively. GIP inhibits gastric secretion. Many non endocrine tissues secrete hormones known as growth factors, which are important for normal growth of tissues and their repairing and regeneration.

Mechanism of Hormone Action

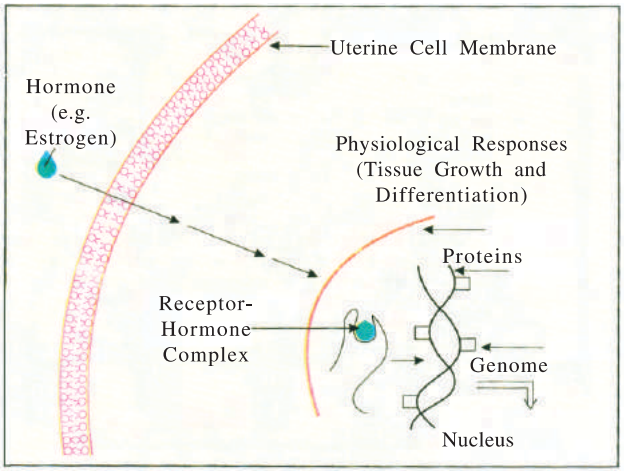
Hormones exhibit their effects on target cells by binding to specific proteins known as hormone receptors proteins, found only in the target cells. These hormone receptors, found on the cell membrane of the target cells, are known as membrane-bound receptors. Receptors found inside the target cells are known as intracellular receptors. Binding of a hormone to its receptors leads to formation of hormone receptors complex. Each receptor is specific to one specific hormone only and hence receptors are specific. Formation of hormone receptor complex creates certain biochemical changes in the target cells. Metabolic processes and physiological processes in target cells are regulated by hormones. On the basis of their chemical nature, hormones can be divided into following groups.

(i) peptide, polypeptide, protein hormones (e.g. insulin, gulcagon, pituitary hormones, hypothalamus hormones). (ii) steroid (eg. cortisol, testosterone and progesterone) (iii) iodothyronines (thyroid hormones) (iv) amino acid derivatives (epinephrine).

Hormones which interact with membrane-bound receptor generally do not enter the target cell and generate second messengers (eg. cyclic AMP, Ca^{2+} IP_3 (Inositol tri phosphate) which in turn regulate cellular metabolism. Hormones which bind with intracellular receptors such as steroid, mostly regulate gene expression by the interaction of hormone-receptor complex with the genome. As a result of many biochemical reactions, physiological reactions and development are affected.



Mechanism of Peptide Hormone



Mechanism of Steroid Hormone

SUMMARY

The nervous system controls speedily, but its effects are of very short period. Continuous regulation of cellular functions is necessary. This control and coordination is done by endocrine system. Endocrine is ductless gland and mainly secretes the chemicals termed hormones. Hormones are effective in minute quantity to stimulate or inhibit specific physiological processes of the body. The endocrine system consists of hypothalamus, pituitary, pineal, thyroid, adrenal, pancreas, parathyroid, thymus testis and ovary. In addition to these endocrine glands, some other organs. eg. gastrointestinal tract, heart and kidney also secrete hormones.

The hypothalamus contains several groups of neurosecretory cells, which produce releasing hormones (RH) and inhibiting hormones (IH). The pituitary gland is divided into three parts, anterior pituitary, intermediate lobe and posterior lobe. The anterior pituitary secretes six hormones, intermediate lobe secretes only one hormone and posterior lobe secretes two hormone. The pituitary hormones regulates the growth, and induce secretion of sex hormones. Pineal gland secretes melatonin which regulates 24 hour rhythm of body temperature.

The thyroid hormone plays an important role in the control of general metabolism and maintains BMR of the body. The parathyroid gland secretes parathyroid hormone (PTH) which increases the Ca^{+} level in blood. Thymus secretes hormone thymosins which stimulates development of T-lymphocytes and provide cell-mediated immunity. It also stimulates the production of antibodies to provide humoral immunity.

Adrenal gland have two regions known as adrenal cortex and adrenal medulla.The adrenal medulla secretes adrenaline and noradrenaline. The role of these hormones is often called flight or fight reaction. The hormones increase alertness, and cause warm red face, pupillary dilation and faster heart beat. The adrenal cortex secretes mineralocorticoids which regulate mineral metabolism, and the balance of water and Na^{+}. Glucocorticoids hormone regulates carbodydrate, protein and fat metabolism.

The main glucocorticoids is sex corticoids, which includes male and female sex hormones. Testosterone is a male sex hormone while oestrogen and progesterone are female sex hormones. The pancreas secretes hormones glucagon and insulin. Glucagon stimulates glycogenolysis and gluconeogenesis resulting in hyperglycemia. Insulin stimulates cellular glucose uptake and glycogenesis resulting in hypoglycemia. Insulin deficiency results in a disease called diabetes mellitus.

Testis secretes sex hormone mainly testosterone which stimulates development, maturation and functions of the male accessory sex organs. The ovary secretes estrogen which stimulates growth and development of female reproductive system and secondary sex characters. Progesterone plays an important role during delivery and prevents ovulation. Relaxin relaxes the cervix of the uterus for easy birth of the young one. The atrial wall of the heart secretes ANF which decreases blood pressure. The kidney produces erythropoietin which stimulates formation of RBC. The gastrointestinal tract secretes gastrin, secretin, cholecystokinin and gastric inhibitory peptide(GIP). These hormones regulate the digestive enzyme secretion and help in digestion.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

(1) Which of the following does not secrete any hormone?

(a) Spleen ◯ (b) Ovary ◯ (c) Testes ◯ (d) Pancreas ◯

(2) The number of hormones secreted by anterior pituitary is

(a) 3 ◯ (b) 4 ◯ (c) 6 ◯ (d) 8 ◯

(3) The disease caused by hypo secretion of thyroxine is

(a) Goiter ◯ (b) Cretinism ◯

(c) Acromegaly ◯ (d) Addison's disease ◯

(4) Gigantism and acromegaly result from hypersceretion of

(a) ADH ◯ (b) GH ◯ (c) TSH ◯ (d) ACTH ◯

(5) Emergency gland of body is

(a) Thymus ◯ (b) Testis ◯ (c) Adrenal ◯ (d) Pituitary ◯

(6) Progesterone hormone is secreted by

(a) Corpus callosum ◯ (b) Corpus luteum ◯

(c) Corpus albicans ◯ (d) Thymus ◯

(7) To whom secretin stimulates ?

(a) Lungs ◯ (b) Gall bladder ◯

(c) Pancreas ◯ (d) Gastric glands ◯

(8) Which of the following is not a steroid hormone?

(a) Aldosterone ◯ (b) Androgen ◯

(c) Estrogen ◯ (d) Thyroxine ◯

2. Answer the following questions in short :

(1) Which are the two main types of glands in our body ?

(2) Define Hormone.

(3) What is the location of hypothalamus ?

(4) Name the gland which acts as an exocrine as well as an endocrine gland.

(5) Name the cells which secrete testosterone.

(6) Name the cells which secrete estrogen.

(7) Name the hormones secreted by thymus gland.

3. Do as directed :

(1) Differentiate between exocrine and endocrine glands.

(2) What is acromegaly ?

(3) Why is an injection of oxytocin hormone given at the time of childbirth ?

(4) State the differences between cretinism and myxoedema.

4. Answer the following questions in detail :

(1) What is hormone ? Describe thyroid gland in detail.

(2) Give an account of adrenal gland.

(3) Give an account of pancreas as a gland.

3

Reproduction in Organisms

All organisms reproduce. Reproduction is a biological process in which an organism gives birth to offspring similar to itself. The offspring grow, mature and in turn produce new offspring. Thus, there is a cycle of birth, growth and death. Reproduction enables the retention continuity of the species, from generation to generation. The genetic variation is created and inherited during reproduction.

There is a large diversity in the biological world and each organism has evolved its own mechanism to multiply and produce offspring. The organism's habitat, its internal physiology and several other factors are collectively responsible for how it reproduces. There are two types of reproduction in organisms, asexual and sexual. When offspring is produced by a single parent without the involvement of gamete formation, the reproduction is called asexual. When two parents (opposite sex) participate in the reproduction process and also involve fusion of male and female gametes, it is called sexual reproduction.

Asexual Reproduction

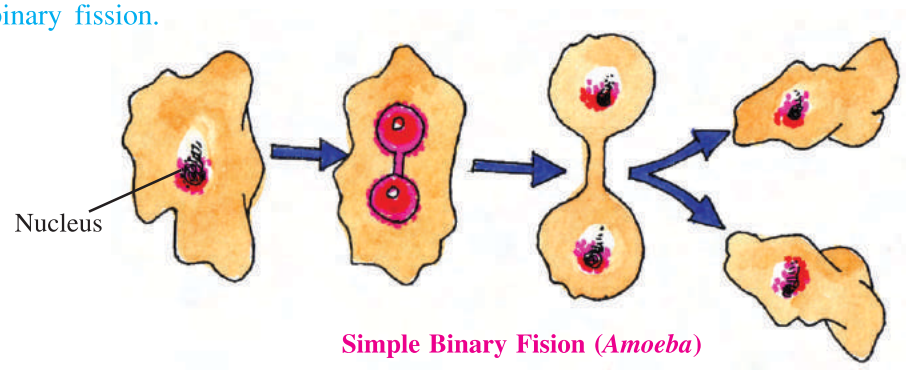
In asexual reproduction a single, parent is involved and is capable of producing offspring. As a result, the offsprings that are produced are not only identical to one another but are also exact copies of their parent. Asexual reproduction is common among single-celled organisms, and in plants and animals with relatively simple organizations. It is also seen in multicellular organisms.

Asexual Reproduction in Animals

In animals the common modes of asexual reproduction are as follows :

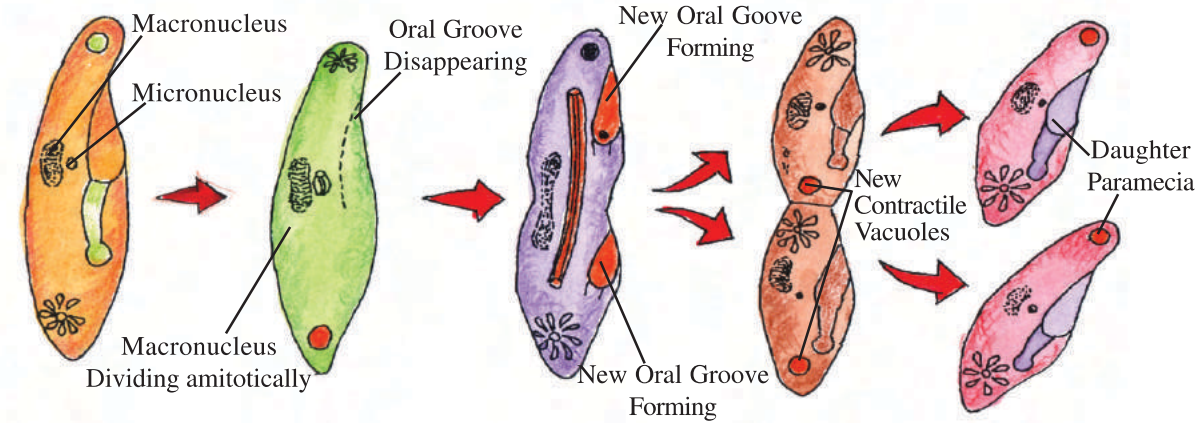
(1) Fission : This method is observed in Protists and Monerans. In fission, the nucleus divides first and the cytoplasm next. Subsequently, the mother cell splits into two equal sized daughter cells. This division is of cell division type.

When the cytoplasmic division passes through any direction (e.g. *Amoeba*) the fission is called simple binary fission.



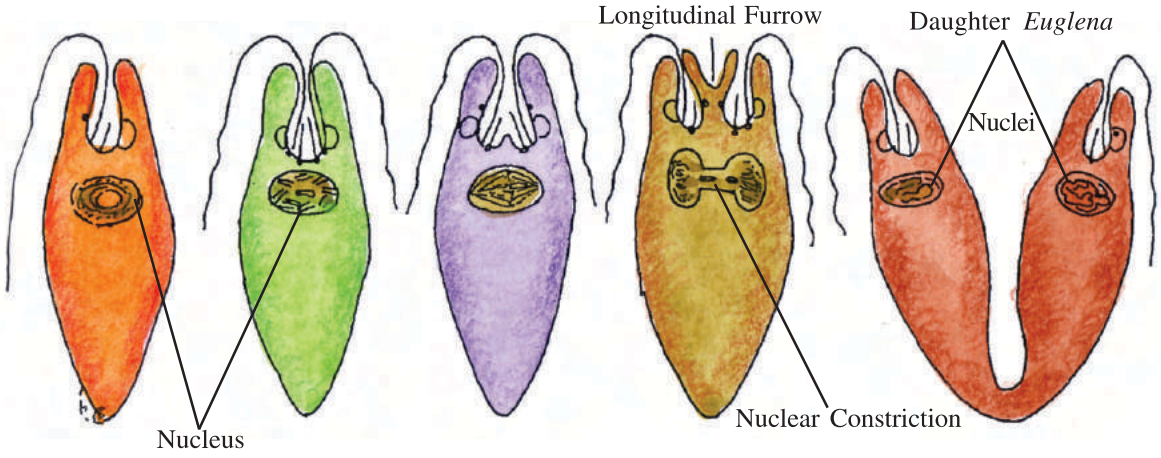
Simple Binary Fision (*Amoeba*)

If the plane of cytoplasmic division coincides with the transverse axis of the individual, the fission is termed transverse binary fission. Eg. *Paramoecium* and *Planaria*.



Transverse Binary Fission in *Paramoecium*

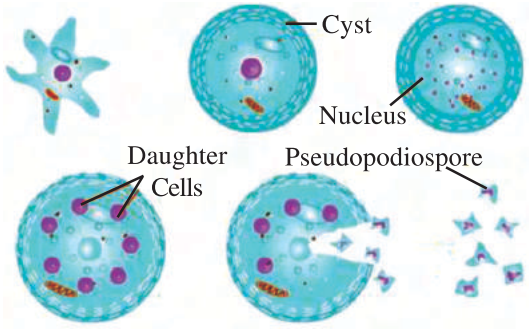
In *Euglena* and *Vorticella*, the plane of cytoplasmic division coincides with the longitudinal axis of the individual. This kind of fission is designated as longitudinal binary fission.



Longitudinal Binary Fission in *Euglena*

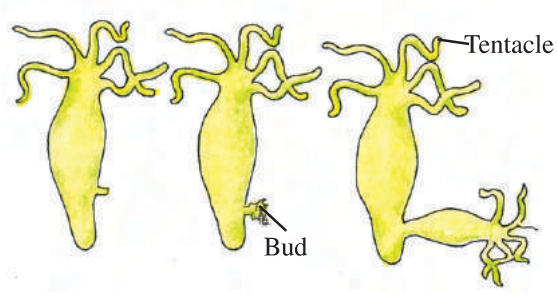
Binary fission involves mitosis only and consequently the resultant offsprings are genetically identical to the parent and to each other. It may be mentioned here that genetically identical offsprings resulting from a single parent are considered as clones.

Sometimes, the nucleus divides several times by amitotic nuclear division. Thus large numbers of nuclei are formed. Cytoplasm does not divide during this period. Then cytoplasm collects around each nucleus. Thus, within one maternal cell, innumerable unicellular and uninucleate offspring are formed. In course of time, they live as independent, unicellular organisms. This method of reproduction is called multiple fission. Multiple fission is observed in *Amoeba* and *Paramoecium*, *plasmodium*.



Sporulation in Amoeba

(2) Sporulation : Sporulation occurs during unfavorable conditions. Organisms like *Amoeba* withdraw their pseudopodia and become round in shape. They create a hard protective three layered cyst around themselves, this process is called encystations. When conditions become favorable, the nucleus of encysted *Amoeba* undergoes multiple divisions and a large number of *Amoeba* are formed. These are called pseudopodiospores. This process is called sporulation. When the cyst ruptures all new *Amoebae* are released. In *Plasmodium* this process occurs at a specific stage in its life cycle.

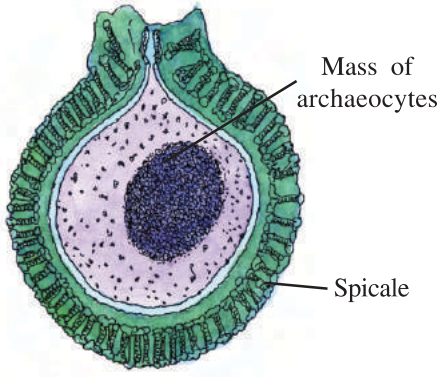


Exogenous Bud in Hydra

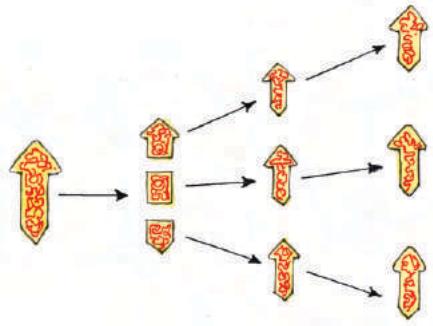
(3) Budding : In this method, first of all, cells of some part of the body of the animal repeatedly undergo mitotic cell divisions and the raised regions of cell masses, called bud, are formed. From such a bud a young animal develops. It separates from the parent body and lives as an independent animal.

If such a bud is produced on the outside of the body it is called exogenous budding. In *Hydra*, exogenous budding is observed.

In fresh water sponge (e.g. *Spongilla*) and marine sponge (e.g. Sycon) specialized cell masses are produced towards the inside of the body. An envelope surrounds this cell mass. Such structures are called internal buds or gemmules. Each gemmule gives rise to a new animal. This is called endogenous budding.



Internal Buds in Spongilla



Regeneration in *Planaria*

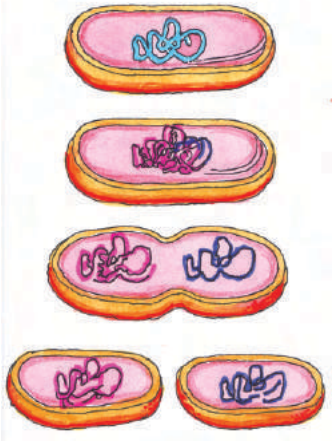
(4) Fragmentation : In this method of reproduction, the body becomes fragmented into several distinct parts. Each part develops the remaining body parts and becomes a complete animal. This capacity is known as regeneration. Fragmentation is observed in *Planaria*, *Hydra,* Starfish etc.

Asexual Reproduction in Plants

The common modes of asexual reproduction in plants is as following :

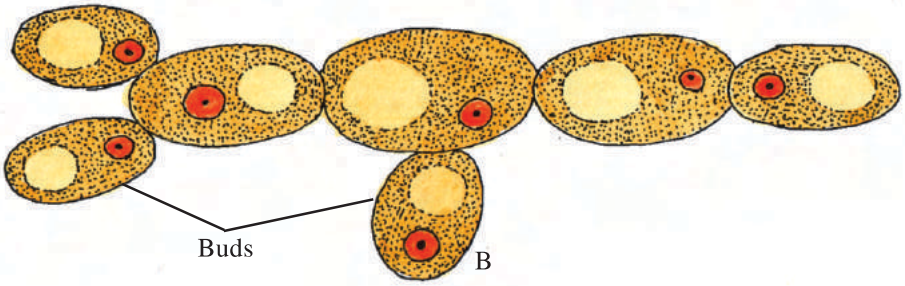
(1) Fission :

It is the simplest method, commonly found in algae, fungi and monerans (bacteria). In this process, the unicellular mother cell divides mitotically to form two daughter cells; each eventually grows into an independent organism.



Fission in Bacteria

(2) Buds : Some algae produce adventitious branches (e.g. *Dictyota, Fucus*) or buds (e.g. *Protosiphon*) where as fungus like yeast produces buds. These structures are formed due to unequal division and are attached to the parental cell which eventually gets separated and matured into a new organism.



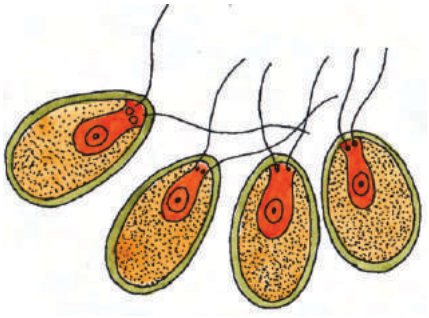
Buds in Yeast

(3) Fragmentation : In some algae (e.g. *Ulothrix, Oedogonium, Spirogyra and Zygnema*) and fungi (e.g. *Mucor, Rhizophus, Saprolegnia*), the vegetative thallus or hyphae break up into small segments due to mechanical pressure and each segment is capable of growing into a new mycelium

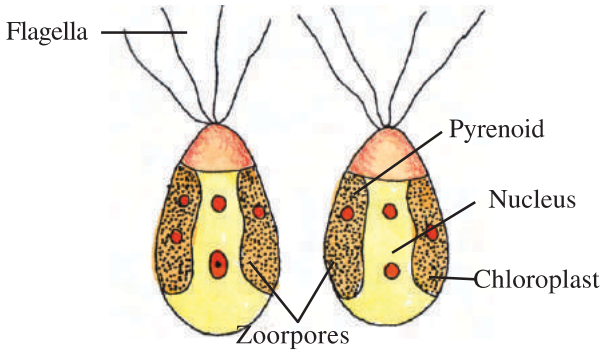
(4) Spore Formation : Asexual reproduction takes place by a variety of motile or non motile spores/conidia.

Ciliate motile spore, called zoospores are produced by algae and fungi, which swim in water for some time with the help of their flagella and then directly develop into new independent individuals, e.g. *Ulothrix, Chlamydomonas, Oedogonium*.

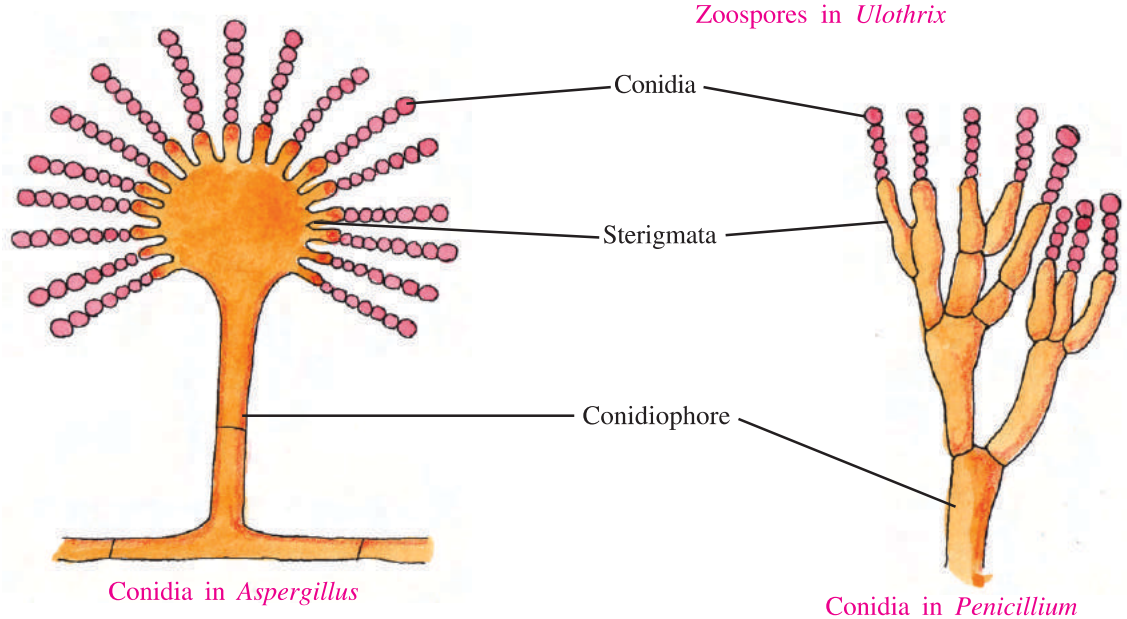
Non-flagellate and non-motile spore/conidia of various kinds are most common among terrestrial fungi. Such spores are light, dry and provided with a tough coat, and are well adapted for dispersal by wind e.g. *Penicillium, Aspergillus*.



Zoospores in *Chlamydomonas*



Zoospores in *Ulothrix*



Conidia in *Aspergillus*

Conidia in *Penicillium*

Spore Formation

True spores are always borne by a sporophyte. Thus, the sporophyte of mass reproduces asexually by spores. Similarly ferns (Nephrolepis) bear spores and reproduce asexually by them. These plants are homosporous (bear only one kind of spores). While in *Selaginella* (a pteridophyte) and gymnosperms they are heterosporous (bears two types of spores).

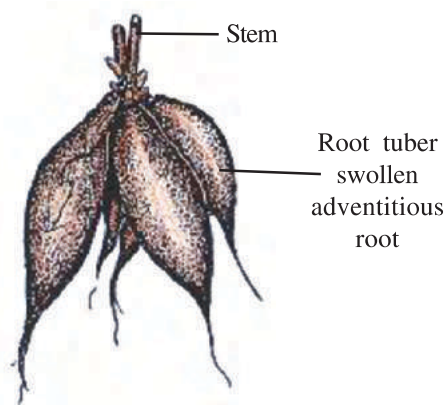
In animals and other simple organisms, the term asexual is used unambiguously while in plants, the term vegetative reproduction is frequently used.

In flowering plants the methods of vegetative propagation or reproduction are grouped into natural and artificial.

(i) Natural Methods

In natural methods of propagation, the development of a new plant from some organ of the mother plant under suitable environmental conditions is very common. Such special reproductive organs develop from stem, leaf, root or even flower.

Vegetative reproduction occurs through roots in Sweet potato, *Asparagus* and Dahlia.

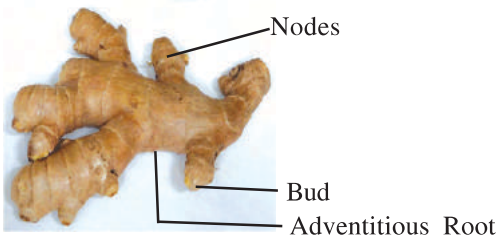


Roots of Dahlia

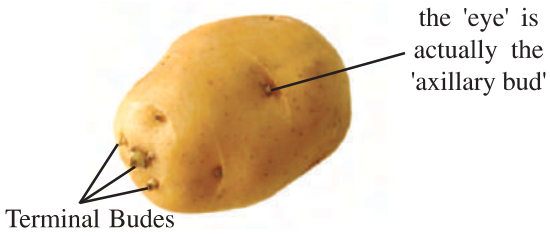
Sweet Potato

Vegetative Reproduction by Root

Ginger, Turmeric, *Amorphophalus*, potato and onion reproduce vegetatively through stem.



Ginger

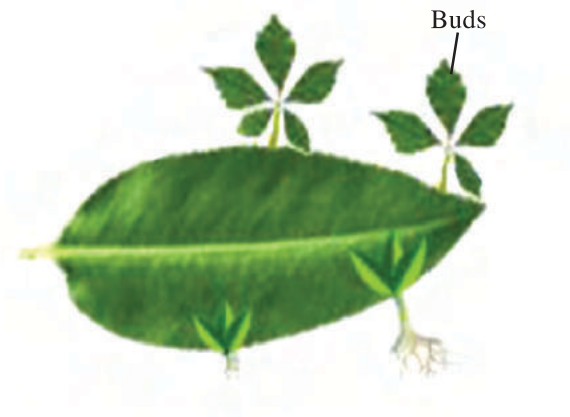


A Stem Tuber : Potato

Vegetative Reprodauction by Stem

In plant like *Bryophyllum,* buds develop in the margins of leaves. These buds produce new plants.

In plants like *Agave* and *Oxalis*, floral buds produce new plants and in *Dioscorea*, axillary buds do so.



Vegetative Reproduction by Leaf in *Bryophyllum*

Vegetative Reproduction by Floral Buds in *Agave*

Among the other natural methods of vegetative propagation, runners observed in lawn grass, offsets found in *Pistia*, stolons in *Nephrolepis* and suckers in mint plant are noteworthy.

(ii) Artificial Methods

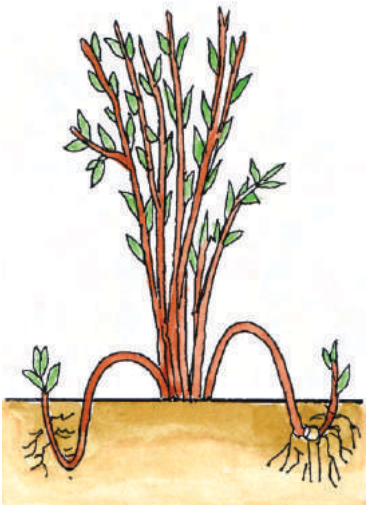
Methods are developed for artificial vegetative propagation in which some part of the plant organ is utilized for obtaining a new complete plant. Amongst them the most common methods are – cutting, layering and grafting.

(1) Cutting : Cut pieces of root are planted in moist soil and development of adventitious roots is artificially induced. New plants are developed in this way in lemon and tamarind.

In Rose, Sugarcane, *Croton*, China-rose and *Chrysanthemum* plants, proper sizes of stem pieces are obtained and are planted in moist soil to develop new plants. From the underground parts of stem, adventitious roots develop and buds on the aerial parts of stems sprout. The plant, so developed is called a "cutting". Later, these cuttings are transplanted in proper places.

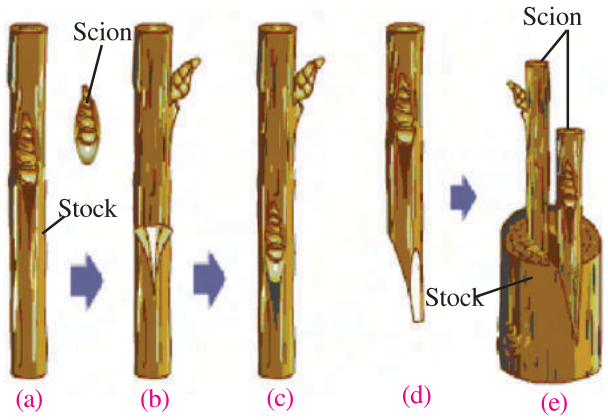
(2) Layering :

This method is employed in the cultivation of Rose, Lemon, Grape, *Hibiscus* and Jasmine. The lower branches of the plant are bent and pressed under the soil in such a way that the tip of the branch remains outside the soil and the middle portion is buried inside the soil. When adventitious roots develop from this buried region of plant stem, this branch is cut and separated from the parent plant. Thus, a new plant is obtained.



Layering

(3) Grafting : Grafting is practised in plants which do not root easily, or have a weak root system. In this method a union is established between two plants of the same or different kinds. Such a union is established between tissues of the two plants. This process can be induced more successfully amongst those plants which possess meristematic tissue.



Grafting

The main supporting plant is called stock plant. The plant which is being grafted on it is called scion. A plant possessing higher and desirable characters is selected as "scion". Various methods of grafting scion are practiced. Mango, Apple, Pear, *Citrus*, Guava, Litchi and many other fruit-yielding plants are thus obtained and maintained.

Grafting may be of different types, namely bud grafting, side grafting, tongue grafting, wedge grafting and crown grafting depending on the methods of uniting the two parts.

Significance of Vegetative Reproduction

(1) Vegetative reproduction is an ideal method of reproduction in plants in which it is desirable to maintain the same characteristics in the offspring which are present in the parents.

(2) Plants showing reduced power of sexual reproduction, long dormant period of seed or poor viability can also be multiplied easily through this method.

(3) Vegetative reproduction also helps in removing common infections from the parent plant.

(4) In the plants raised through grafting, it is even possible to bring together the desired characters from two plants.

Sexual Reproduction

Sexual reproduction involves formation of the male and female gametes, either by the same individual or by different individuals of the opposite sex. These gametes fuse to form the zygote which develops to form the new organism. It is a complex and slow process as compared to asexual reproduction. Because of the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.

Though the plants, animals or fungi differ in external morphology, anatomy and physiology, yet their sexual mode of reproduction is similar in pattern. All organisms reach a certain stage of growth and maturity in their life before they can reproduce sexually. This period is called the juvenile phase and in plants it is known as vegetative phase.

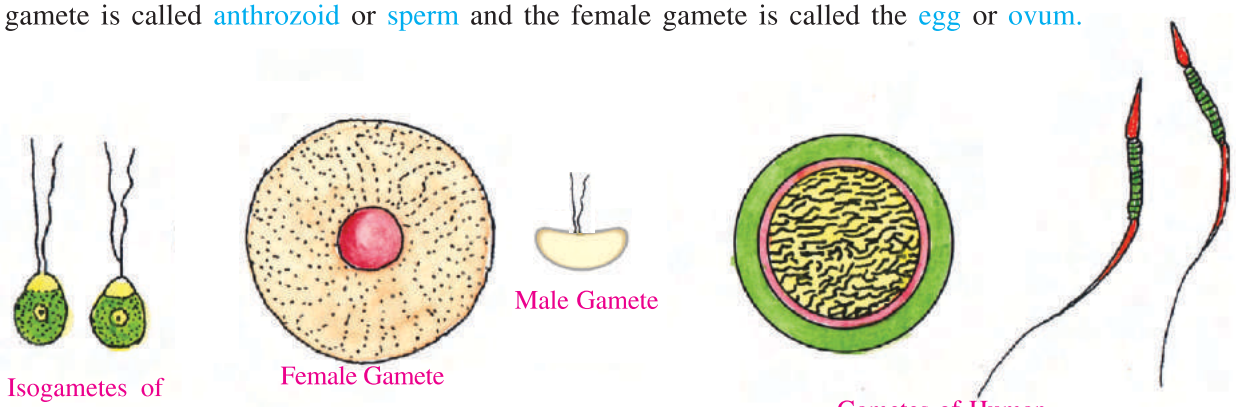
After attaining maturity, all sexually reproducing organisms show events and processes which have fundamental similarity, but the structures associated with sexual reproduction are quite different. In all cases, the sexual reproduction is characterized by the fusion of the male and female gametes of the species. For convenience these sequential events may be grouped into three distinct stages namely, the pre-fertilization, fertilization and the post-fertilization events.

Pre-Fertilization Events

The pre-fertilization events of sexual reproduction are found prior to the fusion of gametes. The two main pre-fertilization events are gametogenesis and gamete transfer.

(1) Gametogenesis : Gametogenesis is the process of formation of gametes. Generally gameter are of two types. i.e. male and female gametes. Gametes are haploid (n) cells. In some algae where two gametes are similar in appearance they are called isogametes or homogametes. It is morphologically and

physiologically similar and usually motile and has flagellates (e.g. *Cladophora, Ulothrix*). However in a majority of sexually reproducing organisms the gametes produced are of two morphologically and physiologically distinct types which are known as heterogametes or anisogametes. The male gametes are smaller and more active whereas the female gametes are larger and sluggish. In such cases the male gamete is called anthrozoid or sperm and the female gamete is called the egg or ovum.



Gametes

Gametes are always haploids, but the parent plant body from which they arise may be either haploid or diploid. A haploid parent produces gametes by mitotic division. Several organisms belonging to Monera, Fungi, Algae and Bryophyta have haploid plant body but in majority of organisms belonging to Pteridophyta, Gymnosperms, Angiosperms and most of the animals, the parental body is diploid. Here meiosis takes place to produce haploid gametes.

In diploid organisms the meiocytes (gamete mother cells) undergo meiosis. At the end of meiosis, only one set of chromosomes (n) gets incorporated in each gamete. Table showing diploid and haploid chromosome numbers of organisms.

Name of Organisms	Chromosome Number in Meiocyte ($2n$)	Chromosome Number in Gamete (n)
Apple	34	17
Maize	20	10
Onion	32	16
Potato	48	24
Rice	24	12
Cat	38	19
Dog	78	39
Human beings	46	23
House fly	12	06

(2) Gamete Transfer : After formation, the male and female gametes are brought together to facilitate fertilization. In a majority of organisms, male gamete is motile and the female gamete is stationary. There is a need for a medium through which the male gametes move. In Algae, Bryophytes and Pteridophytes, water is the medium through which this gamete transfer takes place. A large number of the male gametes, however, fail to reach the female gametes. To compensate this loss of male gametes during transport, the number of male gametes produced is several thousand times the number of female gametes produced.

In Angiosperms pollen grains are the carriers of male gametes and ovule has the egg cell. Pollen grains are produced in anthers and are transferred to stigma, a phenomenon which is known as

pollination. This phenomenon requires the involvement of external agents such as insects, animals, wind and water. Pollen grains germinate on the stigma and the pollen tubes carrying the male gametes reach the ovule and discharge two male gametes near the egg cell.

In bisexual animals, since male and female gametes are formed in different individuals, the organism must evolve a special mechanism for gamete transfer. It is essential for fertilization.

Fertilization

The fusion of two similar or dissimilar gametes is called syngamy and in its result diploid zygote is formed. This process is known as fertilization.

In majority of algae, fishes and amphibians, syngamy occurs in the external medium i.e. water (outside the body of the organism). This type of gametic fusion is called external fertilization. This happens in the bony fishes and frogs where a large number of offspring are produced. A major disadvantage is that the offspring are extremely vulnerable to predators threatening their survival upto adulthood.

In Plant groups (i.e. Fungi, Bryophytes, Pteridphytes), as well as Reptiles, Birds, and Mammals, syngamy occurs inside the body of the organism, hence the process is called internal fertilization. In this process, male gametes are motile and have to reach and fuse with egg. This takes place inside the female body.

In seed plants, the non-motile male gametes are carried to female gamete by pollen tubes.

Post-fertilization Events

The formation of zygote and the process of development of embryo (embryogenesis) are called post-fertilization events.

(1) Zygote : Formation of zygote (2n) is common in all sexually reproducing organisms. In organism with external fertilization, zygote is formed in the external medium (water), whereas in those exhibiting internal fertilization, zygote is formed inside the body of organism. Further development of zygote depends on the type of life cycle the organism possesses and the environment to which it is exposed. In organisms, such as Algae and Fungi, zygote develops a thick wall that is resistant to desiccation and damage. Commonly it undergoes a period of rest prior to germination.

Some unicellular protist animals (e.g. *Paramoecium*) exhibit sexual reproduction by forming male and female gamete nuclei, which they exchange through temporary cytoplasmic bridge, later the cytoplasmic bridge disappears and the gamete nucleus of one individual fuses with that of the other to form zygote nucleus. This mode of sexual reproduction is known as conjugation.

Zygote is the vital link that ensures continuity of species between organisms of one generation and the next.

(2) Embryogenesis : Embryogenesis is the process of development of embryo from the zygote. During embryogenesis, zygote undergoes cell division (mitosis) and cell differentiation.

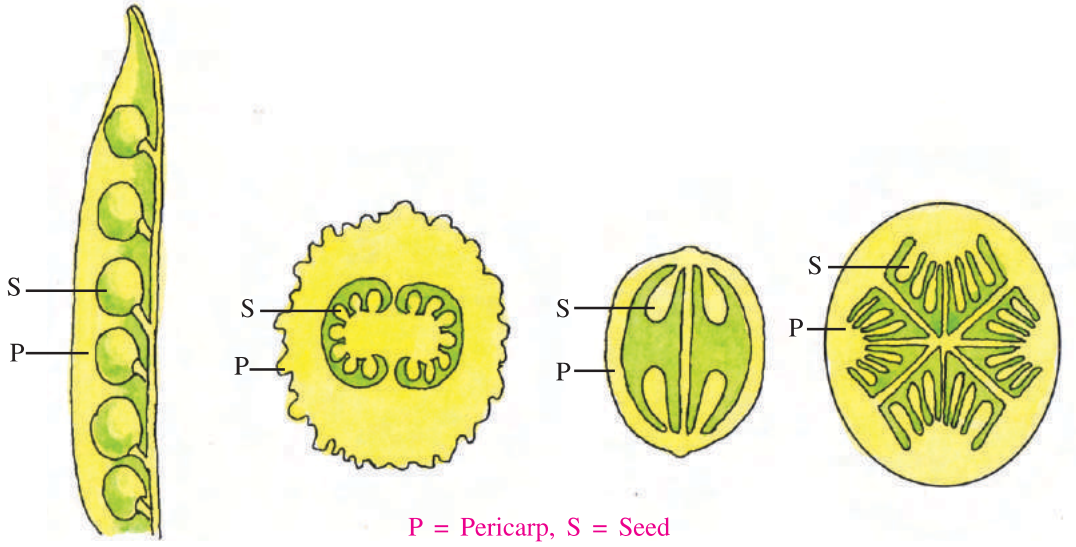
Cell divisions increase the number of cells in the developing embryo while cell differentiation helps groups of cells to undergo certain modifications to form specialized tissues and organs to form an organism.

In animals, when the development of zygote takes place outside the body of the female parent, it is called oviparous, while when it develops inside then it is called viviparous.

Oviparous

In oviparous animals like Reptile and Birds, the fertilized eggs covered by hard calcareous shell are laid in a safe place in the environment; after a period of incubation, young ones hatch out. On the other hand, in viviparous animals like Mammals including human beings the zygote develops into a young one inside the body of the female organism. After attaining a certain stage of growth, the young ones are delivered out of the body of the female parent. Because of proper embryonic care and protection, the chances of survival of young ones is greater in viviparous organisms.

In Angiosperms, the zygote is formed inside the ovule. After fertilization the sepals, petals, and stamens of the flower fall off. The pistil however, remains attached to the plant. The zygote develops into the embryo and the ovules develop into the seed. The ovary develops into the fruit which develops a thick wall called pericarp that is protective in function. After dispersal; seeds germinates under favourable condition to produce new plants.



P = Pericarp, S = Seed

L.S. / T.S. of Various Types of Fruits with Seeds

SUMMARY

Reproduction is a biological process in which an organism gives rise to offspring similar to itself. There are two types of reproduction in an organism, asexual and sexual. In asexual reproduction a single parent is involved and capable of producing offspring. Fission, sporulation, budding and fragmentation are the common modes of asexual reproduction seen in animals and plants. Zoospore, conidia, etc. are the most common asexual structures formed in several Algae and Fungi. In flowering plants vegetative reproductions is natural and artificial. In natural method, the development of a new plant take place under suitable environmental conditions from some organs like stem, leaf, root or even flower of the mother plant.

Runners, offsets, stolons and suckers are the common natural methods of reproduction seen in Angiosperms. The artificial methods of propagation are cutting, layering and grafting. In vegetative reproduction, the offspring are nurtured in the body of the parents.

Sexual reproduction involves formation and fusion of gametes. It is a complex and slow process as compared to asexual reproduction. Events of sexual reproduction may be categorized into the pre-fertilization, fertilization and post-fertilization events.

Pre-fertilization events of sexual reproduction are found prior to the fusion of gametes. The two main pre-fertilization events are gametogenesis and gamete transfer. Gametes are always haploid and homogametes or heterogametes. After formation, the male and female gametes are brought together to facilitate fertilization.

The fusion of two similar or dissimilar gametes is called syngamy which results into formation of diploid zygote; this process is known as fertilization. It is external or internal.

The formation of zygote and the process of development of embryo are called post fertilization events. Zygote is the vital link that ensures continuity of species between organisms of one generation and the next. Embryogenesis is the process of development of embryo from the zygote. During embryogenesis zygote undergoes cell division (mitosis) and cell differentiation. Cell divisions increase the number of Cells while differentiation helps group of cells to undergo certain modifications to form specialized tissues and organs to form an organism.

EXERCISES

1. Put a dark colour in a given circle for correct answer :

(1) Reproduction in *Amoeba* takes place by

(a) Binary fission ○ (b) Budding ○

(c) Zoospore formation ○ (d) Fragmentation ○

(2) What is flagellate motile spore called ?

(a) Conidia ○ (b) Zoospores ○

(c) Homospores ○ (d) Heterospores ○

(3) Non-flagellate spores known as conidia are found in

(a) *Penicillium* ○ (b) *Hydra* ○

(c) *Amoeba* ○ (d) *Chlamydomonas* ○

(4) Which animal reproduce by exogenous budding ?

(a) *Hydra* ○ (b) Spongilla ○

(c) *Plasmodium* ○ (d) *Amoeba* ○

(5) Which animal reproduce by multiple fission ?

(a) *Hydra* ○ (b) *Plasmodium* ○

(c) Spongilla ○ (d) *Amoeba* ○

(6) Which animals have a well developed capacity of regeneration ?

(a) *Hydra*, Starfish ○ (b) *Plasmodium* ○

(c) Earthworm ○ (d) *Spongilla* ○

(7) Sporulation occurs in

(a) *Plasmodium* ○ (b) *Hydra* ○

(c) Starfish ○ (d) Spongilla ○

(8) Which plant carries out vegetative reproduction with the help of root ?

(a) *Oxalis* ○ (b) *Bryophyllum* ○

(c) Onion ○ (d) Dahlia ○

(9) Which plant carries out vegetative reproduction with the help of floral buds ?

(a) *Oxalis* ◯ (b) *Bryophyllum* ◯

(c) Ginger ◯ (d) *Asperagus* ◯

(10) Which part in the plant *Bryophyllum* takes place in vegetative reproduction ?

(a) Stem ◯ (b) Floral buds ◯

(c) Underground roots ◯ (d) Buds in leaf margin ◯

(11) Which special method of vegetative reproduction occurs in Nephrolepis ?

(a) Offsets ◯ (b) Stolons ◯ (c) Runners ◯ (d) Suckers ◯

(12) Which one of the following is not the natural method of vegetative reproduction ?

(a) Suckers ◯ (b) Cutting ◯ (c) Runner ◯ (d) Offsets ◯

(13) Chromosome number in meiocyte of Apple is_____

(a) 17 ◯ (b) 34 ◯ (c) 20 ◯ (d) 10 ◯

(14) Conjugation as a sexual reproduction occurs in which animal ?

(a) *Birds* ◯ (b) *Hydra* ◯ (c) *Paramecium* ◯ (d) *Spirogyra* ◯

(15) Development of zygote which takes place outside the body is called.

(a) Viviparous ◯ (b) Oviparous ◯

(c) Oviviparous ◯ (d) None of these ◯

2. Answer the following questions in short :

(1) Define asexual reproduction

(2) Which animals are reproduced by binary fission ?

(3) Explain-clones

(4) Which animals reproduce by multiple fission ?

(5) What is fragmentation ?

(6) Define-reproduction

(7) What is Stock ?

(8) Explain-juvenile phase

(9) Define-Gametogenesis

(10) Gametes are always _____ (n/$2n$/$3n$) cells

(11) Give chromosome number in meiocytes of onion and house fly

(12) Explain-Fertilization

(13) Give the name of the main events of post fertilization

(14) Give the name of unicellular protist

(15) What is embryogenesis ?

3. Write short notes on :

(1) Sporulation in animal
(2) Spore formation in plants
(3) Fission in animals
(4) Fission in plants
(5) Fragmentation in animals
(6) Fragmentation in plants
(7) Cutting
(8) Layering
(9) Grafting
(10) Significance of vegetative reproduction
(11) Fertilization
(12) Zygote
(13) Embryogenesis
(14) Heterogametes and Homogemetes
(15) Pollination in Angiosperms

4. Answer the following questions in detail :

(1) What is asexual reproduction ? Describe common modes of asexual reproduction in animals.

(2) What is asexual reproduction ? Describe common modes of asexual reproduction in plants.

(3) Describe artificial methods of vegetative reproduction.

(4) Describe pre-fertilization events.

(5) Describe post-fertilization events.

4

Sexual Reproduction in Flowering Plants

Introduction

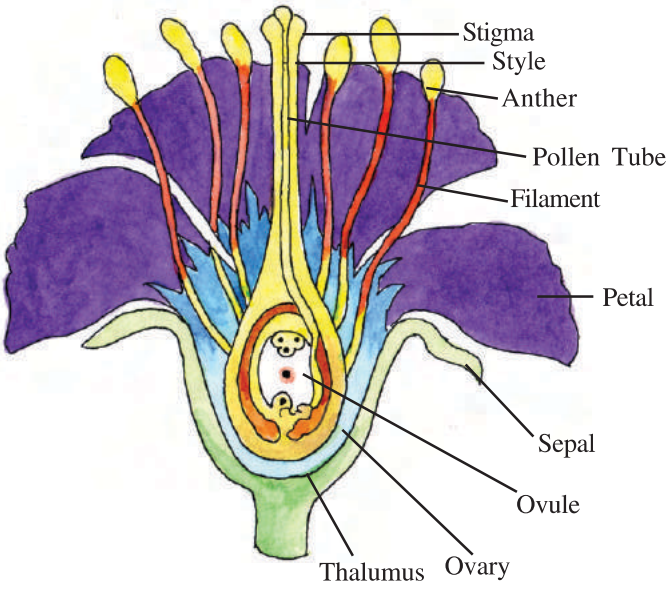
Reproduction is the most important characteristic of all living beings, plants and animals. It is a process of producing offspring and a means of self-perpetuation. The mode of reproduction varies according to individual species and available conditions. In lower angiosperms, it may be simply by division of cell or budding, whereas in higher organisms, it may be with the help of fully developed sex organs.

In higher plants reproduction may be asexual or sexual. In asexual reproduction, sex organs are not involved, and reproduction takes place by means of asexual methods, while in sexual reproduction, fusion of male and female gametes take place. Generally, in angiosperm plants the male and female sex organs are called stamen and pistil respectively. In some cases special modes of reproduction like apomixis and polyembryony are also reported. In this chapter, you will study various processes involved in the reproduction of flowering plants.

Flower : A Sexual Reproductive Part of Angiosperm Plants

Human beings have had an intimate relationship with flowers since time immemorial. Flowers are objects of aesthetic, social, ornamental, religious and cultural value. They have always been used as symbols for conveying important human feelings such as love, affection, happiness, grief, mourning and others.

Flower is the reproductive part of a plant. The flower is a compressed shoot, in which the sepals, petals, stamens and carpels are successive lateral organs. All these lateral organs are homologous to a leaf. The receptacle of the flower resembles structurally a vegetative tip. A typical flower has four sets of appendages, the outer two sets of sterile and the inner two sets of fertile appendages.



L.S. of Flower

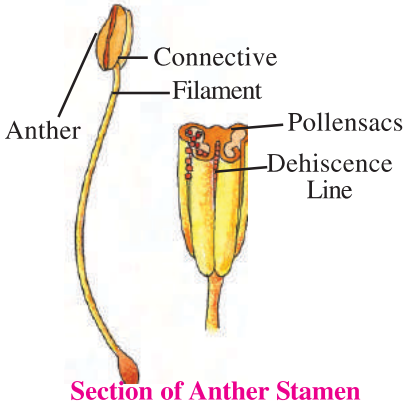
The two types of sterile appendages are sepals, which together form the calyx, and petals which make up the corolla. The two types of fertile appendages are stamens (microsporophylls) which make

up the androecium, and carpels (megasporophylls), which together produce the gynoecium. The stamen is typically a slender organ and includes two distinct parts, a proximal sterile part, the filament, and a distal fertile part, the anther, and the connecting structure between anther and filament is called connective. The carpel is generally divided in to a proximal ovule bearing part, the ovary, a distal pollen receptive part, the stigma, and a sterile region between ovary and stigma, the style.

Pre-Fertilization : Structures and Events

The differentiation and further development of the floral primordium to a flower is due to several hormonal and structural changes. In the flower, the androecium (representing the male reproductive organ) and the gynoecium (representing the female reproductive organ) differentiate and develop.

Stamen, Microsporangium and Pollen Grain



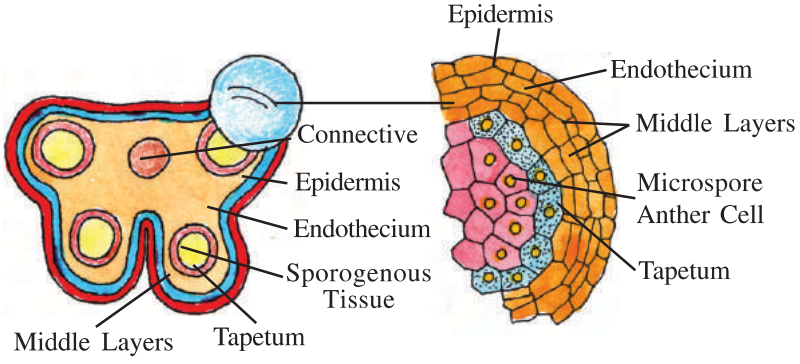
Section of Anther Stamen

Stamen : A stamen is known as microsporophyll. It is regarded as the male reproductive part of flower. A stamen consists of a filament, connective and an anther. The proximal end of the filament is attached to the thalamus of the flower. The number and length of stamens are variable in flowers of different species.

Internal Structure of Anther

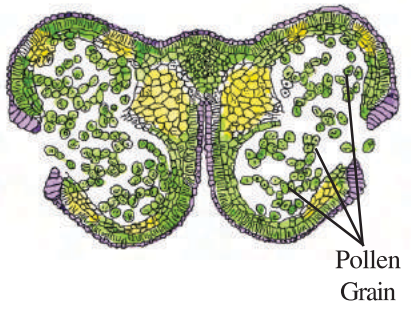
An anther is bilobed with each lobe having two theca, i.e. they are tetrathecous. Often a longitudinal groove runs lengthwise separating the theca. In transverse section, the anther is a tetragonal structure consisting of four microsporangia located at the corners. The microsporangia develop further and become pollen sacs. Pollen sacs are packed with pollen grains.

The typical microsporangium appears near circular in outline. It is generally surrounded by four wall layers – the epidermis, endothecium, middle layers and the tapetum. The epidermis is made of 3 to 5 layers. The cells of epidermis are greatly stretched and flattened. The endothecium is made of fibrous layers. These layers perform the function of protection and help in dehiscence of anther to release the pollen. The innermost layer of the wall develops into a single layered tapetum. It nourishes the developing pollen grains. The cells of tapetum have dense cytoplasm and conspicuous nuclei. The centre of each microsporangium process is made of compactly arranged homogenous cells called sporogenous tissue.



Anther T.S.

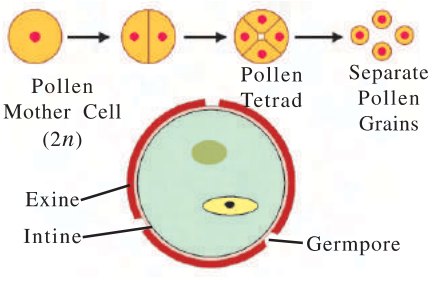
Enlarged View of Microsporangia



Mature Dehisced Anther

Microsporogenesis

As the anther develops, the cells of the sporogenous tissue undergo meiotic divisions to form microspore tetrads. Each one is a potential pollen. The process of formation of microspores from a pollen mother cell through meiosis is called microsporogenesis. The microspores, as they are formed, are arranged in a cluster of four cells- the microspore tetrad. As the anthers mature and dehydrate, the microspores dissociate from each other and develop into pollen grains. Inside each microsporangium several thousands of microspores are formed that are released with the dehiscence of anther.



Mature Microsporogenesis

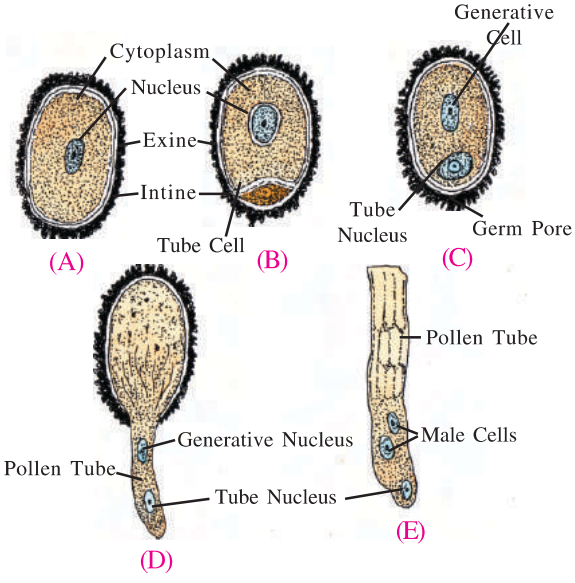
Pollen Grains

The pollen grain or microspore represent the male gametophytes and are possessed in the pollen sac or microsporangia. Pollen grain is a unicellular structure. They are very minute in size and are like particles of dust. Thus may be round, oblong, oval or rod like in shape. Pollen grains are generally spherical measuring about 25-50 micrometers in diameter. Thus may be smooth or spiny.

A pollen grain is uninucleate. The wall of pollen is two-layered. The hard outer layer is called exine. It is made of sporopollenin which is one of the most resistant organic materials known. It can withstand high temperatures and strong acids and alkali. No enzyme that degrades sporopollenin is so far known. Pollen grain exine has prominent aperatures called germpores where sporopollenin is absent. Pollen grains are well preserved as fossils because of the presence of sporopollenin. The inner layer of the pollen grain is called intine. It is thin and made up of cellulose and pectin. The cytoplasm of pollen grain is surrounded by a plasma membrane.

Development of Male Gametophyte

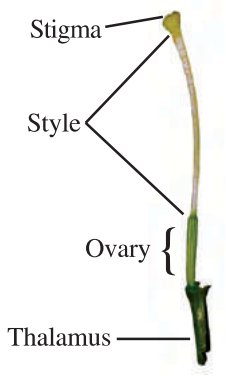
The development of male gametophyte from pollen begins when the pollen is still within the anther. The nucleus increases in size and then mitotically divides to produce two dissimilar cells. The large cell having abundant food reserve and large irregular shaped nucleus is called vegetative cell. The small cell is called generative cell.



Development of Male Gametophyte

When the pollen is at this stage of development, the anther dehisces in various ways and pollen is liberated. The intine of pollen develops as a pollen tube and comes out of a germ pore. It now extends through the style and grow towards the ovary. During this process, the tube cell remains in the terminal region of the pollen tube. It is gradually disintegrated. The generative cell divides mitotically and produces two male gametes.

The Pistil, Megasporangium and Embryo Sac



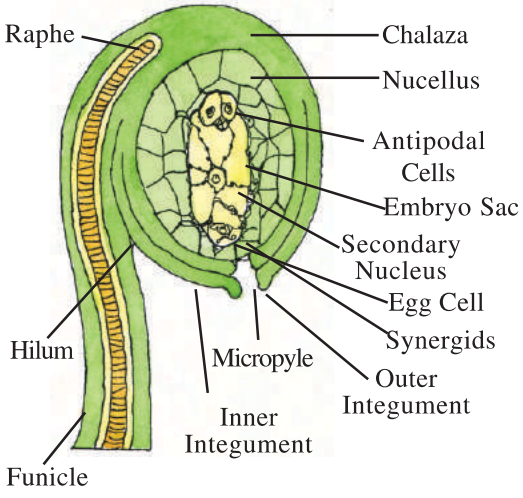
Pistil

Pistil : A gynoecium (pistil) is known as megasporophylls. It is a female reproductive part of the flower. When the pistil consists of only one carpel (e.g. in pea flower), it is called monocarpellary, and when it consists of two or more carpels, the pistil is said to be multicarpellary. The multicarpellary pistil can be apocarpus (free carpels) or syncarpous (united carpels).

Each carpel includes three parts-stigma, style and ovary. The stigma is the terminal end of the style upon which the pollen grain fall, and is generally knob-like and sticky. The style is the slender part beneath the stigma. The surface of the style can be smooth or covered with hairs. The swollen basal part of the pistil is the ovary. Inside the ovary is the ovarian cavity or locule. The placenta is located inside the ovarian cavity. Arising from the placenta is the megasporangia commonly called ovules. The number of ovules in the ovary may be one (wheat, mango) to many (papaya, orchids).

The Megasporangium (Ovule)

The ovule is small, oval structure attached to the placenta by a small stalk termed the funicle. The body of the ovule fuses with funicle in the region called hilum. Thus hilum represents the junction between ovule and funicle. Each ovule has one or two protective envelopes called integuments. A small opening is left at the apex of the integuments, this is termed the micropyle. Opposite the micropylar end, is the chalaza, representing the basal part of the ovule. The main body of the ovule has abundant reserve food materials. The nucellus is enclosed within the integuments. A large oval cell lying embedded in the nucellus toward the micropylar end is the embryo sac or female gametophyte. This makes a significant part of the mature ovule. It is an embryo sac, which bears the embryo later on.



L.S. of Ovule (Megasporangium)

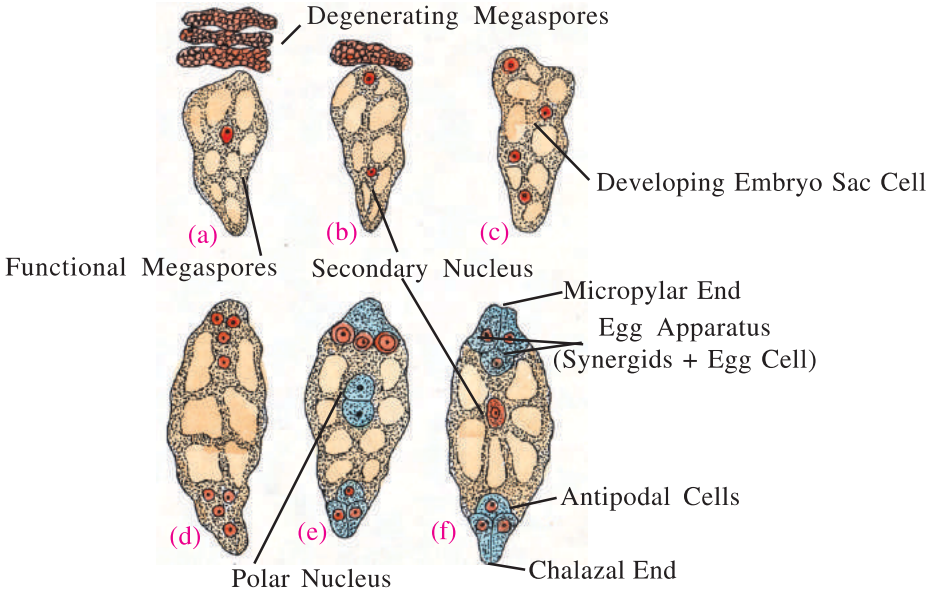
Megasporogensis

The process of formation of megaspores from the megaspore mother cell (MMC) is called megasporogenesis. Ovule differentiates a single megaspore mother cell, in the micropylar region of the nucellus. It is a large cell containing dense cytoplasm and a prominent nucleus. It divides meiotically and forms four haploid megaspores.

Embryo Sac (Female Gametophyte)

The megaspore (n) is the beginning of the female gametophyte generation. Generally of these four, only one becomes functional and produces the female gametophyte while the other three degenerate. This method of embryosac formation from a single megaspore is termed monosporic development.

The nucleus of the functional megaspore divides three times in succession and thus eight nuclei come into existence. A Female gametophyte develops through the organization of these eight nuclei. Three nuclei get organized into an egg-apparatus at the micropylar end. The egg-apparatus consists of one egg cell and two synergid cells. Towards the challazal end three nuclei get organized into three antipodal cells. Two nuclei jointly form a secondary nucleus (the large central cell) in the central region. Thus, a typical Angiosperm embryosac, at maturity, though 8-nucleate is 7-celled.



Development of Female Gametophyte

Pachanan Maheshwari in 1950 classified the female gametophyte into monosporic, bisporic and tetrasporic embryosac depending upon the number of megaspore nuclei taking part in the development.

Pollination

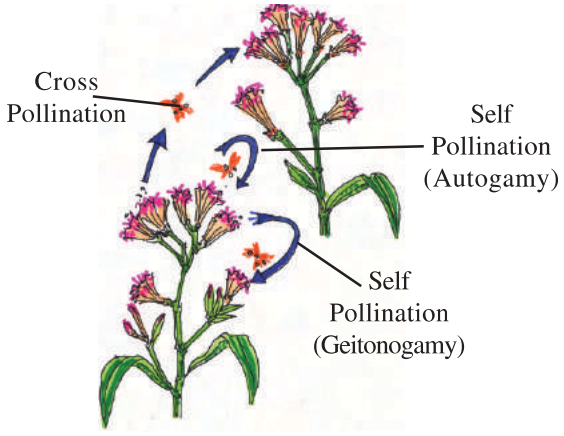
The process of transfer of pollen released from the anther to the stigma of a carpel is called pollination.

Kinds of pollination

Depending on the source of pollen, pollination can divided into two types.

(1) Self Pollination : Transfer of pollen from an anther to the stigma of the same flower of the same plant is called self-pollination. It can exist in bisexual flowers as well as unisexual flowers which exist on the same plant (monoecious condition). The process of self pollination can be of the following two types.

(a) Autogamy : In this type of self pollination, pollen grains of an anther are transferred to the stigma of the same flower. In other words, autogamy means pollination of a flower by its own pollens. Naturally autogamy is possible only in bisexual flowers.



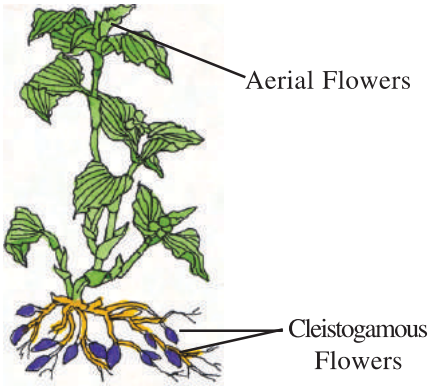
Self and Cross Pollination

In autogamous flowers, the stigma and anthers of a flower ripe almost simultaneously and this facilitates self-pollination. In several members of the Apiaceae, Lamiaceae and Cactaceae, there is a visible bending movement in the style which places the stigma closer to the anther.

(b) Geitonogamy : When the pollens of a flower pollinate any other flower present on the same plant, it is known as geitonogamy. Although geitonogamy is functionally cross-pollination involving a pollinating agent, genetically it is similar to autogamy since the pollen grain come from the same plant.

Adaptations Contrivances for Self Pollination

(i) Homogamy : It is the situation in which anther and stigma of a flower mature at the same time. Therefore the stigma is receptive at the time when anthers shed their pollens as in *Catharanthus roseus* (Barmasi). So there is a grater chance of self pollination although that is not obligatory.



Cleistogamy in *Commelina*

(ii) Cleistogamy : Production of flowers which never open is called cleistogamy and such flower are known as cleistogamous flowers. In such flowers, self pollination is carried out within closed buds. Therefore it is a remarkable way of avoiding cross-pollination e.g. *Viola*, *Oxalis* and *Commelina*.

Many plants which bears cleistogamous flowers also bear chasmogamosus flowers. There flowers open normally during anthesis. In *Commelina* cleistogamous flowers are produced on underground rhizomes or roots. They are small and inconspicuous, while chasmogamous flowers borne on aerial branches are generally bright coloured and attractive. Therefore cleistogamy may be called a facultative character.

(2) Cross Pollination : Transfer of pollen grains from the anther of the flower on one plant to the stigma of the flower on another plant, whether of the same kind or not, is called cross-pollination or allogamy. Cross pollination within a species is called xenogamy. Cross pollination involving different strains of plants yields hybrids. Cross-pollination is possible only in unisexual flowers. Cross-pollination leads to cross-fertilization; it has the advantage of genetic recombination.

The adaptations contrivances for cross pollination as follows :

(i) Dichogamy : In bisexual flowers, male and female sex organs mature at different time.

(ii) Self Sterility : Landing of pollen on stigma is no guarantee for seed set.

(iii) Heterostyly : In flowers which have styles of different lengths.

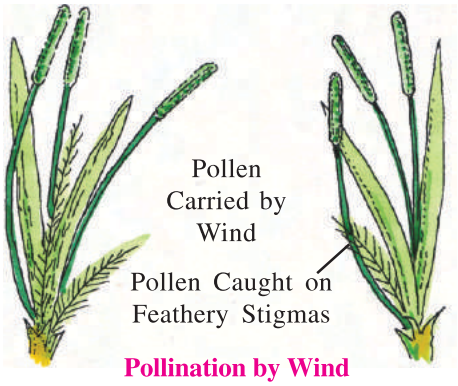
(iv) Herkogamy : In bisexual flower physical barrier between anther and stigma.

Agent of Pollination

Various transporting agents are required for carrying pollen from anther of one flower to stigma of a flower on another plant. Plants use abiotic (wind and water) and biotic (animals) agents to achieve pollination. Majority of plants use biotic agents for pollination. Only a small proportion of plants use abiotic agent. Each type of plants possesses some distinct characters related to their pollinating agent.

Anemophily (Pollination by Wind)

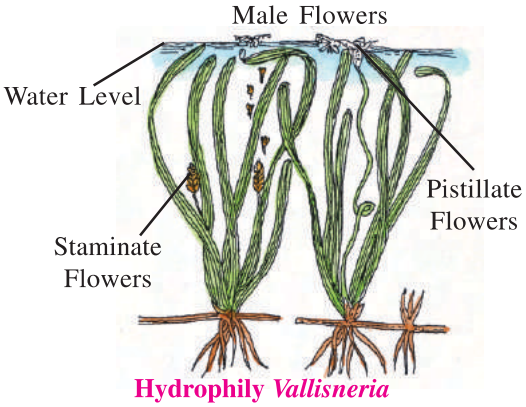
- Transfer of pollen grains through wind is called anemophily.
- Normally in such plants, the flower is unisexual.
- Pollen is produced in large amounts because the probability of their wastage is quite high.
- Pollen is small in size, light, dry and smooth.
- Male flowers are generally located higher on the plant and female flowers occur lower down.
- Stigma is branched, feathery, hairy and sticky.
- Flowers do not possess special shapes, colour, scent or nectar.
- Eg. Maize, Grasses, Coconut.



Pollination by Wind

Hydrophily (Pollination by Water)

- Pollination by water is called Hydrophily.
- It is limited to about 30 genera, mostly aquatic monocotyledons.
- Some examples of water pollinated plants are *Vallisneria, Hydrilla* and marine grasses (such as *Zostera*).
- In *Vallisneria* male flowers come to the surface of water and release their pollen on water surface. The female flowers have long stalks at the ends of which flowers are attached. Their stigma is waxy. As a result, the water around them becomes concave discs. Pollen is drawn into them. The fertilized flowers are withdrawn into water. For this, the stalks become spirally coiled like a spring..



Hydrophily *Vallisneria*

- In marine grasses, female flowers remain submerged in water and the pollen grains are released inside the water.
- In most of the water-pollinated species, pollen grains are protected from wetting by a mucilaginous covering and having specific gravity.

Zoophily

- When animals are also responsible for pollination, the phenomenon is called zoophily.
- Birds (sunbirds and humming birds), bats, squirrels and snails are the common pollination agent.
- In plants like *Bombax* and *Aloevera* pollination takes place by birds.
- In *Kigelia* pollination takes place by Bat.


Pollination by Bird


Pollination by Bats

- Even larger animals such as some primates eg. lemurs, arboreal eg. tree-dwelling rodents or even reptiles gecko lizard and garden lizard have also been reported as pollinators in some species.

Entomophily

- Insects are the most common pollinators, and this process is referred to as entomophily. It is a subtype of zoophily.
- Bees, butterflies, flies, beetles, wasps, ants and moth are common pollination agent.
- Insects, particularly bees are the dominant biotic pollinating agents.
- Flowers of insect-pollinated plants posses various arrangements for attracting specific kinds of insects. Such aspects of attraction are-specific shape, definite kinds of colour, scent, nectar and edible pollen. In some plants, individual flowers collectively form attractive inflorescences.

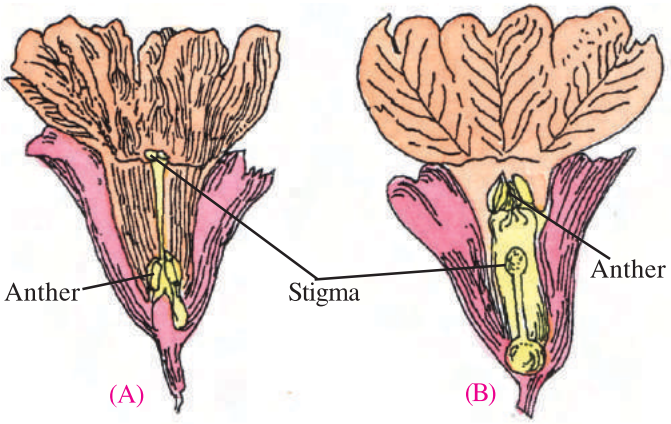
Entomophily

- Flowers produces relatively lower amount of pollen because pollen is to be distributed only when the insects visit them.
- Pollen is hairy, spiny and sticky so that it can stick to the body of the insects.
- *Amorphophallus* is pollinated by flies and *Yucca* by moth.

Outbreeding Devices

Many flowering plants produce bisexual flowers and pollen grains are likely to come in contact with the stigma of the same flowers. Continued self-pollination result in inbreeding depression. Flowering plants have developed many devices to discourage self-pollination and to encourage crosspollination.

In some species, pollen release and stigma receptivity are not synchronized (Dichogamy). Either the pollen is released before the stigma becomes receptive e.g. sunflower, or stigma becomes receptive much before the release of pollen e.g. Palms. In some other species the anther and stigma are placed at different position so that the pollen cannot come into contact with the stigma of the same flower. e.g. Primula.



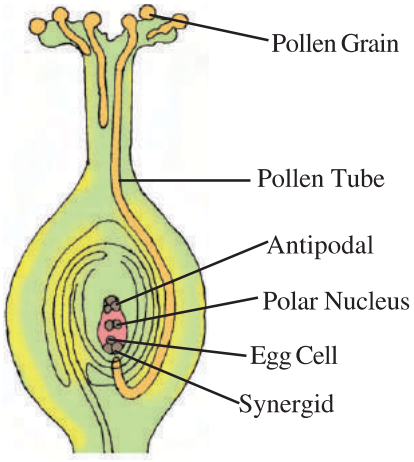
Anther and Stigma are Placed at Different Position in Flower of Primula

Both these devices prevent autogamy. The third devices to prevent inbreeding is self-incompatibility e.g. *Malva*. This is a genetic mechanism and prevents self-pollen (from the same flower or other flower of the same plants) from fertilizing the ovules by inhibiting pollen germination or pollen tube growth in the pistil.

Another device to prevent self-pollination is the production of unisexual flowers. In monoecious plant (eg. castor, maize), a autogamy is prevented, but not geitonogamy. While dioecious plant (eg. papaya) prevents both autogamy and geitogamy.

Pollen-Pistil Interaction

In nature, pollination does not guarantee the transfer of the pollen of the same species as the stigma (Compatible Pollen). Often pollen either from other species or from the same plant (Self-Incompatible), also land on the stigma. The pistil has the ability to recognize whether a particular pollen grain is to be accepted (compatible) or rejected (incompatible).



Longitudinal Section of a Flower showing Growth of Pollen Tube

If the pollen is compatible, the pistil accepts the pollen and promotes post-pollination events that lead to fertilization. If the pollen is self-incompatible, the pistil rejects the pollen by preventing pollen germination on the stigma. The ability of the pistil to recognize the pollen followed by its acceptance or rejection is due to chemical components (pollen wall and its protein contents and release of various hydrolytic enzymes) of the pollen.

In compatible pollination, the pollen grain germinates on the stigma to produce a pollen tube through germpores. The contents of the pollen grain move into the pollen tube. Pollen tube grows through the tissues of the stigma and style and reaches upto the ovary.

In some plants, pollen grains are two celled condition (a vegetative cell and a generative cell) or three celled condition (a vegetative cell and two male gametes produced from division of generative cell), Pollen tubes carry the two male gametes from the beginning. Pollen tube, after reaching the ovary, enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus. The function of filiform is guidance of the entry of pollen tube to the synergids. All the events from pollen deposition on the stigma until pollen tubes enter the ovule are together referred to as pollen-pistil interaction. The knowledge gained in this area would help the plant breeder in manipulating pollen-pistil interaction, even in incompatible pollinations, to get desired hybrids.

Artificial Hybridization

In artificial hybridization desired pollen grains are used for pollination and the stigma is protected from unwanted pollen. This is achieved by emasculation and bagging techniques.

In bisexual flower, removal of anthers from the flower bud before the anther dehisces using a pair of forceps without any injury is called emasculation. Emasculated flowers have to be covered with a bag of suitable size, generally made of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called bagging. When the stigma of bagged flower attains receptivity, mature pollen grains collected from anthers of the male parent are dusted on the stigma, and the flowers are rebagged, and the fruits allowed to develop.

In unisexual flowers, there is no need for emasculation. The female flower buds are bagged before the flower open. When the stigma becomes receptive, pollination is carried out using the desired pollen and the flower rebagged.

Significance

It is a major approach of crop improvement programme.

Double Fertilization

At the end of pollination, pollen becomes deposited on stigma of carpel. Following pollination, fertilization occurs.

A pollen tube develops as a result of the development of pollen grain on the stigma. The pollen tube grows through the style, enters the ovary and reaches an ovule. Two male gametes are included within the pollen tube.

The ovule develops an embryo sac. The pollen tube enters the embryosac through the micropyle. During its entry, the tip region of pollen tube breaks off. The synergid cells of egg apparatus also break down. Two male gametes are released into the cytoplasm of the synergid in the embryo sac.

At this stage the embryo sac contains one egg, one secondary nucleus and three antipodal cells.

One of the male gametes moves towards the egg cell and fuses with its nucleus thus completing the syngamy. Thus, a diploid zygote is formed. It is located towards the (micropyler) end. The other male gamete moves towards the secondary nucleus located in the central region of embryo sac and fuses with them to produce a triploid primary endosperm nucleus (PEN). So, the fusion of three haploid nuclei is termed triple fusion.

Thus, as two structure egg cell and secondary nucleus are fertilized, such a fertilization is called Double fertilization. It is a characteristic of all angiospermic plants.

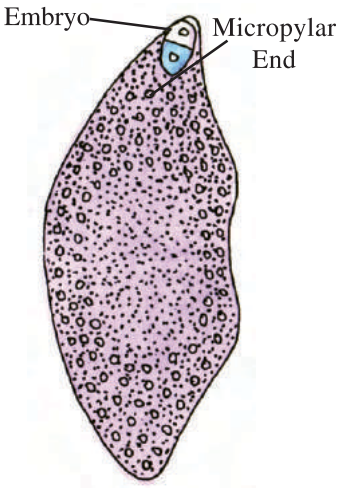
Later, the endosperm will develop from the primary endosperm nucleus and the embryo will develop from the zygote.

Post-Fertilization : Structure and Events

Following double fertilization, events of endosperm and embryo development, maturation of ovule(s) and ovary into fruit are collectively termed post-fertilization events.

Endosperm

As stated earlier, the endosperm develops from the primary endosperm nucleus ($3n$) by its repeated mitotic division and forms a triploid endosperm tissue. Its development begins just before the embryo development and is of three types, namely nuclear, cellular and helobial.



Nuclear Endosperm

The cells of this tissue are filled with reserve food materials and are used for the nutrition of the developing embryo.

In the most common type of endosperm (nuclear type) development, the PEN undergoes repeated nuclear division and produces a large number of free nuclei. The nuclei are arranged peripherally and a large vacuole occurs in the centre of the embryo sac. After this, the process of cytoplasmic division begins. It also begins from peripheral region and gradually extends towards the centre. Finally, a multicellular endosperm comes into existence.

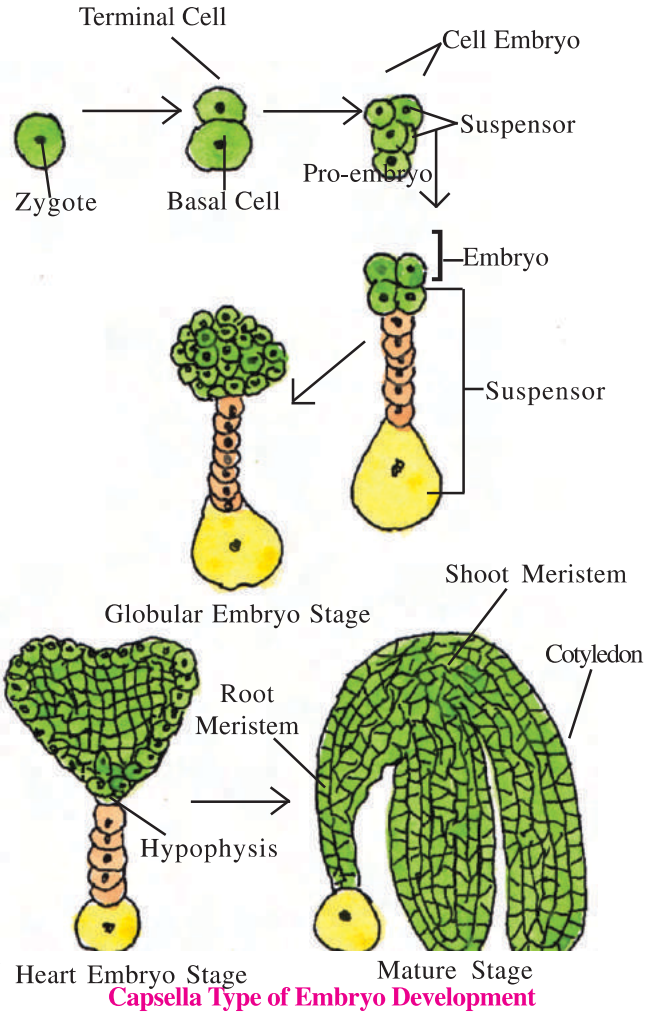
The coconut water from tender coconut is nothing but free-nuclear endosperm (made up of thousands of nuclei) and the surrounding white kernel is the cellular endosperm. In many dicots like pea, bean and groundnuts, endosperm are completely consumed by the developing embryo before seed maturation. However in castor and coconut endosperm may persist in mature seed and be used up during seed germination.

Embryo

Development of embryo occurs from the zygote located near the micropyle. Most zygotes divide only after a certain amount of endosperm are formed. This is an adaptation to provide assured nutrition to the developing embryo.

In *capsella* (dicotyledonous) plants, first the zygote divides transversely and two unequal cells are the result; of these, the larger one and located towards the micropyle is called a basal cell. The smaller one and located toward the chalaza direction is called-an apical cell. Now the basal cell divides transversely and the apical cell divides vertically. The four celled structure formed thus is called pro-embryo. It is subsequently converted into a globular, heart-shaped structure and matures.

If the two basal cells, the one located towards micropyle does not divide any further. The other basal cell repeatedly divides transversely and produces a filamentous structure made up of 20 to 25 cells. This structure is called suspensor. As a result of the development of the suspensor, the embryo developing from the apical cell is pushed towards the middle of the embryo sac. The large cell of suspensor which remains in contact with the apical cell is called hypophysis.



Capsella Type of Embryo Development

In the meantime, the apical cell divides again vertically. This division occurs at right angle to the first division and thus, four apical cells are formed. These four cells divide again and this division is at right angles to the previous both divisions. Thus eight cells come into existence. The following division is periclinal and forms sixteen cells. Thus two octants are formed. The anterior octant occurs towards the chalazal end. It is called apical octant or chalazal octant. The shoot apex or plumule epicotyl and two cotyledons of embryo will develop from this octant. The posterior octant occurs towards the micropylar end. It is called basal octant or micropylar octant. The hypocotyl and the central region of radical of the embryo will develop from this octant. The peripheral region of radical and rootcap of embryo will develop from the hypophysis.

Embryo of monocotyledons possess only one cotyledon. In the grass family the cotyledon is called scutellum. At the other and narrow end of scutellum, the embryonic axis remains attached. At one end of this axis occurs plumule and its protective covering is called coleoptiles. At the other end of this axis occurs radical and its protective covering is called coleorhiza.

Apomixis

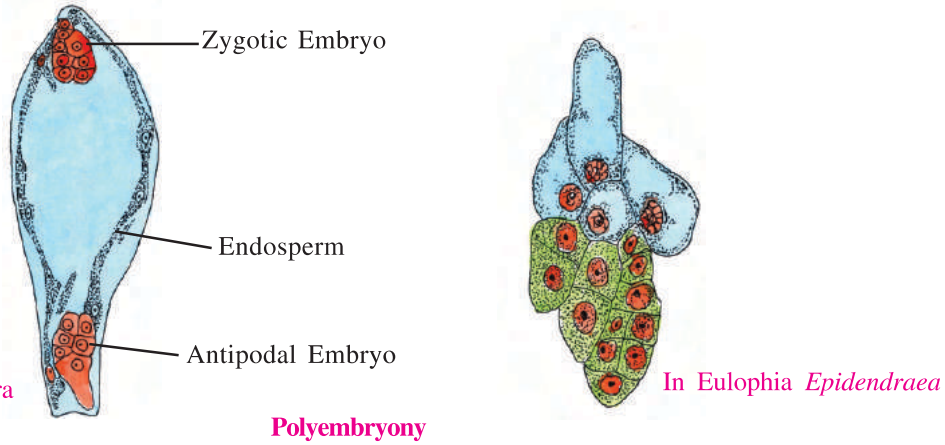
Apomixis is a modified form of reproduction in which seeds are produced without fertilization. This special mechanism is seen in species of Asteraceae and grasses. In another way Apomixis is a form of asexual reproduction that mimics sexual reproduction and the plant which shows it are called apomictic plants. There are several ways of development of apomictic seeds. In some species diploid embryo can arise either from diploid cells of the archesporium (Generative apospory) or from some other cell of the nucellus or integument (somatic apospory). Here there is no meiotic division.

Another form of apomixis is development of embryo from unfertilized egg (Haploid parthenogenesis) or from any cell of the embryo sac apart from the egg (Haploid apogamy). The embryo hence formed is naturally haploid. While another form of apomixis is known as sporophytic budding. Here, the diploid cell of the ovule (not arising from the cells of nucellus or the integument) lying outside the embryo sac is referred to as adventive embryonic cells. It is frequently reported in *citrus* and mango.

Significance of Apomixis : As apomixis does not involve meiosis, there is no segregation and recombination of chromosomes therefore, it is useful in preserving desirable characters for indefinite periods. But the importance of meiosis in evolution and variation cannot be ignored. In obligate apomictic species, desirable characters are preserved for quite a long time but they are deprived of development; on the contrary in facultative apomictic species, sexual and sexual methods occur simultaneously and hence there is great significance of apomixis.

Polyembryony

The phenomenon of development of more than one embryo in the seed is called polyembryony. Polyembryony is commonly observed in conifers (gymnosperms). It is also recorded in angiosperm plants like lemon, orange, onion, groundnut and mango. It may be due to the presence of more than one egg cell in the embryo sac or more than one embryo sac in the ovule, sometimes the synergid cell, antipodal cell or an integument cell mass form the extra embryo.



Polyembryony

Importance of Polyembryony : This phenomenon play an important role in plant breeding and horticulture.

Fruit Formation and Development of Seed

In the angiosperms fertilization produces changes not only in the embryo-sac but also in the ovary and at times, in other parts of the flower. Generally as ovules mature in to seeds the ovary develops into a fruit, i.e. the transformation of ovules into seeds and ovary into fruit proceeds simultaneously. The wall of the ovary develops into the wall of fruit called pericarp. The fruits may be fleshy as in mango, guava, orange etc. or may be dry as in groundnut and mustard etc. Many fruits have evolved mechanism for dispersal of seeds. For such mechanism specific fruits and seeds have papus (*Veronia*), coma (*Calotropis*), hairy outgrowth (*cotton*), hook-like structure (*Martynia*), stiff hairs (*Xanthium*) and mechanism dispersal (*Ruellia*).

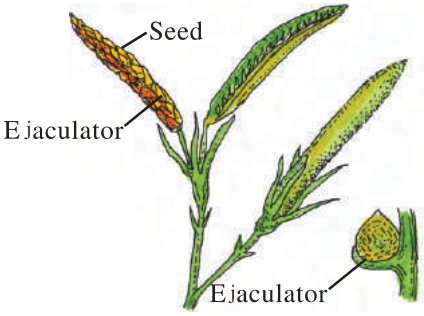
Papus (*Vernonia*)

Coma (*Calotropis*)

Stiff Hairs (*Xanthium*)

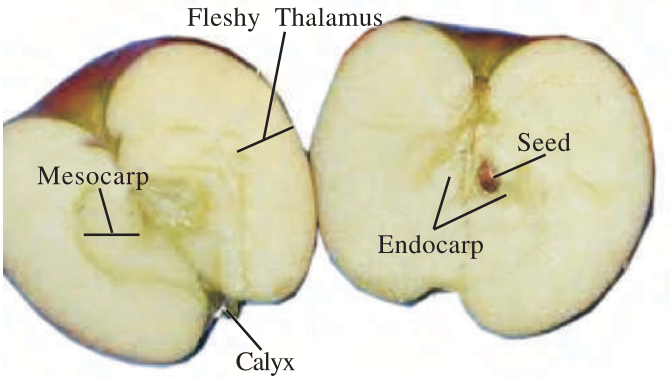
Hook-Like Structure (*Martynia*)

Hairy Out Growth (Cotton)



Mechanism Disposal (*Ruellia*)

In most plants by the time the fruit develops from the ovary, other floral parts degenerate and fall off. However, in a few species such as apple, strawberry, cashew etc the thalamus also contributes to fruit formation. Such fruits are called false fruits.

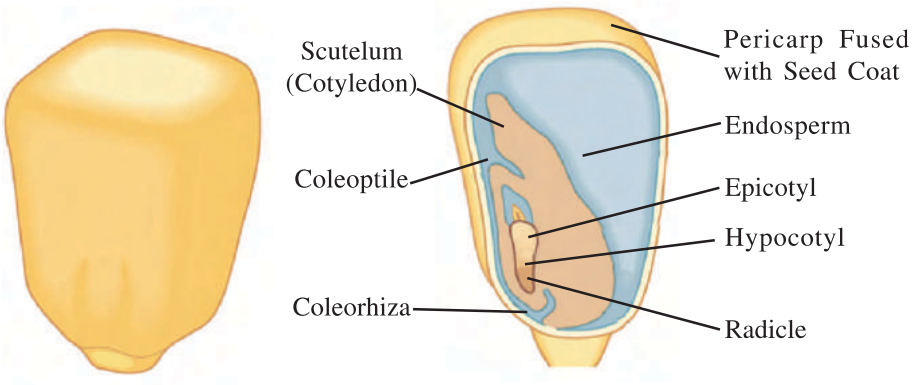


Apple (False Fruit)

Most fruits however develop only from the ovary and are called true fruits. Although in most of the species, fruits are the result of fertilization, there are a few species in which fruits develop without fertilization. Such fruits are called parthenocarpic fruits. e.g. Banana parthenocarpy can be induced through the application of growth hormones and such fruits are seedless.

In angiosperm, the seed is the final product of sexual reproduction. It is often described as a fertilized ovule. Seeds are formed inside the fruits. A seed typically consists of seed coat(s), cotyledon(s) and an embryo axis. The cotyledons of the embryo are a simple structure, generally thick and swollen due to storage of food reserves. Mature seeds

may be non-endospermic or endospermic. Non-endospermic seeds have no residual endosperm as it is completely consumed during embryo development (e.g. pea, groundnut). Endospermic seeds retain a part of endosperm as it is not completely used up during embryo development (e.g. maize, castor). Occasionally, in some seeds such as black pepper and beet remnants of nucellus are also present. This residual, persistent nucellus is the perisperm.



Structure of Monocot Seed

As the seed matures, its water content is reduced and seeds become relatively dry. The general metabolic activity of the embryo slows down. The embryo may enter a state of inactivity called dormancy, or if favorable conditions are available (adequate moisture, oxygen and suitable temperature) they germinate.

Seed is the basis of our agriculture. Dehydration and dormancy of mature seeds are crucial for storage of seeds which can be used as food throughout the year and also to raise crop in the next year. In a few species the seeds lose viability within a few months. Seeds of a large number of species live for several years. Some seeds can remains alive for hundreds of years. There are several records of very old yet viable seeds. A seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date palm (*Phoenix dactylifera*), discovered during the archeological excavation at King Herod's palace near the Dead sea.

SUMMARY

Flowers are the reproductive parts of a plant. A typical flower has four sets of appendages. The outer two sets (Calyx and Corolla) are sterile and the inner two sets (Androecium and Gynecium) are fertile appendages.

Stamens are known as microsporophylls. It is regarded as the male reproductive part of flower. An anther is bilobed structure consisting of four microsporangia. It is generally surrounded by four wall layers-the epidermis, endothecium, middle layers and the tapetum. The center of each microsporangium possesses compactly arranged homogenous cells called sporogenous tissue. The sporogenous tissue undergoes meiotic division (microsporogenesis) to form microspore tetrads. Individual microspores mature into pollen grains. Pollen is two-layered. The hard outer layer is called exine and thin inner layer is called intine. Pollen grain exine has prominent apertures called germ pores where sporopollenin is absent. The intine of pollen develops as a pollen tube and comes out of the germ pores. During male gametophyte stage, the nucleus of pollen grain divides to produce vegetative and generative cells and later on, two male gametes.

A Gynoecium (Pistil) is known as megasporophylls. It is the female reproductive part of the flower. Each carpel includes three parts-stigmas, style and ovary. Ovule (megasporangia) arise from the placenta

located inside the ovarian cavity. The ovules have small stalked funicle, one or two protective integuments and a small opening called micropyle. A single megaspore mother cell (mmc) in the micropylar region of the nucellus divides meiotically and forms four haploid megaspores. Generally, of these four, only one becomes functional and produces female gametophyte (embryo sac). The mature embryo sac is 7-celled and 8-nucleate. Three nuclei get organized into an egg-appratus which consists of one egg cell and two synergid cells. Towards the challazal end three nuclei get organized into three antipodal cells. Two nuclei jointly form a secondary nucleus in the central region.

The process of transfer of pollen released from the anther to the stigma of a carpel is called pollination. Depending on the source of pollen, pollination can be divided into two types: self pollination and cross pollination. Self pollination can exist in bisexual as well as unisexual flowers while cross pollination is possible only in unisexual flowers. Homogamy and cleistogamy are the adaptations for self pollination and Dichogamy, self-sterility, Heterostyled for cross-pollination . Pollinating agents are either abiotic (wind and water) or biotic (animals).

Pollen-pistil interaction involves all events from the landing of pollen grains of the stigma until the pollen tube enters the embryo sac (when the pollen is compatible) or pollen inhibition (when the pollen is incompatible). Following compatible pollination, pollen grain germinates on the stigma and the resulting pollen tube grows through the style, enters the ovules and finally discharges two male gametes in one of the synergids.

Angiosperms exhibit double fertilization because two fusion events occur in each embryo sac, namely syngamy and triple fusion. The products of these fusions are the diploid zygote and the triploid primary endosperm nucleus. Zygote develops into the embryo and the primary endosperm nucleus forms the endosperm. These are known as post fertilization events. The divisions during the development of endosperm may occur in a different manner and result in the production of nuclear or cellular or helobial type of endosperm.

The developing embryo passes through different stages such as the pre-embryo, globular and heart-shaped stage before maturation. Mature dicotyledonous embryo has two cotyledons and an embryonal axis with epicotyl and hypocotyl. Embryo of monocotyledons possesses only one cotyledon. After double fertilization, ovary develops into fruit and ovules develop into seeds.

Apomixis is a modified form of reproduction in which seeds are produced without fertilization. It is seen in species of Asteraceae and grasses. The phenomenon of development of more than one embryo in the seed is called polyembryony. This phenomenon plays an important role in plant breeding and horticulture.

EXERCISES

1. Put a dark colour in a given circle for the correct answer :

(1) Which is called male reproductive organ of the following ?

(a) Corolla ◯ (b) Calyx ◯ (c) Gynoecium ◯ (d) Androecium ◯

(2) Anther generally consists of ..... .

(a) One microsporangia ◯ (b) Two microsporangia ◯

(c) Three microsporangia ◯ (d) Four microsporangia ◯

(3) In a pollen grain larger irregular shaped nucleus is:

(a) Archesporical nucleus ◯ (b) Vegetative cell ◯

(c) Prothallial nucleus ◯ (d) generative cell ◯

(4) A microspore mother cell forms.

(a) Embryo Sac ◯ (b) Pollen Grains ◯

(c) Nucellus Nucleus ◯ (d) Tapetum ◯

(5) The ovule is attached to the placenta by a small stalke which is known as.

(a) Hilum ◯ (b) Funicle ◯ (c) Nucellus ◯ (d) Chalaza ◯

(6) How many megaspore mother cells are produced in a Nucellus ?

(a) Two ◯ (b) Eight ◯ (c) Four ◯ (d) One ◯

(7) What forms when meiotic division in an ovule takes place ?

(a) Archesporium Tissue ◯ (b) Megaspore Mother Cell ◯

(c) Megaspore ◯ (d) Generative cell ◯

(8) The mature embryo sac has how many cells ?

(a) Five cells ◯ (b) One cell ◯ (c) Eight cells ◯ (d) Seven cells ◯

(9) Transfer of pollen to the stigma of another flower of the same plant is:

(a) Allogamy ◯ (b) Xenogamy ◯ (c) Autogamy ◯ (d) Geitonogamy ◯

(10) Hydrophily occurs in which plant ?

(a) *Vallisnaria* ◯ (b) Maize ◯

(c) Grasses ◯ (d) *Yucca* ◯

(11) Which plants among the following are pollinated by flies ?

(a) *Yucca* ◯ (b) *Amorphophallus* ◯

(c) *Zostera* ◯ (d) Maize ◯

(12) Cleistogamy occures in which plant ?

(a) *Commelina* ◯ (b) *Yucca* ◯

(c) *Malva* ◯ (d) *Hydrallia* ◯

(13) What is the name of the larger cell of the suspensor that remains in contact of apical cells ?

(a) Hypophysis ◯ (b) Endosperm ◯

(c) Apical cell ◯ (d) Single cell ◯

(14) What does egg apparatus contain ?

(a) Egg cell + synergids ◯ (b) Egg cell + secondary nucleus ◯

(c) Three antipodals ◯ (d) Synergids + secondary nucleus ◯

(15) Autogamy occurs in which family ?

(a) Apiaceae & Lamiaceae ◯ (b) Verbenaceae & Moraceac ◯

(c) Menispermaceae & Lamnaccae ◯ (d) Apocynaceae & Rhanaceae ◯

(16) Which plant is pollinated through wind ?

(a) Commelina ◯ (b) Maize ◯

(c) Malva ◯ (d) Moras ◯

(17) The adaptation of Self-pollination is :

(a) Dichogamy ◯ (b) Self-sterility ◯

(c) Cleistogamy ◯ (d) Herkogamy ◯

(18) Synergids are of which type ?

(a) Diploid ◯ (b) Triploid ◯ (c) Haploid ◯ (d) Tetraploid ◯

(19) Embryosac is found in –

(a) Embryo ◯ (b) Seed ◯ (c) Ovule ◯ (d) Endosperm ◯

(20) In embryo development, the basal cell which produces 20 to 25 cell structures is called

(a) Apical cell ◯ (b) Suspensor ◯

(c) Hypophysis ◯ (d) Central cell ◯

(21) The development of embryo from unfertilized egg is :

(a) Haploid apogamy ◯ (b) Haploid Parthenogenesis ◯

(c) Generative apospory ◯ (d) Somatic apospory ◯

(22) What is haploid Parthenogenesis?

(a) Development of egg without fertilization ◯

(b) Development of fruit without fertilization ◯

(c) Development of seed without fertilization ◯

(d) Development of egg with fertilization ◯

(23) Polyembryony is recorded in which angiosperm plant?

(a) Lemon ◯ (b) Conifers ◯ (c) Cycads ◯ (d) Grasses ◯

(24) Who is having hook-like structure ?

(a) Cotton ◯ (b) *Xanthium* ◯ (c) *Calotropis* ◯ (d) *Martynia* ◯

(25) Mechanism dispersal is seen in which species ?

(a) *Calotropis* ◯ (b) *Ruellia* ◯

(c) *Malva* ◯ (d) *Zostera* ◯

2. Answer the following questions in short :

(1) What is male reproductive organ ?

(2) Give the name of fibrous layer in anther.

(3) Give the full form of PMC.

(4) Give the diameter of pollen grains.

(5) Give the name of irregular shaped nucleus in pollen.

(6) What is the swollen basal part of ovary called ?

(7) Define funicle.

(8) What is pollination ?

(9) What is cleistogamy ?

(10) Which tissue develops from primary endosperm nucleus ?

(11) **Define it :**

(1) Double fertilization (2) Self-pollination

(3) Cross pollination (4) Apomixis

(5) Gengative apospory (6) Somatic apospory

(7) Haploid apogamy (8) Haploid Parthenogenesis

(9) Polyembryony (10) Dormancy

3. Write a short note on the following :

(1) Microsporogenesis
(2) Pollen grains
(3) Development of male gametophyte
(4) Megasporogenesis
(5) Pistil
(6) Autogamy
(7) Homogamy
(8) Cleistogamy
(9) Anemophily
(10) Hydrophily
(11) Zoophily

4. Describe in detail :

(1) Sexual reproductive part of Angiosperms.
(2) Anther and its internal structure.
(3) Ovule and embryo sac.
(4) What is pollination ? Describe cross pollination.
(5) Abiotic pollinating agent.
(6) Double fertilization.
(7) Development of endosperm.
(8) Development of dicot embryo.
(9) Apomixis.
(10) Formation of fruits.

5

Growth and Development in Plants

We know that all plant organs are made up of a variety of tissues. Is there any relationship between the structure of a cell, a tissue, an organ and the function they perform? Can the structure and the function of these be changed? All cells of a plant are descendents of the zygote. Development is considered as the sum of two process-(1) Growth and (2) Differentiation. It is essential to know that the development of a mature plant from a zygote follows the highly ordered succession events. During this process, a complex body organization is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. In this chapter, let us study some of the internal as well as external factors which govern and control these developmental processes.

Growth

Growth can be defined as an irreversible increase in the size and weight of an organism.

Growth as the Progressive Development of an Organism : New cells are added through the process of cell division. These cells cause growth in tissues and organs. Physiologically growth is an outcome of metabolism. Anabolic activities are synthetic and catabolic activities are degrading. Both, anabolic and catabolic activities are interlinked. When anabolic activities occur in excess of catabolic activities, growth results. There is an increase in the dry weight as an outcome of growth.

Characteristics of Growth : In plants, growth is limited to meristematic tissues only. Such a tissue constitutes shoot apex and root apex. New cells are added there and the cells increase in size. These newly added cells differentiate into tissues.

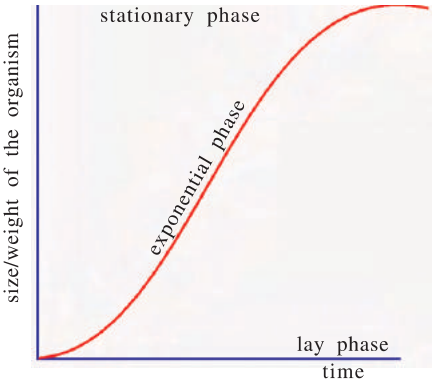
Process of Growth : Thus, three main activities are involved in the process of growth : (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation.

Primary Growth and Secondary Growth : Growth takes place in stem, root and their sub-branches. Length increases from time to time in plant organs due to the activity of apical meristems arranged at their tips. Such a growth is called-primary growth.

In the stems and roots of dicot plants, after the completion of primary structure of organs, through the activity of lateral meristem known as cambium, the addition of new and more cells in the girth of concerned organ occurs, this is called-secondary growth. The intercalary meristem located in the nodal region of monocot plants is also responsible for growth.

Rate of Growth : The increased growth per unit time is termed as growth rate. Initially, the rate of growth in plant is slow. Then it increases very rapidly. In course of time, it again slows down. Suppose we draw a graph of growth-rate based on the increase in number of cells against time taken. Such a graph will be a typical - S - shaped graph. (S = sigmoid curve). After an initial period of slow growth-rate, an exponential period of growth follows and finally a stable state of growth occurs.

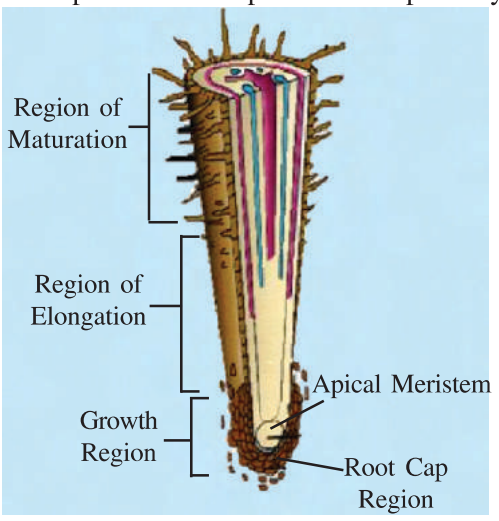
We should note that such a graph of growth is obtained for growth of an organism and that of a population also. Parameters other than an increase in the number of cells can also be used in measurement of Growth.



Growth Curve

Phases of Growth : Growth is divided into three phases : (1) Phase of cell division, (2) Phase of cell enlargement and (3) Phase of cell differentiation.

(1) Phase of Cell Division (Formation or Meristematic) : The meristematic cells located in shoot apex and root apex divide repeatedly and continuously and add new cells. The meristematic cells possess dense protoplasm, a large nucleus and a thin cell wall made up of cellulose. Faster rate of metabolism occurs in them.



Region of Root

(2) Phase of Cell Enlargement (Elongation) : In this phase, the new cells formed through cell divisions increase in size. The volume of cells increases. The growth in cell wall is mainly responsible for such enlargement. The size of vacuole in the cell also increases.

(3) Phase of Cell Differentiation (Maturation) : Now, the cells assume forms based on their functions. Their size and form become permanent. They become associated with the constitution of various tissues. The phase of becoming differentiated is called-differentiation phase.

These phases of growth are also known as distinct regions. These regions are called respectively - region of formation; region of enlargement and region of maturation. These regions can be observed in the longitudinal sections of root apex and shoot apex. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors Affecting Growth

(1) Water : Water is essential for turgidity of cells undergoing growth. Water is also required as a medium for various biochemical processes.

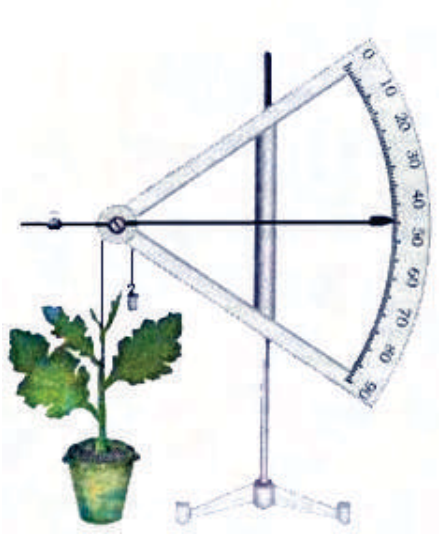
(2) Oxygen : Oxygen is inevitable for respiration.

(3) Temperature : Proper temperature is required for germination. Normally, the optimum range is between 28°C and 30°C.

(4) Light : Light is required for photosynthesis. Food is prepared in this way.

(5) Nutrients : Availability of proper amount of nutrients is required for plant growth. The materials and energy required for synthesis of protoplasm are obtained from the nutrients. Deficiency of various nutrients and various kinds of stresses hinder the process of growth.

Measurement of Growth : At a cellular level, growth is an increase in the amount of protoplasm. Since it is difficult to measure it directly, so it can be measured in some quantity which is more or less proportional to it.



Arc-Auxanometer

There are various methods of measuring growth. The growth in length of a plant can be measured by a simple measuring-tape. It can also be measured by counting an increase in the number of branches, number of leaves etc. from time to time. Similarly, it can be measured by considering the normal weight or the dry weight of the plant. The aerial spread of plant can also be taken into account.

For a more exact measurement of growth in length of a plant, an arc- auxanometer is employed. One end of a thread is tied to the apical bud area of the plant. The thread is then passed over a pulley which is attached to the apparatus and suspended by a weight attached to the other end of the thread. The position of the indicator on the arch is noted. As growth occurs, the weighed end of the thread is lowered. As this happens, the indicator also moves along the arch. This distance is measured at proper time-intervals and growth is calculated.

Development

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. Growth, differentiation and development are very closely related events in the life of a plant. It means that development is the sum of two processes: growth and differentiation. Development in plants(both growth and differentiation) is under the control of internal and external factors. The earlier includes intracellular(genetic) or intercellular(plant growth regulators) while the later includes light, temperature, water, oxygen, nutritients etc.

Growth-Regulators

The life of plants is controlled by a number of different hormones. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Plants synthesize specific organic chemicals which act as growth regulators. Their synthesis occurs in specific regions. From there, they are conducted to some specific regions and influence growth occurring there or influence some activities there. Such an influence may be either stimulatory or inhibitory. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Ethylene and Abscisic acid. Some vitamins also act as growth-regulators.

Growth Promoters (Auxins, Gibberrelins and Cytokinins)

(i) Auxins : Auxin was first isolated from human urine. This and other such substances obtained naturally or synthesized are known as *Indole-Acetic-Acid*(IAA). The effect of auxin and its hormone like properties were studied first of all in Oat coleoptile. IAA and IBA (*Indo1e-Butyric-Acid*) are obtained from plants. 2-4-D (2, 4–*Di-chlorophenoxy-acetic-acid*), NAA (*Napthalene Acetic Acid*) are synthetic auxins.

Effects of Auxins

- Induces formation of adventitious roots, apical dominancy and development of seedless fruits(parthenocarpy).
- Stimulates the process of flowering.
- Stimulates the respiration process.
- Stops premature fall of leaves and fruits.
- Regulates phototropic movement of plant organs.
- Acts as weed-controllers and weed-eradicators.
- Are useful in stimulating cell division in tissue-culture also.

(ii) Gibberrelins : Gibberellins are another kind of promoter plant growth regulator. This hormone was discovered during the investigation of disease in paddy plants. It was discovered in Japan. The disease was named 'bakane' which means *'foolish plant'*.

Such diseased plants are abnormally long, yellow, thin and normally sterile. This happens due to the disease induced by secretion of *gibberrela* fungus. Their secretion is called-gibberrelin.

Later, occurrence of gibberrelin was established in other plants also. More than 100 different kinds of gibberrelins have been discovered from fungi and other higher plants. These are known as GA_1, GA_2, GA_3... etc. Their synthesis is higher in darkness. All kinds of gibberrelins are acidic in nature. There is a great variation in their effects. Their structure and mode of action are different from those of auxins.

Effects of Gibberrelins

- Remove the expression of genetic dwarfism.
- Induce elongation of stem. The internodes develop longer. They also increase leaf area.
- Mobilization of storage compounds during germination
- Responsible for removal of dormancy of buds and seeds. They stimulate synthesis of various enzymes which activate the embryo.
- Induce flowering in some plants.

(iii) Cytokinins : Cytokinin was first discovered as kinetin(a modified form of adenine-a purine) from the sperms of herring fish. These hormones have a remarkable influence on cell division. It does not occur naturally in plants. A substance called *zeatin*, having effects similar to that of cytokinin was obtained from maize grain as well as from coconut milk. Later, it has become possible to obtain some natural cytokinins and other synthetic compounds having similar effects. They are produced in the regions actively involved in cell division.

Effects of Cytokinins

- Stimulate the processes of cell division, cell enlargement and cell differentiation.
- Reduce apical dominance.
- Retard the process of senescence.
- Retened chlorophyll in leaves.
- Translocate nutritients and organic substances.

Growth Inhibitors (Abscisic Acid and Ethylene)

(iv) Abscisic Acid(ABA) : It was first discovered as a substance inducing fall of cotton fruits. It contributes in regulating abscission and dormancy. Generally ABA acts as a general plant growth inhibitor and an inhibitor of plant metabolism.

Effects of Abscisic Acid

- The most remarkable effect of abscisic acid is inducing leaf fall and seed dormancy.
- Under the condition of water-stress, it stimulates the process of closing of stomata.
- It inhibits seed germination and the development of excised embryo.
- Resistance to stress conditions.

(v) Ethylene : Ethylene is a simple gaseous plant growth regulator, which is volatile in nature. Its concentration remains high in tissues undergoing senescence and in the ripening fruits.

Effects of Ethylene

- It inhibits the length wise growth in root, stem and leaves
- It induces senescence in plants.
- It induces leaf-fall and fall of flowers.
- It stimulates the process of ripening of fruits.
- It induces drooping of leaves and flowers.

Seed Dormancy

Seed dormancy is defined as a state in which seeds are prevented from germinating even under favorable environmental conditions. For this various internal factors are responsible.

During the period of dormancy, the growth of seed is arrested. Some seeds remain dormant for days, while others remain dormant over months or even years.

Types of Seed Dormancy : There are mainly four types**:** (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy.

(1) Exogenous Dormancy : Exogenous dormancy is caused by conditions outside the embryo and is often classified into three subgroups:

(a) Physical Dormancy : Which occurs when seeds are impermeable to water or to the exchange of gases.

(b) Mechanical Dormancy : Mechanical dormancy occurs when seed coats or other coverings are too hard to allow the embryo to expand during germination.

(c) Chemical Dormancy : Includes growth regulators that are present in the coverings around the embryo.

(2) Endogenous Dormancy : Endogenous dormancy is caused by conditions within the embryo itself, and it is also often divided into the following three subgroups.

(a) Physiological Dormancy : Physiological dormancy prevents embryo growth and seed germination until chemical changes occur.

(b) Morphological Dormancy : It occurs when the embryos are not differentiated into different tissues at the time of fruit ripening; it means embryo is underdeveloped or undifferentiated.

(c) Combined Dormancy : Seeds have both morphological and physiological dormancy (Morpho-physiological dormancy).

(3) Combinational Dormancy : Combinational dormancy is caused by both exogenous (physical) and endogenous (physiological) conditions in some seeds.

(4) Secondary Dormancy : The conditions that are not favorable for seed germination, like high temperatures causes secondary dormancy.

Various Causes for Seed Dormancy

- Underdeveloped embryo.
- Seed coats impermeable to water.

- Mechanically hard and strong seed coats which do not permit germination.
- Physiologically immature embryo.
- Presence of some germination-inhibiting chemicals. Amongst them the main one is Abscisic acid.

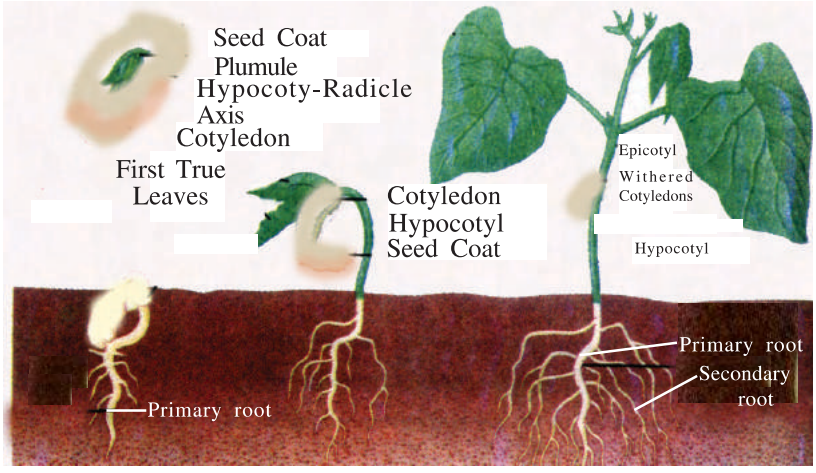
Amongst hormones, Gibberrelins are absent in dormant seeds. At this time, ABA remains active. It inhibits the transcription of genes. As a result, proper enzymes are not synthesized.

Removal of Seed Dormancy

When production of Gibberrelins begins in the seed and when their concentration exceeds that of ABA, the effect of ABA is removed and the embryo becomes active. To induce germination of seed, it is necessary to remove its dormancy. Such a removal of dormancy can also be artificially achieved. Some of these methods are as under -

- Seeds can be scraped lightly with sandpaper. Thus, their seed coats become permeable to water and germination is induced.
- A similar result can be achieved by using chemicals.
- Soaked seeds in an O_2 containing environment, can be provided higher or lower temperature for a definite period. Dormancy is removed in this way.

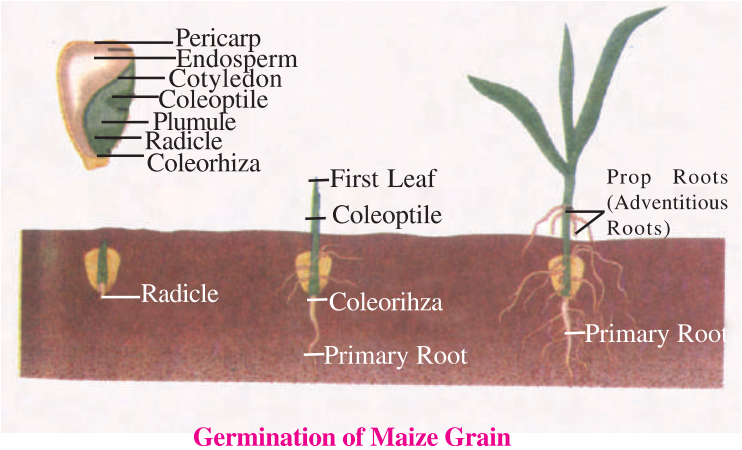
Seed Germination



Germination of Bean Seed

The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. With seed-germination the growth of a plant begins. After the completion of the dormancy period, if suitable environmental factors are available, germination occurs. Optimum water, sufficient O_2 and favourable temperature are preconditions for germination.

The seed, first of all, imbibes water. As the seed coats become loose, rapid absorption of water occurs through the micropyle. Embryo becomes active. Digestion of food, either stored in endosperm or in the cotyledons, begins with the help of proper enzymes. The developing embryo is nourished in this way. First of all, the radicle of the embryo develops into a primary root which comes out from the micropyle. This is known as 'sprouting'. This indicates initiation of germination. The primary root develops and forms a root system.



Germination of Maize Grain

In the meantime, development of plumule also begins. Shoot, that is stem and leaves, is formed through development of plumule.

Growth-related processes like cell division, cell enlargement and cell differentiation take place in the formation of root-system and shoot-system during germination. During the entire process a high respiratory rate is maintained. Some hormones are secreted and some enzymes become active.

Viviparous Germination

Viviparous Germination : 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination..The seed germinates while it is still in the fruit and attached to the parent plant. Later, as the weight of the sapling increases, it drops vertically straight into the mud and becomes anchored. Lateral roots develop and proper establishment is achieved. Such a germination is called- 'Viviparous Germination'. *Rhizophora* and *Avicennia* are the examples.

Senescence : Senescence is a period between complete maturation of an individual and the death of that individual. It is also known as 'ageing'. During senescence, the rate of catabolic activities remains high. There is depreciation in the organ and in the body. Efficiency decreases. It seems that hormones have an influence on this process.

Such senescence affects the individual organs as well as the entire body. Annual plants like wheat, other cereals and other plants experience senescence of the entire body. All organs are involved. In some biennial plants, the aerial shoot experiences this. In autumn, all leaves drop off in this way.

Abscission : The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In such organs a specific 'abscision layer' develops. The cells in this layer undergo degradatory processes and become weak. As a result, a weakness is generated in that region. At a proper time, the leaf, flower or the fruit breaks away from that region and drops off. A hormonal-imbalance is responsible for inducing abscission.

In a healthy leaf, the synthesis of auxins is higher. During senescence it is reduced. Synthesis of growth-inhibiting hormones like ethylene and abscisic acid increases. Under their influence, the middle lamella which is made up of pectin and which interconnects the cellulose cell wall, become degraded. With other accompanying degradatory activities, the abscission layer develops.

Photoperiodism : In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. The stems of plants growing in dark are long, thin, yellow and weak and it is called "etiolated position" . In adequate light, they are normal, healthy and with green leaves. The period for which light is available has a remarkable influence on flowering.

Long Day Plants : Some plants require a longer period of light to come into flowering. Such plants are called-long day plants. Wheat, Poppy, Oat, Beet etc. are long day plants.

Short Day Plants : Some plants require a shorter period to flower. Such plants are called - short day plants. Paddy, Soyabean, *Xanthium* etc. are short-day plants.

Day Neutral plants : In some other plants the period of available light does not have any influence on their flowering. Such plants are called - Day neutral plants. Tomato, *Cucumis* and *Maize* etc. are day neutral plants.

For a photoperiodic response, the continuity of the period of available light and its following period of dark is inevitable. When a momentary period of dark breaks the continuity of light period in the long-day plants or such a period of light breaks the continuity of dark period in the short-day plants, the response of flowering to this stimulus is not observed. It is believed that some specific pigment as well as some specific hormone is responsible for this process.

Vernalization : Better and earlier germination is induced when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called- vernalization.

Seeds of Wheat, Paddy, Millet and Cotton are provided low temperature between 1°C to 10°C and earlier and higher yield of crop is obtained.

Plants growing under normal natural conditions must get low temperature for a specific period. Only then, they come into flowering. This natural uncertainity can be avoided by vernalization and timely yield can be obtained.

Plant Movements : Plants do not show locomotion as animals do. They live a 'fixed' life at one place. However, plants show movements. Even these movements are not quick. Thus, they are not easily observed. There are two main types of plant movements : (A) Movements of locomotion (B) Movements of curvature.

(A) Locomotory Movements : Such a movement can be that of the protoplasm; that of an organ or that of the entire organism. There are two main kinds of movements of locomotion.

(1) Autonomous Movement : No external factor is responsible for causing this type of movements. (i) Amoebic movement- Plasmodia of slime mold (ii) Ciliary movement- *Chlamydomonas* algae (iii) Circulatory movement- Cytoplasm in *Tradeschantia* anther (iv)Rotation movement- Cytoplasm in *Hydrilla* leaves.

(2) Induced Movement : The induced movements of locomotion are caused as a response to the external stimulus. Such a locomotory movement inducing a change of place is called - Taxis. (i)Phototaxis- Zoospore of *Volvox*. (ii) Chemotaxis- Antherozoids of bryophytes and pteridophytes. (iii) Thermotaxis- *Diatoms* and (iv) Thigmotaxis- Zoospore in *Oedogonium*.

(B) Curvature Movements : Higher plants show the movements of curvature which help them to orient their organs for their work-efficiency. Uneven or unbalanced growth causes such a curvature. There are two main kinds of movements of curvature.

(1) Autonomous Movement : No external factor is responsible for causing such uneven growth. (i) Epinasty : Growth ratio of upper surface is more than lower surface in leaves-open leaf blade. (ii) Hyponasty : Growth ratio of lower surface is more than upper surface in leaves-closing of leaves. (iii) Nutation : Zigzag movement in apical bud of stem (iv) Circumnutation : Spiral and helical growth of shoot in climbers and tendrilar plants (v) Variation : Pulsation in leaflets of Indian telegraph plant(*Desmodium gyrans*).

(2) Induce Movement : The induced movements of curvature are caused as a response to the external stimulus. There are two types-(i) Tropism and (ii) Nastism.

(i) Tropism or Tropic Movements : If the movement of curvature in a plant organ is induced by an external and directional stimulus, it is called-tropism. The curvature induced by tropism is having a directional relationship with the direction of the stimulus. Kinds of tropism are derived on the basis of the directional stimulus.

(a) Phototropism : Light – Stem shows positive phototropism and root shows negative phototropism- Oat Coleoptiles. (b) Geotropism : Gravitation – Stem shows negative geotropism and root shows positive geotropism-Radicle of Maize seedling. (c) Hydrotropism : Water – Roots of higher plants. (d) Thigmotropism : Touch – *Coccinia*.

(ii) Nastism or Nastic Movements : This kind of movement depends on the presence and intensity of external stimulus. It is not necessary that it should affect from any definite direction. Based on the external stimulus these movements are called –

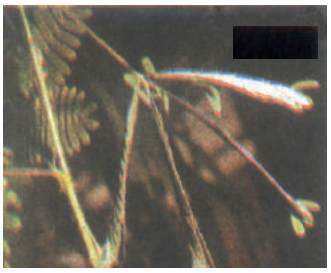
(a) Photonasty : The flowers in lotus and sunflower open in the morning. (b) Thermonasty : Flowers of Crocus and Tulip open at higher temperature. (c) Hydronasty : Plants show nastism through heavy rain and water flow. (d) Thigmonasty : The leaves of *Drocera* and *Mimosa* close and droop when they are touched.

Before Touched

Drocera

Mimosa

After Touched



Thigmonasty

SUMMARY

In plants development is considered as the sum of two process-(1) Growth and (2) Differentiation. During this process a complex body organisation is formed that produces roots, leaves, branches, flowers, fruits, seeds and eventually they die. Growth can be defined as an irreversible increase in the size and weight of an organism. Physiologically speaking, growth is an outcome of metabolism. There is an increase in the dry weight as an outcome of growth.

In plants, growth is limited to meristematic tissues only. There are three main activities involved in the process of growth - (1) Cell division of meristematic cells (2) Enlargement of newly formed cells (3) Cellular differentiation. Growth in length is called-primary growth and growth in the girth is called-secondary growth. The increased growth per unit time is termed as growth rate. Growth is divided into three phases : Phase of cell division; Phase of cell enlargement and Phase of cell differentiation. The entire period, covering the period from cell division to cell differentiation is called-grand period of growth.

Factors which affect growth are Water, Oxygen, Temperature, Light and Nutrients. For a more exact measurement of growth in length of a plant, an auxonometer is employed.

Development is a term that includes all changes that an organism goes through during its life cycle from germination of the seed to senescence. The plant growth regulators(PGRs) are small, simple molecules of diverse chemical composition. Such chemicals are called plant-growth regulators or plant hormones. They are classified into five main groups : Auxins; Gibberrelins; Cytokinins; Abscisic acid and Ethylene. Some Vitamins also act as growth-regulators.

Seed dormancy is defined as a state in which seeds are prevented from germinating even under environmental conditions or external factors normally favorable for germination. There are mainly four types of seed dormancy: (1) Exogenous dormancy, (2) Endogenous dormancy, (3) Combinational dormancy and (4) Secondary dormancy. The entire process from the sowing of the seed in the soil to the emergence of a young sapling from it, constitutes germination. 'Mangrooves' are a special type of vegetation which live in the bassein [creek] region around sea-shore. They exhibit a different kind of germination. Such a germination is called- 'Viviparous Germination'.

Senescence is a period between complete maturation of an individual and the death of that individual. The phenomenon of the dropping of leaf, flower and fruit is called - abscission. In the development of plants and process of flowering, response to the stimulus of 'period of available light' by plants is called-Photoperiodism. Better and earlier germination is induced, when seeds are provided with specific low temperatures for a definite period of time. Flowering is also earlier in the plants which develop from them. This artificial treatment is called-vernalization.

There are two main types of plant movements : (a) Locomotory Movements : (1) Autonomous movement, (i) Amoebic movement, (ii) Ciliary movement, (iii) Circulatory movement and (iv)Rotation movement. (2) Induced movement (i)Phototaxis, (ii) Chemotaxis, (iii) Thermotaxis and (iv) Thigmotaxis. (b) Curvature Movements : (1) Autonomous movement (i) Epinasty, (ii)Hyponasty, (iii) Nutation, (iv) Circumnutation and (v) Variation. (2) Induced movement : There are two types. (i) Tropism (a) Phototropism (b) Geotropism (c) Hydrotropism and (d) Thigmotropism (ii) Nastism (a) Photonasty (b) Thermonasty (c) Hydronasty and (d) Thigmonasty.

EXERCISE

1. Put a dark colour in a given circle for the correct answer :

(1) Anabolic activities are ..... .

(a) Analytical ◯ (b) Synthetic ◯

(c) Degrading ◯ (d) Physiognomic ◯

(2) All kinds of gibberellins are in nature ..... .

(a) Basic ◯ (b) Neutral ◯ (c) Acidic ◯ (d) None of these ◯

(3) The phases of becoming differentiated is called ..... .

(a) Cell Formation ◯ (b) Cell Enlargement ◯

(c) Cell Fusion ◯ (d) Cell Differentiation ◯

(4) Which factor is essential for turgidity of cells undergoing growth ?

(a) Water ◯ (b) Light ◯ (c) Temperature ◯ (d) Oxygen ◯

(5) Which apparatus is employed for measurement of growth in length of a plant ?

(a) Abneymeter ◯ (b) Psycrometer ◯

(c) Auxanometer ◯ (d) Spectrometer ◯

(6) From where was the first auxin isolated ?

(a) Human urine ◯ (b) Plant tissue ◯

(c) Sperm of fish ◯ (d) Paddy plant ◯

(7) The effects of inducing senescence and drooping of leaves are due to .....

(a) Auxin ◯ (b) Ethylene ◯ (c) Abscisic acid ◯ (d) Cytokinin ◯

(8) The example of viviparous germination is…

(a) Maize ◯ (b) Bean ◯ (c) *Rhizophora* ◯ (d) *Mimosa* ◯

(9) The flowers of lotus and sunflower are the examples of ..... .

(a) Thermonasty ◯ (c) Hydronasty ◯

(c) Thigmonasty ◯ (d) Photonasty ◯

(10) The phenomenon of drooping of leaf, flower and fruit is called ..... .

(a) Abscission ◯ (b) Ageing ◯

(c) Photoperiodism ◯ (d) Vernalization ◯

2. Answer the following questions in short :

(1) Mention the three phases of growth.

(2) State the name of factors affecting growth.

(3) Give the full form of IBA, NAA and 2-4-D.

(4) Mention the examples of long day plants.

(5) State the names of two types of plant movements.

(6) What is the meaning of BAKANE ?

(7) What is the grand period of growth ?

(8) Name the synthesized auxins in plants.

(9) State the causes of seed dormancy.

(10) State the factors responsible for seed germination.

(11) What is nutation ?

(12) Define it : Growth, Vivipary germination, Seed dormancy, Tropism, Nastism.

3. Write short notes on :

(1) Characteristics of growth

(2) Rate of growth

(3) Measurement of growth

(4) Plant growth regulators

(5) Effects of Abscissic acid

(6) Effects of Ethylene

(7) Seed dormancy

(8) Removal of seed dormancy

(9) Seed germination

(10) Senescence

(11) Abscission

(12) Photoperiodism

(13) Vernalization

(14) Locomotory movements

(15) Tropism

4. Answer the following questions in detail :

(1) What is growth ? Describe phases of growth.

(2) Mention the factors affecting growth and discuss them.

(3) What are growth-regulators ? Mention growth regulators and describe growth-regulator containing Indole.

(4) Describe seed germination in detail.

(5) What are Plant movements ? Describe types of movements.

6

Human Reproduction

The reproduction is the mechanism by which continuity of generation is sustained and a single cell duplicates its genetic material. In the process, genetic material is passed from generation to generation. In this regard reproduction maintains the life of the species.

Like all other vertebrate animals, humans are also unisexual animals. It exhibits external as well as internal sexual dimorphism. The characters of both male and female are summarised below :

Male (Man)	Female (Woman)
External Characters	
• Mammary gland is namesake only.	• Mammary gland is well developed.
• Beard and mustache develops.	• Beard and mustache is not seen.
• Muscles are strong.	• Muscles are comparatively weak.
• Voice is heavy.	• Voice is shrill.
Internal Characters	
• Man has testes.	• Woman has ovaries.
• Testes are located in the scrotum.	• Ovaries are located in the abdominal cavity.
• Man produces sperms from testes.	• Woman produces ova from ovaries.
• From testes, Testosterone hormone is released.	• From ovaries, Estrogen and Progesterone hormones are released.

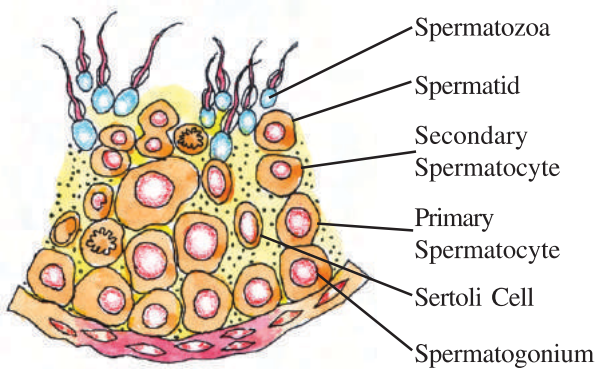
Reproductive System

The male and female reproductive systems are formed by several types of organs, which are discussed below :

Male Reproductive System

The organs of the male reproductive system are : a pair of the testes, a pair of epididymis, a pair of vas deferens, a pair of seminal vesicles, prostat gland, bulbourethral gland, urethra and penis.

The testes are situated in the scrotal sac, which is located outside the body. The development of testes starts when they are within the abdominal cavity. Later they descend into the scrotal sac. The scrotal sac helps to maintain the low temperature of the testes. The temperature of scrotal sac is almost $3^{o}C$ lower than the normal body temperature, which is essential for spermatogenesis.



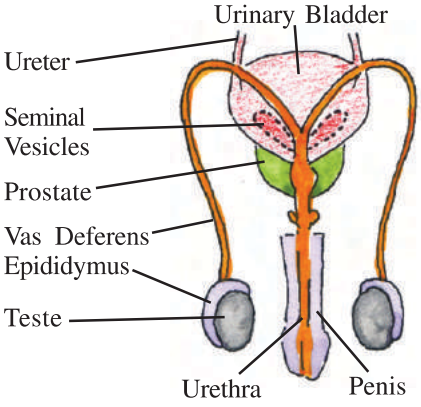
T.S. of Seminiferous tubule

The testes are paired oval-shaped glands measuring about 5cm in length and 2.5cm in diameter. A fibrous connective tissue, the tunica albuginea surround each testis. It extends inward and divides. Each testis into several lobules. Each lobule contains one to four tightly coiled seminiferous tubules, which produces sperms.

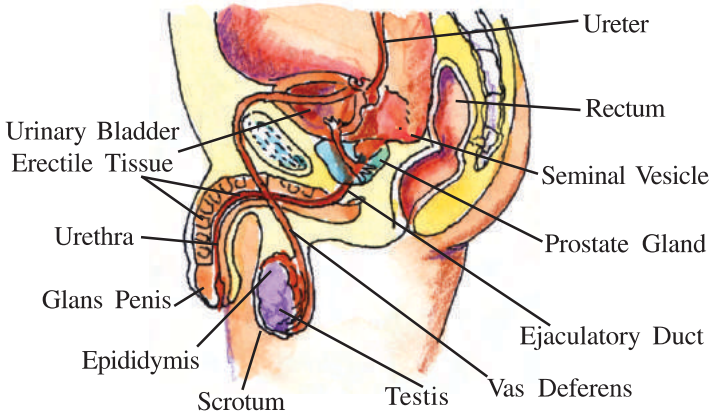
Each seminiferous tubule is lined by two types of cells (i) Germinal cells : They are arranged in 4-8 layers. These cells divide many times and differentiate into sperm, and (ii) Sertoli cells : They are placed in between the developing sperm cells and provides nutrition to the sperm cells. The cells present in the interstitial space between seminiferous tubules are known as interstitial cells or Leydig's cells. They secretes the male sex hormone testosterone.

Seminiferous tubules of each lobe empty sperms into the vasa efferentia. Sperms travel through the vasa efferentia to the epididymis, which surrounds the external surface of the testis.

The epididymis is a highly coiled tube, about 6 meters long. It provides a temporary storage site for the immature sperms, in which sperms complete their maturation process and gain the ability to swim. When a male is sexually stimulated, the walls of the epididymis contract and sperms are transported into vas deferens.



Front View



Lateral View

Male Reproductive System

The vas deferens is a tube which is about 45 cm long. It runs upward from the epididymis through the inguinal canal and enters the abdomen where it loops over the urinary bladder. This tube is connected with blood vessels and nerves. The distal end of vas deferens is expanded and in this region the seminal vesicle opens. Afterwards it is known as an ejaculatory duct. The duct of urinary bladder joins with the ejaculatory duct, now it is known as urethra. Before urethra passes through penis, duct from bulbourethral gland joins with it and finally urethra opens at the tip of the penis.

Accessory Reproductive Glands

The accessory reproductive glands includes paired seminal vesicles, prostate gland and the bulbourethral glands. These glands produce semen.

Seminal Vesicle

The seminal vesicles are located at the base of the urinary bladder. They produce 60% fluid volume of semen. Their thick and yellowish secretion is rich in sugar, vitamin-C and other substances, which nourishes the sperms. The duct of each seminal vesicle joins with vas deferens and form the ejaculatory duct. Thus, sperms and seminal fluid enter the urethra together.

Prostate Gland

The prostate gland is located at the posterior region of the urinary bladder. The secretion of prostate gland is milky. It plays a major role in activating sperms. It enters the urethra through several small ducts.

Bulbourethral Gland

The paired bulbourethral glands are located beneath the prostate gland on lateral side of urethra. Like prostate gland, they secrete alkaline fluid which serves as a lubricant during sexual intercourse.

Semen

Semen is a milky white and sticky mixture of sperms and secretion of accessory glands. The relative alkalinity of semen as a whole (P^H 7.2 – 7.6) helps to neutralize the acidic environment (P^H 3.5 – 4.0) of the vaginal fluid thus protecting the delicate sperms and enhancing their motility. The average volume of semen for each ejaculation is 3 to 4 ml.

Penis

The penis is a cylindrical organ located at the frontal region of scrotal sacs. It is used to deposit sperms into the vagina of female. The distal end of the penis is slightly enlarged, called glans-penis. Glans-penis is covered by loosely fitting skin known as foreskin.

Internally, the penis is composed of three cylindrical masses of tissue bound together by fibrous tissue. Out of these two are located dorsally and one is located ventrally which contains the urethra. All three masses of tissue are spongelike and contain blood sinuses. It is filled with blood during sexual arousal. This causes the penis to enlarge and become rigid. This event is called erection.

Female Reproductive System

The female reproductive system consists of a pair of ovaries, fallopian tubes or oviducts or uterine tubes, uterus, vagina and external genitalia or vulva or pudendum. The mammary glands are also included in female reproductive system.

The ovaries are paired glands with the size and shape of almonds. They is about 3cm long, 2cm wide and 1cm thick. They are situated in the upper pelvic cavity, one on each side of the uterus. The ovaries maintain their position by a series of ligaments. Each ovary contains a hilus, the entry point for blood vessels and nerves. In sectional view, ovary consists of the following parts :

Germinal Epithelium : It is a layer of simple cuboidal epithelium which covers the ovary.

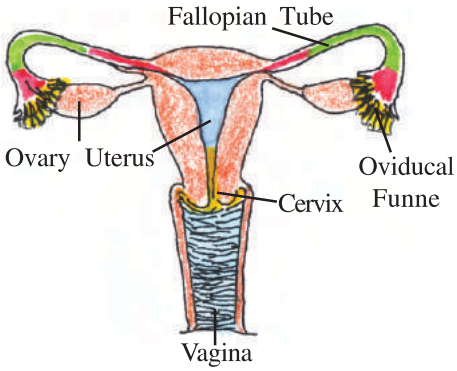
Tunica Albuginea : It is a capsule of collagenous connective tissue immediately after the germinal epithelium.

Stroma : This is a region of connective tissue deep to the tunica albuginea. It is composed by outer cortex and an inner medulla. The cortex contains ovarian follicles.

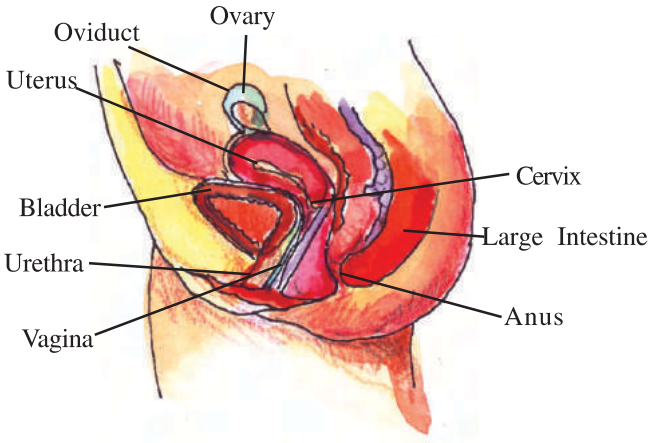
Ovarian Follicles : It consist of ova and their surrounding tissues in various stages of development.

Graffian Follicle : It consist of mature ovum and its surrounding tissues.

Corpus Luteum : Graffion follicle after ovulation produces glandular body. It produces the hormone progesterone.



Female Reproductive System (Front View)



Female Reproductive System (Lateral View)

The ovaries produces ova and secrete female sex hormones. Uterine or fallopian tube or oviduct transports ova from ovaries to uterus. It is 10cm long and situated between the folds of the ligaments of the uterus. It has funnel-shaped open end, called the infundibulum (Oviducal Funnel) which lies very close to the ovary but not attached to it. About once a month ovum is released from ovary near the infundibulum of the uterine tube, this process is called ovulation. The collected ovum run forward in uterine tube by ciliary action. The uterine tube from side runs forwards and becomes associated with the uterus. If an ovum is fertilized, the fertilization occurs in the uterine tube. The uterine tubes from both side join and form the uterus.

The uterus is situated in between the urinary bladder and rectum. It is an inverted, pear-shaped and thick walled muscular structure, where menstruation, implantation of a fertilized ovum and development of the embryo occurs. The wall of the uterus is made of three layers:

(i) Endometrium : It is an innermost layer. If fertilization occurs, the fertilized egg is implanted here and resides there for further development. If the woman does not conceive, the endometrial lining sloughs off periodically, usually after every 28 days.

(ii) Myometrium : It is bulky middle layer of the uterus. It is composed of bundles of smooth muscle. This layer plays an active role during the delivery of a baby.

(iii) Epimetrium : It is the outermost layer of the uterus.

The distal narrow end of the uterus is called cervix, which connect uterus to the vagina.

Vagina is a thin walled tube, it lies between urinary bladder and rectum and it extends from cervix to the outside of the body. Vagina provides a passageway for the delivery and for the menstrual flow to leave the body. The distal end of the vagina is partially closed by a thin fold of the mucosal membrane called the hymen. It can break at anytime either due to vigorous exercise or due to other reasons.

Females have external genitalia. They are Mons pubis, Labia majora, Labia minora and clitoris. Mons pubis is a cushion of fatty tissue which is covered by skin and pubic hair. The labia majora are folds of tissue, which are located below the mons pubis and surround the vulva. The labia minora are also a fold of tissue under the labia majora. The clitoris is a tiny finger like structure which lies at the upper junction of the two labia minora. It contains erectile tissue and is considered equivalent to the male penis. The clitoris differs from the penis in that it lacks a reproductive duct.

Mammary glands are present in both sexes, but normally they are functional in females only. The biological role of the mammary glands is to produce milk and nourish a newborn baby. In the puberty stage, the female mammary glands increase in size, this is stimulated by sex hormone estrogen. They are also considered as accessory reproductive glands.

Gametogenesis

The gametogenesis is the process of gamete formation in the sexually reproducing animals. The animals have two types of cells in their body : Somatic cells and Germinal cells. Somatic cells form various organs of the body, and divide by mitotic division. The germinal cells produce gametes by successive mitotic and meiotic divisions. The male gamete is known as spermatozon or sperm and female gamete is known as ovum or egg. The process of sperm production is known as the spermatogenesis, and the process of production of ovum is known as oogenesis.

Spermatogenesis

The process of spermatogenesis occurs in male gonads or testes.

The Spermatogenesis is a continuous process but for the sake of convenience this process can be studied in two different stages.

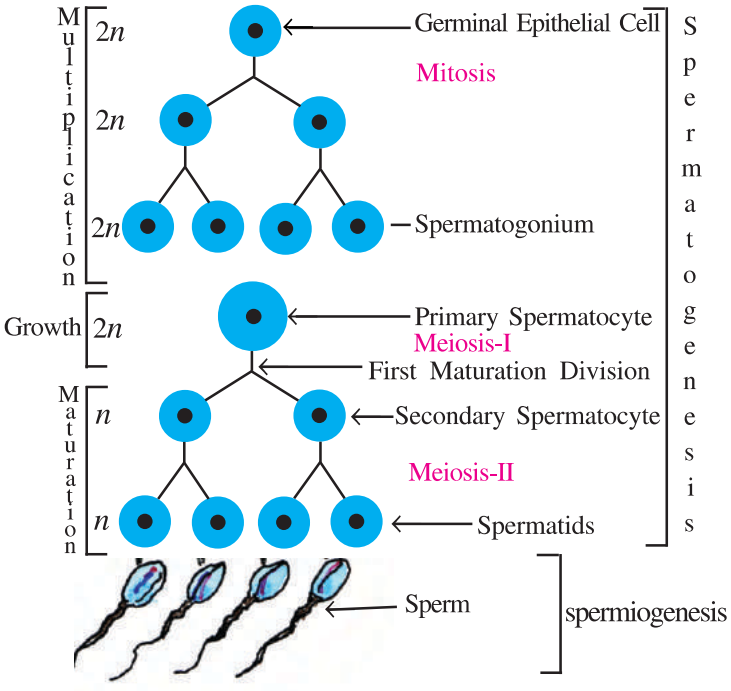
(1) Formation of spermatids (2) Spermiogenesis

(1) Formation of spermatids : The male germinal cells which produce the sperms are known as primary germinal cells. These primary germinal cells pass through the following three phases for the formation of spermatids.

(i) Multiplication phase : The undifferentiated germ cells or primary germina cells contain large sized and chromatin rich nuclei. These cells multiply by mitotic division and produce spermatogonia. Each spermatogonium is diploid.

(ii) The growth phase : In the growth phase the spermatogonia accumulate large amount of nutrient and chromatin material. Now each spermatogonium is known as the primary spermatocytes.

(iii) The maturation phase : Now primary spermatocytes are ready for first meiotic or maturation division. By this, two secondary spermatocytes are formed. Each secondary spermatocyte is haploid. Each secondary spermatocyte passes through the second meiotic or maturation division and produces two spermatids. Thus, by a meiotic or maturation division a diploid spermatogonium produces four haploid spermatids. These spermatids cannot act directly as the gametes, so they have to pass through spermiogenesis.

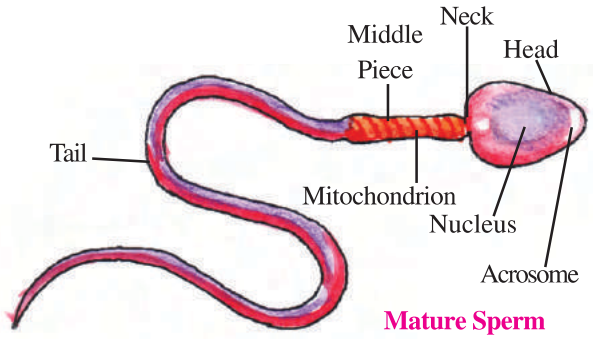


Spermatogenesis

(2) Spermiogenesis : The metamorphosis or differentiation of the spermatids into the sperms is known as spermiogenesis. In it following changes occurs in the spermatids :

(i) Changes in the nucleus : The nucleus loses water, shrinks and assumes ovoid and laterally flattened shape. The RNA and the nucleolus are greatly reduced. The DNA become more concentrated.

(ii) Acrosome Formation : The acrosome occurs at the anterior side of the sperm and contains the protease enzyme hyaluronidase which helps it to penetrate itto in the ovum. The acrosome is formed by the Golgi complex. It is concentrated near the anterior end of the sperm nucleus. One or two vacuoles of the Golgi complex become large and occupy the place between the tubes of Golgi complex. Soon after, a dense granule known as proacrosomal granule develops in the vacuole. The proacrosomal granule attaches with the anterior end of the nucleus and enlarges, which is now known as acrosome.

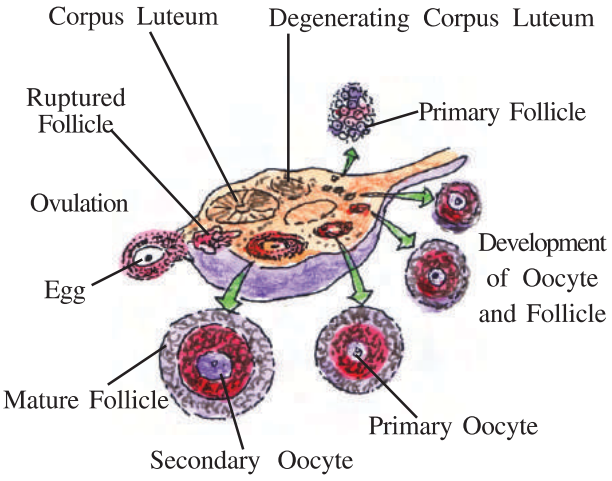


Mature Sperm

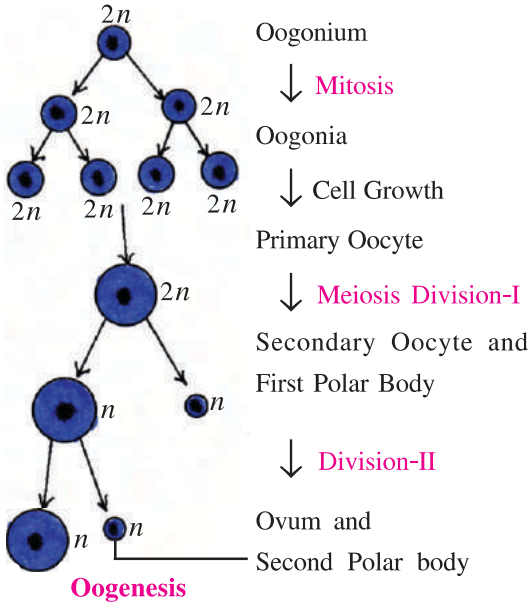
(iii) Centrioles : The two centrioles of the spermatids become arranged one after the other behind the nucleus. The anterior one is known as the proximal centriole and the posterior one is known as the distal centriole. The distal centriole changes into the basal bodies and form axial filament of the sperm. The mitochondria fuse together and twist spirally arround the axial filament. These form a middle piece of the sperm.

Oogenesis

The process of oogenesis occurs in the cells of the germinal epithelium of the ovary. The oogenesis is completed in following three successive phases :



T.S. of Ovary



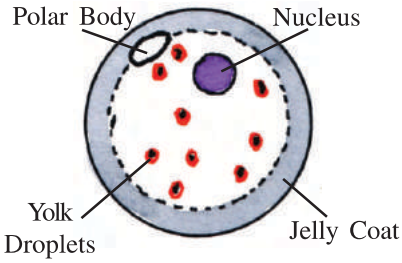
Oogenesis

(1) Multiplication phase : The germinal cells divide repeatedly to form the oogonia. The oogonia multiply by mitotic divisions and form the primary oocytes which enters in the growth phase.

(2) Growth phase : This phase is comparatively longer than the spermatogenesis. In this phase, the size of the primary oocyte increases enormously. In the primary oocyte, fats and proteins present in the form of yolk. The cytoplasm becomes rich in RNA, DNA, ATP and enzymes, moreover, mitochondria golgi complex, ribosomes etc. are also concentrated in it. During this phase, changes also occurs in the nucleus of the primary oocyte and it becomes large due to the increased amount of the nucleoplasm. When the growth of the cytoplasm and nucleus of the primary oocyte is completed, it becomes ready for the maturation phase.

(3) Maturation Phase : The maturation phase is accompanied by the maturation division or meiod (meotic) division (meiosis). This division is quite different from the meiotic division of spermatocyte. Here, after the first division primary oocyte divides unequally to form one large sized haploid secondary oocyte and one small sized haploid first polar body.

Ovulation takes place at the secondary oocyte stage only and enters into oviduct. When sperm penetrates into secondary oocyte it undergoes unequal second meiotic division and produces second polar body and an ovum. In the same way the first polar body undergoes equal second meiotic division and produces two second polar bodies. However, if the sperm does not penetrate into the secondary oocytes, it simply deteriorates without completing meiosis to form the ovum. The mature ovum has a cell like structure.



Secondary oocyte

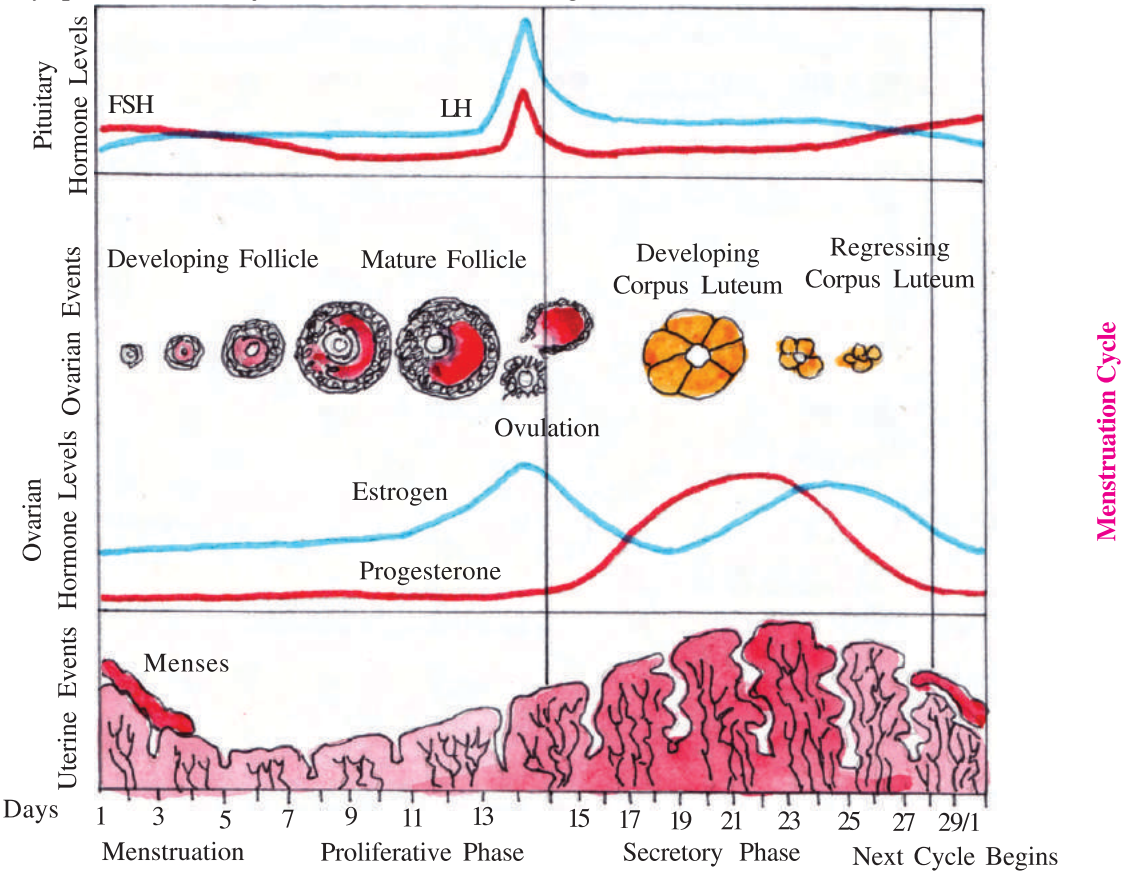
Menstrual Cycle

The events of the menstrual or uterine cycle are the cyclic changes in the endometrium, which occur in cyclic form every month. This is due to the change in the levels of female sex hormones like estrogen and progesterone, in the blood. The events in this cycle can be divided into 28 days.

Days 1-5 : Due to lower concentration of female sex hormones in the blood, the endometrium disintegrates and blood vessels within it break up. Due to this, secretion of blood through vagina takes place It lasts for 3 to 5 days. During this period about 50ml to 150ml blood is lost. This phase is known as a menstrual phase.

Days 6-14 : This phase of the cycle is known as a proliferative phase. This phase is stimulated by rising estrogen levels which is produced by the growing follicles. The endometrium becomes glandular, vascularized and thick. At the end of this phase (on 14th day) ovulation occurs.

Days 15-28 : Rising levels of progesterone produced by the corpus luteum induces development of endometrium and increases its blood supply. Now endometrium is ready for implantation of embryo. If fertilization does not occur, the corpus luteum degenerates. This phase is known as secretory phase. At this juncture, menstruation begins.

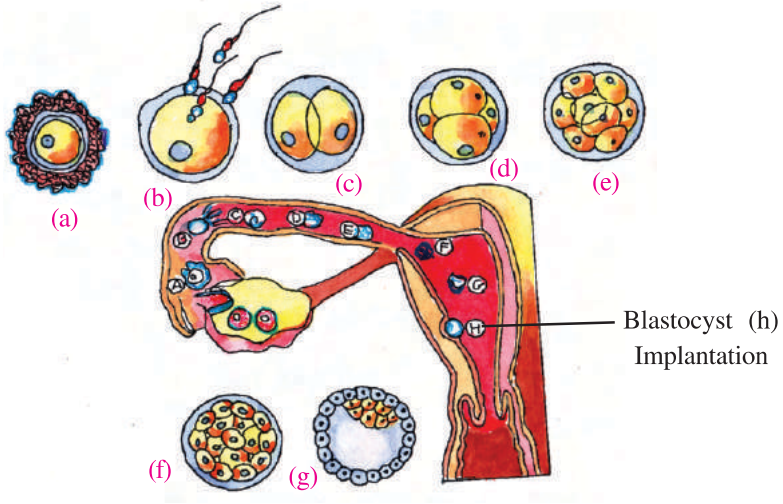


Menstruation Cycle

Fertilization and Implantation

During the act of copulation, male individual deposits semen in the female vagina through the penis. The amount of semen is nearly 3 to 4 ml. It contains billions of sperms.

The sperms, emptied in the vagina, start moving towards oviducts through the uterus. In their locomotion, contractions of vaginal passage and uterine wall are helpful. The slimy secretion of oviduct wall also help in this process. This process takes about 5 to 6 hrs.



(a) Secondary oocyte
(b) Fertilization
(c) & (d) cleavage
(e) Morula
(f) 16 cells stage
(g) Blastocyst
(h) Blastocyst Implantation

Transport of Ovum in Fallopian Tube and Implantation

The secondary oocyte is surrounded by numerous sperms. Oocyte is surrounded by egg membrane and a layer of jelly. Various enzymes are located in the acrosome of sperms, one of which is hyaluronidase which makes the entry of sperm into oocyte possible. The head and middle part of sperm enters the secondary oocyte. The nucleus present in the head of sperm is now known as male pronucleus.

The entry of sperm induces some immediate changes into oocytes. The egg membrane becomes slighty separated from protoplasm. Now it is known as fertilization membrane. This membrane prevents entry of other sperms. Entry of sperm induces completion of maturation of secondary oocyte and forms a female pronucleus. Thus one sperm and one ovum become involved in fertilization. A diploid zygote nucleus is formed through the fusion of male and female pronucleus. Now fertilized ovum is called zygote. During movement of zygote into oviduct, the division of zygote starts, called cleavage. It forms 2, 4, 8, 16 daughter cells called blastomeres. The embryo with 16 cells is called morula. The morula stage continues to divide and transforms into blastocyst as it moves further into uterus. All these changes take place in a period of one week. The fluid within the blastocyst is formed by the cells of trophoblast. Now, the process of implantation of embryo in the uterine wall takes place. The jelly like layer around the embryo is removed. The enzymes secreted from trophoblast cells digest some tissues and blood vessels of uterine wall and make implantation possible. The inner wall of uterus develops and partially envelops the embryo. This process is called implantation of embryo.

Pregnancy and Embryonic Development

The period of development of young one in the female reproductive system is known as pregnancy. In humans the normal period of pregnancy is approximately 266 days to 280 days (40 weeks) from last menstruation from ovulation. However, many babies are born 1 to 2 weeks earlier or later. The fertilized ovum during the first 12 weeks is called embryo and thereafter it known as foetus.

After implantation, the trophoblast part of the blastocyst develops elaborate projections, called chorionic villi, which cooperate with the tissues of the mother's uterus to form the placenta. The placenta functions to deliver nutrients and oxygen to embryo and remove wastes from the embroynic blood. The placenta is connected to the embryo through an umbilical cord; placenta also acts as an endocrine tissue and produces many hormones like human chorionic gonadotropin(hcG), human placental lactogen (hpL), estrogens and progesterone. In the later stage of pregnancy, hormone relaxin is produced from ovary. The hormones like hCG, hPL and relaxin are produced only during pregnancy.

These hormones help in fetal growth, metabolic changes in the mother and maintenance of pregnancy.

The embryonic development is a continues process which is sumarized as under :

Embryo Development

Period	Changes
Embryo Development	
First week	• Zygote undergoes cleavage
	• The blastocyst implants in the uterus.
	• Begins to receive nutrients from the mother.
Second week	• Implantation of blastocyst becomes deep in the endometrium
	• The embryonic disc and amniotic cavity develop.
	• The mesoderm is spreading between ectoderm and endoderm.
Third week	• The embryonic disc broadens.
	• Primitive heart is formed but it is not yet beating.
Fourth week	• The embryo is protected and suspended in amniotic fluid.
	• The primary brain, eyes, stomach, kidneys and heart develop.
	• Heart starts beating, approximately 60 times per minute.
	• The primitive umbilical cord is formed.
	• In this stage, the embryo length is less than 4 cm.
Second month	• The embryo is now looks like a human.
	• The main organs of the body develop and begin their function.
	• In this stage, head is larger compared to the body.
	• It is 2.5 cm long.
Foetus Development	
Third month	• Now embryo called foetus, means `Young one'
	• Foetus reaches 7.5 cm height and about 14 g weight.
	• Body has grown, but head is larger than body.
	• The limbs becomes longer.
	• The external genitalia appear, but it is difficult to identify sex.
	• Some movements of limbs and body occurs.

Fourth Month	• Body is bright red in colour because the blood vessels grow through its transparent skin.
	• The muscles become active.
Fifth month	• Skin is now less transparent and covered with hair.
	• From this stage onwards, the growth of the placenta slows down.
Sixth Month	• The skin is wrinkled because it lacks fat.
	• Two eyelids are separated but a membrane covers the pupils.
	• The foetus measures about 32 cm and weighs about 650 g.
Seventh Month	• The foetus moves round vigorously within the uterus.
	• It can open its eyes.
	• If born at this stage it can now breath but with difficulty.
Eighth Month	• In this stage, foetus is about 42 cm long and its weight is about 1800 g.
	• Development of lungs can now support life.
	• At this stage, if baby is born, it is necessary to provide expert care.
Ninth Month	• At the end of this month, foetus measures about 46 cm.
Tenth Month	• In this stage mother awaits the birth of her child.
	• Generally the child is about 50 cm long and weighs 3300 g. There are wide variations in the weight of the child at birth.

Toward the later part of pregnancy, the human foetus normally assumes a position with its head directed downward, ie. at the time of birth.

Parturition and Lactation

Parturition is also called childbirth. It is the culmination of pregnancy. It usually occurs within 15 days of the calculated due date. The series of events that expel the infant from the uterus are collectively referred to as labour.

Parturition is induced by a complex neuroendocrin mechanism. The signals for parturition originate from the fully developed foetus and the placenta which induce mild uterine contractions called foetal ejection reflex.

At the time of birth, two chemical signals co-operate to creat real labour pain. Some cells of the foetus begin to produce oxytocin, which stimulates the placenta to release prostaglandins. Both hormones stimulate more frequent and powerful contractions of the uterus. At this point, signals for the release of oxytocin is sent by the posterior pituitary. The combined effects of rising levels of oxytocin and prostaglandins initiate true labour. Stronger contractions cause the release of more oxytocin, which causes even more vigorous contractions, forcing the baby even deeper into the mother's pelvis. This leads the baby out of the uterus. Soon after the infant is delivered.

The mammary glands of the female undergo differentiation during pregnancy and start producing milk after delivery; this process is called lactation. Mother feeds this to her new born baby. Milk secreted during initial days of lactation is known as colostrum, which contains antibodies.

SUMMARY

The human is unisexual and viviparous. Reproduction is the mechanism by which continuation of generation is sustained. Like all other vertebrates, humans also exhibits sexual dimorphism. The male and female reproductive systems are organized by several types of organs. The organs of the male reproductive system are, one pair of testes, one pair of epididymis, one pair of vas deferens, one pair of seminal vesicles, prostate gland, bulbourethral gland, urethra and penis. Female reproductive system consists of one pair of ovaries, the uterine tubes, uterus, vagina, external genitalia and mammary glands.

To produce gametes, gametogenesis occurs in both male and female. The male gamete is known as sperm and female gamete is known as ovum. The process of sperm production is known as spermatogenesis and ovum production is known as oogenesis.

Menstrual cycle is the events of the cyclic changes in the endometrium, which it goes through month after month as it responds to change in the levels of female sex hormones in the blood.

The one sperm and one ovum become involved in fertilization. A diploid zygote nucleus is formed through the fusion of male and female pronucleus. Now, fertilized ovum is called zygote. During movement of zygote into oviduct, cleavage occurs. The embryo with 16 cells is called morula. Now, the process of implantation of embryo take place.

The period of development of young one in female reproductive system is known as pregnancy. It takes approximately 266 to 280 days. The process of child birth is called parturition. The mammary glands of the mother undergo differentiation during pregnancy and start producing milk after delivery, this process is called lactation.

EXERCISES

1. Put dark colour in a given circle for the correct answer :

(1) With reference to sex, human is which type of animal ?

(a) Unisexual and Oviparous ◯ (b) Unisexual and Viviparous ◯

(c) Bisexual and Oviparous ◯ (d) Bisexual and Viviparous ◯

(2) From which gland is testosterone hormone released ?

(a) Ovary ◯ (b) Adrenal Gland ◯

(c) Testes ◯ (d) Pituitary Gland ◯

(3) The temperature of scrotal sac is ..... lower than the normal body temperature.

(a) 1 °C ◯ (b) 2 °C ◯ (c) 3 °C ◯ (d) 4 °C ◯

(4) Vas deferens is about ..... long tube.

(a) 45 cm ◯ (b) 40 cm ◯ (c) 30 cm ◯ (d) 35 cm ◯

(5) The fluid containing sperm is known as ..... .

(a) Sperm Fluid ◯ (b) Semen ◯

(c) Reproductive Fluid ◯ (d) Fertilization Fluid ◯

(6) Out of the following which is a part of female reproductive system ?

(a) Uterus ◯ (b) Penis ◯

(c) Bulbourethral Gland ◯ (d) Urinary Bladder ◯

(7) Sixteen celled embryo is called .....

(a) Foetus ◯ (b) Zygote ◯ (c) Morula ◯ (d) Blastocyte ◯

(8) Menstrual cycle takes how many days ?

(a) 26 ◯ (b) 28 ◯ (c) 30 ◯ (d) 24 ◯

(9) How much blood is lost during menstrual cycle ?

(a) 50 ml to 150 ml ◯ (b) 50 ml to 250 ml ◯

(c) 10 ml to 100 ml ◯ (d) 10 ml to 50 ml ◯

(10) The normal period of pregnancy in humans is ..... .

(a) 300 weeks ◯ (b) 40 weeks ◯

(c) 35 weeks ◯ (d) 50 weeks ◯

2. Answer the following questions in short :

(1) Name the reproductive organs of man.

(2) Mention the location of testis.

(3) Write the function of leydig's cell.

(4) Mention the location of prostate gland.

(5) Which layer covers the ovary ?

(6) Which glandular body is formed after ovulation ?

(7) What is spermatogenesis ?

(8) What is fertilization ?

(9) What is pregnancy ?

(10) What is lactation ?

3. Do as directed :

(1) Describe : Sexual dimorphism in human.

(2) Explain : Accessory male reproductive organs.

(3) Describe : Female reproductive system with diagram.

(4) Write note on : Spermatogenesis.

(5) Write note on : Oogenesis.

(6) Explain : Menstrual cycle.

(7) Write note on : Implantation.

(8) Explain : Embryonic development in human.

(9) Explain the changes during foetus development.

(10) Describe : Parturition.

(11) Draw a labeled diagram of : (i) Male reproductive system (ii) Female reproductive system.

7

Reproductive Health

We have already studied human reproductive system and its functions in the previous chapter. Now, let us learn about reproductive health. The normal functions of reproductive system is referred to as reproductive health. According to the World Health Organization (WHO), reproductive health means a total well-being in all aspects of reproduction, i.e., physical, emotional, behavioural and social. Therefore, a society with people having physically and functionally normal reproductive organs and normal emotional and behavioural interactions among them in all sex-related apsects might be called reproductively healthy. Why is it significant to maintain reproductive health ? Let us see.

Reproductive Health-Problems and Strategies

India was the first country in the world to kick off action plans and programmes at a national level to get total reproductive health as a social goal. These programmes are called 'family planning' and were initiated in 1952 and were periodically assessed over the past decades. Improved programmes covering wider reproduction-related areas are currently in operation under the popular name 'Reproductive and Child Health Care (RCH) programmes'. Creating awareness among people about various reproduction related aspects and providing facilities and support for building up a reproductively healthy society are the major tasks under these programmes. With the help of audio-visual and the print-media, governmental and non-governmental agencies have taken various steps to create awareness among the people about reproductive health. Parents, other close relatives, teachers and friends, also have a major role in the dissemination of the above information. Introduction of sex education in schools should also be encouraged to provide right information to the young so as to discourage children from believing in myths and having misconceptions about sex related aspects. Proper information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS, etc., would help people, especially those of adolescent age. Educating people, especially couples and those in marriageable age group, about available birth control options, care of pregnant mothers, post-natal care of the mother and child, importance of breast feeding, equal opportunities for the male and the female child, etc., will make society healthy. Awareness of problems like uncontrolled population growth and of social evils like sex-abuse and sex-related crimes, etc., needs to be created to take up necessary steps to prevent them and thereby build up a socially responsible and healthy society.

The successful implementation of various action plans for reproductive health requires strong infrastructural facilities, professional expertise and material support. It is essential to provide medical assistance and care to people in reproduction-related problems like pregnancy, delivery, STDs, abortions, contraception, menstrual problems, infertility, etc. Implementation of better techniques and new strategies from time to time is required to provide more efficient care and assistance to people. Research on various reproduction-related areas is encouraged and supported by governmental and non-governmental agencies.

Population explosion is an advantage or a nuisance ? In the developed European countries like Spain and Italy, where the population is decreasing, this might be considered as an advantage. however, for the developing countries like India, population explosion is a nuisance and causes damage to the development of the country and its society. The developing countries are already facing a lack of resources, and with the rapidly increasing population, the resources available per person are reduced further, leading to increased poverty, malnutrition, and other large population-related problems.

India is the second most populous country in the world after China. India supports 16.87 percent of the world's population on its meager 2.4 percent world surface area. At the time of independence, the country's population was 342 million. The country's population size had grown from 361 million in 1951 to around 846 million in 1991 and 1027 millon in 2001. The population of India almost tripled during the period of 1951-2001. The phenomenal increase in the population during the last fifty years has led to rapid industrialization and high rate of urbanization which have created tremendous pressure on natural resources like land, air and water.

Decline in death rate and increase in birth rate are the main factors affecting population growth. Increased health facilities along with better living conditions also had impact on the growth of population. Such alarming growth rate could lead us to a scarcity of the basic requirements, i.e., food, shelter and clothing.

The government of India has been organizing several programs for controlling the population increase and has been spending millions of rupees on controlling the birth rate. One of the programmes has been successful, and the rate of increase has also reduced, but has still to reach the sustainable rate. Our main goal to control population growth is decreasing the birth rate. Several government-funded agencies like the Family Planning Association of India spend billion of rupees on promoting family planning. These organizations aim to promote family planning as a basic human right. The family planning methods provided by the family planning programme are vasectomy, tubectomy, IUD (Intra Uterine Devices Copper-T, conventional contraceptives (Condoms, Diaphragms etc.) and oral pills.

Barrier Method

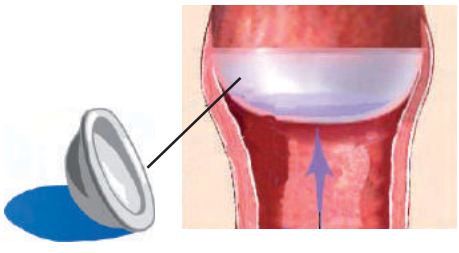
A variety of barrier methods, suitable for both men and women are available. The aim of these methods is to prevent live sperm from meeting the ovum. Barrier methods have increased in popularity due to the absence of side effects and some protection from sexually transmitted diseases.

(i) Physical Methods : In this method condoms are used. It is made of thin rubber and used to cover the penis in the male or vagina and cervix in the female just before coitus so that the ejaculated semen does not enter into the female reproductive tract.

Diaphragm is a vaginal barrier made of synthetic rubber or plastic material and inserted into the female reproductive tract to cover the cervix during coitus. Variations of diaphragm include the conical cap, vault cap and the vinule cap.

Condom for Male

Condom for Female



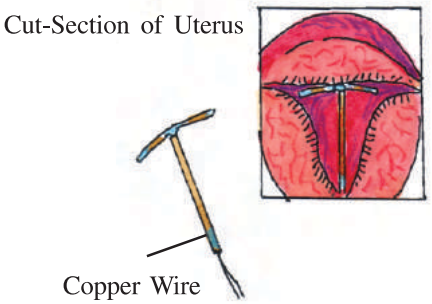
Diaphragm

(ii) Chemical Methods : Spermicides are in the form of foams and creams which attach themselves to sperm and inhibit oxygen uptake and kill sperms.

Intrauterine Devices (IUDS)

Intrauterine devices contraception could also be achieved by introducing a foreign body into the uterus of the female. Such devices are known as Intra Uterine Devices (IUDs)

The non-medicated or inert IUDs are often referred to as first generation IUDs. The copper IUDs comprise the second generation IUDs which release metal ions which have strong anti-fertility effect. The third generation IUDs release hormones (progestasert) which have a direct local effect on the uterine lining.



Copper–T

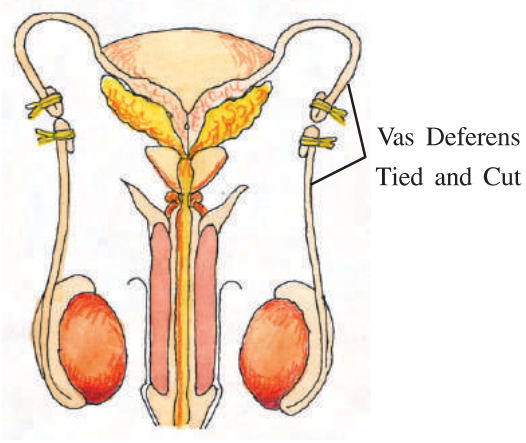
Hormonal Methods

Hormonal contraceptives when properly used are the most effective spacing methods of contraception. Oral administration of small doses of progestogens or progestogen-setrogen combination in the form of tablets which are known as the pills. The pill is given orally for 21 consecutive days beginning on the 5th day of the menstrual cycle followed by a break of 7 days during which period menstruation occurs. They are used prevent the release of ovum from the ovary and also render the cervical mucus thick and scanty and thereby, inhibit sperm penetration.

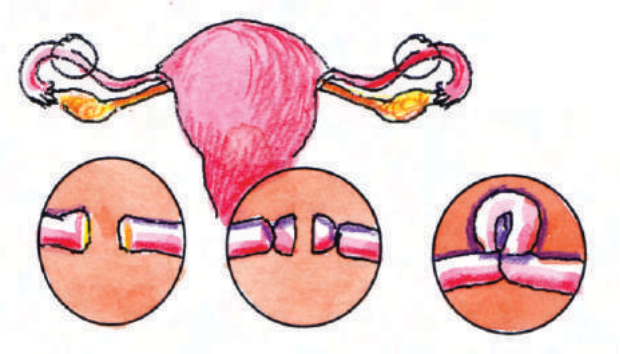
"Saheli", the new oral contraceptive for female contains a non-steroidal preparation. It was developed at Central Drug Research Institute (CDRI) in Lucknow, India It is a "once a week" pill with few side effects and high contraceptive value.

Sterilization

Sterilization is generally advised for the male/female partner as a terminal method to prevent any more pregnancies. Surgical intervention blocks gamete transport and thereby prevents conception. Sterilization procedure in the male (men) is called 'vasectomy' and that in the female (women), 'tubectomy'. In vasectomy, a small part of the vas deferens is removed or tied up through a small incision in the scrotum whereas in tubectomy, a small part of the fallopian tube is removed or tied up through a small incision in the abdomen or through vagina. These techniques are highly effective but their reversibility is very poor. It needs to be emphasised that the selection of a suitable contraceptive method and its use should always be undertaken in consultation with qualified medical practitioner.



Vasectomy



Tubectomy

Natural Methods

Other than above mentioned methods, natural methods are also used which work on the principle of avoiding chances of the meeting of ovum and sperms. Periodic abstinence is one such method in which the couples avoid or abstain from coitus from day 10 to 17 of the menstrual cycle when ovulation could be expected, because chances of fertilization are very high during this period. Therefore, by avoiding intercourse during this period, conception can be prevented. Withdrawal or interruption-coitus interruptus is another method in which the male partner withdraws his penis from the vagina just before ejaculation. In the lactational amenorrhea (absence of menstruation) method, menstruation cycle does not occur during the period of intense lactation following parturition. Therefore, as long as the mother breast-feeds the child fully, chances of conception are almost nil. However, this method has been reported to be effective only upto a maximum period of six months following parturition. As no medicines or devices are used in these methods, side effects are almost nil.

Medical Termination of Pregnancy (MTP)

Voluntary termination of pregnancy before foetus becomes viable is called medical termination of pregnancy (MTP) or induced abortion. Nearly 45 to 50 million MTPs are performed in a year all over the world. Whether to accept / legalize MTP or not is a subject debated in many countries due to emotional, ethical, religious and social issues involved in it.

The MTP Act was passed by Indian Government in 1971 and it came into force from April 1, 1972. It is a health care measure, which helps to reduce maternal mortality resulting from illegal abortion. MTP is required to terminate pregnancy in the following cases :

- Continuation of pregnancy might endanger the mother's life.
- There is substantial risk of the child being born with serious handicaps.
- Where the pregnancy is the result of rape.
- Where the pregnancy is unwanted resulting from failure of any contraceptive device.

MTP can be performed only by registered doctors and it can be done only up to 20 weeks of pregnancy only.

Sexually Transmitted Diseases (STDs)

Diseases or infection which are transmitted through sexual intercourse are collectively called sexually transmitted diseases (STDs). It is caused by bacteria, virus, protozoan and fungi. STDs are becoming a major health problem in India. More than 20 pathogens have been found to be spread by sexual contact. The highest cases are observed in the 20-24 age group; it is followed by the 25-29 age group and the 15-19 age group. Some of these diseases are summarized below :

Summary of STDs

Name of Disease	Name of Pathogens	Major Symptoms
(1) Gonorrhoea	Neisseria gonorrhoeae (Bacteria)	• Pain during passing urine • Pain in lower abdomen
(2) Syphilis	Treponema pallidium (Bacteria)	• A painless rush • Flu-like illness, tiredness. • White patches on the tongue or roof of the buccal cavity. • Patchy hair loss.

(3) Genital herpes	*Herpes simplex virus*	• Many people will not have any visible signs and symptoms. • If person do get signs and symptoms they are : feeling of uneasiness. • Symptoms such as fever, tiredness, headache, itching in the genital or anal area etc. are seen. • Pain while passing urine. • Small, fluid-filled blisters anywhere in the genital or anal area.
(4) Hepatitis B	Hepatitis B virus	• Symptoms like fever, joint pain, fatigue, loss of appetite, jaundice, pain in upper right abdomen etc. are seen
(5) AIDS	Human immunodeficiency virus (HIV)	• Person loses immunity so all diseases are dominated. • No specific symptoms are seen, but some symptoms like, fever for over months, diarrhoea, rapid weight loss, a cough that won't go away, short term memory loss etc. are seen.
(6) Trichomoniasis	*Trichomonas vaginalis* (Protozoan)	• Soreness, inflammation and itching in and around vagina. • Pain or a burning sensation while passing urine.

The diagnosis of these diseases is based on causative organism and the symptoms. The medical examination and symptoms reveal their STD nature. Certain diagnostic tests for these diseases includes culture of the pathogenic organism. Through culturing, microorganisms can be isolated, observed and identified, by microscopic examination using special stains. ELISA (Enzyme Linked Immuno Absorbent Test) test is used for identification of antigen-antibody. In ELISA method, antibodies against HIV antigen are searched out from the patient's blood. This helps in establishing the identification of the pathogenic organisms. DNA–hybridization : In DNA–Hybridization, a short polynucleotide chain of the genetic material of the pathogenic organism is utilized. Polymerase Chain Reaction (PCR) : In the PCR method, the specific section of a gene of the pathogenic organism is multiplied with the help of a suitable primer.

Someone has said "Prevention is the better than cure"; thus prevention of STDs is in your hands. You could be free of these infections if you follow the simple principles given below :

- Avoid sex with unknown partners.
- Always use condoms during coitus.
- In case of doubt, consult a doctor and get treatment if the disease is diagnosed.

INFERTILITY

Amniocentesis

Amniocentesis is also known as amniotic fluid test or AFT. It is a medical procedure used in prenatal diagnosis of chromosomal abnormalities, in which a small amount of amniotic fluid is sampled from the amnion surrounding a developing foetus, and its DNA is examined for genetic abnormalities. Using this process the gender of the foetus can also be determined and hence this procedure has been legally restricted for sex determination in India.

A number of couples all over the world including India are facing infertility, i.e., they are unable to produce children. In India, mostly female is blamed for this, but it is not always true; the problem can lie both in the male or female partner. Infertility clinic could help in diagnosing and curing these disorders and helping these types of couples to have children. The couples could be assisted to have children through certain special techniques commonly known as assisted reproductive technologies (ART). Assisted reproductive technology (ART) is a general term referring to methods used to achieve pregnancy by artificial or partially artificial means. Common methods of ART are *In vitro* fertilization (IVF), Zygote intrafallopian transfer (ZIFT) and Gamete intrafallopian transfer (GIFT).

***In Vitro* Fertilization (IVF) :** It means fertilization outside of the body. IVF is the most effective ART. It is often used when a woman's fallopian tubes are blocked or when a man produces very few sperms. Doctors treat the woman with a drug that causes the ovaries to produce multiple eggs. Once mature, the eggs are removed from the woman. They are kept in a dish in the lab along with the man's sperm for fertilization. After 3 to 5 days, healthy embryos are implanted in the woman's uterus.

Zygote Intrafallopian Transfer (ZIFT) or Tubal Embryo Transfer : It is similar to IVF. Fertilization occurs in the laboratory. Then the very young embryo is transferred to the Fallopian tube instead of the uterus.

Gamete Intrafallopian Transfer (GIFT) : It involves transferring eggs and sperm into the woman's Fallopian tube. So fertilization occurs in the woman's body.

ART procedures sometimes involve the use of donor eggs (eggs from another woman), donor sperm, or previously frozen embryos. Donor eggs are sometimes used for women who can not produce eggs. Also, donor eggs or donor sperm are sometimes used when the woman or man has a genetic disease that can be passed on to the baby. An infertile woman or couple may also use donor embryos. These are embryos that were either created by couples in infertility treatment or were created from donor sperm and donor eggs. The donated embryo is transferred to the uterus. The child will not be genetically related to either parent.

SUMMARY

The normal functions of reproductive system are refered as reproductive health. India was the first country in the world to kick off action plans and programmes at a national level to get total reproductive health as a social goal. These programmes called 'family planning' were initiated in 1952 and were periodically assessed over the past decades.

Proper information about reproductive organs, adolescence and related changes, safe and hygienic sexual practices, sexually transmitted diseases (STD), AIDS, etc., would help people, especially those in the adolescent age group. Educating people, especially couples and those in marriageable age group about available birth control options, care of pregnant mothers, post-natal care of the mother and child, importance of breast feeding, equal opportunities for the male and the female child, etc., can make society healthy.

India is the second most populous country in the world after China. India supports 16.87 percent of the world's population on its meager 2.4 percent world surface area. At the time of independence the country's population was 342 million. The country's population size had grown from 361 million in 1951 to around 846 million in 1991 and 1027 million in 2001. Our main goal is to control population growth by decreasing the birth rate. Several government-funded agencies like the Family Planning Association of India spend billons of rupees on promotion of family planning. The family planning methods provided by the family planning programme are vasectomy, tubectomy, IUD, conventional contraceptives (Condoms, Diaphragms etc.) and oral pills.

Voluntary termination of pregnancy before foetus becomes viable is called induced abortion or MTP.

Diseases or infections which are transmitted through sexual intercourse are collectively called sexually transmitted diseases (STDs). The highest cases of it are observed in the 20-24 age group, it is followed by the 25-29 age group and the 15-19 age group. Amniocentensis is also known as aminotic fluid test or AFT. It is a medical procedure used in prenatal diagnosis of chromosomal abnormalities.

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EXERCISES

1. Put dark colour in a given circle for the correct answer :

(1) The normal functions of reproductive system is referred to ..... .

(a) Reproductive health ◯ (b) Reproductive care ◯

(c) None ◯ (d) a and b both ◯

(2) Which country was the first in the world to kick off action plans and programmes at a national level for family health ?

(a) India ◯ (b) USA ◯ (c) UK ◯ (d) China ◯

(3) India occupies which place in the world according to population ?

(a) Second ◯ (b) First ◯ (c) Fourth ◯ (d) Third ◯

(4) India supports ..... percent of the world's population.

(a) 16.21 ◯ (b) 16.00 ◯ (c) 16.87 ◯ (d) 17.87 ◯

(5) Sterilization procedure in the male (men) is called...

(a) Sterilization ◯ (b) Tubectomy ◯

(c) vasectomy ◯ (d) All of the above ◯

(6) Sterilization procedure in the female (women) is called...

(a) Sterilization ◯ (b) Tubectomy ◯

(c) Vasectomy ◯ (d) All of the above ◯

(7) How many pathogens have been found to spread by sexual contact ?

(a) 21 ◯ (b) 20 ◯ (c) 18 ◯ (d) 19 ◯

2. Answer the following questions in short :

(1) What is reproductive health ?

(2) Give full name of RCH.

(3) Mention the names of barrier methods for family planning.

(4) What is IUD ?

(5) What is meant by MTP ?

(6) Define vasectomy.

(7) Which disease is caused by *Neisseria gonorrhoeae.*

(8) Which disease is caused by *Trichomonas vaginalis.*

(9) Which disease is caused by *Treponema palladium.*

(10) What is IVF ?

(11) What is GIFT ?

(12) Give full name of ELISA :

3. Do as directed :

(1) Describe strategies for reproductive health.

(2) Describe natural method for family planning.

(3) Describe barrier methods of family planning.

(4) Describe hormonal method of family planning.

(5) Explain MTP.

(6) Write a short note on diagnosis of STDs.

(7) Write a short note on ART methods.

8

Heredity and Variation

INTRODUCTION

You may have pondered over such questions as, why do hen's egg always hatch into chicken and not sparrow ? Why do children in a family resemble one another but are not exactly alike ? Why do they only partly resemble their parents ? The answers to these and many more similar questions come from an important branch of biology, called Genetics, the study of heredity. It means there is a continuity of features from one generation to the next. Its information is present in the zygote. The term genetics was first coined by William Bateson in 1906. The word genetics is derived from the Greek term gen which means 'to become'. According to Webster's dictionary, Genetics is the branch of Biology which deals with heredity and variation among related organisms.

There are two main components of this discipline. The first is heredity or the study of factors responsible for the resemblance between the parents and their offspring. Thus, heredity can be defined as the "Transmission of characters from parents to offsprings". The second, called variation is concerned with the forces or influences due to which no two organisms are exactly alike. Thus the occurrence of differences among the individuals of the same species is known as variation.

In the earlier chapter, you have studied about sexual reproduction. Due to this capacity every organism reproduces new generation of offspring that resembles the parental generation. Thus heredity and variation within a progeny is the result of sexual reproduction. But, each species has its own individuality, e.g. each species is recognizable by certain specific characteristics. Thus, by the process of gradual and continuous change, living organisms have evolved to exhibit a wide diversity.

Historical Background of Heredity

The concept of heredity is not new. Selective breeding of horses, donkeys and date palm was also done during the ancient civilization of Babylon and Assyria nearly 6000 years ago. Ancient Chinese writing mentions creating better varieties of paddy nearly 5000 years ago. Hippocrates (400 B.C.) believed that characteristic are inherited from parents because reproductive material is handed over from all parts of the body of an individual. The science of heredity and variation, the scientific principle of the science of genetics originated in 1900 with the re-discovery of a scientific article published in 1866 by Gregor Johann Mendel. Mendel's 'factors', the carriers of heredity information, are known as 'genes', a term coined by Johansen in 1909.

Gregor Mendel–The Father of Genetics

The contribution of Mendel to Genetics is called Mendelism. Mendel is called the father of Genetics.

Gregor Johann Mendel (1822-1884)

Christien Johann Mendel was born in 1822. He came to the monastery at Brunn and was appointed as priest in 1848. In 1856, he began to collect and observe the numerous varieties of the garden pea. These varieties differed in seed, pod, flower and a number of other characteristics. He grew each variety in different plots, so that any variation from the listed characteristics could be easily spotted. He carried out experiments for seven years (1856–1863) in the monastery gardens. He presented the results of his study of hybridizations together with generalisations at the Natural History Society of Brunn in 1865. No one at that time read Mendel's research papers. They lay neglected until 1900 when they were discovered almost simultaneously and independently by Karl currens, Hugo de varies and von Tschermark. He died in 1884. When Mendel's work was recognized and appreciated, he was no more.

Mendel's Work

Mendel did his work on garden pea (*Pisum sativum L.*). The following were the reasons for the success of Mendel :

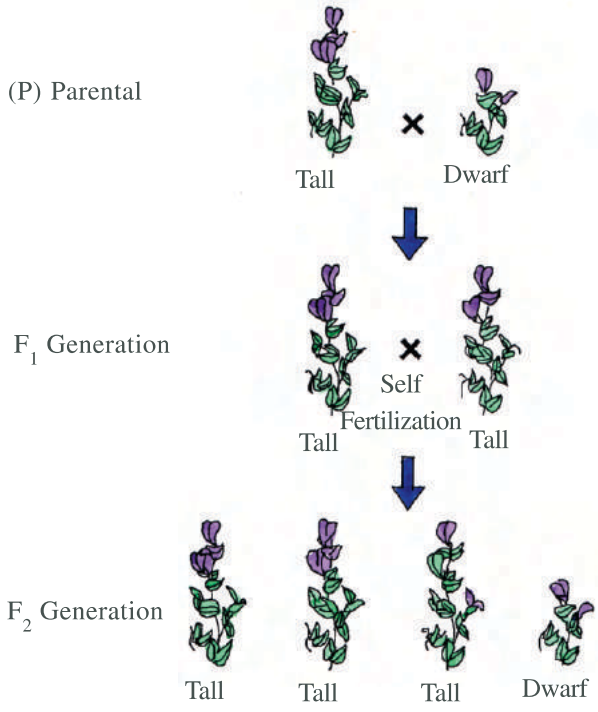
- It is very easy to cultivate the pea plants in open ground.
- The flowers of pea plants are normally self-fertilized.
- The pea plant shows a number of contrasting characters.
- The hybrid of garden pea are perfectly fertile.
- Cross pollination is not very difficult in pea plant.
- Artificial fertilization was almost successful.
- He studied the inheritance of only one character at a time in most of the experiments.
- He maintained statistical records of his results. It helped Mendel to drive numerical ratios of significance.

Mendel crossed two plants differing in two characters, such as flower position and height of the stem. The plants involved in the above crosses are called parent plants. It was marked by P. The first Hybrid generation resulting from a cross between parental plants is called the first filial generation and is marked as F_1. The second generation of hybrids arising from the self or cross-fertilization of F_1 hybrid generation is called the second filial generation and is marked as F_2.

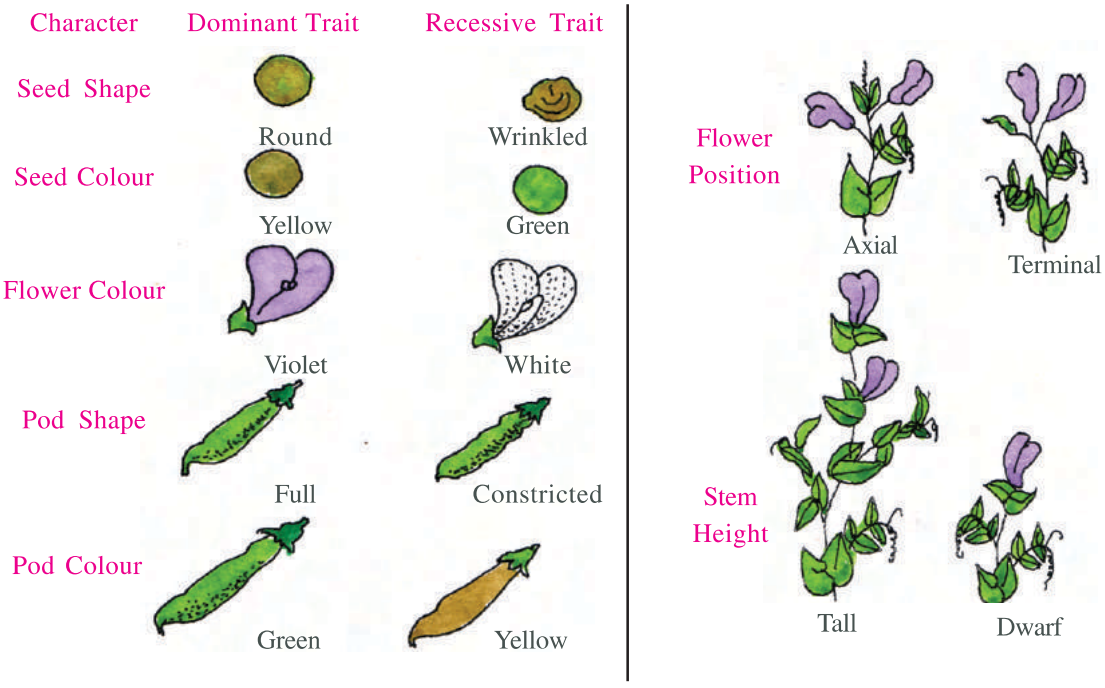
Monohybrid Cross Experiments (Single Gene Inheritance)

The experiments considering the inheritance of any one character are called monohybridization experiment. Mendel selected two pea plants, one with a tall stem and the other with a dwarf or short stem. These plants were considered as parental plants (P) and were pure breeding. This was done by first removing the anther of an immature flower of tall plants. This flower was than covered with a small plastic bag when this flower matured, the pistil was dusted with pollen received from the dwarf plant. Seeds were collected from this plant. These seeds were sown and a group of plants were raised. These plants represent F_1 generation.

In Mendel's above referred experiment, all plants in F_1 generation were tall. They were as tall as their parents in P generation. The F_1 plants were inbreed. The seeds were collected and the next generation F_2 was raised. In the F_2 generation two type of plants were found. They were tall and dwarf. Mendel counted the number of tall and dwarf plants of the 1064 plants of F_2 generation, 787 plants were tall and 277 plants were dwarf. This ratio is approximately (3 : 1). Mendel carried out similar experiments, involving seven different characters. Each time he obtained similar results.



Diagrammatic Representation of Monohybrid Experiment



Seven Pairs of Contrasting Traits in Pea Plant Studied by Mendel

Contrasting Traits Studied by Mendel in Pea

No.	Characters	Alternative	
		Dominant	Recessive
(1)	The length of the stem	Tall	Dwarf
(2)	The position of the flower	Axial	Terminal
(3)	The colour of the pod	Green	Yellow
(4)	The shape of the pod	Inflated	Constricted
(5)	The shape of the seed	Round	Wrinkled
(6)	The colour of flower	Violet	White
(7)	The colour of the seed	Yellow	Green

Each character that Mendel followed had two alternative appearance or 'Traits', i.e., tall or short stems, round or wrinkled seed, etc. Mendel's differentating characters have been variously called 'factors' or 'genes'. Bateson proposed the name 'Alleomorph' or 'Allele' for them.

Based on his observations on monohybrid crosses, Mendel proposed two general rules to consolidate his understanding of inheritance in monohybrid crosses. Today these rules are called the Principles or Laws of inheritance. The First Law or Law of Dominance and the Second Law or Law of Segregation.

Laws of Dominance

When two different alleles for a character occur in an organism, only one of the two alleles expresses itself. The other allele remains unexpressed. The allele which is expressed is called dominant gene and the allele which is not expressed is called recessive gene.

Let us now examine results obtained from self-fertilization amongst F_1 individuals. All F_1 plants are tall and have Tt genotype. As a male parent, they will produce two types of gamets (T and t gametes), as a female parent also they will produce two types of gamets (T and t) – two types of gamets can fertilize two types of gametes in four possible ways (TT, Tt, Tt, tt). Of these, three kinds will be tall (TT, Tt, Tt) and one kind will be dwarf (tt). Thus in F_2 generation 3/4 of the total offsprings obtained exhibit dominant expression and 1/4 of them exhibit recessive expression. Thus, the ratio of 3:1 is obtained. Based as such results, Mendel derived the law.

Law of Segregation

When a pair of contrasting traits are brought together in a hybrid, the two factors (alleles) remain together without mixing. When the gametes are formed from each other, only one enters each gamete. Thus any gamete contains only one gene for an expression of a character, this is also called Law of Purity of gametes. An organism can be homozygous or heterozygous for a character, but its gametes will always be pure for a particular expression of that character.

Test Cross

A cross, arranged for deciding whether an organism is homozygous or heterozygous is called test cross. Selected cross breed of pea may be homozygous tall or heterozygous tall. If we cross a tall plant with a dwarf plant, two outcomes are possible. This will depend on the genotype of tall plant. If homozygous tall (TT) is cross with dwarf plant (tt) all offspring will be tall. If it is heterozygous tall (Tt) 50 % will be tall and 50 % will be dwarf. Thus, through such a cross, genotype of the plant can be determined. Hence, it is called test cross. The ratio obtained is 1 : 1.

Inheritance of Two Genes (Dihybrid Experiment)

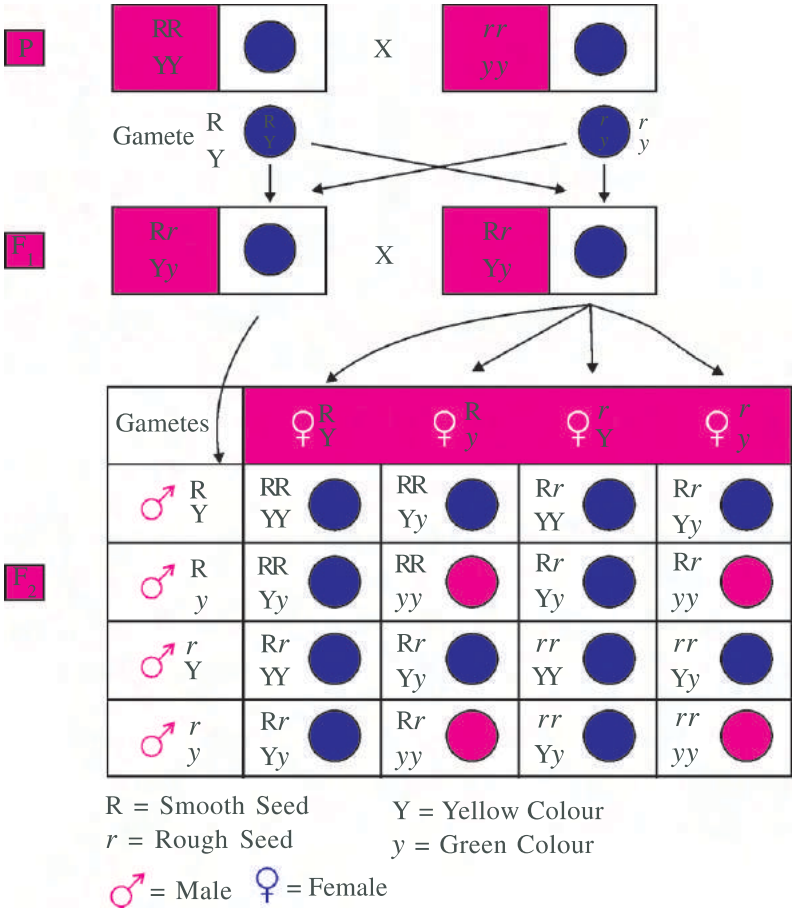
The crossing of two plants differing in two characters is called dihybrid experiment. Mendel arranged experiments to follow simultaneous inheritance of two characters in pea plants e.g. shape of seed and colour of seed. Mendel selected pure-breeding yellow, round seed producing plant and another pure breeding green, wrinkled seed producing plant. These two plants were treated as parents and were crossed. Here, the gene for round shape of seeds 'R' is dominant over the gene for wrinkled shape of seed (r). Gene for yellow colour of seed 'Y' is dominant over the gene for green colour seed (y).

In his experiment, the F_1 generation plants produced only yellow round seed.

Details of Mendel's experiments are expressed with chart as under :

Results in F_2 offsprings are as follow.

Round Yellow seeded plant		Wrinkled Yellow seeded plant		Round Green seeded plant		Wrinked Green seeded plant
$\frac{9}{16}$	:	$\frac{3}{16}$	:	$\frac{3}{16}$	:	$\frac{1}{16}$



Dihybrid Experiment – Seed Colour and Shape

Law of Independent Assortment

The segregation of genes controlling one character is independent of the segregation of genes controlling another character. This law is based on dihybrid experiment.

During gamete formation of a dihybrid cross, the factors (genes) for yellow colour assort out independently of the factors for round shape. The gene Y may combine with the dominant gene R or the recessive gene r of the other character and enter a gamete. In the same way the gene y may combine with the dominant gene R or the recessive gene r and enter a gamete. So the F_1 dihybrid plants produce four types of gametes and they are YR, Yr, yR and yr.

In this dihybrid cross (see figure), the phenotypes round-yellow; wrinkled-yellow, round-green and wrinkled-green appeared in the ratio 9 : 3 : 3 : 1. Such a ratio was observed for several pairs of characters that Mendel studied.

This law also has only limited expression. It is true only in those cases where the two pairs of genes, controlling two different characters are located on two different pairs of homologous chromosomes. Genes on the same pair of chromosomes are not independently assorted.

Evaluation of Mendel's Work

All conclusions and deductions by Mendel have not been found true in all cases.

- His belief that of two alleles of a gene, one is dominant and the other is recessive is not true in all cases.
- Many exceptions are found where both genes express their effects jointly.
- It is also not true that there are only two alleles of a gene.
- It is also not true that one character is controlled by one pair of genes. One such example is incomplete dominance.

Incomplete Dominance (1 : 2 : 1)

Incomplete dominance can be studied though experiments on Mirabilis jalapa plant. Three colours occur in the flowers of this plant: red, white and pink.

When homozygus red flowered and homozygous white flowered plants are crossed, all offsprings in F_1 generation are pink flowered. When these F_1 generation are self-fertilized in F_2 generation, three kinds of plants are obtained. 25% plants are red flowered, 25% are white flowered and 50% are pink flowered plants.

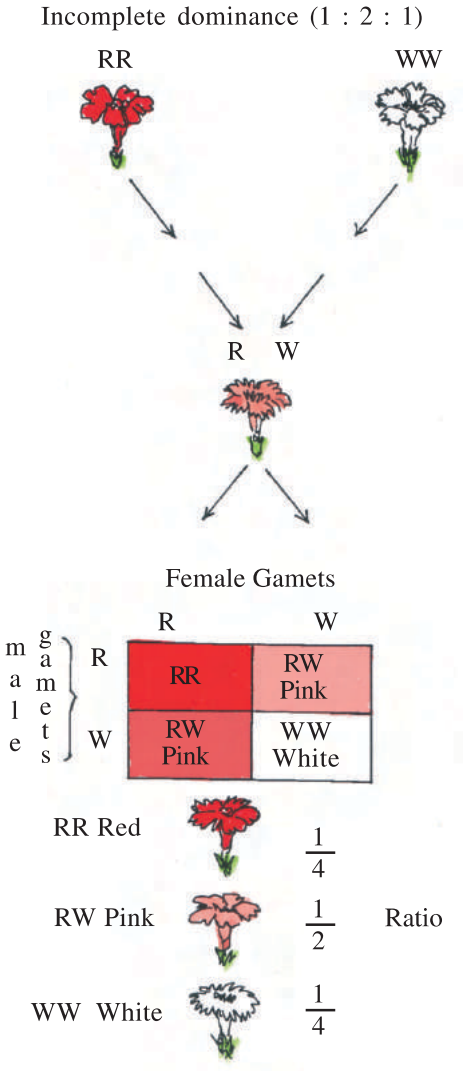
If we represent gene for red colour by 'R' and gene for white colour by 'W', the details of experimental results can be displayed as under :

Homozygous red flowered plants have both genes of 'R' type. Their genotype is RR. All gametes which they produce will contain gene 'R'. Homozygous white flowered plants have both genes of 'W' type. Their genotype is WW. All gametes produced by them will contain gene 'W'.

F_1 plants formed through their cross will contain one 'R' gene and one 'W' gene. Their genotype is RW. All plants will produce pink coloured flowers.

If R gene were dominant over 'W' gene, the plants should have been red flowered. If 'W' gene were dominant over 'R' gene, the plants should have been white flowered. However, all plants are obtained pink flowered. This indicates that a mixed effect of both genes is observed. No allele is dominant over the other.

F_2 plants produced by self cross of F_1 plants yields 1 Red flowered : 2 Pink flowered : 1 White flowered ratio. It means RR produces red colour flowers, WW produces white flowers and RW produces pink flowers. This example is called Incomplete dominance. Similar examples occur in the animal world also.

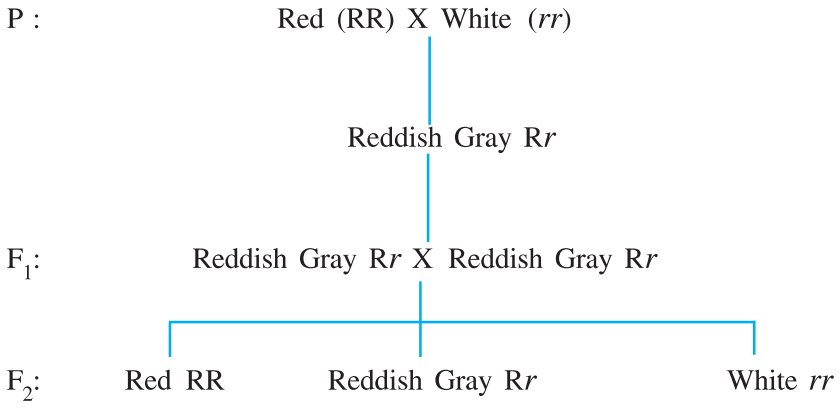


Incomplete Dominance Mirabilis Experiment

Co-dominance

In co-dominance, both dominant and recessive alleles lack their dominant and recessive relationships and both the genes expresses their expression independently.

In these cases the dominant character is not mixed with the recessive character. In short horn cattle, there are two pure varieties, both red and white for coat colour. A cross between the two varieties (Red RR X White rr) leads to the formation of a new variety (Rr) with reddish grey colour coat. Such contains both red hair and white hair.



Inheritance of Coat Colour in Cattle (Case of Codominance)

Polygenic Inheritance

Two or more independent pairs of factors or genes which affect the same characteristic but in an additive manner are known as multiple genes or cumulative genes. These affect the degree of development of a character quantitatively. Here the effect is dependent upon the number of doses of genes present in the individual.

According to Dervenport, skin colour in man is determined by multiple genes. Human skin colour is generally controlled by three separate genes. Each gene contributes to a unit of darkness due to incomplete dominance. These three genes can be designated as A, B and C, and thus the skin shade has to vary from a very dark in a AABBCC individual to very light in aabbcc individual.

Multiple Alleles

As per Mendel, every character is controlled by one pair of alleles. There are only two optional forms, one of which is dominant and the other one is recessive.

Cases are observed where there are more than two optional forms of a gene for one character. Thus when three or more alleles are responsible for a single characteristic, they are known as multiple alleles. All these alleles occupy the same specific locus on the chromosomes. In a diploid cell, only two alleles can be present at a time on the homologous chromosomes. A well known example is the ABO blood type in humans. Here the inheritance is based on three alleles i.e. I^A, I^B, *i*. I^A and I^B are dominant and i is recessive.

The gene for producing antigen is I and its allele for non producing antigen is *i*. I^A is responsible for producing antigen- A. Gene I^B is responsible for producing antigen B. These two alleles are codominant which means that both can express themselves in presence of each other. Thus three alternatives are possible. Various persons in different blood groups can have following probable genotypes.

Blood Group	Possible Genotype
A	$I^A I^A$ or $I^A i$
B	$I^B I^B$ or $I^B i$
AB	$I^A I^B$
O	*ii*

If blood group of parents are known, probable blood groups in their children can be known. Conversely, if blood group of a child is known, the blood groups of its parents can be known.

Landsteiner described human blood groups. Four blood groups occur. These are A, B, AB and O. Two aspects are to be considered in deciding these blood groups-which kind of antigen occurs on RBC_S and which kind of antibody occurs in blood plasma in a person.

Person belonging to A blood group has A antigen on RBCs and b antibody in blood plasma where as person belonging to B blood group has B antigen on RBCs and a antibody in blood plasma. Person belonging to AB blood group has A antigen and B antigen in other RBCs where as blood plasma does not have *a* or *b* antibodies. Person belonging to O blood group does not have any antigen in RBCs. Its blood plasma contains "*a*" as well as "*b*" antibodies. An antigen is indicated by a capital letter and the antibody effective against it is indicated by the same letter in small script. Antibody reacts against the antigen and causes agglutination of RBCs which possess that antigen. Thus clotting takes place. Reactions between antibody and antigens are shown in a chart.

Because of this fact, compatibility of blood groups is checked for blood transfusion. Serum test is carried out to determine the blood group of a person.

Serum From Blood Group	(Antibodies Present in Serum a, b)	Cells from Blood Group			
		O	A	B	AB
O	*a* *b*				
A	*b*				
B	*a*				
AB	–				

Human Blood Groups – Serum Test

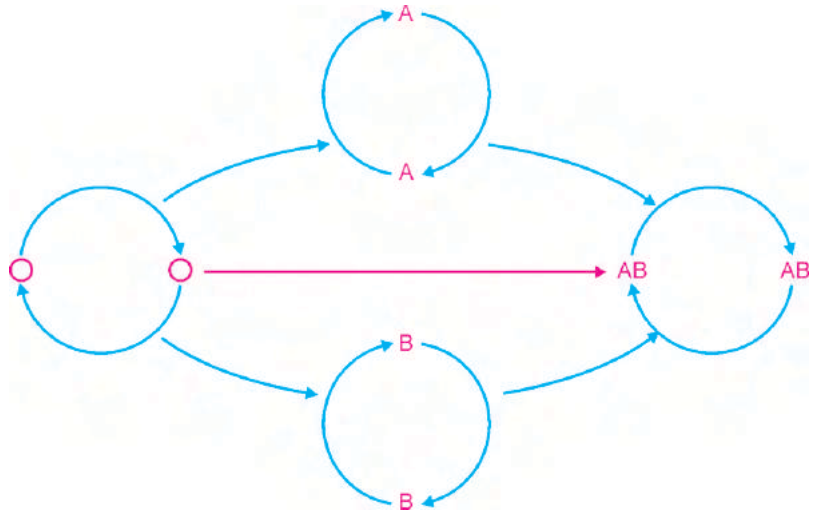
Following table shows which person can accept blood from whom and can donate blood to whom.

Blood Group	Antigen Present on RBC	Antibody Present in Blood Plasma	To Whom Can he/she Donate	From Whom Can he/she Receive
A	A	*b*	A, AB	A, O
B	B	*a*	B, AB	B, O
AB	A, B	–	AB	A, B, O, AB (Universal recipient)
O	–	*a, b*	A, B, AB, O (Universal donor)	O

The following table indicates the effects that would be produced during transfusing blood between antigen and antibody of different types of donor and recipient.

Blood Group based on Corpuscles of	Blood Group of Receipiant			
Donor	A	B	AB	O
A	–	+	–	+
B	+	–	–	+
AB	+	+	–	+
O	–	–	–	–

+ agglutination takes place, – agglutination does not takes place



Simple Explanation

Table : Exclusion of Paternity based on ABO Blood Groups

Child	Mother	Father must be of Blood Group	Father Can Not be of Blood Group
A	O	A or AB	O or B
A	A	A, B, AB or O	–
A	B	A or AB	O or B
B	B	A, B, AB or O	–
B	O	B or AB	O or A
B	A	B or AB	O or A
AB	A	B or AB	O or A
AB	B	A or AB	O or B
AB	AB	A, B or AB	O
O	O	O, A, or B	AB
O	A	O, A or B	AB
O	B	O, A, or B	AB

Pleiotropism (Expression of Many Characters through One Gene)

It is the effect of a single gene upon two or more characters which are not related. Let us see some of their examples. In Drosophila, the recessive gene for vestigial wings produces vestigial wings in homozygous condition. In addition to wing length it is also responsible for the production of

(1) The tiny wing like balancer behind the wing,
(2) Certain bristles,
(3) The structure of the spermatheca and
(4) Low number of eggs.

This phenomenon of multiple effect of a single gene is called pleiotropism. Genes which have multiple effects are called pleiotropic genes. The ability of a gene to have many effects is known as pleotropy. Its important example is sickle cell anemia.

Chromosomal Basis of Inheritance

Mendel published his work on inheritance of characters in 1866 but for following reasons, it remained unrecognized till 1900.

- Communication was not easy.
- His thoughts on factors that controlled the expression of traits were not accepted by his contemporaries.
- Mendel's approach of using statistical analysis to explain biological phenomena was totally new in those days.
- He could not provide any physical proof for the existence of the factors. The location of these factors (now genes) in the cell was unknown to him.
- In those days neither the role of nucleus in reproduction nor the existence of chromosomes in the nucleus was known.

In 1900, de Varies, Correns and Van Tschermak independently rediscovered Mendel's results on the inheritance of characters. Thus, Mendel's work was rediscovered. Also, by this time, due to advancements of microscopy that were taking place, scientists were able to carefully observe meiotic cell division.

Mendel's fact were first pointed out in 1902 by Sutton and Boveri; they put forward the theory that chromosomes form the physical basis of factors or genes which determine the heredity of living organisms. This is known as the "chromosome theory of heredity".

It was also established that chromosomes were separated during formation of gamets. So haploid gametes are formed through meiosis. When ovum (n) fuses with a sperm (n) during fertilization, the diploid status is reestablished in the zygote ($2n$). Sutton demonstrated similarities in the behaviour of chromosomes located with the nucleus and the behaviors of Mendel's hypothetical 'factors'. For example, genes (= factors) occur in pairs. Chromosomes also occur in pairs. Each gamete possesses any one gene from a pair Each gamete possesses any one chromosome from a pair of homologous chromosomes. Mendel's Law of independent assortment can also be explained on chromosomal basis.

Organisms of each species have a fixed number of chromosomes. But Mendel's hypothetical units are not chromosomes. They are genes. Genes are located on chromosomes in various numbers of each chromosome. Chromosomes as well as genes occur in pairs. The two alleles of a gene pair are located at homologous sites on homologous chromosomes. Sutton united the knowledge of chromosomal segregation with Mendelian principles and called it the chromosomal theory of inheritance. It was also verified by Thomas Hunt Morgan. He worked on fruit fly, Drosophila melanogaster. He suggested that genes are arranged in a linear fashion on chromosomes. All such aspects establish that there is a chromosomal basis for laws of inheritance proposed by Mendel.

Linkage and Recombination

Early in his work, Mendel discovered the principle of independent assortment. For most of the characters for which he made crosses in garden pea plant, he found that the factors freely assorted as test crosses always showed 1 : 1 : 1 : 1 ratio. For example :

Parents AABB x *aabb*

↓

A*a* B*b*

Test cross consist of back cross of F_1 with recessive parent.

Parents A*a*B*b* x *aabb*

Gametes AB, A*b*, *a*B, a*b* and *ab*

F_2 $\frac{1}{4}$ A*a*B*b* : $\frac{1}{4}$ A*abb* : $\frac{1}{4}$ *aa*B*b* : $\frac{1}{4}$ *aabb*

Ratio 1 : 1 : 1 : 1

Test Cross

However in 1903, Sutton and later T.H. Morgan in 1911 found that genes do not assort freely as envisaged by Mendel. Bateson and Punnet in their study in the same pea plant found that when they crossed red flowers and spherical pollen plant with a plant having purple flowers and cylindrical pollen, the test cross yielded a ratio of 7 : 1 : 1 : 7 instead of the expected 1 : 1 : 1 : 1 ratio.

Thus, we have noted that Mendel's law of independent assortment is not true in all cases. If the two pairs of genes controlling two different characters are located in the same pair of homologous chromosomes, they cannot be segregated separately. Such genes are called Linked genes and their inheritance is called Linkage.

(1) Linkage in Sweet Pea Plant : Experiments indicative of Linkage were first performed by Bateson and Punnet on sweet pea plants (*Lathyrus Odoratus*; L). In those plants, purple flower colour is dominant over red flower colour. The respective genes are P and *p*. Long shape of pollen grains is dominant over round shape of pollen. The respective genes are L and *l*. They used the same method as Mendel followed.

In F_1 generation, all plants had purple flowers and long pollen. This result was as per expectation. But the expected F_2 result, if assortment of these characters was independent, was as under :

Purple flower Long pollen	:	Purple flower round pollen	:	Red flower Long pollen	:	Red flower round pollen
9	:	3	:	3	:	1

However, the actual results obtained indicated the ratio as under:

11 : 1 : 1 : 3

Linkage and Recombination as per Morgan

T. H. Morgan
(1866-1945)

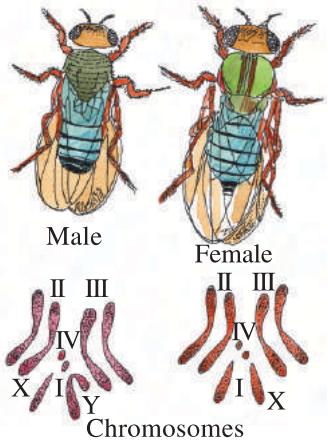
Morgan carried out several dihybrid cross experiments in Drosophila to study genes that were sex-linked. The crosses were similar to the hybrid crosses carried out by Mendel in peas. For example Morgan hybridised Yellow-bodied, White-eyed females to brown bodied, red-eyed males and intercrossed to get their F_1 progeny. He observed that the two genes did not segregate independently of each other and the F_2 ratio deviated very significantly from the 9 : 3 : 3 : 1 ratio.

Logical explanation of linkage and recombination was given by Morgan through his experiments.

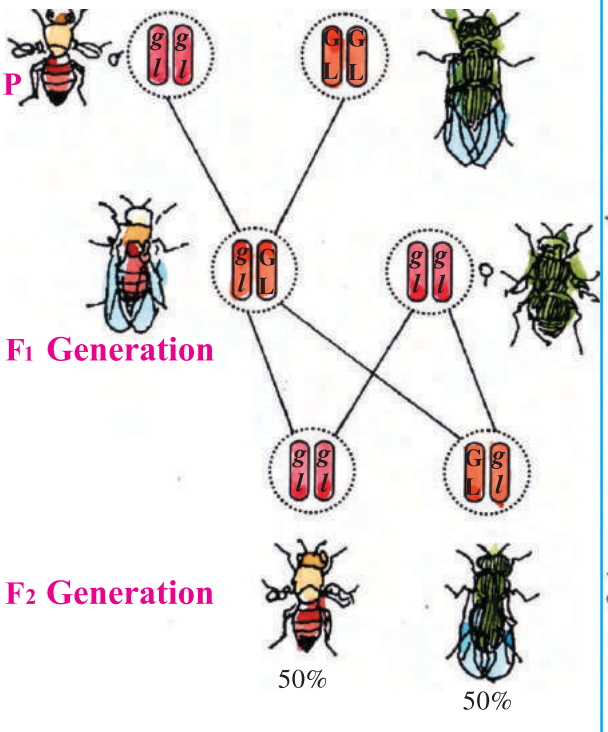
(2) Linkage in Drosophila : Drosophila can be easily grown in laboratory. Its lifespan is also of about fifteen days. It produces a large number of offsprings, more over, male and female flies are separate. Thus, chances of self-fertilization are not there.

Morgan had collected data regarding various characters through monohybrid experiments. Body colour grey is dominant over black body colour. Long wing is dominant over vestigial (under developed) wings. G represents gene for grey body colour. Its allele g is recessive for black colour. Similarly, gene L is for long wings and its allele *l* for vestigial wings is recessive.

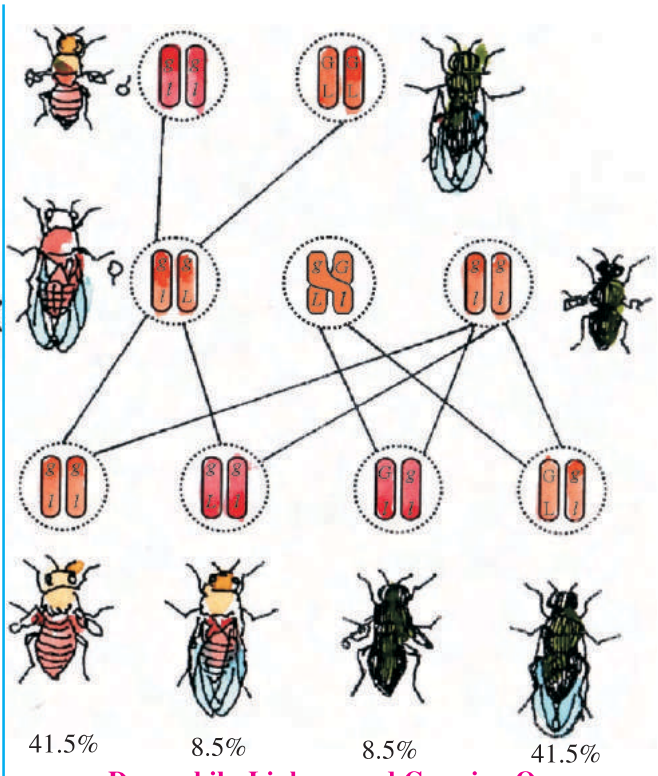
He took flies with grey body colour and long wings as one parent and flies with black body colour and vestigial wings as another parent. All F_1 generation flies were grey and long winged. This was expected result. Now, Morgan test - crossed F_1 flies with a parent which is recessive for both the characters (Figure A). Of the flies he had obtained, 50% were grey and long winged and 50% were black and vestigial winged. No flies were obtained with new combinations of characters. Such results represent complete linkage. This is because no crossing over occurs in male drosophila.



Male and Female Fruit Fly Drosophila and their Chromosomes



Drosophila-Complete Linkage



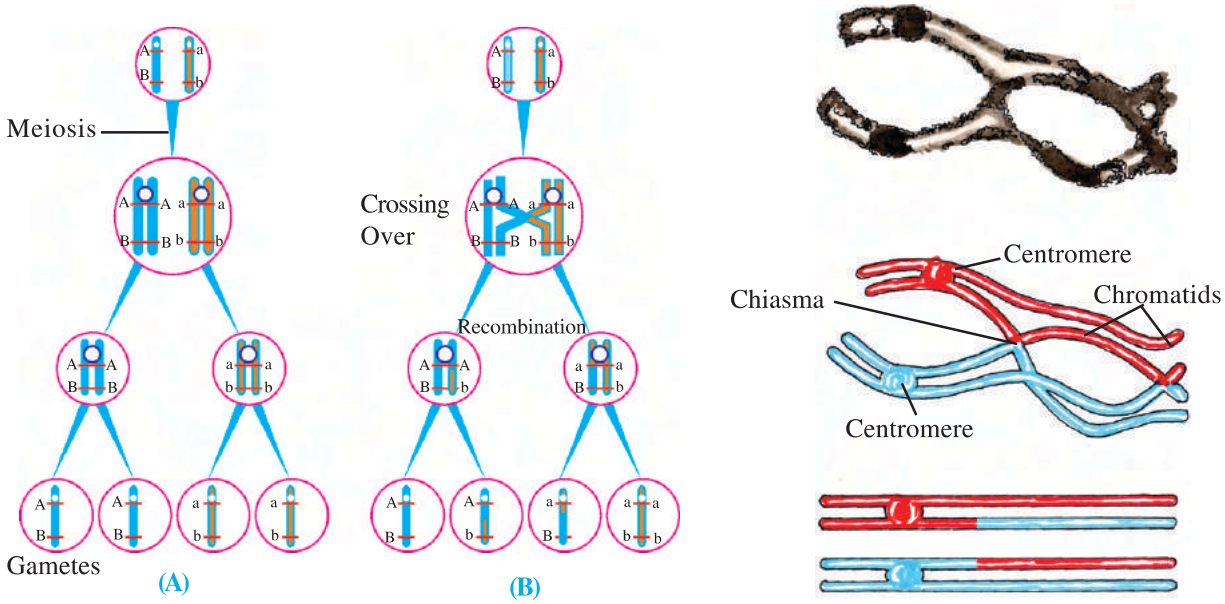
Drosophila-Linkage and Crossing Over

In the second experiment like the one above, when he used F_1 female's flies to cross with double recessive male flies, he obtained the following result :

Parental combinations : 83 percent	Grey long winged = 41.5 percent
	Black vestigial winged = 41.5 percent
Recombinations : 17 percent	Grey vestigial = 8.5 percent
	Black long winged = 8.5 percent

Morgan explained that this unusual ratio is because of the presence of the genes for black and vestigial on the same chromosomes. Here the genes are linked together. The two pairs of gene Gg and L*l* are not assorted independently.

Morgan explained crossing over as given in the following diagram.



Crossing Over and its Results

Morgan attributed this due to the physical association or linkage of the two genes and coined the term linkage to describe this physical association of genes on a chromosome. The term recombination is used to describe the generation of non parental gene combination.

The following figure is given only to understand the detailed process.

Sex Determination

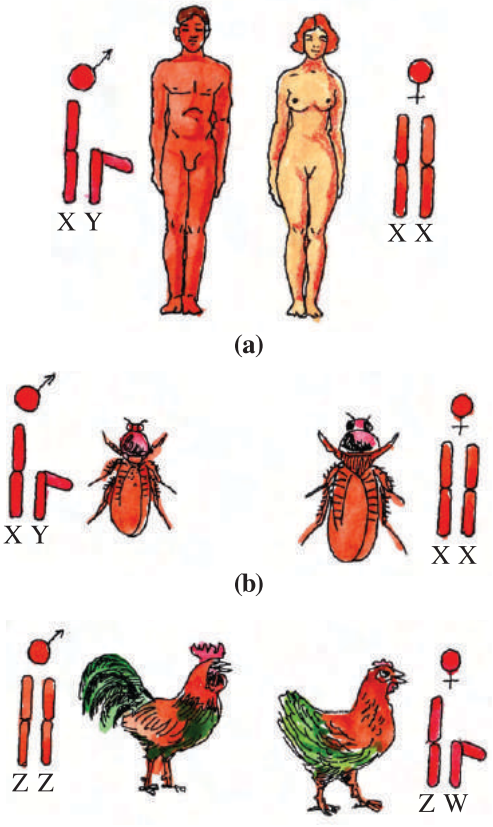
One of the most prominent and interesting aspects of hereditary differences observable among individuals of the same species is sex. No satisfactory explanation of the hereditary basis for the sex difference was given before the rediscovery of Mendel's laws. After this discovery, and after the establishment of the chromosome theory of heredity, it was found that in most animals, sex just like any other character, had its physical basis in the chromosomes.

Sex is a character and it consists of two alternatives, namely maleness and femaleness. The organisms producing eggs are known as females and those producing sperms are known as males. Sex behaves as a Mendelian character and it follows Mendel's laws of inheritance. The morphological, cytological, genetical, physiological and environmental factors determine the sex. Based on this, sex determination is explained by different aspects in different cases worked out by different scientists.

Chromosomal Theory of Sex Determination

In the nineteenth century, Henking observed that in insects, two kinds of sperms are produced. The difference was in the presence or absence of one chromosome. He had described this chromosome as X-body. He was unable to identify it as a chromosome. Later, Mc Lung identified X-body as a chromosome. Mc Lung also noted that in insects like grasshopper, male has an odd number of chromosomes and female has an even number of chromosomes.

The chromosomal theory of sex determination was proposed by Miss. Stevens (1905) and Bridges (1922), and Gold Schmidt (1938) supported this theory. According to this there are two types of chromosomes in an organism. They are the autosomes and allosomes (sex chromosomes). The autosomes contain genes which determine the somatic characters of the organism. The sex chromosomes determine the sex of an organism. There are two types of sex chromosomes. They are X chromosomes and Y chromosomes. These two chromosomes differ not only in appearance but also in genetic composition. The X chromosome is larger than Y. X is straight while Y has a bend at one end.



Determination of Sex by Chromosomal Differences

In a normal animal, there are two sex chromosomes. The two sex chromosomes may be XX or XY. In man, insects etc, the female has two X chromosomes. But in birds the male has two ZZ chromosomes and the female has one Z chromosome and one W chromosome.

The chromosomal theory is sub-divided into the following types for understanding.

(1) Theory of heterogamesis
(2) Genetic balance theory
(3) Haploid and Diploid mechanism
(4) Environmental effect on determination of sex
(5) Hormonal influences.

Theory of Heterogamesis

This theory was proposed by Correns in 1906. According to this theory, one sex produces two types of gamete and each type of gamete determines a different sex on fertilization. It can be (1) XX – XY type or (2) XX – XO type.

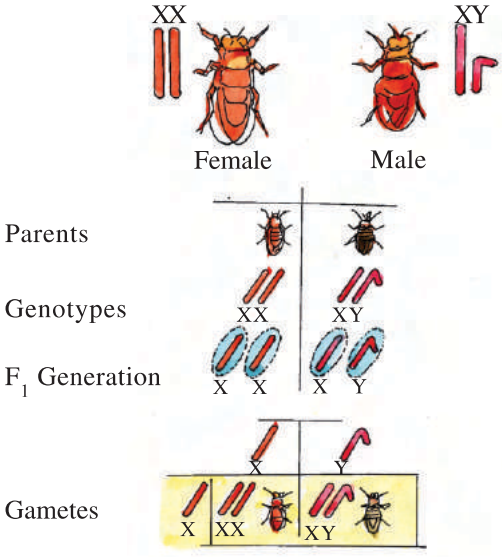
XX - XY Type

There are two different patterns of sex determination. (a) Through XX-female, XY-male type or (b) Through XY-female, XX-male type.

(a) XX-Female, XY-Male Type Sex Determination : It was studied in Drosophila and Man.

(i) Sex Determination in Drosophila

Morgan had discovered sex chromosomes in Drosophila; Morgan studied chromosomal constitution in male and female. Drosophila has four pairs of chromosomes, out of it there are three pairs of autosomes (3AA) and one pair of sex chromosome. In female this is represented by 3AA + XX and in male 3AA + XY. The female produces only one type of ova which carry 3A + X. But the male produces two types of sperms and they are 3A + X and 3A + Y type of chromosomes. Sex is determined by the type of sperm, fertilizing an egg. If an egg is fertilized by X type sperm, the resulting individual is a female and if by Y type sperm, resulting individual is male.



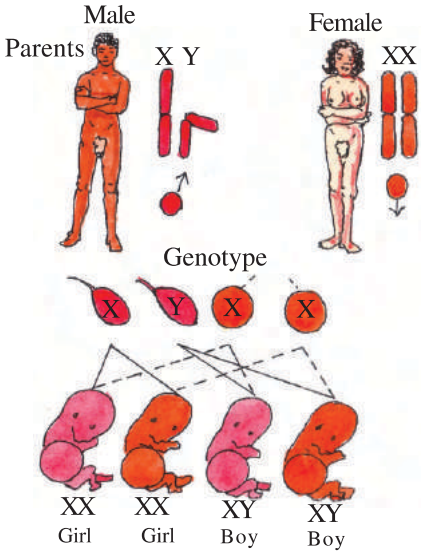
Sex Determination in Drosophila

This method of sex determination is also called XY male method. Similar pattern of sex determination is observed in many animals and plants. In humans also, the same method is observed with some variations.

(ii) Sex Determination in Human

In humans, 23 pairs of chromosomes occure. Of these, twenty-two pairs are of autosomes. They are similar in man and woman. In woman, twenty third pair consists of two similar X sex chromosomes. In man, one chromosome in twenty third pair is X-chromosome, and its homologous chromosome is smaller in size and is called Y-chromosome.

All eggs of woman are similar. Each egg contains 22 autosomes and one X-sex chromosome. In man sperms are of two types. Half the number of sperms have 22 autosomes and X-sex chromosome, while the other half contains 22 autosomes and one Y-sex chromosome. Whether the child will be a boy or a girl depends on the kind of sperm that fertilizes the egg.

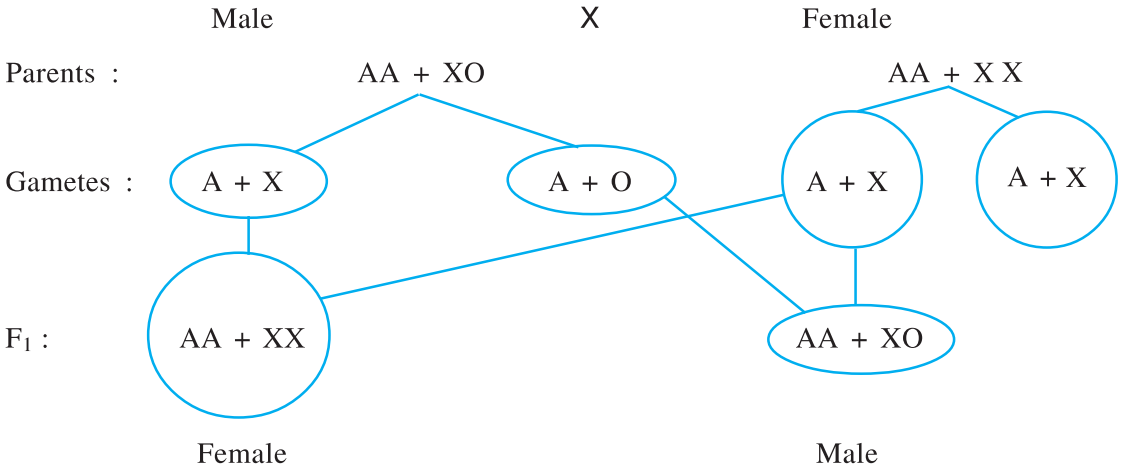


Sex Determination in Human

(b) XY-Female, XX-Male Type : In this type of sex determination, the female is sexually heterozygous having X and Y chromosomes. The male is sexually homozygous having two X chromosomes. Males produce only one type of sperms while the females produce two types of eggs. In birds, the X and Y chromosomes are designated as Z and W chromosomes. So the chromosomal structure of the female is AA + ZW and the male is AA + ZZ.

XX–XO Type

This type of sex determination was first studied in squash bug (Protenor). Here the sex of the animal is determined by the number of X chromosomes present in the cell. In female, XY chromosomes are present and in the male only one X chromosomes is present e.g. bugs and grasshopper. The process is given in a figure :



XX-XO Type of Sex Determination

Female XO and Male XX

In some insects like Fumia of order Lepidoptera, the female has one X chromosome and the male has two X chromosomes. Sex determination pattern is as in other insects.

Genetic Balance Theory

This theory was formulated by Bridges (a student of Morgan). According to this theory, sex is determined by the relative number of X chromosomes and autosomes. It is actually the ratio between the X chromosomes and autosomes that determines the sex.

Drosophila flies having XO-chromosome were male. However, they were sterile. They had only one X - sex chromosome, it means, Y - sex chromosome is not essential for maleness. Bridges during his experiments found triploid female flies. These were fertile, they had three sets of autosomes and three X-sex chromosomes.He arranged cross breeding amongst such triploid female flies and normal diploid male flies. The probabilities are indicated in the table given below :

Female (AAA + XXX)

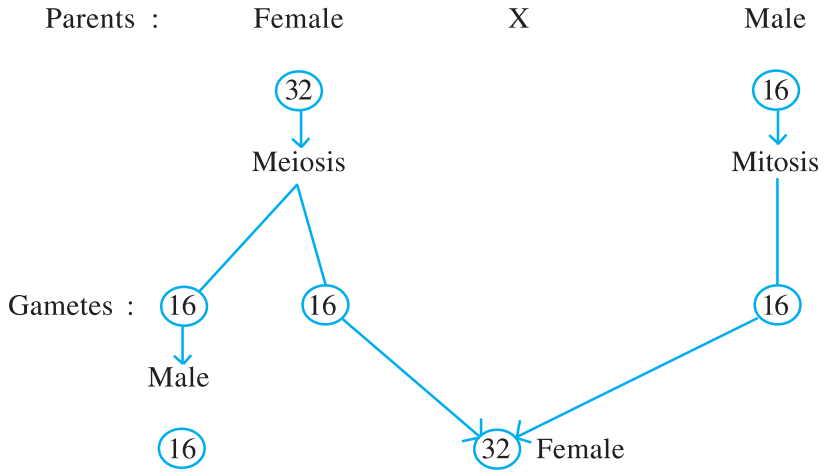
Male AA + XY	Kinds of Eggs →	A + X	AA + XX	A + XX	AA + X
Kinds of Sperms					
A + X		AA + XX Normal female $\frac{XX}{AA} = \frac{2}{2} = 1$	AAA + XXX Normal female $\frac{XXX}{AAA} = \frac{3}{3} = 1$	AA + XXX super sterile female $\frac{XXX}{AA} = \frac{3}{2} = 1.5$	AAA + XX Sterile $\frac{XX}{AAA} = \frac{2}{3} = 0.67$
A + Y		AA + XY Normal Male $\frac{X}{AA} = \frac{1}{2} = 0.5$	AAA + XXY Intersex sterile $\frac{XX}{AAA} = \frac{2}{3} = 0.67$	AA + XXY Normal female $\frac{XX}{AA} = \frac{2}{2} = 1$	AAA + XY super male sterile $\frac{X}{AAA} = \frac{1}{3} = 0.33$

Bridges noted that the offsprings contained normal males, normal females, sterile males, sterile females and sterile intersex flies. It seems that the ratio of X- sex chromosomes to autosomal chromosomes (X/A) is responsible for these results. Bridges suggested on the basis of results that in Drosophila, the genes for maleness are distributed over autosomes and those for femaleness are located on X-sex chromosomes. Sex depends on their balance.

Haploidy and Diploidy Mechanism

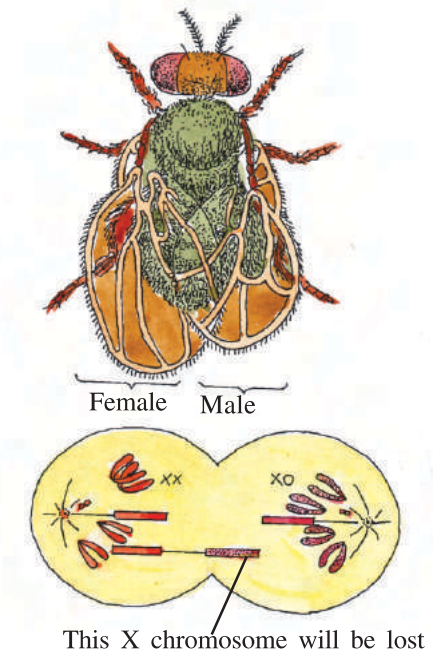
Development of an ovum into a young one without fertilization is known as parthenogenesis. An individual produced parthenogenetically is called parthenote.

In some hymenopterans like honey bees, wasps and ants, the females are diploid and the males are haploid. The female lays the normal egg which carries the haploid sets of chromosomes. The unfertilized haploid eggs develop parthenagenetically into functional males or drones. These drones carry only half the number (16) of chromosomes than that of of the female (32). If the eggs are fertilized; the zygote develops into a diploid female. In these, two types of females are produced from the fertilized eggs and they are (1) fertile normal diploid Queen and (2) sterile non functional diploid female workers. The diploid larva which gets the Royal jelly as the food material develops into Queen and the others develop into workers.



Sex Determination in Honey Bee

Gynandromorphs



Gynandromorphs are individuals who show male characters on some part of the body and female characters on other parts of the body. They are sterile. It happens in rare cases. They occur in Drosophila, butterflies, beetles, wasps, bees, silk worms etc. It happens due to loss of X-chromosomes or due to binuleated eggs.

The loss of an X-chromosome during mitosis in a 2A + XX cell leads to the derivation of two daughter cells one having 2A + XX and the other having 2A + X

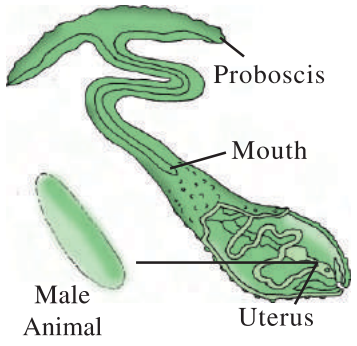
Barr-body Test

The mammalian cells of certain sexes contain a darkly stained body in the nucleus. It is called sex chromatin or Barr body. It was discovered by Barr and Bertram in 1949. It helps to identify the sex of the animal. The number of Barr bodies is always one less than the number of X chromosomes. It is given in a table as below.

Chromosomes	No. of Barr bodies	Sex
22 AA + XY	No Barr body	Male
22 AA + XX	One Barr body	Female
22 AA + X	No Barr body	(Turner's syndrome) Female
22 AA + XXY	One Barr body	Male (Klinefelter's syndrome)

Environmental Effect on Determination of Sex

Cases have been noted, where sex determination is influenced by environmental conditions. Baltzar (1935) stated that in Bonellia, sex is determined by environmental factor. In Bonellia (marine animal) all zygotes are genetically identical-whether the embryo will develop into a male or a female depends on where it develops. If it enters the body of the female and develops into a male animal. If it develops away from female, it develops into a female animal. Bonellia exhibits sexual dimorphism. It is believed that the proboscis secret a hormone like substance which prevents the development of femaleness.



Sex Determination in Bonellia

In tortoise, if the water temperature where it lives is higher than 30°c zygote develops as a female, at a lower temperature, male development occurs. In crocodile, the reverse is observed. A higher temperature induces male development and a lower temperature induces female development.

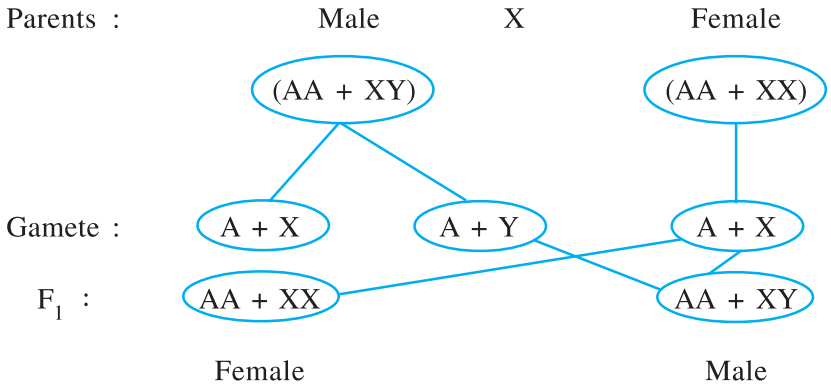
Hormonal Theory of Sex Determination

Generally, in higher animals secondary sexual characters are under the influence of their related sex hormones. But Lillie found that when twins of opposite sex (One female and other male) are born, the male is normal but the female is sterile with many male characteristics. Such sterile females are called free martin. In cattle, twins occur frequently. During development both the twins are connected by a common umbilical cord. The gonads of the male develop earlier than those of the female, at that time, the male hormones reach the female embryo and influence the development of male sex in the female embryo.

Sex Determination in Plants

The mechanism of sex determination has been studied in a large number of plants. In most of the plants the sex is controlled by the Y-chromosomes as in the case of man. If Y chromosomes are absent, the plant will be female.

In plants chromosomes were first studied by Allen in Liver Worts. In Liver Worts, the sex organs are located on a haploid gametophyte. In sphaerocarpes, the male gametophyte has seven autosomes and one Y chromosomes (7 A + Y), the female has (7 A + X). In Angiosperm, female is homogametic and male heterogametic type.



In Flagellaria plant, female is heterogametic and male homogametic. But in Dioscoria sinulate, female is homogametic (AA + XX) and male is heterogametic (AA +XO), where as in Humulus japanic, the female has two X chromosomes, but the male has one X chromosome and two Y chromosomes.

Sexual Differentiation in Monoecious Plants

Maize is monoecious, having both staminate flowers and pistilate flowers on the same plant. The female flowers normally develop along the sides of the stalk, and the male flower at the top of the plant. But in some cases the grains of corn may actually be produced at the tip of the plant. Why is it so ? There is a mutant gene called ta. In homozygous condition (t*a* t*a*) it converts the male flowers into female flowers. There is another mutant gene (*bs*); it suppresses the development of the female flowers. In Spinach sex is controlled by a single gene m which is located in the X-chromosome.

Genetic Variation

It is not always that offspring only resemble parents, but they also vary from them. Of course the resemblances are due to the genes they inherit. However, not all the inherited genes express themselves i.e. exhibit their phenotype. Some may be hidden or may be recessive in the presence of dominant counter-parts during expression. Genetic variation in sexually reproducing species develops primarily because parental genes are shuffled into new combinations i.e. new genotypes, in the offspring. Here, the process responsible for creating variations is called "recombination".

Let us consider some other processes responsible for creating variations. Variations can arise due to any change in the number of chromosomes, any structural changes in individual chromosomes and due to a change in the constitution of genes. All such changes are considered mutations. Mutations are the basis of discontinuous variation in population.

Mutation

The term "Mutation" was first utilized by De Vries. Mutation can be defined in various ways.

Mutation is a phenomenon which results in alteration of DNA sequences and consequently results in changes in the genotype and the phenotype of an organism.

Mutation is a sudden change of a gene or chromosome from one form to another. It produces an alteration in the character under its control. Dobzhansky stated that mutation is a mistake or misprint in cell division.

Types of Mutations

Mutations can be classified into various types. Its summary is given in the following table.

No.	Type	Explanation
(1)	Somatic mutation	Occurring in the somatic cells. It is not inherited.
(2)	Germinal mutation	Occurring in the germ cells. It is inherited.
(3)	Gametic mutation	Takes place in gametes.
(4)	Zygotic mutation	It occurs in zygote.
(5)	Dominant mutation	Mutation produces a dominant gene.
(6)	Recessive mutation	Mutation produces recessive gene, it does not express immediately.
(7)	Back mutation	This is the reversal of mutation. Rarely does it happen.
(8)	Lethal mutation	As a result the mutant dies.
(9)	Spontaneous mutation	It occurs in the absence of any obvious cause. Most of the mutations occurring in nature are of this type.
(10)	Induced mutation	Mutations caused by external factors. The factors are called mutagens. e.g. ionizing radiations, mustard gas, peroxides, colchicine, formaldehyde, dimethyl sulphate, nitrous acid, etc.
(11)	Biochemical mutation	Mutation causing changes in the metabolites or their end products. Mostly it happens in enzymes. These are metabolic errors.

Mainly there are three types of mutations :

(1) Numerical mutations in chromosomes (2) Structural mutations in chromosomes. (3) Gene mutations.

Numerical mutations in chromosomes. (= Ploidy)

We know that the number of chromosomes is fixed for every species. Change in the number of chromosomes can be either in the number of sets of chromosomes or in the number of chromosomes in one set. These changes cause loss of one chromosome from one set or an addition of chromosomes. Chromosomal abberration are broadly classified into two, namely euploidy and aneuploidy.

(1) Euploidy : Euploidy refers to the change in the number of chromosomes sets. It is further classified into two, namely 1. Haploidy and 2. Polyploidy.

(i) Haploidy or Monoploidy : Sometimes a set of chromosomes is lost and leads to haploidy.

(ii) Polyploidy : If there is an increase in the number of chromosomes which is in a multiple of the basic number n, the change is called polyploidy. The number can be $3n$, $4n$, $5n$, etc. Many of our cultivated crops are developed in this way. In plants, generally the polyploidy produces larger leaves and flowers and heavier fruits and seeds.

Aneuploidy

Aneuploidy refers to the loss or gain of one or more chromosomes in a pair. Normally, there are two members in a homologous pair of chromosomes. Instead, there may be only one or nil member or three or four members.

Monosomy ($2n - 1$) : If there is only one member instead of two in a pair, the condition is called monosomy.

Nullisomy ($2n - 2$) : If a homologous pair of chromosomes is totally missing, the condition is called nullisomy ($2n - 2$). Normally, it is lethal.

Trisomy ($2n + 1$) : If there are three members instead of two in a given pair of chromosomes, the condition is called trisomy.

Tetrasomy ($2n + 2$) : If there are four members in a pair of chromosomes instead of two, the condition is called tetrasomy.

Depending on the kind of chromosomes involved, aneuploidy can be of two kinds.

Autosomal aneuploidy: It involves autosomal pairs of chromosomes.

Sex chromosomal aneuploidy: It involves sex chromosomes.

Structural Abnormalities in Chromosomes

Chromosomal Abberrations : Each species is characterized by the presence of a specific number of chromosomes and each chromosome is arranged at definite location and in a definite sequence. Sometimes, changes occur in the number and arrangement of genes and in the number of chromosomes. These changes are called chromosomal aberrations or chromosomal mutation. Four kinds of chromosomal aberrations can occur. These are deletion, duplication, inversion and translocation.

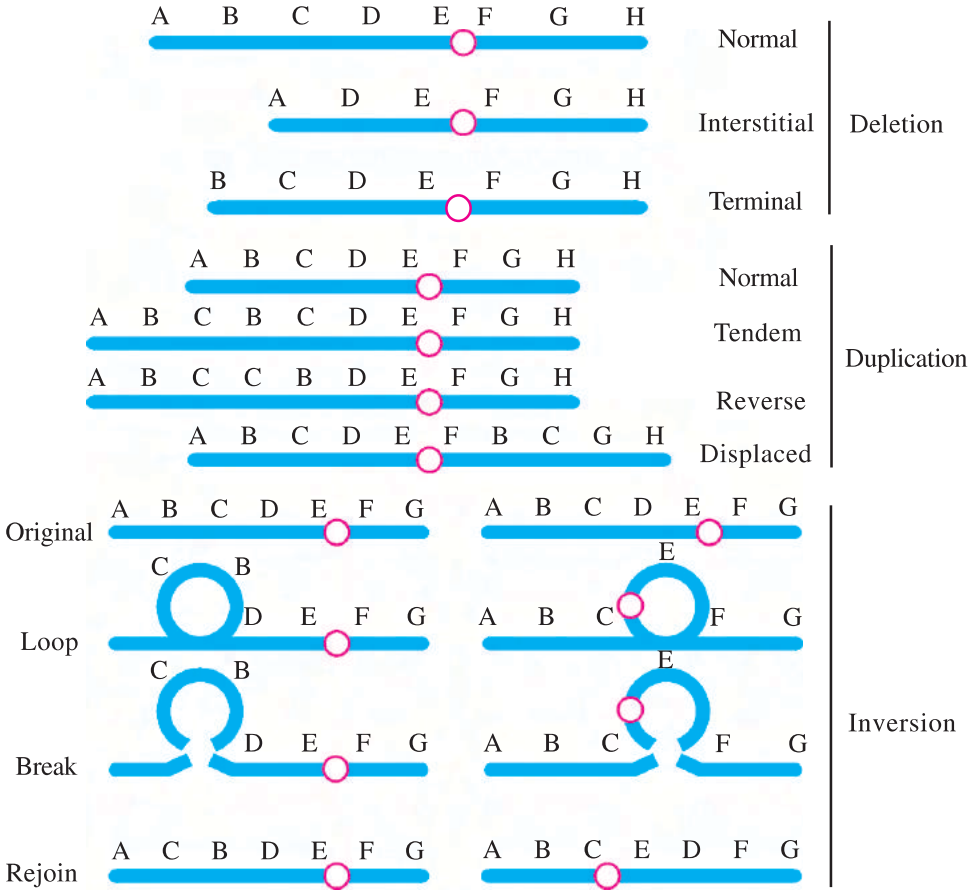
Deletion : Deletion is the loss of one or more genes from a chromosome and it is due to the loss of a chromosome segment. During deletion some genes are lost, so the organism shows some defects. Such a loss can be from the end region or from the inner region of a chromosome, i.e. deletion may be 'terminal' or 'intercalary'.

In human, a disease called cri-du-chat results due to deletion from the short arm of chromosome number five. Similarly a deletion from the long arm of chromosome number twenty two is responsible for the disease Philadelphia syndrome.

Duplication : In such an abnormality, a part of a chromosome occurs twice. This can occur during replication of DNA. In such cases, the sequence of genes is either maintained or inverted. For example, say the sequence of gene is A B C D E F G and genes C D E are duplicated. The new sequences can either A B C D E C D E F G or A B C D E E D C F G. Abnormality in size of eyes in Drosophila appears to be due to this reason. Duplications play a role in evolution. Owing to the repetition of genes, additional characters are produced.

Inversion : In inversion, there is no loss or gain of genes. But a particular segment of a chromosome is broken and is attached to the same chromosome in an inverted position. So there is rearrangement of the original genes. For example chromosome A B C D E F G is cut between B and C and between E and F. The separated piece C D E undergoes inversion and then rejoins the original chromosome. The new chromosome will have a sequence A B E D C F G. The sequence of gene is changed. Due to this, sometimes phenotypic effects may change.

Translocation : Sometimes a part of a chromosome becomes separated. This separated piece joins with another chromosome which is not its homologus chromosome. This is called translocation. It plays a significant role in evolution. Chromosomal aberrations are commonly observed in cancer cells.



Chromosomal Aberrations

Gene Mutation

Any mutation induced by a change in the constitution of a gene is called gene mutation. DNA is the genetic material. A definite length of a DNA molecule acts as one gene. Mutation also arises due to change in a single base pair of DNA. Such mutation may alter the sequence of the nucleotides within a part of the DNA molecule. This alteration changes the information on the DNA and results in differences in the proteins being produced. This is known as point mutation. A classical example of such mutation is sickle cell anemia, where haemoglobin becomes defective and RBCs take a sickle shape.

The following points are noteworthy regarding gene mutation.

- Generally a mutated gene is harmful to the individual.
- Any gene can undergo mutations.
- Mutations may be spontaneous or they may be induced.
- Mutation is an evolutionary agent and mutability is a property of the genetic material.
- Such genetic variations are useful in natural selection and evolution of a species.

Genetic Disorders

Pedigree Analysis : After the discovery of Mendel's work the practice of analyzing inheritance pattern of traits in humans beings began. A record of the occurrence of traits in several generations

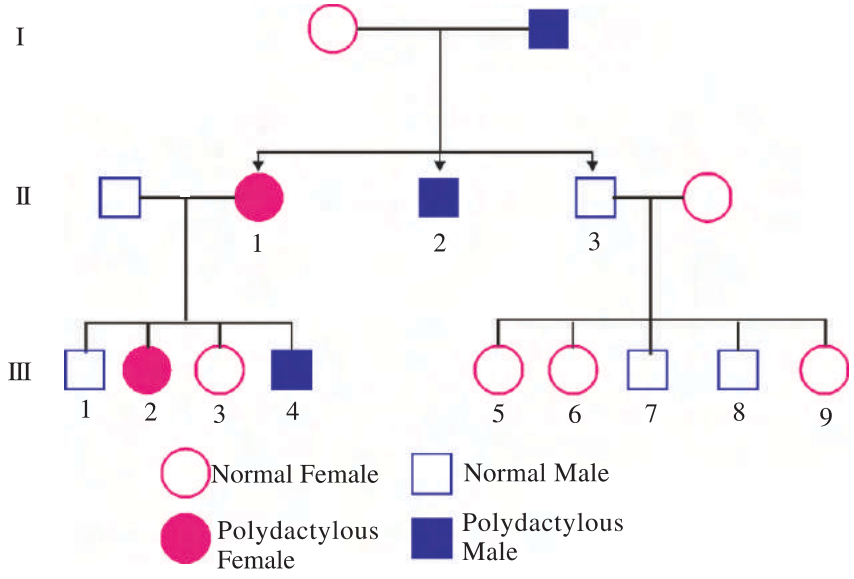
of a human family is known as pedigree analysis. For such type of analysis, information about the family history for particular traits is first collected. Then the expressions of the traits are assembled in a chart.

The pedigree of a family is represented in the form of a chart. The females are represented by circles and the males are represented by squares. The marriage is indicated by a horizontal bar connecting a circle and a square. The offsprings are suspended from the marriage bar by vertical lines. Individuals in one horizontal line belong to the same generation. Each generation is numbered by roman numbers (I, II, III, etc) and the individuals in each generation are numbered by 1,2,3,4 and so on.

Normal individuals are represented by open circles or squares and affected individuals are represented by closed circles or squares. Heterozygous individuals are represented by closing half of the circles or squares.

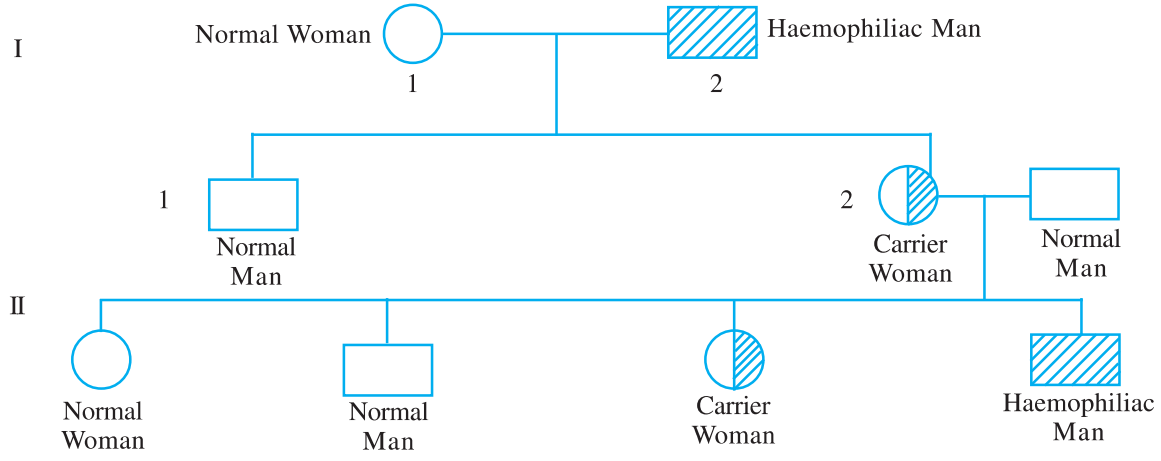
For example, in the following illustration, a pedigree analysis has been made for polydactylys (the occurrence of extra fingers).

The chart shows a marriage between a polydactylous man and a 'normal' woman (generation I). They produce three children, a polydactylous daughter, a polydactylous son and a normal son (generation II). The first and third individuals of second generation each marry 'normal' persons, their children are shown in third generation from the results. We can conclude that a polydactyl offspring appears only when at least one person is polydactylous.



Pedigree of Polydactylys in Man

(1) A family pedigree of haemophilia is given below :



(2) A family pedigree for sickle-cell anemia : Simple pedigree analysis has extensive use in medical research. Before marriage, for some possible hereditary diseases, such chart is very useful for making a decision.

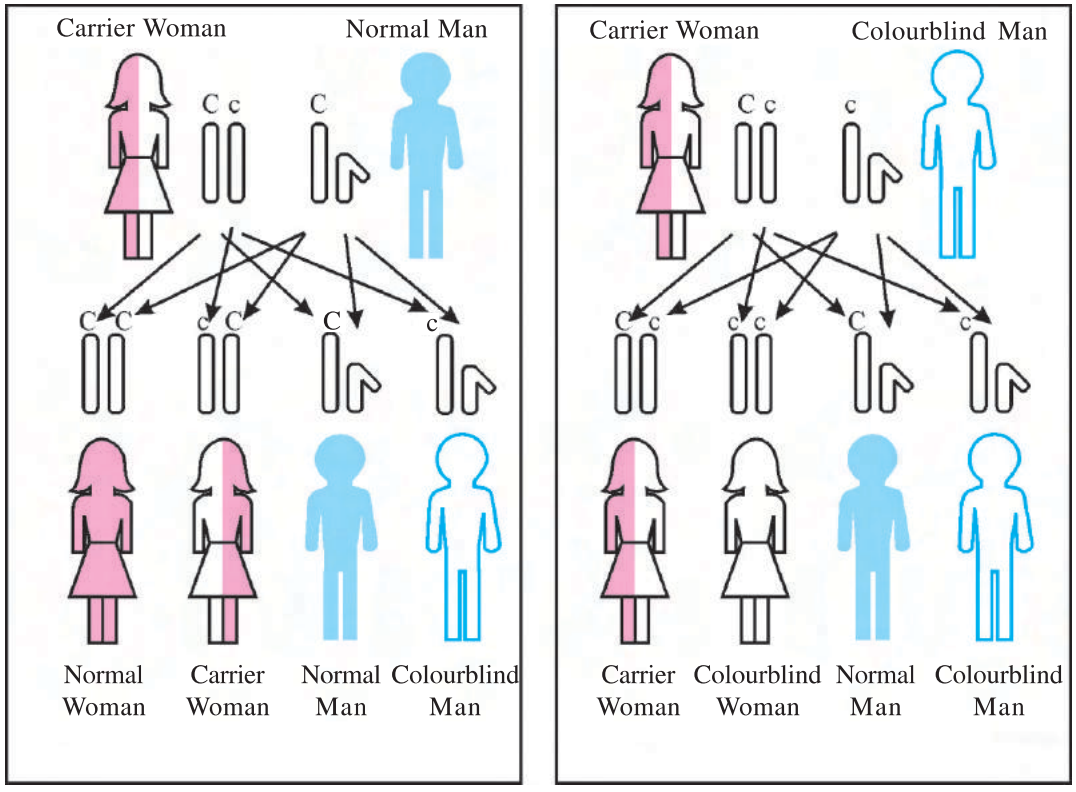
Mendelein Disorders

Mendelein disorders are mainly determined by alteration or mutation in the single gene. These disorders are transmitted to the offspring on the same lines as we have studied in the principle of inheritance. Most common disorders are haemophilia, colour blindness, sickle-cell anaemia, thalassamia, phenylketonuria, cystic fibrosis, etc.

Haemophilia

It is a hereditary blood disease caused by delayed blood clotting. This is because of the absence of a factor in the blood-antihaemophilic globulin. Haemophilia is a sex linked recessive character and the genes are located on X chromosome. It is caused by recessive genes represented by hh and the normal condition is due to dominant gene H. The family pedigree of Queen Victoria shows a number of haemophilic descendants as she was a carrier of the disease.

Colour Blindness



Inheritance of Colour Blindness

In it, the affected persons cannot distinguish red colour and green colour. It is a recessive character. It is caused by recessive genes represented by cc. The normal persons contain the genes CC or Cc or C alone (in man). The genes for colour blindness are located on the X chromosomes. Their alleles are absent from Y chromosome. This character is common in man but rare in woman. The daughter carring one recessive gene for colour blindness is called carrier. The carriers are normal in their vision.

Thalassaemia

In this case, the required haemoglobin is not generated in the blood of a person who suffers from this disease through inheritance. It has different types. Out of it test of B Thalassaemia is essential before arranging marriage. Out of male or female, one or both can be thalassaemic minor or thalassaemia major is possible. If out of father or mother, this effective gene is inherited from any one or the two, such offspring does not have the disease, but becomes a carrier for this effective gene. Effective gene from both parents passed to the next generation offspring can be the source of thalassaemia. In such a case both parents are thalassaemic minor. Their child is known as thalassaemia major. Out of husband-wife, if one is thalassaemic minor, they live their family life without any trouble; their children have no fear for thalassaemia major but any one child can be a thalassaemic carrier. Pattern of this disease follows Mendelian principles, and its pedigree is same as colour blindness and haemophilia.

Sickle Cell Anaemia

It is a hereditary disease. This disease is characterized by the presence of sickle-shaped RBCs under low oxygen pressure. It is due to the presence of defective haemoglobin called haemoglobin S (Hb^S). Sickle cell anaemia is a recessive character caused by the recessive genes Hb^S Hb^S. The normal adult haemoglobin is produced by dominant genes Hb^A Hb^A. The heterozygous (Hb^A Hb^S) persons are normal and are the carriers of sickle cell genes. The defect is caused by the substitution of Glutamic acid by Valine at the sixth position of the beta chain of the haemoglobin molecule.

Inborn Errors of Metabolism

Certain metabolic reactions are defective caused by recessive genes. They are the following:

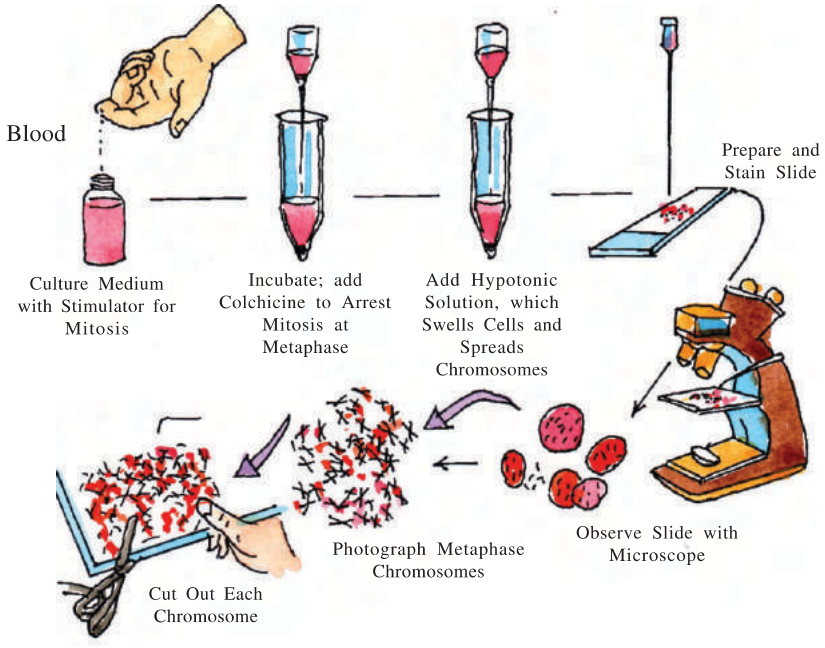
(1) Phenyl Ketonuria : It is an inborn error in metabolism. It is a recessive character caused by recessive genes represented by pp. When these recessive genes are present, the enzyme phenylalanine hydroxylase is not produced. In the absence of this enzyme, phenyl alanine cannot be converted into tyrosine. Phenyl alanine and its derivatives accumulate in the blood and cerebrospinal fluid. The excess of phenyl alanine is excreted in the urine.

(2) Alkaptonuria : It is an inborn error in metabolism. It is a recessive character caused by recessive genes represented by aa. When these genes aa are present, the enzyme homogentisic acid oxidase is not produced. In absence of enzyme, homogentisic acid can not be converted to acetoacetic acid as a result homogentisic acid accumulates in the blood. The urine of such persons turns black when exposed to air.

(3) Albinism : It is a hereditary defect where the melanin pigments are absent from the skin, hair, eye, etc. It is also an inborn error in metabolism caused by recessive genes represented by cc. When cc are present, the enzyme tyrosinase cannot be produced. Hence tyrosine cannot be converted into melanin pigments.

Chromosomal Disorders

To understand chromosomal disorders, first we have to understand Human Karyotype for study of human chromosomes. The blood culture method is very common. After blood preparation on slide, the number, kind, size, etc of chromosomed can be noted in WBC under microscope study. At this stage, we can photograph the chromosomes observed at metaphase stage. If individual chromosomes are cut out, paired as per size and shape and then arranged in a descending order of size, we can construct a karyotype of chromosomes. For the understanding, it is shown in a chart as below :



Human Karyotype

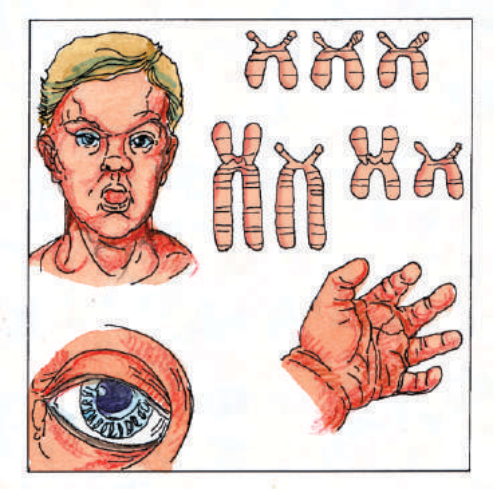
Through the study of Karyotype, we can collect information regarding each chromosome. Here, human disorders caused due to abnormalities in chromosomes are discussed.

Down's Syndrome

This disorder is caused by trisomy of 21st pair of chromosomes. There are three members in 21st pair instead of two. The total number of chromosomes becomes 47.

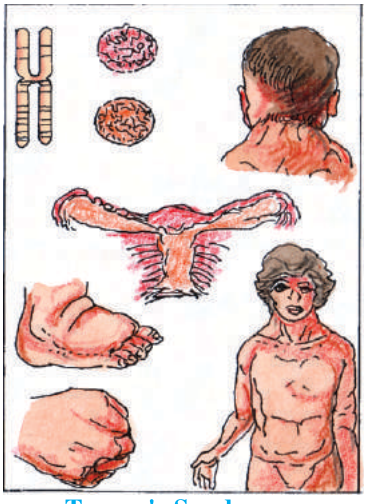
Symptoms Related to the Disorder

- Short structure, large head, short neck.
- Flat, round face
- Folded eyelids as are commonly observed in mongoloid race.
- Large thick and swollen tongue and drooping lips.
- Mental reterdation. Lower sensitivity.
- Short, stubby finger : Flat palm.
- Poorly developed reproductive organs.
- Sterile.



Turner's Syndrome

This is a sex-linked disorder. When a woman has only one X-sex chromosome, instead of the normal two, this disease occurs. Thus, this disorder is caused by monosomy of sex chromosomes.



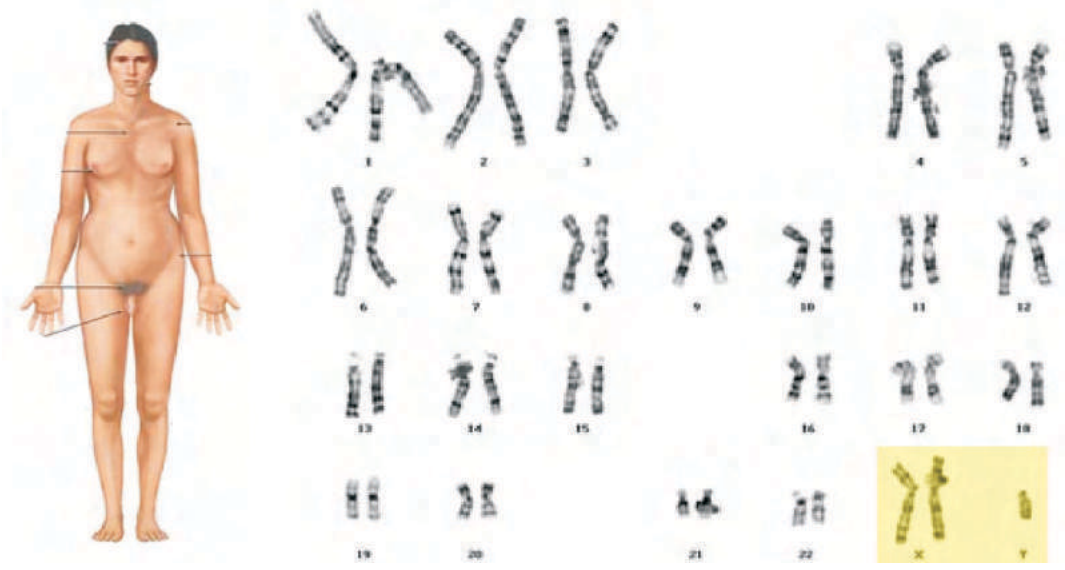
Turner's Syndrome

Symptoms Related to the Disorder

- Short stature. Short, webbed neck.
- Phenotypically a woman, but reproductive organs are poorly developed.
- Almost flat chest.
- Uterus underdeveloped.
- Sterile.

Klinefelter's Syndrome

This is a sex-linked disorder. When there are two or more X-sex chromosomes in a man instead of one, this disorder occurs. Thus, this disorder is caused by trisomy of sex chromosomes.



Klinefelter's Syndrome

Symptoms Related to the Disorder

- Phenotypically a man, but sterile.
- Testes under developed
- Tall in size, legs much longer. Trunk shorter.
- Sparse hairs on body.
- Amount of facial hairs low.
- Breast development as in women. Broad and flat pelvic girdle and shrill, feminine voice.
- Mentally retarded.

SUMMARY

A branch of Biology called genetics is the study by heredity and variation among related organisms. Heredity means continuity of features from one generation to another and variation means the occurrence of differences among the individuals of the same species. The scientific approach for heredity was done by Gregor Johann Mendel. He used the word 'Factor', now it is known as 'gene'. Mendel is called the father of Genetics.

Mendel did his work on garden pea (*Pisum satival*). Mendel crossed two plants differing in two characters. The experiments considering the inheritance of only one character are called mono hybridization experiments. Whereas for two characters, it is known as dihybridization. Based on his observations on monohybrid crosses, Mendel proposed two general rules :

(1) Law of Dominance and (2) Law of Segregation.

Test cross is arranged for deciding whether an organism is homozygous or heterozygous.

There were deviations from Mendel's findings. Their examples are: (1) Incomplete dominance (2) Co-dominance (3) Multiple genes (4) Actions of multiple alleles (ABO blood group system) (5) Pleiotropism.

The crossing of two plants differing in two characters is called dihybrid experiment. On the basis of dihybrid cross, Mendel derived a law of Independent Assortment. With certain limitations, Mendel worked. After rediscovery of his work, chromosome based inheritance was established. Morgan suggested Linkage and Recombination. He worked on Drosophila (fruit fly.)

No satisfactory explanation of the hereditary basis for the sex difference was given before the rediscovery of Mendel's work. As per chromosome theory of heredity, it was found that sex characters are determined by sex chromosomes. Several experiments were done to understand sex determination in animals and plants. The chromosomal theory is subdivided into: (1) Theory of heterogamesis (2) Genetic balance theory (3) Haploid and Diploid mechanism (4) Environmental determination of sex (5) Hormonal influences.

It is not always true that offsprings only resemble parents but they also vary from them. All such changes are considered mutations in nature. Mutations can be classified into various types. There are numerical mutations in chromosomes, structural abnormalities in chromosomes, and gene mutation.

To understand the genetic disorders, pedigree analysis is done. There are certain Mendelian disorders. Haemophilia, colour blindness, thalassaemia, sickle cell anaemia. Some are inborn errors of metabolism: e.g. Phenylketonuria, alkeptonuria, albinism. Some are chromosomal disorders. e.g. Down's syndrome, Turner's syndrome, Klinefelter's syndrome.

EXERCISES

1. Put a dark colour in a given circle for correct answer :

(1) Turner's syndrome is due to ……..

(A) Polyploidy ○ (B) Polysomic chromosomes ○

(C) Trisomic chromosomes ○ (D) Monosomic chromosomes ○

(2) Klinefelter's syndrome has ……..

(A) 66 + XXY ○ (B) 44 + XO ○

(C) 45 + XY ○ (D) 44 + XXY ○

(3) XXY chromosome is found in .....

(A) Turner's syndrome ○ (B) Klinefelter's syndrome ○

(C) Down's syndrome ○ (D) Cri-du-chat ○

(4) Autosomes in humans are .....

(A) 22 Pairs ○ (B) 23 Pairs ○

(C) 43 Pairs ○ (D) 11 Pairs ○

(5) A Trisomic individual has a chromosome number of .....

(A) $2n - 1$ ○ (B) $2n + 3$ ○

(C) $2n + 1$ ○ (D) $2n + 2$ ○

(6) The law of segregation was rediscovered by ?

(A) De Vries ○ (B) Correns ○

(C) Tschermark ○ (D) All of the above ○

(7) Mendel worked on ..... .

(A) *Lathyrus* ○ (B) *Drosophila* ○

(C) *Pisum* ○ (D) In all of the above organisms ○

2. Match the following :

(A)

Column I	Column II
(i) Sickle-cell anaemia	(a) Homogentisic acid
(ii) Alkeptonuria	(b) Lack of melanin
(iii) Albinism	(c) Accumulation of amino acid
(iv) Phenylketonuria	(d) Defective haemoglobin

(B)

(i) William Bateson	(a) Used the word gene
(ii) Johansson	(b) Used the term factor
(iii) Mendel	(c) Blood group
(iv) Landsteiner	(d) The term Genetics was first coined

3. Answer the following questions in short :

(1) What is heredity ?

(2) Define variation ?

(3) What is "genetics" ?

(4) Name the plant on which Mendel worked.

(5) Give name of the father of genetics.

(6) What are Mendel's hypothetic factors in modern terminology ?

(7) What is Mendel's monohybrid ratio ?

(8) What is dominant factor-axial flowers or terminal flowers ?

(9) What is Mendel's dihybrid ratio for phenotypes ?

(10) What is hybrid ?

(11) Name three principles proposed by Mendel.

(12) What is a pleiotropic gene ?

(13) Name the plant that shows incomplete dominance with respect to the colour of the flower.

(14) What are sex chromosomes ?

(15) Name two sex-linked diseases.

4. Short Answer Questions (2 marks each) :

(1) Which heredity principle can be derived from a cross showing 3:1 ratio in the F_2 generation?

(2) Which heredity principle can be derived from a cross showing 9 : 3 : 3 : 1 ratio in the F_2 generation?

(3) Make a list of the seven pairs of contrasting traits selected by Mendel for breeding experiments.

(4) What is aneuploidy ? Give an example of it.

(5) How is sex determined in human beings ?

(6) **State whether the following sentences are True or False :**

(1) Father of genetics is Morgan.

(2) Human blood groups are determined by multiple alleles.

(3) The term mutation was introduced by Darwin.

(4) A cross between F_1 individual and a recessive parent is called test cross.

5. Answer the following questions in detail :

(1) Why did Mendel use pea as the experimental material in his experiments ?

(2) Give a brief outline of the experiments conducted by Mendel.

(3) Discuss Mendel's laws of inheritance in brief.

(4) Which law of Mendel do you think is most important and why ?

(5) Which are the deviations from expectations of Mendel's laws ?

(6) Difference between the following :

(a) Dominant gene and Recessive gene (b) Homozygous gene and Heterozygous gene

(c) Monohybrid and Dihybrid

(7) Explain the law of the dominance.

(8) Define and design a test cross.

(9) **Explain the following :**

(a) Co-dominance (b) Incomplete dominance.

(10) Briefly mention the contribution of T. H. Morgan in genetics.

(11) Prepare a chart of Monohybrid cross.

(12) Prepare a chart of Dihybridization.

(13) In pea, inflated pods (I) are dominant, shrunken pods (i) are recessive. State the probable phenotypes and their ratio in II × *ii*, and I*i* × *ii*.

(14) Explain the terms : heredity, allele, factor, gene, genotype, linkage.

(15) **Give explanation of the following :**

(a) Law of segregation (b) Law of independent assortment

(16) **Write a short note on :**

(a) Chromosomal basis of Inheritance. (b) Genes responsible for blood groups.

(17) Describe the test cross experiment.

(18) Explain sex determination in Drosophila.

(19) What is genetic balance.

(20) Describe environmental influence on sex-determination in Bonellia.

(21) Explain inheritance of colourblindness.

(22) Haemophilia is a case of recessive expression of, in case of two sons of a couple, one is haemophilic. What is the probability of inheritance of haemophilia in their daughter ? Explain.

(23) State main types of mutation.

(24) What is chromosomal aberration ?

(25) State and explain one example based on chromosomal aberration.

(26) How does genetic mutation arise ?

(27) Explain the following terms :

Mutation, Translocation, Nullisomy, Trisomy, Autosomal aneuploidy

(28) **Write short note on :**

(1) Euploidy (2) Aneuploidy (3) Deletion (4) Inversion

(29) Mention the diseases caused by chromosomal aneuploidy.

(30) Explain the genetic basis of the following diseases:

(1) Phenylketonuria (2) Alkeptonuria (3) Sickle Cell Anaemia (4) Albinism

(31) **Write a Short note on :**

(1) Down's Syndrome (2) Turner's Syndrome (3) Klinefelter's Syndrome

(32) Why should thaelassemia test be perfomed ? Explain.

9

Molecular Basis of Inheritance

DNA is the Genetic Material

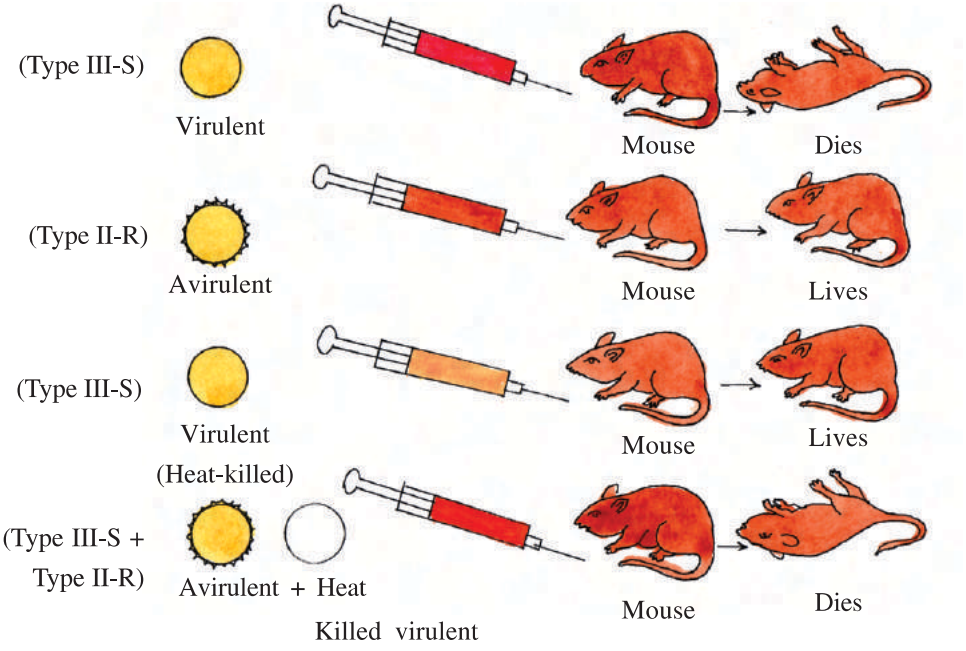
We have studied that children look more like their parents than like other persons. This is because children receive many characters from their parents. Most of the organism is formed from a unicellular zygote which is a fusion of male and female gametes. In the gamete, which component carries the hereditary characters has been a matter of discussion for a long time. In the previous chapter the chromosome theory of inheritance was discussed and it was emphasized that chromosomes mainly consist of nucleoproteins. Nucleoproteins have two components, nucleic acids and proteins, and one of these should obviously constitute the genetic material. Recent developments in molecular biology revealed that the nucleic acids of the chromosomes are responsible for the transmission of hereditary character. DNA is found to be the genetic material in almost all the living beings except plant viruses where DNA is not found and RNA acts as a genetic material.

The Search for Genetic Material

The following experiments conducted by the molecular biologists provide direct evidence for DNA being the genetic material.

Bacterial Transformation or Griffith-Effect

Griffith in 1928 carried out a series of experiments with Pneumococcus bacteria, namely virulent (S-III) and avirulent (R-II). Virulent strains have smooth polysaccharides capsules and give smooth (S) colonies. Avirulent strains have no capsules and give rough colonies (R). These two strains also differ in their antigenic properties and virulence for the disease pneumonia. Virulence is determined by genetic factors. When virulent strains were injected into mice; they killed them by causing pneumonia fever. When mice were inoculated with a virulent bacterium, there was no ill effect when mice were injected with virulent bacteria. After killing the bacteria with heat, no ill effect is produced and the mice survive. When mice were injected with a mixture of avirulent and heat-killed virulent bacterium, the mice were found dead due to pneumococcus infection. The analysis of dead mice shows that they contain virulent stain responsible for the transformation of avirulent bacteria into virulent smooth bacteria. Something from the heat-killed (dead) virulent bacteria was transformed to the live avirulent bacteria. As a result the avirulent bacteria are transformed into the virulent bacteria. This phenomenon is known as Griffith effect or bacterial transformation.



Griffith Experiment

In 1944, Avery, McCarty and Macleod supported the Griffith experiment by molecular explanations. They found that the DNA isolated from the heat killed smooth (S) bacterial cells, when added to rough (R) bacterials cells have changed their surface character from rough (R) to smooth (S), and also made them virulent. By this experiment, it was shown that DNA was the genetic material responsible for inducing the smooth (S) character of the cells and their property of virulence in mice. Their experiment proved that bacterial transformation involves transfer of a part of DNA from the dead bacterium to the living bacterium that expresses the character of dead cells, and so it is known as recombinant.

Dr. Hargovind Khorana has been successful in synthesizing one gene of yeast containing 77 nucleotides. American biochemists in Harward University have synthesized a more complex gene in mouse, which contains 650 nucleotides and controls the synthesis of haemoglobin. These synthetic activities leave no doubt that genes are molecules.

Biochemical Evidences for DNA as a Genetic Material

Strong supporting evidences that DNA is a hereditary material come from biochemical study :

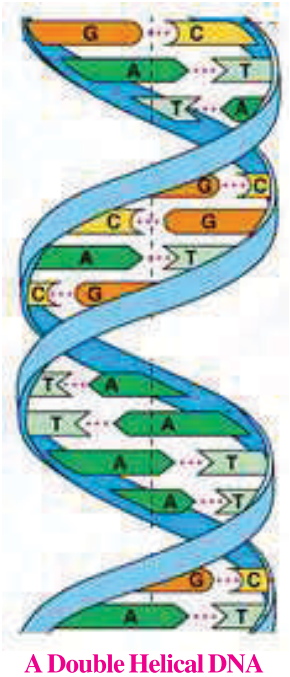
(1) The amount of DNA in any given species of cell or organism is remarkably constant and can not be altered by environmental circumstances or by changes in the nutrition etc.

(2) The amount of DNA per cell appears to be in proportion to the complexity of the cell and the amount of genetic information it contains.

The DNA

DNA is a long polymer of Deoxy ribonucleotides covalently linked by 3' – 5' phosphodiester bonds. DNA exists as a double stranded molecule wound with each other in a spiral known as a double helix. In a double helix one DNA strand runs 3' – 5' direction while the other runs 5' – 3' direction. Thus, the two complimentary strands run in anti-parallel manner.

DNA is a polymer of nucleotides. There are four kinds of nucleotides, each nucleotide consists of nitrogen base, pentose sugar (Deoxyribose) and phosphate (You have studied in XI standard, Semester-I).



A Double Helical DNA Molecule

Erwin Chargaff in 1949 proposed Chargaff's rules regarding the composition of bases in DNA as follows:

(i) Total amount of purine nucleotides always equals the total amount of pyrimidine nucleotides i.e. (A) + (G) = (T) + (C).

(ii) The proportion of A is equal to T and also proportion of G is equal to C, but amount of (A)+(T) is not necessarily equal to (G) + (C). Therefore (A) = (T) : (G) = (C). But $\frac{A+T}{G+C}$ = varies with the organism.

Properties of Genetic Material (DNA) Versus RNA

We have seen that by various experiment it became an established fact that it is DNA that acts as genetic material. However, it subsequently became clear that in some viruses, RNA is the genetic material (for example, Tobacco mosaic virus). Answer to some of the questions such as, why DNA is the predominant genetic material, where as RNA performs dynamic functions of messenger and adapter ?

A molecule that can act as a genetic material must fulfill the following criteria :

(i) It should be able to generate its replica (Replication).

(ii) It should be chemically and structurally stable (See Griffith's experiment).

(iii) It should be able to express itself in the form of Mendalian characters.

Both DNA and RNA are able to mutate. RNA can directly code for the synthesis of proteins. DNA, however, is dependent on RNA for synthesis of proteins. The above discussion indicates that both RNA and DNA can function as genetic material, but DNA being more stable is preferred for storage of genetic information. For the transmission of genetic information, RNA is better.

After various investigations, the double-helix model of DNA became established. Watson, Crick and Wilkins were awarded the Noble Prize in 1962 for their contribution. The most crucial outcome of Watson and Crick's double helix model of DNA was the implicit suggestion for a mechanism by which the genetic material (DNA) can be copied and transmitted to progeny. This is known as DNA replication. As a result of this, new horizons opened up in the fields of genetics and molecular biology. With their development, biotechnology and genetic engineering has developed. Knowledge of DNA is at the root of these fields.

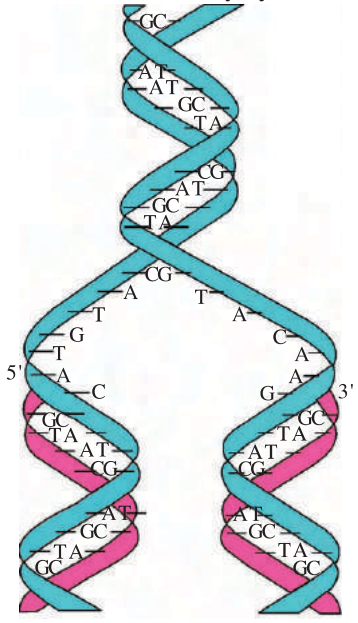
Replication of DNA

One of the most important requirements of a hereditary unit is that it should be able to form its own copy. It should be able to replicate in order to pass on from one generation to the next.

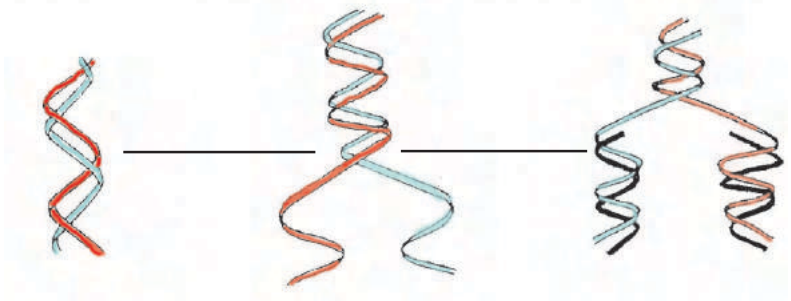
Growth of any organism occurs through divisions of its cells. During the growth of cells, its structural constituents must also increase, so that the two newly formed cells can receive sufficient material. Naturally, during this, its genetic material DNA must also increase in such a way that the new cells receive it in the same amount and of the same kind. For this, the amount of DNA must increase in such a way, that at the time of cell division, two molecules of DNA are formed which are exact copies of the original DNA molecule. The number, the kinds and the arrangement of nucleotides must be the same as they were in the original DNA. The process by which two such molecules of DNA are formed from the original DNA molecule is called DNA replication. It is controlled by DNA itself.

Thus synthesis of new DNA molecule from pre existing DNA is called replication. By replication, each DNA molecule produces exact copies of its own structure. Watson and Crick suggested that there is a self duplication of DNA molecule. The constituents of DNA viz; nitrogen bases, sugar molecules and phosphates are synthesized within the nucleus, these substances pair up to form the nucleotides and form new DNA molecule during replication.

They have concluded that the two strands would separate and act as a template for the synthesis of new complementary strands. After the completion of replication, each DNA molecule would have one parental and one newly synthesized strand, this method was termed as semi conservative DNA replication.



Watson-Crick Model for Semiconservative DNA Replication

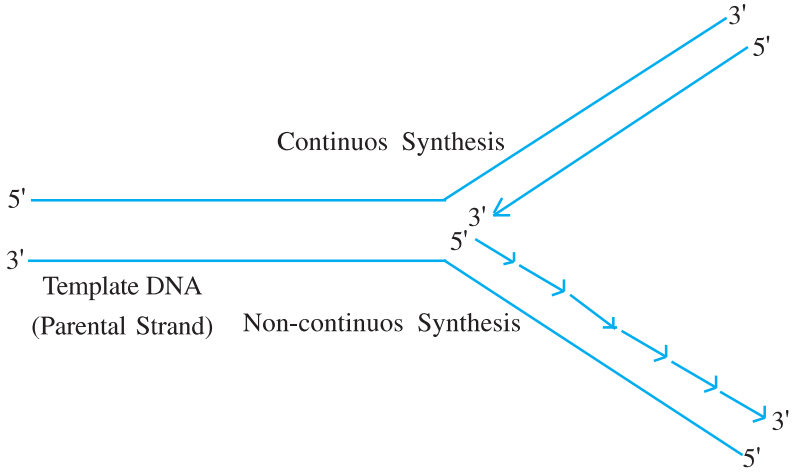


Semiconservative Method of Replication

Mechanism of DNA Replication

- In the process of DNA replication, the weak hydrogen bonds between two polynucleotides chains are sequentially broken with the help of proper enzymes.
- The two chains move away from each other. New complementary chains are synthesized along these two separated chains.
- In the end, in the molecules of DNA, one chain is of parental DNA and the other chain is a new one.
- The process begins from a specific site. Then it progresses towards both directions. The enzymes responsible for this are gyrase and helicase.
- The two separated polynucleotide chains appear like a fork. This is called replication fork. As the process of replication progresses in two directions, it is considered bidirectional.

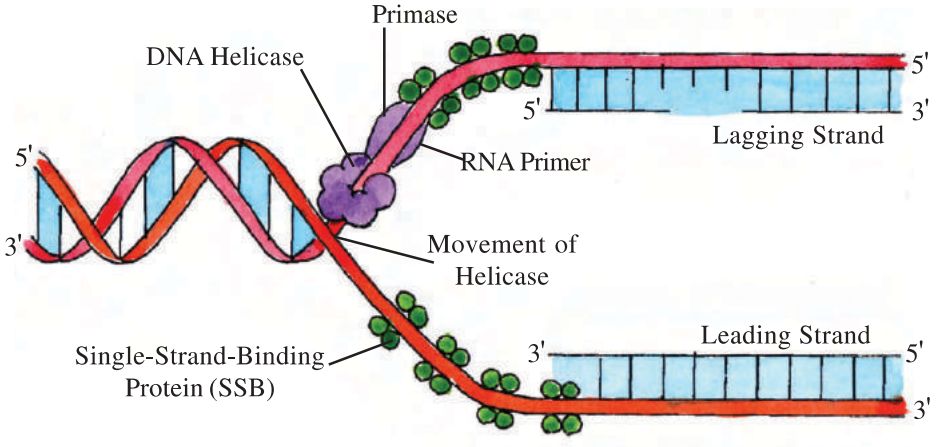
- As each separated polynucleotide chain provides information for synthesis of the new chain, it is called template chain. The sequence of nucleotides or the template chain determines the sequence of the new chain. The synthesis of new chain is carried out by enzyme-DNA polymerase-III. Synthesis of new chain always begins from 5' end and progresses towards 3' end.



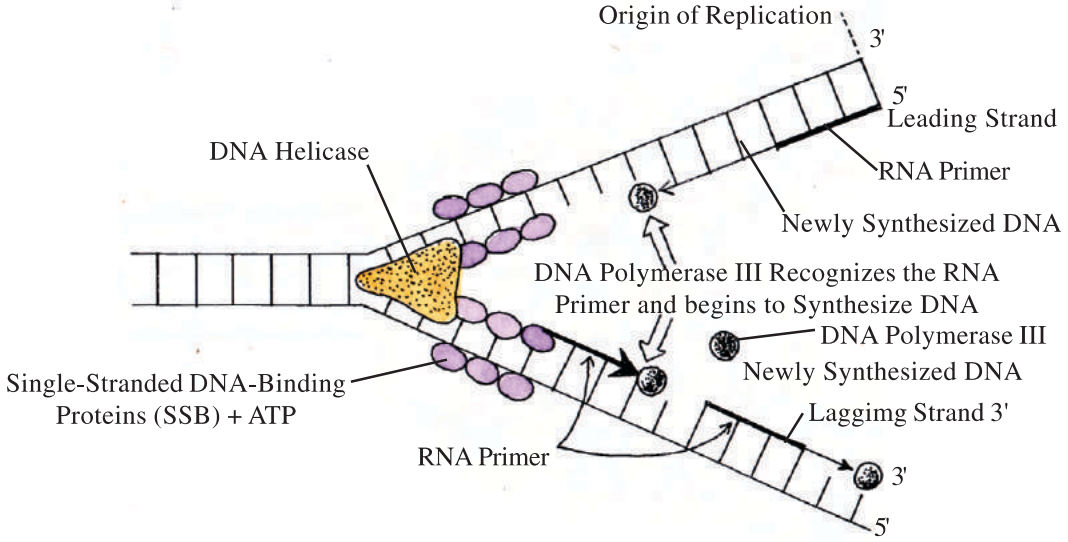
Replication Fork

- First of all RNA-polymerase forms a short RNA chain, complementary to the template DNA as its initial region. This is called a primer. Only after the primer is formed, the enzyme DNA polymerase-III becomes active.
- Based on the direction of the replication, one chain is synthesized continuously in 5' $\longrightarrow$ 3' direction. Such a chain is called leading chain. The new chain synthesized on the other template is synthesized discontinuously and in the 5' $\longrightarrow$ 3' direction. Such a chain is called lagging chain. On this template, short pieces of DNA along with RNA- primer are joined. Such fragments are called Okazaki fragments. At the end of DNA replication the enzyme ligase joins pieces of nucleotides with phospho-diester bonds.

Thus, two new molecules are formed, which are exact replicates of parent - DNA molecule.



Formation of Leading and Lagging Strand during DNA Replication



Involved Chemicals in the Process of Replication

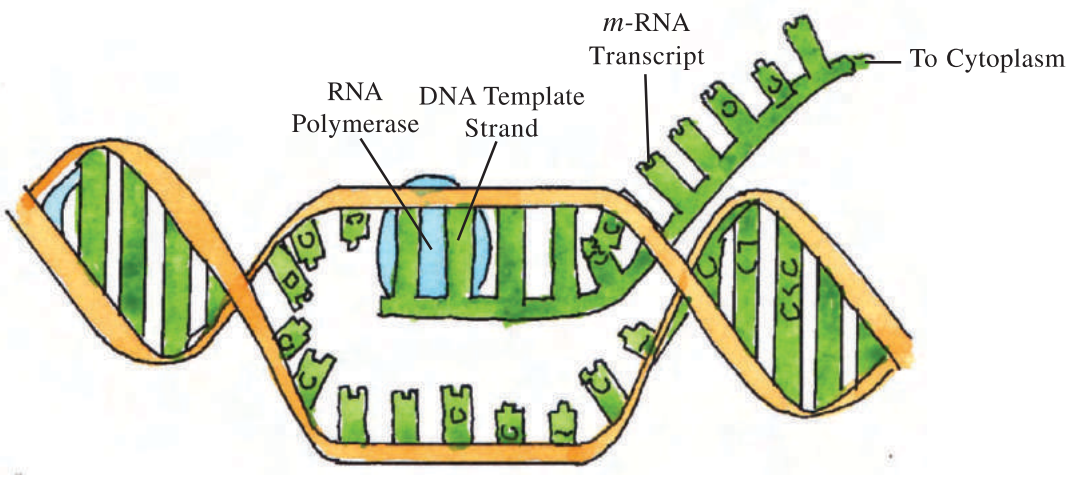
Transcription : DNA to m-RNA

The messenger RNA (m-RNA), is derived from DNA by a process which is approximately similar to the process of DNA Replication. The process where DNA gives its information to RNA is called transcription, which involves the formation of an RNA strand on the DNA template.

Transcription occurs in three steps. First of all, the enzyme transcriptase becomes attached at the initial region of the DNA (gene) which is to be transcribed. As a result, the two polynucleotide chains in that region move away from one another. In the second stage, one of these two separated chains acts as a template chain. This chain provides information for synthesis of m-RNA.

Based on the sequence of nucleotides on the template chain, enzyme transcriptase arranges complementary RNA-nucleotide units one after the other and phospho di- ester bonds are formed between them. Thus m-RNA chain is synthesized.

The third and the last phase are of completion. A specific protein attaches with m-RNA and separates it from template - DNA and transcriptase enzyme. Some times m-RNA gets separated by itself. Then the m-RNA is translocated to cytoplasm where it associates with ribosomes.



Process of Transcription

Genetic Code

We now know that proteins are synthesized by DNA. The secret of the storage (Blue print) of genetic information lies in the arrangement of definite linear sequence of nitrogen bases of a DNA strand. A DNA strand in a chromosome may represent many genes. Each gene is represented in a small sector of a DNA molecule and may have its unique sequence of nucleotides in that length of DNA.

Gene A and B

Each gene may contain thousands of based of unique sequence. Here, only a few based are shown to illustrate the difference between two genes in sequence.

The information present in the DNA is transcribed and carried by the m-RNA to the cytoplasm for protein synthesis. This information is designed as genetic codes. Thus, genetic code is defined as the sequence of nitrogen bases (nucleotides) in m-RNA molecule which contains the information for the synthesis of protein molecules.

Triple Code

The main problem of genetic code was to determine the exact number of nucleotides in a codon which codes for one amino acid. Since there are only four nitrogenous bases in m-RNA for 20 amino acids, combination of only one or two nitrogenous bases cannot provide sufficient codons of 20 amino acids. A singlet code consisting of only one nucleotide provides just four codons A, C, G and U. These are insufficient to code 20 amino acids. Similarly combination of two nitrogenous bases (doublet code) provides $4 \times 4 = 16$ codons which are still insufficient for 20 amino acids. Gamov (1954) pointed out the possibility of three letter code, i.e. each codon consists of three nitrogen bases. This will give $4 \times 4 \times 4 = 64$ codon words of codons, which are more than enough to code twenty amino acids. The table given provides the list of codons for each amino

Probable Singlet Codons

A
C
G
U

Probable Doublet Codons

	A	C	G	U
A	AA	AC	AG	AU
C	CA	CC	CG	CU
G	GA	GC	GG	GU
U	UA	UC	UG	UU

SECOND BASE

FIRST BASE	U	C	A	G	THIRD BASE
U	UUU, UUC } Phe UUA, UUG } Leu	UCU, UCC, UCA, UCG } Ser	UAU, UAC } Tyr UAA Nonsense (STOP) UAG Nonsense (STOP)	UGU, UGC } Cys UGA Nonsense (STOP) UGG Try	U C A G
C	CUU, CUC, CUA, CUG } Leu	CCU, CCC, CCA, CCG } Pro	CAU, CAC } His CAA, CAG } Gln	CGU, CGC, CGA, CGG } Arg	U C A G
A	AUU, AUC, AUA } Ileu AUG Met (START)	ACU, ACC, ACA, ACG } Thr	AAU, AAC } Asn AAA, AAG } Lys	AGU, AGC } Ser AGA, AGG } Arg	U C A G
G	GUU, GUC, GUA, GUG } Val	GCU, GCC, GCA, GCG } Ala	GAU, GAC } Asp GAA, GAG } Glu	GGU, GGC, GGA, GGG } Gly	U C A G

Triplet Codons of *m*-RNA for Amino Acids Represented in Tabular Form

acid.

The main properties of genetic code are as under :

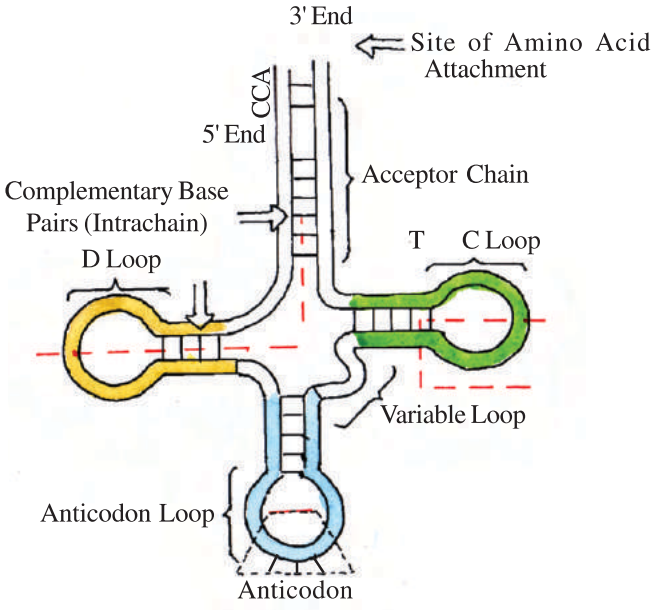
- Genetic code is a universal type of code which determines the same amino acid in all organisms including virus, bacteria, plants and animals.
- Genetic code is specific. Any one codon specifies the position of one kind of amino acid only.
- The codon is triplet. 61 codons code for amino acid and 3 codons do not code any amino acid. A single amino acid may be specified by many codons (see table). Such codons are called degenerate codons.
- The synthesis of a polypeptide chain is initiated by a codon called initiation codon.
- UAA,UGA and UAG codons are termination codons. They indicate termination at synthesis of protein. These codons do not code for any amino acid, hence these are called non-sense codons.
- AUG has dual functions. It is the codons for methionine and it also acts as initiator codon.
- The sequence of genetic codes and the sequence of amino acids in protein molecule shows linear parallelism.

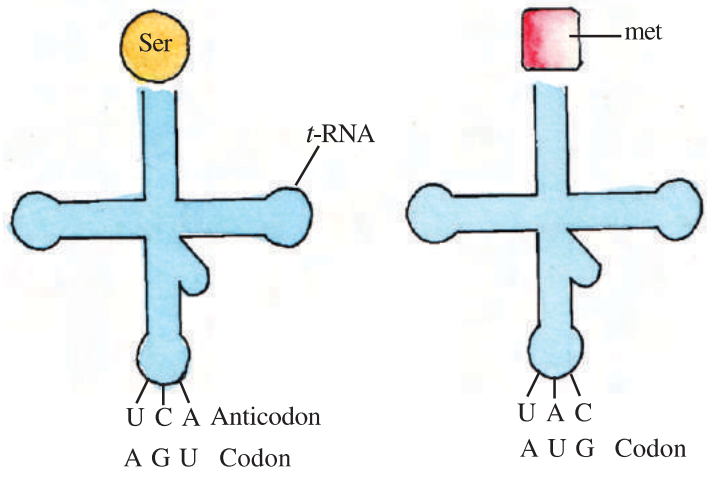
Mutations and Genetic Code

We have studied that sometimes there is a point mutation. A classical example is sickle cell anaemia. Let us see with one example. Once a student wrote a sentence- God is no where. Teacher read it and He/ She insrted a letter W, at the end of now the sentence had changed with the meaning. "God is now here." The same problem occurs in Gene mutation.

t-RNA (Transfer – RNA)

t-RNA has an anticodon loop that has bases complementary to the code, and it also has an amino acid accepter by which it binds to amino acid. t-RNA are specific for each amino acid (See Figure).





Structure of *t*-RNA

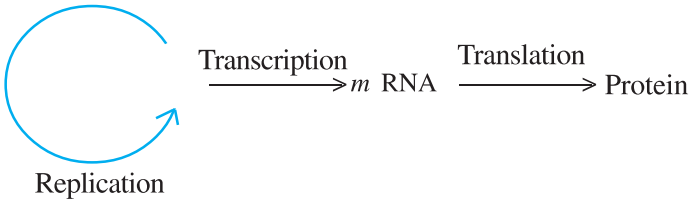
Central Dogma

Now we are aware that DNA gives its genetic information to m-RNA. With the help of m-RNA and RNA protein synthesis takes place. This unidirectional flow of information was first described by F.H.C. Crick in 1958 as the central dogma of molecular biology.

The expression of the genetic material (DNA) which occurs generally through the production of protein synthesis involves two consecutive steps: (1) transcription and (2) translation.

It states that the genetic information flows from DNA → m-RNA → Protein replication.

DNA transcript m-RNA translation protein



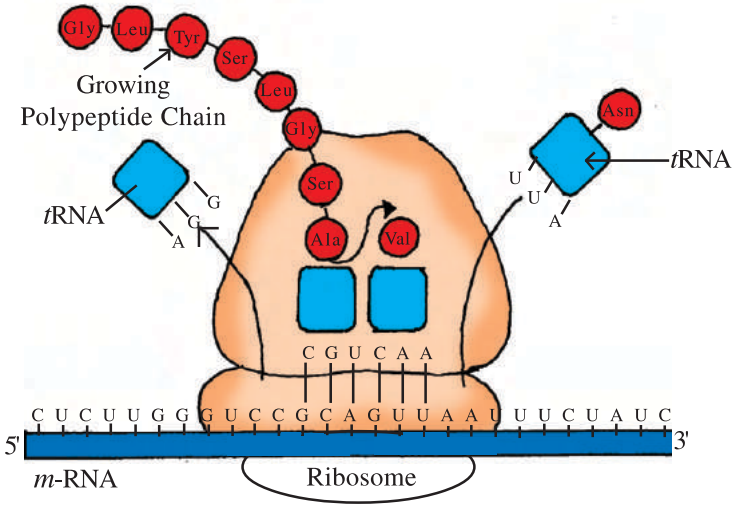
Central Dogma

In some viruses the flow of information is in reverse direction. It was brought to light by H.M.Temin and D.Baltimore. According to them, many tumour viruses contain RNA as a genetic material and replicate by first synthesizing a complementary DNA. This process is called or reverse transcription. It is done with the help of RNA - dependant DNA polymerase called reverse transcriptase. It is observed in HIV.

Translation : Biosynthesis of Proteins

Translation is the process in which the genetic message carried by messenger RNA from the DNA is converted into the form of a polypeptide chain having a specific sequence of amino acids.

Now we know that m-RNA contains information for synthesis of protein. The information for this is stored in the sequence of nucleotides in m-RNA. A unit of three successive nucleotides indicates the position of a particular amino acid in the constitution of protein. This unit is called genetic code of triplet code.

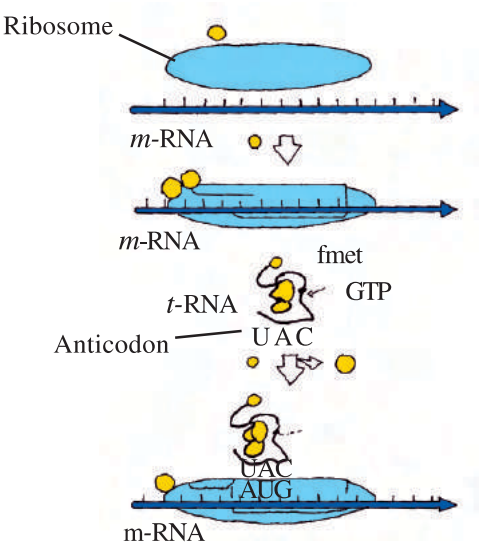


Translation

Translation occurs in three steps : initiation, elongation and termination. Three other key components which take part in these three steps. They are (i) ribosomes (ii) t RNA and (iii) amino acids.

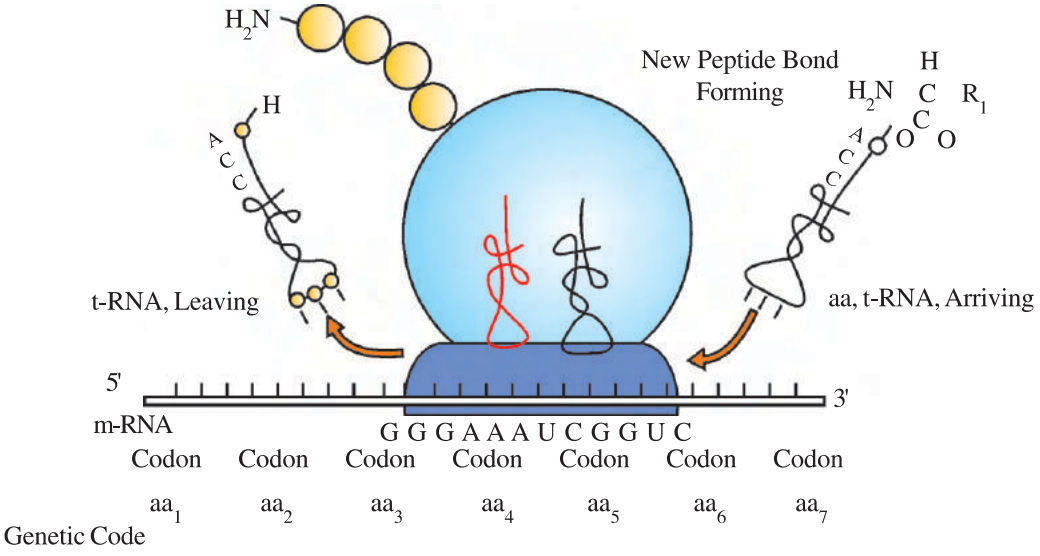
(i) Initiation : Synthesis is always initiated with amino acid methionine. Amino acid molecules of various kinds located in the cytoplasm are transported by t-RNA molecules. A t-RNA - synthetase enzyme, specific for the amino acid molecule is essential in this. The amino acyl t-RNA with its specific amino acid now moves towards m-RNA.

In eukaryote cell, methionine is arranged on m-RNA at its proper location. To decide this, a sequence of three nucleotides occurs on the t-RNA which is complementary to the genetic codon on m-RNA molecule. This unit of three nucleotides on t-RNA is called anticodon. The genetic code for methionine on m-RNA is AUG. Hence, anticodon on t-RNA is UAC. Formyl-methionine acyl t-RNA with its amino acid get attached here. Thus, synthesis of protein is initiated.



Protein Synthesis – Initiation

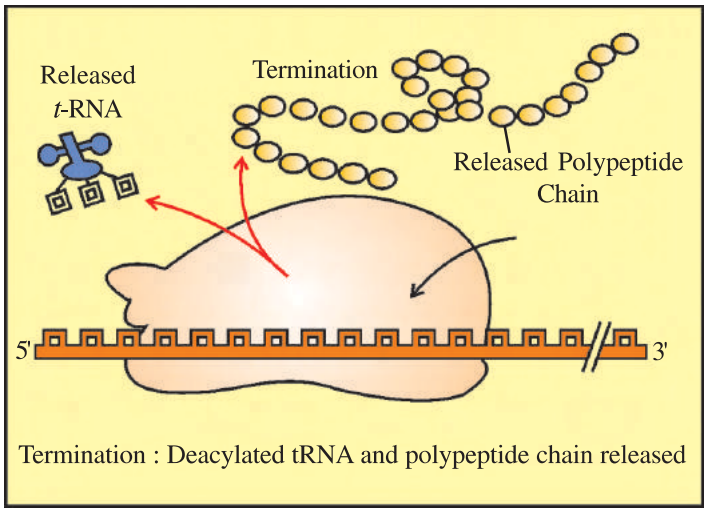
(ii) Elongation : Now, other t-RNA molecules carrying their specific amino acid molecules and possessing anticodon specific to the genetic codes on m-RNA become sequentially arranged. Proteins known as elongation factors and GTP as energy source are helpful in this. Methionine, at the first position is joined to the second position amino acid by a peptide bond. Now the t-RNA carring formyl-methionine is released. Thus a dipeptide is formed. Now, ribosome moves along m-RNA in 3' direction by distance of one codon. As a result, t-RNA which is responsible for methionine transfer is released from the surface of the ribosome. The t-RNA caring dipeptide now occupies the vacant region. Thus, one by one, t-RNA molecules carring their amino acid get arranged, and the peptide chain elongates. This phase is elongation phase.



Protein Synthesis Elongation

(iii) Termination : The genetic code located at 3' end of m-RNA does not indicate the position of any amino acid. Such codon is called nonsense codon or termination codon. The function of such codons is to release the synthesized polypeptide chain from ribosomes.

From the first amino acid of the released polypeptide chain, formyl-methionine, the formyl group is removed. Sometimes, even methionine is removed. Then, the polypeptide gets ready to perform its function.



Protein Synthesis Termination

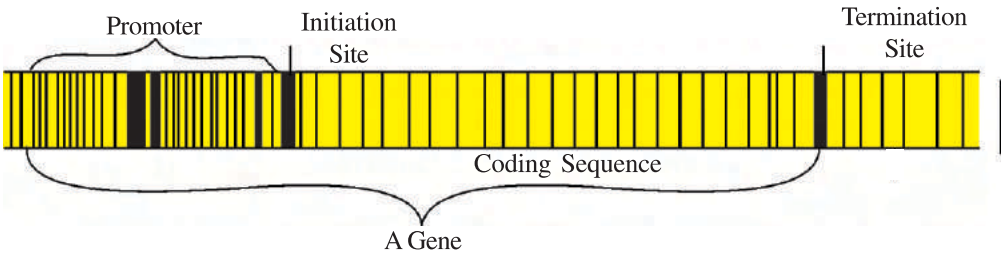
Gene

After a long discussion we have got the idea that what is gene. It is actually a "factor" as per Mendelian theory. It is a segment of DNA present in the chromosome. Thus gene is the hereditary unit. It controls characters. It transmits characters from parents to offspring.

The gene consists of four main regions namely promoter, initiation site, coding sequence and termination site. The promoter is at one end of the gene. The RNA polymerase is attached to this region during RNA synthesis. The initiation site is located next to the promoter. The m-RNA synthesis begins from this site.

The coding sequence is the middle segment of the gene. All these nucleotides are copied into the m-RNA.

The termination is at the other end of the gene, where m-RNA synthesis is stopped.

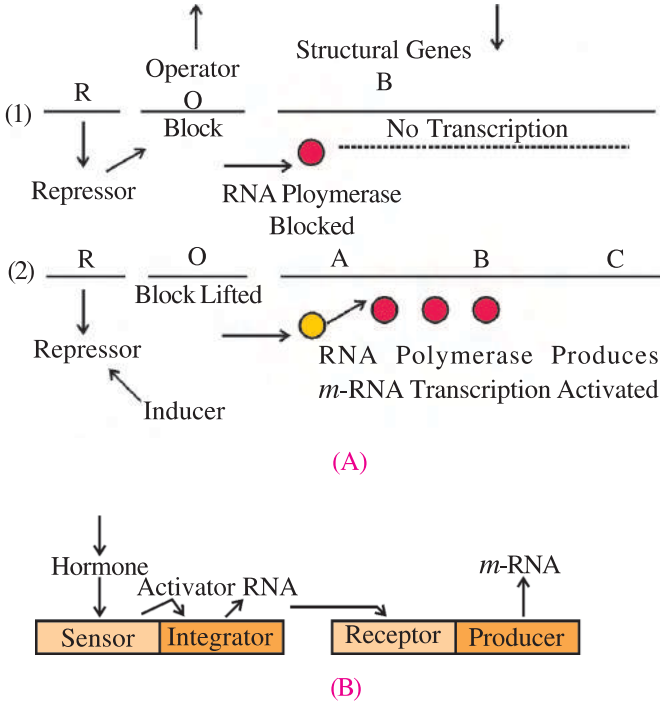


DNA

Regulation of Gene Expression

Different genes in an organism are meant for the synthesis of different proteins. All these proteins are not needed at the same time. Enzymes are needed at different times in the life cycle of an organism, for instance, the enzymes needed for seedling growth may not be needed in adults. Conversely the enzymes needed for flower development would not be needed at seedling stage. However, at all times in the life cycle, every cell contains the same set of genes. It would be necessary, therefore, to have a mechanism which would allow only the received genes to function at a particular time. The activity of other genes will have to be controlled at that time. Several mechanism have been suggested. The mechanism involved in this process is difficult to work out particularly in higher organisms. While in bacteria (prokaryotic cells) detailed information has been obtained regarding regulation of gene expression. Mechanisms in prokaryotes and eukaryotes differ due to their different levels of complexity of organisms.

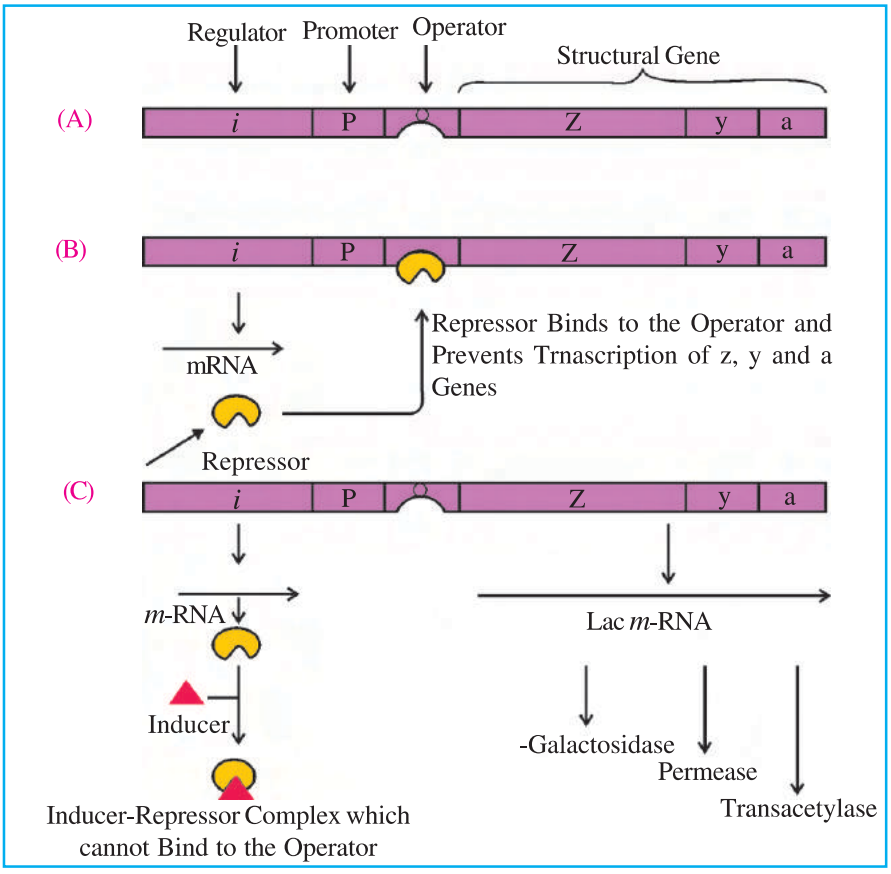
French scientists Jacob and Monad discovered a mechanism in E-coli bacteria and won the Nobel Prize for the same. They found that for an expression of a gene, there may be a few other genes are involved. The gene whose product is required may be expressed; such a gene is called a structural gene. The repressor gene can produce a product which will block operator gene so that the RNA polymerase will not form m-RNA. That means it prevents transcription of one or many structural genes. If an inducer which could be a substrate, precursor or a hormone, when provided will bind the repressor proteins and thus open up the operator gene. Now RNA polymerase gets bound to promotersite and starts transcription process to produce m-RNA.



Role of Hormone as an Inducer Substance

Jacob and Monad proposed that metabolic pathways are regulated as a unit. They studied the change in the nature of enzymes of E.Coli when provided with different kinds of sugars. They found that when sugar lactose is added to the cultures of E. coli, it induces three enzymes necessary to break down the lactose into golatose. These newly synthesized enzymes are (i) β-glycosidase (ii) permease and (iii) transacetylase. According to them, the synthesis of these three enzymes are controlled by a long DNA segment known as operon which is divisible into an operator site O and three structural genes *z*, *y* and *a*. The action of structural genes is regulated by operator site with the help of a repressor protein produced by the action of gene 'I' known as the regulator gene. The genes are expressed or not expressed depends on whether the operator switch is on or off. When the switch is on, the three genes are transcribed by RNA polymerase into *a* single

stretch of messenger RNA covering all the three genes. The switching on or off of the operator switch is achieved with the help of a protein known as repressor. When this protein ties together to the operator (O) and blocks it, the switch is turned off and the three genes (*z*, *y* and *a*) are not expressed.



(A) Structuire of Lac Operon (B) Repressed State of Lac Operon (C) Active State of Lac Operon

Thus an Operon consists of

Operon = Regulator gene + Promoter gene + Operator gene + structural gene.

The genes composing operon are classified into two categories :

(1) Structural gene : They are segments of DNA which carry codes for the synthesis of proteins.

(2) Control genes : These control the activity of structure genes either by induction or suppression. These genes are as follows :

(i) Regulator gene : The regulator gene produces some specific enzyme which RNA polymerase binds. It intially acts as a repressor substance.

(ii) Promoter gene : The promoter gene (P) is the DNA segment at which the transcription of the structure genes takes place. It controls the rate of m-RNA synthesis.

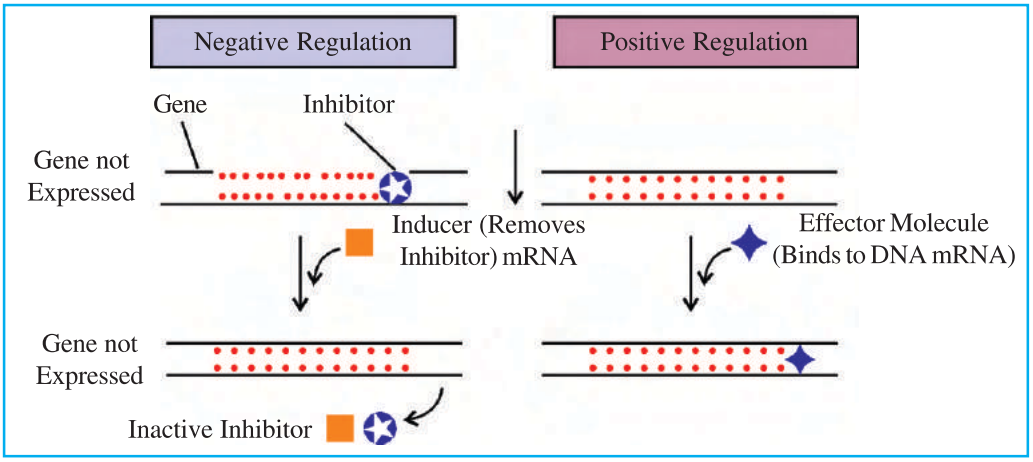
(iii) Operator gene : The operator gene (O) is the segment of DNA which exercises a control over transcription.

Negative and Positive Control

The regulator gene exercises a negative control on the functioning of lac operon, because the enzyme produced by the regulator gene switches off the activity of operon gene and the gene is not allowed to function till not required protein.

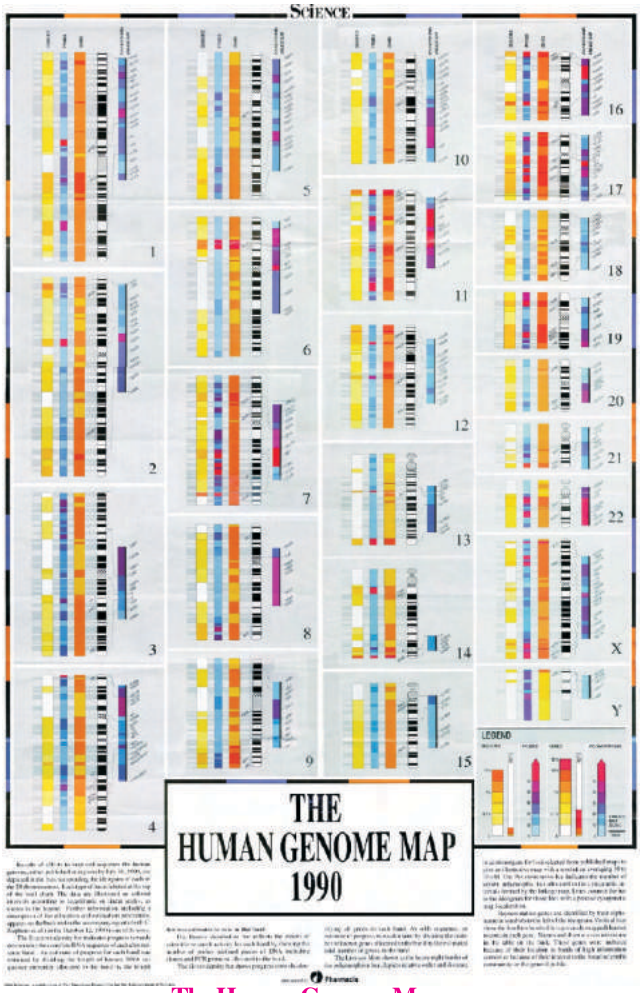
Certain substances exercise a positive control. These substances when added to the medium initiate the regulator gene to produce the stimulant which stimulates the production of enzyme by the operator gene.

Various scientists invented various aspects of molecular genetics. Structural and functional aspects of genes have also been identified. Now, they thought about how genes can be useful to mankind. As a result of it the human Genome project was founded in 1990. Let us see it in detail.



Human Genome Project (HGP)

The Human Genome Project (HGP) is an international scientific research project. The Primary goal of the project is of determining the sequence chemical base pairs which make up DNA, and identifying and mapping the approximately 20,000 - 25,000 genes of the human genome.



The Human Genome Map

In 1990, the Project was initiated by the joint efforts the of U.S. Department of Energy and the National Institute of Health. A working draft of the genome was announced in 2000. In February 2001, the analysis of the working draft was published.

Following set of goals were there:

- To prepare a "genetic map" of all genes in human beings in full detail.
- The information of nucleotide sequence of each gene and its mode of expression should be determined and stored.
- To store information in data bases and improve the projects tools for data analysis and transfer related technologies to the private sector.
- To understand social, ethical and legal complications related to the project and find out proper solutions for them.

In April 2003 the HGP sequencing was completed. The human genome contains 3 billion chemical nucleotide bases (A, C, T and G). The average gene consists of 3000 bases. The total number of genes is estimated at around 35,000 – lower then previous estimates of 80,000 to 1, 40,000. The deciphering of nucleotide sequence and its store is referred to as "data base ". It is a molecular database. While the objective of HGP is to understand the genetic makeup of the human species, the project has also focused on several other non human organisms such as E. coli, the fruit fly and the laboratory mouse. Scientists have found the following information.

Organism	Genome size	Estimated Genes
Human (*Homo sepians*)	>3 billion	30,000
Laboratory mouse (*M. musculus*)	2.6 billion	30,000
Fruit fly (*D. melanogaster*)	137 million	13,000
Bacterium (*E. coli*)	4.6 million	3200
Human immunodeficiency virus (HIV)	9700	9

Future Challenges of HGP

- Gene number, exact locations and functions
- Gene regulation
- DNA sequence organization
- Coordination of gene expression
- To understand disease susceptibility prediction based on gene sequence variation.

Application of Human Genome Project

(1) Molecular Medicine : It improves diagnosis of disease and is also used in gene therapy. Inprove understanding of several diseases like Alzheimers, Parkinsons disease, etc.

(2) Microbial Genomics : It rapidly detects and treats pathogens in clinical practice; develops new energy sources, and monitors environment to detect pollutants.

(3) Risk Assessment : It is used to evaluate the health risks faced by individuals who may be exposed to radiation and to cancer - causing chemicals and toxins.

(4) DNA Identification (Forensics) : It is used to identify potential suspects whose DNA may match the evidence left at crime scenes, to establish paternity and other family relationships.

(5) Agriculture, livestock breeding : It is used to develop biopesticides, incorporate edible vaccines incorporated into food products.

(6) The project's goal included not only identifying all the genes in the human genome, but also addressing the ethical, legal and social issues (ELSI).

Thus Human genomics will provide a healthy and disease-free life.

Salient features of Human Genome

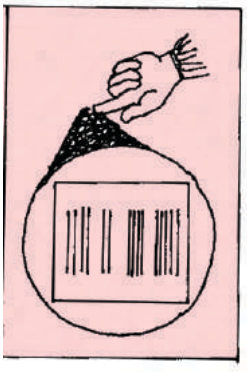
Some of the salient observations drawn from human genome project are as follows:

- The human genome contains 3 billion nucleotide bases.
- The average gene consists of 3000 bases.
- The total number of genes is estimated at 30,000. Almost all (99.9 per cent) nucleotide bases are exactly the same in all people.
- The functions are unknown for over 50 percent of the discovered genes.
- Less than 2 percent of the genome codes for proteins.
- Repeated sequences make up a very large portion of the human genome.
- Chromosome 1 has most genes (2968) and Y has the fewest (231).

It is expected that we will soon have snapshots of more than 1200 genes that are responsible for common cardiovascular aliments, endocrine diseases like diabetes, neurological disorders like Alzheimer's disease, cancer etc. The human genome sequencing not only holds promise for a healthier living, it also holds the prospects of a vast database of knowledge about designer drugs, genetically modified diets and finally, our genetic identity.

DNA Fingerprinting

Like the fingerprinting that came into use by detectives and police labs during the 1930s, due to its specification, each person has a unique DNA Fingerprint (see figure). Unlike a conventional fingerprint that occurs only on the fingertips, a DNA fingerprint is the same for every cell, tissue and organ of a person. DNA



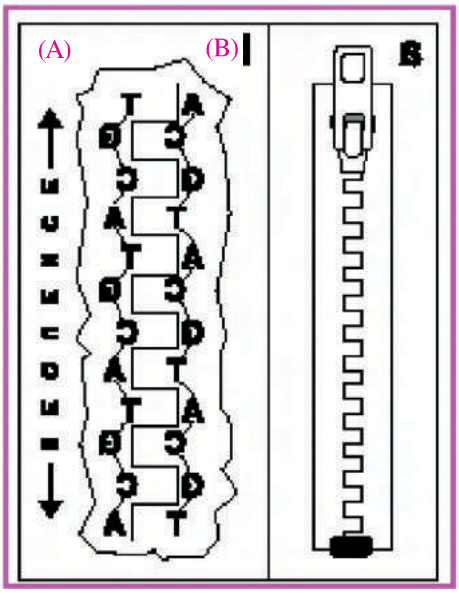
DNA Fingerprint

Two Types of Fingerprints

Conventional Fingerprint

fingerprint cannot be altered by any known treatment but fingerprint can be changed by surgery. Consequently, DNA fingerprinting is rapidly becoming the primary method for identifying and distinguishing individual human beings. An additional benefit of DNA fingerprint technology is the diagnosis of inherited disorders in adults, children and unborn babies. Even bloodstained clothing from Abraham Lincoln has been analyzed for evidence of a genetic disorder called Marfan's syndrome.

You have studied the detailed structure of DNA in semester I. The molecular structure of DNA can be imagined as a zipper with each tooth represented by one of four letters (A, C, G and T) and with opposite teeth forming one of two pairs, either AT or GC.



Zipper DNA

The information contained, in the DNA is the sequence of letters along the zipper. For example, the sequence ACGCT represents different information than the sequence AGTCC. In the same way that the word "POST" has a different meaning from "STOP" or "POTS" even though they use the same letters. Living organisms that look different and have different characteristics also have different DNA sequences. DNA fingerprint is a very quick way to compare the DNA sequences of any two living organisms.

There are 23 pairs of human chromosomes, with >3 billion genome size (bases). You known that not all segments of DNA code for proteins; some DNA segments have a regulatory function, while others are intervening sequences (introns), and still others are repeated DNA sequence. For DNA fingerprinting, short repetitive nucleotide sequences which are specific for a person are important. These nucleotide sequences are known as variable number tandem repeats (VNTR). It was initially developed by Aleojeffreys. He used a satellite DNA as probe that shows a very high degree of polymorphism.

Making DNA Fingerprints

As every cell contains DNA, extremely small amount of blood, semen, hair bulb or any other cell from the body of a person are sufficient to detect the individual. Thus it is a laboratory procedure that requires the following steps.

(1) Extraction of DNA from the sample cells.

(2) Restriction digestion DNA is cut into sections by using restriction endonucleases.

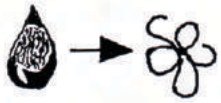
(3) Separation of DNA fragments by electrophoresis.

(4) The DNA band pattern is transferred to a nylon membrane or nitrocellulose.

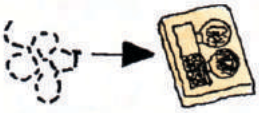
(5) A radioactive DNA probe is introduced. The DNA probe binds to specific DNA sequence on the nylon membrane. There after, any DNA not attached to the probes is washed off.

(6) The radioactive DNA pattern is transferred to X-ray film by direct exposure. When developed, the resultant reveals a unique pattern of dark and light bands.

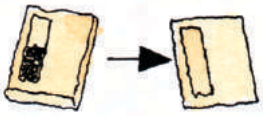
(1) The process begins with a blood or cell sample from which the DNA is extracted



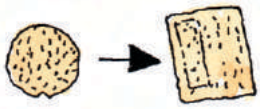
(2) The DNA is out into fragments using a restriction enzyme. The fragments are then separated into bands by electrophoresis through an agarose gel.



(3) The DNA band is transferred to a nylon membrane.

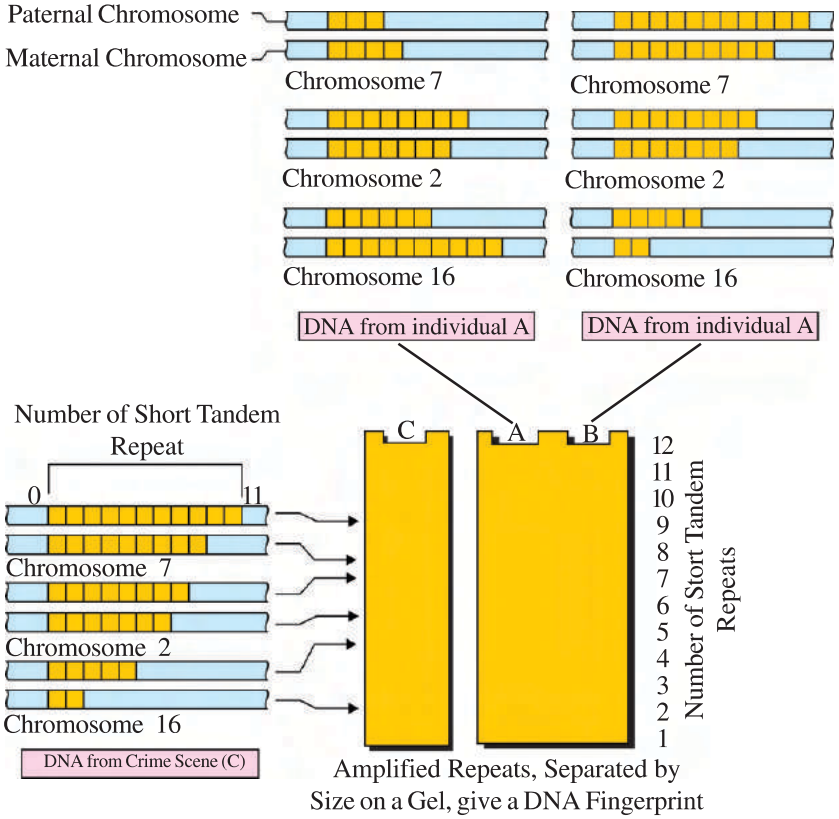


(4) A radioactive DNA probe are introduced. The DNA probe binds to specific DNA sequences on the nylon membrane.



(5) The excess probe materials is washed away leaving the unique DNA band pattern.

(6) The radioactive DNA pattern is transferred to X-ray film by direct exposure. When developed, the resultant visible pattern is the DNA finger print.



Application of DNA Fingerprints

DNA Fingerprints are useful in several areas of society. They are used by professionals in human health and justice system. It can be used to help identify individuals who may have carried out crimes such as rape, settling paternity disputes, deterring relationships in inherited diseases and monitoring bone marrow transplants. It is used to diagnose inherited disorders like cystic fibrosis, haemophilia, Huntington's disease, Alzheimer's, Sickle cell anaemia, thalassemia and many others.

SUMMARY

DNA is a genetic material (except plant viruses). The identification of DNA as the genetic material is based on Bacterial transformation experiment and biochemical evidence. Synthetic genes leave no doubt that genes are molecules. Gene is a segment of DNA which is actually a "factor" as per Mendelian theory. DNA is a long polymer and double helical structure of Deoxyribose and nucleotides covalently linked by 3',5'-phosphodiesster bonds. In a molecule of DNA A = T: G = C is there but = Varies with the organism. DNA can be copied and transmitted to progeny. It is done by DNA replication. Mechanism of DNA replication is done through proper enzymes.

Biosynthesis of protein as a unidirectional process is described as a central dogma by F.H. Crick. It is always initiated with amino acid Methionine arranged on m RNA as its whole process takes place through Transcription and Translation. Initiation, elongation and termination happen one by one. The information present in DNA transcribed by m RNA is called Genetic Code. They are triplet, universal and specific.

The Gene's expression is regulated by operon. It consists of structural gene and control gene like regulator gene, promoter gene, and operator gene. There is a negative and positive control.

The Human Genome Project (HGP) is an international scientific research project. Its primary goal was to determine the sequence of chemical base pairs which make up DNA. The human genome contains >3 billion chemical nucleotide bases. The HGP will be helpful in the fields of molecular medicine, microbial genomics, risk assessment, forensics etc.

DNA Fingerprint is the same for every cell, tissue and organ of a person. It cannot be altered. Blood, semen or hair bulb or any other cells are used to make DNA Fingerprints. It is useful for identifying human beings who may have carried out crimes and to diagnose inherited disorders. Thus, this technique is used by professionals in human health and justice system.

EXERCISE

1. Put dark colour in a given circle for the correct answer :

(1) The principal genetic material of living being is ..... .

(a) RNA ○ (b) DNA ○ (c) Both a and b ○ (d) None of above ○

(2) "Factor" word for heredity was first used by

(a) H. Khorana ○ (b) Griffith ○

(c) Watson and Crick ○ (d) Mendel ○

(3) Transcription means the synthesis of

(a) DNA ◯ (b) RNA ◯ (c) Proteins ◯ (d) Lipids ◯

(4) Genetic code means

(a) Singlet code ◯ (b) Doublet Code ◯

(c) Triplet code ◯ (d) None of the above ◯

(5) RNA is genetic material in

(a) Bacteria ◯ (b) Plant Viruses ◯

(c) Fungi ◯ (d) None of the above ◯

(6) Griffith's experiment was with

(a) Virus ◯ (b) Escherichia coli ◯

(c) Pneumococcus ◯ (d) Rhizobium ◯

(7) TMV contains a genetic material

(a) DNA ◯ (b) RNA ◯

(c) DNA and RNA ◯ (d) Chromosome ◯

(8) Duplication of DNA is called

(a) Transduction ◯ (b) Translation ◯

(c) Replication ◯ (d) Chromosome ◯

(9) Gene is a .....

(a) A segment of DNA ◯ (b) One nucleotide ◯

(c) DNA and RNA both ◯ (d) Protein synthesis ◯

(10) In operon model, regulator gene functions as

(a) Repressor ◯ (b) Regulator ◯

(c) Inhibitor ◯ (d) All of the above ◯

(11) Nucleic acids occur in

(a) Viruses ◯ (b) Bacteria ◯ (c) Mammals ◯ (d) All of the above ◯

(12) Transfer of information from DNA to RNA is called

(a) Transcription ◯ (b) Translation ◯

(c) Transduction ◯ (d) Migration ◯

(13) Who supported Griffith experiment by molecular explanation

(a) Watson and Crick ◯

(b) M. Nirenberg and M. Khorana ◯

(c) Miescher and Fleming ◯

(d) Avery, Mc Carty and MacLeod ◯

(14) Gene Controls

(a) Heredity but not protein synthesis. ○

(b) Biochemical reaction of some enzymes. ○

(c) Protein Synthesis and heredity ○

(d) Protein Synthesis but not heredity ○

(15) Protein Synthesis takes place on the surface of

(a) DNA ○ (b) Mitochondria ○ (c) Nucleus ○ (d) Ribosomes ○

(16) Anticodon is associated with

(a) t-RNA ○ (b) *r*-RNA ○ (c) m-RNA ○ (d) DNA ○

2. Answer the following questions in short :

(1) What is genetic code ?

(2) What is gene mutation ?

(3) How is protein synthesis initiated in a cell ?

(4) Why is genetic code a triplet one ?

(5) What are the functions of m-RNA ?

(6) What is the role of t-RNA in a cell ?

(7) What anticodons will be required to recognize the following codons:

(i) UAU (ii) GCA (iii) AAU

(8) If the sequence of one strand of DNA is written as follows.

ATG CAT GCA TGC ATG. Write down the sequence of its complementary strand.

(9) Why is the Human Genome project called a mega project ?

(10) Explain (in one or two lines) the function of the following :

(i) m-RNA (ii) promoter (ii) t–RNA

3. Write a Short Note on :

(1) Transcription

(2) Central dogma

(3) Genetic code

(4) Application of DNA fingerprinting

(5) Initiation of protein synthesis

4. Answer the following questions in detail :

(1) Genetic material is DNA and not protein. How did Griffith prove this experiment ?

(2) Explain : Biochemical evidences for DNA as a genetic material.

(3) Sketch and label only : A double helical DNA molecule.

(4) Which are the properties of genetic material (DNA versus RNA).

(5) Discuss the mechanism of DNA replication.

(6) Explain briefly the steps of protein synthesis.

(7) Describe the transcription of RNA from DNA.

(8) Discuss the characteristics of genetic code.

(9) Write the structure of DNA molecule.

(10) Explain the operon concept.

(11) How is gene expressed in prokaryotes ?

(12) Give application of human genome project.

(13) Which are the future challenges of Human Genome Project ?

(14) Give salient features of human genome project.

(15) What is DNA fingerprinting ? How it is useful to mankind ?

(16) How is DNA fingerprinting done ?

10

Evolution

Through the previous study you are awared that all living organisms try to adopt their habitat or nature. With respect to it they change their structure and functions also. Body organisation changes as per requirement. Due to these reasons from earlier simple organisms, through a very long period, evolved into complex forms. Due to such changes, new species develop which can not met with original species. It is known as 'speciation', which becomes course of evolution. Hence Herbert stated that, evolution is the development of more complex forms of life from simpler and earlier forms. Thus evolation is a structural change and is a study of history of life forms on the earth.

Origin of Life

Living systems are mixtures of very large and complex molecules functioning together in a co-ordinated way. Life may be defined as a dynamic physico-chemical functional system, which contains the genetic material (DNA or RNA) and exhibits the attributes of metabolism, development, growth, adaptation, irritability and reproduction.

Origin of life or protobiogenesis means, the origin of first life from non-livings on the earth about 3000 million years ago. The first life did show the attributes of replication, nutrition, adaptation and biosynthesis. Organic evolution has taken place since the formation of first life on earth.

Many theories and speculations are advocated by scientists and philosophers regarding the origin of life on the earth. Different religious have also advocated different ideas regarding the origin of life viz. Abiogenesis, Biogenesis, Meteority theory, Theory of catatrapism, Theory of special creation and Biochemical origin of life.

(1) Abiogenesis : This theory was believed that the formatian of life was from non-living substances. This belief was remained up to 17^{th} centuary. According to abiogenesis, different living organisms are evolved from mud, soil, meat, organic manure.

(2) Biogenesis : F. Reddy had proposed this principle in 17^{th} centuary. According to him biogenesis means formation of new life from pre existing organisms through reproduction.

(3) Meteority Theory : This theory believed in cosmozoa, as per it for life formation cosmos came from other planets and on gettng favourable canditions they developed into organisms.

(4) Theory of Eternity : As per this theory life was there when abiotic components were also present on earth in its earlier stage. This theory was not accepted by any one.

(5) Theory of Catatrophism : Qvier proposed this theory. He thought that the universe has been subjected to catatrophes or sudden revolution at different intervals.

(6) Theory of Special Creation : There were no evidences for this theory. However, Christian Saurez believed that all elements were created within six days.

(7) Theory of Organic Evolution : As per this theory, the world has been evolved and not been created. Non living substances have reacted to form organic compounds which developed into colloidal systems. Simple life was developed from them..

Oparin–Haldane Hypothesis

Modern biologists strongly believe that life is originated in the remote past from interaction of chemical substances. It was formulated by Haeckel, on this basis theory was developed by Oparin and Haldane. This theory suggests that life is originated from simple inorganic substances. These substances might be transformed into a colloidal system to produce life. The various stages in the process of origin of life are as follows :

(A) CHEMICAL EVOLUTION

(1) Origin of Earth : It is now scientifically established that the earth was formed from the sun some 5000 millions years ago. The earth as a piece, was fragmented from the sun which gradually moved away from the sun. When it was fragmented from the sun, it was a glowing fire containing a molten mass of gases and vapours of various elements. The temperature was very high about 5000 ^{o}C to 6000 ^{o}C. As the earth was moving away from the sun, it was getting cooled. This led to the condensation of gases. The heavy elements like iron, nickel etc. occupied the core of the earth where as the lightest elements like helium, hydrogen, oxygen, nitrogen, carbon etc. occupied the atmosphere of the earth. Life originted only from these elements. The chemical changes leading to the formation of life is called chemical evolution or molecular evolution of origin of life.

(2) Formation of Water, Ammonia and Methane : The primitive earth contained a large amount of hydrogen, nitrogen, carbon and oxygen. Of these, hydrogen was very active. It combined with nitrogen to form ammonia (NH_3), with oxygen to form water (H_2O); and with carbon to form methane (CH_4). As the temperature of the earth was high, ammonia and methane remained as gases and water as superheated steams.

$$N_2 + 3H_2 \rightarrow 2NH_3$$
$$C + 2H_2 \rightarrow CH_4$$
$$\frac{1}{2} O_2 + H_2 \rightarrow H_2O$$

As years passed, the temperature of the earth came down. Steam condensed into water and resulted in rain. Since the earth was very hot, the rain drops were evaporated immediately on reaching the surface of the earth. As this process was repeated for millions of years, the surface of the earth became cooled. Water gradually accumulated and this led to the formation of rivers, streams, lakes, seas and oceans. Compounds like ammonia, methane etc. were dissolved in rain water and were accumuleted in the sea. Minearal rocks also dissolved leading to the accumulation of minerals and salts in sea water. Thus the first chemicals formed on the earth were water, ammonia and methane.

(3) Formation of Micromolecule : The next step in molecular evolution was the formation of micromolecules. Amino acids, fatty acids, monosaccharides, purine, pyrimidines, adanosine monophosphate (AMP) and adenosine diphosphate (ADP) appeared as colloidal droplets in the sea. These were distinct

bodies, which did not mix with the surrounding sea water. They were contents of proteins, nucleo-proteins and other organic and inorganic molecules in various ratio. The surface layer of the droplet had the ability for selective absorption of substances from the medium.

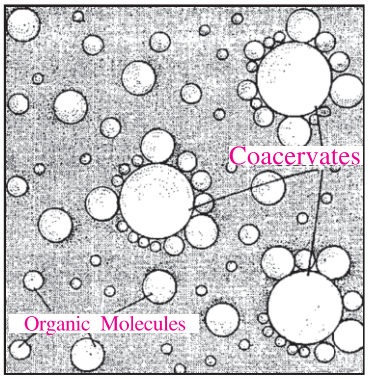
(4) Formation of Macromolecules : The next step was the formation of macromolecules. When the micromolecules were formed, they combined in various ways to form large molecules called macromolcules. They consisted of proteins, lipids, polysaccharides, nucleic acids, nucleoproteins etc. The combination of smaller molecules into macromolecules is called polymerization.

(5) Formation of Nucleic Acids : In the formation of nucleic acids, first of all, nucleotides were formed. The nucleotides included purine or pyrimidine, sugar and phosphate. Number of nucleotides were linked together in different combinations to produce nucleic acids.

(6) Formation of Nucleoproteins : The nucleic acids and proteins combined together to form nucleoproteins which are very important macromolecules to create a life.

(B) BIOLOGICAL EVOLUTION

(1) Formation of Coacervates : When macromolecules were formed they undergo aggregation and precipitation in the sea. Which led to the formation of organised structures called coacervates. The coacervates were distinct bodies, which did not mix with the surrounding sea-water. They contained proteins, nucleoproteins and other organic and inorganic molecules in various rations. The surface layer of the coacervates had the ability for selective absorption of substances from the medium. Oparin considered the coacervates as the sole living molecules which gave rise to cells.



Coacervates

(2) Formation of Precells or Protocells : The protocells were spherical in shape and a double-layered membrane was present around them. They exhibited reproduction by binary fission. The protocells were heterotrophs; they obtained the energy formed by the fermentation of organic substances which were dissolved in the sea. Thus the protocells were anerobic

(3) Formation of precells to Cells : When DNA-RNA system developed within protocells, they looked like a bacteria or virus. The DNA acquired the ability for self-duplication and protein synthesis. Thus life originated after a long process of molecular evolution. The protocells in course of time differentiated into cells.

Cells
↑
Precells or protocells
↑
Coacervates
↑
Macromolecules
↑
Micromolecules
↑
H_2O, H_2, NH_3, CH_4
↑
C, H, N, O
↑
Primitive Earth

Main Stages in the Origin of Life

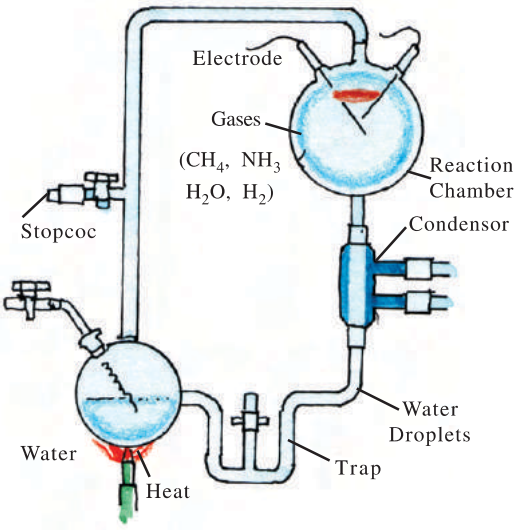
Experimental Evidences for Molecular Evolution of Life

The molecular evolution of life is supported by a number of laboratory experiments performed by different scientists.

Urey and Miller's Experimeut

The origin of life by molecular evolution was first proposed by Oparin and Haldane. Their views and ideas remained without any experimental evidence until 1953. In 1953 Urey and his student Miller devised an experiment to give direct evidences of molecular evolution.

Urey and Miller in their experiment created a condition which was similar of that of the primitive earth. In their experiment they boiled water to produce steam. The steam was allowed to mix with vapours of ammonia, methane and hydrogen in a reaction chamber. The mixture was treated with an electric shock by electrodes, mixture was then coolled in a condensor and liquified, then liquid was collected in another flask. After two weeks of treatment the liquid was analysed by chromatography. The liquid contained simple organic compounds such as amino acids, hydroxy acids and alophatic acid. Miller stated that amino acids would have been produced on the primitive earth under the influence of ultra violet light and lightening.



Urey and Miller's Experiment

Stages of Evolution of Life Forms

As per requirement organells were formed after protocells. Prokaryotic cells and eukaryotic cells developed. After it how different division / phyla of plant kingdom and animal kingdom were developed, that you have studied in detail in Semester-I. In plant kingdom the way of evolution was thallophytes – bryophytes pteridophytes – seed contained plants. In animal kingdom protista group with well developed nucleus was developed first. After it animals developed which were multicellular but without tissue. Organs and appendages were developed and at the end cronologically vertebrates life was existed. First marine vertebrates were created. After long period when earth crust was dried, amphibians and reptiles were existed. From reptiles two groups were formed : Aves and mammals. Apes and man are animals of class mammalia. Let us see their evidences whether it happened or not ?

EVIDENCES FOR EVOLUTION

As evolution is incredible and an unimaginar slow process, the evolutionary process cannot be seen by man during his short life span. Hence, evolution can be understood only by a comparative study between the living and the extinct animals and plants. So it is inevitable to give convincing evidences to understand evolution. To prove that organic evolution did take place since the origin of life, concrete evidences came out from the following sources.

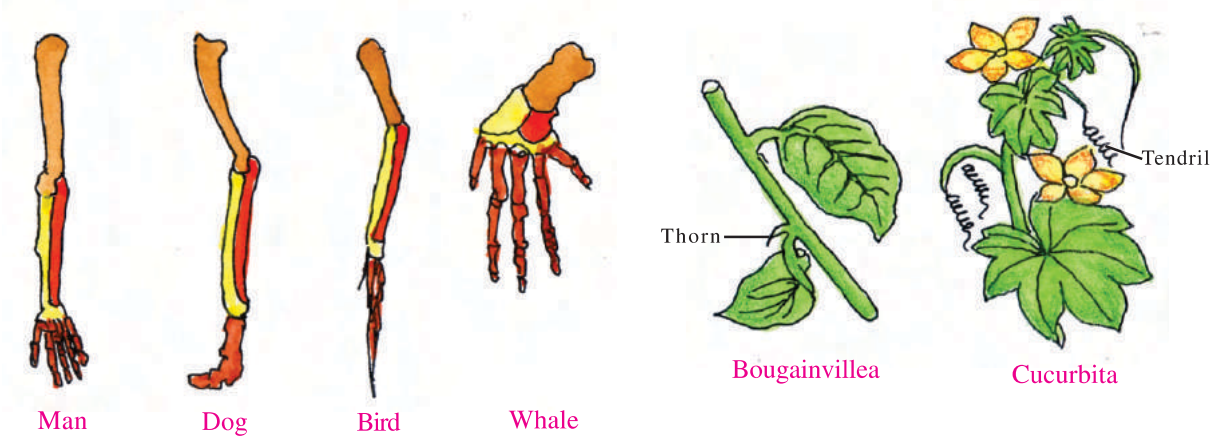
(1) Morphology (2) Embryology (3) Physiology (4) Palaeontology

(1) Morphology : Morphology refers to the external structures and anatomy refers to the internal structures. These structures provide simple evidences of evolution. The sources of evidences of evolution from morphology and comparative anatomy are the following :

(i) Homologous Organs : The organs which are similar in their morphology, anatomy, and embryology but dissimilar in their functions are called homologous organs. The relationship between homologous organs is called homology.

Example : • The forelimbs of higher vertebrates (man, dog, bird, whale)

• The thorn and tendrils of Bougainvillea 87and cucurbita.



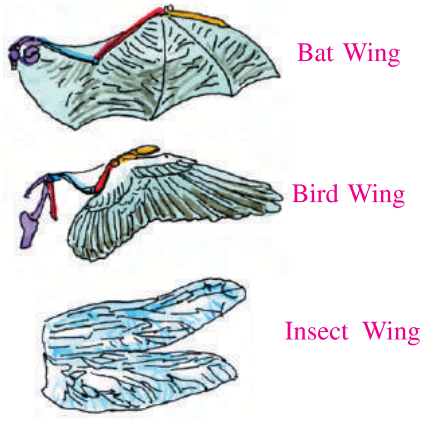
Homologous Organs

(ii) Analogous Organs : The organs which are superficially similar but anatomically dissimilar doing similar functions are called analogous organs.

"Similarity of structures connected with similarity of function is termed analogy."

Example : • Wings of insects, birds and bats

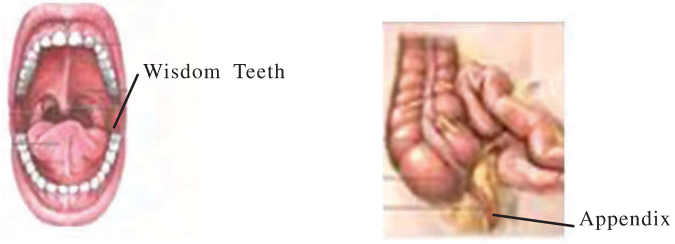
• Fins of fishes and whales.



Analogous Organs

(iii) Vestigial Organs : Vestigial organs are the useless and functionless degenerate structures which were functional in some other animals or in ancestors.

Example : Vermiform Appendix, Nictitating membrane, Ear muscles, Wisdom Teeth



Vestigial Organs

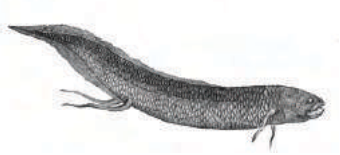
(iv) Connecting Links : The animals exhibiting characters of two adjacent taxonomic groups are called connecting links.

Example : • Peripatus : Connecting link between annelida and Arthropoda

- Balanoglossus : Connecting link between invertebrates and chordates
- Lung Fish : Connecting link between fishes and amphibians.
- Archeopterix : Connecting link between Reptile and Aves.

Peripatus

Balanoglossus



Lung Fish

Archeopterix

Morhological Evidence Connecting Links

(2) Embryology : The early embryos of all vertebrates are very similar in their appearance. This will be very clear when embryos of a fish, an amphibian, a reptile, an opposum, a monkey and a man are arranged side by side.

(3) Physiological Evidence : The studies on physiology and biochemistry prove that the process of evolution has occured biochemically. The protoplasm which is the basic unit of life has the same quantitative and qualitative attributes in cell of living organism.

(4) Palaeontological Evidence : The direct evidences of the process of evolution can be obtained by comparing fossils of the organisms that lived in the past with the organisms living today. The fossils are the written documents of evolution.

Eg. : Available fossils of Mesozoic era of different dinasaurs were large sized Lizards, that can be prove.

Fossil

Adaptive Radiation

Organisms depend on the environment for their survival. Environmental factors are not stable. They are changing from time to time and place to place. Hence organisms also adjust themselves to the changes of the environment in which they live. This adjustment of the organisms to their environment is called adaptation. When organisms of the same group occupy different environments or habitats, they

develop different kinds of adaptations. Hence organisms of the same group show different adaptation in different habitats and this is called adaptive radiation. The law of adaptive radiation was proposed by Osborn. Adaptive radiation is nothing but divergence or divergent evolution. It is caused by following.

(i) Need for food (ii) Need for safety (iii) Need for better breeding grounds (iv) Migration to a new habitat (v) Absence of enemies (vi) Isolation etc.

Adaptive radiation is broadly classified into three types :

(1) Local adaptive branching (2) Continental adaptive radiation (3) Contemporaneous radiation

(1) Local Adaptive Branching : It refers to the development of diversification in a largely distributed population.

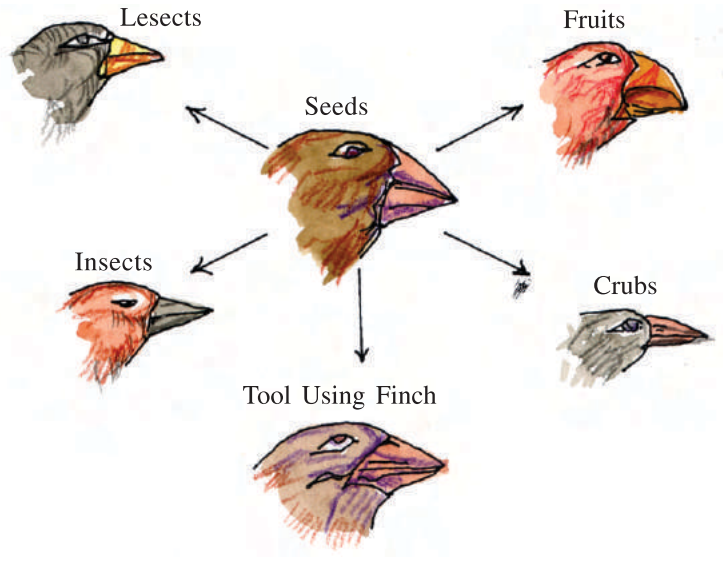
Example : In Africa, two distinct types of Rhinoceros are found. One is grazing which lives in open land areas and second is a browsing type with lives in wooded areas.

(2) Continental Adaptive Radiation : It refers to the evolutionary lines occurring in organisms of particular classes living in a continent.

Example : Australian marsupials, Each marsupials differs from other.

(3) Contemporaneous Radiation : It refers to the adaptive radiations in the great zoo-geographic division of the world.

Darwin during his journey went to Galapagos islands. There he observed diversity in small black birds (finche), later this bird is known as Darwin finches. He observed that there were many varieties of finches in the same island. He conjectured that the varieties, evolved on the island itself. In the original seed-eating features modification in the beak of finch according to habitat and availibity of food is found.



Darwin Finches

Biological Evolution

We have seen earlier that sequencial evolution of an organism is a result of adaptation as per the requirement. With respect to this different theories were proposed. Its abstracts are as follows.

Lamarkism

Lamarkism is also referred as "Inheritance of acquired characters". The main aspects of the principle were as under :

- Organisms and their organs are constantly increasing in size.
- Development of organs is induced and maintained under environmental pressure.
- Those organs which are constantly used they also develop constantly. Unused organs become defunct gradually or degenerate.
- Those characters which organism acquires in this way are inherited to their offsprings. Thus, the development of a character increases or decreases generation to generation.

Drawbacks of Lamarkism

- The first point is true in some cases and false in some others. In cases of horse and elephant it is true. But in case of flowering plants it is not true. Herbs and shrubs are smaller in size and trees are tall, though they are more primitive.
- The second point is also not true. As an example : The neck of an Giraffe cannot be made longer as per its wish. Moreover, organs cannot be moulded as per organism's wish.
- The third point appears partially true. Muscles can be developed by constant use. Loss of limbs, due to disuse in snakes or weak eyesight in cave-dwellers can be quoted as other examples. But eyes of a voraceous reader do not become larger or brighter. The heart which beats throughout life does not become bigger.

It is also difficult to accept that acquired characters get inherited.

Hence, Lamarckism is not accepted.

Darwinism

The theory of 'Natural Selection' proposed by Darwin is the prime one to explain evolution of living world. It was proposed in 1859 in his book titled 'Origin of Species by Means of Natural Selection'. He believed that all present-day lifeforms are modified forms of organisms which lived in the past. New species originate only from a pre-existing one. Darwinism is based on the following main aspects.

Large Population

The reproductive rate in all organism is high, if all the offsprings survive the population growth will be unimaginable. All organisms of a species have specific requirements for living. If all organisms reproduce and produce a large number of offsprings the world will be flooded by them. This does not happen. The population of all species, generally remains the same from generation to generation. Diseases, lack of food and other natural factors are responsible for this.

Struggle for Existence or for Survival

If materials required and other conditions neccessary for survival are not proper, organisms can not live. The natural resources required for life are available in a limited amount. Any habitat can sunstain only a specific number of organisms of some particular species.

If the resources are limited and the number of organisms dependent on them is unlimited, it is obvious that all organisms can not get sufficient resources. Thus, a competition for resources amongst organisms of one species becomes inevitable. Such competition can also be with organisms of another species, if their requirements are identical. Thus organisms have to compete for survival, growth and reproduction.

Natural Selection or Survival of the Fittest

It is quite obvious that when organisms compete for specific resource, some may get it and others may not get it or may not get in enough quantity. Some may fail or success which depends on the nature. Those who succeed will live longer and reproduce. Thus, their hereditary characters will survive in the next generation.

Variations

All individuals of a species are not alike. These differences in characters amongst individuals of a species are called variations.

Organisms live a life adopted to their environment. Those organisms which can use their environment in the best way, succeed and those who cannot do so, fail. Those variations which are suited to their environment, survive and succeed. This is called survival of the fittest.

Thus natural selection operates on variations from generation to generation. Nature is always changing, hence, the effects of natural selection on variations also keep changing. In due course of time, the degree of variations increases so much that the organisms become totally isolated from their parents and constitute a new species.

Limitations of Darwinism

The greatest drawback of Darwinism is that it does not explain the origin of variations, if characters are hereditary, for which genes are responsible. If we can explain the mechanism of inheritance, we can explain the variations in offsprings and their conservation over generations.

De Vries Theory

De Vries theory is also called 'Theory of mutation'. The main points of his belief are as under :

- New characters, i.e. new variations in characters, appear spontaneously. Such a sudden variation is called mutation.
- Once formed, a mutation becomes permanent. This would mean that it will appear constantly once it is formed.

- Mutation occurs simultaneously in a large number of organisms. This occurs frequently. Thus, chances of natural selection improve.
- Mutation does not occur in a specific direction. Mutation creates many variations. Thus one or another character changes. The character may either develop or may disappear.

De Vries does not accept Darwin's theory of a gradual increase or decrease in variation. Thus he does not believe that evolution is a gradual process.

Modern Concept of Evolution

It is the result of important work done by many workers in the last few dacades. As a result, it was realized that mutations and natural selection both are important for biological evolution. It was also realized that there are other factors which were not considered by Darwin and Hugo de vries in their theories, but they are significant in guiding the direction of evolution of the subject. The incompleteness of Darwin's theory and Hugo de vries's theory was mainly due to ignorance. According to the modern concept, there are five basic factors involved in the process of biological evolution. These are : (i) Gene mutations (ii) Changes in chromosome structure and number (iii) Genetic recombination (iv) Natural selection and (v) Reproductive isolation. Above first three factors are responsible for genetic variation and last two are responsible for giving direction to the evolutionary processes.

Besides the five factors outlined above, there are two accessory processes, migration of individuals from one population to another and hybridization between races, species and related general, are responsible for biological evolution.

These processes increase the genetic variation in the population.

Some important worker like Dobzhansky, R.A.Fisher, J.B.S. Haldane, Sewall Wright, Mayr and G.L. Stebbins gave their contribution to the modern synthetic theory.

Mechanism of Evolution

Diffrent opinions arise for how variation originated and how speciation occurs. Mendel states about inheritance. Darwin was not aware. Hugo de Vries worked on evening primrose and gave idea of mutations. According to him large difference arising suddenly in a population is called mutation. He believed that mutation is the cause of evolution. Mutation is random and undirectional. Thus natural selection, adaptation to habitat, and mutation are the major and sequencial factors for mechanism of evolution.

Hardy-Weinberg Law

Hardy-Weinberg law was proposed in 1908 by the independent contributions of two scientists, namely Hardy of England and Weinberg of Germany. Their contribution to evolution is immense. They laid the foundation for the development of population genetics. A clear understanding of Hardy-Weinberg law gains through knowledge of gene pool and gene frequency.

Gene Pool

Gene pool is defined as "the sum total of genes present in a mendelian population" or "A gene pool comprises diveres form of a gene combination and recombination by the process of sexual reproduction".

Gene Frequency

The ratio of a gene in a gene pool or in a populaition is called gene frequency.

When the gene frequency of one allele is known, the freqnency of other allele in the population can be calculated by applying a simple formula. If the gene frequeney of M-allele is p and that of m-allele is q. Then $p + q = 1$. When q is known, p can be calculated, $p = 1 - q$; similarly, when p is known q can be calculated; $q = 1 - p$; For example p is 0.6. Then $q = 1 - p = 1 - 0.6 = 0.4$.

Practical Application of the Law

This formula can be applied to any population to findout the frequency of genes. Let us apply this formula to a hamster population containing equal number of M and m genes.

The frequency of M gene in the population is = 50% = $\frac{1}{2}$

So, $p = \frac{1}{2} = 0.5$

The frequency of m gene in the population is = 50% = $\frac{1}{2}$

So, $q = \frac{1}{2} = 0.5$

$(p + q)^2 = p^2 + 2pq + q^2$

$= (0.5)^2 + 2\ (0.5)(0.5) + (0.5)^2$

$= 0.25 + 0.5 + 0.25$

= 25% MM : 50% Mm : 25% mm

The natural population will not contain the equal numbers always. Most of the populations have different proportions of genes. The above formula can be applied to any population containing any proportions of genes. When the proportion of genes in a population is known, the proportions of the offspring and genotypes can be easily calculated by applying Hardy-Weinberg formula. Let us take a hamster population containing 90%M genes and 10% m genes.

The frequency of M gene p = 90% = 0.9

The frequency of m gene q = 10% = 0.1

$(p + q)^2 = p^2 + 2pq + q^2$

$= (0.9)^2 + 2\ (0.9)\ (0.1) + (0.1)^2$

$= 0.81 + 0.18 + 0.01$

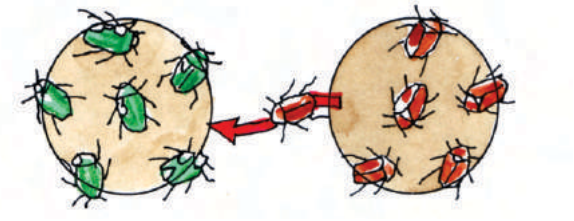
= 81% MM : 18% Mm : 1% mm

Significance

- This law states that the gene frequencies in a large population, remain constant generation after generation when there is no selection and mutation. In small population this equilibrium cannot be maintained.
- When the population is in equilibrium there is no possibility for evolutionary change and hence the rate of evolution is zero. Evolution occurs only when this equilibrium is upset.

Gene Flow

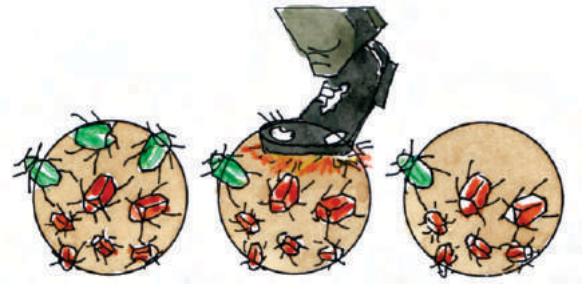
Animals are not static. They have the tendency to migrate. When an animal migrate and comes in contact with another population, it mates with the inmate of the population. Thus the genes of one population are transferred into another population. This is called gene flow. If genes are carried to a population, where these genes previously did not exist, this event of gene flow can be very important source of genetic variation.



Gene Flow

Genetic Drift

Genetic drift is an evolutionary force operating in small population. This matter was discribed by Seth Wright in 1931. Hence it is called Seth Wright effect. According to Hardy-Weinberg law in a large population the gene frequency remains constant from generation to generation when there is no selection and mutation. But in small population, the gene frequencies are found to fluctuate purely by chance. This change in the frequency of gene purely by chance is called genetic drift. The effect of genetic drift is in significant in large population. But in small population it has a significant effect. As a result of this, in small population, some gene may be reduced in frequency or even lost by chance and other may be increased in frequency by chance.



Genetic Drift

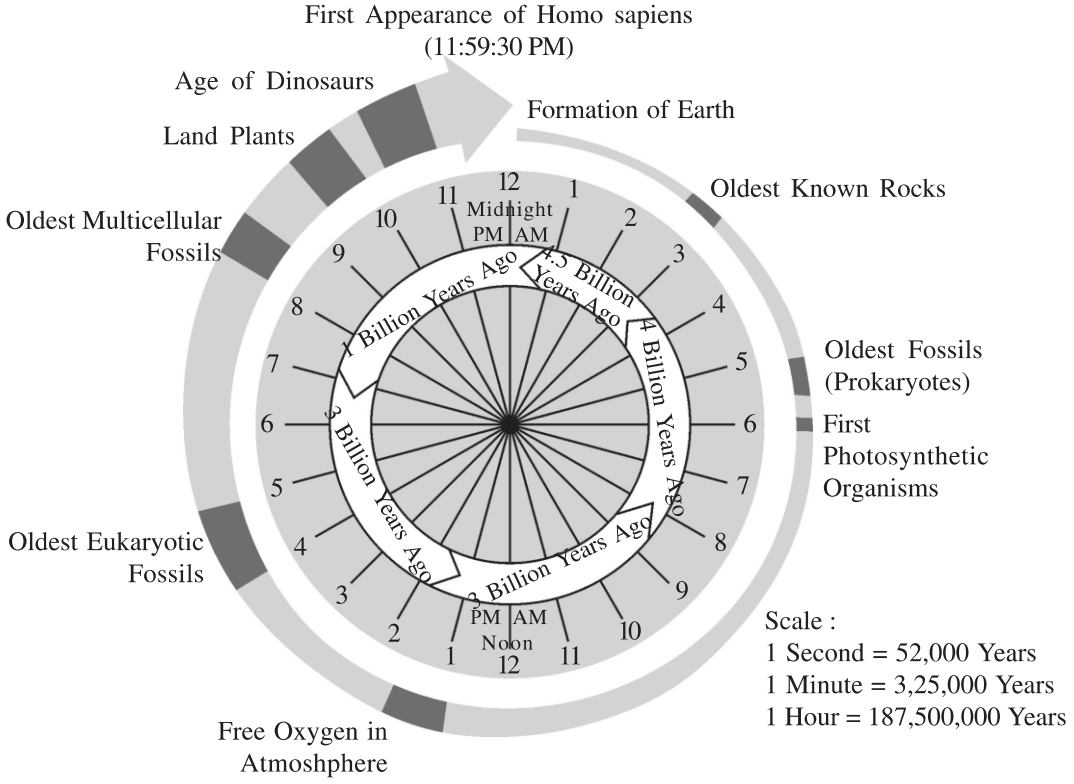
Brief account of Evolution

Earth originted about 5000 million yeare ago. Fossils record shows that the oldest fossil so far collected belongs to animal which lived 1000 million years ago. It is estimated that life should have originated about 3000 million years ago.

Compared to the age of earth and life, our age is very brief. To understand how brief it is, it is essential to know the age of major groups of animals. Life in the form of cell, originated about 3000 millions years ago; some of these cells had the ability to release O_2. The process is similar to the light reaction of photosynthesis. Slowly single-celled organisms were transformed into multi-cellular lifeforms. About 500 million years ago invertebrates were originated. Sea weeds and few plants existed probably around 320 million years ago. They were widespread on land when animals invaded onland. The period of origin of other animals are shown in the following table :

Taxa	Origin (Million years ago)
Fishes	360
Amphibians	325
Reptiles	250
Mammals	165
First Man	2

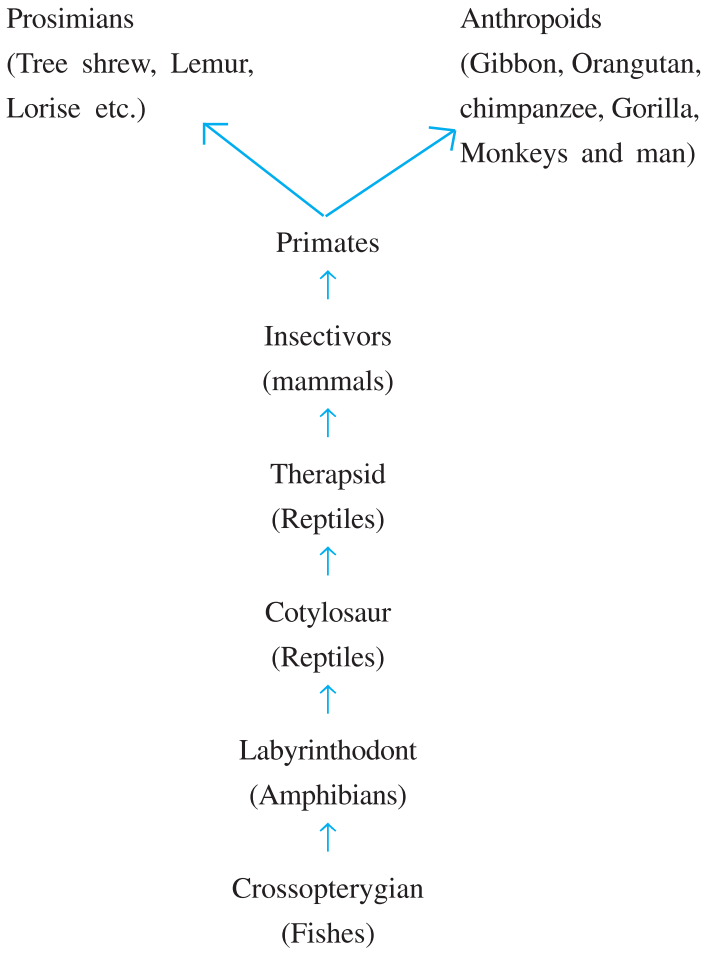
The account of biological evolution and age of different animals will be still more clear if the time of the origin of life is compared to a 12 hours scale. If it is imagine that life originated at 12.00 midnight, then fishes appered at 8.00 p.m. amphibians at 8.30 p.m., reptiles appeared at 9.00 p.m., mammals appeared at 10.00 p.m. and man appeared at ll.59 p.m. The illustration already shows that man came into existence in this world only a few seconds ago when compared to the age of other animals.



Geological Clock

Origin and Evolation of Man

Like other animals man exhibits peculiar the origin and evolutionary patterns. To get a clear view of the ancestry of man, it is necessary to look into the root of the evolutionary tree of vertebrates. It is a surprise to know that about 480 million years ago our distant ancestors of our order lived in fresh water ponds in the form of crossopterygian fishes. The other ancestors in the path of primates evolution are as under.



Human Evolutionary Trends

Like other animals, human evolution exhibits directional progressive changes, which are summarised below :

- The change of arboreal life into terrestrial life is the most important evolutionary trend.
- Loss of opposable toes from hind limbs.
- Development of erect posture.
- Development of bipedal locomotion.
- The development of chin
- Increase in the size of brain.
- Development of intelligence.
- Disappearance of simian shelf.
- Use of fore limbs for non-locomotory purposes, etc.

Fossil Record of Man's Evolution

The gradual evolution of man from ape is fully supported by available fossils. A sufficient number of fossils of apes, man-like apes (ape-men) and primitive-men obtained which helps to construct the evolutionary tree of man.

(1) Propliopithecus : It was an ape-like primate. But in the possession of short arms, it resembled man. It lived, about 30 million years ago.

(2) Aegyptopithecus : It is similar to propliopithecus; but it is more identical to apes than propliopithecus. It is believed that it was ancestral of the Dryopithecus. Another view did not support this.

(3) Dryopithecus : It is a group of apes that lived in Miocene period, about 20 million years ago. It decended from Aegyptopithecus or Propliopithecus. It's forelimbs were shorter than hindlimbs. In this respect, it is belived that it is the distant ancestor of man. It is also ancestor of modern apes like Chimpanzee and Gorilla.

(4) Oreopithecus : In the structure of teeth, in shortering of face and erect walking, it resembles to man, but having long forelimbs so it resembles to apes. **Straus** (1963) and **Simpson** (1963) suggest that man and Oreopithecus have parallel evolution, and hence it is not ancestral to man.

(5) Ramapithecus : It lived during late Miocene and early Pliocene. The fossil of it contains only jaws and dentition. The dentition is more identical to dentition of man. Fossils of Ramapithecus was collected from India and Africa. It lived 12 to 14 million years ago.

(6) Kenyapithecus : It is closely related to Ramapithecus. Its fossil is collected from East Africa.

(7) Australopithecus : It was an ape-man because it exhibited many characters of ape and man. It is considered as the connecting link between ape and man. It was 2 to 5 million years old. The characters of Australopithecus like man and ape are as below :

Man like Characters

- Erect posture.
- Bipedal locomotion.
- Dentition is like that of man.

Ape like Characters

Australopithecus

- The teeth were larger than modern man.
- Absence of chin.
- The eye-brow ridges projected over the eyes.

(8) *Homo erectus* : It is erect ape-man. They are commonly called Java man because their fossils were collected from Java. Other fossils were collected from Peking in china so, it was commonly called peking man. The java man and peking man are similar. They lived about 5,00,000 years ago. They were the first true men. *Homo erectus* form a connecting link between Australopithecus and *Homo sapiens* (Mordern man). The main characters of *Homo erectus* are as under.

- They had upright bipedal locomotion.
- They were slightly taller than Australopithecus.
- The face was chinless.
- They used fire and variety of tools.
- They inhabited caves.
- They were hunters.

Homo erectus

(9) *Homo sapiens* : *Homo sapiens* were descended from *Homo erectus*. They were more or less similar to modern man. Number of fossils are known.

(i) Neanderthal man : The fossils were collected from the Neanderthal valley of Germany. They existed about 75,000 years ago and became extinct by 25,000 years ago. The main characters are given below :

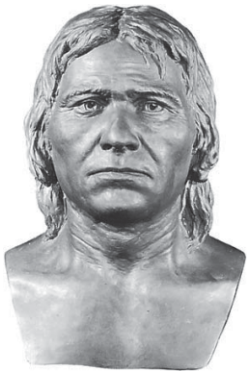
Neanderthal Man

- Their eyebrow ridges were heavy and protruding.
- They had no chin.
- Their teeth were large.
- They prepared their tools much more skillfully than the pre previous men.
- Their cranial capacity was about 1400CC.

(ii) Rhodesian Man : The fossils were collected from Rhodesia. The cranial capacity was about 1300 CC.

Rhodesian Man

(iii) Cro-Magnon Man :



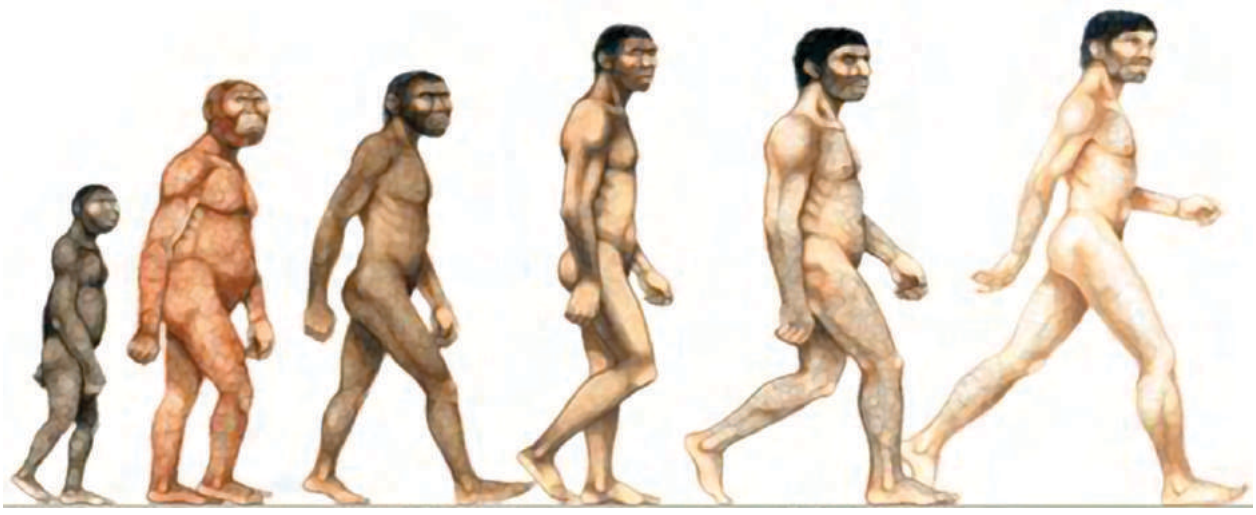
Cro-Magnon Man

These were the men who lived in Europe during the last 30,000 years. They were more nearer to the modern men. They possessed almost all characteristics of modern man.

(iv) Modern Man (*Homo* sapiens sapiens) : The successors of cro-Magnon man, which originated about 8000 years ago. Attempts for food production from plants and domestication of animals led them towards present day civilization. The cranial capacity of modern man is 1450 CC.

Modern Man

Man is classified into different races according to appearance, characters and zoo-geographical distribution. The main man (human) races are five (5), like Caucasoid race, Negroid race, Mongoloid race, American race, Indian race and Australian race.



Australopithecus | *Homo erectus* | Homo Neanderthalensis | *Homo sapiens*

Evolution of Man

SUMMARY

- Evolution is the development of more complex forms of life from simpler and earliar forms.
- Living systems are mixtures of very large and complex molecules functioning together in a co-ordinated way.
- Many theories and speculations are advocated by scientists and philosophers regarding the origin of life on earth.
- Modern biologist strongly believe that life is originated in the remote past from chemical substances. i.e. primitive earth $\rightarrow$ C, H, N, O $\rightarrow$ H_2O, H_2, NH_3, CH_4 $\rightarrow$ Micro-molecules $\rightarrow$ Macromolecule $\rightarrow$ Coacervates formation $\rightarrow$ Precells formation $\rightarrow$ Cells formation.
- Urey and Miller gave experimental evidence for molecular evolution.
- To prove that organic evolution did take place since the origin of life, concrete evidences come out from the morphology, embryology, physiology and palaentology sources.
- Organisms depend on the environment for their survival. They adjust themselves to the changes of the environment. Development of different kinds of adaptations is called adaptive radiation.
- For the biological evolution some theories were proposed. like; Lamarkism Darwinism, De vries theory and modern concept.
- Hardy weinberg law is important to calculate the gene frequency.
- Like other animals man exhibits the origin and evolutionary pattern. The gradual development of man from ape is fully supported by fossils which follows the main pattern of evolution.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

(1) Who proposed the theory of special creation ?

(a) Aristotle ○ (b) Father Sudrez ○

(c) Prayer ○ (d) F. Reddy ○

(2) Who believed that coacervates as the sole living molecules which gave rise to cells.

(a) Prayer ○ (b) Father Sudre ○

(c) Oparin ○ (d) F. Reddy ○

(3) The forelimbs of higher vertebrates is the example of what ?

(a) Analogous Organs ○ (b) Homologous Organs ○

(c) Connecting Link ○ (d) Vestigial Organs ○

(4) What is explained through Marsupials of Australia ?

(a) Local Adaptive Branching ○ (b) Continental Adaptive Radiation ○

(c) Contemporaneous Radiation ○ (d) None ○

(5) In which year Hardy Weinberg law was proposed ?

(a) 1908 ○ (b) 1909 ○ (c) 1910 ○ (d) 1911 ○

(6) How many years ago earth was originated ?

(a) 4000 million ○ (c) 5000 million ○

(b) 2000 million ○ (d) 3000 million ○

(7) From which fossil Ramapitecus is decended ?

(a) Dryopithecus ○ (b) Oreopithecus ○

(c) Kenyapithecus ○ (d) Homo Erectus ○

(8) Which fossil man is very nearer to modern man ?

(a) Cro-magnon Man ○ (b) Homo erectus ○

(c) Neanderthal Man ○ (d) Dryo Pithecus ○

2. Answer the following questions in short :

(1) What is evolution ?

(2) What is analogous organs ?

(3) Balanoglossus is the connecting link between what ?

(4) What is adaptive radiation ?

(5) What is mutation ?

(6) Define : Gene pool.

(7) Define : Genetic Drift.

(8) Mention any two characters of Australopithecus.

(9) Mention any two characters of *Homo erectus*.

(10) Mention the cranial capacity of modern man.

3. Do as directed :

(19) Describe : formation of water, amonia and methane.

(20) Describe : Formation of Coacervates.

(21) Explain : Experimental evidences for molecular evolution.

(22) Write note on : Adaptive radiation.

(23) Write note on : Darwinism.

(24) Write note on : Australopithecus and *Homo sapiens*.

11

Biotechnology : Principles and Processes

Biotechnology may be defined as the use of microorganisms, animals or plant cells or their components to generate products and services useful to human beings. Biotechnology does not mean hunting and gathering animals and plants for food; however domesticating animals such as sheep and cattle for use as livestock is a classical example of biotechnology. Our early ancestors also took advantage of microorganisms and used fermentation to make breads, cheeses, yogurts and alcoholic beverages such as beer and wine. During fermentation some strains of yeast decompose sugars to derive energy, and in the process they produce ethanol as a waste product. Alcohol produced by the yeast evaporates when the bread is cooked but the remnants of alcohol remain in the semisweet taste of most bread.

Modern biotechnology is often associated with the use of genetically altered microorganisms such as *E .coli* or yeast for the production of substances like insulin or antibiotics. It can also refer to transgenic animals or plants such as Bt cotton. Biotechnology is also associated with medical therapies to treat diabetes, Hepatitis B, Hepatitis C, Cancer, Arthritis, Haemophilia, Bone fracture etc.

As per the European Federation of Biotechnology (EFB) Biotechnology can be defined as "The integration of natural science and organisms, cells and their parts" thereof and molecular analogues for products and services.

Principles of Biotechnology

Following two core techniques have given birth to modern biotechnology :

(1) Genetic Engineering : It is a broad term referring to manipulation of nucleic acids (DNA and RNA) of an organism. Organisms whose genes have been artificially altered for a desired affect is often called genetically modified organism (GMO).

(2) Maintenance of Sterile Condition : Condition in chemical engineering processes in order to enable the growth of only the desired microorganisms or eukaryotic cells in large quantities for the production of biotechnological products like antibiotics, enzymes, hormones, vaccines etc.

While asexual reproduction preserves the genetic information, sexual reproduction provides opportunity for variations and formation of new combination of genetic setup, some of which may be beneficial to the organisms as well as the population.

For thousands of years, humans have used selective breeding to improve production of crops and livestock to use them for food. In selective breeding, organisms with desirable characteristics are hybridized to produce offspring with the same characteristics. However in this traditional hybridization multiplication of undesirable genes along with desirable genes takes place very often. The technique of genetic engineering , overcome this limitation and allow us to isolate and introduce only one or set of desirable genes without introducing undesirable genes into the target organism.

In the technique of genetic engineering, the desired DNA fragment is isolated from the suitable cell of an organism and is transferred into a recipient cell . This DNA fragment would not be able to multiply unless and until it gets integrated into the genome of recipient. This is because the DNA of recipient cell has a specific sequence called the origin of replication, which initiates DNA replication. Thus integrated DNA fragment replicates and multiplies itself in the recipient cell. This can also be called as cloning.

The basic principles of recombinant DNA technology are very simple and broadly involve the following stages :

(1) Generation of DNA fragments and selection of the desired piece of DNA

(2) Insertion of the selected DNA into a cloning vector i.e. plasmid, to create a recombinant DNA

(3) Introduction of the recombinant vectors into host cells (e.g. bacteria)

(4) Multiplication and selection of clones containing the recombinant molecules.

(5) Expression of the gene to produce the desired product.

Tools of DNA Recombinant Technology

For the production of recombinant DNA following tools are required :

(1) Restriction enzymes (2) Cloning vectors and (3) Competent host

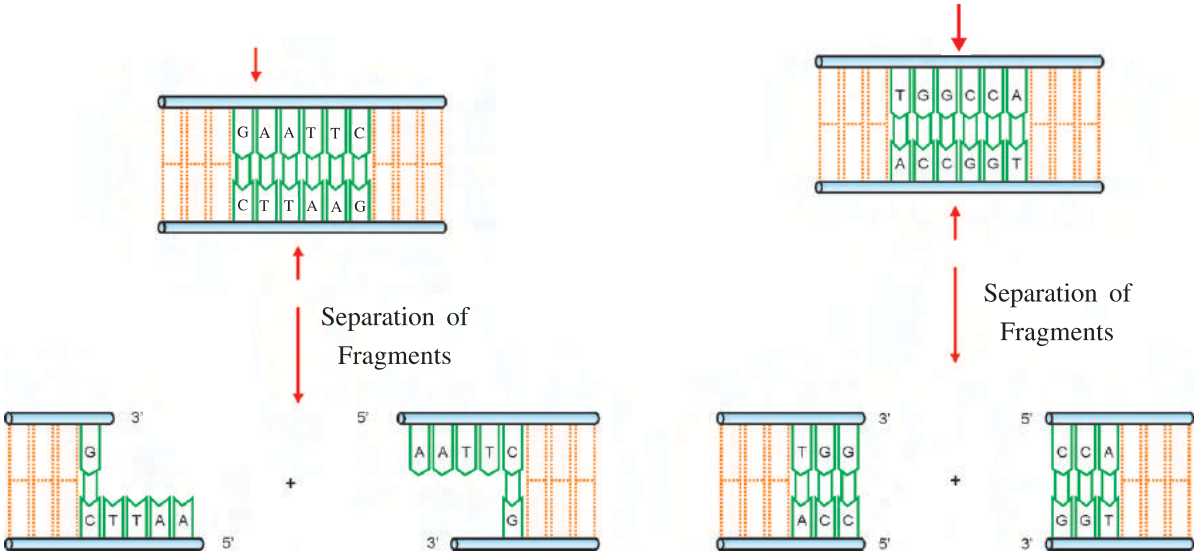
(1) Restriction Enzymes : The technique involved in recombinant DNA technology is to cut the desired DNA segment and introduce it into a vector (e.g. plasmid). This is achieved using specific bacterial enzymes called restriction enzymes or restriction endonucleases. These enzymes recognize short sequences of double stranded DNA as targets for cleavage. Different enzymes recognize different but specific sequences, each ranging from 4-8 base pairs. This specific base sequence is known as the recognition sequence.

Today we known more than 900 restriction enzymes that have been isolated from over 230 strains of bacteria. These enzymes are named by a three letter or four letter abbreviation that identifies their origin e.g. EcoRI is derived from *E. coli.* The letter 'R' is derived from the name of strain. Roman numbers following the names indicate the order in which the enzymes were isolated from that strain of bacteria.

Restriction enzymes belong to a large class of enzymes called nucleases. Nucleases are of two types : (1) exonucleases and (2) endonucleases. Exonucleases remove nucleotides from the ends of DNA where as, endonucleases make cuts at specific site within DNA.

Restriction endonucleases recognize short palindromic sequences and cut at specific sites. The palindromic sequence is a sequence of base pairs in double stranded DNA that reads the same backwards and forward across the double strand. When a restriction endonuclease acts on palindrome, it cleaves both the strands of DNA molecule. While some enzymes cut the two strands symmetrically leaving blunt ends ,others cut two strands assymetrically leaving sticky ends.

Only those enzymes that cut the DNA and form sticky ends are useful in recombinant DNA technology. When both vector (plasmid) and desired DNA cut by the same enzyme, the resultant DNA fragments have the same kind of sticky ends and these can be joined together using DNA ligases.



Sticky-end Fragments

Blunt-end Fragments

Two Types of Cuts Made by Restriction Enzymes

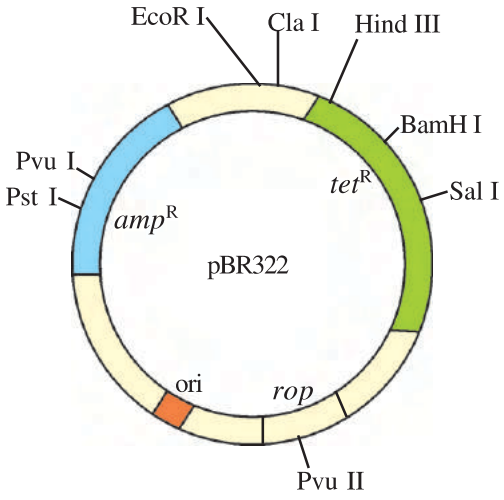
(2) Cloning Vectors : Vectors are the DNA molecules which can carry a foreign DNA fragment to be cloned. The most important vectors are plasmids and bacteriophages which can replicate in the bacterial cells independent of the control of chromosomal DNA. Bacteriophages, because of their high number per cell, have very high copy numbers of their genome within the bacterial cells. Similarly, all bacterial cells have plasmids containing low copy number (1-4 per cell) or a high copy number (10-100 per cell). If we are able to link desired piece of DNA with bacteriophage or plasmid DNA, we can multiply its number equal to the copy number of bacteriophage or plasmid.

The following features are required to facilitate cloning into a vector :

(i) Origin of Replication : The origin of replication (also called the replication origin) is a particular sequence in a genome at which replication is initiated. Any fragment of DNA when linked to this sequence can be made to replicate within the host cell. This sequence is also responsible for controlling the copy number of the linked DNA.

(ii) Selectable Marker : Beside origin of replication, the vector should have a selectable marker. Selectable markers are the genes which help in identifying and eliminating nontransformants and selectively permitting the growth of the transformants. As they often possess antibiotic resistance genes, they protect the organism from a selective agent like antibiotics, that would normally kill it or prevent its growth. Normally, the genes encoding resistance to antibiotics such as ampicillin, chloramphenicol, tetracycline or kanamycin are considered useful selectable markers for *E. coli*. The normal *E. coli* cells do not carry resistance against any of these antibiotics.

(iii) Cloning Sites : In order to link the desired DNA, the vector should have very few, preferably single recognition site for the commonly used restriction enzymes. The plasmid pBR322 carries within its sequences an origin of replication and two antibiotic resistance genes : amp^R (ampicillin resistance) and tet^R (tetracycline resistance). These antibiotic resistance genes possess restriction enzyme recognition sites. The amp^R gene has Pst I recognition site while tet^R gene has recognition sites for Hind III, Bam H I and Sal I.



Structure of *E. coli* Plasmid, Cloning Vector pBR322

For example, if the foreign DNA is cut with Bam H I, and the plasmid is too, they can be recombined and sealed together with ligase. However, as the Bam H I cuts the plasmid in the gene that codes for resistance to tetracycline, the resistance to tetracycline is inactivated. Even though recombinants can be selected out from non-recombinant ones by plating the transformants on ampicillin containing medium. The recombinants will grow in ampicillin containing medium but not on that containing tetracycline.

(iv) Vectors for Cloning Genes in Plants and Animals : A cloning vector is a carrier DNA molecule in which a desired DNA fragment can be integrated in such a way that the carrier molecule does not lose its capacity for self replication. It is used to introduce desired (donor) DNA into host cells. The Tumor inducing (Ti) plasmid of *Agrobacterium tumifaciens*, which is pathogenic and responsible for the

production of tumor in most of dicot plants, has now been modified into a cloning vector which is no more pathogenic to the plants but is still able to use the mechanism to deliver genes of our interest into a variety of plants. Similarly retroviruses, having capacity to transform normal cells into cancerous cells are now modified and used to deliver desirable genes into animal cells.

(3) Competent Host : DNA usually can not get across cell membrane since it a hydrophilic molecule. In order to force bacteria to take up the recombinant DNA , the bacterial cells must be made competent to take up DNA. This can be done by :

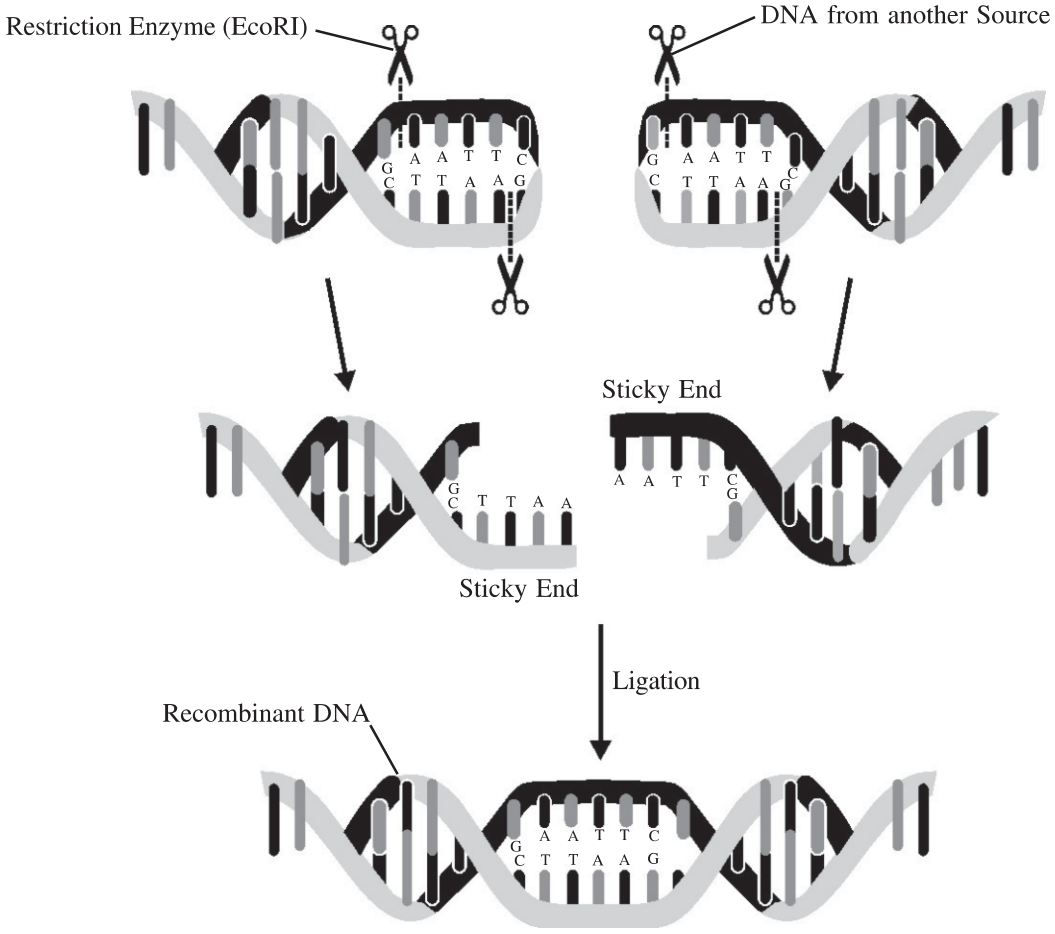
- Treating cells and the DNA with high Ca^{2+} which allows DNA uptake by cells. High Ca^{2+} causes membrane changes that reduce the barriers to DNA movement. Recombinant DNA can be forced into bacterial cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42 ^{o}C and then putting them back on the ice.
- Electroporation : Cells are exposed to rapid pulse of high voltage current to render the plasma membrane permeable to recombinant DNA
- Micro-injection : Recombinant DNA is directly injected to the nucleus of animal cell through micro-injection.
- Lipofection : Recombinant DNA is coated with lipid which allows it to pass through the plasma membrane.
- Particle Bombardments : Tiny high velocity particles of tungsten or gold are coated with recombinant DNA and then shot into cells. This method is also known as biolistics or gene gun.

Process of Recombinant DNA Technology

Recombinant DNA is DNA created artificially by combining the DNA from two or more organisms into a single recombinant molecule. The term DNA recombinant technology refers to the transfer of a segment of DNA from one organism to another organism (host cell) where it reproduces. The process involves a sequence of steps as set forth below.

(1) Isolation of the Genetic Material (DNA) : Recombinant DNA technology begins with the isolation of a gene of interest i.e., the donor DNA. This can be achieved by cutting the DNA with the enzymes. In order to cut DNA with restriction enzymes, it needs to be in pure form, free from other macromolecules. As in eukaryotes, DNA is enclosed within the membranes, we have to break membranes to release DNA along with other molecules like RNA, proteins, carbohydrates and also lipids. This can be achieved by treating the bacterial or plant or animal cell with enzymes such as lysozyme (bacteria), cellulase (plant cell) and chitinase (fungus). RNA can be removed by treating with ribonuclease while proteins can be removed by treating with protease. Other molecules are removed by appropriate treatments and purified DNA ultimately precipitates out after addition of chilled ethanol.

(2) Cutting of DNA at Specific Locations : To do this, a known DNA sequence from the donor cell is identified and removed with a restriction enzyme. When cut, each fragment of DNA has an overhanging piece of single stranded DNA on its ends called sticky ends. With the help of these ends the fragment is able to attach with any DNA molecule that contains a complementary sticky ends in presence of enzyme ligase. The fragments of DNA can be separated using Agarose gel electrophoresis. Because of its phosphate groups, DNA is negatively charged and when it is placed in a semisolid gel and an electric field is applied the DNA molecules migrate toward the positive pole.

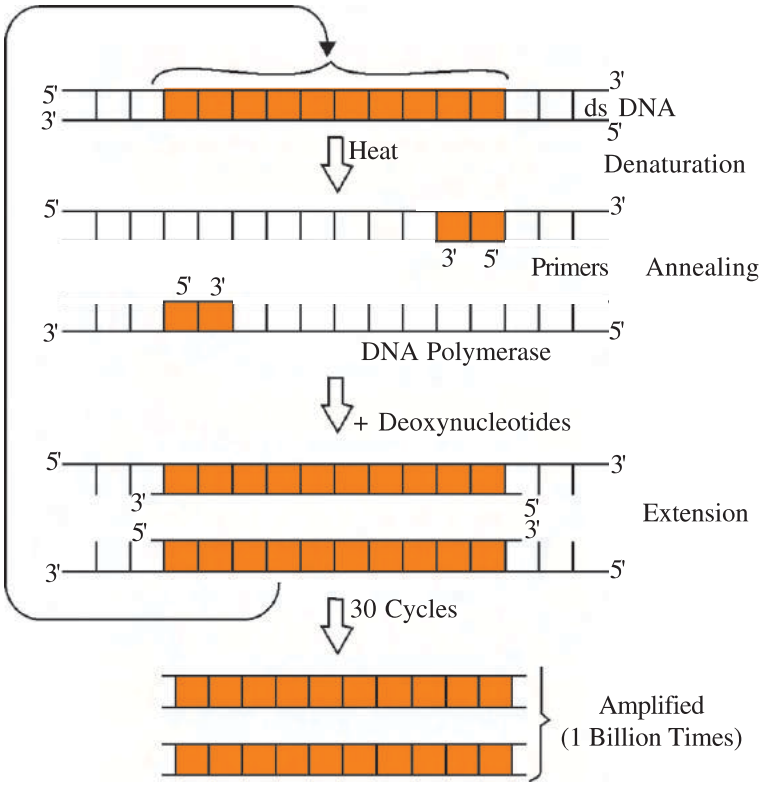


Cutting of DNA at Specific Location

(3) Amplification of Gene of Interest Using PCR : Polymerase Chain Reaction (PCR) is used to produce identical copies of a short DNA sequence. This process includes three stages as follow :

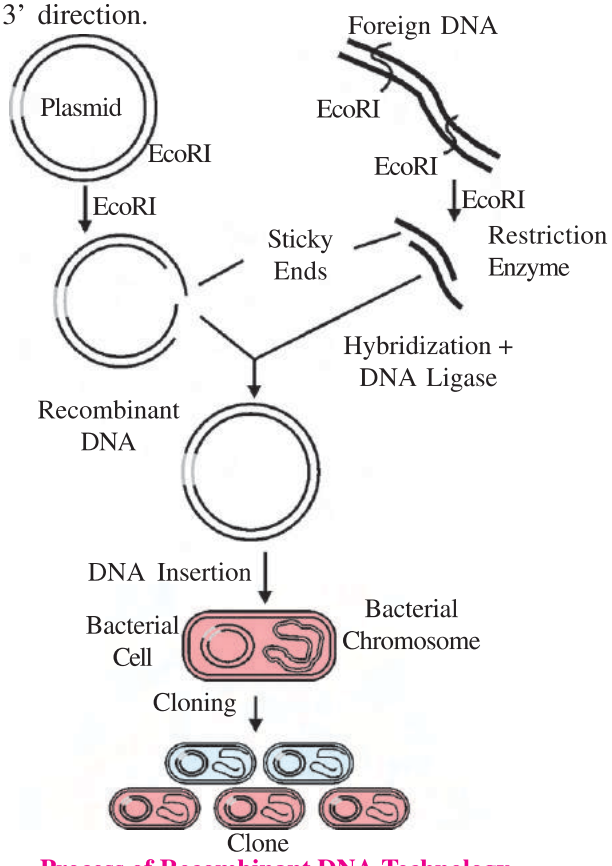
(i) Denaturation : A DNA molecule of interest is denatured by heat at 90-95 °C. The two strands separate due to breakage of the hydrogen bonds holding them together.

(ii) Annealing : In the presence of an excess of nucleotides (building blocks of new DNA material), oligonucleotide primers are added. The primers are complementary to either end of the target sequence but lie on opposite strand. As the mixture cools at lower temperature (50-65 °C) each sequence of DNA molecule becomes annealed with an oligonucleotide primer.



Polymerase Chain Reaction (PCR)

(iii) Extension : DNA polymerase (isolated from a bacterium *Thermus aquaticus*) is then added and complementary strands are synthesized. The polymerase causes synthesis of new strand in the 5' to 3' direction.



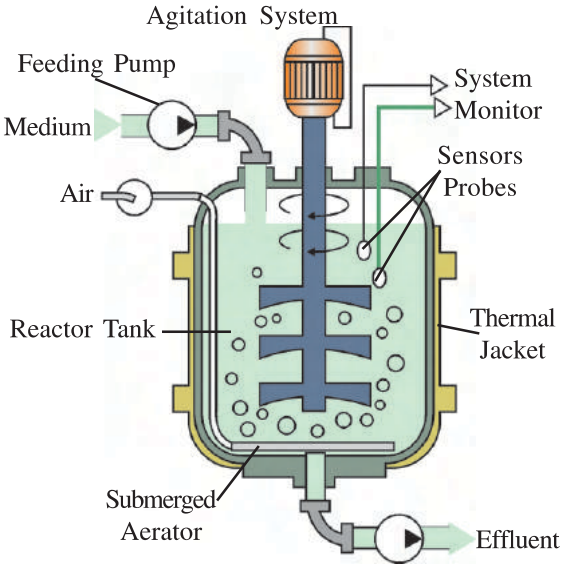
Process of Recombinant DNA Technology

If this process is repeated many times, the segment of DNA can be amplified to approximately billion times, i.e., 1 billion copies are made.

(4) Insertion of Recombinant DNA into the Host Cell/ Organism : The recombinant DNA is introduced into the host cell in a process called "transformation". Recipient cells after making them competent to receive, take up DNA present in its surrounding. If a recombinant DNA possessing antibiotic resistance gene (E.g. ampicillin) is transferred into *E. coli* cells, the host cells become transformed into ampicillin resistant cells. If we put transformed cells on agar plates containing ampicillin, only transformants will grow, untransformed recipient cells will die. The ampicillin resistant gene in this case is called a selectable marker.

(5) Obtaining the Foreign Gene Product : As the ultimate aim of recombinant technology is to produce a desirable protein, the gene introduced in a recipient cell should be allowed to express. The recipient cells possessing cloned genes may be grown on a small scale in the laboratory. The cultures may be used for extracting the desired protein and then purifying it by using different separation techniques.

For the large scale production of the products, bioreactors , where large volumes (100-1000 litres) can be used. A bioreactor provides the optimal conditions for achieving the desired product by providing optimal growth conditions like temperature, pH, substrate, salts, vitamins or oxygen etc.



Bioreactor

(6) Downstream Processing : The processes like separation and purification of the products are collectively referred to as downstream processing. The product has to be preserved with suitable preservatives.

SUMMARY

Biotechnology may be defined as the use of microorganisms, animals or plant cells or their components to generate products and services useful to human beings. Genetic engineering and maintenance of sterile condition in chemical engineering process have given the birth to modern biotechnology.

The Basic Principles of Recombinant DNA Technology Involve the Stages like generation of DNA fragments and selection of the desired pieces of DNA, insertion of the selected DNA into a cloning vector i.e. plasmid, to create a recombinant DNA, Introduction of the recombinant vectors into host cells (e.g. bacteria), multiplication and selection of clones containing the recombinant molecules and expression of the gene to produce the desired product. The tools required in the recombinant DNA technology include restriction enzymes, cloning vectors and competent host.

The term DNA recombinant technology refers to the transfer of a segment of DNA from one organism to another organism (host cell) where it reproduces. The process involves a sequence of steps like isolation of genetic material, cutting of DNA at specific site, amplification of gene of interest using PCR, insertion of recombinant DNA into the host cell organism obtaining the foreign gene product and downstream processing.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

(1) Domesticating animals such as sheep and cattle for use as livestock is an example of :

(a) Plant Breeding ○ (b) Animal Breeding ○

(c) Biotechnology ○ (d) Genetic Engineering ○

(2) Bt cotton is a ..... .

(a) Transgenic Animal ○ (b) Transgenic Plant ○

(c) Product of Tissue Culture ○ (d) Transposable Element ○

(3) GMO stands for ..... .

(a) Genetically Matured Organism ○

(b) Genetically Modified Organism ○

(c) Genes Modified in Organism ○

(d) Genetically Modified Organs ○

(4) Specific sequence which initiates DNA replication is known as …

(a) Point of Replication ○ (b) Origin of Replication ○

(c) Replication Sequence ○ (d) Integrated DNA Replication Point ○

(5) How many restriction enzymes have been isolated till today ?

(a) More than 700 ○ (b) More than 800 ○

(c) More than 900 ○ (d) More than 600 ○

(6) In EcoRI, the R is derived from ..... .

(a) Replication ○ (b) Restriction ○

(c) Name of strain ○ (d) Repetition ○

(7) Restriction enzymes belong to a class ..... .

(a) Polymerases ○ (b) Nucleases ○

(c) Endonucleases ○ (d) Isomerases ○

(8) The most important cloning vectors are ..... .

(a) Cosmids ○ (b) Plasmids ○

(c) Plasmids and bacteriophages both ○ (d) Recombinant DNA ○

(9) ..... can transform normal cells into cancerous cells.

(a) *Agrobacterium* ○ (b) Retroviruses ○

(c) Recombinant DNA ○ (d) Endonuclease ○

(10) In which of the following process cells are exposed to rapid pulse of high voltage current to render the plasma membrane permeable to recombinant DNA ?

(a) Micro-injection ○ (b) Electroporation ○

(c) Lipofection ○ (d) Particle ○

2. Answer the following questions in short :

(1) At what temperature the DNA molecule of interest is denatured ?

(2) Give full form of PCR.

(3) Define transformation.

(4) What do you mean by recombinant DNA ?

(5) What is palindromic sequence ?

(6) Define micro-injection and lipofection.

(7) What is particle bombardment ?

(8) What is the function of ligase ?

(9) Write the role of bioreactors in recombinant DNA technology.

(10) What do you mean by downstream processing ?

3. Do as directed :

(1) What is the role of bioreactor in recombinant DNA technology ?

(2) Explain annealing stage of amplification of gene.

(3) Mention the stages of basic principles of recombinant DNA technology.

(4) How restriction enzymes are named ?

(5) What are the functions of endonuclease and exonuclease ?

(6) What are the selectable markers ?

(7) Write a note on cloning vector.

(8) Explain the step of process of isolation of genetic material.

(9) Explain how recombinant DNA is inserted into the host cell ?

(10) Explain how foreign gene product can be obtained ?

4. Answer the following questions in detail :

(1) Describe principles of Biotechnology.

(2) Explain the tools used in the production of recombinant DNA.

(3) Describe the process of recombinant DNA technology.

12

Biotechnology and its Applications

Biotechnology is the most exciting and revolutionary science of this century. It is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts. In general biotechnology has applications in four major industrial areas including : (1) health care (medical), (2) crop production and agriculture, (3) non food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, biofuels etc.) and (4) environmental uses. In this chapter we will learn how human beings have used biotechnology to improve the quality of life, especially in the field of food production and health.

Biotechnological Applications in Agriculture

There are following three options in order to increase the food production:

(1) Agro-chemical based agriculture

(2) Organic agriculture

(3) Genetically engineered crop based agriculture.

The world population has topped 6 billion people and is predicted to double in the next 50 years. Ensuring an adequate food supply for this booming population is going to be a major challenge in the years to come. The green revolution succeeded in tripling the food supply but yet it is not enough to feed the growing human population. The increased production have not only been due to the use of improved crop varieties but also due to use of agrochemicals like fertilizers and pesticides. However in developing countries the use of agrochemicals is very expensive for the farmers. Sometimes agrochemicals also reduce the fertility of soil and cause pollution. So question arises that is there any way to minimize the use of agrochemicals and to get maximum production ? The answer is - use genetically modified crops. A genetically modified organism (GMO) is an organism whose genetic material has been altered using genetic engineering technique. GM plants are :

(1) Pest Resistance : Growing pest resistance plant can help to eliminate the application of chemical pesticides and to reduce the cost of bringing a crop to market.

(2) Herbicide Tolerance : Crop plants genetically-engineered to be resistant to very powerful herbicide, could help to prevent environmental damage by reducing the amount of herbicides needed.

(3) Disease Resistance : There are many viruses, fungi and bacteria that cause plant diseases. GM plants are resistance to these diseases.

(4) Cold, drought, salt and heat tolerance

(5) With enhanced nutritional value of food , e.g., vitamin A enriched rice.

Genetically Modified Organisms :

A Genetically modified organism is an organism whose genetic material has been altered using genetic engineering technique. The main advantage of utilizing this technique in agriculture is possibility of increase productivity through the use of newer varieties that possess property such as resistance to pest. The damage to the crops is mainly caused by insect larvae and to some extent adult insects. The majority of the insects that damage crops belong to Lepidoptera (bollworms), Coleoptera (beetles), Orthoptera (grasshoppers) and Homoptera (aphids).

Imparting the property of pest resistance through the transfer of gene from *Bacillus thuringiensis* (Bt) into target plant through modern biotech method is presently considered to be one of the most advanced application of biotechnology. Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insect without the need for insecticides. Bt cotton, Bt corn, Bt brinjal etc. have been produced by transferring the Bt toxin gene into target plant.

Bt Cotton

Bt Cotton

Bt cotton is a genetically modified crop that contains a foreign gene isolated from *Bacillus thuringiensis*. This bacterial gene produces a toxic insecticidal crystalline protein which destroys bollworms. Actually, *B. thuringiensis* produces this toxic protein in an inactive form, but when an insect ingests this inactive protein, it is converted into an active form of toxin due to the alkaline pH of gut which solubilises the crystals. This activated toxin binds to the surface of midgut epithelial cells and creates pores that causes death of the insect. The toxin is coded by a gene named ***cry*** and hence, toxin is termed as ***cry*** protein.

Biotechnological Applications in Medicine

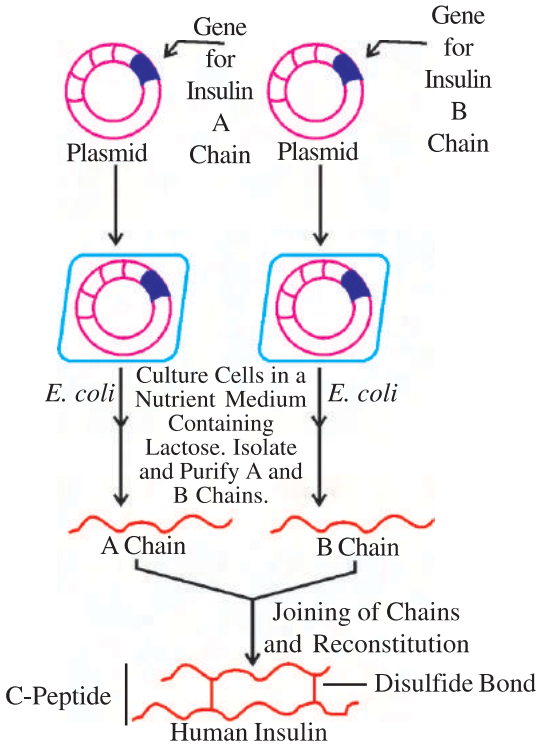
Most development in biotechnology originated for their potential applications in health care. In medicinal field, biotechnology techniques are used frequently in diagnosing and treating different diseases. These techniques also give opportunities for the people to protect themselves from dangerous diseases. The field of biotechnology has introduced techniques like gene therapy, recombinant DNA technology and polymerase chain reaction which use genes and DNA molecules to diagnose diseases and insert new and healthy genes in the body which replace the damaged gene or DNA.

Genetically Engineered Insulin

Insulin, a hormone, regulates sugar metabolism in human and it is of immense value to diabetics. Insulin is produced by the β -cells of islets of Langerhans of pancreas. Human insulin contains 51 amino acids , arranged in two polypeptide chains. The chain **A** has 21 amino acids while **B** has 30 amino acids. Both are held together by disulfide bonds.

Insulin used for diabetes was earlier extracted from pancreas of slaughtered cattle and pigs. Insulin obtained from animal pancreas, causes allergy or other types of reactions in some patients.

In 1980 recombinant DNA technology was used to produce human insulin in bacteria (*E. coli*) which is called Humelin. Normally insulin is synthesized as proinsulin which has an extra stretch called the **C** peptide. This **C** peptide is not found in mature insulin and is removed during maturation into insulin. In 1983, Eli Lilly company of United States has produced two DNA sequences corresponding to A and B chains of human insulin and introduced them in plasmids of *E. coli* to produce insulin chains. These separately produced chains are then extracted and combined by creating disulfide bonds to form human insulin.



Production of Human Insulin

Gene Therapy

Gene therapy is a technique of biotechnology which is used to treat and diagnose diseases like Cancer, Parkinson's disease etc. Gene therapy may be defined in broad general term as "introduction of a normal functional gene into cells, in order to replace defective or mutated gene". Other method involves directly correcting a mutation or using DNA that encodes a therapeutic protein drug to provide treatment.

Application of gene therapy involves the following basic development in genetics, molecular biology and biotechnology :

(1) Identification of the gene that plays the key role in the development of a genetic disorder,

(2) Determination of the role of its product in health and disease,

(3) Isolation and cloning of gene and

(4) Development of an approach for gene therapy.

Gene therapy may be classified into (i) germ line gene therapy and (ii) somatic cell gene therapy. (i) In germ line gene therapy, germ cells, i.e., sperms or eggs are modified by introduction of functional gene, which are ordinarily integrated into their genomes. Therefore, change due to therapy would be heritable. (ii) In somatic cell gene therapy the gene is introduced only in somatic cells, especially of those tissue in which expression of the concerned gene is critical for health. Expression of the introduced gene relieves or eliminates symptoms of the disorder.

There are basically two ways of implementing a gene therapy treatment :

(1) *Ex vivo*, which means "outside the body". Cells from the patient's blood or bone marrow are removed and grown in the laboratory. They are then exposed to a virus carrying the desired gene. The virus enters the cells, and the desired gene becomes part of the DNA of the cells. The cells are allowed to grow in the laboratory before being returned to the patient by injection into a vein.

(2) *In vivo,* which means "inside the body"- No cells are removed from the patient's body. Instead, vectors are used to deliver the desired gene to cells in the patient's body.

Transgenic Animals

The dependence of man on animals such as cattle, sheep, poultry, pig and fish for various purposes (milk, meat, eggs, wool etc.) is well known. Improvement of genetic characteristics of these animals in early days was carried out by selective breeding methods which involve a combination of mating and selection of animals with improved genetic traits. With the advent of modern biotechnology, it is now possible to carry out manipulation at the genetic level to get the desired characteristics in animals.

Transgenesis refers to the phenomenon of introduction of exogenous DNA into the genome of an animal to create and maintain a stable heritable character. The foreign DNA that is introduced is called transgene. And the animal whose genome is altered by adding one or more transgenes is said to be transgenic animal.

Why are these animals being produced ? How can man benefit from such modifications ? Let us see some of the common reasons.

- Transgenesis has become a powerful tool for studying the gene expression and developmental processes in higher organisms, besides the improvement in their genetic characteristics.
- Transgenic animals serve as good models for understanding the human diseases and also for the investigation of new treatments for diseases. Today transgenic models exist for many human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.

- Several proteins produced by transgenic animals are important for medical and pharmaceutical applications. In 1997, the first transgenic cow , Rosie, produced human protein-enriched milk (2.4 grams per litre). The milk contained the human alpha-lactalbumin and was nutritionally a more balanced product for human babies than natural cow milk.
- Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans. Earlier transgenic mice were used to test the safety of the polio vaccine.

Ethical Issues

Ethics includes 'moral principles' that control or influence a person's behavior. It includes a set of standards by which a community regulates its behavior and decides as to which activity is legitimate and which is not. Bioethics may be viewed as a set of standards that may be used to regulate our activities in relation to the biological world. Now-a-days, biotechnology, particularly recombinant DNA technology, is used for exploitation of the biological world by various ways. The major bioethical concerns pertaining to biotechnology are summarised below .

(1) Use of animals in biotechnology causes great suffering to them.

(2) When animals are used for production of certain pharmaceutical proteins, they are treated as factory or machine.

(3) Introduction of a transgene from one species into another species violates the integrity of species.

(4) Transfer of human genes into animals or vice-versa is great ethic threat for humanness.

(5) Biotechnology is disrespectful to living beings, and only exploits them for the benefit of human beings.

(6) Biotechnology may pose unforeseen risks to the environment, including risk to biodiversity.

Biopatent

Various researches are carried out in the world for human welfare. The right to these researches belong to the concerned researchers only. The economic gain obtained through these researches must be available to the researchers. Government grants patent rights for this. Thus a patent is the right granted by a government to prevent others from commercial use of researcher's invention. Patents for bioscientific researches are called biopatents. A patent is granted for :

(1) An invention, including a product

(2) An improvement in an earlier invention

(3) The process of generating a product and

(4) A concept or design.

In India as per Indian Patent Act (1970) greater importance is given to the process of obtaining a product rather than to the material or the object itself. Normally, the duration of patent is of five years. Biopatents are awarded for the following :

(1) Strains of micro-organisms

(2) Various kinds of tissue-cultured cells

(3) Genetically modified varieties of plants and animals

(4) Specific DNA sequences

(5) The proteins encoded by DNA sequence

(6) Biotechnological methods

(7) Products, process and application.

Many social institutes object to the process of biopatents because it raises several moral and political issues e.g. many plants belonging to genus Brassica are of economic importance. If a single biopatent covers all genetically modified plants in it, some individual, institute or a country can have supreme control over it. Agricultural researches will be curbed and with a decreasing food production, the world can get into a food problem.

Biopiracy

When big organization and multinational companies exploit patent biological resources or bioresources of other nations without proper authorization from the countries concern; such exploitation is called biopiracy.

Generally the developed countries are rich in technology and financial resources. However, they are poor in biodiversity and traditional knowledge related to bioresources (Bioresources are those organisms which can be used to derive commercial benefits). While developing nations are poor in technology and financial resources, but quite rich in biodiversity and traditional knowledge related to bioresources. Traditional knowledge related to bioresources is an outcome of experiences of local populations and society over centuries. When this is utilized by other countries, they greatly save the time, energy and money. By modernizing the methods, they become more and more prosperous. Thus it is necessary to bring awareness regarding biopiracy and to stop it.

Turmeric, Neem and Basmati rice are our bioresources. We know many examples of biopiracy of economically important plants. Multinational companies thus exploit the developing countries. This is done in various ways such as :

(1) America obtained a patent for germplasm of our Basmati rice.

(2) Biomolecules of many plants are patented in other countries.

(3) Isolate useful genes and then obtain patent for them.

(4) Pirate or steal the traditional knowledge and publish the same as a new finding.

A plant *Pentadiplandra brazzeana* of West Africa, produces a protein called brazzein. This protein is approximately two thousand times as sweet as sugar. Moreover, this is a low calorie sweetner. This property is put to use in the treatment of diabetes. America obtained a patent for brazzein and fused it in maize. Through this genetically modified variety they manufacture sugar.

Hence, it is necessary to form strict rules to curb biopiracy at international level. This will prevent a competition between developed and developing countries. Damages can be properly recompensated and exploitation can be stopped.

Biosafety Issues

Biosafety is the prevention of large scale loss of biological integrity, focusing both on ecology and human health. Under biosafety programmme main emphasis has been given to facilitate and implement biosafety procedure and guidelines for ensuring safety from the use of genetically modified organism and products in research.

Recombinant DNA technology enables man to combine DNA sequences from different sources to create functional DNA molecules with novel properties. These molecules are expressed in genetically modified organisms (GMO), which are then used in biomedical, agricultural and environmental areas. It was feared that genetically engineered microorganisms may disturb the ecosystem and its processes, in which they might be released, in the following two ways :

(1) they may rapidly multiply and out-compete the native microbes and

(2) they may also transfer genes related to pathogenesis into the native bacterial populations and, thereby increase their virulence.

Similarly, genetically modified plants could pose biological and ecological risks that may be summed up as follows :

(1) Production of toxic or allergic metabolites

(2) Unexpected new susceptibilities to pathogens

(3) Transmission of the new traits to related sexually compatible weed species and

(4) The ecosystem may be disturbed by dispersal, persistence or altered reaction to parasites, symbionts or competitors.

The biosafety guidelines are developed to ensure an adequate level of protection in the fields of safe transfer and use of living modified organisms resulting from modern biotechnology that may have adverse effects on sustainable use of biological diversity, and to reduce risks to human health.

SUMMARY

It is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts. A genetically modified organism (GMO) is an organism whose genetic material has been altered using genetic engineering technique. GM plants are : pest resistance, herbicide tolerance, disease resistance, cold, drought, salt and heat tolerance and with enhanced nutritional value of food. e.g., vitamin A enriched rice.

Imparting the property of pest resistance through the transfer of gene from *Bacillus thuringiensis* (B*t*) into target plant through modern biotech method is presently considered to be one of the most advanced application of biotechnology.

The field of biotechnology has introduced techniques like gene therapy, recombinant DNA technology and polymerase chain reaction which use genes and DNA molecules to diagnose diseases and insert new and healthy genes in the body which replace the damages gene or DNA. Gene therapy may be defined in broad general term as "introduction of a normal functional gene into cells, in order to replace defective or mutated gene".

Gene therapy may be classified into (1) germ line gene therapy and (2) somatic cell gene therapy.

Transgenesis refers to the phenomenon of introduction of exogenous DNA into the genome of an animal to create and maintain a stable heritable character. The foreign DNA that is introduced is called transgene. And the animal whose genome is altered by adding one or more transgenes is said to be transgenic animal.

Bioethics may be viewed as a set of standards that may be used to regulate our activities in relation to the biological world.

A patent is the right granted by a government to prevent others from commercial use of researcher's invention. Patents for bioscientific researches are called biopatents.

When big organization and multinational companies exploit patent biological resources or bioresources of other nations without proper authorization from the countries concern; such exploitation is called biopiracy. While Biosafety is the prevention of large scale loss of biological integrity, focusing both on ecology and human health.

EXERCISE

1. Put a dark colour in a given circle for correct answer :

(1) How many folds food supply has increased due to green revolution ?

(a) Two Folds ○ (b) Three Folds ○

(c) Multi Folds ○ (d) None of them ○

(2) Bt stands for

(a) Biotechnology ○ (b) *Bacillus thuringiensis* ○

(c) Biologically Trained Plant ○ (d) None of them ○

(3) Inactive toxin is converted into toxin form due to ..... .

(a) Acidic pH ○ (b) Neutral pH ○

(c) Alkaline pH ○ (d) Enzymes ○

(4) By which type of gene toxin protein is produced ?

(a) Cyr Gene ○ (b) B*t* Gene ○

(c) Cry Gene ○ (d) Toxic Gene ○

(5) How many amino acids are present in human insulin ?

(a) 31 ◯ (b) 21 ◯ (c) 51 ◯ (d) 30 ◯

(6) Change due to which therapy would be heritable ?

(a) Somatic Cell Gene Therapy ◯ (b) Germ Line Gene Therapy ◯

(c) *Ex vivo* Gene Therapy ◯ (d) *In vivo* Gene Therapy ◯

(7) Transgene means .....

(a) Foreign DNA ◯ (b) External DNA ◯

(c) Internal DNA ◯ (d) Any Gene ◯

(8) Which animal is being developed for use in testing the safety of Polio vaccine.

(a) Rabbit ◯ (b) Mice ◯ (c) Pig ◯ (d) Chick ◯

(9) Plant *Pentadiplandra brazzeana* belongs to ..... .

(a) Unites States ◯ (b) South America ◯

(c) South Africa ◯ (d) West Africa ◯

2. Answer the following question in short :

(1) Define Genetically modified organism.

(2) Name any two crops produced by transferring the Bt toxin gene into target plant.

(3) Name the protein produced by Cry gene.

(4) Which company of United States produced two chains of human insulin.

(5) Define gene therapy.

(6) What is bosafety ?

(7) Define biopatent.

(8) Give examples of transgenic genes.

(9) Classify gene therapy.

3. Do as directed :

(1) How multinational companies exploit the developing countries ?

(2) Write a note on Bt cotton.

(3) Explain various ways of implementing a gene therapy treatment.

(4) For what the biopatents are awarded ?

(5) Explain the structure of human insulin.

4. Answer the following questions in detail :

(1) Write a note on genetically modified organisms.

(2) Explain genetically engineered insulin.

(3) Describe gene therapy.

(4) Describe the significance of transgenic animals.

(5) Write a note on ethical issue.

(6) Describe biopatent.

(7) Write a note on biopiracy.