ONLYIAS BY PHYSICS WALLAH

PSC WALLAH

BPSC SAMPOORNA

Comprehensive Booklet for Prelims+Mains

GENERAL SCIENCE

A Detailed Coverage of Bihar Civil Services Exam Syllabus

EDITION: First

Published By:

Physics Wallah

ISBN: 978-81-19211-10-4

MRP : 0/-

Mobile App: Physics Wallah (Available on Play Store)

Website: www.pw.live

Youtube Channel: Physics Wallah - Alakh Pandey
UPSC Wallah
UPSC Wallah - Hindi Medium
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PREFACE

A highly skilled professional team of PW ONLY IAS works arduously to ensure that the students receive the best content for the BPSC exams.

A plethora of BPSC Study Material is available in the market but PW ONLY IAS professionals are continuously working to provide supreme quality study material for our BPSC students.

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This book adopts a multi-faceted approach to mastering and understanding the concepts by having a rich diversity of questions asked in the examination and equipping the students with the knowledge for this competitive exam.

The main objective of the study material is to provide short, crisp, concise, and high-quality content to our students.

BOOK FEATURES

- Holistic discussion of topics, strictly as per exam syllabus
- One-stop solution for subject-wise coverage
- Diagrams, Flowcharts and Timelines for quick understanding and revision
- Integrated Preparation of Prelims and Mains stages of this exam

CONTENTS

1 Physics

1.1 UNITS AND MEASUREMENTS

- A unit of measurement is a definite magnitude of a quantity, defined and adopted by convention or by law. It is used as a standard for measurement of the same kind of quantity.
- *To measure Physical quantities, four systems are in application.*

1.1.1 CGS System

It is based on–

Centimetre	Unit of length
Gram	Unit of mass
Second	Unit of time

1.1.2 FPS System

It is based on–

Foot	Unit of Length
Pound	Unit of mass
Second	Unit of time

1.1.3 MKS System

It is based on–

Metre	Unit of Length
Kilogram	Unit of mass
Second	Unit of time

1.1.4 International System of Units (SI Units)

- The International System of Units or SI units defines standard units for measurement of all physical quantities.
- In principle, any physical quantity can be expressed in terms of seven Fundamental units.

Fundamental Units

Property	Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	Candela	cd

Derived S.I. Units

Derived Quantity	Derived unit
Area	m^2
Volume	m^3
Speed,Velocity	$m\ s^{-1}$
Acceleration	$m\ s^{-2}$
Wave number	m^{-1}
Density	kgm^{-3}
Surface density	kgm^{-2}
Specific volume	$m^3\ kg^{-1}$
Current density	$A\ m^{-2}$
Magnetic field strength	$A\ m^{-1}$
luminance	$Cd\ m^{-2}$
Mass concentration	kgm^{-3}
Amount of substance concentration	$mol\ m^{-3}$
Force	$kgm\ s^{-2}$ (Newton-N)
Pressure	$kgm^{-1}\ s^{-2}$ (Pascal- Pa)
Frequency	s^{-1} (Hertz- Hz)
Energy, work, amount of heat	$kgm^2\ s^{-2}$ (Joule- J)
Electric Charge	A s (Coulomb- C)
Voltage/ Potential Difference	$kgm^2\ s^{-3}\ A^{-1}$ (volt- V)

Some Important Measuring Devices and Scales

Apparatus	Application
Ammeter	Measure electric current in a circuit
Anemometer	Measure wind speed and wind pressure
Barometer	Measure atmospheric pressure
Cardiograph	Record graphically the movements of the heart
Dynamo	Converts mechanical energy into electrical energy
Electroscope	Detect the presence and magnitude of electric charge on the body
Electroencephalograph	Record the electrical activity of the brain
Endoscope	Look inside the body
Fathometer	Measure the depth of the sea
Galvanometer	Detect electrical current
Hydrometer	Measure the relative density of liquids
Sonar	Uses sound propagation to navigate, communicate with or detect objects on or under the surface of water.

Apparatus	Application
Hygrometer	Measure relative humidity of the atmosphere
Lactometer	Check the purity of milk by measuring its density
Microphone	Converts sound waves into electrical signals
Odometer	Measure the distance travelled by a wheeled vehicle
Periscope	Observation over, around or through an object
Photometer	Measure intensity of light
Rain Gauge	Measure amount of liquid precipitation over a set period of time
Sphygmomanometer	Measure blood pressure
Stethoscope	Listen to the sound of heart
Speedometer	Measure instantaneous speed of a vehicle
Wind Vane	Direction of the wind
Radar	Object detection system that uses radio waves to determine the range, angle or velocity of the objects.

1.2 KINEMATICS

- **Distance:** The length of a specified path traveled between two points by an object.
- **Displacement:** Shortest distance between the initial position and the final position of a body.
- **Speed:** Speed is the ratio of a distance covered by a body in a given amount of time, to that time. It is measured in meters per second.

  Speed = Traveled distance/Time
- **Velocity:** velocity is speed measured in a particular direction. Velocity is a vector quantity, which is one in which both the magnitude and direction are stated.

  Velocity = Displacement/Time
- **Acceleration:** Acceleration is the rate of change of velocity. Acceleration may be defined as the change in velocity over a given time interval. Acceleration is measured in m/s^2 (or ms^{-2}).

  Acceleration = Final velocity-Initial velocity/Time

1.2.1 Newton's Laws of Motion

- **Newton formulated the well-known laws of motion.** He designed an astronomical telescope to carry out astronomical observations. He invented a new branch of mathematics, called Calculus.
- **First Law:** An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force.
  - In other words, all objects resist a change in their state of motion.
  - Means a body/object wants to remain in an undisturbed situation. If it is motion then want to remain in motion or if in rest then want to remain in rest. (Inertia)
- **Second Law:** States that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.
- **Third Law:** For every action, there is an equal and opposite reaction.

- The statement means that in every interaction, there is a pair of forces acting on the two interacting objects.
- The size of the forces on the first object equals the size of the force on the second object.

Momentum

- Product of the mass and velocity of an object.

  Momentum= Mass × Velocity

Change in Momentum

- The rate of change in momentum of an object is proportional to the imposed force on an object. The change in momentum occurs always in the direction of the force. It is the other form of Newton's second law of motion.

  Force ∝ Change in momentum/Time
- In other words

  Force = Mass × Velocity/Time = Mass × Acceleration
  Force = Mass × Acceleration

Work

- Force is said to do work if, when active, there is a displacement of the point of application in the direction of force. If no displacement occurs after applying force, no work is done.
- The value of work is equal to-

  Work = Force × Displacement in the direction of force
  $W = F \times S$
  where, W = work
  F = Force
  S = Displacement
- If the force is not in the direction of displacement, forming an angle θ with it, then

  $W = F \cos \theta \times S$
- Work is a scalar quantity.

Power

- Power is the rate of doing work by a machine or anybody.

  Power = Work(w)/Time(t)

Energy

- Energy is the capacity for doing work. Different forms of energy are mechanical energy, heat energy, light energy, sound energy etc. Energy is a scalar quantity.
  - ***Mechanical Energy***
    - Mechanical energy is the sum of kinetic and potential energy in an object that is used to do work.
  - ***Kinetic Energy***
    - The kinetic energy of an object is the energy that it possesses due to its motion. If the mass of the body is m kg and speed v m/sec, then

      K.E.= ½ mv^2
  - ***Potential Energy***
    - Potential energy is the energy in the body due to its position.

      P.E = mgh
    - where m = Mass, g = Acceleration due to gravity and h= Height

1.2.2 Newton's Law of Gravitation

According to this law every particle in the universe attracts every other particle in the universe. Newton's Law of Gravitation is

$F = Gm_1m_2/r^2$

Where G is the '**universal gravitational constant**'. Further experiments on gravity proved that:

$\mathbf{G = 6.673 \times 10^{-11} Nm^2 kg^{-2}}$

Gravitation Constant

Gravitation Constant the force of attraction between two objects with unit mass and positioned at unit distance.

1.2.3 Gravity

- **Gravity is the force by which a planet or other body draws objects toward its centre**. The force of gravity keeps all of the planets in orbit around the sun.
- **Universal Law of Gravitation:** Anything that has mass also has gravity. Objects with more mass have more gravity. Gravity also gets weaker with distance. So, the closer objects are to each other, the stronger their gravitational pull is.
- The universal law of gravitation successfully explained several phenomena which were believed to be unconnected:
  - Force that binds us to the earth;
  - Motion of the moon around the earth;
  - Motion of planets around the sun; and
  - Tides due to the moon and the Sun.
- When an object is thrown or dropped freely, it falls towards the earth due to the gravity of earth and its falling rate is continuously increasing due to the production of acceleration, which is known as **gravitational acceleration**.
- It is represented by **'g'.** It's unit is $\mathbf{m/s^2}$.
- The value of 'g' **does not depend upon the mass** of the object.
- The value of 'g' differs at different places on Earth's surface. It is **minimum at Equator** and **maximum at poles**.

Relation Between 'g' and 'G'

$\mathbf{g = GM_e/R_e^2}$

1.2.4 Circular Motion

- When a body or object moves in a circular path, it is said to be in a **circular motion** i.e. motion in a circle is a circular motion. When a body or object moves along a circular path, then its direction of motion or direction of speed keeps changing continuously.
- If an athlete moves with a constant speed along a circular path, then the velocity of the athlete will not be constant because velocity is the speed in a specified direction and here the direction of speed changes continuously.

- Since, the velocity changes with the continuous change in direction, therefore, the motion along a circular path is said to be accelerated.

Uniform Circular Motion

- When a body moves in a circular path with uniform speed or constant speed, its motion is known as Uniform Circular motion. It is possible for a body to move in a circular path with uniform speed as long as it is travelling equal distances in equal intervals of time. But the velocity of the body moving in a circle with uniform speed is not uniform because the direction of motion is constantly changing.

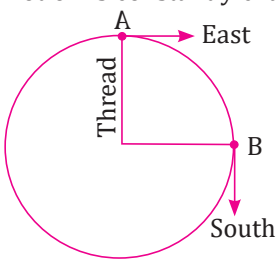


Fig. 1.1

- Suppose a stone is tied to a thread and is rotated in a circular path with uniform speed in clockwise direction. Now, when a stone reaches a certain point, say A, then its speed is directed towards east. And if the stone is released when it is at A, it will fly off in the east direction.When the stone is at point B, its speed is directed towards south. And if the stone is released when it is at point B, it will fly off in the south direction.
- Thus when a body moves in a circular path, the direction of speed is not the same at any two points. And when there is a change in the direction of speed of the body, its velocity is not uniform. Therefore, circular motion is accelerated even though the speed of the body remains constant. A force is needed to produce circular motion. The force needed to make an object travel in a circular path is **Centripetal Force**.
- **Examples Of Uniform Circular Motion Are:**
  - Artificial satellites move in uniform motion around the earth. Therefore, the motion of a satellite around the earth is accelerated.
  - The moon moves in a uniform circular motion around the earth.
  - Movement of earth around the sun is also a uniform circular motion. So, the motion of earth around the sun is accelerated.
  - The tip of a second's hand of a watch exhibits uniform circular motion on the circular dial of the watch.

1.3 PHYSICAL PROPERTIES OF MATTER

- Generally, there are three states of matter-
  1. Solid
  2. Liquid and
  3. Gas
- The three states of matter have some special properties, which are as follows:
  - In solid- Elasticity
  - In liquid- Pressure, Surface Tension, Capillarity and Floating
  - In Gas- Atmospheric Pressure.

1.3.1 Elasticity

- Generally, the meaning of a rigid substance is a hard solid, which has a definite shape and size. But these can be stretched, compressed and deformed.
- When an external force is applied on any substance, both its shape and size are deformed. After withdrawing force, it gains its normal shape or size. The property of any substance by which it tries to gain its normal shape after being stretched or compressed is called elasticity.
- "Ability of an object or material to resume its normal shape after being stretched or compressed" is **elasticity**.
- Based on the property of elasticity, matters are of two types:
  1. **Perfectly elastic substance:** Matter which resumes perfectly its normal state after withdrawing the applied force.
  2. **Perfectly plastic substance**: Matter which does not resume its normal state after withdrawing the external force, it remains deformed forever.

Do You Know?

Quartz can be considered as perfectly elastic matter and wax is perfectly plastic matter.

Stress

- During the application of external force on a matter to change its shape or size, an internal reaction force of equal amount is produced in the opposite direction on every section. This force is known as stress, and it tries to resume a normal state of matter. Then

  Stress = F/A
- Its SI unit is newton/meter^2.

Strain

- When the shape or size of a matter is changed by applying an external force, it is known as strain. Since it is a ratio hence it is without any unit.

Hooke's Law

- If the strain in the matter is nominal, applied stress on the matter is directly proportional to strain developed in it. The ratio of stress and strain is a constant value, known as **elasticity coefficient (E).**

  E = stress/strain

1.3.2 Surface Tension

- Surface Tension is the elastic tendency of a fluid surface which makes it acquire the least surface area possible. It is measured in force per unit length.

- Its SI unit is **newton/metre.**
- The value of surface tension of any liquid depends upon its nature, temperature and the medium present on another side of the liquid surface.
- Surface tension decreases with rise in temperature. It becomes zero at the critical temperature.
- If the liquid has negligible weight, its shape will be completely spherical. For example - rainwater drops and soap bubbles.

1.3.3 Cohesive and Adhesive Force

- According to molecular theory, every matter is made up of small particles, known as molecules. These molecules attract each other. Cohesive force is the force of attraction between molecules of the same matter. Adhesive force is the force of attraction between molecules of different matters.

1.3.4 Capillarity

- The capillary tube is a glass tube with a very small diameter, opened at both ends. The tendency of a liquid to rise or fall because of surface tension in the capillary tube is known as capillarity. Liquids which wet the glass, rise up and liquids which do not wet the glass, fall down in the capillary tube.

1.3.5 Pressure

- The pressure is a force applied perpendicularly on the per unit area surface of an object.

  Pressure = Force/Area

  SI unit of Pressure is newton/meter^2

Pressure Within Liquid at Any Point

- Pressure at a point, situated at h depth from the free surface of the liquid is-

  $P = h \times d \times g$

- Where, d is density of liquid; g is gravitational acceleration.

Upthrust Force

- When a solid is put into the liquid, loss in weight of the object appears. This apparent loss is due to a force which is exerted by the liquid on the matter in the upper direction. This force is known as the upthrust force.

Archimedes' Principle

- It states that the upward force that is exerted on a body immersed in a liquid, whether fully or partially submerged, is equal to the weight of the liquid that the body displaces and it acts in the upward direction at the centre of mass of the displaced liquid.

Law of Floatation

- When a solid is in liquid, the following two forces act on it-
  1. The weight of solid acts perpendicularly inwards.
  2. Upthrust force of liquid acting upwards on solid, in perpendicular direction.
- The value of F (upthrust) is equal to the weight of the liquid displaced by the solid.
- The sinking or floating of any object in liquid depends upon the relative values of these two forces.

(i) If W > F: resulting force (W F) it will act inwards - object will sink
(ii) If W = F: object will float.
(iii) If W < F: leaving the object free, it will start to come upward.

1.4 OPTICS

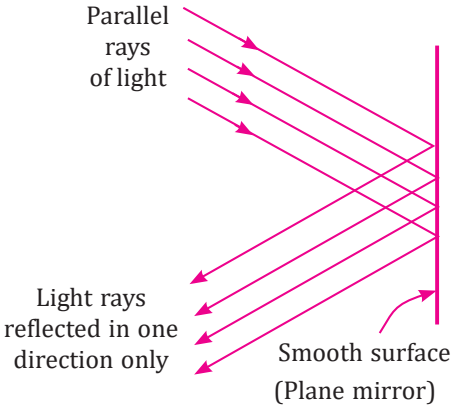
- Light is a form of energy which enables us to see objects and the straight line along which it travels is called ray of light. Light travels in a straight line. It can either be reflected or refracted.

Reflection of Light

- The process through which light rays falling on the surface on an object are sent back is called reflection of light. Thus, when light falls on the surface of an object it sends back the light.
- The objects having shiny or polished surfaces reflect more light compared to the objects having dull or unpolished surfaces. Silver metal is the best reflector of light. This is why a plane mirror is made by depositing a thin layer of silver metal on one side of a plane glass sheet. The silver coating is protected by a red paint.

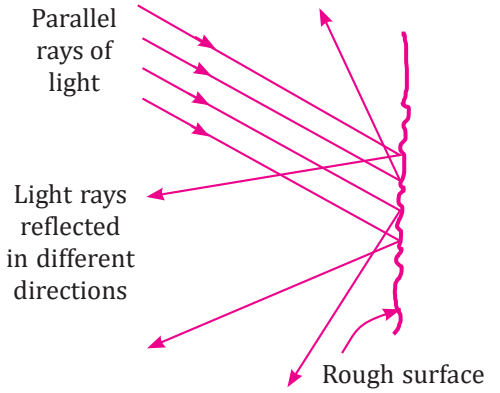
Regular Reflection and Diffuse Reflection of Light

- In regular reflection, a parallel beam of incident light is reflected as a parallel beam in one direction. In this case, parallel incident rays remain parallel even after reflection and go only in one direction and it occurs from smooth surfaces like that of a plane mirror or highly polished metal surfaces. Thus, a plane mirror produces regular reflection of light.
- Since the angle of incidence and the angle of reflection are the same or equal, a beam of parallel rays falling on a smooth surface is reflected as a beam of parallel light rays in one direction only. It is explained below in the figure



Regular reflection: Incident light is reflected in only one direction

Fig. 1.2



Diffuse reflection: Incident light is reflected in different direction

Fig. 1.3

- In diffuse reflection, a parallel beam of incident light is reflected in different directions. In this case, the parallel incident rays do not remain parallel after reflection, they are scattered in different directions. It is also known as irregular reflection or scattering and so, takes place from rough surfaces like that of paper, cardboard, chalk, table, chair, walls and unpolished metal objects.
- Since, the angle of incidence and angle of reflection are different, the parallel rays of light falling on a rough surface go in different directions as explained above in the figure.

Reflection of Light From Plane Mirror

- **Incident ray:** The ray of light falling on the surface of a mirror is called incident ray.
- **Point of incidence:** The point at which the incident ray falls on the mirror surface is called point of incidence.
- **Reflected ray:** The ray of light which is sent back by the mirror from the point of incidence is called reflected ray.
- **Normal:** A line perpendicular or at the right angle to the mirror surface at the point of incidence is called normal.
- **Angle of incidence:** The angle made by the incident ray with the normal is called angle of incidence.
- **Angle of reflection:** The angle made by the reflected ray with the normal at point of incidence is called angle of reflection.

Laws of Reflection of Light

- The laws of reflection of light apply to both plane mirrors as well as spherical mirrors.
- **First law of reflection:** According to the first law, the incident ray, reflected ray and normal, all lie in the same plane.
- **Second law of reflection:** According to the second law, the angle of reflection is always equal to the angle of incidence.

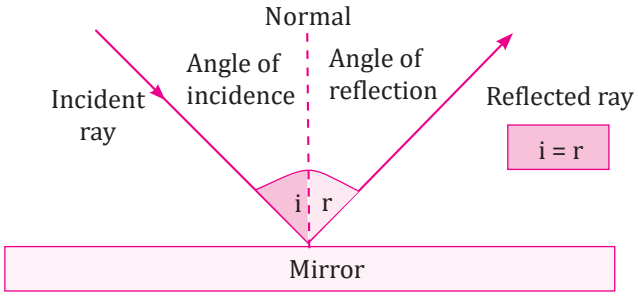


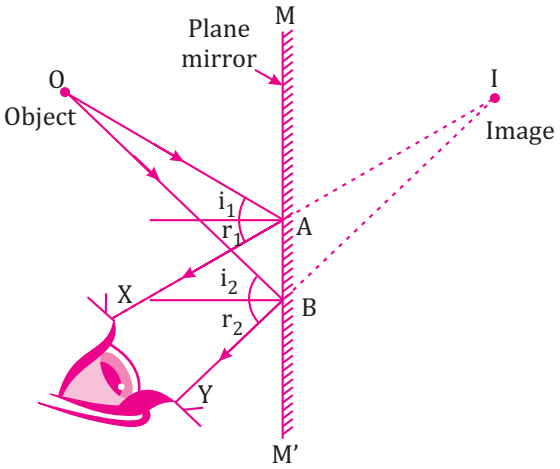
Fig. 1.4

- Also, when a ray of light falls normally on the surface of the mirror then the angle of incidence and the angle of reflection for such a ray of light will be zero. This ray of light will be reflected back along the same path.

Objects and Images

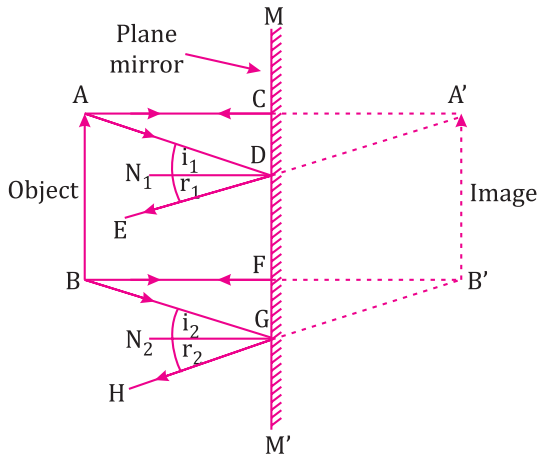
- Anything which gives out light off its own or reflected by it is called an object. For example, a bulb, a candle, a tree etc.
- When the light rays coming from an object are reflected from a mirror then an optical appearance which is produced is called an image. For example, when we look into the mirror, we see the image of our face.
- **Images are of two types**:
  1. **Real image:** The image which can be seen on screen is called a real image.
  2. **Virtual image:** The image which cannot be obtained on a screen is called virtual image.
- **Lateral inversion:** When we stand in front of a mirror and lift our right hand then the image formed will lift its left hand. Therefore the right side of our body becomes the left side in its image and the left side of our body becomes the right side in its mirror image.
- The change of sides of an object in its mirror image is called lateral inversion. It happens due to the reflection of light.

Formation of Image in a Plane Mirror



Formation of image in a plane mirror.

Fig. 1.5



The formation of image of an extended object (here an arrow AB) in plane mirror

Fig. 1.6

The nature of image formed by a plane mirror is:

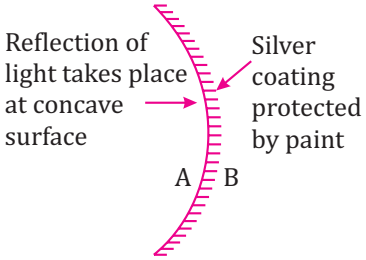
- Virtual and erect.
- The size of the image formed is equal to the size of the object.
- The image is formed behind the mirror.
- The image is at the same distance behind the mirror as the object is in front of the mirror.
- The image formed in the plane mirror is laterally inverted.

Uses of plane mirror

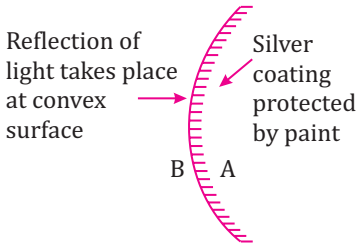
- Mirrors on our dressing table and bathrooms are plane mirrors and are used to see ourselves.
- They are fixed on the inside walls of jewellery shops to make them look big.
- They are fitted at blind turns on the roads so that the driver can see the vehicles coming from the other side.
- Used in making periscopes.

Reflection of Light From Spherical Mirrors

- A spherical mirror is that mirror whose reflecting surface is the part of a hollow sphere of glass.
- Spherical mirrors are of two types: concave mirror and convex mirror.
- In a **concave mirror** reflection of light takes place in the bent surface or concave surface. The inner shiny surface of a spoon is an example of a concave mirror.
- In a **convex mirror** the reflection of light takes place at the bulging-out surface or convex surface. The backside of a spoon is an example of a convex mirror.



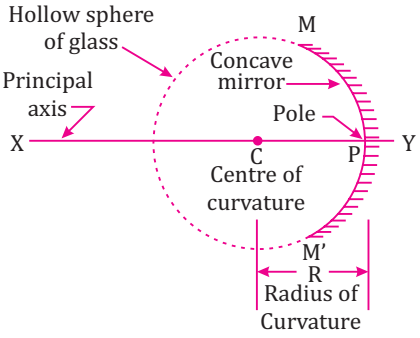
(*a*) A concave mirror



(*b*) A convex mirror

Fig. 1.7

- **Centre of curvature:** In a spherical mirror the centre of curvature is the centre point of the hollow sphere of a mirror. In a concave mirror, the centre of curvature is in front of it but in convex mirror it is behind the mirror.
- **Pole:** The centre point on the spherical mirror is called pole.
- **Radius of curvature:** The distance between centre of curvature and pole is called radius of curvature.
- **Principal axis:** The straight line passing through the centre of curvature and pole.
- **Aperture of mirror:** The portion of mirror from which reflection of light takes place.
- **Principal focus of concave mirror:** The point on the principal axis to which all the light rays which are parallel to the axis converge after reflection from the concave mirror.
- **Focal length of concave mirror:** The distance between pole and principal focus.
- **Principal focus of a convex mirror:** A point on the principal axis from which a beam of light rays appear to diverge after being reflected from the convex mirror.



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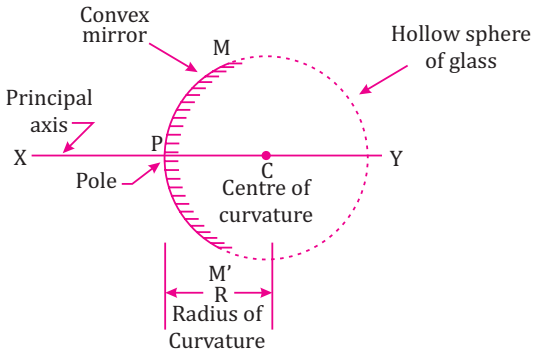
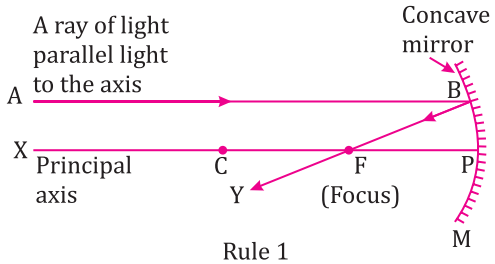


(*b*)

Fig. 1.8

Rules for Obtaining Images Formed by Concave Mirror

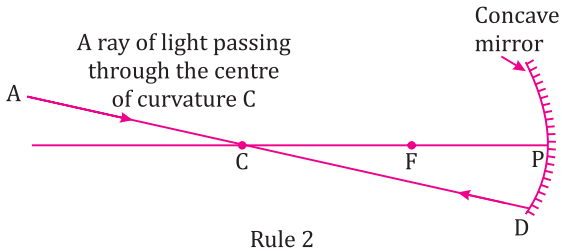
Rule 1: When a ray of light which is parallel to the principal axis gets reflected, it passes through its focus.



Rule 1

Fig. 1.9

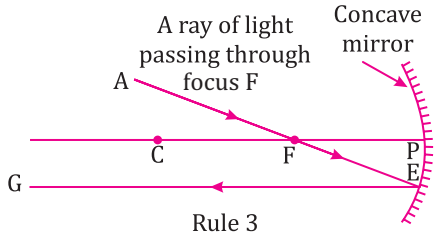
Rule 2: When a ray of light passes through the centre of curvature, it gets reflected back along the same path.



Rule 2

Fig. 1.10

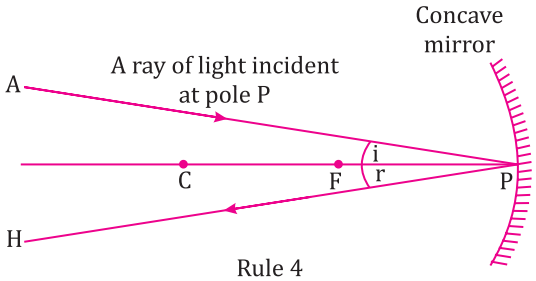
Rule 3: When a ray of light passes through the focus, it becomes parallel to the principal axis after reflection.



Rule 3

Fig. 1.11

Rule 4: A ray of light which is incident at the pole is reflected back making the same angle with the principal axis.



Rule 4

Fig. 1.12

Formation of Image by Concave Mirror

- **Case 1:** When an object is placed between the pole and focus (between P & F) of the concave mirror, then the ray of light will pass through focus and centre of curvature. The two reflected rays do not intersect each other on the left side and thus, are produced backwards to form an image.
- The image formed is: behind the mirror, virtual and erect, larger than the object.

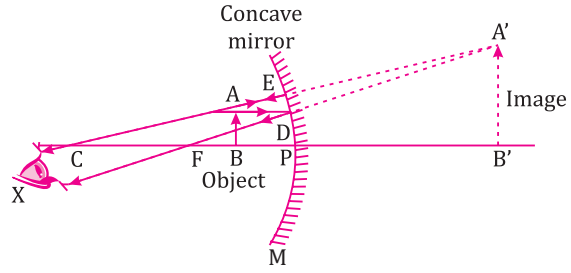


Fig. 1.13

- **Case 2:** When an object is placed at the focus *(at F)*, the reflected rays of light pass through focus and centre of curvature.
- The image formed is: at infinity, real and inverted and highly enlarged.

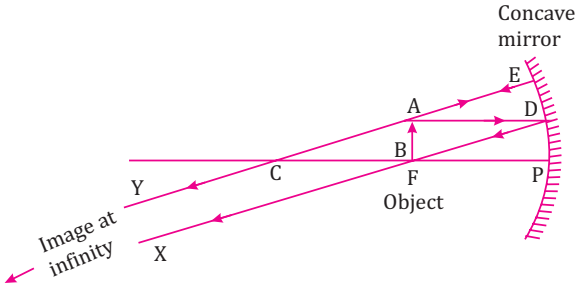


Fig. 1.14

- **Case 3:** When an object is placed between focus and centre of curvature (between F & C), the first ray of light passes through focus and second ray of light passes through centre of curvature. When these rays are further extended in the downward direction.
- The image formed is: real and inverted, larger than the object.

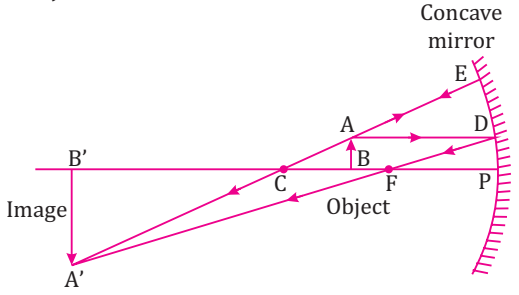


Fig. 1.15

- **Case 4:** When an object is placed at the centre of curvature (at C) both the rays pass through focus.
- The image formed is: at the centre of curvature, real and inverted, same size as that of an object.

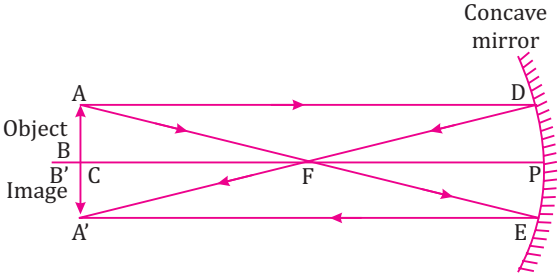


Fig. 1.16

- **Case 5:** When an object is beyond the centre of curvature (beyond C).
- The image formed is: between F and C, real and inverted, smaller than the object.

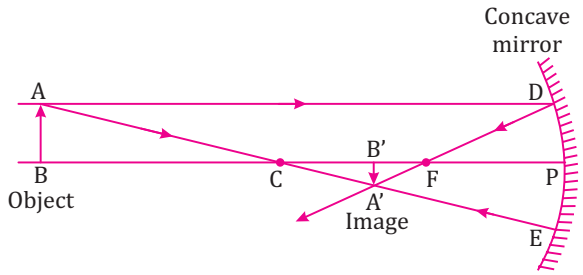


Fig. 1.17

- **Case 6:** When an object is at infinity (at infinity)
- The image formed is: at the F, real and inverted, much smaller than the object.

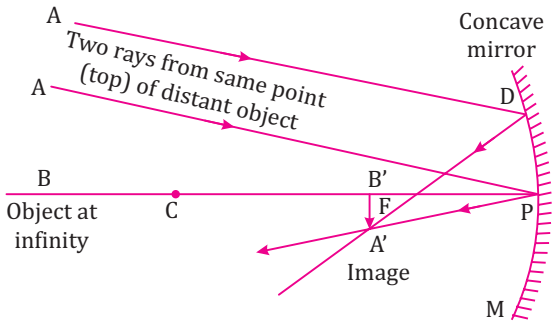


Fig. 1.18

Uses of Concave Mirror

- As reflectors in torches, vehicle head-lights and searchlights to get powerful beams of light.
- As shaving mirrors.
- They are used by dentists to see large images of teeth.
- They are used in the field of solar energy to focus sun's rays for heating solar furnaces.

Rules for Obtaining Images Formed by Convex Mirror

Rule 1: After reflection, a ray of light parallel to the principal axis appears to be coming from focus.

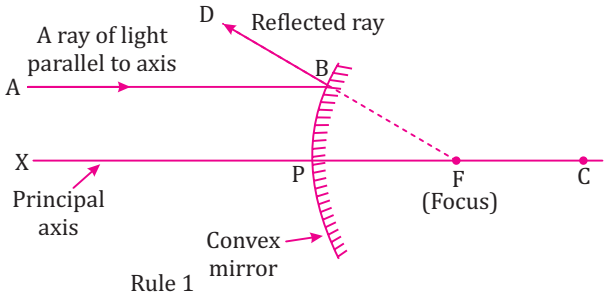


Fig. 1.19

Rule 2: A ray of light going towards the centre of curvature is reflected back along the same path.

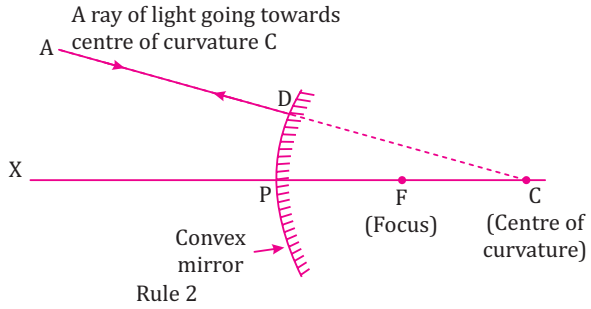


Fig. 1.20

Rule 3: After reflection, a ray of light going towards the focus becomes parallel to the principal axis.

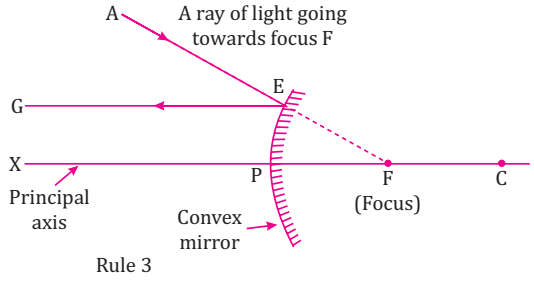


Fig. 1.21

Rule 4: Ray of light which is incident at the pole is reflected back making the same angle with the principal axis.

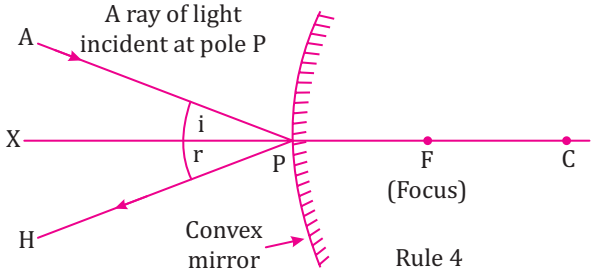


Fig. 1.22

Formation of Image by Convex Mirror

Case 1: When the object is placed anywhere between pole and infinity *(between P and infinity)*,

The image formed is: behind the mirror between P and F, virtual and erect, diminished.

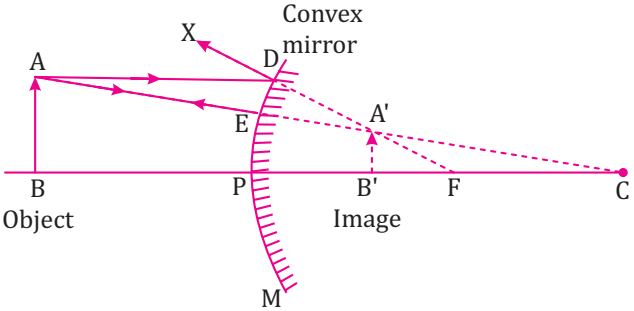


Fig. 1.23

Case 2: When the object is placed at infinity (at infinity), The image formed is: Behind the mirror at F, virtual and erect, highly diminished.

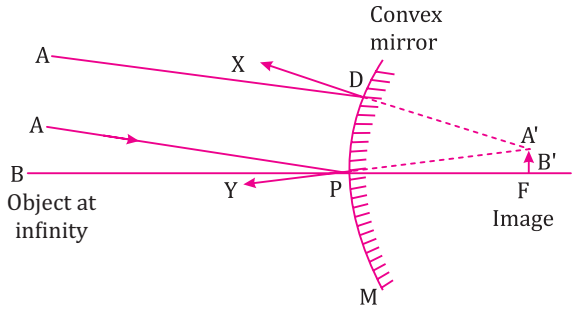


Fig. 1.24

Uses of Convex Mirror

- Enables drivers to view a much larger area of the traffic behind him.
- Big convex mirrors are used as 'shop security mirrors'.

Mirror Formula

- A formula which gives the relationship between image distance (v), object distance (u) and focal length (f) of a spherical mirror.

$$\frac{1}{\text{Image distance}}+\frac{1}{\text{Object distance}}=\frac{1}{\textit{Focal length}}\ i.e.,\ \frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

- Where v = Distance of image from mirror
  u = Distance of object from mirror
  f = Focal length of the mirror.
- The ratio of the height of an image to the height of an object is known as linear magnification.

$$\text{Magnification}=\frac{\text{Height of image}}{\text{Height of object}}\ \text{i.e. m}=\frac{h_2}{h_1}$$

- Where m = Magnification, h_1 = height of image, h_1 = height of object
- The height of the object (h_1) will always be positive. The height (h_2) of a virtual image will be positive and that of a real image will be negative. In other words, if the magnification has a plus sign, then the image is virtual and erect and if the magnification has a minus sign, then the image is real and inverted.
- Also, the linear magnification produced by a mirror is equal to the ratio of the image distance to the object distance, with a minus sign.

$$\text{Magnification}=\frac{-\text{ Image Distance}}{\text{Object Distance}}\ \text{i.e. m}=-\frac{v}{u}$$

- Where m = magnification, v = image distance, u = object distance
- Therefore, if $m = h_2/h_1$ and $m = -v/u$

Then, $\frac{h_2}{h_1}=-\frac{v}{u}$

1.4.2 Refraction of Light

Refraction of light takes place when light travels from one medium to another. It takes place at the boundary between the two mediums. The speed of light is different in different mediums. So, it occurs due to the change in speed of light on going from one medium to another. If the light rays are travelling from one medium to another they change their direction at the boundary between two mediums.

Refraction of Light

- When the light rays either bend or change their direction while passing from one medium to another it is called refraction of light. The refraction of light takes place when light travels from air into glass, from glass into air, from air into water or from water into air.
- The example of optical instruments that work on the basis of refraction of light are camera, microscope etc.
- **Incident ray:** The light rays passing from air into glass or water are called incident rays.
- **Refracted ray:** When the light rays bend after passing into another medium, they are called refracted rays.
- **Normal:** The point of incidence is called normal.
- **Angle of incidence:** The angle between incident ray and normal is called angle of incidence.
- **Angle of refraction:** The angle between refracted ray and normal is called angle of refraction.
- The angle of refraction is either smaller or greater than angle of incidence.

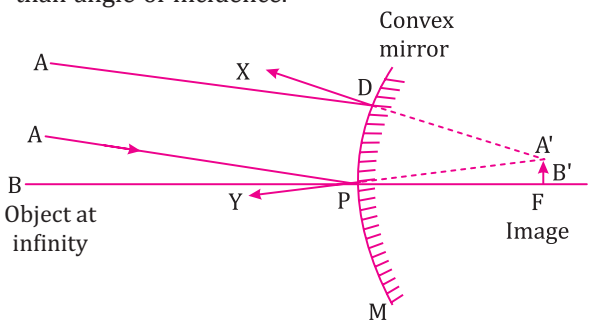


Fig. 1.25

Causes of Refraction

- Light travels at different speeds in different mediums. For example light travels faster in air than in glass. Therefore, it is due to the change of speed of light in different mediums that the light rays are refracted.

Optically Rarer Medium

- A transparent substance (medium) in which the speed of light is more is called optically rarer medium.

Optically Denser Medium

- A transparent substance (medium) in which the speed of light is less is known as optically denser medium.
- Glass is an optically denser medium than air and water.

Rules for Refraction of Light

- **Case 1:** When light rays travel from optically rarer medium to denser medium then they bend towards normal. In this case the angle of refraction is smaller than angle of incidence.

- When light rays travel from air into glass or from air into water, it bends towards normal. This is because the speed of light rays decreases while travelling from air into glass or water.

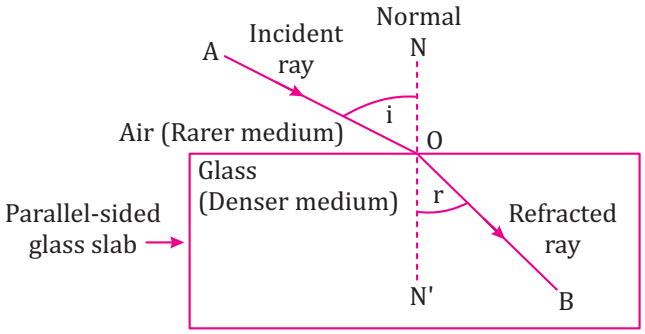


Fig. 1.26

- **Case 2:** When light rays travel from optically denser medium to rarer medium then they bend away from the normal. In this case the angle of refraction is greater than angle of incidence.
- When light rays travel from glass into air or from water into air they bend away from the normal. The speed of light rays increases while travelling from glass or water into air.

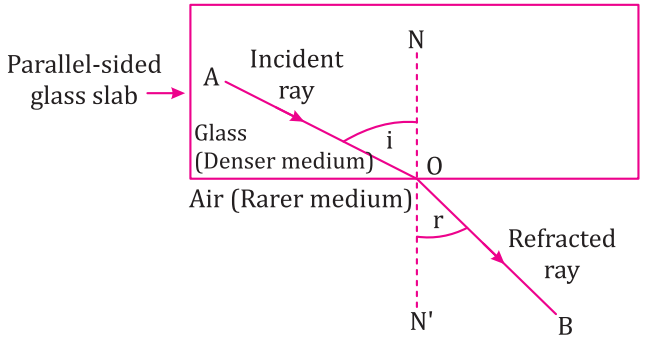


Fig. 1.27

Case of Light Going From Air Into Glass and Ggain Into Air

- In this case refraction of light takes place two times. One when it enters the glass slab from air and second time when it enters the air through glass slab.
- When light rays travelling through air enter a glass slab, they get refracted and bend towards the normal. Now the direction of the refracted ray changes again when it comes out of the glass slab into air. Since the ray of light travels from denser medium to rarer medium, it bends away from the normal.
- In this case the incident ray and the emergent ray are parallel to each other. The perpendicular distance between the original path of incident ray and the emergent ray coming out of the glass slab is called **lateral displacement of the emergent ray of light** and the angle which the emergent ray makes with the normal is called the *angle of emergence*.

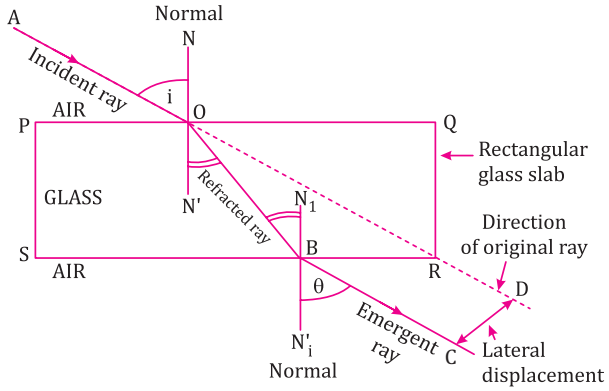


Fig. 1.28

Light Falling Perpendicularly on Glass Slab

- When light falls perpendicularly or normally on the surface of a glass slab, it goes straight. There is no bending of ray of light on entering the glass slab or coming out of it. In this case angle of incidence and angle of refraction is zero.
- The same happens if the ray of light falls perpendicularly on the surface of water.

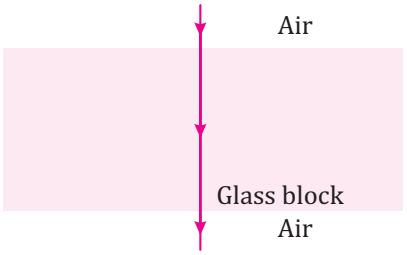


Fig. 1.29

Effects of Refraction of Light

- It is due to refraction of light that when we hold a stick obliquely and partially immersed in water it appears to bend at the surface of water.

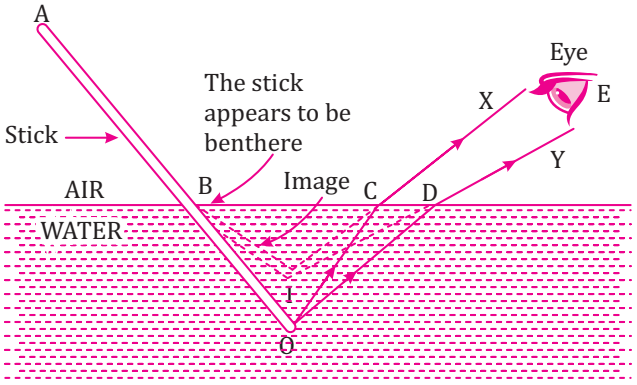


Fig. 1.30

- An object appears to be raised when placed under water.
- The pool of water appears less deep than it actually is.
- If a lemon is kept in a glass of water it appears to be bigger when viewed from the sides of the glass.

- It is due to refraction of light that stars appear to twinkle at night.

Laws of Refraction of Light

1. The incident ray, refracted ray and normal at the point of incidence, all lie in the same plane, i.e. the surface.

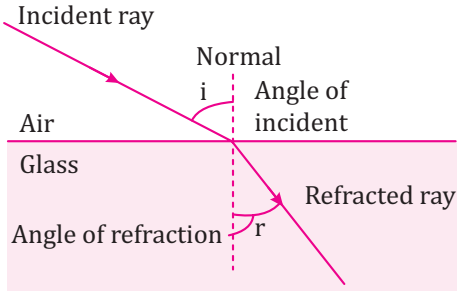


Fig. 1.31

2. The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media.

- Sine of angle of incidence/ sine of angle of refraction = Constant
- Constant is called refractive index.
- Or Sin i/ Sin r = constant
- The refractive index of a medium helps to know the light-bending ability of that medium.

Refractive Index and Speed of Light

- The refractive index of medium 2 with respect to medium 1 is equal to the ratio of speed of light in medium 1 to the speed of light in medium 2.

Relative Refractive Index

- When light travels from one medium to another other than vacuum and air, then the value of the refractive index is called relative refractive index.
- Refractive Index = Speed of light in vacuum/Speed of light in medium
- Or Refractive index = Speed of light in medium 1/ Speed of Light in medium 2
- For example, light travelling from water into glass.

Absolute Refractive Index

- When light travels from vacuum to another medium, it is called absolute refractive index. The substance that has higher refractive index is optically denser than another substance having lower refractive index. Also, the refractive index for light going from medium 1 to medium 2 is equal to the reciprocal of the refractive index of light going from medium to 2 to medium 1.

Refraction of Light by Spherical Lenses

- Refraction is the change in direction of light when it passes from one medium to another. The working of a lens is based on the refraction of light when they pass through it. Lens is a piece of transparent glass bound by two spherical surfaces and is used to magnify objects. They are of two types: convex and concave. The image produced by convex lens is enlarged and the image produced by concave lens is diminished.

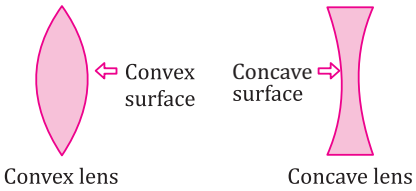


Fig. 1.32

- **Convex lens:** This lens bulges out at the centre and is thinner at the edges, i.e. the two sides.
- **Concave lens:** This lens is thinner at the centre and thick at the two sides.
- **Optical centre:** The centre point of a lens is called optical centre. The ray of light passing through the optical centre goes straight and does not deviate.
- **Principal axis:** A line passing straight through the optical centre in such a way that it is perpendicular to its sides from the centre, it is called principal axis.
- **Principal focus of a convex lens:** It is a point on the principal axis of the convex lens where all the light rays parallel to the principal axis converge after passing through the lens.
- If the light rays are coming from the left hand side they will converge at the right hand side of the lens and vice versa. That is why a lens has two foci. They are at equal distance from the optical centre.
- **Focal length of a convex lens:** The distance between the optical centre and principal focus of a lens is called *focal length.*

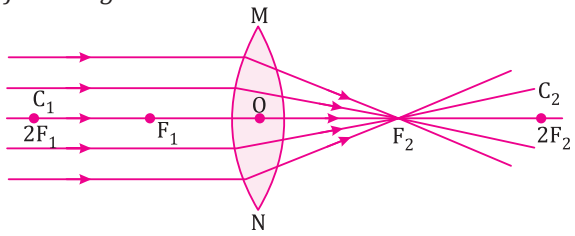


Fig. 1.33

- Focal length of a lens depends on the refractive index of the glass and its curvature. In case of higher refractive index, focal length will be short. Similarly, if the curvature of the lens is more than also the focal length will be short.
- A convex lens is also called a converging lens as the parallel beam of light rays passing through it converges at a single point.
- **Principal focus of concave lens:** All the light rays after passing through the concave lens diverge and when produced backwards appear to meet at a point on the principal axis of the lens. This point is known as the principal focus of a concave lens.
- Thus refracted rays appear to diverge from the focus. Concave lens is opposite to convex lens. The parallel beam of light rays is diverged after passing through it. The concave lens also has two foci. If the parallel light rays fall from the left side then they appear to diverge from a point on the left side only and if the light rays

fall from the right hand side they appear to diverge from a point on the right hand side.

- A concave lens is also known as a diverging lens. The image formed by this lens is virtual.
- **Focal length of concave lens:** The distance between optical centre and principal focus is called focal length of a concave lens.

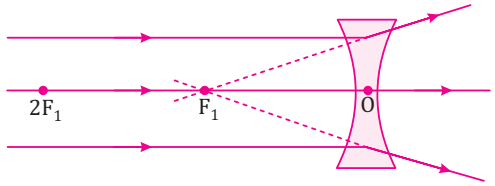


Fig. 1.34

Rules for Obtaining Images Formed by Convex Lens

- In **convex lenses,** the image is always formed at a point where at least two refracted light rays meet.
- **Rule 1:** A ray of light which is originally parallel to the principal axis passes through the focus after refraction through the lens.

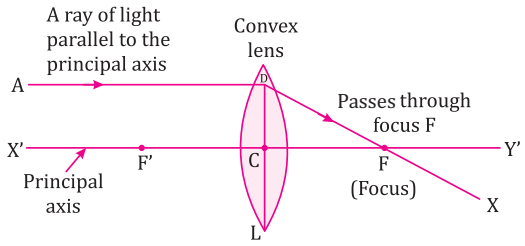


Fig. 1.35

- **Rule 2:** A ray of light passing through the optical centre of the convex lens does not bend after refraction but goes straight. Also, a ray of light going along the path of the principal axis of a convex lens also goes straight and does not deviate.

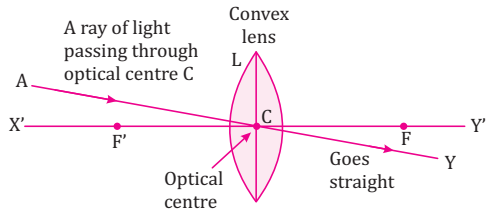


Fig. 1.36

- **Rule 3:** When a ray of light passes through the focus of the convex lens then it becomes parallel to the principal axis after refraction through the lens.

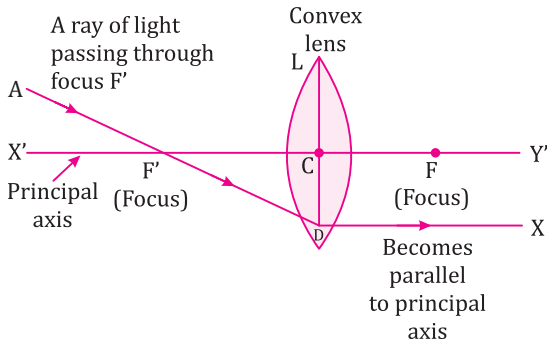


Fig. 1.37

Types of Images Formed by a Convex Lens

- The type of image formed by a convex lens depends on the position of the image.
- **Case 1:** If the object is placed between optical centre and focus (between C and F') then the first ray of light starting from the top of the object is parallel to the principal axis.
- Therefore, as per the rule, it passes through another focus after refraction through the lens. Another ray of light from the object passes through the optical centre of the lens and thus as per the rule goes straight after refraction through the lens.

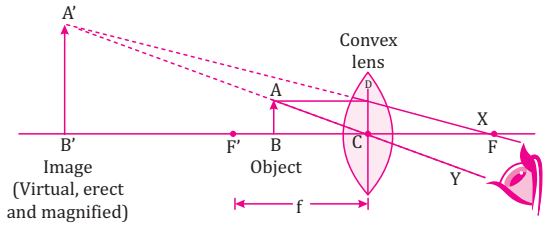


Fig. 1.38

- Thus, both the light rays diverge after refraction through the lens and do not meet. Therefore, both the refracted rays are produced backwards so that they meet at a point to form an image. The image formed will be: Behind the object, virtual and erect and larger than the object.
- **Case 2:** When the object is placed at the focus of the convex lens (at F') then it means that the object is placed at the distance equal to the focal length of the lens.
- One ray of light becomes parallel to the principal axis of the lens and thus, passes through another focus after refraction through the lens. Another ray of light passes through the optical centre of the lens and goes straight.

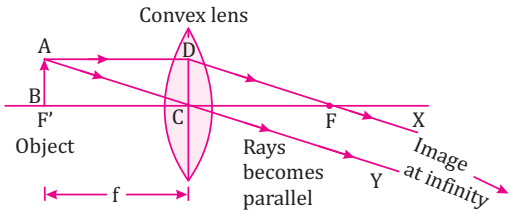


Fig. 1.39

- Therefore, the image formed is: At infinity, Real and inverted, highly enlarged.
- **Case 3:** When the image is placed between focus and distance less than twice the focal length (F' and 2F') then a ray of light parallel to the principal axis of the lens passes through another focus (F) after refraction through the lens.
- Another ray of light passes through the optical centre of the lens and goes straight.

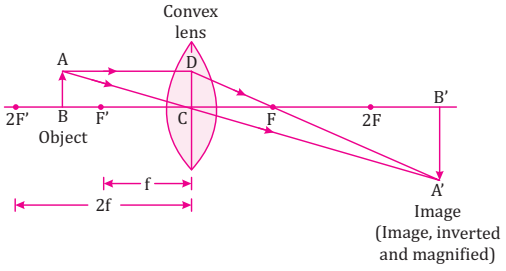


Fig. 1.40

- Therefore, the image formed is: Real and inverted, Larger than object and beyond 2F.
- **Case 4:** When the object is placed at the distance equal to twice the focal length (at 2F') of the convex lens then one ray of light becomes parallel to the principal axis and passes through another focus of the lens after refraction.
- Another ray of light passes through the optical centre and goes straight after refraction. Both the refracted light rays meet at 2F` on another side.

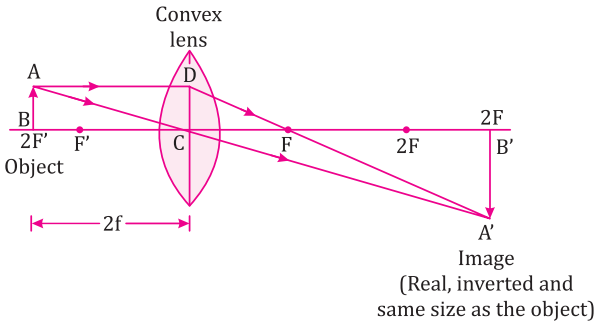


Fig. 1.41

- The image formed is: Real and inverted, same size as that of an object.
- **Case 5:** When the object is placed at a distance greater than twice the focus (beyond 2F') one ray of light becomes parallel to the principal axis and passes through focus after refraction through the lens and another light ray passes through optical centre and goes straight after refraction.

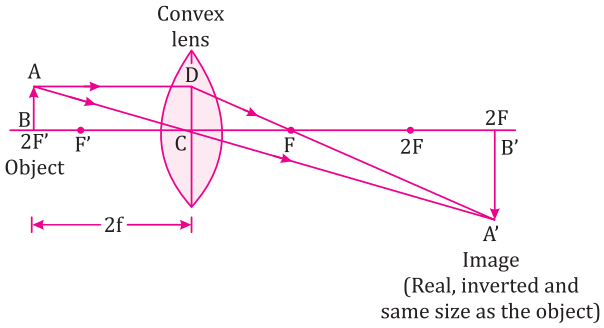


Fig. 1.42

- The image formed is: Between F and 2F, Real and inverted, Smaller than object.
- **Case 6:** When the object is placed at infinity, the light rays become parallel after reaching the lens.

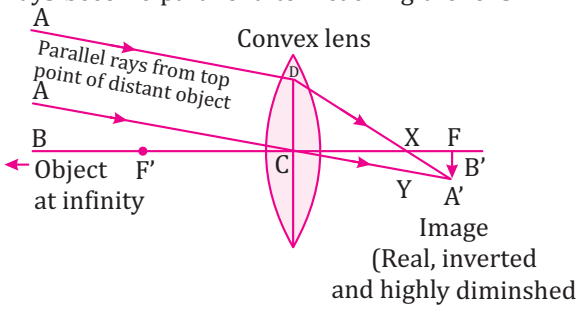


Fig. 1.43

The image formed is: At the focus on another side, Real and inverted, highly diminished.

Lens formula

- 1/image distance (v) – 1/object distance (u) = 1/focal length (f)

Magnification produced by the lens

- The size of the image relative to the object is given by the linear magnification. The ratio of the height of the image to the height of the object is called linear magnification.
- Magnification (m) = height of image (h_2)/height of object (h_1)
- **Another formula in terms of distance;**
- Magnification = image distance/object distance

Rules for Obtaining Images Formed by Concave Lens

- **Rule 1:** A ray of light parallel to the principal axis of the concave lens appears to be coming from focus after refraction through the lens.

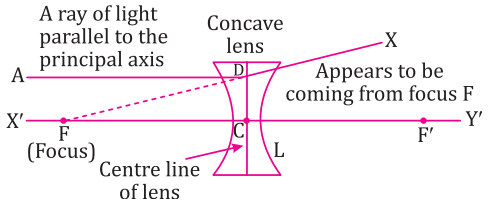


Fig. 1.44

- **Rule 2:** A ray of light passing through the optical centre of the concave lens goes straight after refraction through the lens.

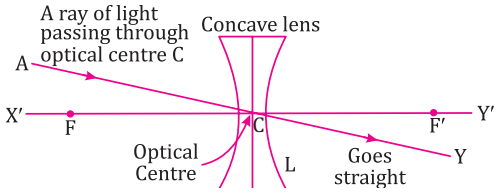


Fig. 1.45

- **Rule 3:** A ray of light going towards the focus on another side of the concave lens becomes parallel to the principal axis after refraction through the lens.

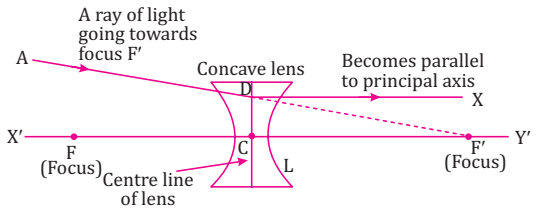


Fig. 1.46

Formation of Images by Concave Lens

- **The image formed by concave lens is always:** Virtual, Erect and Diminished.

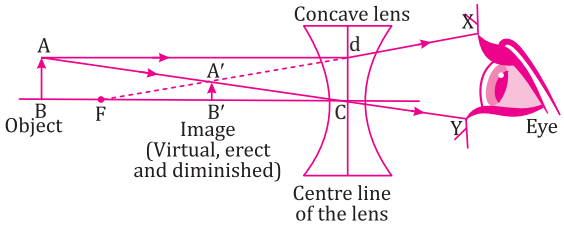


Fig. 1.47

- **Case 1:** When an object is placed anywhere between optical centre and infinity, the image formed is between optical centre and focus.
- **Case 2:** When an object is placed at infinity, the image formed by a concave lens will be at focus.

Power of Lens

- A measure of the degree at which a lens can converge or diverge, light rays falling on it is called power of lens.
- Power of lens (P) = 1/ focal length of the lens (f, in metres)
- A lens of short focal length has more power compared to a lens with long focal length. The SI unit of the power of lens is dioptre.

Power of Combination of Lenses

- The power of combination of lenses is equal to the algebraic sum of power of individual lenses.

  $P = p_1 + p_2 + p_3$.....
- The combination of lenses is used in cameras, microscopes, telescopes etc. Combination of lenses increases the sharpness of the image which is free from many defects.

1.4.3 Refraction of Light Through a Glass Prism

- Refraction is the bending of light when it goes from one medium to another so, when a ray of light passes through a glass prism, refraction of light occurs both, when it enters the prism as well as when it leaves the prism. Since the refracting surfaces are not parallel, therefore, the emergent ray and incident ray are not parallel to one another. In this case the ray of light is deviated on passing through the prism.
- A glass prism is a transparent object having two triangular ends and three rectangular sides. The refraction of light in a glass prism is different from a glass slab. This is because in a glass prism, the incident ray of light is not parallel to the emergent ray of light.

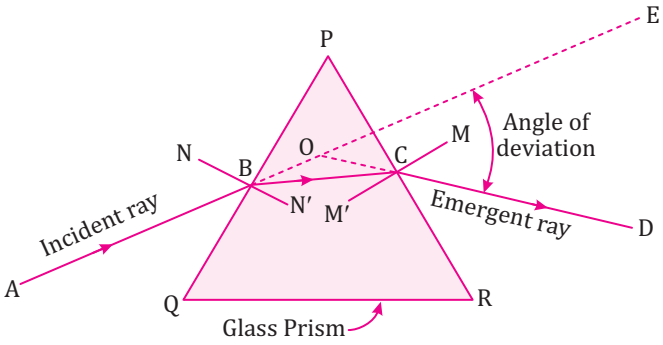


Fig. 1.48

- When a ray of light enters the glass prism it gets deviated two times. First when it enters the glass prism and second when it comes out of the prism. This is because the refracting surfaces of the prism are not parallel to each other. Also, when the ray of light passes through the prism it bends towards its base.

Dispersion of Light

- In 1665, Isaac Newton discovered that white light consists of seven colours. He found that if a beam of white light is passed through a glass prism then it will split into seven colours. These colours are red, orange, yellow, green, blue, indigo and violet (VIBGYOR).
- **Spectrum of white light:** The band of seven colours formed when a beam of white light passes through a glass prism is called spectrum of white light.
- **Dispersion of light:** The splitting of white light into seven colours on passing through a transparent medium is called dispersion of light.
- The dispersion of white light happens because the angle of refraction of lights of different colours is different while passing through the transparent medium. For example, red colour deviates least and is formed at the upper part of the spectrum and violet colour is deviated maximum and is formed at the bottom of the spectrum.

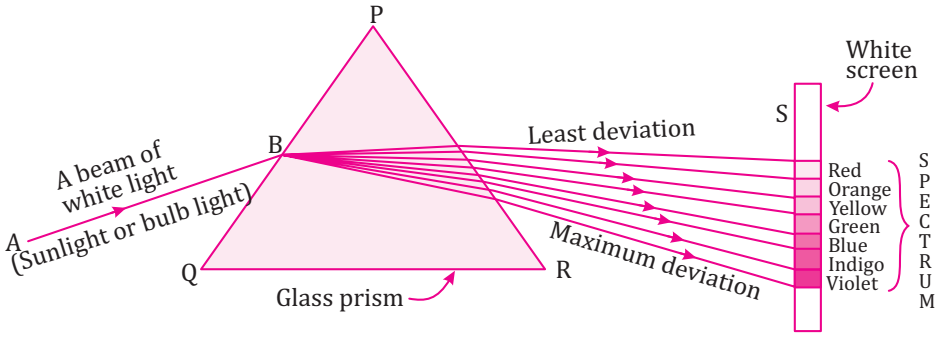


Fig. 1.49

Recombination of Spectrum of Colours

- A spectrum of seven colours of lights can be recombined to form back white light. This can be done by placing two glass prisms side by side. But, place the second glass prism in an inverted position. When white light passes through the first prism it disperses the light into seven colours and when this beam of light enters the second prism which is placed in an inverted position, a white light is obtained when it comes out of the second prism.

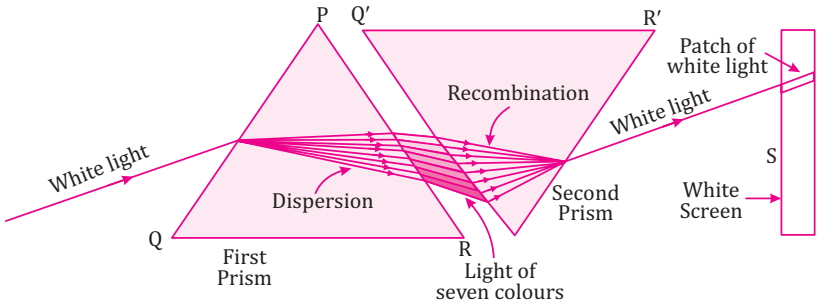


Fig. 1.50

The Rainbow

- A rainbow is formed when it is raining at the time of sunshine. When the white sunlight falls on the raindrops and leaves them, then the white light is refracted and an arc of seven colours is formed in the sky. In this situation, tiny raindrops act as glass prisms splitting the white sunlight.

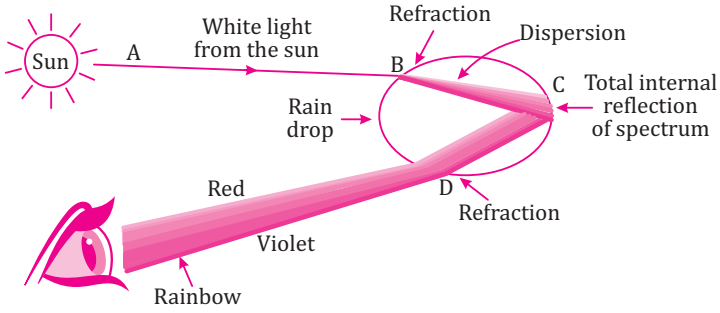


Fig. 1.51

Atmospheric Refraction

- When the refraction of light takes place due to earth's atmosphere it is called **atmospheric refraction**. So, when light rays enter the atmosphere there is air and every air layer has a different temperature. These air layers have different optical densities. Cooler air layer is an optically denser medium for light rays whereas warmer air layer is optically rarer medium for light rays.
- The following are the examples of atmospheric refraction of light.
  1. **Twinkling of stars:** Stars twinkle at night because their light is refracted in the atmosphere. When the light of a star enters the earth's atmosphere it undergoes refraction due to different optical densities of the air. Therefore, stars appear bright at one moment and dim in another.
  2. **Stars appear higher than they are:** The light from stars is refracted as it comes down into earth's atmosphere. The air higher up in the sky is rarer and near the earth's surface is denser. As the star light falls down the dense air bends it more and thus stars appear higher than they actually are.

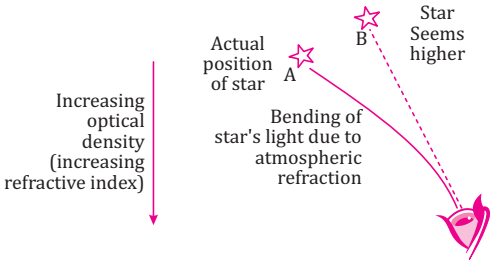


Fig. 1.52

  3. **Advance sunrise and delayed sunset:** It is due to refraction of light that we are able to see the sun two minutes before sunrise and two minutes after actual sunset. At the time of sunrise the sunlight is coming from less dense air to more dense air. In this case the sunlight is refracted downwards and because of this the sun appears to be raised above the horizon than it actually is.

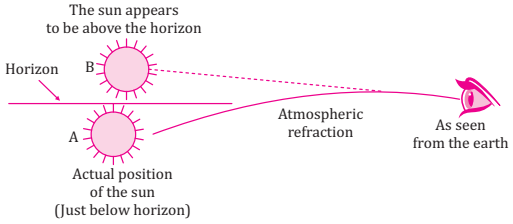


Fig. 1.53

Scattering of Light

- Throwing light in various random directions on various types of suspended particles is called scattering of light.

Tyndall Effect

- When light is scattered due to particles in its path, it is called the Tyndall effect. The way a beam of sunlight becomes visible when it passes through dust particles in a room, when sunlight passes through a canopy of dense forest etc., are examples of Tyndall effect.
- In 1859, Tyndall discovered that when white light is passed through clear liquid having small suspended particles, then the blue colour of white light has shorter wavelength and is scattered more than the red colour that has longer wavelength.

- The colour of scattered light depends on the size of particles
  - It is due to the scattered large dust particles and water droplets in the atmosphere that when white sunlight falls on them it is reflected in such a way that the scattered light also appears white. Dust particles and water droplets in the atmosphere are larger than the wavelength range of the visible light.
  - The extremely small air molecules in the atmosphere scatter mainly blue light when white sunlight falls on them. This is because blue colour has lower wavelength and is much more by the air molecules.

Why is the Sky Blue?

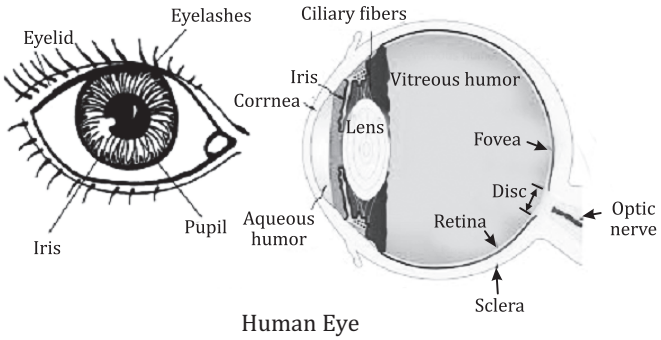
When white sunlight falls in the atmosphere, lights with longer wavelengths are not scattered by the air molecules. It is only the blue light which has a shorter wavelength that is scattered most by the air molecules in the atmosphere. This is why the sky looks blue.

Why Does the Sun Appear Red at Sunrise and Sunset?

At the time of sunrise and sunset all the blue coloured light is scattered out and is away from our sight. So the light reaching us mainly at the time of sunrise and sunset is red which has a longer wavelength.

1.4.4 The Human Eye: Anatomy, Structure, Working, Function and Defects

- The Human eye works on the refraction of light through a natural convex lens made up of transparent living material and enables us to see things around us. Also, the ability to see is called vision, eyesight, or drishti.



Human Eye

Fig. 1.54

- Sometimes a person cannot see distant or nearby objects clearly and have a defect of vision which can be fixed by wearing spectacles. The human eye consists of the cornea, iris, pupil, ciliary muscles, eye lens, retina, and optical nerve.

Construction of Eye

- The front part of the eye called the cornea is made of a transparent substance and its outer surface is convex in shape. It is through the cornea that the light coming from objects enters the eyes. Just behind the cornea is the iris which is also called coloured diaphragm. A hole in the middle of the iris is called the pupil. Then behind it is the eye lens which is a convex lens. It is due to the support of ciliary muscles that the eye lens is held in position. The eye lens is flexible and thus can change its focal length and shape with the help of ciliary muscles.Behind the eye lens is the retina on which the image is formed in the eye.

Working of the Eye

- The light rays coming from the object enter the eyes through the pupil and fall on the eye lens. The eye lens then converges the light rays and produces an image of the object on the retina which is real and inverted. Retina has a large number of light-sensitive cells that can generate electrical signals. After the image is formed on the retina it sends electrical signals to the brain and we have a sensation of image. Also, even though the image formed on the retina is inverted our mind interprets it as erect.
- So, the eye lens is the convex lens and the retina is the screen of the eye.

The Function of Iris and Pupil

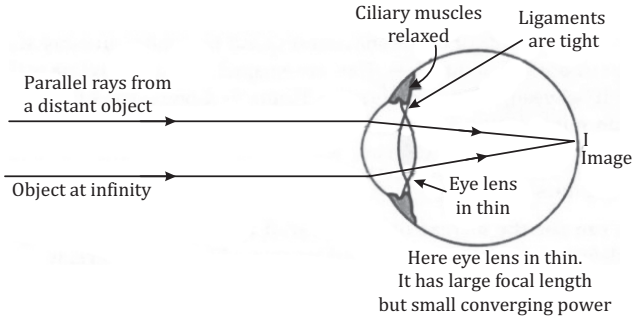
- The function of iris is to adjust the size of the pupil. If the amount of light entering the eye is less then the pupil expands so that more light can enter the eye and in case the amount of light entering the eye is large then the pupil contracts.
- The adjustment of the size of the pupil takes some time and this is the reason when we go outside in the sunlight from a dark room we feel glare in our eyes or if we enter a dark room after coming from outside we see things clearly after some time.

How do we see colours

- **The light-sensitive cells in the retina of our eye are of two shapes; rod shaped and cone shape.** The function of rod-shaped cells is to respond to the brightness of the light. And the function of cone-shaped cells is to make us see colours and distinguish between them.
- Seeing distant and nearby objects
- **Distant objects:** When the rays of light are coming from distant objects they are diverging at the beginning but become parallel when they reach our eye. Therefore to see a distant object, we need to have a convex eye-lens of low converging power to focus them to form an image on the retina of the eye. The convex eye-lens of low converging power have a large focal length and are quite thin.
- **Nearby objects:** When the rays of light are coming from the nearby objects they diverge when they reach our eyes. Therefore, to see a nearby object we need to have a convex eye-lens of high converging power so as to focus and form an image on the retina. Convex eye-lens with high converging power have short focal length and are thick.

Power of Accommodation of the Eye

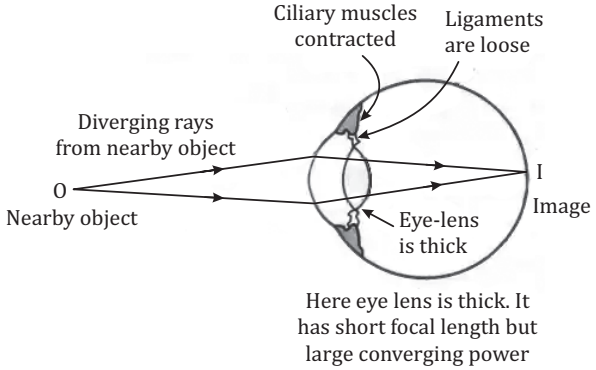
- The ability of the eye to focus distant as well as nearby objects clearly on the retina of the eye is called **accommodation**.
- When our eyes see distant objects then the ciliary muscles relax and the focal length is maximum in this position. The eye-lens then converge the parallel rays of light to form an image of the distant object on the retina. When the eye sees the distant object they are said to be unaccommodated.



An eye focused on a distant object (at infinity)

Fig. 1.55

- And when our eyes see nearby objects then the ciliary muscles get stretched and its focal length decreases. Due to this, the converging power of the eye lens increases, and the diverging rays of light coming from objects converge to form an image on the retina. When the eyes see the nearby objects they are said to be accommodated.



An eye focused on a nearby object

Fig. 1.56

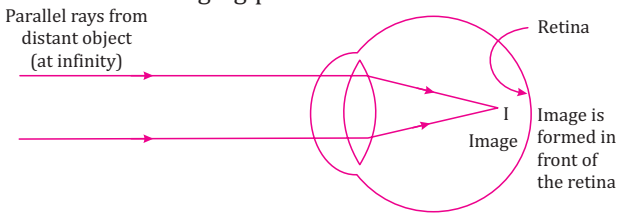
- The power of accommodation of a normal eye that enables it to see clearly an object is as close as 25 cm and as far as at infinity.

Defects of Vision and Their Corrections

- There are three common defects of vision. They are:
  1. Myopia (Short-sightedness or Near-sightedness)
  2. Hypermetropia (Long-sightedness or Far-sightedness)
  3. Presbyopia

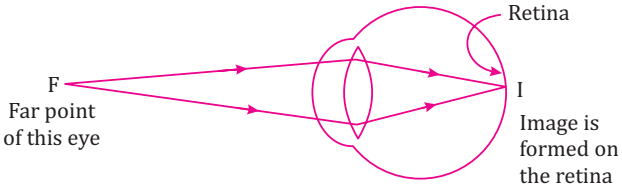
Myopia

- The defect of an eye in which it cannot see distant objects clearly is called *myopia*. A person with myopia can see nearby objects clearly. Myopia is caused due to:
  - High converging power of the lens
  - Eye-ball being too long
- Due to the high convergence of the eye-lens, the image is formed in front of the retina and a person cannot see distant objects. In another case, if the eyeball is too long then the retina is at a larger distance from the eye-lens. In this case, also the image is formed in front of the retina even though the eye-lens has correct converging power.



In a myopic eye, image of distant object is formed in front of the retina (and not on the retina)

Fig. 1.57



The far point (F) of a myopic eye is less than infinity

Fig. 1.58

- **Myopia or short-sightedness can be corrected by wearing spectacles containing a concave lens.** This is because when a concave lens of suitable power is used for the myopic eye then the concave lens first diverges the parallel rays of light coming from a distant object. Therefore, first, a virtual image is formed at the far point of the myopic eye. Now since the rays of light appear to be coming from the eye's far point, they are easily focussed by the eye-lens, and the image is formed on the retina. A concave lens is used for a myopic eye so as to decrease the converging power of the eye-lens.

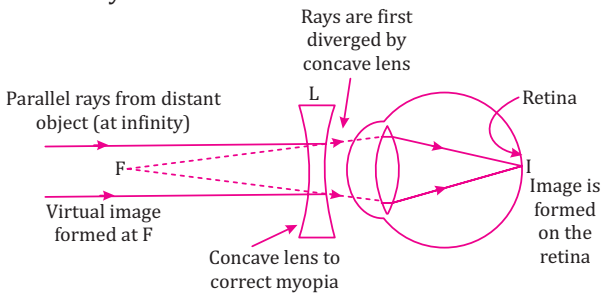
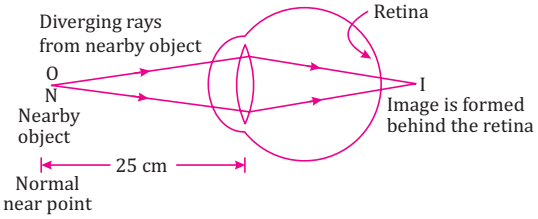


Fig. 1.59: Correction of myopia. The concave lens placed in front of the eye froms a virtual image of distant object at far point (F) of the myopic eye

- The formula for calculating the power of the concave lens to correct myopia is:
- 1/image distance (v) – 1/object distance (u) = 1/focal length (f)

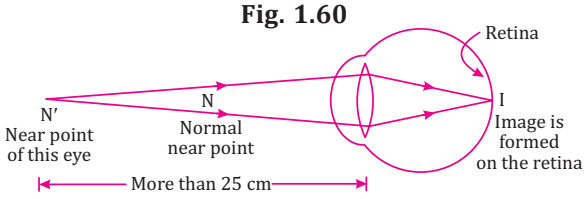
Hypermetropia

- **Hypermetropia or long-sightedness** is a defect of an eye where a person cannot see nearby objects clearly. The near-point of the hypermetropic eye is more than 25 cm away. This defect of the eye is caused due to:
- Low converging power of eye-lens
- Eye-ball being too short
- In the case of hypermetropia, the image of an object is formed behind the retina and therefore, a person cannot see clearly nearby objects.



In a hypermetropic eye, the image of nearby object lying at normal near point N (at 25 cm) is formed behind the retina.

Fig. 1.60



The near point N′ of hypermetropic eye is farther away from the normal near point N

Fig. 1.61

- The near-point of an eye having hypermetropia is more than 25 cm. **The condition of hypermetropia can be corrected by putting a convex lens in front of the eye.** This is because when a convex lens of suitable power is placed in front of the hypermetropic eyes, then the convex lens first converges the diverging rays of light coming from a nearby object at the near point of the eye at which the virtual image of the nearby object is formed. Since the light rays now appear to be coming from the eye's near point, the eye-lens can easily focus and form the image on the retina. A convex lens is used for hypermetropia so as to increase the converging power of the eye-lens.

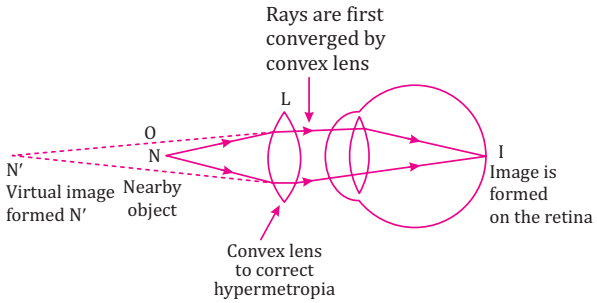


Fig. 1.62

- **Correction of Hypermetropia:** The convex lens forms a virtual image of the object (lying at normal near point N) at the near point N' of this eye.
- The formula for calculating power of convex lens to correct hypermetropia is:

$$1/v - 1/u = 1/f$$

- In this formula, the object distance that is u is normal near the point of the eye (25 cm).

Presbyopia

- This defect of vision usually happens in old age when ciliary muscles become weak and can no longer adjust the eye-lens. The muscles become inflexible in this condition and cannot see nearby objects clearly.
- The near-point of an old person having presbyopia is much more than 25 cm. Presbyopia can be corrected by wearing spectacles having a convex lens.
- *Another point to be noted is that a person can have both myopia and hypermetropia. In such a condition, spectacles having a bifocal lens are worn. The upper part of the bifocal lens is concave and the lower part consists of a convex lens.*

Cataract

- Yet another defect of the eye which usually comes in old age is the **cataract**. The medical condition in which the lens of the eye of a person becomes progressively cloudy resulting in blurred vision. It develops when the eye-lens of a person becomes cloudy due to the formation of a membrane over it. It decreases the vision of the eye gradually and can lead to a total loss of vision of the eye. It can be restored after getting surgery. The opaque lens is removed and an artificial lens is inserted in its place via operation. This defect cannot be corrected by any type of spectacle lens.

Why do we have two eyes for vision?

- Two eyes give a wider field view of 180 degrees.
- Two eyes help judge the distance of an object more accurately.

1.5 HEAT AND THERMODYNAMICS

1.5.1 Heat

- Heat is the energy that gets transferred from one system to another system because of the difference in temperature. Its SI unit is Joule. Calorie is also used as a unit of heat.

1.5.2 Temperature

- Temperature is a thermal state of an object, which expresses the direction of flow of heat. Heat always transfers from a substance of higher temperature to a substance of lower temperature.

1.5.3 Measurement of temperature-

- A thermometer is an apparatus used for measuring temperature. To measure temperature, following thermometers are in use-

1. **Celsius (Centigrade) Scale:** A scale of temperature in which O°C represents the melting point of ice and 100°C represents the boiling point of water.

2. **Kelvin Scale:** On Kelvin Scale, ice melting point is 273 K while the boiling point of water is 373K. Thus 0°C temperature on the Celsius scale is equal to 273 K on the Kelvin scale. So, temperature on Kelvin scale = temperature on Celsius scale + 273.

   K = C + 273

3. **Fahrenheit Scale:** On this scale the melting point of Ice is 32°F and boiling point of water is 212°F.

Relation Netween Celsius and Fahrenheit Scale

- If Temperature C is at the Celsius scale & F on Fahrenheit scale, then

  C/5 = F – 32/9

1.5.4 Effects of Temperature on Matter

- With the increase in temperature solid state converts into liquid state and liquid state converts into a gaseous state while a decrease in temperature, gaseous form converts into liquid form and liquid converts into a solid form.

  1. **Melting:** A process in which solid converts into liquid by heating. The temperature at which solid matter melts and converts into a liquid at atmospheric pressure is known as its melting point. For example, ice melts at 0°C into water. So, the melting point of ice is 0°C.
  2. **Boiling:** The process in which Liquid converts into vapours by heating is known as boiling. The temperature at which liquid boils and converts into vapours very fast at atmospheric pressure is termed as boiling point. Different liquids have different boiling points.
  3. **Condensation:** The condensation process is the change of physical condition of matter from gas to liquid and it is the contrast phenomenon of vaporisation.
  4. **Freezing:** It is the process in which a liquid turns into a solid when its temperature is lowered below its freezing point and this process is the contrast of melting. On cooling a liquid, the temperature at which it turns into a solid is known as its freezing point. The freezing point of water is 0°C. The freezing point of the liquid and the melting point of solid are the same. For example-water freezes at 0°C and ice melts at 0°C.

1.5.5 Latent Heat

- The heat required to turn a solid into a liquid or vapour or a liquid into vapour, without change of temperature is known as latent heat.

Latent Heat is of Two Types

(i) Latent heat of **melting.**

(ii) Latent heat of **vaporisation.**

Latent Heat of Melting

- The energy required for converting solid into liquid phase is called latent heat of melting. The value of latent heat of ice is 3.34 × 10' joule/kg.

Latent Heat of Vaporisation

- The energy required for converting liquid into vapour is called latent heat of vaporisation. The value of latent heat of water is 22.5 × 10' joule/kg.

1.5.6 Sublimation

- On heating when a solid changes directly into vapour and on cooling when vapour changes directly into solid then that phenomenon is known as sublimation. Some substances having this property are Ammonium chloride, Iodine, Camphor and Naphthalene, etc.

1.5.7 Evaporation

- The process in which liquid turns into vapours below its boiling point is termed as evaporation. It may occur at room temperature.
- Wet clothes dry due to evaporation of water. The rate of evaporation of any liquid is maximum at its boiling point.

1.5.8 Heat and work

- Heat as energy is collectively possessed by the particles making up a gas, liquid or solid. A body which possesses energy has the ability to do work. Work is done when a force (F) moves through a distance (d): W = F × d. If F is measured in newtons and d in metres, then W is measured in Nm, otherwise called joules.

1.5.9 Thermodynamics

- Thermodynamics is the study of the behaviour and properties of heat, energy and temperature within systems.

The First Law of Thermodynamics

- The first law of thermodynamics states that the total amount of energy in any closed system always remains the same. In other words, energy is always conserved as it is transferred from one form to another.

The Second Law of Thermodynamics

- The second law of thermodynamics states that heat will always flow from a hotter object to a colder one, and not the other way round. It involves the term entropy. Entropy is a measure of the disorder of a system.

The Third Law of Thermodynamics

- The third law states that on approaching absolute zero, extracting energy from a system becomes increasingly harder. All bodies have thermal energy, or heat. Absolute zero is the theoretical point at which a body ceases to have any heat.
- This value is –273.15°C (–459.67°F) or 0°K (Kelvin). At this temperature, which is impossible to physically attain, the molecules in a body will cease to vibrate, and thus the body will have no internal energy.

1.5.10 Thermal Expansion of Solids, Liquids and Gases

- The change in temperature of a body causes expansion or contraction of that body. Most of the substances expand on heating and contract on cooling. This is called thermal expansion. The level of mercury rises with temperature, wires attached to electric poles contract or expand with change in season, etc. This all is due to thermal expansion.
- It has been observed that bottles which are tightly sealed with a metallic lid are easily opened when the bottle is kept upside down in hot water for some time in such a way that just the lid is immersed in water. In this way the metallic lid expands and opens easily.

Thermal Expansion of Solids, Liquids and Gases

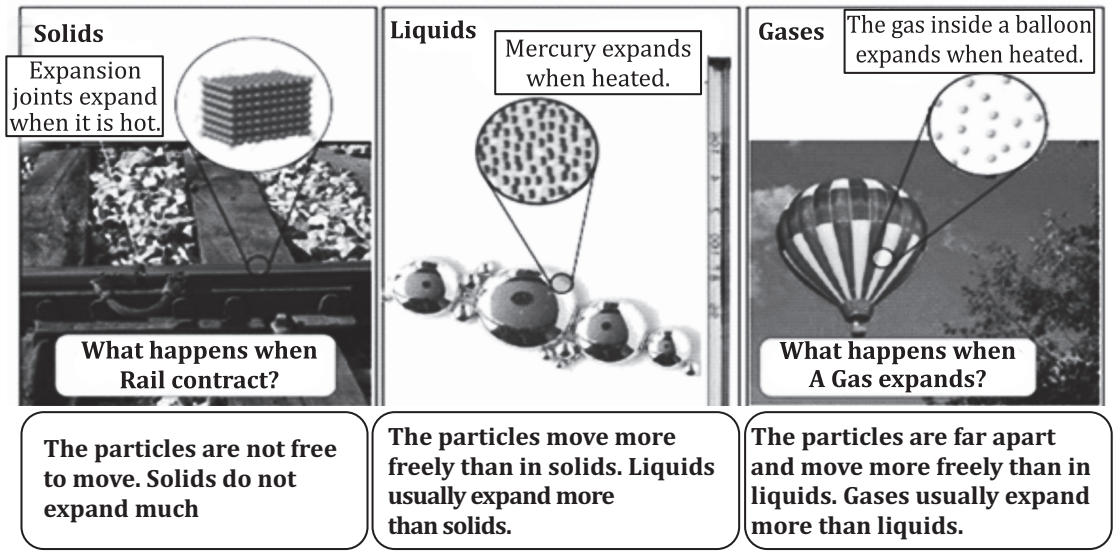


Fig. 1.63

- In case of gases, when a balloon is partially inflated in a cool room it expands to full size when put in warm water. This all is due to thermal expansion.
- So, the increase in dimension of a body due to increase in temperature is thermal expansion. The expansion in length is called **linear expansion**. The expansion in area is called **area expansion**. The expansion in volume is called **volume expansion**. Coefficient of thermal expansion measures the fractional change in size due to small change in temperature.
- Metals expand more and have relatively high values of coefficient of linear expansion.
- The fractional change in volume of a substance due to change in temperature is called the coefficient **of volume expansion.**
- In terms of thermal expansion water shows a typical behaviour. It contracts on heating between 0°C and 4 degree C. The volume of a given amount of water decreases as it is cooled from room temperature, until its temperature reaches 4°C. Below 4°C, the volume increases and density decreases.
- This means that water has a maximum density at 4°C. Due to this property water bodies like lakes and ponds freezes at the top first.
- At ordinary temperature gases expand more than solid and liquid. The coefficient of gas expansion is dependent on temperature. For an ideal gas, the coefficient of volume expansion at constant pressure can be found from the ideal gas equation:

  $PV = \mu RT$
- At constant pressure

  $P\Delta V = \mu R\, \Delta T$

  $\Delta V/V = \Delta T/T$

i.e. $\alpha v = 1/T$ for ideal gas

- At 0°C, $\alpha v = 3.7 \times 10^{-3}\ K^{-1}$, which is much larger than that for solids and liquids.
- There is a relation between the coefficient of volume expansion and coefficient of linear expansion. If thermal expansion of a rod is prevented by fixing its ends rigidly the rod will undergo compressive strain due to external forces provided by the rigid support at the ends. The corresponding stress set up in the rod is called **thermal stress**.

1.6 WAVES

- A wave is a phenomenon whereby energy is moved without the transference of any material. X-rays, ultraviolet rays, light and radio waves all travel at the same speed through a vacuum. Examples of waves include water waves, sound waves, light and X-rays.
- A wave is a vibratory disturbance in a medium which carries energy from one point to another without there being a direct contact between the two points.

- We can say that a wave is produced by the vibrations of the particles of the medium through which it passes.
- There are two types of waves: Longitudinal waves and Transverse waves.
- **Longitudinal Waves**: A wave in which the particles of the medium vibrate back and forth in the 'same direction' in which the wave is moving. Medium can be solid, liquid or gases. Therefore, sound waves are longitudinal waves.
- **Transverse Waves**: A wave in which the particles of the medium vibrate up and down 'at right angles' to the direction in which the wave is moving. These waves are produced only in solids and liquids but not in gases.

1.6.1 Wavelength and Frequency

- The distance between successive wave crests is called the wavelength, λ (lamda).
- The frequency (f) of a wave is defined as the number of complete oscillations per second. Frequency is measured in hertz (Hz). Audible sound frequencies range from 20 Hz to about 20,000 Hz.
- The speed of a sound wave in air at 20°C (68°F) is 344 m/s, but in water sound travels at 1461 m/s and in steel its speed is 5000 m/s.

1.6.2 Properties of Waves

- Waves have several properties, including reflection, refraction, diffraction and interference.

Reflection

- Reflection is the process whereby part or all of a wave is returned when it encounters the boundary between two different materials or media.
- An important example of a wave reflection is an *echo*, when sound waves bounce off a faraway surface.

Refraction

- Refraction is the change of direction of a wave front as it passes obliquely (at any angle which is not perpendicular or parallel) from one medium to another in which its speed is altered.
- An example is when light enters a lens or prism – the light is bent. It is the principle of refraction that makes the lenses in spectacles work.

Diffraction

- Diffraction occurs when waves passing through a slit which is narrow compared to the wavelength are spread out and depart from the expected straight line direction.
- This explains how we can hear the words of someone who is facing away from us.

Interference

- Interference is the phenomenon that occurs when two or more waves combine together as dictated by the principle of superposition.
- The superposition principle states that when two waves are in the same place at the same time, their amplitudes (heights) are combined.
- If the resultant wave amplitude is greater than that of the individual waves then constructive interference is taking place. If the resultant wave is smaller, then destructive interference is taking place.

1.6.3 Electromagnetic Waves

- **Electromagnetic waves** are caused by a mutual fluctuation in electric and magnetic fields.
- All the properties of sound and water waves, such as refraction and diffraction, exist in electromagnetic waves, but they differ in that they are able to transmit energy in a vacuum.
- They travel extremely fast: at 299,792,458 m/s in a vacuum.
- Electromagnetic waves include light, microwaves, infrared radiation and X-rays.

Sr/no	Wave	Discoverer	Wavelength	Application
1	**Gamma rays**	**Henri Becquerel Paul Villard**	10^{-14} to 10^{-10}	Maximum penetrating power. Application in nuclear reaction and artificial radioactivity. Also used in Radiotherapy to kill cancer cells.
2	**X rays**	**Rontgen**	10^{-10} to 3×10^{-8}	Medical sciences and Industries
3	**Ultra violet rays**	**Ritter**	10^{-8} to 4×10^{-7}	Medical sciences, food and drug industries, production of Vitamin D
4	**Visible light**	**—**	4×10^{-7} to 7.8×10^{-7}	Sense of Sight for Human Eye
5	**Infrared rays**	**Herschel**	7.8×10^{-7} to 10^{-3}	Night vision camera, TV remote, Also used for heating
6	**Microwaves**	**Hertz**	10^{-3} to 1	Transmission of radio and TV signals, RADAR, Microwave Oven
7	**Long wave radio**	**Marconi**	1 to 104	Transmission of Radio and TV programmes, Communication

1.7 SOUND

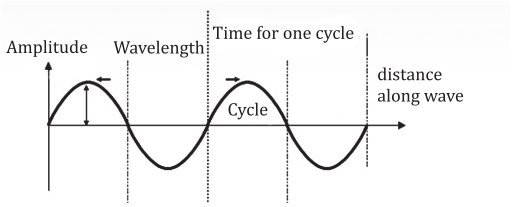


Fig. 1.64

- Sound is a form of energy which makes us hear. It travels in the form of waves.
- *Sound travels in the form of waves.*
- *Sound is a longitudinal wave which consists of compressions and rarefactions travelling through a medium.*

1.7.1 Sound Waves Can be Described by Five Characteristics

Wavelength

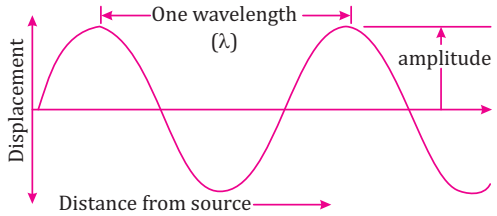


Fig. 1.65

- The minimum distance in which a sound wave repeats itself is called its wave length. It is the length of one complete wave. It is denoted by a Greek letter λ (lambda). The S.I unit for measuring wavelength is metre (m).
- In a sound wave, the combined length of a compression and an adjacent rarefaction is called its wavelength. Also, the distance between the centres of two consecutive compressions or two consecutive rarefactions is equal to its wavelength.
- The distance between the centres of a compression and an adjacent rarefaction is equal to half of its wavelength i.e. λ/2.

Amplitude

- When a wave passes through a medium, the particles of the medium get displaced temporarily from their original undisturbed positions. The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave.
- Amplitude is used to describe the size of the wave. The S.I unit of measurement of amplitude is metre (m) though sometimes it is also measured in centimetres. The amplitude of a wave is the same as the amplitude of the vibrating body producing the wave.

Time-Period

- The time required to produce one complete wave or cycle or cycle is called time-period of the wave.
- One complete wave is produced by one full vibration of the vibrating body. So, the time taken to complete one vibration is known as time-period. It is denoted by the letter T. The unit of measurement of time-period is second (s).

Frequency

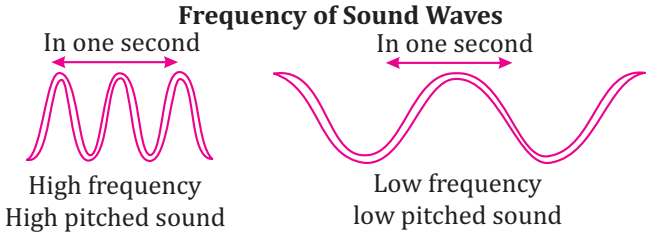


Fig. 1.66

- The number of complete waves or cycles produced in one second is called frequency of the wave.
- Since one complete wave is produced by one full vibration of the vibrating body, the number of vibrations per second is called frequency. For example: if 10 complete waves or vibrations are produced in one second then the frequency of the waves will be 10 hertz or 10 cycles per second.
- The frequency of a wave is fixed and does not change even when it passes through different substances.
- The S.I unit of frequency is hertz or Hz. A vibrating body emitting 1 wave per second is said to have a frequency of 1 hertz. That is 1 Hz is equal to 1 vibration per second. Sometimes a bigger unit of frequency is known as kilohertz (kHz) that is 1 kHz = 1000 Hz. The frequency of a wave is denoted by the letter f.
- The frequency of a wave is the same as the frequency of the vibrating body which produces the wave.

Relation Between Time-Period and Frequency of a Wave:

- The time required to produce one complete wave is called the time-period of the wave.
- Suppose the time-period of a wave is T seconds.
- In T seconds number of waves produced = 1.
- So, in 1 second, the number of waves produced will be = 1/T.
- The number of waves produced in 1 second is called its frequency. thus, F = 1/Time-period

  $f = 1/T$

  where f = frequency of the wave

  T = time-period of the wave

Velocity of Wave (Speed of Wave)

- The distance travelled by a wave in one second is called velocity of the wave or speed of the wave. It is represented by the letter v.
- The S.I unit for measuring the velocity is metres per second (m/s or ms-1).

1.7.2 Relationship Between Velocity, Frequency and Wavelength of a Wave

- Velocity = Distance travelled/ Time taken
- Let $v = \lambda / T$
- Where T = time taken by one wave.
- $\mathbf{v = f \times \lambda}$
- This formula is known as the **wave equation.**
- Where v = velocity of the wave
  f = Frequency
  λ = Wavelength
- Velocity of a wave = Frequency × Wavelength
- This applies to all the waves i.e. transverse waves like water waves, longitudinal waves like sound waves and the electromagnetic waves like light waves and radio waves.

1.8 ELECTRIC CURRENT

- The rate of flow of electric charge in a conductor is termed as electric current.
- The direction of the flow of positive charge is considered the direction of flow of electric current. Thus, the direction of flow of electric current is just opposite to that of the direction of flow of electrons.
- The SI unit of electric current is **Ampere**.
  1 Ampere = 1 coulomb/second.
- **Types of Electric Current**:
- It is of two types-
  (i) **Direct Current (DC):** An electric current flowing in one direction only. A battery is a suitable example of DC power supply.
  (ii) **Alternating Current (AC):** An electric current that reverses its direction many times a second at regular intervals, typically used in power supply. The main advantage of AC over DC is that AC can be transmitted to a long distance without much electric energy loss.
- **Electromotive Force (EMF):** Electromotive force is the electrical intensity or pressure developed by a source of electrical energy such as a battery or generator.
- **Voltage (Electric Potential)**: The work done to bring a unit positive charge from a position to any point in the electric field is termed as the voltage of that particular point. Its SI Unit is **Volt.**
- **Potential Difference**: The difference in electric potential between two points in an electric field; the work has to be done in transferring unit positive charge from one point to another. Its SI unit is also **Volt**.
- If work W joule is done to flow q charge between two points, then the potential difference between these points is-
  V = Work done/Flow of charge
  = W joule/ q coulomb
  = W/q volt
- **Resistance**: Resistance is a physical quality of conductor which resists the flow of electric current in the conductor. Its unit is **Ohm (Ω)**. It is represented by 'R'.
- **Ohm's Law:** Ohm's Law states that the current through a conductor between two points is directly proportional to the voltage across the two points.
- If V potential difference is applied at both ends of conductor and flow of electric current is I then,
  $I \propto V$ or $V \propto I$
  $\Rightarrow V = RI$
- Where R is a constant, known as the **resistance of the conductor.**
- **Factors Affecting the Resistance**:
- Resistance of conductor (R) is directly proportional to its length.
  or $R \propto L$
- The resistance of conductor (R) is inversely proportional to its cross-sectional area (A).
  or $R \propto 1/A$
- From these two equations,
  $R \propto L/ A0$
  $R = \rho L/ A$
- Where ρ is a proportional constant which is known as **Specific Resistance** or resistivity.
- Resistivity ρ of any conductor depends only upon the nature of matter.
- Its SI unit is **Ohm-metre.**

1.8.1 Measuring Current

- A one-volt battery supplies one joule of energy to each coulomb of electric charge that it produces.
- Mechanical power is measured in watts (joules per second). If a 6v battery is supplying 5 amps (5 coulombs per second), it is thus producing 6 joules per coulomb and a total of 5 × 6 = 30 joules per second.
- The general formula for power supplied is:
  $\mathbf{P = V \times I}$
- Where P is the power in watts, V is the voltage (also known as Potential Difference) and I is the current in ampere.

1.8.2 Magnetic Effects of Electric Current

- A current carrying conductor creates a magnetic field around it, which can be comprehended by using magnetic lines of force or magnetic field lines. The magnetic field in a current carrying straight conductor is in the form of concentric circles around it.

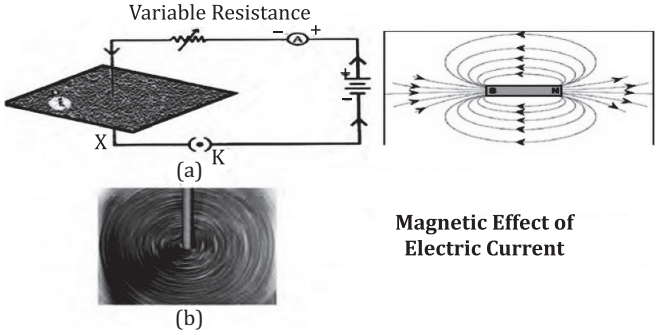


Fig. 1.67

- The direction of magnetic field; in relation to direction of electric current through a straight conductor can be depicted by using the Right Hand Thumb Rule which is also known as Maxwell's Corkscrew Rule.

1.8.3 Magnetic Effects of Electric Current

- Magnetic effect of electric current is one of the major effects which functions as the basic principle in appliances used in various fields of activities. The magnetic field around a current carrying conductor can be depicted by using magnetic field lines which are represented in the form of concentric circles around it. The direction of magnetic field through a current carrying conductor is determined by the direction of flow of electric current.

The Right Hand Thumb Rule

- The Right Hand Thumb Rule also known as Maxwell's Corkscrew Rule is known to determine the direction of magnetic field in relation to direction of electric current through a straight conductor.
- As the direction of the electric current changes, the direction of the magnetic field also gets reversed.
- If the direction of electric current in a vertically suspended current carrying conductor is from south to north, the magnetic field will be in the anticlockwise direction.
- If the current is flowing from north to south, the direction of the magnetic field will be clockwise.

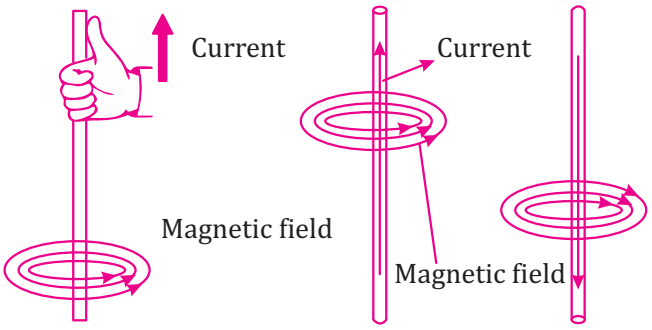


Fig. 1.68 : Right hand thumb rule

- If a current carrying conductor is held by the right hand; keeping the thumb straight and if the direction of electric current is in the direction of the thumb, then the direction of folding of other fingers will show the direction of magnetic field. Magnitude of the magnetic field is directly proportional to the number of turns of coil. If there are 'n' turns of coil, the magnitude of magnetic field will be 'n' times of magnetic field in case of a single turn of coil.

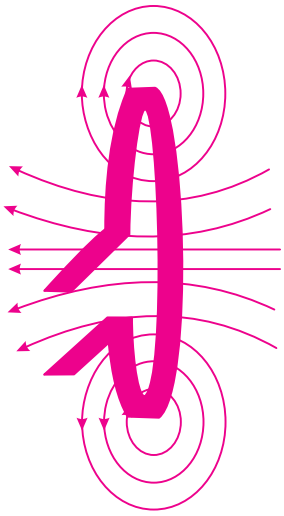


Fig. 1.69: Magnetic field lines

Application of Maxwell's Right Hand Thumb Rule

- If the conductor is in the form of a circular loop, the loop behaves like a magnet. In a circular current carrying conductor, the magnetic field is stronger near the periphery of the conductor.

Circular Loop Shaped Current Carrying Conductor

- As suggested by Marie Ampere, a current carrying conductor exerts a force when a magnet is placed in its vicinity. Similarly, a magnet also exerts equal and opposite force on the current carrying conductor. The direction of force over the conductor gets reversed with the change in direction of flow of electric current.
- It is observed that the magnitude of force is highest when the direction of current is at right angles to the magnetic field. If the current is flowing in an electric circuit from South to North direction and a magnetic compass is placed over the conducting wire, the needle of the compass deflects in the direction of west. This is known as *SNOW* rule which helps to predict the direction of the magnetic field.

Fleming's Left Hand Rule

- According to Fleming's left hand rule, if the forefinger, middle finger and thumb of the left hand are stretched such that they are at right angles to each other, then the forefinger gives the direction of the magnetic field. The middle finger points in the direction of the current. The thumb gives the direction of the force acting on the current-carrying conductor placed in the external magnetic field.

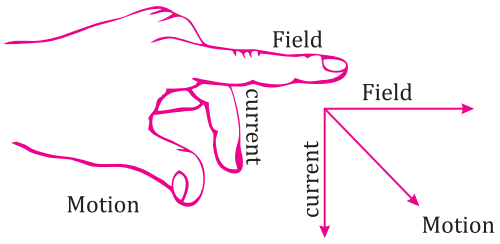


Fig. 1.70: Fleming's left hand rule (Motor rule)

Electric Motor

- An electric motor converts electrical energy into mechanical energy using the magnetic effect of electricity.
- In an electric motor, a rectangular coil is suspended between the two poles of a magnetic field. The electric supply to the coil is connected with a Commutator which reverses the direction of flow of electric current through a circuit. When the electric current is supplied to the coils of the electric motor, it gets deflected because of the magnetic field.
- As it reaches the half way, the split ring which acts as Commutator reverses the direction of flow of electric current. Reversal of direction of electric current reverses the direction of forces acting on the coil. The change in direction of force pushes the coil, and it moves another half turn. Thus, the coil completes one rotation around an axle. Continuation of this process keeps the motor in rotation.

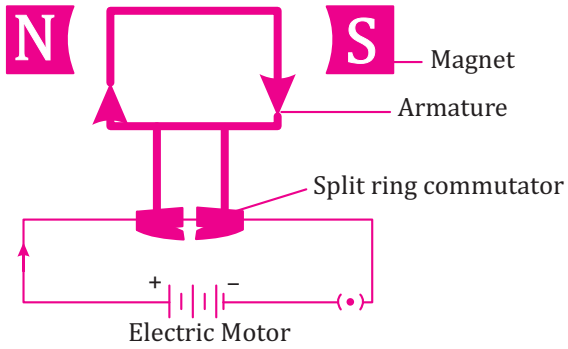


Fig. 1.71

1.9 ELECTROMAGNETISM

Electromagnetism is the study of the effects caused by stationary and moving electric charges.

1.9.1 Magnetism

Pieces of some metallic ores, such as lodestone, are magnetic. When suspended freely from a thread, they point north-south. Such magnetic compasses have been used since 500 BC.

1.9.2 Electromagnetic Spectrum

At present, science recognises a spectrum of electromagnetic radiation that extends from about 10-15 m to 10° m.

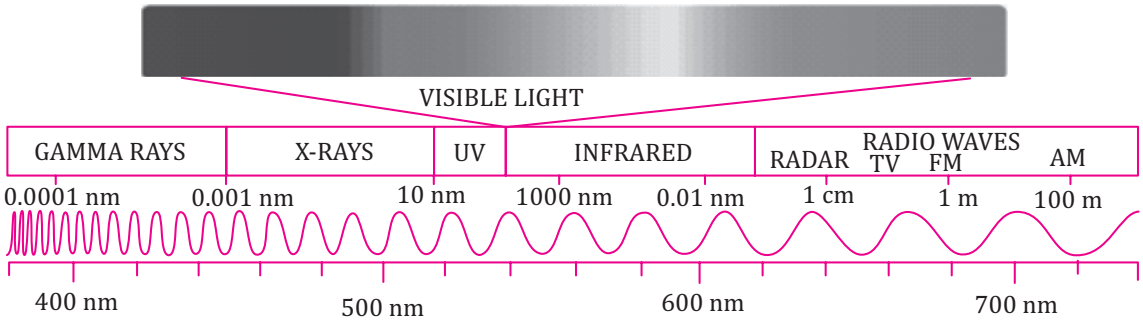


Fig. 1.72: Electromagnetic spectrum

- **Radio waves** have a large range of wavelengths, from a few millimetres up to several kilometres.
- **Microwaves** are radio waves with shorter wavelengths, between 1 mm and 30 cm, and are used in radar and microwave ovens.
- **Infrared waves** of different wavelengths are radiated by bodies at different temperatures. The Earth and its atmosphere, at a mean temperature of 250 K (-23°C or -9.4°F) radiates infrared waves with wavelengths centred at about 10 micrometres.
- **Visible waves** have wavelengths of 400-700 nanometres (nm; 1 nm = 10-6 m).
- **Ultraviolet waves** have wavelengths from about 380 nm down to 60 nm. The radiation from hotter stars, above 25,000°C (45,000°F), shifts towards the violet and ultraviolet parts of the spectrum.
- **X-rays** have wavelengths from about 10 nm to 10-4 nm.
- **Gamma rays** are emitted by certain radioactive nuclei in the course of nuclear reactions.

Earth itself has magnetic properties. A magnet has two poles, one of which is attracted to the Earth's magnetic North Pole, while the other is attracted to the South Pole

1.9.3 Static Electric Charges

- Static electricity involves electric charges at rest.
- In 1785, Coulomb formulated the Law of Attraction and Repulsion between electrically charged bodies:

$$F = kQ_1Q_2/r^2$$

- where F is the force, k is a constant, Q1 and Q2 are the sizes of the charges (+ or -), and r is the distance between the charges.

1.10 NUCLEAR FISSION AND FUSION

1.10.1 Nuclear Fission

- When an isotope of uranium-235 was bombarded with neutrons, it split into two lighter nuclei along with, on average, three neutrons.
- These neutrons were capable of bombarding and splitting other nuclei, causing more fission to take place.
- If the mass of uranium-235 was above a certain level (the critical mass) this produced a chain reaction. It was the production of this chain reaction which, in turn, led to the development of the first nuclear bomb. **Fission is used in both nuclear reactors and atomic weapons.**

1.10.2 Nuclear Fusion

- Occurs when two small nuclei collide and combine, breaking the weak nuclear force and releasing energy.
- This type of reaction releases considerably more energy than a fission process for a given mass of material.
- However, unlike nuclear fission, humankind has not yet found a way to properly contain or control the process. Many scientists today are searching for the key to controlled room-temperature fusion referred to as 'cold fusion'.
- An example of uncontrolled fusion reaction is the hydrogen (thermonuclear) bomb, which relies on the fusion of light atoms to give heavier atoms, with the destruction of matter releasing the observed energy.

1.10.3 Nuclear Particles

- The proton and neutron, which were once thought to be the basic blocks of matter, are now known to be made up of over 200 elementary particles.
- Elementary particles can be divided into two types:
  1. **Hadrons** which are heavy particles subject to the strong force, and
  2. **Leptons** which are small particles not subject to the strong force.
- Elementary particles have a further distinction between **fermions**, which are permanently existing particles, and **bosons**, which can be produced and destroyed freely.
- Every type of particle is thought to have a companion antiparticle, which is opposite to it in some characteristic way.
- **The positron**, with positive charge, is the antiparticle of the electron, with a negative charge. Some particles, such as the photon, serve as their own antiparticles.
- Protons and neutrons are composed of smaller particles called **quarks**. The six types of quark are: **up, down, charmed, strange, top and bottom.** The proton is considered to consist of two up quarks and a down quark, whilst the neutron consists of two down quarks and an up quark.
- **Mesons** are short-lived subatomic particles composed of two quarks each. Mesons jump between protons and neutrons, thus holding them together.
- **Neutrinos** are particles which can carry much energy away from nuclear reactions, such as those involved in radioactivity, but they are difficult to detect, as they only interact very weakly with ordinary matter. They are capable of passing right through the Earth undetected.

1.11 CONDUCTIVITY

1.11.1 Electric Conductivity

- Within the atom, electrons nearest to the nucleus are strongly bound to positive ions (protons) of the nucleus by attractive force. The electrons far from the nucleus have poor attractive force.
- Due to poor attractive force, such electrons are easily removed from their original state. Such electrons are known as free electrons. The electrons which are not bound to the nucleus of an atom and free to move when external energy is applied are called **free electrons**.
- Any electron that is not attached to an ion, atom or molecule and is free to move under the influence of an applied electric or magnetic field is called free electron.
- A metal with a good number of free electrons is a good conductor of electricity. Silver is the best conductor of electricity. Other metals-copper, gold and aluminium are respectively good conductors of electricity.
- Electric conductivity is also found in some liquids and gases.
- In metals, electric conductivity is due to the movement of free electrons, while in liquid & gases it is due to the movement of positive and negative ions.
- In gases, electric conductivity takes place only at a definite pressure range (approx. 10 mm Hg to 10^3 mm Hg). Above the maximum limit of pressure (10mm Hg) and below the minimum limit (10^3 mm Hg) of pressure, gases are a bad conductor of electricity.

1.11.2 Non-Conductor

- The matter having very low or zero numbers of free electrons is known as a non-conductor or an insulator of electricity. The flow of charge in such matters is not possible due to the absence of free electrons.

1.11.3 Semiconductor

- The matter whose electric conductivity lies between conductor and non-conductor (insulator) is known as semiconductor. The conductivity of such matter is due to the addition of an impurity or due to temperature effect.
- The process of adding controlled impurities to a semi-conductor is known as *doping*. Doped Semi- conductors are referred to as extrinsic. Their resistance decreases as their temperature increases, which is a behaviour opposite to that of a metal.
- Examples of semiconductors are - Germanium, Selenium Silicon and Carbon.

1.11.4 Superconductivity

- It is a phenomenon of exactly zero electrical resistance and expulsion of magnetic flux fields occurring in certain materials called superconductors, when cooled below a characteristic critical temperature.
- The temperature at which resistance of a matter suddenly becomes zero is known as 'Transition Temperature'.

Transition Temperature of some Matters

Sr/no	Name of Matter	Transition temperature
1	Mercury	4.2 K
2	Tungsten	0.01 K
3	cadmium	0.56 K
4	Aluminium	1.19 K
5	Tin (Stanus)	3.7 K
6	Lead	7.2 K

1.11.5 Application of Superconductivity

- Powerful superconducting electromagnet used in maglev trains.
- Magnetic Resonance Imaging (MRI).
- Nuclear Magnetic Resonance (NMR) Machines.
- Magnetic Confinement Fusion Reactors (e.g. tokamaks).
- Beam steering and focusing magnets used in particle accelerators.
- Low loss of power cables.

2 Chemistry

2.1 BASICS OF THE CHEMISTRY

State of Matters

- Anything which has mass and occupies space is called matter.
- Conventionally matter can exist in three physical states viz. solid, liquid and gas.

Solid

- Particles are held very close to each other in solids in an orderly fashion and there is not much freedom of movement.
- Solids have definite volume and definite shape.

Liquids

- In liquids, the particles are close to each other but they can move around.
- Liquids have definite volume but do not have definite shape.

Gases

- In gases, the particles are far apart as compared to those present in solid or liquid states and their movement is easy and fast.
- Gases have neither definite volume nor definite shape.
- On heating, a solid usually changes to a liquid, and the liquid on further heating changes to gas (or vapour). In the reverse process, a gas on cooling liquifies to the liquid and the liquid on further cooling freezes to the solid.

4th state of Matter

Plasma, the fourth state of matter, is an ionised gas consisting of approximately equal numbers of positively and negatively charged particles.

5th Bose Einstein Condensates

- Albert Einstein and Indian scientist Satyendra Nath Bose proposed the existence of a Bose-Einstein condensate almost a century ago.
- When atoms of certain elements are chilled to temperatures approaching absolute zero, an unusual substance emerges.
- Clusters of atoms begin to behave as a single quantum object with both wave and particle qualities at that moment.
- BECs are highly fragile, and even the tiniest interaction with the outside world can cause them to overheat and condense.

2.2 CHEMICAL COMPOSITION

- The matter is divided into three groups on basis of chemical composition: **elements, compound and mixture.**
- **Elements:** It is that fundamental substance or matter which cannot be decomposed or disintegrated into two or more different components which have different properties or characteristics by any physical or chemical process.
- On the basis of electronic configuration, an element is that substance or matter whose atoms have the same nuclear charges. It is of two types- Metal and Non-metal. Metals are usually good conductors of electricity and heat and mostly found in solid states which are malleable and ductile whereas non-metals are bad conductors of electricity and heat, and these are brittle.
- **Compounds:** It is that substance which is formed by the chemical combination of two more elements composed in a definite ratio, and also the physical and chemical properties of the formed compound are different from that of its constituents or components elements. For example: Water is formed from hydrogen and Oxygen.
- **Mixture:** It is substance or matter which is formed by two or more pure elements by the means of only a physical combination without definite proportion. For example: air, brass (Copper+ Zinc) etc.

Some key terms

- **Atom:** An atom is a particle of matter that uniquely defines a chemical element. An atom consists of a central nucleus that is usually surrounded by one or more electrons. Each electron is negatively charged. The nucleus is positively charged, and contains one or more relatively heavy particles known as protons and neutrons.
- **Fission:** During a nuclear fission, an atom splits into several smaller fragments. These fragments, or fission products, are about equal to half the original mass. Two or three neutrons are also emitted.
- **Radioactive decay:** Many nuclei are radioactive. This means they are unstable, and will eventually decay by emitting a particle, transforming the nucleus into another nucleus, or into a lower energy state. There are three main types of radiations i) Alpha radiation ii) Beta radiation iii) Gamma radiation
- **Nucleosynthesis**: A star's energy comes from the combining of light elements into heavier elements in a process known as fusion, or "nuclear burning".

- It is generally believed that most of the elements in the universe heavier than helium are created, or synthesized, in stars when lighter nuclei fuse to make heavier nuclei. The process is called nucleosynthesis.

2.3 ATOMS AND MOLECULES

- **Atomic Structure:** Atoms are the smallest particle of an element that can exist, and can be regarded as the building blocks of everything. Atoms can combine to form molecules. Molecules are the smallest particle of either an element or a compound that can exist independently.

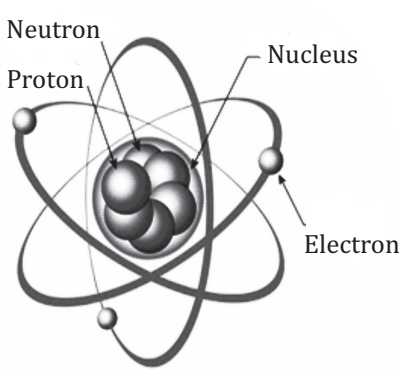


Fig. 2.1: Atomic structure

- **Subatomic Particles**: The atom is made up of subatomic particles: *the proton, the neutron and the electron.*
- The *protons and neutrons* are concentrated together in a tiny, enormously dense structure in the center of the atom, called the *nucleus*. The *electrons* orbit this nucleus at a very high speed. The various elements differ from each other in the number of protons and electrons they have. For example, gold has 79 protons in its nucleus, whilst carbon has 6. The subatomic particles carry an electrical charge: *the proton is positively charged*, the *electron is negatively charged*, whilst the *neutron is neutral*. Atoms are electrically neutral because they contain equal numbers of protons and electrons.
- The chemical properties of elements depend on the structure of their atoms. It is the arrangements of the electrons around the nucleus that give elements their particular chemical properties. Electrons are arranged in 'shells' and it is the state of the outermost shell which is crucial. A stable atom has a complete outer shell - only the elements known as the noble gases (such as helium) have this structure, and so they are stable as single atoms. Other elements have incomplete outer shells, so they bond with other atoms to form stable molecules.
- **Mole Concept:** Mole is a SI unit and used in chemical calculations and can be defined as one mole of substance is equal to 6.023×10^{23} entities (atoms, molecules or ions) or molecular mass/ atomic mass/ formula mass in grams or 22.4 L of a gas at a standard temperature and pressure.
- **Molecule:** A molecule is the smallest particle in a chemical element or compound that has the chemical properties of that element or compound.
- Molecules are made up of atoms that are held together by chemical bonds.
- **Molecular size**: The size or hydrodynamic radius RH can be determined in two ways. The first method is by Dynamic Light Scattering (DLS), which is generally used as a batch technique to measure the average size in the whole sample, but can be used as a detector for Size Exclusion Chromatography.
- **Molecular formula:** Chemical formulas such as $HClO_4$ can be divided into empirical formula, molecular formula, and structural formula. Chemical symbols of elements in the chemical formula represent the elements present, and subscript numbers represent mole proportions of the proceeding elements. Chemical formula, such as H_2O for water. This formula implies that the water molecules consist of 2 hydrogen, and 1 oxygen atom. The formula H_2O is also the molecular formula of water.
- **Molecular geometry:** Molecular geometry or molecular structure is the three-dimensional arrangement of atoms within a molecule. It is important to be able to predict and understand the molecular structure of a molecule because many of the properties of a substance are determined by its geometry.
- **Molecular spectroscopy:** Spectroscopy is the use of the absorption, emission, or scattering of electromagnetic radiation by atoms or molecules to qualitatively or quantitatively study the atoms or molecules, or to study physical processes. The interaction of radiation with matter can cause redirection of the radiation and transitions between the energy levels of the atoms or molecules.
- **Atomic number:** It is the number of protons in one atom of a particular element. An undisturbed atom is electrically neutral, so the number of electrons in it is the same as its atomic number.
- **Atomic mass:** The mass of an atom or a molecule is often called its atomic mass. Mass is a basic physical property of matter and strictly speaking there is no difference between mass and atomic mass.
- **Nomenclature:** A system of names used in a particular discipline, as in medicine and surgery, anatomy and biochemistry, etc. A standard system of nomenclature presupposes the existence of an organized classification of the entities within that field.
- **Isotopes:** Atoms of the same element can have different numbers of neutrons; the different possible versions of each element are called isotopes.
- **Allotropes:** An allotrope is a variant of a substance consisting of only one type of atom. It is a new molecular configuration, with new physical properties. Substances that have allotropes include carbon, oxygen, sulfur, and phosphorus.

2.4 PHYSICAL AND CHEMICAL CHANGES

- In our daily life, we encounter many changes in our surroundings, though we do not notice them, such as souring of milk, rusting of iron, stretching of a rubber band, bread becoming toast, melting of wax, etc.
- All these changes that take place around us are either a physical change or chemical change.
- **Physical Changes:** Physical changes are the changes that change the physical traits of the substance, without making any change in their internal structure.
- In physical changes no chemical bonds are broken or formed. Some examples of physical changes are:
  - Melting of wax
  - Melting of ice
  - Freezing of water
  - Vaporization of water
  - Dissolving sugar in water
  - Chopping in wood
  - Crumpling of paper

Physical Change is a Reversible Process

- **Chemical Changes:** A chemical change is defined as the process in which the atoms of one or more substances are rearranged or combined to form a new substance. When a substance undergoes a chemical change, the chemical properties of the substance changes and it is transformed into a different substance with different chemical composition. Energy change is one of the characteristics of a chemical change, because of the formation of a new product.
- Once the chemical change takes place, it cannot be reversed.
- Some examples of chemical changes are as follows-
  - Adding vinegar to baking soda
  - Bleaching a stain
  - Fermenting of grapes
  - Burning of magnesium wire and paper
  - Nail rusting
  - Sour of milk
  - Cooking of food

Comparison Chart of Physical and Chemical Changes

Basis for Comparison	Physical Change	Chemical Change
Meaning	Physical change refers to a change in which molecules are rearranged but their internal composition remains the same	Chemical change is a process in which the substance transforms into a new substance, having different chemical composition.
Nature	Reversible	Irreversible
Original Matter	Can be recovered	Cannot be recovered
Involves	Change in physical properties of the substance, i.e. shape, size, colour etc.	Change in physical and chemical properties and composition of the substance
Product Formation	No new Product is formed.	A new product is formed.
Energy	Very little energy (or no energy) is either absorbed or evolved.	Absorption and evolution of energy take place during the reaction.

2.5 SOLUTION

Solution

- In chemistry, a solution is a special type of homogeneous mixture composed of two or more substances.

  Other characteristics of the solutions are:
  - The particles of solute in a solution cannot be seen by the naked eye.
  - A solution does not allow beams of light to scatter.
  - A solution is stable.
  - From a solution, the solute cannot be separated by filtration.
- **Solvent**: Solvents are molecules that have the ability to dissolve other molecules, known as solutes. A solvent can be solid, liquid or gas. The molecules of the solvent work to put the solute molecules apart. Eventually, the molecules of solute become eventually distributed throughout the solvent.

Types of Solution

1. **Gaseous Solution:** If the solvent is gas, only gases are dissolved under a given set of conditions.

   An example of a gaseous solution is air (Oxygen and other gases dissolved in Nitrogen).
2. **Liquid Solution:** If the solvent is a liquid, then almost all gases, liquids and solids can be dissolved.

Examples of liquid solutions are as follows-

- Gas in liquid: Oxygen in water.
- Liquid in liquid: Alcoholic beverages are basically solutions of ethanol in water.
- Solid in liquid: Sucrose in water; Sodium chloride in water.

3. **Solid solutions:** If the solvent is solid, then gas, liquid and solid can be dissolved.
   - Gas in Solid - Hydrogen dissolves in palladium, this is studied as a means of hydrogen storage.
   - Liquid in solid - Mercury in gold forming amalgam; Hexane in paraffin wax.
   - Solid in solid - Alloys like bronze are a solution of copper and zinc.

- **Dilute Solution:** A dilute solution in chemistry is a solution that can accept more solute, until it becomes saturated, or in which there is a relatively small amount of solute dissolved in the solution.
- **Concentrated Solution**: The concentrated solution is a solution that contains a large amount of solute relative to the amount that could dissolve.
- **Saturated solution**: A saturated solution is a solution that can not dissolve any more of the substance that's been mixed into it.
- **Solubility**: Amount of a substance that dissolves in a unit volume of a liquid substance to form a saturated solution under specified conditions of temperature and pressure. Solubility is expressed usually as moles of solute per 100 grams of solvent.

2.6 CHEMICAL BONDS

- The substances that exist in the universe are made up of atoms/molecules/ions.
- Chemical bonding is the binding force of the constituents' atoms of the molecule to maintain a mutual atomic order and a definite but specific geometric shape.
- There are three types of chemical bonding: Electrovalent or Ionic, Covalent bonding and Coordinate covalent bonding.

Types of Chemical Bonding

- **Electrovalent Bond**: They are formed by transfer of electrons and have high melting and boiling points. These are soluble in water and conduct electricity in molten state or in aqueous solution. These bonds are held together by the strong electrostatic attractions between the positive and negative charges.
- **Covalent Bond:** They are formed by sharing of electrons and have low melting and boiling point. These are soluble in organic solvents and are non-conductors of electricity. Graphite and diamond are covalent compounds but they have a very high melting point because of their giant structure. The properties of covalent bonds are given below:
- They are mostly gases and liquids.
- These compounds have low melting point and boiling point because intermolecular forces among the atoms are weaker as compared to the electrovalent compounds.
- Most of the covalent bonds exist in molecular forms and these compounds take part very slowly in the chemical reactions with another covalent compound.
- **Coordinate covalent bonding**: The pair of electrons in this bonding is obtained by only through a single atom and in this bonding, the atom which supplies electrons pair is called donar and the atom which takes such pair of electrons is called acceptor. The electrons pair donated by the donor atom is called singleton pair. It is generally represented as an arrow. Here a convention is followed in which a +ve charge (S^+) is given to the donor atom and a –ve charge (S^-) on the acceptor atom.
- For example: NH3 (g) + HCl (g) →NH4Cl(s) NH_3 (g) + HCl (g) → NH_4Cl(s)
- Ammonium ions, NH_4^+, are formed by the transfer of a hydrogen ion (a proton) from the hydrogen chloride molecule to the lone pair of electrons on the ammonia molecule.

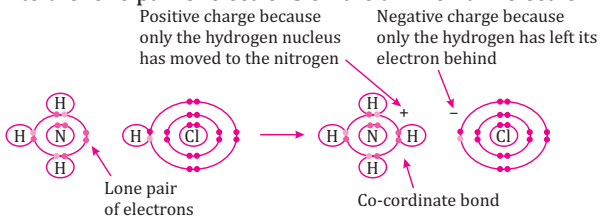


Fig. 2.2

2.7 CHEMICAL GROUPS

The broad classifications of the elements are **metals** and **non-metals.** Each of these groups can then be further divided and categorized.

METALS

- Metals form the majority of the elements and their chemical reactivity ranges from gold, which is found 'native', to metals such as potassium and sodium. Metal oxides are basic. A basic oxide is able to react with an acid to produce a salt and water only, for example:

$$\underset{\text{magnesium oxide}}{MgO} + \underset{\text{sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{magnesium sulfate}}{MgSO_4} + \underset{\text{water}}{H_2O}$$

- The alkali metals are the most reactive metals in the Periodic Table. These elements - lithium, sodium, potassium, rubidium, caesium and francium -(located in group 1 of the Periodic Table) are soft metals. Their softness and low melting point are the result of the weakness of their metallic bonding.
- The alkaline earth metals are the elements of group 2 - beryllium, magnesium, calcium, strontium, barium and radium. Of these elements, calcium and magnesium are the most common. The alkaline earth metals are not as reactive as the alkali metals.

Do You Know?

- More than 75% of the known elements have the characteristic properties of metals.
- The ability of metals to be drawn into thin wires is called ductility. Gold is the most ductile metal. Thus, metals can be given different shapes according to our needs.
- The metals that produce a sound on striking a hard surface are said to be sonorous.
- They are good conductors of Electricity.
- Almost all metals combine with oxygen to form metal oxides. Different metals show different reactivities towards oxygen. Ex: Potassium and sodium react so vigorously that they catch fire if kept in the open.
- Hence, to protect them and to prevent accidental fires, they are kept immersed in kerosene oil.
- At ordinary temperature, the surfaces of metals such as magnesium, aluminum, zinc, lead, etc., are covered with a thin layer of oxide. The protective oxide layer prevents the metal from further oxidation.
- All metals do not react with water. Metals like potassium and sodium react violently with cold water.
- Magnesium does not react with cold water. It reacts with hot water to form magnesium hydroxide and hydrogen.
- Mercury is the only metal which is found in liquid state at room temperature.

NON-METALS

- Non-metals' atoms generally have four, five, six or seven electrons in their outermost shells. By sharing electrons with other non-metal atoms, so as to create 'bonding-pairs' of electrons, non-metal atoms can manage to resemble their aristocratic cousins, the noble gases. Nonmetal oxides are either acidic or neutral.

- Materials like coal and sulphur are soft and dull in appearance. They break down into a powdery mass on tapping with a hammer.
- They are not sonorous and are poor conductors of heat and electricity. These materials are called non-metals.
- Non-metals generally do not react with acids.
- Non Metals generally do not conduct electricity. But in exceptional cases it can conduct electricity.

Periodic Table of Elements

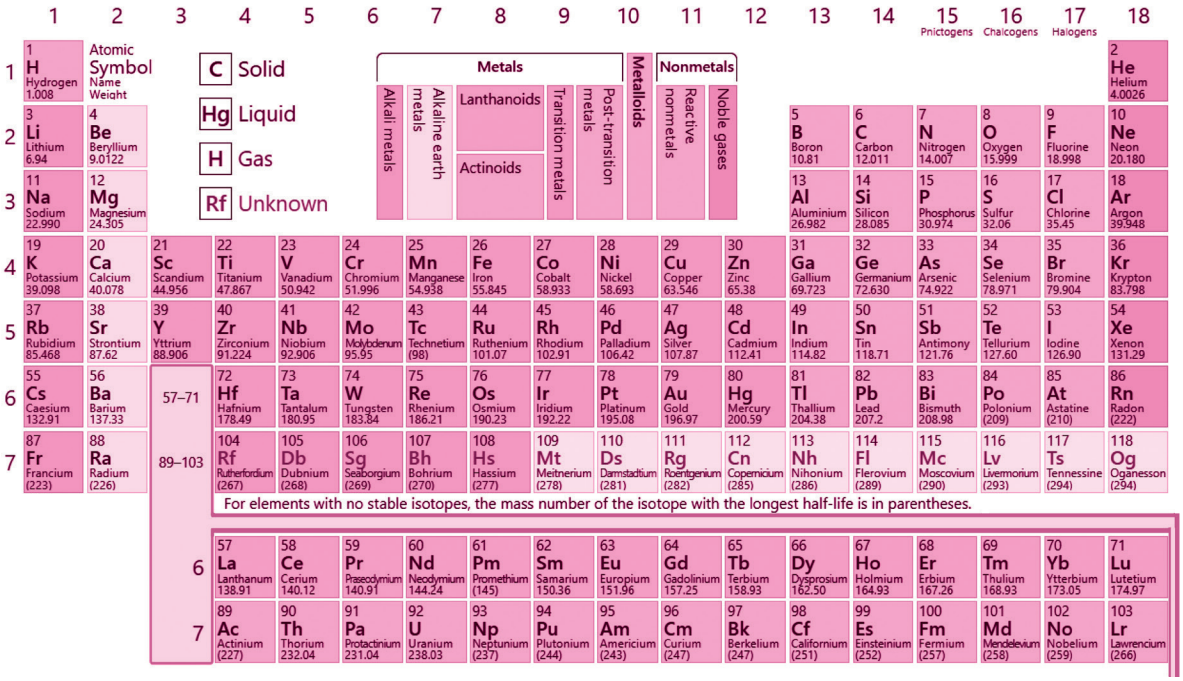


Fig. 2.3: Periodic table

- **Metals:** As discussed earlier, Metals are those elements which lose electrons and provide cation. In the periodic table, these elements are located and confined towards left and middle. Also the elements which are located extremely left have the most metallic properties.

Physical Properties of Metals

- They are good conductors of heat and electricity and are malleable and ductile.
- They have lustre.
- They are heavy and sonorous.
- These elements form positive ions by losing electrons (or donating).
- Aluminium, Iron, Calcium, Sodium, Potassium, and Magnesium are the major metals is found abundance in the earth's crust (names are in decreasing order)
- They are solid at room temperature (Except Mercury).
- They have high melting and boiling points (except Sodium and potassium).
- They have high densities (except Sodium and Potassium).

Chemical Properties of Metals

- Metals are very reactive and tend to lose electrons easily and form positively charged ions; therefore metals are called electropositive elements. Sodium metal forms sodium ions Na^+, Mg forms positively charged Magnesium ions $Mg^{2+}$and aluminium forms aluminium ions Al^{3+}. The electropositive nature allows metals to form compounds with other elements easily. The chemical metal chemical properties of metals are discussed below:
- **Reaction of Metals with Oxygen**: When metals are burnt in air, they react with the oxygen to form metal oxide. For Example –

$$4Na + O_2 \longrightarrow 2Na_2O$$

Sodium Oxygen Sodium oxide

- Sodium oxide is a basic oxide which reacts with water to form sodium hydroxide.

$$Na_2O + H_2O_2 \longrightarrow NaOH$$

Sodium Oxide Sodium hydroxide

- Mg does not react with oxygen at room temperature. On heating, Mg burns in air with intense light and heat to form MgO.

$$2Mg + O_2 \xrightarrow{\Delta} 2MgO$$

- **Reaction of Metals with Water**: Metals react with water to form a metal hydroxide and Hydrogen gas.
- For Example:
- Sodium reacts vigorously with cold water forming sodium hydroxide and hydrogen.

$$2Na + H_2O \longrightarrow 2NaOH + H_2\uparrow$$

- Metals from magnesium to iron in the activity series of metals, react with steam (but not H_2O) to form the metal oxide and hydrogen gas.

Magnesium + Steam ⟶ Magnesium oxide + Hydrogen

$$Mg + H_2O \longrightarrow MgO + H_2\uparrow$$

Aluminium + Steam ⟶ Aluminium oxide + Hydrogen

$$2Al + 3H_2O \longrightarrow AI_2O_3 + 3H_2\uparrow$$

- **Reaction of Metals with Acids:** Metals usually displace hydrogen from dilute acids (Except copper, silver and gold do not displace hydrogen from dilutes acid because they are less reactive than other metals).
- For Example-

Magnesium + Sulphuric acid → Magnesium sulphate + Hydrogen

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\uparrow$$

Magnesium + Hydrochloric acid → Magnesium chloride + Hydrogen

$$Mg + 2HCI \rightarrow MgCI_2 + H_2\uparrow$$

Zinc + Sulphuric acid → Zinc sulphate + Hydrogen

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$$

- **Reaction of Metals with Salt Solutions:** Reactive metals can displace any metal less reactive than itself, from the oxide, chloride or sulphate of the less reactive metal in solution or their molten state. If metal A displaces metal B from its solution, it is more reactive than B.

Metal A + Salt solution of B → Salt solution of A + Metal B

Iron + Copper (II) sulphate → Iron (II) sulphate + Copper

$$Fe + CuSO_4 \rightarrow FeS0_4 + Cu$$

The Reactivity Series of Metal

In the reactivity series, the most reactive metal is placed at the top whereas the least reactive metal is placed at the bottom.

Reactivity series of metals

Potassium	↑ Most reactive
Sodium	
Calcium	
Magnesium	
Aluminum	
Carbon	
Zinc	
Iron	
Tin	
Lead	
Hydrogen	
Copper	
Silver	
Gold	
Platinum	↓ Less reactive

Non-Metals

- Non-Metal are those elements which do not exhibit the metallic characteristics. In the periodic table nonmetals are kept almost in the right most. In the modern periodic table there are 22 non-metals in which there are 11 gases, 1 liquid and 10 solid. Bromine occurs in the state of liquid and hydrogen, nitrogen, oxygen, chlorine etc are found in gaseous forms. But carbon, sulphur, phosphorus, iodine etc solid non-metals.

Physical Properties of Non-metal

- They do not produce metallic lustre.
- They are bad conductors of electricity.
- They are bad conductors of heat.

- They are electronegative.
- They cannot be drawn into sheets and wires.
- They have low specific gravity.
- They do not reflect light.
- They do not produce metallic sound.
- They are found in all states of matter.

Chemical Properties of Non-metal

The chemical properties of non-metal are given below:

- Non metallic oxides are acidic in nature.
- They do not dissolve in dilute mineral acids.
- They form stable compounds with hydrogen.
- Their chlorides are completely hydrolyzed by water.
- **Reaction of non-metals with oxygen:** They react with oxygen to form acidic oxides or neutral oxides.
- **Reaction of non-metals with water:** They do not react with water (steam) to evolve hydrogen gas.
- **Reaction of non-metal with acids:** They do not react with acids because they are negatively charged electrons.
- **Reaction of non-metal with salt solution**: They do not react with salt solution but displaces less reactive non-metal from the salt.
- **Reaction of non-metal with chlorine**: They react with chlorine to form covalent chlorides which are non- electrolytes.
- **Noble gases**: The noble gases, a family of elements found on the far right of the Periodic Table, are extremely unreactive. This seems to be associated with the fact that they have an especially stable arrangement of electrons in their outermost shells.
- **Halogens**: Halogens, consisting of fluorine, chlorine, bromine and iodine (plus astatine), are reactive non-metals. Halogen atoms have one electron less in their outer shells than noble gases, and must gain an electron to gain a stable structure, making them reactive. Halogens react vigorously with metals and hydrogen to form halides.

2.8 BASICS OF METALLURGY

- Metallurgy is a domain of materials science and engineering that studies the physical and chemical Metallurgy is a term that refers to the process of extracting metals in their purest form.
- Minerals are metal compounds that are mixed with soil, limestone, sand and rocks.
- Metals are mined commercially from minerals at a low cost and with little effort.
- Ores mined from the earth are usually contaminated with large amounts of impurities such as soil, sand, etc., called gangue.
- The impurities must be removed from the ore prior to the extraction of the metal.
- The metals produced by metallurgy are not very pure. They contain impurities, which must be removed to obtain pure metals.
- The most widely used method for refining impure metals is electrolytic refining.

Electrolytic Refining

Many metals, such as copper, zinc, tin, nickel, silver, gold, etc., are refined electrolytically.

- In this process, the impure metal is made the anode and a thin strip of pure metal is made the cathode. A solution of the metal salt is used as an electrolyte.
- The soluble impurities go into the solution, whereas, the insoluble impurities settle down at the bottom of the anode and are known as anode mud.

Corrosion and Rusting

- Corrosion is the process by which certain materials, metals and non-metals, deteriorate as a result of oxidation.
- The most important form of corrosion is the rusting of
- iron and steel.
- Rusting is a process of oxidation in which iron combines with water and oxygen to form rust, the reddish-brown crust that forms on the surface of the iron.
- The rusting of iron can be prevented by painting, oiling, greasing, galvanising, chrome plating, anodising or making alloys.
- Galvanisation is a method of protecting steel and iron from rusting by coating them with a thin layer of zinc.
- The galvanised article is protected against rusting even if the zinc coating is broken.
- Although metals like aluminium, chromium and zinc corrode more readily than iron, their oxides form a coating that protects the metal from further attack.

Anodising

- Anodising is a process of forming a thick oxide layer of aluminium. Aluminium develops a thin oxide layer when exposed to air. This aluminium oxide coat makes it resistant to further corrosion.

2.9 DIFFERENT TYPES OF COMPOUND

- Compounds are defined as substances containing two or more different chemical elements. They have distinct chemical structures characterised by a fixed ratio of atoms held together by chemical bonds.
- Covalent Compounds: Covalent or molecular compounds form when elements share electrons in a covalent bond to form molecules. Molecular compounds are electrically neutral.
- Ionic compounds: Ionic compounds are compounds composed of ions, charged particles that form when an atom (or group of atoms, in the case of polyatomic ions) gains or loses electrons.

Aqua regia: Aqua regia is a freshly prepared mixture of concentrated hydrochloric acid and concentrated nitric acid in the ratio of 3:1. It can dissolve gold, even though neither of these acids can do so alone. Aqua regia is a highly corrosive, fuming liquid. It is one of the few reagents that is able to dissolve gold and platinum.

Do You Know?

Pure gold, known as 24 carat gold, is very soft. It is, therefore, not suitable for making jewelry. It is alloyed with either silver or copper to make it hard.
Generally, in India, 22 carat gold is used for making ornaments. It means that 22 parts of pure gold are alloyed with 2 parts of either copper or silver.

2.10 ALLOY

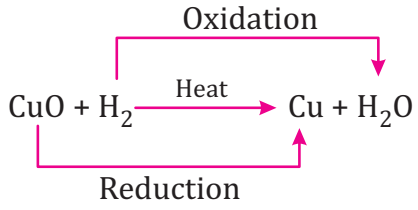
- An alloy is a uniform mixture. It is made up of two or more chemical elements, of which at least one is a metal.
- An alloy has properties different from the metal it is made of. Steel is an alloy which is made by mixing carbon (0.5% to 1.5%) with iron. Sterling silver is an alloy of silver that consists of 92.5% pure silver and 7.5% of other metals, usually copper. Sterling silver is used in jewelry, silverware and decorations. Alloying with copper maintains the silvery color of metal while increasing stability and rigidity.

List of Some Alloys, Their Components and Uses

Sr/no	Alloy	Components	Uses
1	Brass	Copper, Zinc	Utensil making and decorative items
2	Steel	Iron, Carbon	Buildings, Infrastructure, tools, ships, automobiles, appliances, weapons
3	Stainless Steel	Steel, Chromium, Nickel, Carbon	Utensils, Surgical tools, Medical equipments, automotive and aerospace
4	Solder	Lead, Tin	Joining two or more metals by heating
5	Bronze	Copper, Tin	Bronze bearings, spark free tools, medals, coins, sculptures, musical instruments
6	Duralumin	Aluminum, Copper, Magnesium, Manganese	Aircraft Construction, making Cookwares
7	German silver	Copper, Zinc, Nickel	Extensively used because of its hardness, toughness, and resistance for corrosion. Tablewares, heating coils, marine fittings, plumbing fixtures, etc.
8	Alnico	Iron, Aluminium, Nickel, Cobalt	Used to make permanent Magnet
9	Nichrome	Nickel, Iron, Chromium, Manganese	Used in Heating Elements

2.11 CHEMICAL REACTIONS AND EQUATIONS

- Chemical reactions occur all the time - when fuels are burnt, in the industrial extraction of metals from their ores, and in many natural life processes. Chemical reactions involve the breaking and making of bonds between atoms to produce new substances.



Chemical Reactions

- **Combination** reaction is a reaction in which two reactants combine to form one product.
- **Decomposition** Reactions: Decomposition reactions are those in which one compound breaks down (or decomposes) to form two or more products.
- **Displacement Reactions**: Displacement reactions are those in which an element reacts with a compound to form a new compound.
- **Double Displacement Reaction:** reactions in which there is an exchange of ions between the reactants are called double displacement reactions.
- **Oxidation and Reduction**: one reactant gets oxidised while the other gets reduced during a reaction. Such reactions are called oxidation-reduction reactions or redox reactions.
- **Exchange Reactions:** Exchange reactions are those in which cations and anions that were partners in the reactants are interchanged in the products. In exchange reactions, the products must remain electrically neutral.
- **Chemical Equations:** Information about reactions can be recorded using balanced chemical equations.

The equation will describe, in quantitative terms, how much of a product will be formed from a given mass of reactants. An example of a chemical reaction is when coal is burnt in air: $C + O_2 \rightarrow CO_2$

- Here, coal (a form of carbon) reacts with oxygen molecules to give carbon dioxide (and heat).
- **Rates of Reaction:** Reactions can occur at different speeds. The rate of reaction depends mostly on the reactants concerned - some naturally react faster than others. However, certain factors can help speed up reactions. These factors are increasing the heat of the reactants, increasing the concentration of the reactants, use of a catalyst etc.

Chemical Reactions and Equations

- Chemical reaction is the process of combination of different atoms to form different products which involve a change in the physical and chemical properties like:
  - Change in the colour of the substance
  - Change in the state of the substance
  - Change in heat energy: Absorption of energy or release of energy
  - Release of gas
  - Evolution of light and sound
- **Chemical Equations:** The symbolic representation of the reactants and the products using their chemical formulae is known as Chemical Equation. A chemical equation consists of:
  - Reactants
  - Products
  - An arrow separates the reactants and products
- *Reactants* are those substances which take parts in the chemical reaction. *Products* are those substances which are produced during chemical reaction.

$$\underset{\text{Reactants}}{C + O_2} \rightarrow \underset{\text{Product}}{CO_2}$$

Representation of Physical States of Reactants and Products

- For solids it is "(s)".
- For liquids it is "(l)".
- For gases it is "(g)".
- For aqueous solutions it is "(aq)".
- For gas produced in the reaction it is "(↑)".
- For precipitate formed in the reaction it is "(↓)".
- Direction of reaction is indicated by "(→)".

For Example:

$$\underset{\text{(Reactants)}}{Zn\ (s) + \text{dil. } H_2SO_4\ (aq)} \rightarrow \underset{\text{Products)}}{ZnSO_4\ (aq) + H_2\ (g)\ (\uparrow)}$$

- A chemical equation is helpful to understand a chemical reaction in an easy way. In a chemical equation the masses of reactants and products may or may not be equal. But according to the law of conservation of mass "the total mass of the reactants and the products should be equal". So in order to maintain the law true it is necessary to balance a chemical equation.

2.12 FUNDAMENTALS OF INORGANIC CHEMISTRY

- Inorganic chemistry is that chemistry which deals with the synthesis and behaviour of inorganic and organometallic compounds. This part of chemistry covers all chemical compounds except the myriad organic compounds (carbon based compounds, usually containing C-H bonds), which are the subjects of organic chemistry.

Important Term Used in Inorganic Chemistry

- **Allotropy**: The two or more than two forms of any element are called allotropes; it can also be defined as a variant of a substance consisting of only one type of atom. It is a new molecular configuration, with new physical properties. Substances that have allotropes include carbon, oxygen, sulphur, and phosphorus while the presence of elements in more than one form is called allotropy.

Elements	Allotropes
Carbon	Diamond, graphite, wood charcoal, bone charcoal, blood charcoal etc.
Phosphorous	White or Yellow phosphorus, red phosphorous, black violet etc.
Oxygen	Ozone
Sulphur	Rhombic sulphur, monoclinic sulphur, amorphous sulphur, plastic sulphur

- **Phosphorescence**: It is that phenomena of substance, when any substance like calcium sulphide etc is kept open in sunlight then the optical radiations are absorbed by such substance and even after removing sunlight source it also emits radiation.
- **Fluorescence**: If the visible light is absorbed by certain substances then their atomic electrons become excited and sometimes, when these electrons come in their original state then different radiations of different wavelengths are obtained then it is said to be the phenomena of fluorescence.
- **Efflorescence:** The salts like NaCl. $10H_2O$, Na_2CO_3. $10\ H_2O$ etc. have excess of water and when these are left in air then these water crystals vaporise and salts transform into crystal powder, this phenomenon is called efflorescence.
- **Sublimation:** It is a process in which certain solid substances like benzoic acid, anthracin, camphor, anthaquibinon, ammonium chloride etc on heating directly transform themselves into gaseous state and when these are cooled appropriately then come into original solid state.

- **Isotope:** Atoms of the same element can have different numbers of neutrons; the different possible versions of each element are called isotopes. For example- Hydrogen has three isotopes- protium ($_1H^1$), deuterium ($_1H^2$), and tritium ($_1H^3$).
- **Isobar:** The element which has equal atomic number but different mass number then it is called Isobar. For example- Argon ($_{20}Ar^{40}$), Potassium ($_{19}K^{40}$) and Calcium ($_{20}Ca^{40}$).
- **Corrosion:** When the metallic surfaces are affected by moisture, water, air etc then it is called corrosion of the metals.
- **Malleability and Ductility:** The property of something that can be worked, hammered or shaped without breaking; and the malleability of something that can be drawn into threads, wires or hammered into thin sheets
- **Physical Changes and Chemical changes**: Physical changes occur in the physical shape, size, physical state etc. while Chemical changes occur in the internal molecular composition.
- **Galvanization:** It is a process of laminating a thin layer of fusing or molten zinc through an appropriate process of electrolysis to protect the metals like iron, copper etc. from rusting and corrosion.
- **Atomicity**: It is a number atom present in a molecule of any element or compound.
- **Catalysis:** It is a chemical substance that increases or decreases the rate of any chemical reaction but does not take part in the chemical reaction is called catalyst and the process is called catalysis.
- **Enzyme:** It is a biological molecule (proteins) that act as catalysts and help complex reactions occur everywhere in life. Let's say you ate a piece of meat. Proteases would go to work and help break down the peptide bonds between the amino acids

2.13 ACIDS, BASES AND SALTS

- **Acids:** An acid is a substance which furnishes hydrogen ions (H^+) when dissolved in water. For example, in its aqueous solution hydrochloric HCl (aq) dissociates as:
- $HCl\ (aq) \rightarrow H^+(aq) + Cl^-(aq)$
- Acid is a water-soluble compound having a sour taste and capable of turning litmus red and reacting with a base to form a salt. It is a compound which contains replaceable hydrogen atoms, a part or whole of which can be replaced by means of a metal or a positive radical. For Example: HCl, HNO_3, H_2SO_4 etc are acids because they contain replaceable hydrogen atoms.

Characteristics of Acids

- They taste sour.
- They turn blue litmus and methyl orange.
- They react with base and alkali to form salt and water.
- Strong acids like HCl, HNO_3, and H_2SO_4 etc. are good conductors of electricity in their aqueous solution.

Types of Acids

- Oxy Acids: These types of acids contain both hydrogen and oxygen. For example: HNO_3, H_2SO_4 etc.
- Hydra Acids: In this acid, only hydrogen is present and oxygen is absent. For example: HCl, HBr, HCN etc.

Uses of Acids

- Steel used in construction is treated with acid before being painted. Dilute sulphuric or hydrochloric acid will remove any surface rust which would otherwise spread under the painted surface. Rust remover which is used to repair cars is dilute phosphoric acid - H_3PO_4.
- Acids are used to make fertilizers.
- Lime scale removers contain weak acids. Lime scale is the name given to the calcium carbonate that forms in kettles and pipes. The formation of limescale is also called furring. To remove lime scale you can try using lemon juice (citric acid) or vinegar (ethanoic acid).
- Baking powder used in cooking contains tartaric acid.
- It is used in petroleum exploration, in the preparation of various types' explosives, colors, and medicines and in the construction of accumulated batteries.

Base

- A base is a substance which furnishes hydroxide ions (OH^-) when dissolved in water. For example, sodium hydroxide NaOH (aq), in its aqueous solutions, dissociates as:

$$NaOH\ (aq) \rightarrow Na^+(aq) + OH^-(aq)$$

Characteristics of Bases

- Bases release a hydroxide ion (OH^-) into water. The more ions that are released the stronger the base.
- Bases react with acids. When an acid and a base react, they form water and a substance called salt.
- **Bases taste bitter:** There are very few food materials that are alkaline. It is even more important that care be taken in tasting bases. Tasting bases is more dangerous than tasting acids because of the property of stronger bases to denature protein.
- **Bases release a hydroxide ion in a water solution.**
- **Bases neutralise acids in a neutralisation reaction:** The word reaction means that an acid plus a base makes water plus a salt. Symbolically, "Y" is the anion of acid "HY". 'X' is the cation of base 'XOH' and 'XY" is the salt in the product, the reaction is
- $HY + XOH \rightarrow HOH + XY$
- **Bases denature protein:** This accounts for the slippery feeling on the hands when exposed to a base. Strong bases that dissolve in water well, such as sodium or potassium lye, are very dangerous because a great amount of the structural material of human

beings is made of protein. Serious damage to flesh can be avoided by careful use of strong bases.

- **Bases turn red litmus to blue:** This is not to say that litmus is the only acid base indicator, but that it is likely the oldest one.

Types of Bases

- The number of ionizable hydroxide (OH^-) ions present in one base molecule is called baseline acidity.
- Based on acidity bases, three forms can be classified: mono acidic, diacidic, and triacidic.
- **Monoacidic base** is a base that produces one hydroxide ion when one of its molecules undergoes complete ionisation. Examples of such bases include potassium hydroxide and sodium hydroxide.
- **Diacidic base** is a base that produces two hydroxide ions when one of its molecules undergoes complete ionisation. Examples of such bases include magnesium hydroxide and barium hydroxide.
- **Triacidic base** is a base that produces three hydroxide ions when one of its molecules undergoes complete ionisation. Common examples of triacidic bases include iron (II) hydroxide and aluminium hydroxide.

Use of Bases

We use bases at home as cleaning agents, and as antacid medicines. Popular examples of homemade bases include soaps; lye, for example, used in oven cleaners; magnesia milk; and Tums. Each one has a pH of more than seven, has the ability to consume free hydrogen, and can neutralise acids.

Difference Between Acids And Bases

Acids	Bases
Taste sour	Taste bitter
Are corrosive to metals	Feel slippery or soapy
Changes blue litmus red	Change red litmus blue
Become less acidic on mixing with bases	Become less basic on mixing with acids

Salts

- Salts are ionic compounds made of a cation other than H^+ ion and an anion other than OH^- ion.
- Acids react with metal oxides to produce salt and water.
- Bases react with non-metal oxides to produce salt and water.
- Salt is an ionic compound that results from the neutralization reaction of an acid and a base. It is composed of related numbers of cations and anions so that the product is electrically neutral. They may be simple salts such as NaCl, KCl, and Na_2SO_4; acid salts like $NaHCO_3$ and NaH_2PO_4; or double salts like $KAl(SO_4)_2$.
- A salt is a compound formed by partial or complete replacement of the replaceable hydrogen atoms from an acid molecule by means of metal or a radical which acts like a metal. For example:

$$HCl + NaOH \rightarrow NaCl\ (Salt) + H_2O$$

$$HnO_3 + KOH \rightarrow KNO_3\ (Salt) + H_2O$$

Types of Salts

- **Normal Salt:** A normal salt is a salt formed by the complete replacement of replaceable hydrogen atoms from an acid molecule by means of a metal or a group of elements acting like a metal. Examples: The compounds like KCl, NaCl, $FeS0_4$, Na_2S0_4, $FeCl_2$ etc are normal salts. Obviously a normal salt doesn't contain a replaceable H-atom in its molecule.
- **Acid Salt:** An acid salt is that which contains one or more replaceable hydrogen atoms in its molecule and is formed by partial replacement of H^- atoms present in an acid molecule by means of metal or positive radical. Examples: The compounds like $NaHS0_4$, $NaHC0_3$, $KHC0_3$, NaH_2PO etc are acid salts.

$$HCI + Mg(OH)_2 \longrightarrow Mg(OH)CI + H_2O$$

- **Basic Salt:** A salt which contains 0_2- or OH^- group in its molecule is called basic salt. Examples: The compounds like Mg (OH) Cl, $[Mg(OH)_2 . MgC0_3]$, [Cu $(OH)_{2.CuCO3}$) etc are basic salts.

$$NH_4OH + HCl \longrightarrow NH_4Cl + H_2O$$

- **Acidic Salt:** A normal salt which is formed by the neutralisation of a strong acid and weak base is called acidic salt because its aqueous solution turns blue litmus red. Examples: The compounds like $FeCI_3$, $ZnCl_2$, $HgCl_2$, $Fe_2(SO_4)_3$, $HgSO_4$ etc are acidic salts.

$$2NaOH + H_2CO_3 \longrightarrow Na_2CO_3 + 2H_2O$$

- **Alkaline Salt:** Normal salts which are formed by the neutralisation of weak acids and strong bases are called alkaline salts because their aqueous solutions turn red litmus blue. Examples: The compounds like Na_2CO_3, CH_3COONa, $Na_2C_2O_4$, $Na_2B_4O_7.10H_2O$ etc are alkaline salts.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

- **Neutral Salt:** They are formed by the neutralisation of strong acids and strong bases, are called neutral salts because their aqueous solutions are neutral to litmus. Examples: The compounds like NaCl, KCl, K_2SO_4, $NaNO_3$, $KClO_3$, $KClO_4$ etc are neutral salts.
- **Double Salt:** A double salt is a mixture of two salts which on dissolution in water gives two types of metal ions. Examples: The compounds like Potash Alum $[K_2SO_4 . Al_2 (SO_4)_3 . 24\ H_2O]$, Mohr's salt $[FeSO_4 . (NH_4)_2SO_4 . 6H_2O]$, Ferric Alum $[K_2SO_4 . Fe_2 (SO_4)_3 . 24\ H_2O]$ etc are double salts.
- **Complex Salt:** A complex salt is a salt which contains a complex ion or complex neutral molecule in which there is a central metal ion surrounded by a number

of neutral molecules or negative ions. Examples: The compounds like potassium ferrocyanide ($K_4[Fe(CN)_6]$), potassium argento cyanide ($K[Ag(CN)_2]$) tetra amino cupric sulphate ($[Cu(NH_3)_4]SO_4$) etc are complex salts.

Some Commonly Used Salts

- **Baking soda:** Baking soda, also known as sodium bicarbonate or bicarbonate of soda, is a popular baking ingredient. It gives foods like bread, cakes, muffins and cookies a light, fluffy texture.
- **Washing soda:** Washing soda is used for washing clothes. It is mainly because of this chemical that the clothes washed by a washer man appear so white. Chemically, washing soda is sodium carbonate decahydrate.
- **Bleaching Powder:** Bleaching is a process of removing colour from a cloth to make it whiter. Bleaching powder has been used for this purpose for a long time. Chemically, it is calcium oxychloride.
- **Plaster of Paris:** These are made of plaster of paris, also called POP. The only difference between gypsum and plaster of paris is in the less amount of water of crystallisation.

2.14 MINERALS AND ORES

Natural materials

- The Earth is the main source of minerals and ores. Most of the elements are not found in the Free State because of their reactive tendencies. Potassium, sodium, calcium, magnesium, aluminium, zinc, iron, lead etc are the metals found in combined state. Minerals are the natural materials in which the metals and their compounds are found in earth. Ores are those minerals from which metals are extracted conveniently and profitably. These ores contain a good percentage of metal.

Abundances of the Metals in the Earth's Crust

Aluminum	8.1 %
Iron	5.0 %
Calcium	3.6 %
Sodium	2.8 %
Potassium	2.6 %
Magnesium	2.1 %
All others	1.5 %

- Aluminium is the most abundant metallic element but iron has played a much greater role in human history and is an essential part of everybody, literally! Iron is one of 94 naturally occurring elements. It is a metallic material with a silver-grey colour and metallic lustre. Its Atomic Number is 26 and its symbol is Fe. Iron is found in all parts of the planet. It comprises about 5% of the Earth's crust but is thought to make up perhaps as much as 80% of the planet's core. There are four naturally occurring stable isotopes of iron with at least four unstable isotopes also known to exist.

Characteristics of a Mineral

- It must occur naturally.
- It must be inorganic.
- It must be a solid.
- It must possess an orderly internal structure, that is, its atoms must be arranged in a definite pattern.
- It must have a definite chemical composition that may vary within specified limits."

Ores

Ores are those minerals from which metals are extracted conveniently and profitably.

Types of Ores

There are mainly four types of ores such as **Oxides;** *Carbonate Ores; Sulphide; Halides Ores*.

Types of Ores	Element	Name of Ores
Oxides	Aluminium	Bauxite ($Al_2O_3.2H_2O$)
	Copper	Cuprites (Cu_2O)
	Iron	Hematite (Fe_2O_3)
	Tin	Casseterite (SnO_2)
Carbonate Ores	Calcium	Limestone ($CaCO_3$)
	Zinc	Calamine ($ZnCO_3$)
	Iron	Siderite ($FeCO_3$)
Sulphide	Zinc	Zinc blende (ZnS)
	Copper	Copper glance (Cu_2S)
	Lead	Galena (PbS)
	Mercury	Cinnabar (HgS)
Halide Ores	Sodium	Rock Salt (NaCl)
	Fluoride	Fluorspar (CaF_2)
	Silver	Horn silver (AgCl)

Ores and Methods of Extraction of Some Common Metals

Metals	Occurrence	Extraction method
1. Lithium	Spodumeme $LiAl(SiO_3)_2$; Lipidolite	Electrolysis of fused LiCl/ KCl
2. Sodium	Rock salt (NaCl)	Electrolysis of fused NaCl/ $CaCl_2$

3. Magnesium	Carnallite ($KCl\ MgCl_2.6H_2O$); Magnesium ($MgCO_3$)	Electrolysis of fused MgO or $MgCl_2$/KCl carbon reduction of MgO
4. Calcium	Limestone ($CACO_3$) ; Dolomite ($MgCO_3.CaCO_3$); Gypsum ($CaSO_4$)	Electrolysis of fused $CaCl_2/CaF_2$
5. Copper	Cuprites (Cu_2O); Copper glance (Cu_2S)	Roasting of sulphide partially and reduction $1Cu_2O + Cu_2S + 6Cu+SO_2$
6. Aluminum	Bauxite ($Al_2O_3.2H_2O$) ; Cryolite (Na_2AlF_6)	Electrolysis of Al_2O_3 dissolved in molten Cryolite or in Na_2AlF_6
7. Zinc	Zinc blende (ZnS) ; Zencite (ZnO) ; Calamine ($ZnCO_3$)	Roasting and then reduction with C
8. Lead	Galena (PbS)	Roasting of sulphide ore then reduction of the oxide
9. Iron	Hematite (Fe_2O_3); Magnetite (Fe_2O_4); Siderite ($FeCO_3$); Iron pyrite (FeS_2); Limonite ($Fe_2O_3.3H_2O$)	Reduction with the help of CO and Coke in a blast furnace, chemical reduction with CO, Calcination followed by reduction with CO. Roasting followed by reduction with CO.

2.15 CARBON AND ITS COMPOUNDS

The common properties of nonmetals are:

- High ionization energies.
- High electronegativities.
- Poor thermal conductors.
- Poor electrical conductors.
- Brittle solids-not malleable or ductile.
- Little or no metallic luster.
- Gain electrons easily.
- Dull, not metallic-shiny, although they may be colourful.
- These are generally gases as - Hydrogen, Oxygen, Fluorine, Chlorine, Argon, Krypton, etc.; solids as- Carbon, Phosphorus, Sulphur, Selenium, Iodine, etc.; and liquid-Bromine (only).

- **Oxocarbon**: An oxocarbon or oxides of carbon is an inorganic compound, consisting only of carbon and *oxygen*. The simplest and most common oxo carbons are carbon monoxide and carbon dioxide with IUPAC (International Union of Pure and Applied Chemistry) names Carbon (II) exide and Carbon (IV) oxide respectively.
- **Carbon has three main allotropes:**
  (1) Graphite
  (2) Diamond
  (3) Buckminsterfullerene
- **Graphite**: It is a crystalline form of the element carbon with its atoms arranged in a hexagonal structure. It occurs naturally in this form and is the most stable form of carbon under standard conditions. Under very high pressure and temperature, it converts into a diamond.It is soft and used to prepare lead pencils. This is useful in applications where wet lubricants, as oil, can not be used. So it is called *dry lubricant*. It is a good conductor of electricity.
- **Diamond:** Diamond is a solid form of carbon with its atoms arranged in a crystal structure called diamond cubic. Diamonds are used as an abrasive because it is very hard. Small particles of diamonds are embedded in saw blades, drill bits and grinding wheels for the purpose of cutting, drilling or grinding hard materials. It has a high index of refraction and high luster. Due to these properties, diamond is the most valuable and popular gemstone of the world. Its thermal conductivity is highest with respect to other natural materials. It is used to inscribe words on glass.
- **Buckminsterfullerene:** It is a type of fullerene with the formula C_{60}. It has a cage-like fused-ring structure that resembles a soccer ball, made of 20 hexagons and 12 pentagons, with a carbon atom at each vertex of each polygon, and bonds along each polygon edge. It is used for the drug delivery system in the body. They can act as hollow cages to trap other molecules. This is how they can carry drug molecules around the body and deliver them to where they are required and trap dangerous substances in the body and remove them. It is also used as a lubricant and catalyst.

Solid Carbon Dioxide

- Solid (frozen) carbon dioxide is known as dry ice, because it looks like ice and it melts (sublimes) straight from solid to gas, without changing in liquid. Dry ice sublimes at -78.5°C (-109.3°F) at earth atmospheric pressure. It is useful for preserving frozen foods where mechanical cooling is unavailable.

2.16 BASICS OF ORGANIC CHEMISTRY

Hydrocarbon

Hydrocarbons are the Organic compounds obtained by the simple combination of hydrogen and carbon-like petrol, diesel, and kerosene oil, etc.
It is usually divided into two categories: Aliphatic hydrocarbon; Aromatic hydrocarbon.

Types of Hydrocarbon

Aliphatic hydrocarbon: It is an Open chain hydrocarbon that is odourless. It is categorised into two groups- Aliphatic hydrocarbon may further be divided into groups- Saturated hydrocarbon or Alkane or Paraffin; Unsaturated hydrocarbon

- ***Saturated hydrocarbon or Alkane or Paraffin:*** This is also called alkane or paraffin. Paraffin is a Latin word, which implies- less active and because of lesser activities of saturated hydrocarbons, these are called paraffin. The general formula of the members of the series of saturated hydrocarbons is given by C_nH_{2n+2}; where n is the number of members of the series. The organic compounds like methane, ethane, propane, butane, pentane, etc are saturated hydrocarbons in which all carbon atoms are attached with a single covalent bond to each other.
- ***Unsaturated hydrocarbon:*** Those compounds of aliphatic hydrocarbons in which carbon atoms have double or triple covalent bonds called unsaturated hydrocarbons. This is also of two types- *Alkenes or Olefin; Acetylene hydrocarbon or alkynes.*
  - ***Alkenes or Olefin:*** Those compounds of unsaturated aliphatic hydrocarbons in which carbon atoms have double covalent bonds called Ethylene hydrocarbons or olefin or alkenes. The general formula for the members of this series is C_nH_{2n}. The organic compound Ethylene (C_2H_4) is an example of alkenes.
  - ***Acetylene hydrocarbon or alkynes:*** Those compounds of unsaturated aliphatic hydrocarbons in which carbon atoms have triple covalent bonds are called acetylene or alkynes. The general formula for the members of this series is $CIIH_{2n\_2}$. The organic compound acetylene (C_2H_2) or ethane is the simplest example of this hydrocarbon.
- **Aromatic hydrocarbon:** It is a closed chain hydrocarbon which has a special type of smell (odour). Those compounds of hydrocarbons which are composed from hydrogen and carbon and have the branches like benzene, called aromatic hydrocarbons. The general formula of the members of this series is $C_nH_2n_{-2}$. There are various compounds like benzene; toluene, napthalene, anthracene etc are examples of aromatic hydrocarbons in which benzene is the simplest one. Sometimes aromatic hydrocarbons are also called Arenes.

Organic Compounds of Carbon, Hydrogen and Oxygen

- There are various organic compounds of carbon, hydrogen and oxygen obtained by the definite composition and combination of various functional groups like alcohols, ether, esters aldehydes, ketones, carboxylic acids etc whose in details are given as below:
- **Alcohols:** These are the simplest compounds of carbon, hydrogen and oxygen in which hydrogen atoms of alkanes are replaced by - OH functional group and the compound obtained is called alcohol. Also the alcoholic compound in which only one- OH is present is called monohydric alcohol while that of two - OH is called dihydric alcohol. The compounds like methanol (methyl alcohol), ethanol (ethyl alcohol) etc are the examples of monohydric alcohols, while glycol is the examples of dihydric alcohols. The general formula of the members of this series is $C_nH_{2n+}OH$.
- **Aldehydes**: Organic compounds in which - CHO functional group is present are called aldehydes, whose general formula of their members are C_nH_{2n+1} CHO. The compounds like formaldehyde, acetaldehyde, propionaldehyde etc are the examples of aldehydes.
- **Ketones:** Organic compounds in which > C = 0 functional group is present are called ketones. The general formula of the members of this family is $(C_nH_{2n+1})_2$ CO. The compounds like acetone or dimethyl ketone, methyl ethyl ketone, diethyl ketone etc are the examples of ketone.
- **Carboxylic acids:** Organic compounds in which the -COOH functional group is present are called carboxylic acids and the general formula of their family's members is $C_nH_{2n+1}COOH$ or $C_{2n}H_{2n+2}O_2$. The compounds like formic acid, acetic acid, propionic acid, butyric acid etc are examples of carboxylic acids.
- **Acid anhydrides:** Organic compounds in which R(CO)O(CO)R' functional group is present are called acid anhydrides. The general formula of the members of this family is $(C_nH_{2n+1}CO)_2O$. The compounds like acetic anhydride, propionic anhydride etc are the examples of acid anhydrides.
- **Esters:** Organic compounds in which the R–COO–R' functional group is present are called esters. The general formula of the family's members is $C_nH_{2n+1}COOR$ or $C_nH_{2n+1}CO_2R$. The compounds like methyl formate, ethyl formate, methyl acetate, ethyl acetate etc are the examples of esters. The ethyl acetate is used in making artificial perfumes, scented colour, dyes etc.
- **Ethers:** Organic compounds in which -0- functional group is present are called ethers. General formula of family's members is $(C_nH_{2n+l})_2O$. The compounds like dimethyl ether, diethyl ether etc are examples of ethers. Diethyl ether is used in the form of anesthesia and it is also called ether only.

General Formula of Organic Compounds

Organic Compound	General Formulae	Organic Compound	General Formulae
Alkane	C_nH_{2n+2}	Ether	$C_nH_{2n+2}O$
Alkene	C_nH_{2n}	Aldehyde and Ketone	$C_nH_{2n}O$
Alkynes	C_nH_{2n-2}	Carboxylic Acid	$C_nH_{2n}O_2$
Alcohols	$C_nH_{2n+2}O$	Primary aliphate amine	$C_nH_{2n+1}NH_2$
Alkyle halides	$C_nH_{2n+}X$	Carbohydrate	$C_x(H_2O)_y$

2.17 SOAPS AND DETERGENTS

Soaps and detergents are chemical compounds or mixtures of compounds used as a cleansing agent.

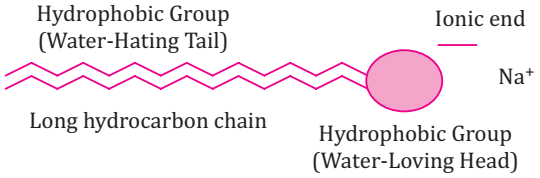


Fig. 2.4: A detergent or soap molecule

Soap

- Soap is a sodium salt or potassium salt of many combinations of fatty acids having cleansing action in water. Some of the examples are: Sodium stearate, sodium oliate and sodium palmitate formed using stearic acid oleic acid and palmitic acid. The soaps contain fats and oils.
- **Manufacturing Process of Soap:** The fats and oils required for manufacturing soaps are extracted from the plants and animals. To make the fatty acids called triglyceride molecules, three fatty acid molecules are added with the one molecule of glycerine. Fatty acids are weak acids composed of two parts. A carboxylic acid group having one hydrogen (H) atom, two oxygen (O) atoms, and one carbon (C) atom, and a hydrocarbon chain attached to the carboxylic acid group. Normally, it is made up of a long straight chain of carbon (C) atoms carrying two hydrogen (H) atoms. Earlier the alkali required for making soaps were obtained from the animals but now they are clinically composed. The common alkalis used in soap making are sodium hydroxide (NaOH), also called caustic soda; and potassium hydroxide (KOH), and also called caustic potash.
- **Saponification:** Saponification is the most common process used for soap making. A number of fats and oils are heated and mixed with a liquid alkali to produce soap and water (neat soap) plus glycerine.

Neutralization

- Fats and oils are hydrolyzed with a high-pressure steam to get crude fatty acids and glycerine. The fatty acids are purified by distillation and neutralized with an alkali to produce soap.
- When sodium is used as alkali, the soaps formed are solid and hard. On the other hand the soaps having potassium as Alkali are much softer and liquid in shape. The cleaning property of soaps depends on the hardness of the water which contains harmful minerals.
- **Detergents:** Detergents are much better solutions for the cleaning purpose as the hardness of water does not affect them. Today detergent is a better liquid form solution used for cleaning purposes. The surfactants used in detergents are made up of petrochemical solutions. Some of them are: Petrochemicals and Oleochemicals, sulfur trioxide, sulphuric acid and ethylene oxide. As an alkali potassium and sodium are used.
- **Manufacturing of Detergents**
  - ***Anionic Surfactants:*** The chemical reaction of hydrocarbons extracted from petroleum or fats and oils produce new acids similar to fatty acids. Then an alkali is added to the new acid to produce anionic surfactant molecule.
  - ***Non-ionic Surfactants:*** The hydrocarbons are first converted to an alcohol and then made to react with ethylene oxide. Thus produced surfactants are then reacted further with sulphur-containing acids to form another type of anionic surfactant.

3 Biology

INTRODUCTION

Lamarck and Treviranus introduced the term "biology". It is the study of living organisms, divided into many specialized fields that cover their morphology, physiology, anatomy, behavior, origin, and distribution.

3.1 BRANCHES AND SUB-BRANCHES OF BIOLOGY

- **Zoology:** Detailed study of different living and extinct animals.
- **Botany:** Detailed study of plants and their life.
- **Paleontology:** The study of history of life on Earth as based on fossils. Fossils are the remains of plants, animals, fungi, bacteria and single celled living things that have been found in layers of phenomenon. rock materials or impressions of organisms preserved in rocks.
- **Palaeobotany:** Study of plant fossils.
- **Bionomics:** The study of the mode of life of organisms in their natural habitat and their adaptations to their surroundings. Bionomics is the comprehensive study of an organism and its relation to its environment. It is also referred to as **"ecology"**.
- **Biometry:** It is also known as **biostatistics**. It is the development and application of statistical and mathematical methods to analyze the data results from biological observations and phenomena.
- **Anthology:** Study of flowers.
- **Ecology:** The branch of biology that deals with the relation of organisms to one another and to their physical surroundings.
- **Genetics:** The study of heredity or how the characteristics of living things are transmitted from one generation to the next. Every living thing contains the genetic material that makes up DNA molecules which is passed on when organisms reproduce. The basic unit of heredity is **"Gene"**.
- **Physiology:** Study of normal functions of living creatures and their parts.
- **Pedology:** It is the study of soils in their natural environment. It deals with pedogenesis, soil morphology and soil classification.
- **Serology:** The scientific study or diagnostic examination of blood serum, especially with regard to the response of the immune system to pathogens or introduced substances.
- **Pathology:** The science of the causes and effects of diseases. Especially the branch of medicine that deals with the laboratory examination of samples of body tissue for diagnostic or forensic purposes.
- **Parasitology:** Parasitology is the study of parasites (viruses, bacteria, fungus, worms, insects), their hosts and the relationship between them. Parasites are organisms that use other species of plants and animals as a host. The hosts provide the environment in which the parasite lives.
- **Oncology:** A branch of biology that deals with the prevention, diagnosis and treatment of tumors/ cancer.
- **Virology:** Virology is the study of viruses-submicroscopic, parasitic particles of genetic material contained in a protein coat and virus-like agents.
- **Bacteriology:** Study of the morphology, ecology, genetics and biochemistry of bacteria as well as many other aspects related to them.
- **Entomology:** A branch of zoology that deals with insects.
- **Serpentology:** A branch of zoology that studies snakes.
- **Herpetology:** Herpetology is the branch of zoology which deals with the study of reptiles and amphibians such as snakes, turtles, lizards, tortoises, crocodilians etc. It deals with their behavior, geographic ranges, physiologies, development, genetics etc.
- **Ornithology:** Ornithology is a branch of zoology that deals with the study of birds.
- **Dermatology:** A branch of medicine concerned with the diagnosis and treatment of skin, nails and hair diseases.
- **Cell biology:** Cell biology is a branch of biology that studies the structure and function of the cell, which is the basic unit of life.
- **Embryology:** A branch of biology concerned with the study of embryos and their development.

- **Phycology or Algology:** A branch of biology which deals with the scientific study of seaweeds and other algae.
- **Mycology:** A branch of biology which deals with the scientific study of fungi.
- **Apiculture:** The raising and care of bees for commercial (honey production) and agricultural purposes (cross pollination).
- **Aviculture:** The breeding and rearing of birds.
- **Aquaculture:** The rearing of aquatic animals or the cultivation of aquatic plants for food.
- **Pisciculture:** The controlled breeding and rearing of fishes.
- **Agriculture:** The science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool and other products.
- **Sericulture:** The production of silk and the rearing of silkworms for this purpose.
- **Horticulture:** Horticulture is the science and art of growing fruits, vegetables, flowers and crops like spices, condiments and other plantation crops.
- **Floriculture:** Floriculture/ flower farming, is a discipline of horticulture concerned with the cultivation of flowering and ornamental plants for the floral industry.
- **Olericulture:** Olericulture is the science of vegetables growing, dealing with the culture of non-woody plants for food.
- **Agronomy:** A branch of agriculture dealing with crop production and soil management.
- **Vermiculture:** The cultivation of earthworms, especially in order to use them to convert organic waste into fertilizers.
- **Viticulture:** Cultivation and harvesting of grapes.

3.2 CELL

3.2.1 Structure of The Cell

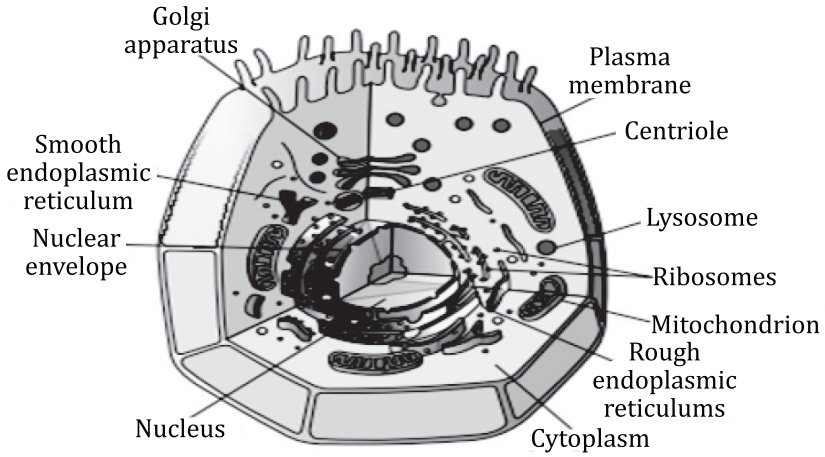


Fig. 3.1: Structure Of The Cell (Animal Cell)

- Biology is the **study of living organisms**. The detailed description of their form and appearance only brought out their diversity.
- The **cell is the fundamental, structural and functional unit** of all living organisms.
- **Anton Van Leeuwenhoek** first saw and described a live cell. **Robert Brown** later discovered the nucleus.
- Cells are characteristically microscopic in size. Although there are exceptions, a typical eukaryotic cell is 10 to 100 micrometers (μm) in diameter, while most prokaryotic cells are only 1 to 10 μm in diameter.

Cells Differ Greatly in Size, Shape and Activities

- For example, Mycoplasmas, the smallest cells, are only 0.3 μm in length while bacteria could be 3 to 5 μm.
- The largest isolated single cell is the egg of an ostrich. Small cells like Paramecium, amoeba, euglena frequently change their shape.

Components of Cell

- The general plan of cellular organization varies between different organisms, but despite these modifications, all cells resemble one another in certain fundamental ways.
- But **four major features all cells** have in common:

Fig. 3.2: Features All Cells

3.2.2 Plasma Membrane

- The plasma membrane encloses a cell and separates its contents from its surroundings.
- The plasma membrane is **flexible** and it is made up of **phospholipids and proteins**.
- It is selectively permeable and **regulates the transport of molecules** in and out of the cell.

3.2.3 Cytoplasm

- A **semifluid matrix** called the cytoplasm fills the interior of the cell.
- The cytoplasm contains the various organelles and micro and macro molecules which help in the functioning of the cell.
- In eukaryotic cells, cytoplasm refers only to the region between the nucleus and the plasma membrane.
- The part of the cytoplasm that contains organic molecules and ions in solution is called the **cytosol.**

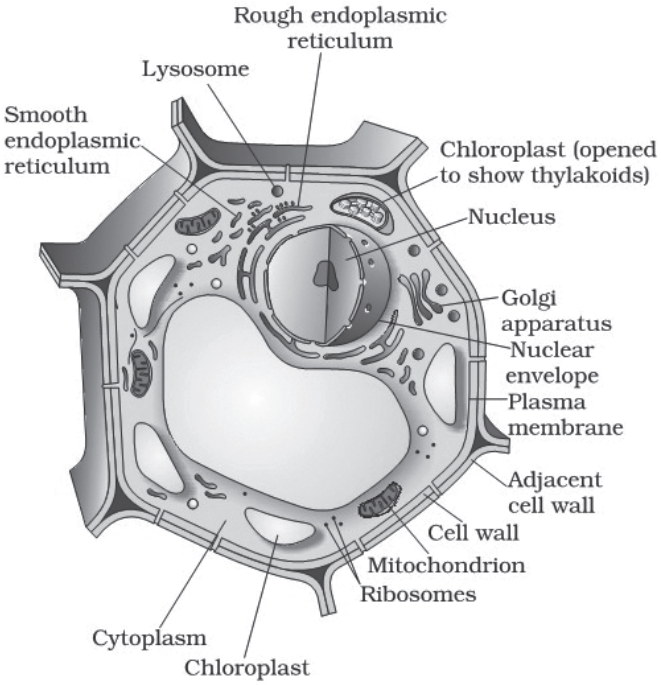


Fig. 3.3: Plant Cell

3.2.4 Nucleoid and Nucleus

- Every **cell contains DNA** (deoxyribonucleic acid), the hereditary molecule.
- In prokaryotes, the simplest organisms, most of the genetic material lies in a single circular molecule of DNA.

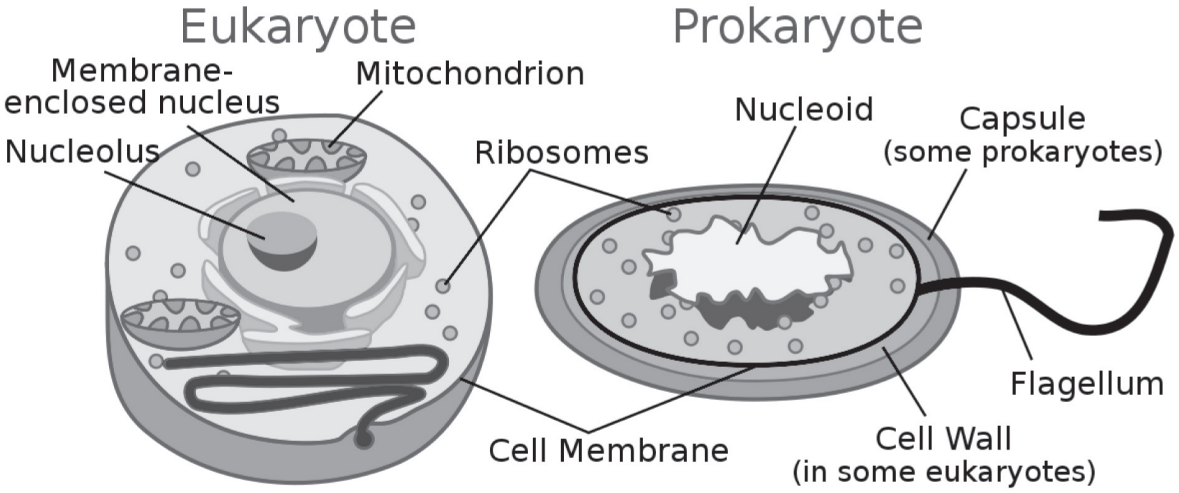


Fig. 3.4: Nucleoid or Nucleus

- It typically **resides near the center of the cell** in an area called the **nucleoid**.
- The DNA of eukaryotes is contained in the nucleus, which is surrounded by a double-membrane structure called the nuclear envelope.

Major Components of The Nucleus

- The nucleoplasm is the central area in the cell that contains the genetic material.
- The nucleolus is the distinct structure present in the nucleus of eukaryotic cells. Primarily, it participates in assembling the ribosomes, alteration of transfer RNA and sensing cellular stress. The **nucleolus is composed of genetic materials and proteins**, which form around specific chromosomal regions.

Chromatin: Chromatin is a complex of DNA and proteins that forms chromosomes within the nucleus of eukaryotic cells.

3.2.5 Ribosomes

- The ribosome is a complex molecule made of ribosomal RNA molecules and proteins that form a factory for protein synthesis in cells.
- The eukaryotic ribosomes are the 80S while the prokaryotic ribosomes are 70S.
- Here S (Svedberg's Unit) stands for the sedimentation coefficient; it is indirectly a measure of density and size.

3.2.6 Cell Organelles

- Organelles are **specialized structures that perform various jobs inside cells**. The term literally means little organs.
- Organelles serve specific functions to keep a cell alive. For example, Mitochondria produce ATP (adenosine triphosphate) which acts as the energy currency of cells.

3.2.7 Mitochondria

- Each mitochondrion is a **double membrane-bound structure** with the outer membrane and the inner membrane.
- Mitochondria are the sites of aerobic respiration. They produce cellular energy in the form of ATP (adenosine triphosphate), hence they are called power houses of the cell.

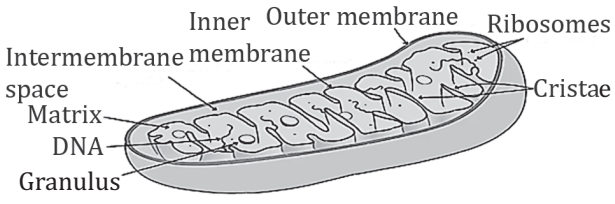


Fig. 3.5: Mitochondria

- They also possess a double stranded circular DNA molecule, a few RNA molecules, ribosomes (70S) and the components required for the synthesis of proteins.

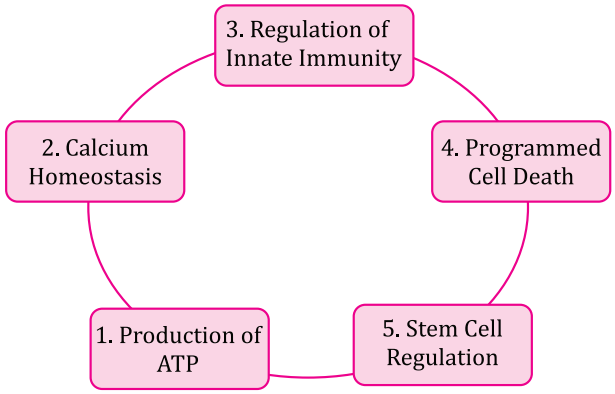


Fig. 3.5 A: Five Roles Mitochondria Play in Cells

3.2.8 Endo-Membrane System

- Many of the organelles are considered **together** as an endomembrane system because their functions are coordinated.
- The endomembrane system includes endoplasmic reticulum (ER), Golgi complex, lysosomes and vacuoles.

Endoplasmic Reticulum (ER)

- Endoplasmic reticulum is a **network of membranes** inside a cell through which proteins and other molecules move.

Types of Endoplasmic Reticulum (ER)

- **Rough ER:** It has ribosomes attached to its surface and it is an active site for protein synthesis.
- **Smooth ER:** In the absence of ribosomes they appear smooth and are called Smooth Endoplasmic Reticulum (SER). The smooth endoplasmic reticulum is the major site for synthesis of lipids. In animal cells lipid-like steroidal hormones are synthesized in SER.

Golgi Apparatus

- A Golgi body, also known as a Golgi apparatus, is a cell organelle that helps **process and package proteins and lipid molecules.**

Lysosomes

- A lysosome is a membrane-bound cell organelle that contains various hydrolytic enzymes.
- These enzymes **help in destruction and breakdown of various worn out cell parts** of the cell. Thus, they help in detoxification of the cell.
- They also **destroy pathogens**, such as bacteria and viruses and play a role in immunity.
- They are also called as **suicidal bag** of the cell because they help in self destruction of the cells.

Vacuoles

- The vacuole is the membrane-bound space found in the cytoplasm.
- It contains water, sap, excretory products and other materials not useful for the cell.
- The vacuole is bound by a single membrane called tonoplast.
- In plant cells the vacuoles can occupy up to 90 per cent of the volume of the cell.

3.2.9 Plastids

- Plastids are found in all plant cells and in euglenoids.
- They bear some specific pigments, thus **imparting specific colours** to the plants.
- Based on the type of pigments, plastids can be **classified into chloroplasts, chromoplasts and leucoplasts.**
- Like mitochondria, the chloroplasts are also double membrane-bound. It also contains small, double-stranded circular DNA molecules and ribosomes.

3.2.10 Stem Cells

- Stem cells are undifferentiated or partially differentiated cells in multicellular animals that can specialize into many types of cells and multiply endlessly to produce additional stem cells.

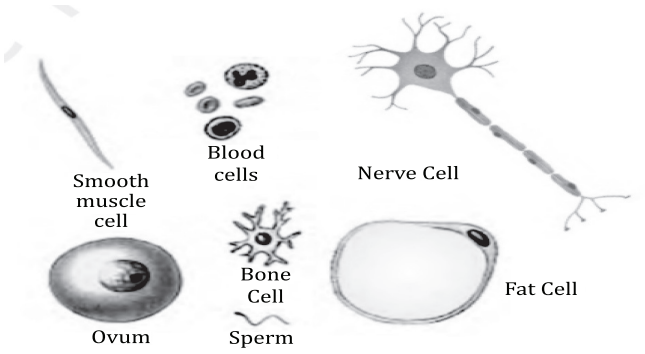


Fig. 3.6: Types of Cells

3.2.11 Classification of Cells

- On the basis of complexity, cells can be classified as **Eukaryotic cells and Prokaryotic cells.**
  - ***Eukaryotic cells*** contain well-defined membrane-bound nuclei.
  - ***Prokaryotic cells*** do not have well-defined membrane- bound nuclei.
- On the basis of components, Eukaryotes are divided into Animal cells and Plant cells.Plant cells have a cell wall outside the cell membrane.

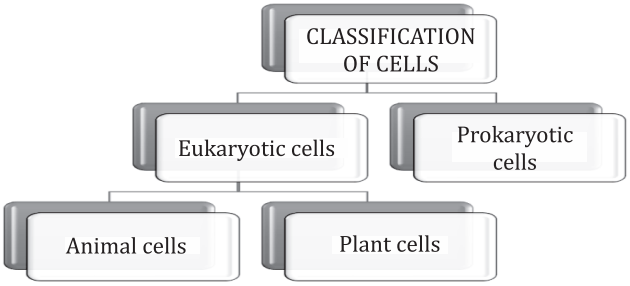


Fig. 3.7: Classification of cell

Characteristic	Prokaryotic cell	Eukaryotic cell
Size of cell	Typically 0.2-2.0 μm in diameter	Typically 10-100 μm in diameter
Well defined	Bacteria and Archaea	Animals and Plants
Nucleus	Absent	Present
Membrane-enclosed organelles	Absent	Present: Examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria and chloroplasts.
Flagella	Consist of two protein building blocks	Complex: consist of multiple microtubules
Cell wall	Usually present: chemically complex	Only in plant cells and fungi (chemically simpler)
Plasma membrane with steroid	Usually no	Yes
Cytoplasm	No cytoskeleton or cytoplasmic streaming	Cytoskeleton: cytoplasmic streaming

Ribosomes	Smaller	Larger
Cell division	Binary Fission	Mitosis
Number of chromosomes	One, but not true chromosome	More than one
Sexual reproduction	No meiosis: transfer of DNA fragments only (conjugation)	Involves meiosis

S.N.	Plant Cell	Animal Cell
1.	Usually they are larger than animal cells	Usually smaller than plant cells
2.	Cell wall present in addition to plasma membrane and consists of middle lamella, primary and secondary walls	Cell wall absent
3.	Plasmodesmata present	Plasmodesmata absent
4.	Chloroplast present	Chloroplast absent
5.	Vacuole large and permanent	Vacuole small and temporary
6.	Tonoplast present around vacuole	Tonoplast absent
7.	Centrioles absent except motile cells of lower plants	Centrioles present
8.	Nucleus present along the periphery of the cell	Nucleus at the center of the cell
9.	Lysosomes are rare	Lysosomes present
10.	Storage material starch grains	Storage material a glycogen granules

Deviation From Basic Cell Types

- **Virus:** Virus means **venom or poisonous fluid**. They are inert outside their specific host cell. Viruses are obligate parasites.
- **Virions:** The main difference between virus and virion is that virus is the nucleoprotein particle whereas virion is the **active, infectious form of the virus**.

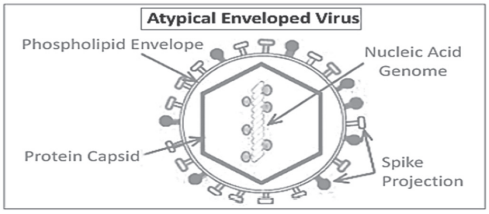


Fig. 3.8: A typical Enveloped Virus

General Structure of the Viruses

- A fully assembled infectious virus is called a virion.

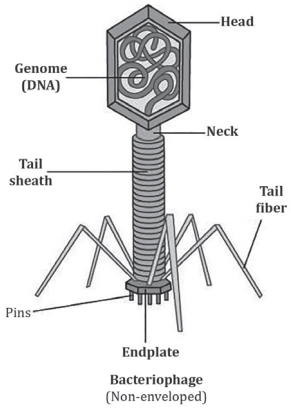


Fig. 3.9: virus structure

The Simplest Virions Consist of two Basic Components

- Nucleic acid (single- or double-stranded RNA or DNA);
- A protein coat, the capsid, which functions as a shell to protect the viral genome from nucleases during infection; It attaches the virion to specific receptors exposed on the prospective host cell.

- Some virus families have an additional covering, called the envelope, which is usually derived in part from modified host cell membranes.
  - Viral envelopes consist of a lipid bilayer that closely surrounds a shell of virus-encoded membrane-associated proteins.
  - The exterior of the bilayer is studded with virus-coded, glycosylated (trans) membrane proteins. Therefore, enveloped viruses often exhibit a fringe of glycoprotein spikes or knobs.
- Viruses cause diseases like **mumps, smallpox, herpes and influenza.**
- **Prions:** They are the misfolded proteins capable of producing many harmful pathogenic diseases. prion proteins that are found most abundantly in the brain.
- Viroids are infectious agents that consist only of naked RNA without any protective layer such as a protein coat.
  - Viroids infect plants (but no other forms of life) and are replicated at the expense of the host cell.

- Viroid genomes are small single-stranded circles of RNA that are only 250–400 bases long.

- **Lichens:** Lichens are **symbiotic associations** i.e. mutually useful associations, between **algae and fungi.**
  - The algal component is known as **phycobiont** and **fungal** component as mycobiont, which are autotrophic and heterotrophic, respectively.
  - Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner.
  - Lichens are very **good pollution indicators** – they do not grow in polluted areas

Adenoviruses: Adenoviruses are common viruses that cause a range of illnesses. They can cause cold-like symptoms, fever, sore throat, bronchitis, pneumonia, diarrhea, and pink eye (conjunctivitis).

Retroviruses: A type of virus that has RNA instead of DNA as its genetic material. It uses an enzyme called reverse transcriptase to become part of the host cells' DNA.

What is a Positive Sense and Negative Sense RNA Virus?

Positive Sense single (stranded RNA virus)	Negative-Sense single (stranded RNA virus)
• In the host cell, the positive-sense RNA of the virus is directly translated into viral proteins. • It is 5' to 3' as the host mRNA. • Since the host ribosome moves from 5' to 3' for translation, the positive- sense single-stranded RNA is directly used for protein synthesis.	• These viruses contain negative -sense RNA as genetic material. • It is not readable by the host ribosome. • First, the negative-sense RNA (3' to 5') is converted into positive-sense RNA (5' to 3') by virus RNA- dependent RNA polymerase. • The positive-sense RNA then functions as mRNA and is translated into protein by the ribosome

3.3 GRADES OF ORGANIZATION

- **An animal (or a plant for that matter) is composed of many units organized into successive units:** Molecules are the units of organelles, Organelles are the units that make up cells, Cells are the units that make up tissues, Tissues are the units that make up organs, and Organs make up organ systems.
- **Protoplasmic grade of organization:** All life functions are confined within the boundaries of a single cell. Within the cell, the protoplasm is differentiated into organelles capable of carrying out specialized functions. (e.g., the protists)

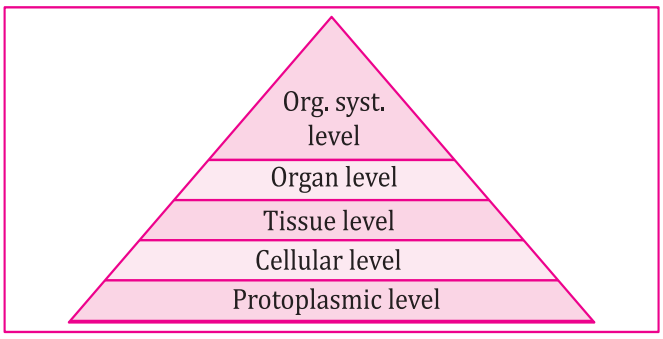


Fig. 3.10: Grades of Organization

- **Cellular grade of organization:** Cellular organization is an aggregation of cells that are functionally differentiated.
  - A division of labor is evident, so that some cells are concerned with, for example, reproduction, others with nutrition.
  - Such cells do not become organized into true tissues but may form definite patterns or layers. Sponges are at this level of organization.
- **Tissue grade of organization:** A tissue is an aggregate of cells in an organism that have similar structure and function.
  - For example: Plant tissues are meristematic tissues and vascular tissues.
- **Organ grade of organization:** The aggregation of different kinds of tissues into organs is a further advancement. For example: Kidney.
- **Organ system grade of organization:** When organs work together to perform some function (circulation, respiration, reproduction, digestion, etc.).

3.4 CLASSIFICATION OF ORGANISMS

- Aristotle was the earliest to attempt a more scientific basis for classification.
- He used simple morphological characters to **classify plants into trees, shrubs and herbs.**
- He also divided **animals into two groups**, those which had red blood and those that did not.
- The technique of classifying organisms is known as Taxonomy.

Taxonomic Category

- There are seven main taxonomic ranks: **kingdom, phylum** or division, **class, order, family, genus, species.**
  - **Kingdom:** The kingdom is the **highest level of classification**, with subcategories at other levels.
  - **Phylum:** Phylum is the classification of living organism to find some kind of **physical similarities** among organisms within the Kingdom. For

example: Phylum Arthropoda under Kingdom Animalia.

- **Class:** A class is a rank used in the biological taxonomy of all organisms. Each class is split into orders.
- **Order:** It is a group of organisms above taxa Family, sharing a **similar set of characters**. For example order primates contain human and other mammals having a similar character that is having mammary glands to feed young ones.
- **Family:** It is a taxonomic group containing one or more genus sharing a common set of characters.
- **Genus:** Condensed group of related species having similar characters in common.
- **Species:** Its basic unit of classification. For example: Homo Sapiens.

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Carnivora
Family	Felidae
Genus	Panthera
Species	Pardus

Two Kingdom systems of classification with **Plantae and Animalia kingdoms** were developed that **included all plants and animals** respectively. This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms.

3.4.1 Five Kingdom Classification

- **R.H. Whittaker** (1969) proposed a Five Kingdom Classification. The kingdoms defined by him were named **Monera, Protista, Fungi, Plantae and Animalia.**

Kingdom Monera

- **Bacteria** are the sole members of the Kingdom Monera. They are the most abundant microorganisms.
- Some of the bacteria are autotrophic, i.e., they synthesize their own food from inorganic substrates.
- They may be photosynthetic autotrophic or chemosynthetic autotrophic.
- The vast majority of bacteria are heterotrophs, i.e they depend on other organisms or on dead organic matter for food.

Example: Methanogens are present in the gut of several ruminant animals such as cows and buffaloes and they are responsible for the production of methane (biogas) from the dung of these animals.

- The Mycoplasma are organisms that completely lack a cell wall. They are the smallest living cells known and can survive without oxygen. Many mycoplasma are pathogenic in animals and plants.

Kingdom Protista

- **All single-celled eukaryotes** are placed under Protista.
- Members of Protista are primarily **aquatic**.
- The protist cell body contains a well-defined nucleus and other membrane-bound organelles.

Kingdom Fungi

- Fungi are **multicellular**, with a cell wall it is made up of Chitin, organelles including a nucleus, but no chloroplasts.
- They have **no** mechanisms for **locomotion.**
- Mushroom belongs to this Phylum. They are saprophytic, decomposers, parasitic or coprophilous (growing on dung).

Mucormycosis

- It is also known as black fungus because it produces necrosis and blackening of the tissue it affects.
- Mucormycosis is a fungal infection caused by a group of microorganisms belonging to the phylum Glomeromycota.
- It is a dangerous but rare fungal infection produced by a group of moulds known as mucormycetes

Kingdom Plantae

- Kingdom Plantae includes all eukaryotic chlorophyll-containing organisms commonly called **plants**.
- A few members are partially heterotrophic such as the insectivorous plants or parasites.
- Bladderwort and Venus fly trap are examples of insectivorous plants and Cuscuta is a parasite.
- The plant cells have an eukaryotic structure with prominent chloroplasts and cell walls mainly made of cellulose.

Animal Kingdom

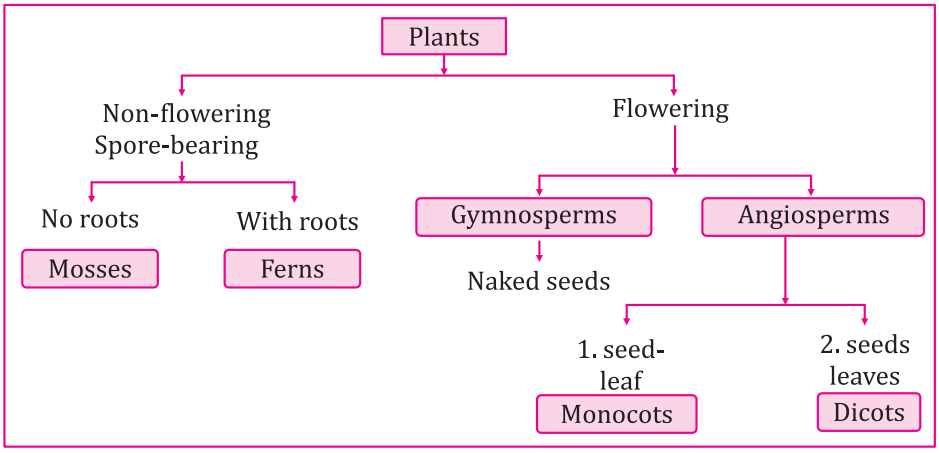
- This kingdom is characterized by heterotrophic eukaryotic organisms that are multicellular and their cells **lack cell walls.**
- They directly or indirectly depend on plants for food.
- Their mode of nutrition is holozoic – by ingestion of food.

Five Kingdoms					
Characters	**Monera**	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic polysaccharide + amino acid	Present in some	Present with chitin	Present (Cellulose)	Absent
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multicellular/loose Tissue	Tissue/organ	Tissue/organ/ Organ system
Mode of nutrition	Autotrophic (chemosyn-thetic and Photosynthetic) and Heterotrophic (Saprophytic parasitic)	Autotrophic photosynthetic and heterotrophic	Heterotrophic (Saprophytic/ Parasitic)	Autotrophic (Photosynthetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

3.4.2 Classification of Plant Kingdom

Algae

- **Algae are chlorophyll-bearing, autotrophic and largely aquatic** (both freshwater and marine) organisms.
- They occur in a variety of other habitats: moist stones, soils and wood.
- Some of them also occur in association with fungi (lichen) and animals. For Example: on sloth bear.



- Algae are **useful to man** in a variety of ways.
- At least a half of the total **carbon dioxide fixation on earth** is carried out by algae **through photosynthesis**.
- Being photosynthetic they increase the level of dissolved oxygen in their immediate environment. For example: Chlorella, a unicellular alga rich in proteins, is used as a food supplement even by space travellers.

Bryophytes

- Bryophytes include the various mosses and liverworts that are found commonly growing in moist shaded areas in the hills.
- Bryophytes are also called **amphibians of the plant kingdom** because these plants can live in soil but are dependent on water for sexual reproduction.
- They lack true roots, stems or leaves. They may possess **root-like, leaf-like or stem-like structures.**
- Bryophytes in general are of little economic importance but some mosses provide food for herbaceous mammals, birds and other animals.
- **Species of Sphagnum**, a moss, provide peat that have long been used as fuel, and as packing material for trans- shipment of living material because of their **capacity to hold water.**

Pteridophytes

- Pteridophytes are used for medicinal purposes and as soil- binders.
- They are also frequently grown as ornamentals.
- Evolutionarily, they are the first terrestrial plants to possess vascular tissues – **xylem** and **phloem.**

Gymnosperms

- The gymnosperms (gymnos : naked, sperma : seeds) are **plants in which the ovules are not enclosed by any ovary wall and remain exposed**, both before and after fertilisation.
- The seeds that develop post-fertilisation, are not covered, i.e., are naked.
- Gymnosperms include medium-sized trees or tall trees and shrubs
- Roots in some genera have fungal association in the form of mycorrhiza (Pinus), while in some others (Cycas) small specialised roots called **coralloid roots** are associated with N_2 - fixing cyanobacteria.
- Fruits and vegetables continue their metabolic activity after harvest. **Metabolic Activity is manifested by respiration.** Reduction of temperature is an effective means of reducing the rate of respiration.

Angiosperms

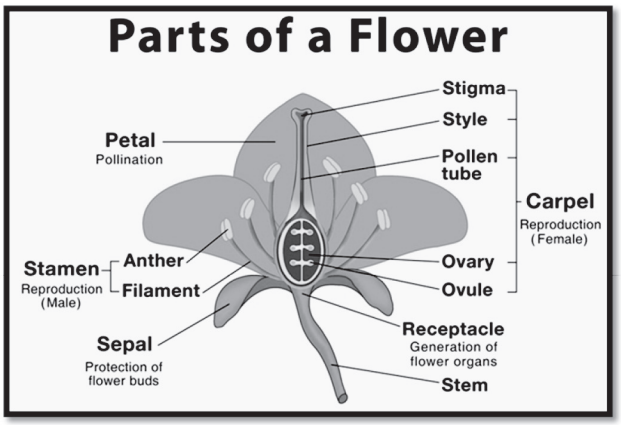


Fig. 3.11: Parts of flower

- They are also called Flowering plants.
- The pollen grains and ovules are developed in specialized structures called **flowers.**
- The **male sex organ** in a flower is the **stamen**.
- Each stamen consists of a slender filament with anther at the tip.
- The **female sex organ** in a flower is the **pistil**. Pistil consists of a swollen ovary at its base, a long slender style and stigma.
- In angiosperms, the seeds are enclosed in fruits. The angiosperms are an exceptionally large group of plants occurring in a wide range of habitats.

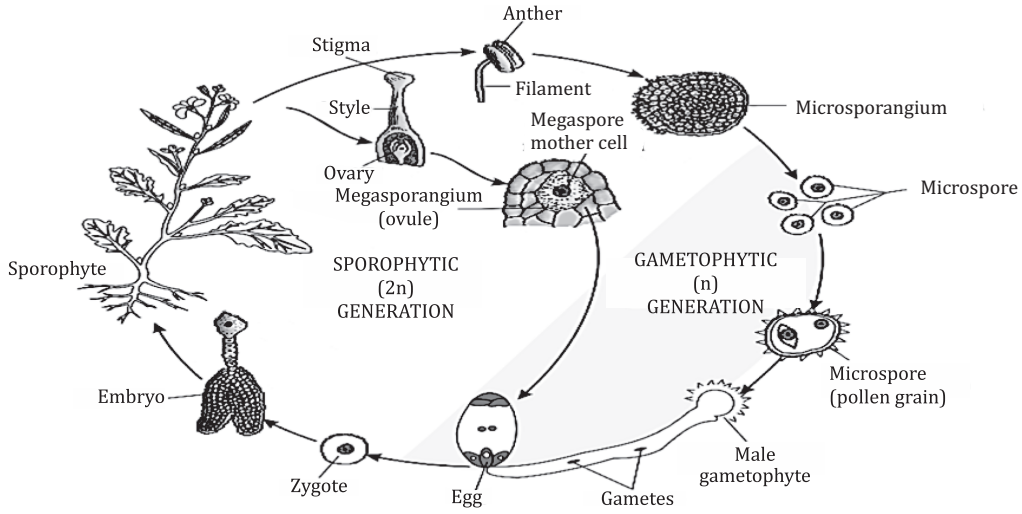


Fig. 3.12: Life Cycle of an Angiosperm

Do You Know?

- Vegetative reproduction is a form of asexual reproduction in plants. It is a process by which new organisms arise without production of seeds. It helps in the development of clones.
- Vegetative propagation involves only mitosis, this ensures that the genetic information in DNA of vegetative **progeny** (child) is same as in the mother plant and can be practiced throughout the year.
- However it does not help in elimination of viruses. Plant once systematically infected with a virus, usually remains infected for its lifetime. Thus any vegetative parts taken for propagation remain infected.

Different types of vegetative propagation include:

- **Natural Vegetative Propagation:** Runners, bulbs, Tubers, Corms, Suckers, Plantlets, Keikis, Apomixis
- **Artificial Vegetative Propagation:** Cutting, Grafting, Layering, Suckering, Tissue culture

3.4.3 Classification of Animals

Phylum – Porifera

- Members of this phylum are commonly known as sponges. They are generally **marine and mostly asymmetrical animals.**
- Most species are marine, and they range in size from a few millimeters to a few meters.
- **Sponges are filter feeders:** They filter out food particles suspended in the surrounding water as they draw it through their body. Sponges have a water transport or canal system. Sponges lack tissues.
- The body is supported by a skeleton made up of spicules or spongin fibres.
- Sexes are not separate (hermaphrodite), i.e., eggs and sperms are produced by the same individual.

Phylum – Coelenterata (Cnidaria)

- They are **aquatic**, mostly marine, sessile or **free-swimming**.
- The name cnidaria is derived from the cnidoblasts or cnidocytes.
- Cnidoblasts are used for anchorage, defense and for the capture of prey.
- Cnidarians exhibit tissue level of organization and are diploblastic.

Example: All coral reefs. Physalia (Portuguese man-of-war), Adamsia (Sea anemone).

Phylum – Platyhelminthes

- **Phylum:** Platyhelminthes commonly known as **Flatworms**
- These are mostly endoparasites found in animals including human beings.
- Flatworms are bilaterally symmetrical, triploblastic and acoelomated animals with organ level of organization.
- Specialized cells called flame cells help in osmoregulation and excretion.
- Some members like Planaria possess high regeneration capacity.

Example: Taenia (Tapeworm), Fasciola (Liver fluke).

Phylum – Aschelminthes

- Phylum – Aschelminthes commonly called as **Roundworms.**
- They may be free living, aquatic and terrestrial or parasitic in plants and animals.
- Roundworms have an organ-system level of body organization.
- Males and females are distinct. Often females are longer than males.

Example: Ascaris (Roundworm), Wuchereria (Filarial worm), Ancylostoma (Hookworm).

Phylum – Annelida

- They may be **aquatic** (marine and freshwater) or **terrestrial**; free-living, and sometimes parasitic. They exhibit organ-system level of body organization.
- Their body surface is distinctly marked out into segments or metameres and, hence, the phylum name Annelida.
- Their excretory and osmoregulatory organ is called Nephridia.

Example: Pheretima (Earthworm) and Hirudinaria (Blood sucking leech).

Phylum – Arthropoda

- This is the largest phylum of Animalia which **includes insects**. Over two-thirds of all named species on earth are arthropods.
- The body of arthropods is covered by a chitinous exoskeleton.
- Respiratory organs are gills, book gills, book lungs or tracheal system.
- Circulatory system is of open type.
- Sensory organs like antennae, eyes (compound and simple) statocysts or balancing organs are present.
- Excretion takes place through malpighian tubules.

Example:
Economically important insects – Apis (Honey bee), Bombyx (Silkworm), Laccifer (Lac insect) Vectors – Anopheles, Culex and Aedes (Mosquitoes)

- **Gregarious pest – Locusta (Locust).**
- **Living fossil – Limulus (King crab).**

Phylum – Mollusca

- This is the second largest animal phylum.
- Molluscs are terrestrial or aquatic (marine or freshwater) having an organ-system level of organisation.

- **Body is covered by a calcareous shell** and is unsegmented with a distinct head, muscular foot and visceral hump.

Example: Pila (Apple snail), Pinctada (Pearl oyster), Sepia (Cuttlefish).

Phylum – Echinodermata

- These animals have an endoskeleton of calcareous ossicles and, hence, the name Echinodermata.
- All are marine with organ-system level of organisation.
- The most distinctive feature of echinoderms is the presence of a water vascular system which helps in locomotion, capture and transport of food and respiration.
- An **excretory system is absent.**

Example: Asterias (Star fish), Echinus (Sea urchin), Cucumaria (Sea cucumber).

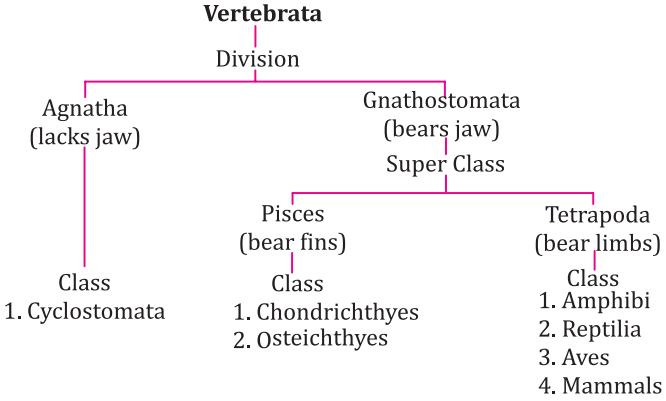
Phylum – Chordata

- Animals belonging to phylum Chordata are fundamentally characterised by the presence of a notochord, a dorsal hollow nerve cord and paired pharyngeal gill slits.

S.N.	Chordates	Non-chordates
1.	Notochord present.	Notochord absent.
2.	Central nervous system is dorsal. hollow and single.	Central nervous system is ventral. solid and double.
3.	Pharynx perforated by gill sits.	Gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post anal tail is present.	Post-anal tail is absent.

Phylum Chordata

It is divided into three subphyla: Urochordata or Tunicata, Cephalo-chordata and Vertebrata.



Subphylum Vertebrata

- Possess notochord during the embryonic period. The notochord is replaced by a cartilaginous or bony vertebral column in the adult. Thus all vertebrates are chordates but all chordates are not vertebrates.

Class – Cyclostomata

- All living members of the class Cyclostomata are ectoparasites on some fishes.
- Cyclostomes have a sucking and circular mouth without jaws.
- Their body is devoid of scales and paired fins.
- Cranium and vertebral columns are cartilaginous.

Example: Petromyzon (Lamprey) and Myxine (Hagfish).

Class – Chondrichthyes

- They are **marine animals with streamlined bodies** and have cartilaginous endoskeleton.
- Notochord is persistent throughout life.
- The **skin is tough,** containing minute placoid scales.
- Heart is two-chambered (one auricle and one ventricle).

Example: Scoliodon (Dog fish), Pristis (Saw fish).

Class – Osteichthyes

- It includes both marine and fresh water fishes with bony endoskeleton.
- Heart is two chambered (one auricle and one ventricle).
- They are cold-blooded animals.

Example: Marine – Exocoetus (Flying fish), Hippocampus (Sea horse);
Freshwater – Labeo (Rohu), Catla (Katla).

Class – Amphibia

- Amphibians can live in aquatic as well as terrestrial habitats.
- Most of them have two pairs of limbs.
- Body is divisible into the head and trunk.
- The eyes have eyelids.
- Respiration is by gills, lungs and through skin.
- The heart is three chambered (two auricles and one ventricle).
- These are cold-blooded animals.

Example: Bufo (Toad), Rana (Frog), Hyla (Tree frog)

Class – Reptilia

- The class name refers to their creeping or crawling mode of locomotion (Latin, repere or reptum, to creep or crawl).

- They are mostly terrestrial animals and their body is covered by dry and cornified skin, epidermal scales or scutes.
- They do not have external ear openings.
- Tympanum represents the ear.
- Heart is usually three-chambered, but four-chambered in crocodiles.

Example: Chelone (Turtle), Testudo (Tortoise), Chameleon (Tree lizard). Poisonous snakes – Naja (Cobra), Bangarus (Krait).

Class – Aves

- The characteristic features of Aves (birds) are the presence of **feathers and most of them can fly** except flightless birds (e.g., Ostrich).
- They possess beaks.
- The forelimbs are modified into wings.
- The hind limbs generally have scales and are modified for walking, swimming or clasping the tree branches.
- Skin is dry without glands except the oil gland at the base of the tail.
- Endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities (pneumatic).
- Heart is completely **four chambered**.
- They are **warm-blooded** (homoiothermous) animals, i.e., they are able to maintain a constant body temperature.

Example: Corvus (Crow), Columba (Pigeon), Psittacula (Parrot), Struthio (Ostrich)

Class – Mammalia

- They are found in a variety of habitats – polar ice caps, deserts, mountains, forests, grasslands and dark caves.
- Some of them have adapted to **fly or live in water**.
- The most unique mammalian characteristic is the presence of **milk producing glands** (mammary glands) by which the young ones are nourished.
- **External ears** or pinnae are present. Different types of **teeth** are present in the jaw. Heart is four chambered.

Example: Oviparous-Ornithorhynchus (Platypus); Viviparous - Macropus (Kangaroo), Pteropus (Flying fox Balaenoptera (Blue whale), Panthera tigris (Tiger), Panthera leo (Lion).

Recent Advancements

- The **three-domain system is a biological classification introduced by** Carl Woesein 1990.
- It **divides cellular life forms into** archaea, bacteria, and eukaryotic domains.

Genetics

- Humans knew from as early as 8000-1000 B.C. that one of the causes of variation was hidden in sexual reproduction. They exploited the variations that were naturally present in the wild populations of plants and animals to selectively breed and select for organisms that possessed desirable characteristics.
- The meaning of genetics is a branch of biology that deals with the heredity and variation of organisms.

Hibernation

- Hibernation is a state of inactivity and metabolic depression in endotherms, which is characterized by low body temperature, slow breathing and heart rate, and low metabolic rate. It is found in **bats, bears and rodents** etc.
- Hibernation functions to conserve energy when sufficient food is not available.
- To achieve this energy saving, an endothermic animal decreases its metabolic rate and thereby its body temperature.
- Hibernation may last days, weeks, or months—depending on the species, ambient temperature, time of year, and the individual's body-condition.
- Before entering hibernation, animals need to store enough energy to last through the duration of their dormant period, possibly as long as an entire winter.
- Larger species become hyperphagic, eating a large amount of food and storing the energy in fat deposits. In many small species, food caching replaces eating and becoming fat.

HUMAN ANATOMY AND PHYSIOLOGY

3.5 DIGESTIVE SYSTEM

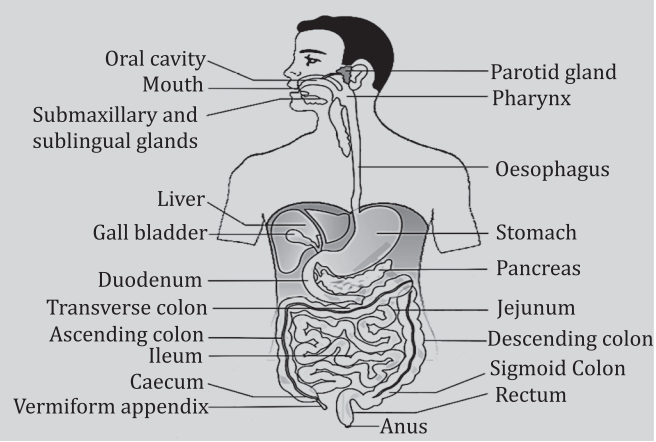


Fig. 3.13: Human Digestive System

- The digestive system contributes to homeostasis by breaking down food into forms that can be absorbed and used by body cells. It also absorbs water, vitamins, and minerals, and it eliminates wastes from the body.
- **Two groups of organs compose the digestive system:** the gastrointestinal (GI) tract and the accessory digestive organs.
- The gastrointestinal (GI) tract, or alimentary canal (alimentary 5 nourishment), is a continuous tube that extends from the mouth to the anus.

- The wall of the GI tract from the lower oesophagus to the anal canal has the same basic, four-layered arrangement of tissues. The four layers of the tract, from deep to superficial, are the mucosa, submucosa, muscularis, and serosa/adventitia.
- The accessory digestive organs include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

Process Involved in Digestion System

- **Ingestion:** This process involves taking foods and liquids into the mouth (eating).
- **Secretion:** Each day, cells within the walls of the GI tract and accessory digestive organs secrete a total of about 7 liters of water, acid, buffers, and enzymes into the interior space of the tract.
- **Mixing and propulsion:** Alternating contractions and relaxations of smooth muscle in the walls of the GI tract mix food and secretions and move them towards the anus.
- **Digestion:** Mechanical and chemical processes break down ingested food into small molecules.
- **Absorption:** The entrance of ingested and secreted fluids, ions, and the products of digestion into the epithelial cells lining the lumen of the GI tract is called absorption.
- **Defecation:** Wastes, indigestible substances, bacteria, cells sloughed from the lining of the GI tract, and digested materials that were not absorbed in their journey through the digestive tract leave the body through the anus in a process called defecation.

Oral Cavity

- Performs two major functions, mastication of food and facilitation of swallowing.
- The saliva secreted into the oral cavity contains electrolytes and enzymes, salivary amylase and lysozyme.
- The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the salivary amylase.
- Lysozyme present in saliva acts as an antibacterial agent that prevents infections.

Oesophagus

- The oesophagus secretes mucus and transports food into the stomach. It does not produce digestive enzymes, and it does not carry on absorption.

Stomach

- The stomach **stores the food for 4-5 hours.**
- The food mixes thoroughly with the acidic gastric juice of the stomach by the churning movements of its muscular wall and is called the chyme.
- The proenzyme pepsinogen, on exposure to hydrochloric acid gets converted into the active enzyme pepsin, the proteolytic enzyme of the stomach.
- Pepsin converts proteins into proteoses and peptides.
- The mucus and bicarbonates present in the gastric juice play an important role in lubrication and protection of the mucosal epithelium from excoriation by the highly concentrated hydrochloric acid.

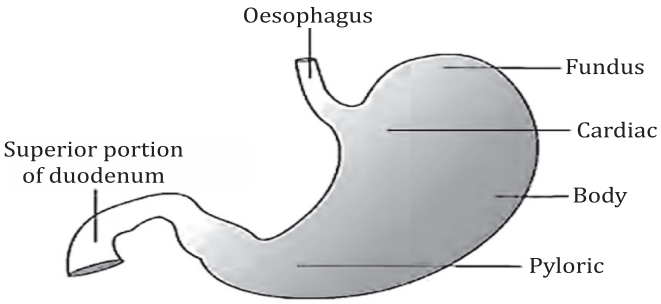


Fig. 3.14: Human Stomach

Small Intestine

- The bile, pancreatic juice and the intestinal juice are the secretions released into the small intestine.
- Pancreatic juice and bile are released through the hepato-pancreatic duct.
- The intestinal mucosal epithelium has goblet cells which secrete mucus.
- The secretions of the brush border cells of the mucosa along with the secretions of the goblet cells constitute the intestinal juice or succus entericus.
- This juice contains a variety of enzymes.
- The breakdown of biomacromolecules occurs in the duodenum region of the small intestine.
- The simple substances thus formed are absorbed in the jejunum and ileum regions of the small intestine.

Large Intestine

- The undigested and unabsorbed substances are passed on to the large intestine.
- No significant digestive activity occurs in the large intestine.

The Functions of Large Intestine

- Absorption of some water, minerals and certain drugs;
- Secretion of mucus which helps in adhering the waste (undigested) particles together and lubricating it for an easy passage.

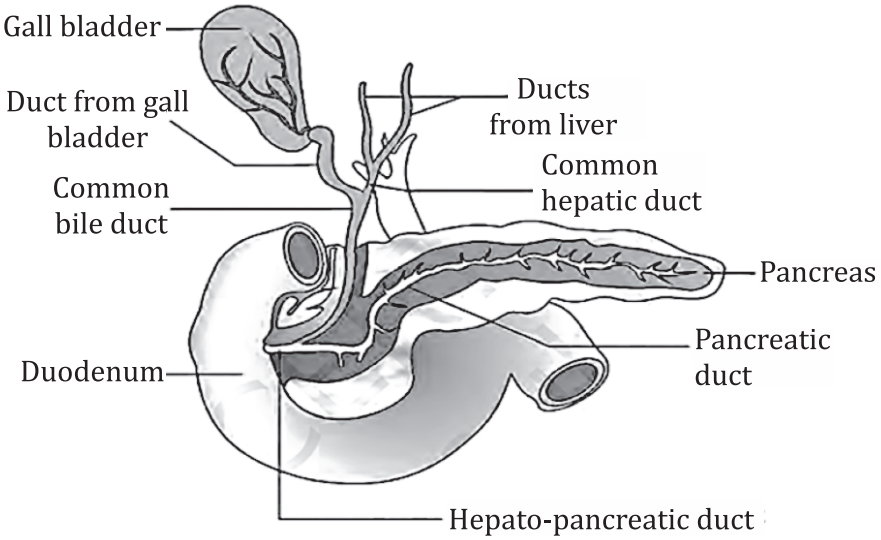


Fig. 3.15: The Duct Systems of Liver, Gallbladder and Pancreas

Pancreas

- Each day the pancreas produces 1200–1500 ml (about 1.2–1.5 qt) of pancreatic juice, a clear, colorless liquid consisting mostly of water, some salts, sodium bicarbonate, and several enzymes.
- The pancreatic juice contains inactive enzymes – trypsinogen, chymotrypsinogen, procarboxypeptidase, amylases, lipases and nucleases. Trypsinogen is activated by an enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin.
- Pancreatic acinar cells also secrete a protein called trypsin inhibitor that combines with any trypsin formed accidentally in the pancreas or in pancreatic juice and blocks its enzymatic activity.

Liver

- The liver is the **heaviest gland of the body**, weighing about **1.4 kg**.
- Each day, hepatocytes secrete 800–1000 ml (about 1 qt) of bile, a yellow, brownish, or olive-green liquid.
- The principal bile pigment is bilirubin.
- The liver is especially important in **maintaining a normal blood glucose level**.
- The liver can **detoxify substances** such as alcohol and excrete drugs such as penicillin, erythromycin, and sulphonamides into bile.

3.6 RESPIRATORY SYSTEM

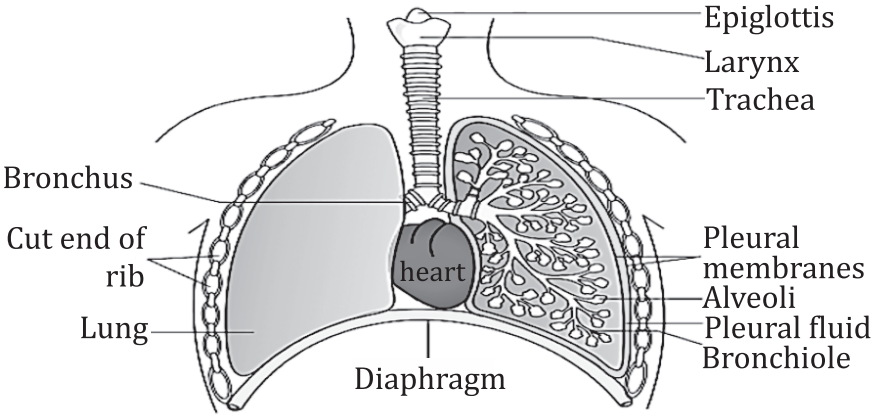


Fig. 3.16: Human Respiratory System

OR

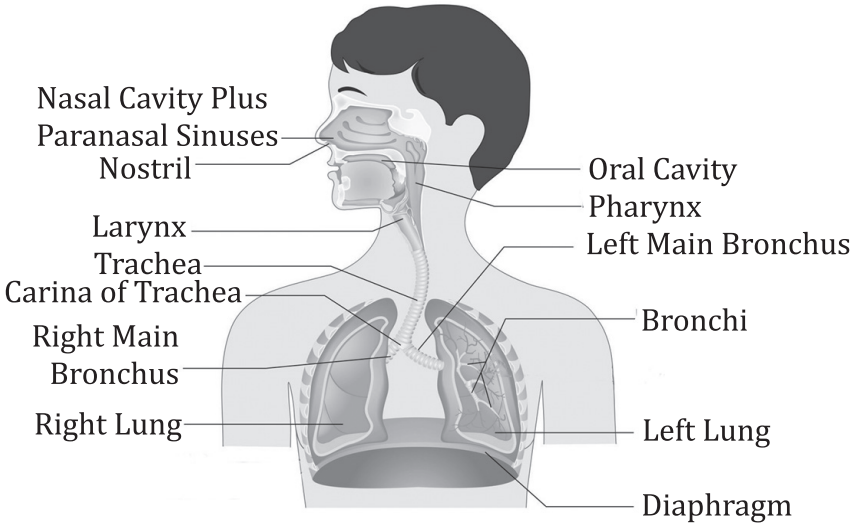


Fig. 3.17: Respiratory System

- The **process of exchange of O_2 from the atmosphere with CO_2** produced by the cells is called breathing,commonly known as respiration.
- The respiratory system contributes to homeostasis by providing for the exchange of gases — oxygen and carbon dioxide — between the atmospheric air, blood, and tissue cells. It also helps adjust the pH of body fluids.
- Mechanisms of breathing vary among different groups of animals depending mainly on their habitats and levels of organisation.

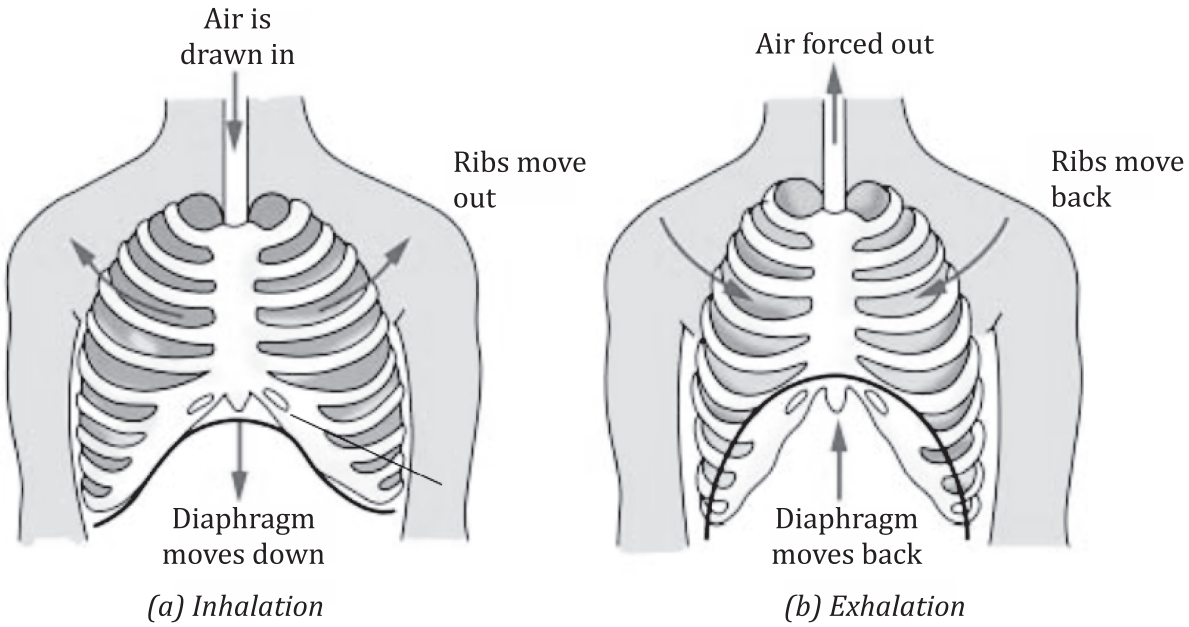


Fig. 3.18: Mechanism of Breathing in Human Beings

- Lower invertebrates like sponges, coelenterates, flatworms, etc., exchange O_2 with CO_2 by simple diffusion over their entire body surface.
- Earthworms use their moist cuticle and insects have a network of tubes (tracheal tubes) to transport atmospheric air within the body.
- Special vascularised structures called gills (branchial respiration) are used by most of the aquatic arthropods and molluscs whereas vascularised bags called lungs (pulmonary respiration) are used by the terrestrial forms for the exchange of gases.

- Among vertebrates, fishes use gills whereas amphibians, reptiles, birds and mammals respire through lungs.

Human Respiratory System

- The respiratory system structurally extends from the nose, mouth and the upper respiratory tract, all the way to the alveoli of the lungs.

Nose and Nasal cavity

- We have a pair of external nostrils opening out.
- It leads to a nasal chamber through the nasal passage.
- The nose warms, moistens, and filters air and functions in olfaction and speech.

Sinuses

- The sinuses are air-filled spaces in the skull. They are located behind the **forehead, nasal bones, cheeks and eyes.**
- Healthy sinuses contain no bacteria or other germs.
- Most of the time, mucus is able to drain out and air is able to flow through the sinuses.

Pharynx

- The pharynx (throat) is a muscular tube lined by a mucous membrane.
- The pharynx opens through the larynx region into the trachea.

Trachea

- The trachea (windpipe) extends from the larynx to the main bronchi. It is composed of C-shaped rings of cartilage and smooth muscle.
- It divides into tubes known as Bronchial tubes.

Larynx

- Larynx is a **cartilaginous box** which helps in **sound production** and hence called the sound box.
- The larynx contains vocal folds, which produce sound as they vibrate. Taut folds produce high pitches, and relaxed ones produce low pitches.
- It contains the thyroid cartilage (Adam's apple); the epiglottis, which prevents food from entering the larynx.

Bronchial tubes

- These **tubes let air in and out of your lungs**, so you can breathe. The bronchial tubes are sometimes referred to as bronchi or airways.
- Bronchitis is an inflammation of the lining of your bronchial tubes.
- The Bronchial tubes split up again into smaller air passages called bronchioles in the lungs.

Alveoli

- The alveoli are where the lungs and the blood exchange oxygen and carbon dioxide during the process of breathing in and breathing out.

Diaphragm

- Located below the lungs, is the major muscle of respiration.
- It is a large, dome-shaped muscle that contracts rhythmically and continually, and most of the time, involuntarily.
- Upon inhalation, the diaphragm contracts and flattens and the chest cavity enlarges.

Transportation of Gasses

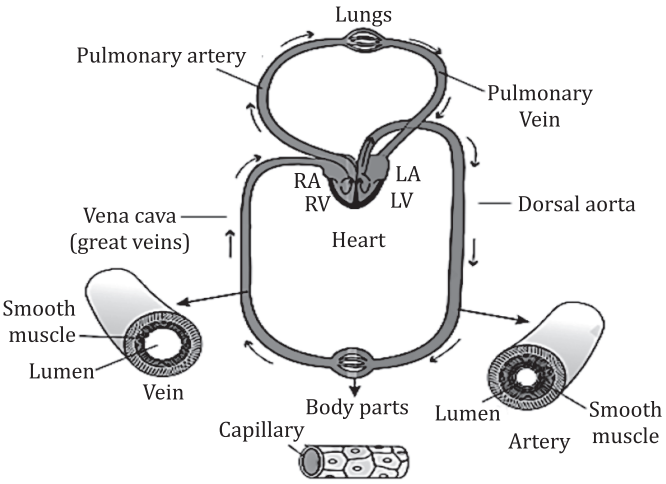


Fig. 3.19: Schematic plan of Blood Circulation in Human

- Once the respiratory gases have diffused in the lungs, resulting in the blood becoming O_2 rich and CO_2 being exhaled, the next stage of transporting the O_2 rich blood to the tissues that need it takes place.
- The transportation of gases throughout the body takes place in the bloodstream through the action of the cardiovascular system (heart and blood vessels).
- Oxygenated blood leaving the lungs flows back to the heart via the pulmonary veins and is then pumped to the rest of the body from the left ventricle via the aorta and its branches.
- As the oxygen rich blood reaches the capillaries gas exchange occurs, oxygen is delivered to the tissues and deoxygenated blood (loaded with CO_2) leaves the tissues of the body and flows back to the heart where it is pumped to the lungs via the pulmonary arteries.
- Once CO_2 is transported to the lungs it diffuses out of the capillaries into the alveoli and exhales out of the lungs.
- In each **100 mL** of oxygenated blood, 1.5% of the O_2 is dissolved in blood plasma and 98.5% is bound to haemoglobin as oxyhaemoglobin ($Hb–O_2$).

- In each 100 mL of deoxygenated blood, **7%** of CO_2 is dissolved in blood plasma, **23%** combines with haemoglobin as carbaminohemoglobin (Hb–CO_2), and 70% is converted to bicarbonate ions (HCO_3).

Cellular Respiration

- Cellular respiration is a metabolic pathway that breaks down glucose and produces **ATP.**

Asthma

- A disorder characterised by chronic airway inflammation, airway hypersensitivity to a variety of stimuli, and airway obstruction. Asthma is more common in children than in adults.

Exercise-Induced Asthma in Athletes

- Exercise-induced asthma is a condition of the respiratory tract where an increase in lung ventilation irritates the bronchial tree causing airway constriction.
- The resistance to airflow increases, and the breathing pattern of the athlete becomes difficult.

Pneumonia

- **Pneumonia is an acute infection** or inflammation of the alveoli. It is a common infectious cause of death.
- When certain microbes enter the lungs of susceptible individuals, they release damaging toxins, stimulating inflammation and immune responses that have damaging side effects.
- The most common cause of pneumonia is the pneumococcal bacterium Streptococcus pneumoniae.

3.7 CIRCULATORY SYSTEM

- The **heart contributes to homeostasis by pumping blood** through blood vessels to the tissues of the body to deliver oxygen and nutrients and remove wastes.

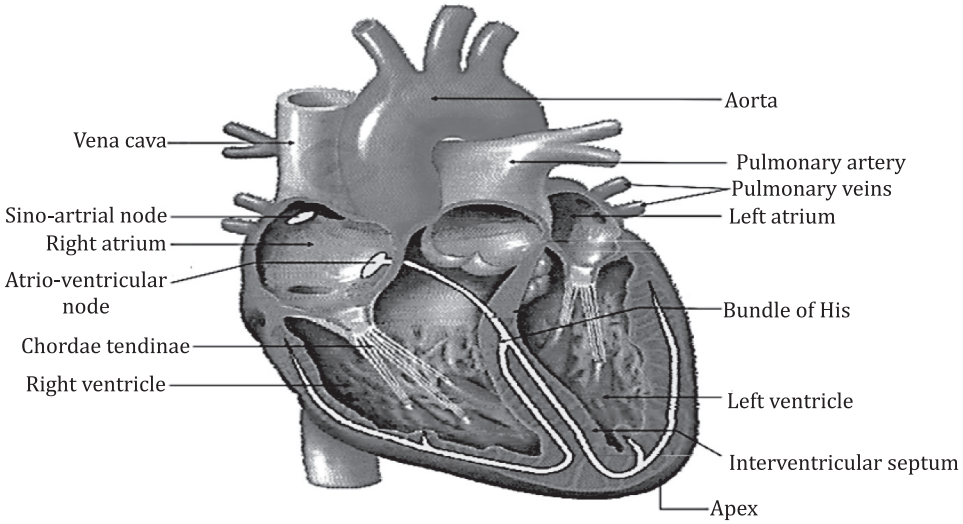


Fig.3.20: Blood Circulation in Human Heart

Functions of the Circulatory system

- The heart pumps blood via the circulatory system, which is made up of a network of arteries, veins, and capillaries.
- Its principal function is to supply the body with necessary nutrients, minerals, and hormones.
- The circulatory system, on the other hand, is in charge of collecting metabolic waste and toxins from the cells and tissues, which are either cleaned or removed from the body.

Components of the Circulatory system
Heart
• The heart is a muscular organ that lies between the lungs in the chest cavity. It is located in the thoracic area, some- what to the left, and is surrounded by the pericardium. • The human heart is divided into four chambers, two upper chambers known as atria (plural: atrium) and two lower chambers known as ventricles.
Arteries
• Carry blood from the heart to the various body parts. • All arteries carry oxygenated blood except pulmonary arteries.
Veins
• Carry blood from the body parts to the heart. • Carry deoxygenated blood from the various parts except the pulmonary vein.

3.7.1 Blood

- Blood is a **special connective tissue** consisting of a fluid matrix, plasma, and formed elements.

Components of Blood are as follows

Plasma

- Plasma is a straw coloured, **viscous fluid** constituting nearly 55 per cent of the blood.

- 90-92 percent of plasma is water and proteins contribute 6-8 percent of it.
- Plasma also contains small amounts of minerals like **Na^+, Ca^{++}, Mg^{++}, $HCO3^-$, Cl^-**, etc. **Glucose, amino acids, lipids,** etc., are also present in the plasma.
- Plasma without the clotting factors is called **serum**.

Formed Elements

- Erythrocytes, leukocytes and platelets are collectively called formed elements and they **constitute nearly 45 percent of the blood.**
- Erythrocytes or **Red Blood Cells** (RBC) are the most abundant of all the cells in blood.
- RBCs are devoid of nucleus in most mammals and are biconcave in shape. They have a red coloured, iron containing complex protein called haemoglobin, hence the colour and name of these cells.

Leucocytes

- Leukocytes are also known as **White Blood Cells** (WBC) as they are colourless due to the lack of haemoglobin.
- They are nucleated and are relatively lesser in number.
- The two main categories of WBCs – **granulocytes** and **agranulocytes**. **Neutrophils, eosinophils** and **basophils** are different types of granulocytes, while lymphocytes and monocytes are the agranulocytes.

Platelets

- Platelets, also called thrombocytes, are cell fragments produced from megakaryocytes (special cells in the bone marrow).
- A reduction in their number can lead to clotting disorders which will lead to excessive loss of blood from the body.

Blood Groups

- The surfaces of erythrocytes contain a genetically determined assortment of antigens composed of glycoproteins and glycolipids.
- These antigens, called agglutinogens (a-gloo-TINoÉ-jens), occur in characteristic combinations.
- Based on the presence or absence of various antigens, blood is categorised into different blood groups.

ABO Group

- ABO grouping is based on the presence or absence of two surface antigens (chemicals that can induce immune response) on the RBCs namely A and B.
- People with type AB blood do not have anti-A or anti-B antibodies in their blood plasma.
- They are sometimes called universal recipients because theoretically they can receive blood from donors of all four blood types.
- People with type O blood have neither A nor B antigens on their RBCs and are sometimes called universal donors because theoretically they can donate blood to all four ABO blood types.
- Type O persons requiring blood may receive only type O blood.

Transfusions

- A transfusion is the **transfer of whole blood or blood components** (red blood cells only or blood plasma only) .
- A transfusion is most often given to alleviate anaemia, to increase blood volume (for example, after a severe haemorrhage), or to improve immunity.
- In an incompatible blood transfusion, antibodies in the recipient's plasma bind to the antigens on the donated RBCs, which causes agglutination, or clumping, of the RBCs.
- Agglutination is an antigen–antibody response in which RBCs become cross-linked to one another.

Rh Grouping

- Rh antigen, **similar to one present in Rhesus monkeys** (hence Rh), is also observed on the surface of RBCs of the majority (nearly 80 per cent) of humans.
- Such individuals are called Rh positive (Rh+ve) and those in whom this antigen is absent are called Rh negative (Rh-ve).
- An Rh-ve person, if exposed to Rh+ve blood, will form specific antibodies against the Rh antigens.
- Therefore, the **Rh group should also be matched before transfusion**s.
- The most common problem with rh incompatibility, haemolytic disease of the newborn (Hdn), may arise during pregnancy.
- Normally, no direct contact occurs between maternal and fetal blood while a woman is pregnant.
- However, if a small amount of rh+ blood leaks from the fetus through the placenta into the bloodstream of an rh- mother, the mother will start to make anti-rh antibodies.
- An injection of anti-rh antibodies called anti-rh gamma globulin (rhoGaM) can be given to prevent Hdn. rh- women should receive rhoGaM® before delivery, and soon after every delivery.

Carbon Monoxide Poisoning — The Silent Killer

- Carbon monoxide (CO) gas is odorless, colourless, tasteless and non-irritating, but highly deadly to humans and animals alike.
- CO has a greater affinity for haemoglobin than does O_2, and the resultant bond formed between CO and haemoglobin is 240 times stronger than the O_2 and haemoglobin bond.
- When CO binds to haemoglobin it forms carboxyhemoglobin (COHb).
- Due to the high affinity, CO molecules easily displace oxygen, causing oxygen saturation to quickly decrease.
- This means that even a very small amount of inhaled CO is extremely dangerous and can be fatal.

Lymph (Tissue Fluid)

- The fluid present in the lymphatic system is called the lymph. **Lymph is a colourless fluid containing specialised lymphocytes** which are responsible for the immune responses of the body.
- Lymph is also an important **carrier for nutrients, hormones,** etc. Fats are absorbed through lymph in the lacteals present in the intestinal villi.

3.8 EXCRETORY SYSTEM

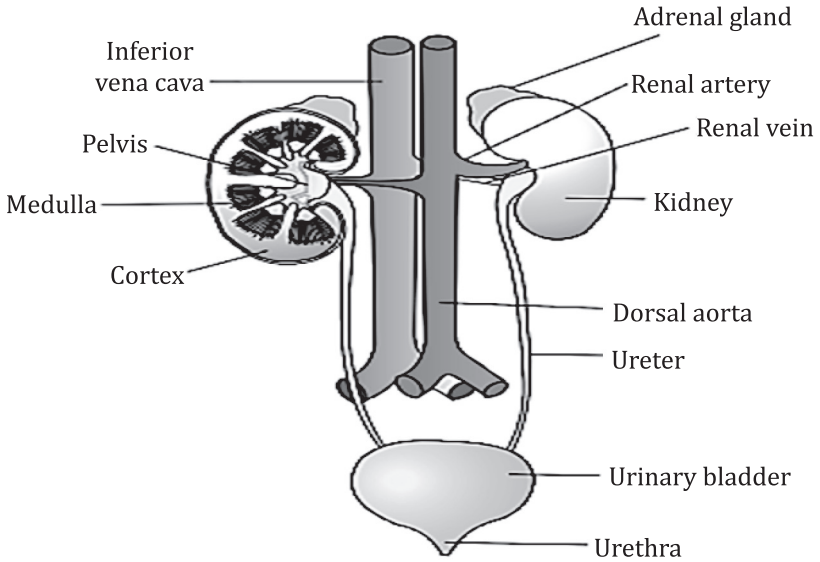


Fig.3.21: Human Excretory System

- Animals accumulate **ammonia, urea, uric acid, carbon dioxide, water** and **ions like Na^+, K^+, Cl^-, phosphate, sulphate,** etc., either by metabolic activities or by other means like excess ingestion.
- These substances have to be **removed totally or partially**.
- The process of excreting ammonia is Ammonotelism. Many bony fishes, aquatic amphibians and aquatic insects are ammonotelic in nature.
- Terrestrial adaptation necessitated the production of lesser toxic nitrogenous wastes like urea and uric acid for conservation of water.
- Mammals, many terrestrial amphibians and marine fishes mainly excrete urea and are called **ureotelic animals**.
- Ammonia produced by metabolism is converted into urea in the liver of these animals and released into the blood which is filtered and excreted out by the kidneys.
- Reptiles, birds, land snails and insects excrete nitrogenous wastes as uric acid in the form of pellet or paste with a minimum loss of water and are called uricotelic animals.
- In humans, the excretory system consists of a pair of kidneys, one pair of ureters, a urinary bladder and a urethra.
- Each kidney of an adult human measures **10–12 cm** in length, **5-7 cm in width, 2-3 cm in thickness** with an average weight of **120- 170 g**.
- Inside the kidney, there are two zones, an outer cortex and an inner medulla.
- Each kidney has nearly one million complex tubular structures called nephrons , which are the functional units.
- Each nephron has two parts – the glomerulus and the renal tubule.
- **Urine formed by the nephrons is ultimately carried to the urinary bladder** where it is stored till a voluntary signal is given by the **Central Nervous System** (CNS).
- This signal is initiated by the stretching of the urinary bladder as it gets filled with urine. In response, the stretch receptors on the walls of the bladder send signals to the CNS.
- The process of release of urine is called micturition and the neural mechanisms causing it is called the micturition reflex.
- An adult human excretes, on an average, **1 to 1.5 litres of urine per day.**
- The urine formed is a light yellow coloured watery fluid which is slightly acidic (pH-6.0).

- **Malfunctioning of kidneys can lead to accumulation of urea in blood**, a condition called uremia, which is highly harmful and may lead to kidney failure.
- In such patients, urea can be removed by a process called **hemodialysis**.
- **Renal calculi:** Stone or insoluble mass of crystallised salts (oxalates, etc.) formed within the kidney.

3.9 ENDOCRINE SYSTEM

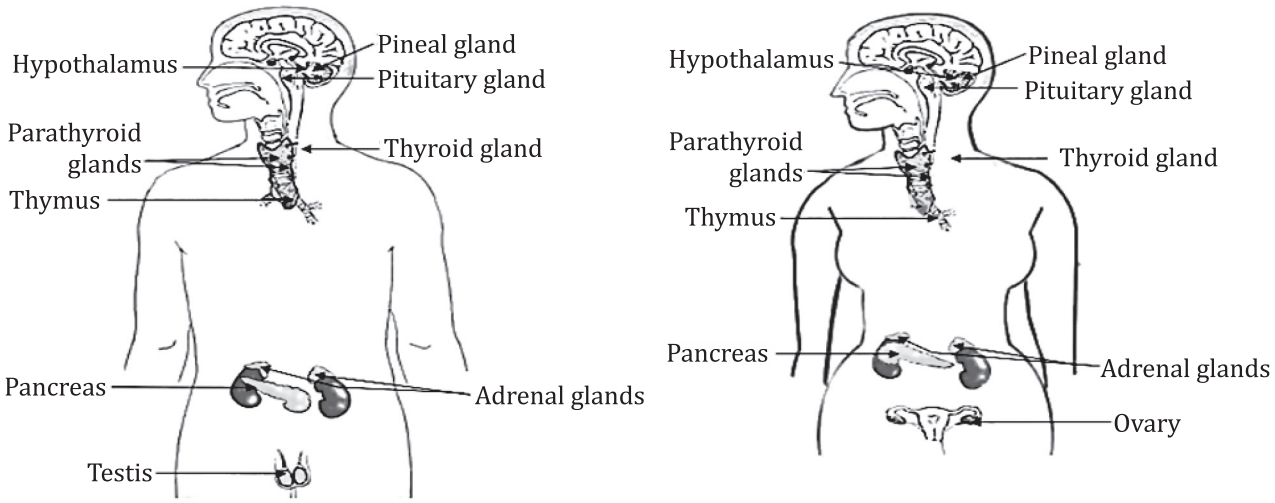


Fig. 3.22: Endocrine Glands in Human Beings (a) Male, (b) Female

- Endocrine glands **lack ducts** and are hence called **ductless glands**. Their secretions are called hormones.
- Hormones are non-nutrient chemicals which act as intracellular messengers and are produced in trace amounts.
- The endocrine glands and hormone producing diffused tissues/cells located in different parts of our body constitute the endocrine system.

Gland	Hormones	Functions
Hypothalamus	• It regulates a wide spectrum of body functions. • It contains several groups of neurosecretory cells called nuclei which produce hormones.	• These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary.
Pituitary	• Oxytocin and Vasopressin, which are actually synthesized by the hypothalamus. • Growth Hormones (GH) • Luteinizing Hormone (LH) • Follicle Stimulating Hormone (FSH)	• Control fluid balance in the body. • GH promotes growth and its Excess secretion results in Acromegaly. • In males, LH stimulates the synthesis and secretion of hormones called androgens from testis. • In females, LH induces ovulation. • FSH stimulates growth and development of the ovarian follicles in females.
Thyroid	Thyroxine	• Controls appetite and body metabolism.
Thymus	Thymosin	• Role in T-cell development and providing immunity.

Pancreas	Insulin and Glucagon	• Regulate Blood sugar level and carbohydrates metabolism
Adrenal	Epinephrine	• Regulate Blood pressure and heart rate. Help in Dealing stressed conditions.
Testes	Testosterone	• Development of male sex characteristics. Promoting axial hair growth and muscle growth.
Ovaries	Estrogen and progesterone	• Control and regulate female reproductive cycle.
Pineal	Melatonin	• Control sleep and wake cycle.

3.10 REPRODUCTIVE SYSTEM

- The **male and female** reproductive systems typify the sexual **differentiation** of humans on both a structural and physiological level.
- The primary responsibility of the reproductive systems is to produce the separate gametes—namely, the male sperm and the female secondary oocyte.

Male Reproductive Organs

- The male reproductive system is characterized by the dominance of the associated anatomical structures located **outside the body** — the **scrotum, penis and testes.**

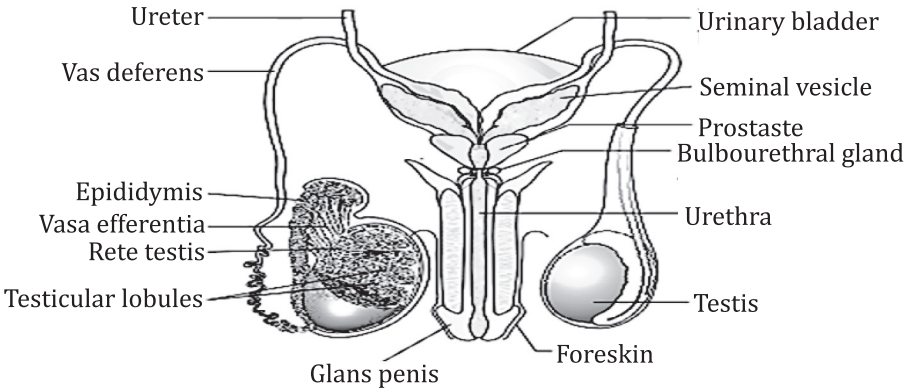


Fig. 3.23: Male Reproductive Organs

Female Reproductive Organs

- The female reproductive system, on the other hand, is located **inside the body**, and includes the anatomical structures of the **vagina, cervix, uterus, fallopian tubes** and **ovaries.**

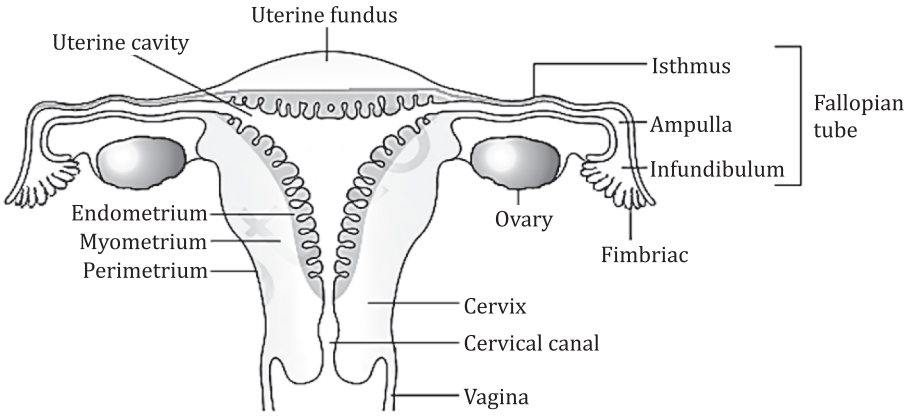


Fig. 3.24: Female Reproductive Organs

- The ovaries, producing secondary oocytes that will make their journey to the uterus for fertilisation, are also under hormonal control.
- **Progesterone and oestrogens**, like the male **testosterone**, are also controlled from the level of the hypothalamus and anterior pituitary gland.

Puberty

- The beginning of sexual maturity.
- It is a process that usually happens between **ages 10 and 14 for girls** and **ages 12 and 16 for boys.** It causes physical changes, and affects boys and girls differently.

Menstrual Cycle

- In females Periodic discharge of blood, tissue fluid, mucous, and epithelial cells that usually lasts for 5 days; caused by a sudden reduction in estrogens and progesterone.
- Also called the **menstrual phase or menses.**

3.11 NERVOUS SYSTEM

- With a mass of only 2 kg (4.5 lb), about 3% of the total body weight, the nervous system is one of the smallest and yet the most complex of the body systems.

Structure of Neurons

- A neuron is a microscopic structure composed of three major parts, namely, cell body, dendrites and axon.

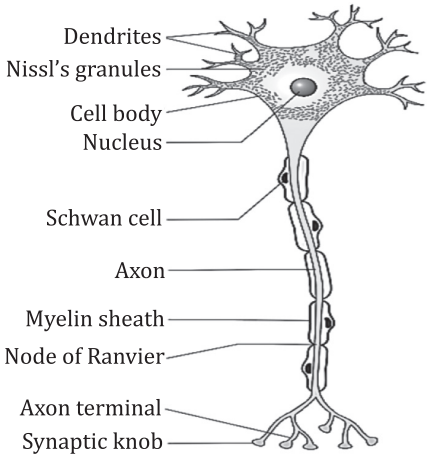


Fig.3.25: Structure of Neurons

- The cell body contains cytoplasm with typical cell organelles and certain granular bodies called **Nissl's granules.**
- Dendrites are projections of a neuron (nerve cell) that receive signals (information) from other neurons.
- The transfer of information from one neuron to another is achieved through chemical signals and electric impulses, that is, electrochemical signals.
- Neurons are excitable cells because their membranes are in a polarised state.
- Different types of ion channels are present on the neural membrane. These ion channels are selectively permeable to different ions.
- A nerve impulse is transmitted from one neuron to another through junctions called synapses. A synapse is formed by the membranes of a pre-synaptic neuron and a post-synaptic neuron, which may or may not be separated by a gap called **synaptic cleft.**

Structure of Brain

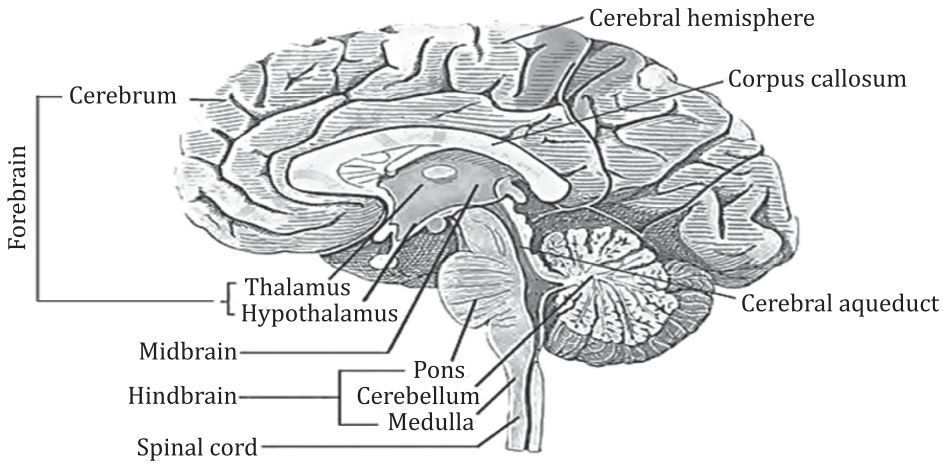


Fig. 3.26: Structure of Human Brain

- The brain is the central information processing organ of our body, and acts as the 'command and control system'.
- The human brain is well protected by the skull. Inside the skull, the brain is covered by cranial meninges.

3.12 MUSCLES AND SKELETAL SYSTEM

Muscle

- Muscle is a **specialised tissue of mesodermal origin**. About **40-50 per cent** of the body weight of a human adult is contributed by muscles.
- They have special properties like excitability, contractility, extensibility and elasticity.

Based on their location, three types of muscles are identified

1. Skeletal
2. Visceral
3. Cardiac

- Skeletal muscles are closely associated with the skeletal components of the body. They have a striped appearance under the microscope and hence are called striated muscles.
- **Visceral muscles** are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc. They do not exhibit any striation and are smooth in appearance. Hence, they are called smooth muscles (nonstriated muscle).
- **Cardiac muscles** are the muscles of the heart. Many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle.
- **Muscle contraction:** Muscle contraction is the tightening, shortening, or lengthening of muscles when you do some activity.

Bones

- Skeletal system consists of a framework of bones and a few cartilages. This system has a significant role in movement shown by the body.
- Bone and cartilage are specialized connective tissues.
- The bone has a very hard matrix due to calcium salts in it.
- The cartilage has a slightly pliable matrix due to chondroitin salts.
- In human beings, the skeletal system is made up of **206 bones** and a few cartilages.

3.13 PLANT PHYSIOLOGY

3.13.1 Mode of Nutrition in Plants

The process by which green plants make their own food from carbon dioxide and water by using sunlight energy in the presence of chlorophyll is called photosynthesis. Green plants also need food to acquire energy. All living organisms need energy to perform various life processes. Plants make their own food in the presence of sunlight and hence they are autotrophs. Plants convert sunlight energy into chemical energy. They use carbon dioxide, water and sunlight to make their own food in the presence of chlorophyll.

There are two types of modes of nutrition in plants. They are:

1. Autotrophic
2. Heterotrophic

Autotrophic Mode of Nutrition

In autotrophic mode of nutrition organisms make their own food with the help of simple inorganic materials like carbon dioxide and water, in the presence of sunlight. Also in this nutrition organic food is made from inorganic materials.

Green plants have an autotrophic mode of nutrition. These organisms are called autotrophs. The autotrophs have green pigments called *chlorophyll* which help in trapping sunlight energy. They use the sunlight to make food by the process of photosynthesis. The food produced by autotrophs is used by human beings and animals as well.

Photosynthesis

Green plants synthesize their own food by the process of *photosynthesis*. Photo means light and synthesis means to build, so photosynthesis means 'building up by light. It is in the presence of chlorophyll that plants use the energy of sunlight to make food from inorganic materials like carbon dioxide and water.

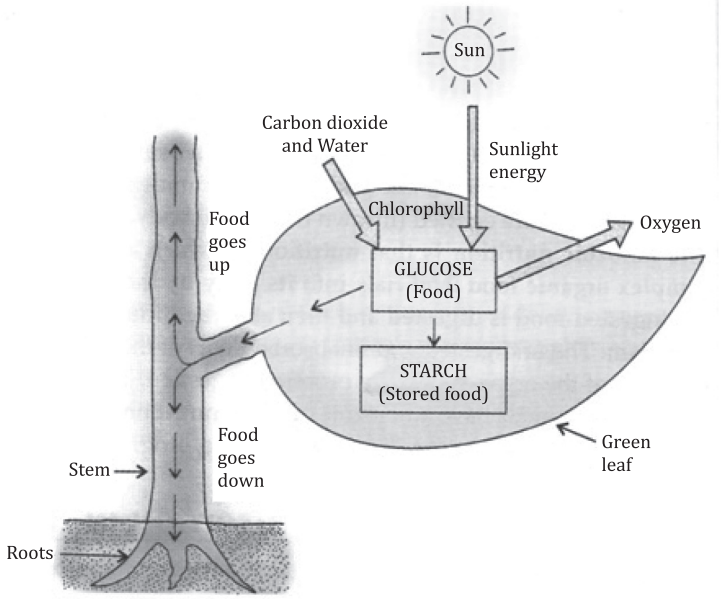


Fig. 3.27: Green Plants Make Their Own Food by Photosynthesis

- Chlorophyll is present in green coloured bodies called chloroplast. The leaves of a plant are green due to the presence of chlorophyll in them.
- In the process of photosynthesis a lot of oxygen gas is released.

$$6CO_2 + 6H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

- *The food prepared by the leaves is in the form of simple sugar called glucose*. This glucose is then sent to other parts of the plant. The extra glucose is stored in the leaves of the plant in the form of starch. *Glucose and starch belong to a category called carbohydrates. Thus green plants convert sunlight energy into chemical energy.*

The steps for photosynthesis are

1. Sunlight energy is absorbed by chlorophyll.
2. Sunlight energy is converted into chemical energy and water is split into hydrogen and oxygen.
3. Carbon dioxide is reduced to hydrogen so that carbohydrates like glucose are formed..

Conditions Necessary for Photosynthesis

Following are the conditions necessary for photosynthesis:

1. Sunlight
2. Chlorophyll
3. Carbon Dioxide
4. Water

3.13.2 Control and Coordination in Plants

- Plants also show movement by growth of their various parts. It is the plant hormones that promote its growth. The movement of plant parts is due to various stimuli like gravity, water, light, chemical, touch, etc. So, the function of control and coordination in plants is performed by the chemical substances called plant hormones or phytohormones.
- Plants use only hormones to coordinate their behavior. They respond to the stimuli very slowly because they have no nervous system.
- **Dormancy:** The inactive condition of a part of a plant in which metabolism almost stops is called dormancy. For example, seed, bud etc.

Plant Hormones

The control and coordination system in plants is done by plant hormones. They affect the growth of a plant in one or the other aspect. The growth of a plant is divided in three stages:

1. Cell division
2. Cell enlargement
3. Cell differentiation

- A plant hormone not only controls these stages of plant growth but also promotes the breaking of dormancy, falling of leaves, fruit growth, ripening of fruits, aging of plants etc.
- The four types of plant hormones responsible for control and coordination in plants are:
  1. Auxins
  2. Gibberellins
  3. Cytokinins
  4. Abscisic acid (ABA)
- While auxins, gibberellins and cytokinins promote the growth of a plant, abscisic acid prevents or hampers the growth of a plant.
- **Auxins:** controls a plant's response to light and gravity. It is made by the cells present at the tip of a stem and roots. This hormone moves the plant away from light and towards gravity. It speeds up the growth of stem and slows down the growth of roots. Auxins promote cell enlargement, cell differentiation and fruit growth.

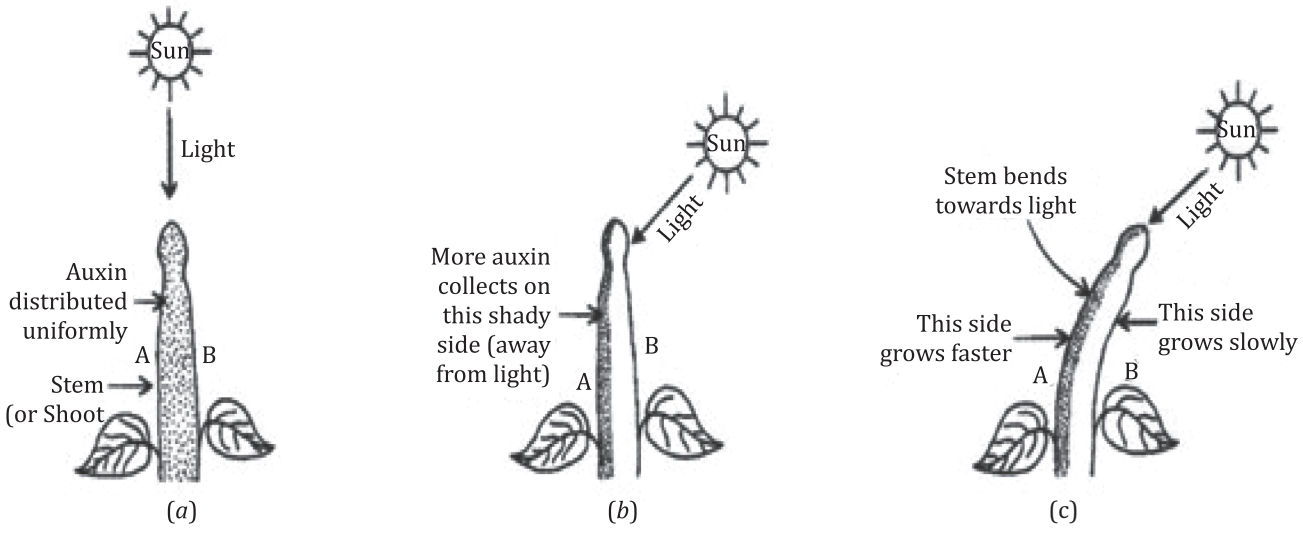


Fig. 3.28: This Diagram Explains the Bending of a Plant Stem or Shoot Towards Light by the Action of 'Auxin Hormone'

- **Gibberellins:** Works in the presence of auxin hormone and promotes cell enlargement and cell differentiation. It also promotes fruit growth, elongation of shoots and in breaking the dormancy in seeds and buds.
- **Cytokinins:** Promotes cell division in plants and breaks dormancy in seeds and buds. They also delay aging in leaves and promote the opening of stomata.
- **Abscisic acid:** This hormone inhibits the growth of a plant. Therefore abscisic acid promotes dormancy in seeds and buds. It promotes closing of stomata, wilting and falling of leaves and detachment of fruit and flower from the plant.

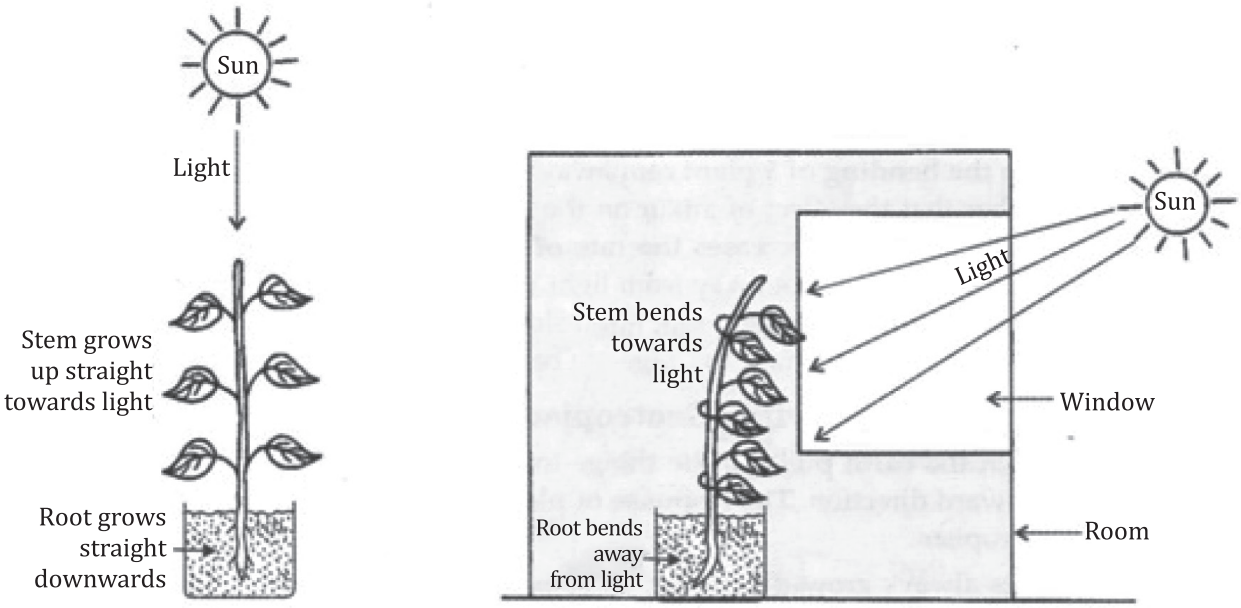
Plant Movement

- Plants are fixed at one place and cannot physically move from one place to another. But plants still show movement by using hormones under the influence of stimuli. This movement is noticed in the unequal growth of the two regions of a plant.
- For example, auxin hormone speeds up the growth of a stem. So if one side of a stem has more auxin hormone than the other, then the side of the stem which has more hormones will bend. This shows movement of a plant.
- Plant movement due to external stimuli are of two types: *tropism* and *nastic*.
- **Tropisms:** When the direction of external stimulus decides the direction of response in the form of growth it is called tropism. Thus, tropism is the directional growth movement of a plant part. It can be in the direction of the stimulus or away from the stimulus. Therefore,
- If the growth of a plant is in the direction of stimulus, it is called positive tropism.
- If the growth of a plant is in the opposite direction or away from that of a stimulus, it is called negative stimulus.

Types of tropism

There are five stimuli in the environment. They are light, gravity, chemical, water and touch. These stimuli give five types of tropism. They are phototropism, geotropism, chemotropism, hydrotropism and thigmotropism.

- **Phototropism:** When a plant part moves in response to light, it is called phototropism. If the stem of a growing plant moves or bends towards light, it is positive phototropism and if the root of a plant moves away from light, this means the roots of a plant show negative phototropism.
- **Geotropism:** When a plant part moves in response to gravity, it is called geotropism. For example, roots of a plant move in a downward direction, so they show positive geotropism and stem moves in the upward direction, so it shows negative geotropism.
- **Chemotropism:** When a plant part moves in response to a chemical stimulus, it is called chemotropism. Here the stimulus is chemical. For example, the growth of pollen tube towards the ovule during fertilization in a flower is called positive chemotropism.
- **Hydrotropism:** When a plant part moves in response to water, it is called hydrotropism. Here the stimulus is water. Roots of a plant moves towards water, so they show positive hydrotropism.
- **Thigmotropism:** When a plant part shows directional movement in response to the touch of an object, it is called thigmotropism. For example, tendrils of a plant climb towards any support which they touch.



(*a*) (*b*)

Fig. 3.29: To Show the Response of a Plant to Light (Phototropism)

Response of plants to light: Phototropism:

- The stem and leaves of a plant moves in the direction of sunlight. So, when a plant is grown in an open ground where sunlight is coming from above then the stem of a plant grows straight in an upward direction. If, however, a plant is kept at a place where sunlight is coming from only one direction then the stem of a plant bends in that direction only. On the other hand, the roots of a plant bend away from the direction of sunlight.
- This happens because of the action of auxin hormone.
- When the sunlight is coming from top, then the auxin hormone present at the tip of the stem spreads uniformly down the stem making it grow straight up.
- When the sunlight falls only on the right side then the auxin hormone prefers to stay in shade and collects on the left side.
- Since there is more auxin hormone on the left side of the stem, it makes the left side grow faster than the right side. Thus, the stem bends towards the right.
- Auxin hormone has the opposite effect on the roots of a plant. That is why when sunlight falls on the right side of the roots, auxin hormone collects on the left side and hampers their growth from that side. That is why, roots bend towards the left.

Response of plants to gravity: Geotropism

Roots of the plant grow towards the earth which shows positive geotropism and the stem grows upward away from the pull of gravity which shows negative geotropism. This can be shown through an experiment.

- Keep a potted plant in a normal position. We see that the roots are growing downwards and the stem is growing upwards.
- Now tilt the potted plant and keep it horizontally on the surface.
- After a few days we notice that roots of the potted plant grow toward the earth and the stem of the plant bends upwards away from the pull of gravity.

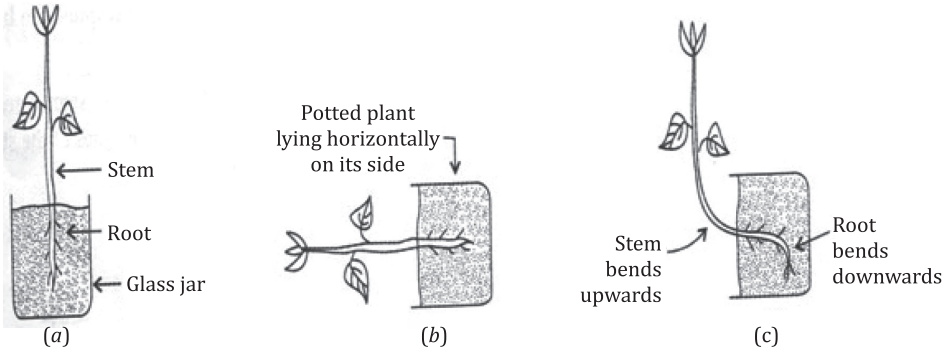


Fig. 3.30: This diagram shows the response of a plant to gravity or geotropism.

Response of Plants to Chemicals: Chemotropism

- Sugary substance acts as a stimulus for the growth of the pollen tube towards the ovule. This happens because ripe stigma in the carpel of a flower secrets a chemical substance into the style towards the ovary. This sugary substance acts as a stimulus for the pollen grain which responds by growing a pollen tube in the downward direction into the style of a carpel and reaches the ovule of the flower for fertilization.

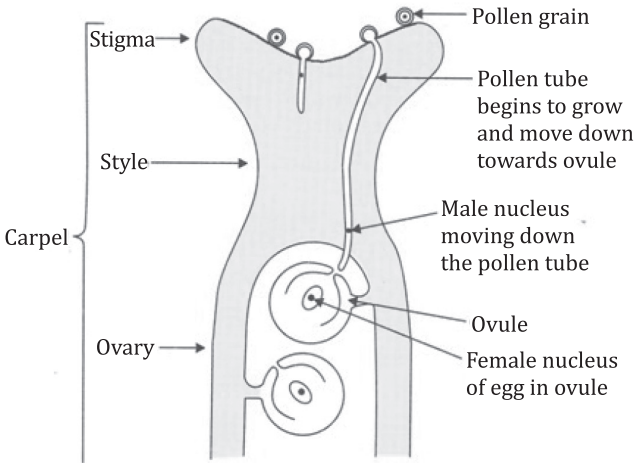


Fig. 3.31: This diagram shows the response of a plant part 'pollen to chemicals secreted by stigma or chemotropism

Response of plants to water: Hydrotropism

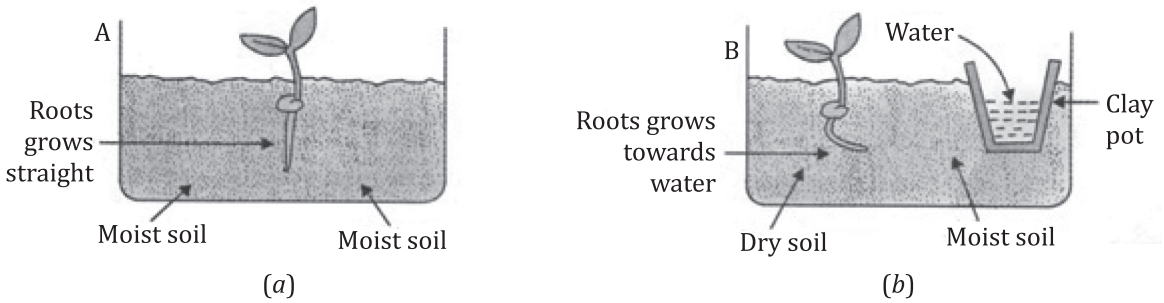
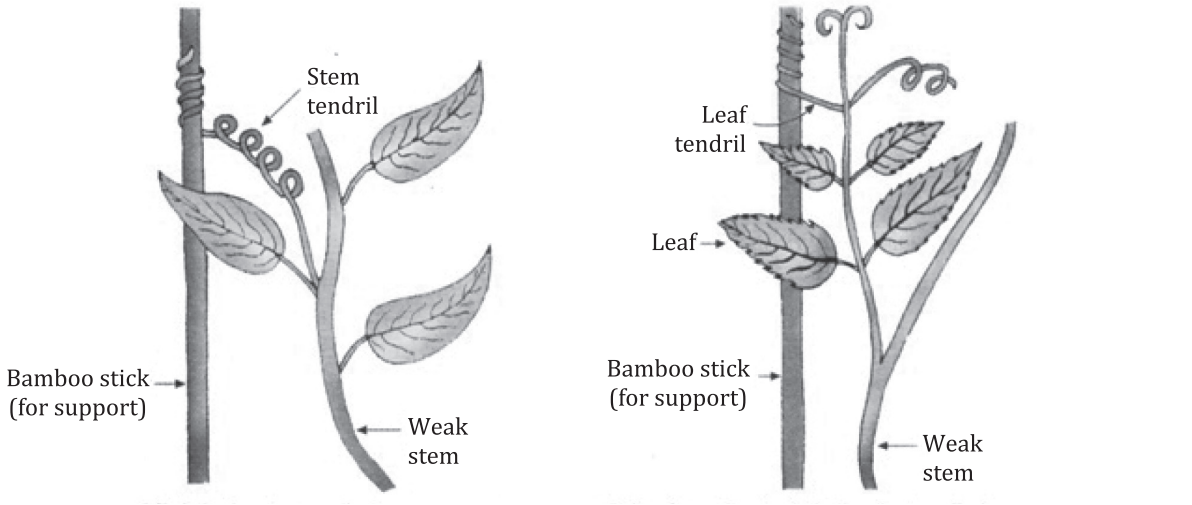


Fig. 3.32: An Experiment to Show the Response of a Plant to Water or Hydrotropism

- Roots always grow in the direction of water, even if they have to grow against the pull of gravity or sideways. Let's take two glass troughs and fill two-third of them with soil. In both the troughs we plant a tiny seedling. In the second trough we place a small clay pot inside the soil. Let's water the soil in the first trough daily and put water in the clay pot placed inside the soil in the second trough.
- This shows that roots of a plant grow towards water.

Directional Response of a Plant to the Touch of an Object: Thigmotropism

- There are some plants which cannot stand upright on their own and need support. These plants are called climbing plants and have organs called tendrils. Tendrils are the thin thread-like growth on the stems and leaves of the climbing plants. Tendrils are sensitive to the touch of other objects. When tendrils come in contact with other objects, it bends towards the object by growing towards it, wind around the object and cling to it. This winding movement of a climbing plant is called thigmotropism.



(*a*) stem tendrils help the plant to climb up a support (*b*) Leaf tendrils also help the plant to climb up a support

Fig. 3.33: This diagram shows the response of a plant part 'tendril to the touch of an object here a bamboo stick

- For example, bitter gourd, bottle gourd, grape vine etc., have stem tendrils and peas, glory lily etc., have leaf tendrils.

The Usefulness of Tropic Movements

- Tropic movements help the plant to survive. For example, roots of the plant are positively geotropic and that is the reason that they will always go downward into the earth even if they are planted upside down. Also the root will grow towards water as it is positively hydrotropic. Also the shoot will grow upward as it is negatively geotropic.

Nasties or Nastic Movements

- When the direction of response in a plant is not determined by the direction of stimulus, it is called nastic movement. Nastic movement is not the directional movement of the plant part.
- In nastic movement, whatever be the direction of stimulus, all the parts of the plant equally move in the same direction. This type of movement is generally seen in leaves, flower petals etc.

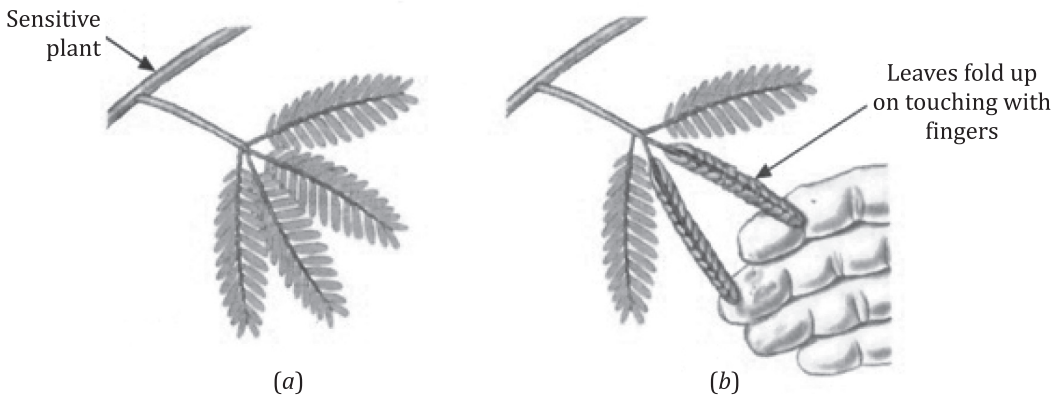


Fig. 3.34: This diagram shows the nastic movements in the leaves of sensitive plants (Mimosa pudica) caused by 'touch'

Following are the examples of nastic movement:

- When we touch the leaves of a sensitive plant like mimosa pudica, they fold.
- It is due to the stimulus of light that the petals of dandelion flowers open in the morning and close in the evening.
- It is due to the stimulus of light that the petals of moonflowers close in the morning and open in the dark at night.

Nastic movement may or may not be a growth movement.

Thigmonasty

- The movement of a plant part in response to the touch of an object is called thigmonasty. In this case the movement of a plant part is non-directional. The stimulus for thigmonasty is touch.
- The sensitive plant mimosa pudica which is also known as touch-me-not is an example of thigmonasty. If we touch the leaves of this plant they fold up immediately and droop.
- The sensitive plant has pulvini at the base of each leaf. This pulvini contains a lot of water in their cells and due to internal pressure of water they are firm and keep the leaf upright. So, as soon as we touch the leaves there is sudden loss of water from pad-like swellings (pulvini). This is why pulvini loses its firmness and leaves droop.
- When we touch the sensitive place electric impulses travel through the cells of the plant and act on plant hormone. The plant hormone migrates water from the cells of the pulvinus to the intercellular spaces of the other half of the pulvinus. This loss of water makes pulvini lose firmness and thus its leaves droop.

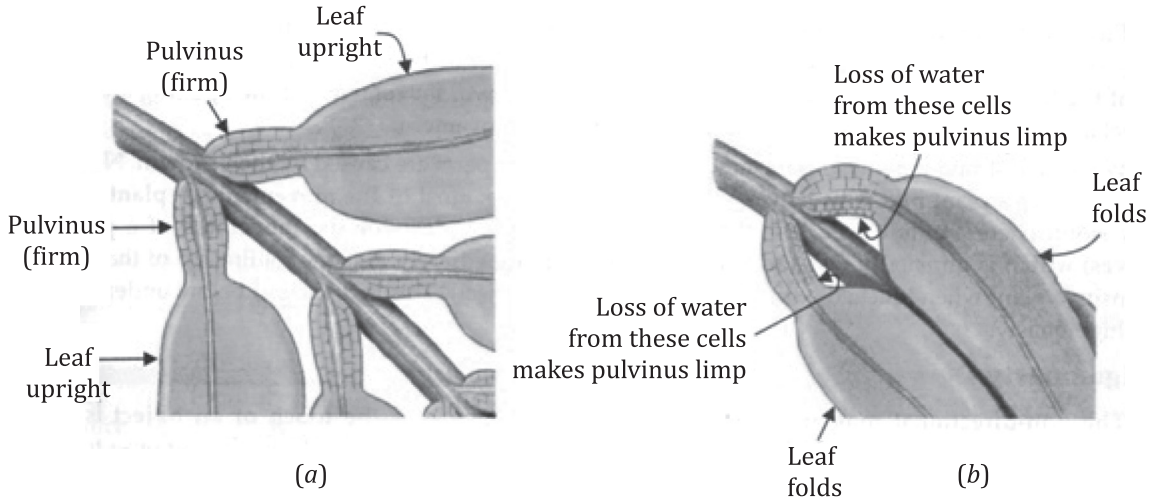


Fig. 3.35: The leaves of sensitive plants fold due to the loss of water from pulvinus at their base.

Photonasty

- The movement of a plant part, usually flower petals, in response to light is called photonasty. The movement is non-directional. The stimulus in photonasty is light. Dandelions and moonflowers are examples of photonasty.
- The opening and closing of flower petals in response to light are growth movements. This is because petals open when their outer surface grows and petals close when their outer surface grows.

Function of Plant Hormones

- Germination of seeds
- Growth of roots, stem and leaves
- Movement of stomata
- Flowering of plants
- Ripening of fruits
- Tropism and nastic movements

3.13.3 Transport System in Plants

Transport in biology means carrying substances absorbed or made in the body of an organism to all other parts of its body. In plants, it is only water and minerals that need to be transported to its other parts. Another thing that needs to be transported to other parts of the plants is the food prepared in leaves. So, for this plants need a transport system in their body to supply all their cells with food, oxygen, water etc.

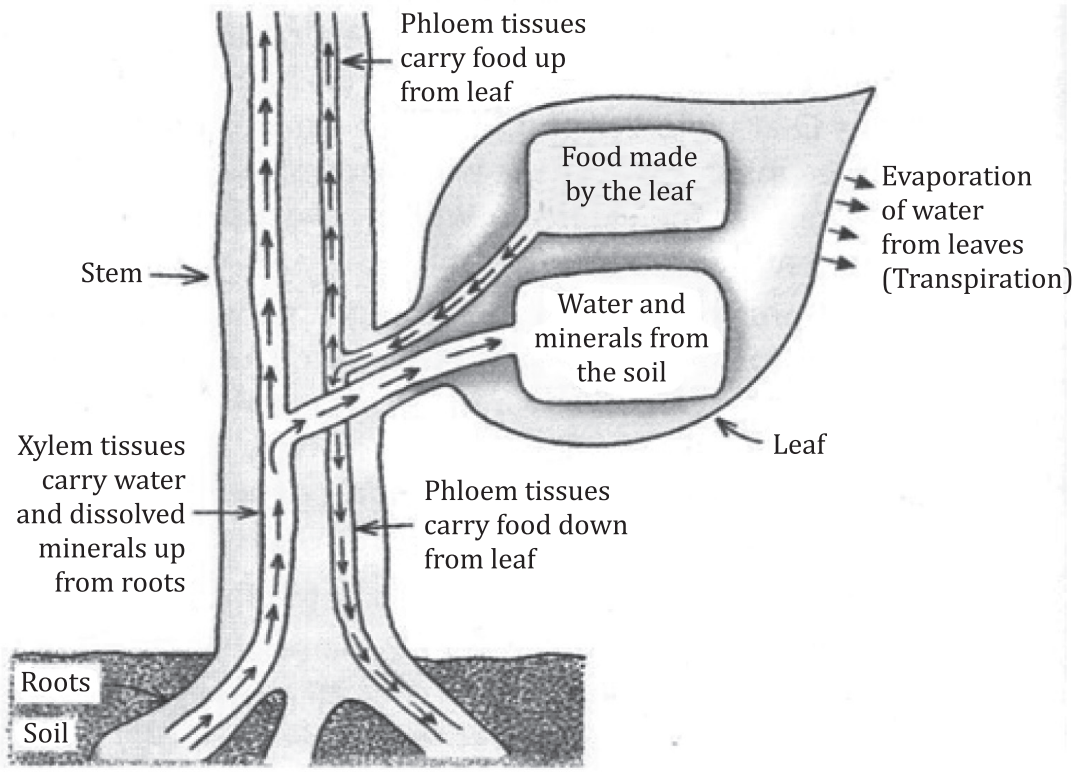


Fig. 3.36: Tranportation system in plants

The two types of conducting tissues that perform the function of transport system in plants are:

1. *Xylem* 2. *Phloem*

3.13.3.1 Transport of Water and Minerals

- Plants need water to make food through the process of photosynthesis and minerals for making proteins. Thus, a plant absorbs water and minerals from soil through roots and transports it to other parts like stem, leaves, flowers etc. It is through two kinds of elements of xylem tissue called xylem vessels and tracheid that water and minerals move from roots of a plant to its leaves.

Xylem Vessels

- A Xylem vessel is a long tube made up of dead cells joined end to end. It is a non-living tube which runs from the roots of the plants and runs through the stem and reaches every leaf. The end walls of the cells are broken so that an open tube is formed.
- Xylem vessels do not have cytoplasm or nuclei and the walls of the vessels are made of cellulose or lignin. Other than transporting water and minerals, the xylem vessel also provides strength to the stem and keeps it upright.
- This is because lignin is very hard and strong. Wood is made of lignified xylem vessels. Xylem vessels have pits in their cell walls where lignin is not deposited. Either xylem vessel or both xylem vessel and tracheid transport water in flowering plants.

Tracheids

- In non-flowering plants tracheids are the only water conducting tissues. Tracheids are dead cells with lignified walls with no open ends. They are long, thin and spindle shaped cells. They have pits in them and it is through pits only that water flows from one tracheid to another. All the plants have tracheid in them.

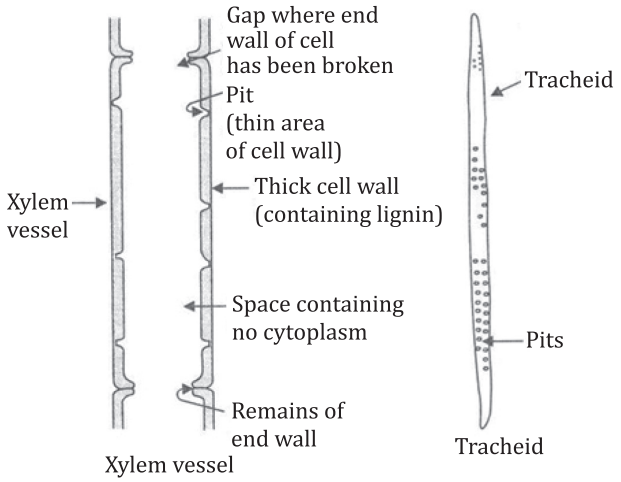


Fig. 3.37

- **Some important terms:**
- **Epidermis:** The outer layer of the cells in the root of a plant is called epidermis. The thickness of epidermis is equal to one cell.
- **Endodermis:** It is the layer of cells around the vascular tissue (xylem and phloem) in the root of a plant. Endodermis is the innermost layer of the cortex.
- **Root cortex:** It is the part of the root between the epidermis and endodermis.
- **Root xylem:** It is the xylem tissue present in the roots. It is present at the center of the root.
- Epidermis, root cortex and endodermis are present between the root hair and root xylem. So, the water which is absorbed by the root hairs from soil first passes through epidermis, root cortex and endodermis and then finally reaches to root xylem.
- Also, minerals are present in soil. Plants take these minerals from soil in inorganic form such as nitrates and phosphates. Minerals from soil dissolve in water to form an aqueous solution. So, when water is transported from roots to leaves, minerals dissolved in water are also transported.

Mechanism of Transport of Water and Minerals in a Plant

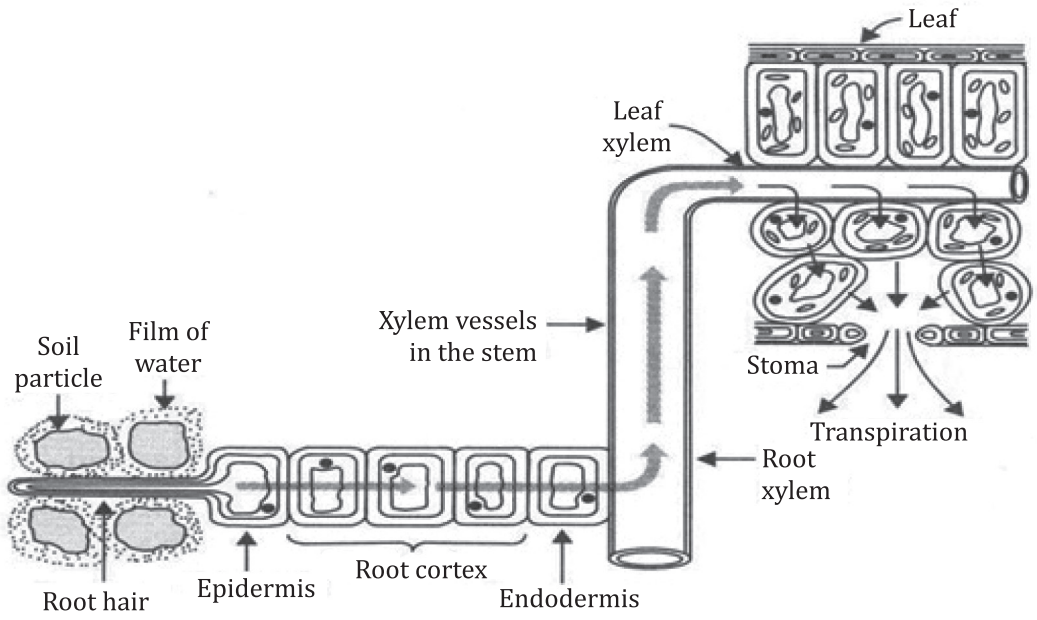


Fig. 3.38: Water & mineral transportation mechanism in plants

- Root hair absorbs the water containing dissolved minerals from the soil. Root hair is directly in contact with the film of water present in-between the soil particles. Water containing minerals gets into the root hair and passes from cell to cell through the process of osmosis and reaches epidermis, root cortex, endodermis and root xylem.
- Xylem vessels of the root are connected with the xylem vessel of the stem of a plant. So the water enters from root xylem vessel to the stem xylem vessel and further reaches into the leaves of the plant from petiole. The plant uses only one or two per cent of the water in photosynthesis. The remaining water is lost in air as water vapor.

Water is Sucked up by the Xylem Vessel

The pressure at the top of the plant (in the leaves) is low whereas pressure at the bottom of the plant is high. It is due to transpiration that the pressure is low at the top of a plant. And it is because of low pressure at the top of the plant that water flows up the xylem vessel into the leaves of a plant.

The continuous evaporation of water from the leaves of a plant is called transpiration. The leaves of a plant have

tiny pores called stomata. It is through them that the water evaporates into the air. This reduces the pressure at the top of xylem vessels and thus water flows up into them.

Transport of Food and Other Substances

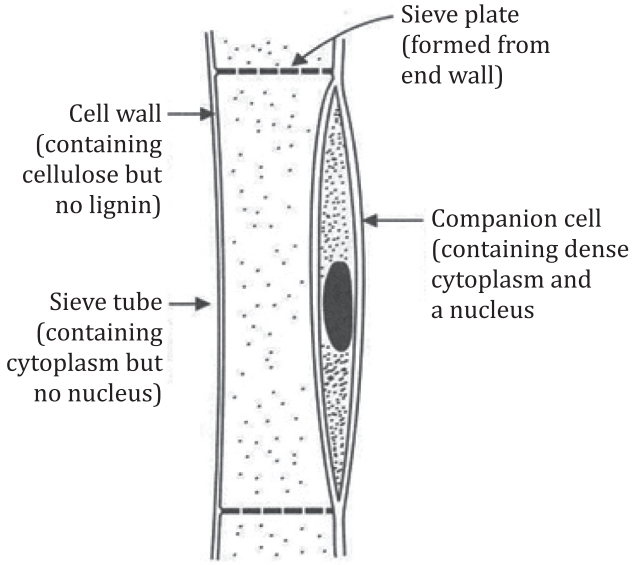


Fig. 3.39

- The food which is prepared by the process of photosynthesis in the leaves of a plant has to be transported to other parts like stem, roots, branches etc. Therefore this food is transported to other parts of the plant through a kind of tube called phloem. The transport of food from leaves to other parts of a plant is called translocation. The food made by the leaves is in the form of simple sugar. Phloem is present in all the parts of a plant.

Phloem Contains Sieve Tubes

- Phloem is a long tube made of many living cells joined end to end. The living cells of phloem are called sieve tubes. The end walls of cells in the phloem have sieve plates which have tiny holes in them. It is through these holes that the food passes along the phloem tubes. Sieve tubes contain cytoplasm in them but have no nucleus. Each sieve tube cell has a companion cell which has a nucleus and many other organelles. The cell wall of sieve tubes contains cellulose but no lignin.
- The food is made by the mesophyll cells of a leaf and from there it enters into the sieve tubes of the phloem. These phloem tubes are interconnected and once the food reaches the phloem tube of a leaf, it is then transported to all other parts of a plant.
- The transport of food is necessary because every part of a plant needs food for:
- Energy
- Building its parts
- Maintaining its life

Other substances like hormones made in the tips of roots and shoots are also transported through phloem tubes.

Mechanism of Transport of Food in a Plant

- It is by using the energy from ATP that the food made in the leaves of a plant is loaded in sieve tubes of phloem tissue. Then by the process of osmosis water enters into sieve tubes that contain sugar. This raises pressure in phloem tissue. This high pressure produced in phloem tissue moves the food to all other parts of a plant having less pressure. In this way food is transported to all parts of a plant through phloem tissue.

3.13.4 Respiration and Excretion in plants

Respiration in Plants

Respiration is the process of releasing energy from food. Like human beings and other animals, plants also need oxygen from the environment and release carbon dioxide. This shows that even plants undergo the process of respiration. So, Oxygen and carbon dioxide are also called *respiratory gases.*

The respiration in plants differ from human beings and other animals in the following aspects:

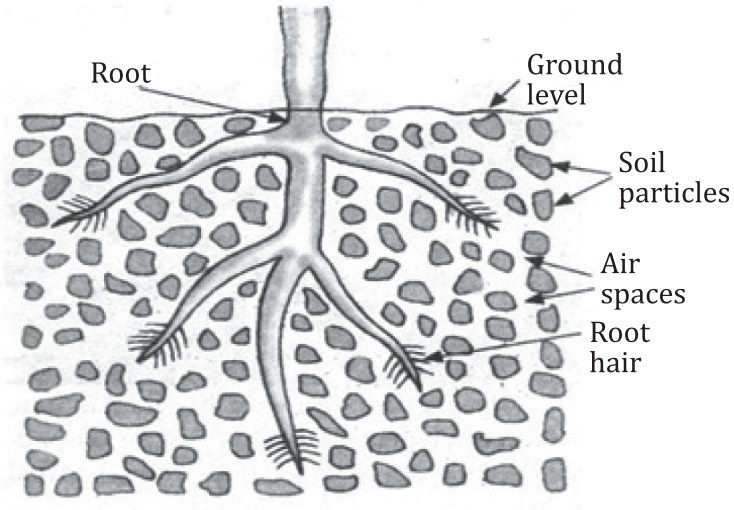
- Respiration takes place individually in all parts of the plants like stem, roots, leaves etc. In human beings and animals respiration takes place through one part only.
- In plants, respiratory gases are hardly transported from one part to another part. On the other hand, in animals and human beings respiratory gases are transported to all parts of the body.
- The rate of respiration is slow in plants whereas it is faster in humans and animals.

Plants get Oxygen by Diffusion

- *Diffusion* is the only process through which much needed oxygen is supplied to all the cells of the plants. Diffusion occurs in roots, stems and leaves.

Respiration in Roots

- Roots of the plant take oxygen from the air that is present in-between the particles of soil. *Root-hair*, which is an extension of the epidermal cells of a root, is in direct contact with the soil. Oxygen diffuses in root hair and reaches all the other cells of the roots. It is through root hairs that only carbon dioxide gets diffused into them and is expelled from the roots of a plant. *Thus, respiration in roots of the plant occurs by diffusion of oxygen and carbon dioxide through root hairs.*



Roots absorb oxygen from air present in-between the soil particles through the root hair

Fig. 3.40

- Plants die if they are waterlogged for long. This is because due to waterlogging air is expelled from in-between the particles of soil and thus, oxygen becomes unavailable to the roots of the plants. Under such conditions plants respire anaerobically which produces alcohol and kills them.

Respiration in Stems

- The soft stems of small herbaceous plants have stomata in them and hard stem of big plants and trees have lenticels in them. *Lenticles* are in the small area of a bark. These cells are loosely placed and therefore allow the gaseous exchange of respiratory gases between air and living cells of the woody stem.

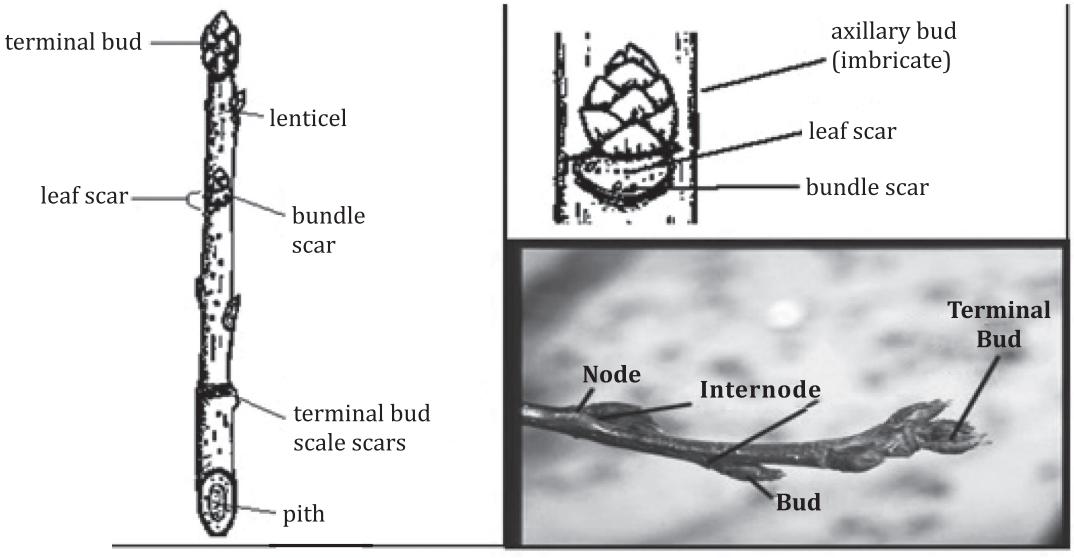


Fig. 3.41

- *Stomata* help in the gaseous exchange of respiratory gases between stems of herbaceous plants and air. It is through stomata that oxygen from air diffuses into the stem and goes to all the cells of a stem for respiration.
- Similarly, carbon dioxide produced in the stems diffuses into stomata of herbaceous plants and lenticels of trees or large plants and goes out into the air.

Respiration in Leaves

- Respiration in leaves takes place through stomata that are present as tiny pores in the leaves of a plant. Oxygen gets diffused in the stomata and reaches other cells of the leaves. The carbon dioxide produced in the process of respiration also gets diffused with stomata and moves out of the leaves.

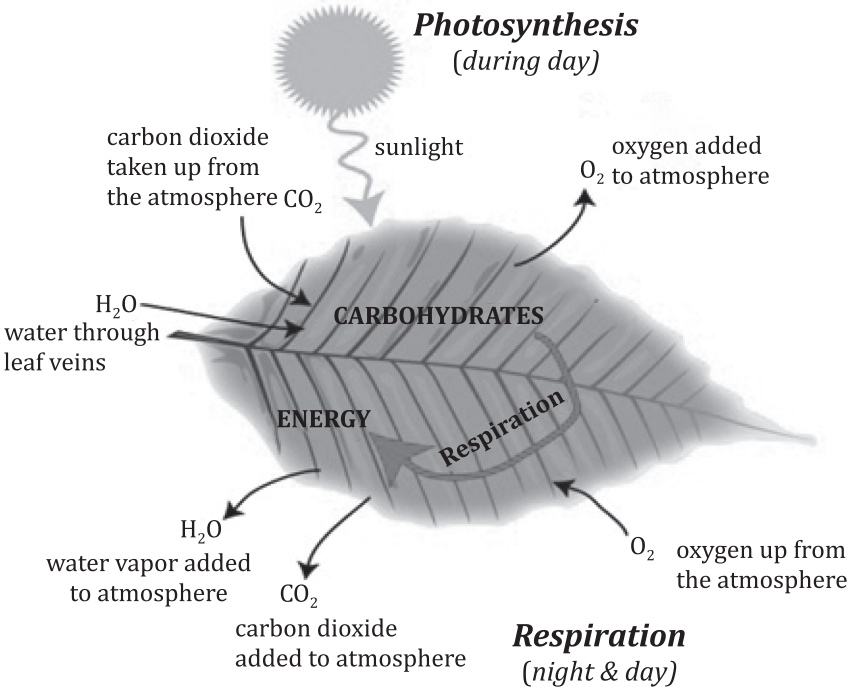


Fig. 3.42

Also, respiration in leaves takes place at both day and night time. But photosynthesis occurs only during day time. Because of this, net gaseous exchange in the leaves of a plant is:

- During day time, oxygen is produced in the leaves. This is because photosynthesis occurs during the day. So leaves use some of this oxygen for respiration and the rest of it is diffused out in the air. The carbon dioxide produced during respiration in the leaves is also used up in photosynthesis. Rather more carbon dioxide is required from the air. Therefore, net gaseous exchange during day time is, oxygen diffuses out and carbon dioxide diffuses in.
- During night time no photosynthesis occurs in the leaves. Therefore, in the process of respiration oxygen diffuses into leaves from the air and carbon dioxide diffuses out in the air. So, the net gaseous exchange in leaves at night is oxygen diffuses in and carbon dioxide diffuses out.

Excretion in Plants

- Excretion is the removal of waste from the body. Plants also produce waste products but very slowly and in very small amounts. They do not have any special organ for the removal of their waste product.
- The waste products of a plant are carbon dioxide, water vapour and oxygen. While carbon dioxide and water vapour are waste products of respiration, oxygen is a waste product of photosynthesis. These waste products are removed through stomata in leaves and lenticels in stems and are released into the air.

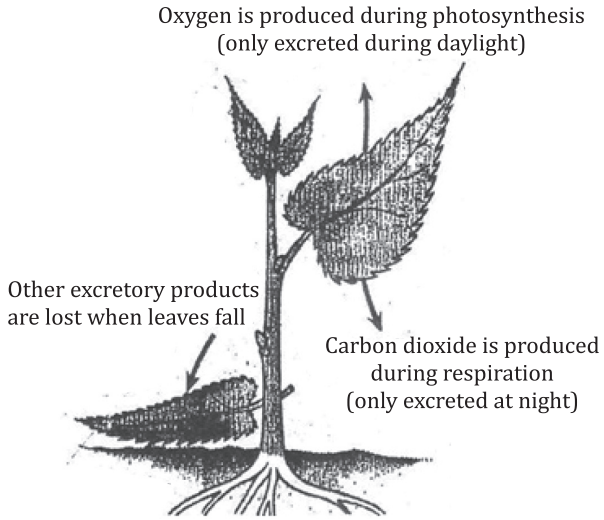


Fig. 3.43

- Some of the waste products are stored in the leaves, bark and fruits of a plant or a tree. Trees get rid of them when dead leaves bark and ripe fruits fall off from them. Some plants store waste in their fruits in the form of solid bodies called *raphides*. For example, fruit yam has needle-shaped raphides on its surface. Plants also secrete waste in the form of gum and resins from their stem and branches.

Therefore, various methods used by plants to get rid of their waste products are:

- Gaseous waste through stomata and lenticels.
- Stored solid and liquid waste by shedding leaves, peeling of bark and falling of fruits.
- By secreting waste in the form of gum and resins.
- Excrete waste into the soil around them.

3.13.5 Asexual Reproduction in Plants

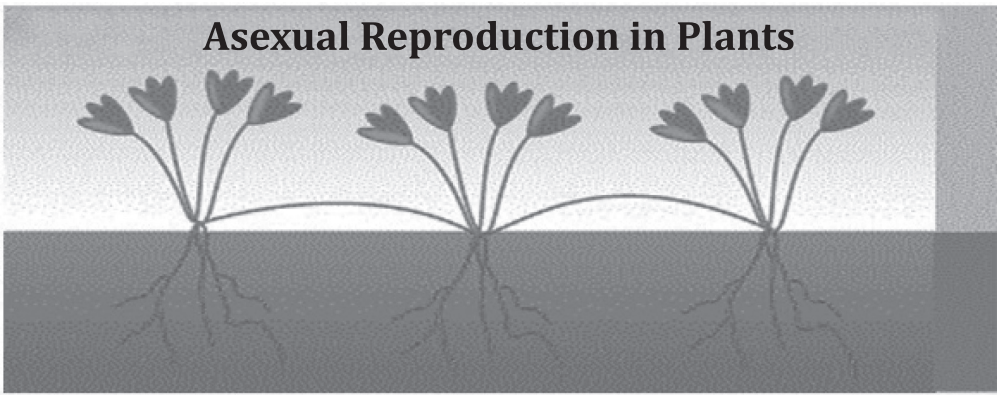


Fig. 3.44

- Asexual reproduction is a process in which a new organism is produced from a single parent without the involvement of gametes or sex cells. Many unicellular and multicellular organisms reproduce asexually. In this process, the parent organism either splits or a part of the parent organism separates to form a new organism.

There are six types of asexual reproduction. They are:

Fission

In fission, unicellular organisms split to form new organisms. It is a process of reproduction in organisms such as protozoa and many bacteria. There are two types of fission:

Binary Fission

- In binary fission, the parent cell divides into two after reaching a point where it has fully grown. In this process, after splitting parent cells do not exist and two new organisms are formed.
- Examples of unicellular organisms that undergo binary fission are amoeba, paramecium, Leishmania etc.

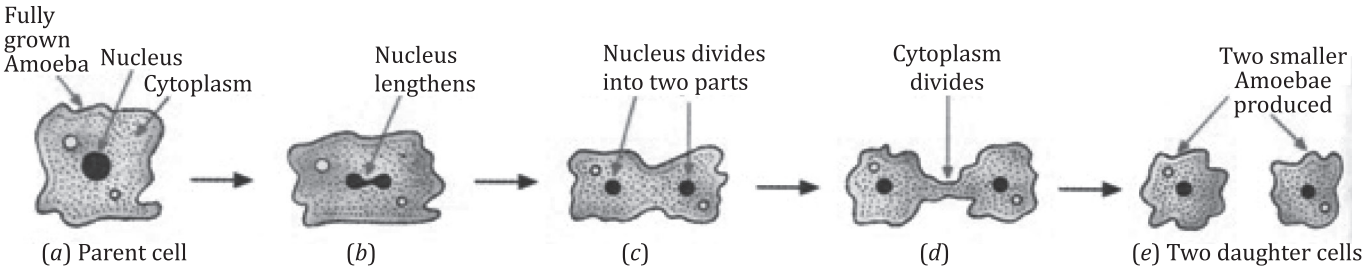


Fig. 3.45: Amoeba Reproduces by Binary Fission

Multiple Fission

- Multiple fission is also a process of asexual reproduction in which the parent cell splits to form many new organisms. This happens when cyst is formed around a unicellular organism. Inside this cyst the nucleus of an organism breaks in many smaller nuclei. When the favourable conditions come, the cyst breaks and the many daughter cells inside it are released.
- Plasmodium undergoes the process of multiple fission.

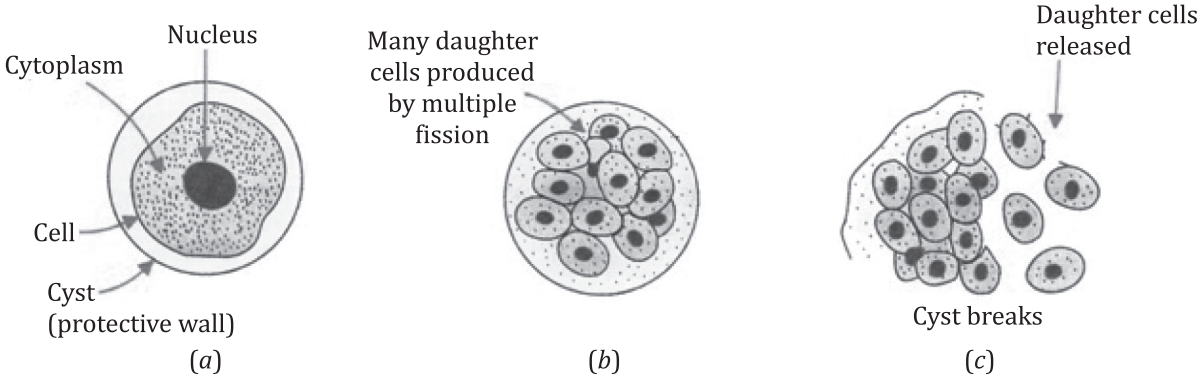


Fig. 3.46: Reproduction by multiple fission

Budding

- The word bud means small outgrowth. In the process of budding, a small bud grows on the body of the parent organism and when the time comes it detaches itself to form a new organism. Hydra and yeast undergo the process of budding.

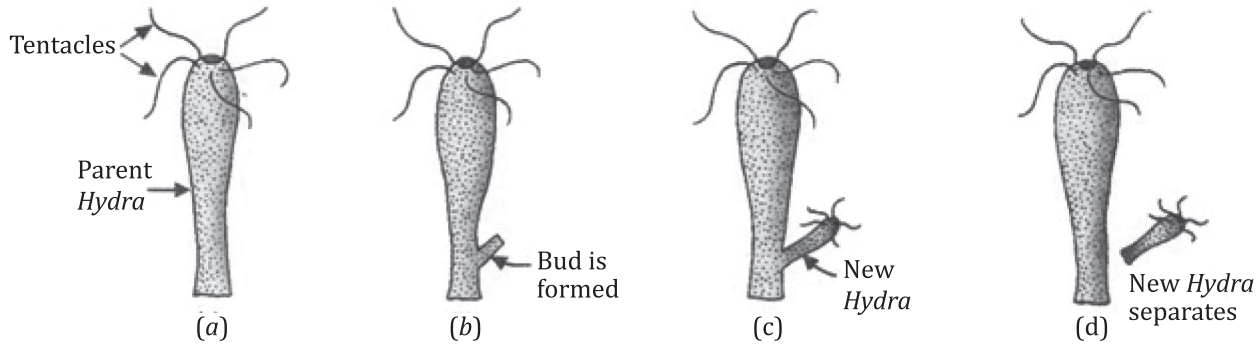


Fig. 3.47: Hydra reproducing by the method of budding

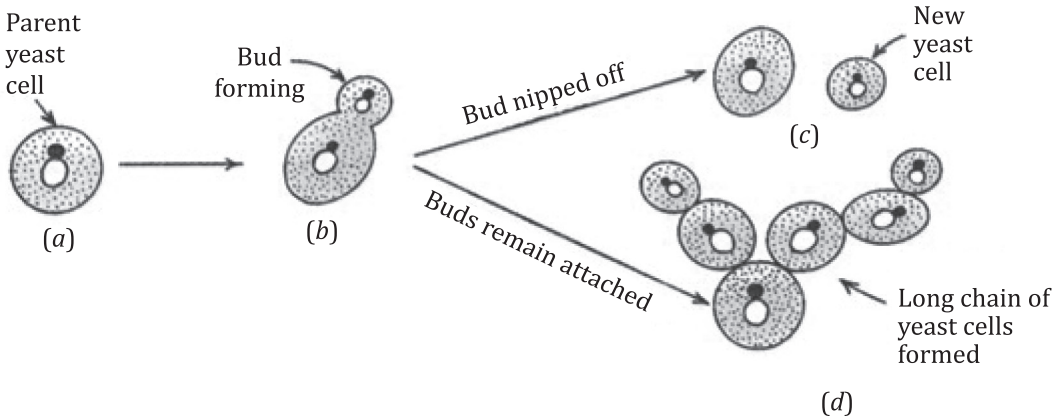


Fig. 3.48: Yeast reproduces by the method of budding

Spore Formation

- The method of spore formation occurs in both unicellular and multicellular organisms. This process takes place in plants. In spore formation, the parent plant produces hundreds of reproductive units called spores in its spore case. When this spore case of the plant bursts, these spores travel in air and land on food or soil. Here they germinate and produce new plants.
- Fungi like Rhizopus, Mucor, etc., are examples of spore formation.

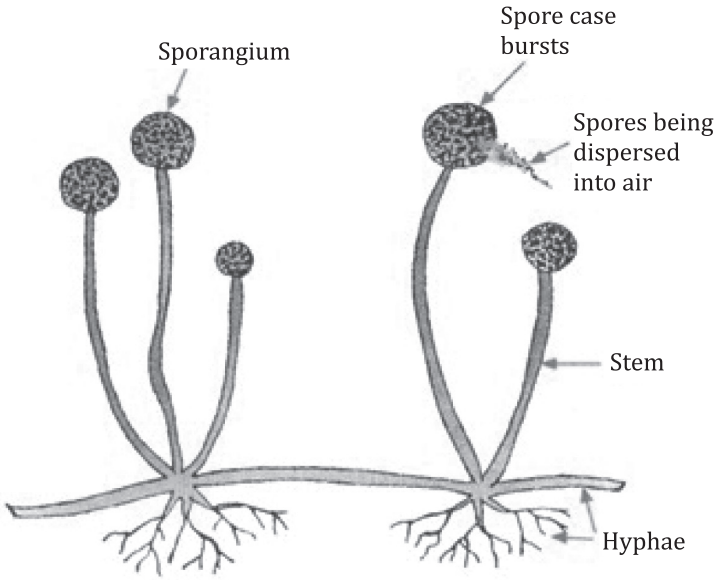
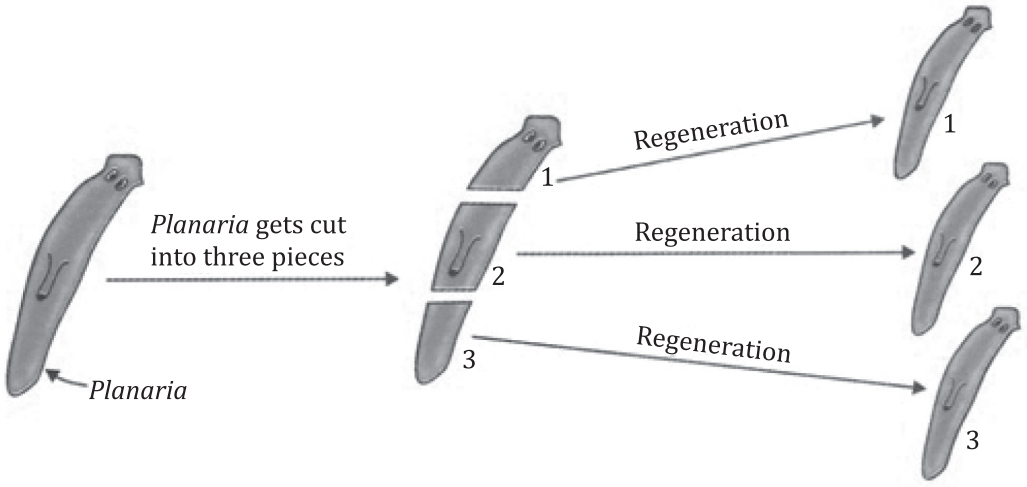


Fig. 3.49: This is a common bread mould plant or rhizopus fungus. It reproduces by forming spores

Regeneration

- Regeneration is an asexual method of reproduction. In this process, if the body of a parent organism gets cut, then each cut part can regenerate and form a whole new organism from its body parts. This happens because when the body of an organism that can undergo regeneration gets cut then the cells of the cut body part divide rapidly and form a ball of cells. These cells then move to their proper places to form organs and body parts.



(*a*) One *Planaria* worm | (*b*) *Planaria* worm cut into three pieces | (c) Three *Planaria* worms produced

Fig. 3.50: Regeneration occurs in both plants and animals. Hydra and planaria undergo regeneration

Fragmentation

- Fragmentation occurs in multicellular organisms, be it plants or animals. In this process the multicellular organism breaks into two or more pieces on maturation. Each piece then grows into a new organism. Spirogyra which is a plant and sea anemones which is a sea animal undergoes the process of fragmentation.

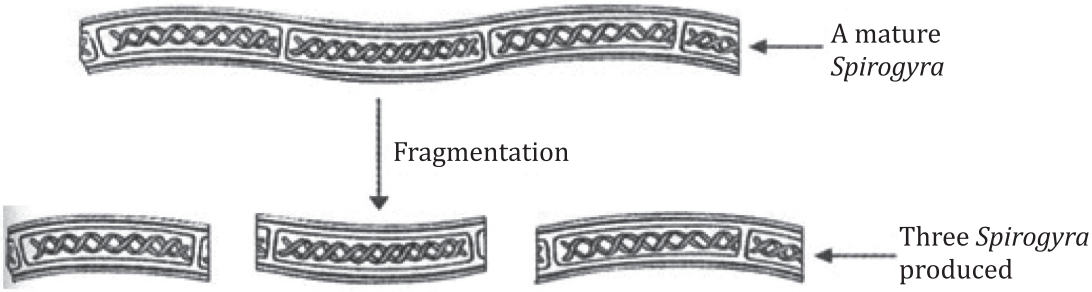


Fig. 3.51: Spirogyra, a filament type algae plant reproduces by the method of fragmentation

Vegetative Propagation

- This form of asexual reproduction occurs in plants only. In vegetative propagation, parts of old plants like stems, roots and leaves are used to grow a new plant. The buds which are present in dormant state in old plants are provided with suitable conditions like moisture and warmth so that they grow and develop to form a new plant.
- Plants that undergo vegetative propagation are green grass, Bryophyllum, money plant, potato plant, onion, banana, etc.

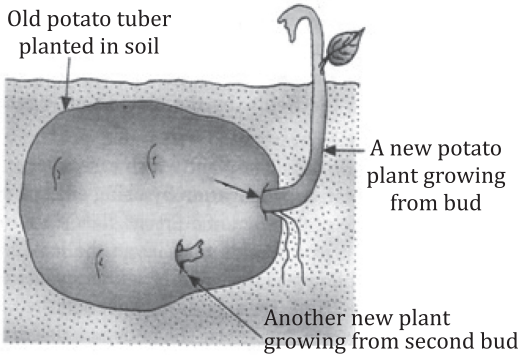


Fig. 3.52: Vegetative propagation of potato plant from a Potato tuber

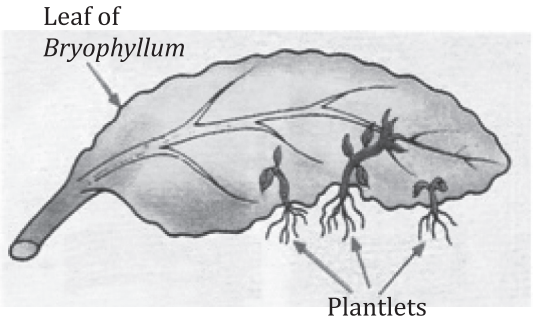


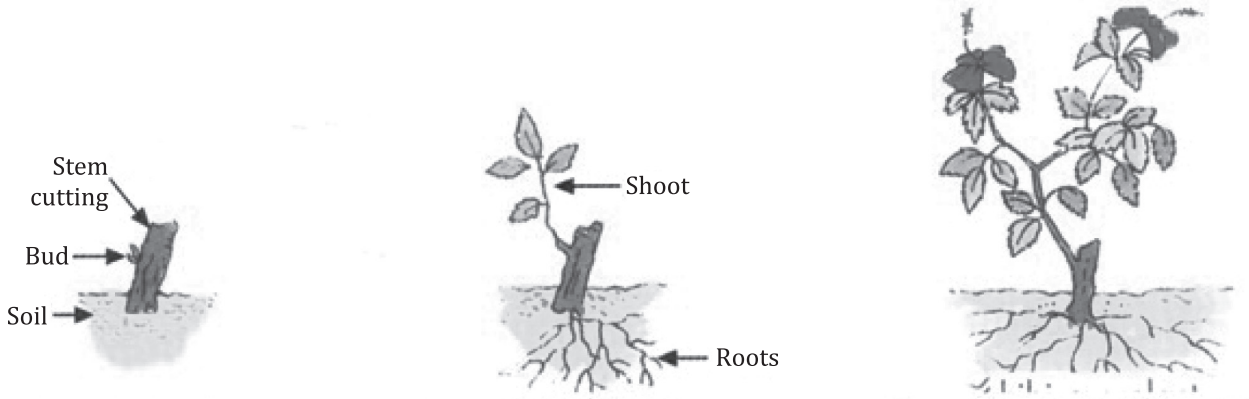
Fig. 3.53: Plantlets growing in the margin of bryophyllum leaf

Artificial Propagation of Plants

- When many plants are grown from one plant using man-made methods, it is called artificial propagation. There are three common methods of artificial propagation of plants. They are:

Cuttings

- A new plant is grown by cutting a small part of a plant which can be a stem or a leaf that has a bud on it. This part is then grown into soil and watered. After a few days one can notice a new plant growing.
- Plants like bougainvillea, chrysanthemum, grapes, etc., can be grown by cutting.



(*a*) A stem cutting (with bud) planted in soil

(*b*) Stem cutting develops roots and shoot

(c) A new plant is formed

Fig. 3.54: The propagation of plants by 'cuttings' method

Layering

- In layering the branches of the parent plant are allowed to go inside the soil in such a way that a part of the branch comes out of the soil. The part of the branch which is inside the soil develops roots and is later cut from the parent plant. In this way a new plant is formed from the buried branch.
- The layering method is used for the plants like Jasmine, Strawberry, raspberry, etc.

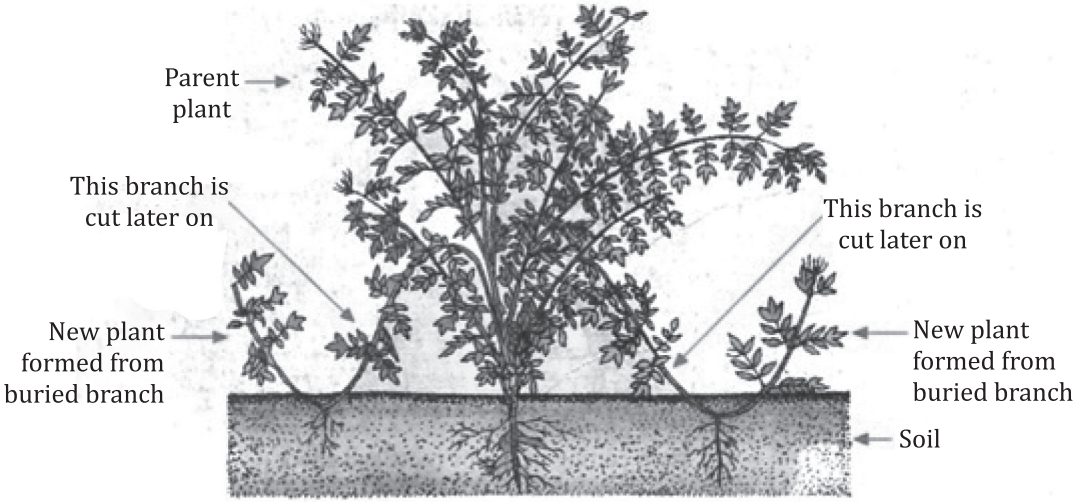


Fig. 3.55: The propagation of Jasmine plant (Chameli) by the layering method

Grafting

- In grafting stems of two different plants are cut and joined in such a way that they grow as one plant. Of the two cut stems, one stem is with the roots and is called stock. The other stem is cut without roots and is called scion. Stock is the lower part of the plant and scion is the upper part of the plant. A slanting cut is made in both the stems.

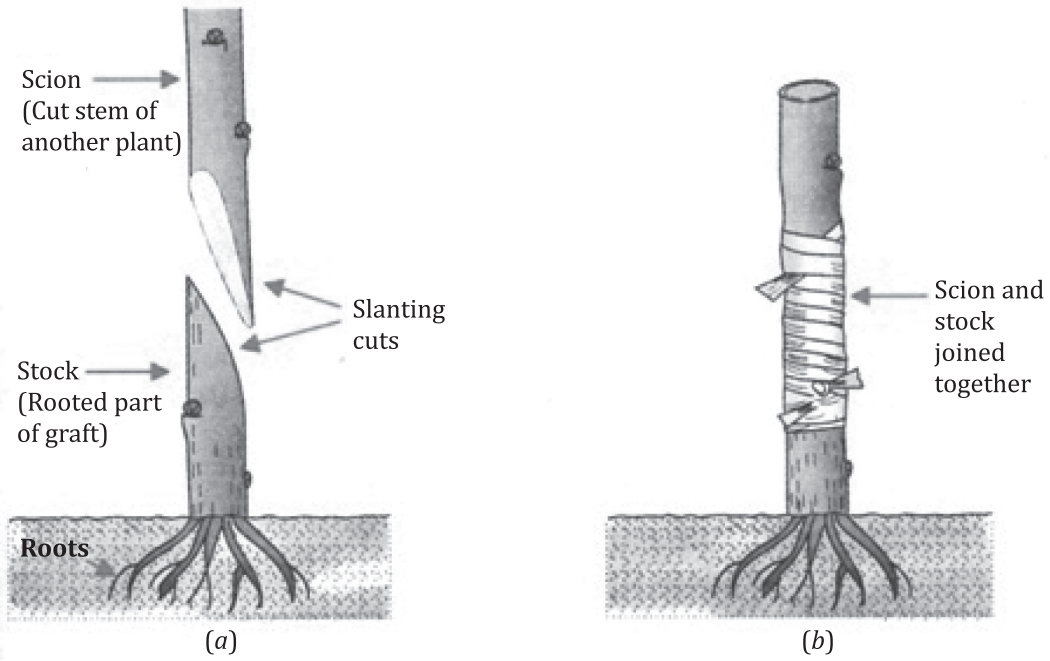


Fig. 3.56: The grafting method for the artificial propagation of plants or trees

- The cut surfaces of scion and stock are fitted and tied together with a piece of cloth and covered with a polythene sheet. This protects the stem from infections and other problems.
- Soon the stock and scion combine and a new plant grows. The fruits of this new plant have the characteristics of both the plants. Examples of fruit which are grafted are apple, peach, apricot etc.

Advantages of Artificial Vegetative Propagation

- The new plant will have exact features as that of the parent plant.
- Fruit trees grown by grafting bear fruit much earlier.
- Plants need less attention in their early years.
- Many plants can be grown from just one parent.
- Can get seedless plants.

3.13.6 Sexual Reproduction in Flowering Plants

- Sexual reproduction is the production of a new organism from two parents by making use of their gametes or sex cells. Plants also have male and female sex organs. These sex organs in plants are carried within the flower and the seeds which are inside a fruit. Such plants are called *angiosperms* or *flowering plants* as they reproduce by sexual reproduction method.
- Most of the plants contain reproductive organs of both male and female in the flowers. The same flower has both male and female reproductive organs. Such flowers make male and female gametes and ensure that fertilization takes place so that new seeds are formed for the reproduction of plants.

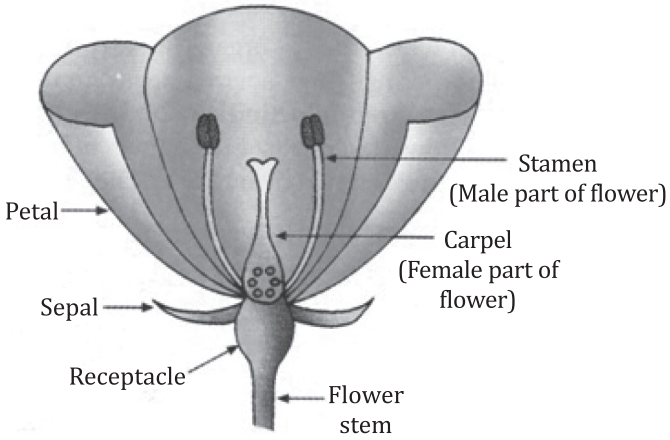


Fig. 3.57: Parts of a Flower

Steps for Sexual Reproduction in Plants

- The male organ of a flower is called *stamen*. It helps in making male gametes of the plant and is present in pollen grains.
- The female organ of a flower is called a *carpel*. It helps in making female gametes or egg cells of the plant and is present in ovules.
- The male gametes fertilize the female gametes.
- The fertilized egg cells grow in ovules and become seeds.
- When germinated, these seeds become new plants.

Various Parts of a Flower

- **Receptacle:** It is a base of a flower above the flower stem. It is at the receptacle that all other parts of a flower are attached.

- **Sepals:** These are the green leaf-like parts which are present on the outermost part of the flower. Sepals help in protecting the flower when it is in the form of a bud. All sepals of a flower together are called calyx.
- **Petals:** Petals are the colourful leaves of a flower. All the leaves of a flower together are called corolla. The petals of a flower have fragrance and they attract insects for pollination. Their function is to protect the reproductive organs present in the center of a flower.
- **Stamen:** Stamens are the male reproductive organ of a plant. They are present inside the ring of petals and are little stalks with swollen tops. Stamen is made of two parts, anther and filament. The stalk of stamen is called filament and the swollen top is called an Anther. The anther of a stamen produces pollen grains and stores them. These pollen grains contain male gametes of the plant. A flower has a lot of stamens in it.

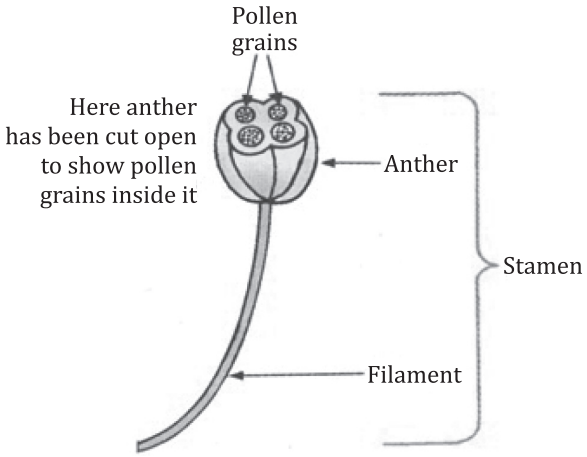


Fig. 3.58: Stamen: Male reproductive organ of a plant.

- **Carpel:** Carpel is the female reproductive organ and is present in the center of a plant. The shape of the carpel is like a flask. Carpel is made of three parts, stigma, style and ovary. The top part of the carpel is called stigma. The stigma is sticky and receives pollen from the anther of stamen. The pollen grains stick to the stigma. The center part of the carpel is called style. Style is a tube which connects stigma to ovary. The bottom part of the carpel which is swollen is called the ovary. It is here that the ovules are made and stored. There are many ovules in the ovary and each ovule contains one female gamete of the plant. The female gamete of the plant which is present inside the ovule is called egg or ovum. Therefore, female gametes are made in the ovary of carpel. The female organ of a plant is also called pistil. Also the carpel is surrounded by a number of stamens.

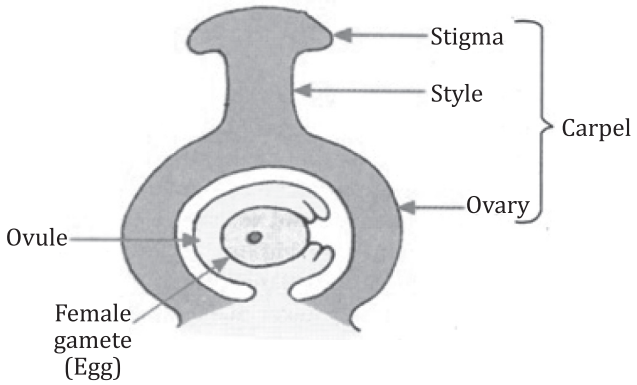
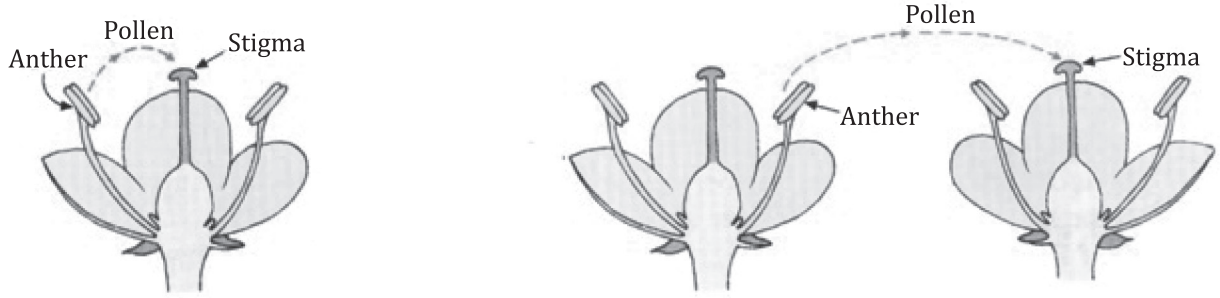


Fig. 3.59: Carpel: Female reproductive organ of a Plant. Carpel is also known as Pistil

- Flowers which have either stamens or carpels are called *unisexual*.. Flowers of papaya and watermelon are examples of unisexual flowers.
- Flowers which have both male and female sex organs are called *bisexual*. Flowers of hibiscus and mustard plants are examples of bisexual flowers.
- In order to make a new seed, male gamete present in a pollen grain unite with the female gamete present in the ovule.
- This process takes place in two steps.
  - Pollination
  - Fertilization

Pollination

- When pollen grains from the anther are transferred to the stigma of a carpel, it is called pollination. It is due to pollination that male gametes are able to combine with female gametes. Pollination is done by insects like bees, butterflies and birds, wind and water.
- There are two types of pollination, self-pollination and cross-pollination. When pollen grains from one flower are carried to the stigma of the same flower or to another flower of the same plant, it is called *self-pollination*. And when pollen grains from a flower of one plant are carried to the stigma of a flower of another similar plant, it is called *cross-pollination.*



(*a*) Self-pollination (*b*) Cross-pollination

Fig. 3.60: Pollination

- Insects help in pollination. This happens when an insect sits on a flower of one plant to suck nectar then the pollen grains from the anther stick to its body. Now, when this insect flies and sits on the flower of another similar plant then the pollen grains are transferred and they stick to the stigma of the flower of another plant. This way insects help cause cross-pollination. Wind too helps in cross-pollination.

Fertilization

- After pollination, the next step is fertilization. In this step, male gametes present in pollen grains join with the female gametes present in ovule.
- When the pollen grain falls on stigma it bursts open and a pollen tube grows which moves through the style towards the ovary and enters the ovule. Male gamete moves down through the pollen tube. The tip of the pollen tube bursts open in the ovule and the male gamete comes out. In the ovule, male gamete combines with the nucleus of female gamete and fertilised egg is formed. This fertilised egg is called

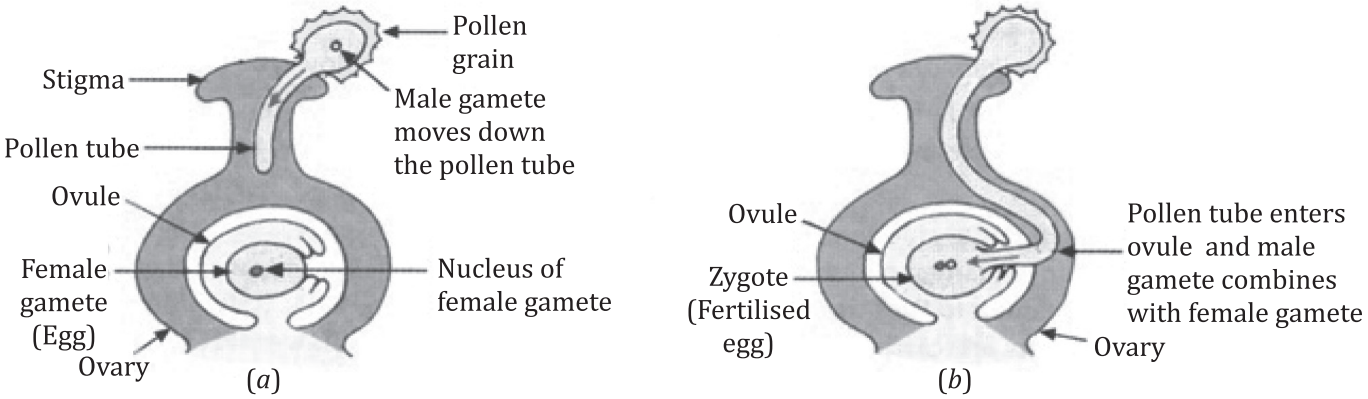
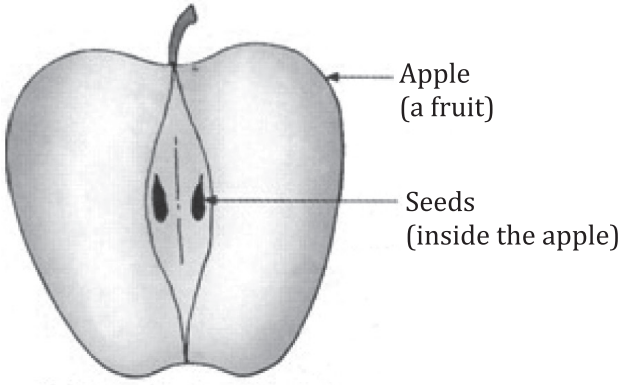


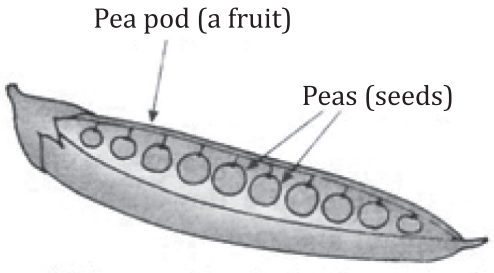
Fig. 3.61: Fertilisation in a Flower

Formation of Fruits and Seeds

- In the ovule, the fertilised egg divides several times to form an embryo. A tough coat is developed around the ovule and it gradually develops into a seed. The ovary of a flower develops to become a fruit which contains seeds inside it. Other parts of the flower like sepal, stamen, stigma and style become dry and fall off. Fruit takes the place of the flower. Seed is protected by the fruit. Some fruits are soft and juicy while the other fruits are hard and dry.



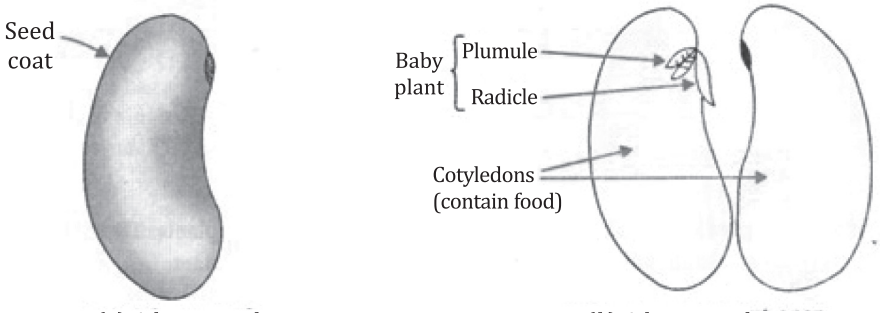
(*a*) An apple is a fruit. It has seeds of apple tree in it.



(*b*) A pea pod is a fruit. It has seeds of pea plant inside it.

Fig. 3.62: A fruit contains seed of the plant inside it

- The seed is the reproductive unit of a plant. With this seed new plant can be grown as the seed contains baby plant and food for the baby plant inside it. The part of the baby plant in seed which grows into leaves is called plumule and the part which develops into roots is called radicle. The part of the seed which stores food for the baby plant is called cotyledon. The baby plant inside a seed is in a dormant state. It is only when we provide it with a suitable environment like water, air, light, etc., it germinates and a new plant grows. Wheat grains, gram, corn, peas, beans etc., are examples of seeds.

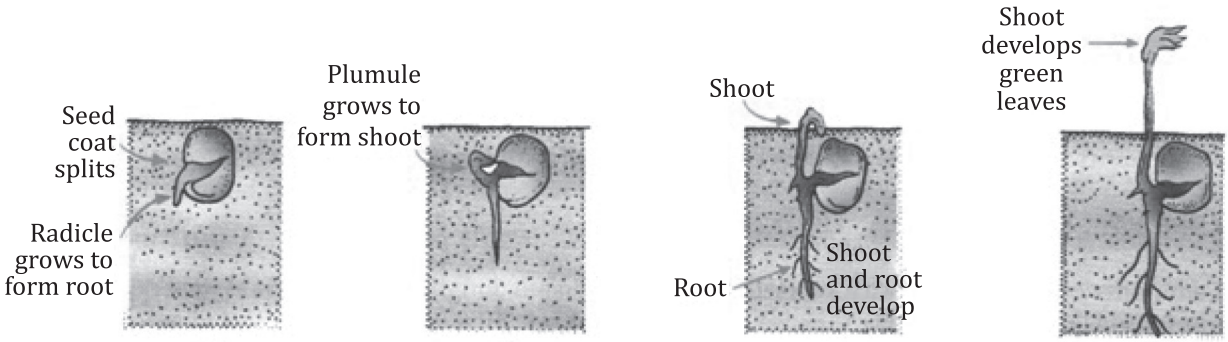


(a) A bean seed (*b*) A bean seed cut open

Fig. 3.63: Parts of a Seed

Germination of Seeds

- The seeds obtained from a plant are in a dry and dormant state. It is only when they get water, air, soil, etc., that they begin to grow into a new plant. The beginning of the growth of a seed is called germination of seeds.
- The germination of a seed begins when it absorbs water, swells and bursts through the seed coat. It is with the help of water that enzymes function in the seed. The enzymes digest stored food and make it soluble. With the help of soluble food, radicle and plumule grow.



(*a*) (*b*) (*c*) (*d*)

Fig. 3.64: Seeds germinate under suitable conditions to produce new plants

- First the radicle of the seed grows to form roots. These roots grow inside soil and absorb water and minerals from the soil. After this plumule grows upwards and shoots are formed. These shoots develop green leaves. The leaves begin to make food with the process of photosynthesis and gradually a whole new plant is developed.

3.14 VITAMINS AND NUTRITION

3.14.1 Food

- Food is any substance consumed to provide nutritional support for an organism.
- It is usually of plant or animal origin and contains essential nutrients such as carbohydrates, fats, proteins, vitamins and minerals. The substance is ingested by an organism and assimilated by the organism's cell to provide energy, maintain life or stimulate growth.

Components of Food

The major components of our food are-

(i) Carbohydrates (ii) Fats
(iii) Proteins (iv) Minerals (salts)
(v) Nucleic Acids (vi) Vitamins
(vii) Water

3.14.2 Carbohydrates

- A carbohydrate is a bio molecule consisting of carbon (C), hydrogen (H) and oxygen (O) atoms, usually with a hydrogen-oxygen atom ratio of 2 : 1.
- Carbohydrates are the main component of food and source of immediate energy to the body.
- Approximately 55-75% energy is provided by carbohydrates to the total energy requirement of the body. It is stored in the liver and skeletal muscles in the form of glycogen which gives energy on requirement.
- **Lactose** is a natural sugar (a carbohydrate). It is milk sugar. It is responsible for the mildly sweet taste of milk. Lactobacillus bacteria convert lactose into lactic acid. These bacteria are employed in the manufacturing of curd and cheese.
- The **starch** and **cellulose** both are of plant origin. Starch is composed of glucose molecules linked in long chains. Cellulose is also a long chain of glucose molecules.

3.14.3 Fats

- Fats are the compounds of Carbon, Hydrogen and Oxygen. In fats, the ratio of oxygen to hydrogen atom is less. The fats are formed with the chemical reaction of one molecule of glycerol and three molecules of fatty acids.
- Fats are the source of stored energy. Fats are broken down in the healthy body to release their constituents, glycerol and fatty acids. Glycerol itself can be converted to glucose by the liver and so become a source of energy.The percentage of fat in a healthy man is 7% to its total body weight.
- The fats have been classified into two groups on the basis of carbon atom bonds in their fatty acids-

(A) Saturated Fats: A saturated fat is a type of fat in which the fatty acid chains behave all or predominantly single bonds.

- Saturated fatty acids are important to nutrition because of their ability to elevate blood lipid levels in humans.The body can synthesize these fatty acids
- **Some saturated fatty acids:**
  - Butyric acid (contained in butter)
  - Lauric acid (contained in coconut oil, palm kernel oil and breast milk)
  - Myristic acid (contained in cow's milk and dairy products)
  - Palmitic acid (contained in butter, palm oil and meat)
  - Stearic acid (contained in meat and cocoa butter)

(B) Unsaturated Fats: An unsaturated fat is a fat or fatty acid in which there is at least one double bond or triple bond within the fatty acid chain. A fatty acid chain is monounsaturated if it contains one double bond, and polyunsaturated if it contains more than one double bond.

- Such fatty acids are found in fish, corn, walnuts, sunflower seeds, soybeans, cotton seeds, olive oil and sunflower oil. Diet high in unsaturated fatty acids and low in saturated fatty acids have been correlated with low serum cholesterol levels. The unsaturated fats have lower melting point and most are liquid at room temperature.
- **Some unsaturated fatty acids:**
  - Palmitoleic acid (found in macadamia nuts)
  - Oleic acid (found in olive oil and canola oil)
  - Myristoleic acid (found in whale blubber)
  - Linoleic acid (found in peanut oil, chicken fat and olive oil)
  - Linolenic acid (found in linseed oil)
- Unsaturated fatty acid can not be synthesized by the body and is therefore essential to the diet.
- *Hydrogenation* is a process in which unsaturated fats such as vegetable oils are hydrogenated to produce saturated fats which have more desirable physical properties e.g. they melt at a desirable temperature (30°C to 40°C).

3.14.4 Proteins

- Proteins are the essential nutrients for the human body. They are one of the building blocks of body tissue and can also serve as a fuel source. As a fuel, proteins provide 4.0K cal energy per gram.
- *Amino acids* are the structural units of the protein.
- There are 10 essential amino acids and 10 non-essential amino acids which are required to synthesize protein in the human body.
  - **Essential Amino Acids:** Essential amino acids are not synthesized in the human body. Humans must obtain them from their diet in order to prevent protein energy malnutrition and resulting death.
  - **Essential amino acids include:** phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, histidine and arginine. Arginine and histidine are essential only for juveniles but not for adults because these are synthesized in adults.
  - **Non-essential Amino Acids:** Non-essential amino acids are such amino acids which are synthesized within the human body. These are alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, and tyrosine.
  - a-Keratin is a protein, which is the main constituent of horn, nail, hoof, hair, skin etc. Tyrosine helps in synthesis of neurotransmitters such as adrenaline, noradrenaline and dopamine in the brain.
  - Due to protein deficiency, marasmus and kwashiorkor diseases are developed in humans.

In milk, the water percentage is approximately 87%. Besides, it contains fats, proteins, carbohydrates, calcium, potassium, so it is considered as a Complete Diet, which is globally accepted food for all ages.

3.14.5 Vitamins

- Certain organic compounds are required in small amounts in our diet but their deficiency causes specific diseases. These compounds are called vitamins.
- Vitamins are classified into two groups depending upon their solubility in water or fat.
  - **Fat soluble vitamins:** These are vitamins A, D, E and K. They are stored in liver and adipose (fat storing) tissues.
  - **Water soluble vitamins:** vitamins B group and vitamin C are soluble in water. Water soluble vitamins must be supplied regularly in diet because they are readily excreted in urine and cannot be stored (except vitamin B) in our body.
- Most of the vitamins cannot be synthesized in our body but plants can synthesize almost all of them.

Main Vitamins, Sources and Deficiency Diseases

Vitamins	Deficiency diseases	Sources
Vitamin A (Retinol)	Night blindness, Xerophthalmia, Keratinization of skin infection	Carrot, milk, cheese, butter, egg, Cod liver oil
Vitamin B1 (Thiamin)	Beri-beri, Growth retardation	Cereals, legumes, soybeans, milk, yeast, green vegetables
Vitamin B2 (Riboflavin)	Cheilosis, glossitis, dermatosis, digestive disorders	Milk, egg white, liver, kidney, Yeast, meat, green leafy vegetables
Vitamin B3 (Niacin)	Pellagra	Egg, meat, fish, milk, yeast, vegetables, mushroom
Vitamin B5 (Pantothenic Acid)	Paraesthesia, burning sensation	Yeast, meat, fish, egg milk, legumes
Vitamin B6 (Pyridoxine)	Anemia, skin problem, muscular twisting	milk, yeast, cereals, egg, grams, yolk
Vitamin B7 (Vitamin-H; Biotin)	Skin disease, fall of hair	Meat, wheat, egg, vegetables, fruits
Vitamin B9 (Folic Acid)	Anaemia, growth retardation	Green vegetables, legumes, yeast, liver
Vitamin B12 (Cobalamin)	Pernicious anemia, abnormality in nervous system	meat, fish, Egg, Curd, bacteria of intestine
Vitamin C (Ascorbic Acid)	Scurvy (bleeding gums)	Amla, tomato, fruits of citrus family, green leafy vegetables
Vitamin D (Calciferol)	Rickets, osteomalacia	Cheese, fish, egg yolk, sunlight
Vitamin E (Tocopherol)	Sterility and weakening of reproductive organ and muscles	Vegetable oils, wheat, soyabean
Vitamin K (Naphtho- quinone)	Increased blood clotting time	Green leafy vegetables, bacteria of intestine

3.15 HUMAN DISEASES

- Disease is defined as any harmful deviation from the normal structural or functional state of an organism, generally associated with certain signs and symptoms and differing in nature from physical injury.

3.15.1 Types of Diseases

On the basis of its nature, character and causes of its spreadness is of two types:

1. ***Congenital Disease*** is the diseases which are present since birth. These are caused due to genetic abnormality or due to metabolic disorders or malfunctioning of any organ. They are basically permanent, generally not easily curable and may be inherited to the children like Harelip, Cleft Palate, Club foot etc. Also due to imbalance in the chromosomes, the appearance of Mongolism, the birth of the blue baby due to cardiac disorder etc are also some examples of it.
2. ***Acquired Disease*** those defects or disorders which are not present by birth but appear due to the various causes and factors. These may be further categorized into following heads:

(i) ***Communicable or infectious diseases:*** These are caused by a variety of pathogenic viruses, bacteria, protozoa, fungi and worms. The pathogens are generally carried with the help of a vector.

(ii) ***Non-communicable or non-infectious or degenerative diseases:*** These occur due to the malfunctioning of some organ or organ system in the body. It may be of various types like *Deficiency diseases*, *Cancerous diseases*, *Allergy, Genetic diseases.*

Endemic - (of a disease or condition) regularly found among particular people or in a certain area.
Epidemic - The rapid spread of a particular disease to a large number of people in a given population within a short period of time.
Pandemic - That has spread across a large region, for instance a whole country, multiple continents or worldwide, affecting a substantial number of people.

3.15.2 Major Diseases

Viral Diseases

Name of disease	Caused by	Parts of body affected	Method of spread	Type of Vaccination
Influenza	A mycovirus (RNA virus)	Respiratory passages: epithelial lining of trachea and bronchi.	Droplet Infection	Killed virus
Common cold	Large variety of viruses, commonly rhinovirus (RNA Virus)	Respiratory passages	Droplet Infection	Intramuscular injection.
Smallpox	Variola virus (DNA virus)	Respiratory passages, then skin	Droplet Infection (Wounds in skin)	Living attenuated virus applied by scratching skin, no longer carried
Chickenpox	Varicella- zoster	Blistering Skin rash	Air-borne droplets	Living attenuated virus
Mumps	A paramyxovirus (RNA virus)	Respiratory passages, infection via blood, salivary glands, testes in adult males	Droplet infection	Living attenuated virus
Measles	A paramyxovirus (RNA virus)	Respiratory passages, spreading to skin and intestines.	Droplet infection	Living attenuated virus
German measles (Rubella)	Rubella virus	Respiratory passages, lymph nodes in neck, eyes and skin.	Droplet infection	Living attenuated virus, more essential for girls because disease causes complications in pregnancy.
Poliomyelitis (polio)	Poliovirus (RNA Virus)	Pharynx and intestines, then blood; occasionally motor neurons in the spinal cord, paralysis may occur.	Droplet infection or via human feces	Living attenuated virus given orally
Yellow fever	An arbovirus i.e., arthropod-borne virus (RNA Virus)	Lining of blood vessels and liver	Vector- arthropods e.g., ticks, mosquitoes	Living attenuated virus
AIDS	Retrovirus (RNA virus)	Skin Cancer	Sexual intercourse homosexuals and heterosexuals	Not available
Ebola hemorrhagic fever	Ebola Virus disease (EVD)	Fatal Illness in Humans, Fever	It is transmitted to people from wild animals and spreads in the human population through human-to-human transmission.	No licensed Ebola vaccine is available

Zika disease	Zika Virus (mosquito borne disease)	Causes mild illness in the people like dengue, yellow fever	Basically, Infection in pregnant women is linked to abnormally small heads in their babies.	No vaccine available

Coronavirus Disease 2019 (COVID-19)

- Coronaviruses are a large family of RNA viruses. In humans, these viruses cause respiratory tract infections, ranging from the common cold to more severe diseases such as SARS (Severe Acute Respiratory Syndromes), MERS (Middle East Respiratory Syndrome) or camel Blue, and COVID-19.
- COVID-19 (Comma Virus Disease 2019) an infectious disease, caused by Novel Coronavirus or Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) was first identified in December 2019 in Wuhan (China), and has resulted in large scale pandemic with millions of cases and lakhs of deaths worldwide. The World Health Organization (WHO) declared the COVID-19 outbreak a **public health emergency of international concern** on 30 January 2020 and a **pandemic** on 11 March 2020.
- Common signs of COVID-19 infection include respiratory symptoms, fever, cough, shortness of breath, breathing difficulties, fatigue and loss of smell and taste.
- While the majority of cases result in no or mild to moderate symptoms, some progress to acute respiratory distress syndrome (ARDS) likely precipitated by a cytokine storm, multi-organs failure, septic shock and severe blood clotting leading to death.
- Preventive measures include physical or social distancing, quarantining, ventilation of indoor spaces, covering coughs and sneezes, hand washing, and keeping unwashed hands away from the face. The use of face masks or coverings has been recommended in public settings to minimize the risk of transmissions.
- On 16 January 2021, India started its national vaccination programme against the SARS-CoV-2 with two vaccines Covishield (Oxford-AstraZeneca Vaccine manufactured by Pune-based Serum Institute of India) and Covaxin (Developed by Bharat Biotech in association with the Indian council of Medical Research and National Institute of Virology).

Bacterial Diseases

Name of disease	Caused by	Parts of body affected	Method of spread	Type of vaccination or antibodies
Diphtheria	Corynebacterium diphtheria	Upper respiratory tract, mainly the throat, also toxins affect the heart.	Droplet infection	Toxoid
Tuberculosis (TB)	Mycobacterium tuberculosis	Mainly lungs	Droplet infection, Drinking milk from infected cattle.	BCG living attenuated bacteria. Antibiotics e.g., streptomycin.
Whooping cough (Pertussis)	Bordetella pertussis	Upper respiratory tract, inducing violent coughing	Droplet infection	Killed bacteria
Gonorrhea	Neisseria gonorrhoeae	Reproductive organs: mainly mucous membranes of the urogenital tract. Newborn infants may acquire serious eye infections if they pass through infected birth canals.	Contagion by sexual contact	Antibiotics, e.g., penicillin, streptomycin

Syphilis	Treponema pallidum	Reproductive organs, then eyes, bones, joints, central nervous system, heart and skin.	Contagion by sexual contact	Antibiotics. e.g., penicillin
Tetanus	Clostridium tetani	Blood. Toxin is produced which affects motor nerves of the spinal cord and hence muscles, causing lockjaw and spreading to the muscles.	Wound infection	Toxoid
Cholera	Vibrio cholera	Alimentary canal: mainly small intestine.	Faecal contamination (a) Food - or water borne of material contaminated with faeces from an infected person. (b) Handling of contaminated Objects. (c) Vectors, e.g., flies moving from human faeces to food.	Killed bacteria: short-lived protection and not always effective Antibiotics e.g., tetracyclines, chloramphenicol.
Typhoid fever	Salmonella typhi	Alimentary canal, then spreading to lymph and blood, lungs, bone marrow, spleen.	Same as cholera	Killed bacteria (TAB vaccine)
Bacterial dysentery	Shigella dysenteriae	Alimentary canal, mainly ileum and colon	Same as cholera	No vaccine.
Bacterial food poisoning (gastroenteritis or salmonellosis)	Salmonella spp.	Alimentary canal	Mainly foodborne meat from infected animals from poultry and pigs. Also, via faecal contamination as cholera	Antibiotics. e.g., tetracyclines.

Diseases Caused by Worms

Disease	Pathogen responsible and its habitat	Mode of transmission	Main symptoms
Ancylostomiasis or 'Hook-worm disease'	Ancylostoma duodenale, small intestine (jejunum) of man	Transmission from person to person, filariform larvae passed out in faeces, man picks up infection walking barefoot on faecally-contaminated soil.	Dermatitis; reddish, severe anemia; duodenal ulcer, constipation. Patient pale, puffy face with swelling of lower eyelids.

Ascariasis	Ascaris Lumbricoides; small intestine (jejunum) of man	Transmission from person to person, ripe eggs passed out in faeces, infection affected by swallowing ripe Ascaris eggs with raw vegetables.	Larvae in the lungs cause pneumonia. May give rise to typhoid-like fever, causes protein and Vitamin A deficiencies resulting in protein-calorie malnutrition and night blindness respectively. Can cause appendicitis, jaundice.
Enterobiasis or 'Pinworm disease'	Enterobius vermicularis, caecum and vermiform appendix	Transmission from one person to another by ingestion of eggs in contaminated food or drink.	Eczematous condition round the anus, bed wetting at night, inflammation of vermiform appendix.
Filariasis	Wuchereria Bancrofti, lymphatic vessels and lymph nodes.	Part of the life cycle in mosquito in which larvae develop and become infectious to man, with mosquito bite larvae deposited on skin which enter through puncture wound and reach lymphatic channels	Elephantiasis i.e., enormous enlargement of certain parts such as that of leg, scrotum, penis, labia, clitoris, breast, forearm.

Diseases Caused by Fungi

Disease	Pathogen responsible	Mode of transmission	Main symptoms
Ringworm (tinea)	Microsporum, Trichophyton	Direct contact from unbathed cats and dogs or objects handled by infected individuals	Contain one or more blistered areas on skin and scalp. Cause partial and temporary baldness in children.
Athlete's foot	Trichophyton	Bad foot hygiene where skin remains warm and moist for long periods.	Painful itching or burning sensation in the infected areas. Cracks appear in the skin, mass of loose dead skin clings between toes.
Madura foot	Maurella Mycetoma	Fungi gain entry through some minor injury to the skin.	Producing a chronic, granulating infection of the lower extremities, the affected part becomes enlarged and develops many deep sores, extensive bone destruction leading to crippling deformities.
Dhobie itch	Several Different Fungi	Direct contact through Objects handled by an infected person.	A type of ringworm infection is usually located in the groin and inner surfaces of thighs, red rash which itches intensely.

3.15.3 Other Diseases

- **A. Cancer:** Cancer is a group of diseases involving abnormal cell growth with the potential to invade or spread to other parts of the body. These contrast with benign tumours, which do not spread.
- Possible signs and symptoms of cancer include a lump, abnormal bleeding, prolonged cough, unexplained weight loss and a change in bowel movements.
- A *metastasis* refers to the spread of cancer cells from their primary location (the organ in which cancer began) to another region of the body. Cancer cells may spread through the bloodstream, the lymphatic vessels.
- An *oncogene* is a gene that has the potential to cause cancer in tumour cells, they are often mutated or expressed at high levels. Most normal cells will undergo a programmed form of rapid cell death (apoptosis), when critical functions are altered and malfunctioning.
- **B. Heart Attack:** The common cause of heart attack is plaque buildup in the arteries (atherosclerosis) that prevents blood from getting to the heart muscle. Heart attacks can also be caused by blood clots or torn blood vessels.
- The risk factors relating to heart attack include-
  - Smoking
  - High cholesterol
  - Obesity
  - Lack of exercise
  - Diet and alcohol consumption
  - Stress
- Anticoagulants and antiplatelet drugs eliminate or reduce the risk of blood clots. Aspirin, a neurologically active medicine used as antipyretic, painkiller and anti-inflammatory, is also used in heart attacks
- ***Heart bypass Surgery:*** Heart bypass surgery or coronary artery bypass surgery is used to replace damaged arteries that supply blood to a heart muscle. A surgeon uses blood vessels, taken from another area of the body, mainly mammary artery or radial artery, to repair the damaged arteries. The saphenous vein is used in bypass surgery.
- ***Cardiac Catheterization*** **Laboratory (Cath Lab):** It is a special hospital room where doctors perform minimally invasive tests and procedures to diagnose and treat cardiovascular disease.
- **C. Diabetes:** Diabetes or Diabetes mellitus (DM) is a group of metabolic disorders in which there are high blood sugar levels over a prolonged period.
- Symptoms of high blood sugar include frequent urination, increased thirst and increased hunger.
- If left untreated, diabetes can cause many complications. Acute complications can include diabetic ketoacidosis, hyperosmolar hyperglycemic state or death. Serious long-term complications include cardiovascular disease, stroke, chronic kidney disease, foot ulcers and damage to the eyes.
- Diabetes is caused due to either the pancreas not producing enough insulin or the cells of the body not responding properly to the insulin produced.
- ***Type 1 diabetes:*** It is also called 'insulin-dependent diabetes'. It used to be called 'juvenile-onset diabetes', because it often begins in childhood. Type I diabetes is an autoimmune condition. It is caused by the body attacking its own pancreas with antibodies. In people with type 1 diabetes, the damaged pancreas does not make enough insulin due to loss of beta cells. This type of Diabetes may be caused by a genetic predisposition. It could also be the result of faulty B-cells in the pancreas that normally produce insulin.
- ***Type 2 diabetes:*** It begins with insulin resistance, a condition in which cells fail to respond to insulin properly. With type 2 diabetes, the pancreas usually makes some insulin, but either the amount made is not enough for the body's need, or the body's cells resist it. This form was previously referred to as 'non-insulin dependent diabetes' or 'adult-onset diabetes'. The most common cause is a combination of excessive body weight and insufficient exercise.
- **World Diabetes Day** is celebrated each year on 14 November in the world which increases awareness about diabetes.
- **Diabetes Insipidus**: Diabetes Insipidus (DI) is a condition caused by not enough antidiuretic hormone (ADH) in the body. This condition is also called water diabetes.
- **ADH** is also known as vasopressin, secreted by the pituitary gland (an endocrine gland). This is a hormone that helps the kidneys keep the correct amount of water in the body.
- **D. Jaundice:** Jaundice is when a buildup bilirubin in the blood causes the skin, mucus membranes, and the white part of the eyes to appear yellowish. Bilirubin is a reddish-yellow substance produced when red blood corpuscles (RBCs) break down. Bilirubin is excreted through the liver in the bile and then out of the body in the stool.
- Jaundice itself is not a dangerous condition, but rather it may be a sign of a more serious condition or disease such as gall bladder stone formation, liver cancer etc. Jaundice sometimes affects newborns (newborn jaundice) because their livers are too immature to process the bilirubin in their bodies.
- Other symptoms of jaundice may include:
- Itchy skin
- Change in urine and stool colour (Urine may be pale or pale yellow-range)
- Fatigue

Micronutrient Deficiency Diseases

Disease	Deficiency	Symptoms
Anemia	Haemoglobin	General Weakness and Pale Complexion
Goitre	Iodine	Painful Joints
Beriberi	Vitamin B1	Weakness, Swelling and pain in legs, loss of appetite, enlarged heart
Scurvy	Vitamin C	Swollen Gums, Late healing of wounds
Rickets	Vitamin D	Sleeplessness, Pale Face, Diarrhoea, Deformessssd Skulls, pelvis and limbs in children
Night blindness	Vitamin A	Loss of Vision in dark
Hypokalemia	Potassium	Rise in heartbeat, kidney damage, Weakness
Xerophthalmia	Vitamin A	Dryness
Dermatosis	Vitamin A	Skin Disease
Pellagra	Vitamin B complex	Diarrhoea, mental lethargy, red skin, itchy hands, feet, elbow and knee
Ariboflavinosis	Vitamin B12	Blurred Vision, Soreness of Tongue

4 Technology

4.1 BIOTECHNOLOGY

- Biotechnology deals with **techniques of using live organisms or enzymes** from organisms to produce products and processes useful to humans.
- The two core techniques that enabled birth of modern biotechnology are
  - **Genetic engineering:** Techniques to alter the chemistry of genetic material (DNA and RNA) to introduce these into host organisms and thus change the phenotype of the host organism.
  - **Bioprocess engineering:** Maintenance of sterile (microbial contamination- free) ambience in chemical engineering processes to enable growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc

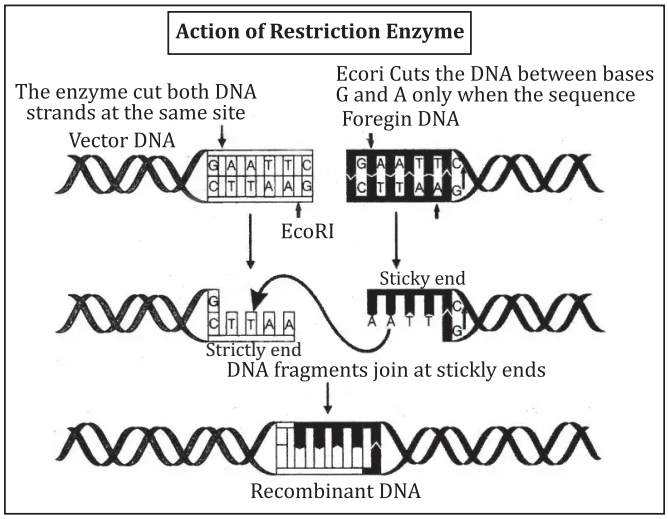


Fig. 4.1: Biotechnology

4.1.1 Biotechnological Applications in Agriculture

Genetically Modified (GM) Food Crops

- Genetically Modified (GM) foods are **foods derived from organisms whose genetic material (DNA)** has been modified in a way that does not occur naturally, e.g. through the introduction of a gene from a different organism.
- GM crops were **first commercially introduced in 1996** all over the world. Their popularity has skyrocketed since then.
- **Corn, cotton, and soybeans** have been genetically modified to withstand insect pests and herbicides, and they are now widely cultivated in many regions of the world.
- The **Government of India approved Bt cotton** as the only genetically modified (GM) crop for commercial production in 2002.

Case of Bt Cotton

- **Bt toxin** is produced by a bacterium called **Bacillus Thuringiensis (Bt)**.
- Bollgard technology is about a genetic sequence from a microorganism called Bacillus thuringiensis (Bt).
- Bt toxin gene has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides.
- B. thuringiensis forms protein crystals during a particular phase of their growth. These crystals contain a toxic insecticidal protein.
- The toxin is coded by a **gene cryIAc named cry.**
- There are a number of them, for example, the protein encoded by the genes cryIAc and cryIIAb control the cotton bollworms, that of cryIAb controls corn borer.

DMH-11

- The commercial release of the **GM mustard Dhara Mustard Hybrid 11** (DMH 11) created by **Delhi University** is pending since the GEAC has urged that thorough safety assessment data on **environmental biosafety**, particularly effects on beneficial insect species, be generated first.
- It is a genetically modified hybrid variety of the mustard species Brassica juncea.
- The transgenic mustard DMH - 11 was developed in 2002 using genetic material isolated from non-pathogenic soil bacteria.
- Three genes, Bar, Barnase and Barstar, were extracted from Bacillus amyloliquefaciens to produce the hybrid seed.
- DMH 11's Glufosinate resistance is due to an enzyme expressed by the Bar (Bialaphos resistance) gene.

Bt Brinjal

- Bt Brinjal is a transgenic brinjal developed by introducing the cry1Ac gene from the Bacillus thuringiensis soil bacterium into Brinjal.
- This brinjal has been genetically modified to withstand insects like the Brinjal Fruit and Shoot Borer (Leucinodes orbonalis).
- Maharashtra Hybrid Seeds Company created Bt Brinjal (Mahyco).

Golden Rice

- Golden Rice is a new form of rice that **contains beta-carotene** (provitamin A), which the body converts to **vitamin A** as needed and gives the grain its **golden colour**.
- It's made possible by genetic engineering, and it produces two new enzymes that finish the beta-carotene expression in rice grains.

Terminator Seed Technology

- The genetic alteration of plants to make them produce **sterile seeds** is known as terminator seed technology.
- **Suicide seeds** are another name for them.
- Genetic Use Restriction Technologies is Terminator's official name, as used by the **UN** and scientists (GURTs).

4.1.2 Biofortification

- It is the **process of improving the nutritional value of food crops** by increasing the density of vitamins and minerals in the crop, which can be accomplished by traditional plant breeding, agronomic methods, or biotechnology.
- These genetically changed and nutrition-added crops, dubbed **biologically fortified** or **biofortified**, vary from commercially available fortified foods in that additional nutrients are genetically entrenched rather than chemically supplied.
- **Example:** Iron-biofortification of rice, beans, sweet potato, cassava and legumes.

4.1.3 Biotechnological Applications in Medicine

Genetically Engineered Insulin

- Insulin **used for diabetes** was earlier extracted from **pancreas of slaughtered cattle and pigs.**
- Insulin from an animal source, though, caused some patients to develop allergy or other types of reactions to the foreign protein.
- In 1983, Eli Lilly, an American company prepared two DNA sequences corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.
- Chains A and B were produced separately, extracted and combined by creating disulfide bonds to form human insulin.

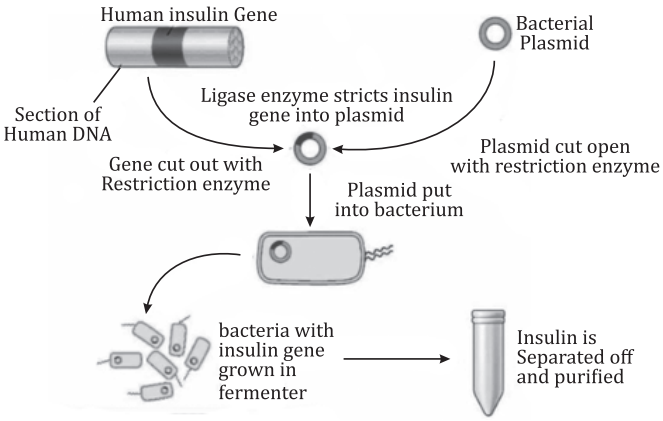


Fig. 4.2: Genetically Engineered Insulin

Gene Therapy

- Gene therapy is a **technique for treating genetic problems** that includes replacing faulty genes with healthy ones.
- It is a way of introducing DNA into human cells that is done artificially.
- Gene therapy can be divided into two categories:

- **Somatic Gene Therapy (SGT)**
  - This type is most commonly seen in the somatic cells of the human body.
  - This is specific to a particular person, and the damaged cells will only be replaced with healthy cells in that person.
  - Therapeutic genes are introduced into the somatic cells of the human body using this procedure.
  - This approach of gene therapy is thought to be the best and safest.
- **Gene Therapy in the Germline**
  - It happens in the human body's germline cells.
  - Generally, this approach is used to address disease- causing genetic abnormalities that are handed on from parents to their children.
  - The procedure entails inserting healthy DNA into the cells that produce reproductive cells, eggs, or sperms.

4.1.4 Application in Bioenergy

- Biofuels derived from biomass are renewable and sustainable energies with the potential to replace fossil fuels.
- Biotechnology can help to speed up the selection of varieties that are more suited to biofuel production with increased:
  - Biomass per hectare,
  - Increased content of oils (biodiesel crops) or

- Fermentable sugars (ethanol crops), or
- Improved processing characteristics that facilitate their conversion to biofuels.

- Utilization of microbial fuel cells is found to be useful for sustainable bioenergy synthesis via completing the wastewater treatment processes with electric energy synthesis.

4.1.5 Environmental Biotechnology

- Environmental biotechnology, specifically, refers to the use of procedures to safeguard and restore the environment's quality.

Bioremediation

- Bioremediation is the **process of using microorganisms to remove or detoxify toxins** from soils, water, or sediments that would otherwise be harmful to human health.
- Bioremediation is also known by the terms **biotreatment, bioreclamation,** and **biorestoration.**
- Microorganisms are employed in **sewage treatment plants** to remove typical pollutants from wastewater before it is discharged into rivers or the sea.
- **Lindane** (Hexa-Chlorocyclohexane) bioremediation technology has been developed.

Phytoremediation

- Phytoremediation is a bioremediation process that **uses various types of plants to remove, transfer, stabilize, and/ or destroy contaminants in the soil and groundwater.**
- Phytoremediation treatment processes have been developed for the degradation of dyes from textile industrial effluent.
- The study showed that the developed process has the potential for textile dyes and effluent treatment.

Phyto-degradation

- In this process, plants actually metabolize and destroy contaminants within plant tissues.

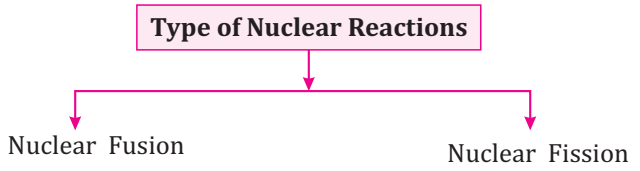
Phyto-volatilization

- In this process, plants take up water containing organic contaminants and release the contaminants into the air through their leaves.

Biosensors

- A biosensor is an **analytical device that converts a biological response into a physical, chemical or electrical signal.**
- The biosensors can be designed to be very selective, or sensitive to a broad range of compounds.
- For example, a wide range of herbicides can be detected in river water using algal-based biosensors; the stresses inflicted on the organisms being measured as changes in the optical properties of the plant's chlorophyll.

4.2 NUCLEAR TECHNOLOGY



Nuclear Fusion

- Nuclear Fusion is defined as the **combining of two lighter nuclei into a heavier one**.
- Fusion reactors do not produce radioactive waste with a high activity or a long half-life. Helium, an inert gas, is used as the fuel in fusion reactors.
- Release higher energy than Nuclear fission.
- Produce many highly radioactive particles.
- It does not involve chain reaction and requires high temperatures.
- In fusion reactors, tritium and deuterium (hydrogen isotopes) atoms are employed.
- Extremely high energy is required to bring two or more protons close enough that reaction can proceed.

Nuclear Fission

- Fission is the **splitting of a heavy, unstable nucleus into two lighter nuclei**, which releases a tremendous amount of energy.
- Fission reactors produce highly radioactive fission products.
- Release low energy than Nuclear fusion.
- Few radioactive particles are produced.
- It involves chain reaction and requires a high speed neutron.
- Uranium and plutonium are most commonly used for fission reactors.
- Take high energy to split two atoms.

Nuclear Power Reactors (Fission Reactors)

- A nuclear reactor is a device that contains and regulates nuclear chain reactions over a long period of time.
- Reactors are used to generate power, move aircraft carriers and submarines, and produce medical isotopes for imaging and cancer treatment.
- They are also used to perform research.

How Does a Nuclear Reactor Produce Electricity?

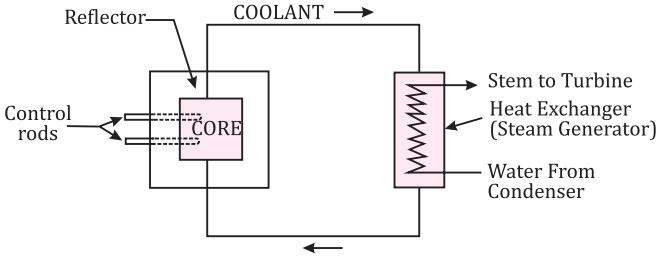
- The release of energy from splitting the atoms of particular elements is produced and controlled by a nuclear reactor.
- The energy released in a nuclear power reactor is used as heat to create steam, which is then used to generate electricity.

Working of The Reactor

- When a neutron hits a nucleus of a radioactive atom, it triggers the break-up of that nucleus into large pieces called fission fragments.
- In addition to these two fragments neutrons are usually released which in turn do the nucleus of the atom in the reactor and this sets up the chain reaction.
- The chain reaction generates a heat which in turn is used to move a turbine to produce electricity.

Components of Nuclear reactor

- **Fuel:** Uranium is the primary source of energy. Typically, uranium oxide (UO_2) pellets are stacked in tubes to make fuel rods. In the reactor core, the rods are stacked into fuel assemblies.
- **Moderator:** The neutrons emitted from fission are slowed by material in the core, causing additional fission. Water is most commonly used, however heavy water or graphite can also be used.
- **Control rods:** These are constructed of neutron-absorbing materials like cadmium, hafnium, or boron, and are added or removed from the core to control or stop the reaction.



- **Coolant:** A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant.

4.2.1 Uranium Enrichment

- Uranium found in nature consists largely of **two isotopes, U-235 and U-238.**
- The production of energy in nuclear reactors is from the **fission or splitting of the U-235 atoms**, a process which releases energy in the form of heat.
- **U-235** is the main **fissile isotope of uranium**.
- Natural uranium contains **0.7%** of the **U-235 isotope**. The remaining **99.3%** is mostly the **U-238** isotope which does not contribute directly to the fission process.
- **Isotope separation is a physical process to concentrate** ('enrich') one isotope relative to others. Most reactors are light water reactors (of two types – PWR and BWR) and require uranium to be enriched from **0.7%** to **3-5% U-235** in their fuel.

On the basis of enrichment, uranium is of two types:

1. **Low Enriched Uranium (LEU):** LEU is used for peaceful purposes like fuel in nuclear reactors (Kudankulam (1.5%) & Jaitapur (5%) required enriched Uranium.
2. **High Enriched Uranium (HEU):** HEU is weapon grade uranium used for conducting nuclear tests and nuclear weapons.

- **U-233 (not found naturally)** is produced in Thermal breeder reactors where **Thorium-232** absorbs a neutron to form **U-233** which is fissile.

4.2.2 Three Stage Nuclear Power Program of India

- **Homi Bhabha** devised India's **three-stage nuclear power programme** in the **1950s** to ensure the country's long- term energy independence by utilizing uranium and thorium supplies found in the monazite sands of South India's coastal regions.

Stage 1- Pressurized Heavy Water Reactor (PHWR)

- The first stage entailed using **natural uranium** to power PHWRs while **Plutonium-239** was produced as a **byproduct**.
- For the first stage, PHWRs were chosen since, in the 1960s, India had the most efficient reactor design in terms of uranium utilization.

Stage 2- Fast Breeder Reactor (FBR)

- The second stage entails producing **fuel from Plutonium- 239** for use in Fast Breeder Reactors.
- **Plutonium 239** is fission to generate energy.
- **Thorium** will be used in the reactor to make **Uranium-233** once a sufficient amount of plutonium-239 has been built up. The third stage requires this uranium.

Stage 3- Advanced Heavy Water Reactor (AHWR)

- The fundamental goal of stage 3 is to create a long-term nuclear fuel cycle.
- **Uranium-233** and Thorium would be combined in the advanced nuclear system.
- India has a large amount of thorium that could be used in a thermal breeder reactor.
- Thorium was saved for the last step because, despite its widespread availability, its use in energy production has been fraught with difficulties. It can't be used straight away.

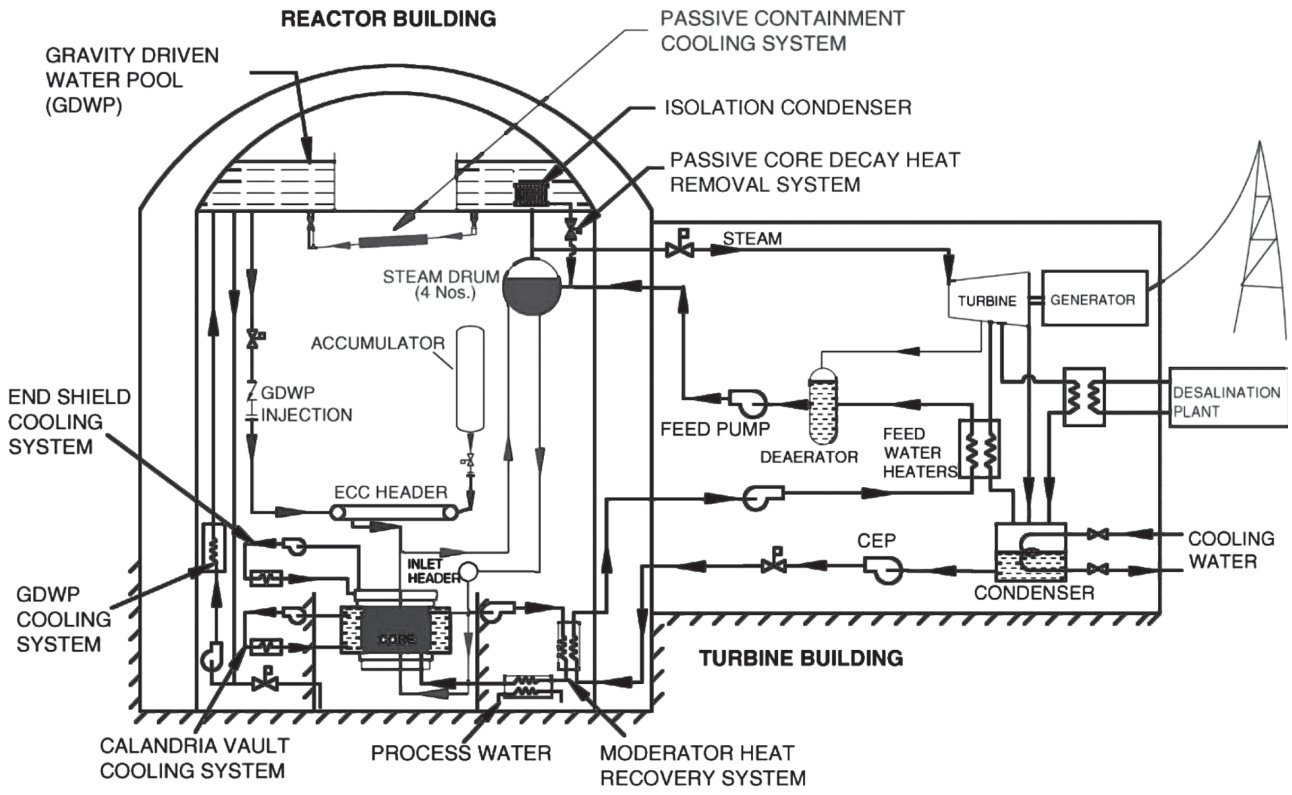


Fig. 4.3: Advanced Heavy Water Reactor (AHWR)

Nuclear Reactors in India

- In **2020**, about **3.3 percent** of the total power generated in India was derived from nuclear energy.
- Nuclear power corporation of India, founded in **1987**, Controls the Nuclear power plants in India.
- Currently India has **22 nuclear reactors** operating in **7 plants**.

Nuclear Fusion Reactors

- Nuclear fusion reactors are only under experimental stages.
- They are not commercially viable when compared to nuclear fission reactors.
- ITER is an ongoing research to achieve the advancement in Fusion reactions.

4.3 SPACE TECHNOLOGY

4.3.1 Types of Satellites

- Satellites can be classified by their function since they are launched into space to do a specific job.
- There are **nine different types** of satellites i.e.
  - Communications Satellite
  - Remote Sensing Satellite
  - Navigation Satellite
  - Geocentric Orbit type satellites - LEO, MEO, HEO
  - Global Positioning System (GPS)
  - Geostationary Satellites (GEOs)
  - Ground Satellite
  - Polar Satellite
  - Nano Satellites, CubeSats and SmallSats

4.3.2 Space Technology in India

Indian Space Research Organisation (ISRO)

- Nodal space research agency of Government of India
- Founded on 15th August, 1969.
- **Headquarter:** Bengaluru, Karnataka
- Managed by the Department of Space (DOS), which **reports directly to the PM.**

Indian National Space Promotion and Authorization Centre (In-Space)

- The Indian National Space Promotion and Authorization Centre (**IN-SPACe**) was established by the Indian government to encourage private sector participation in a wide range of space activities.
- It will **regulate and encourage Indian industry and startups** to construct routine satellites, rockets, and commercial launch services

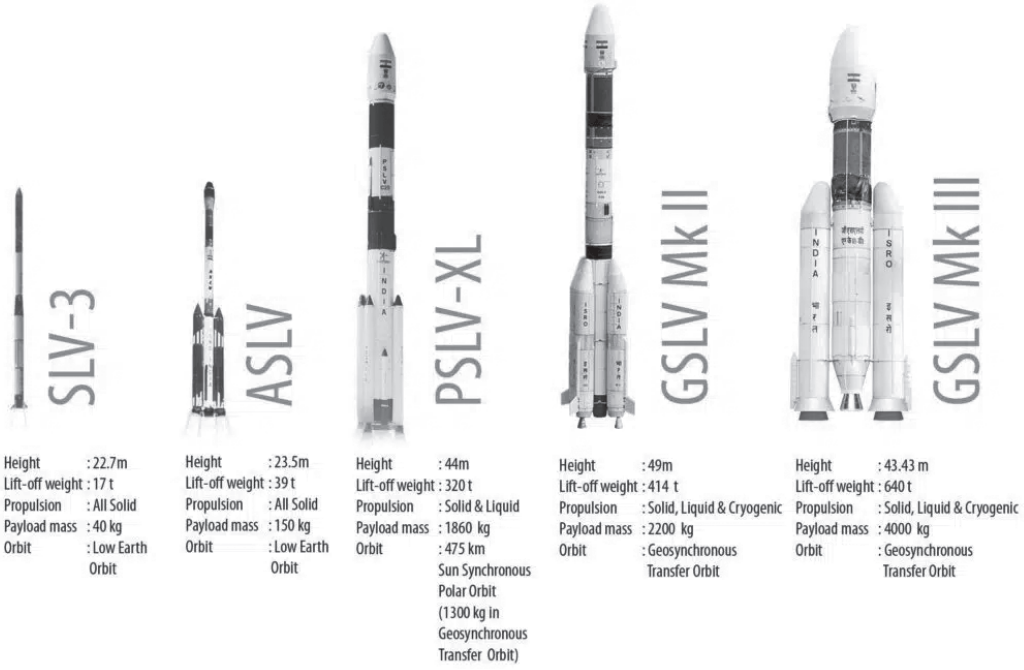


Fig. 4.4: Launch Vehicles

- It will have its own technical, legal, safety and security, monitoring, and activity promotion directorates.
- It will serve as a liaison between ISRO and private parties, assessing how India's space resources might be best utilised and space-based activities expanded.

New Space India Limited (NSIL)

- It is ISRO's commercial arm, with the primary goal of enabling Indian businesses to participate in high-tech space activities.
- It is completely owned by the Government of India, which reports to the Department of Space (DOS).
- NSIL will collaborate with IN-SPACe to enable industry consortiums to take on some of ISRO's responsibilities.

Antrix

- Antrix was founded in 1992 as a government-owned private limited corporation with the mission of promoting and commercialising space products, providing technical consulting services, and transferring ISRO-developed technologies.

4.3.3 Types of Launch Vehicles by ISRO

- Launchers or Launch Vehicles are used to carry spacecraft to space. India has two operational launchers: Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV).
- **In India there are 4 generations of launch vehicles**
  1. **1st Generation:** Satellite launch vehicles.
  2. **2nd generation:** Augmented satellite launch vehicle
  3. **3rd generation:** Polar satellite launch vehicle (PSLV)
  4. **4th Generation:** Geosynchronous satellite launch vehicle (GSLV)
- Primarily used to launch remote sensing satellites.
- **PSLV can deliver payloads of up to:**
  - 3,250kg to LEO (Low Earth Orbit)
  - 1600 kg to SSO (Sun Synchronous orbit)
  - 1400 kg to GTO (Geosynchronous Transfer Orbit)
- **Most famous launches by the PSLV**
  - Chandrayaan-1 in 2008 and
  - Mangalyaan/Mars Orbiter Mission in 2013.
- PSLV-C37 launched 104 satellites on February 15, 2017, the highest number of satellites launched in a single flight so far

Geosynchronous Satellite Launch Vehicle (GSLV)

- GSLV is a 3-stage Launch vehicle with solid fuel in the 1st stage, liquid in the 2nd stage and cryogenic in the 3rd stage.
- It was developed primarily to launch communication satellites (INSAT Series) of 2.5-tonne class in Geostationary Transfer Orbit and about 4.5 tons class in Low Earth Orbit.

GSLV Mk II

- This is the **largest launch vehicle developed by India**, which is currently in operation.
- This fourth-generation launch vehicle is a **three-stage vehicle** with four liquid strap-ons.

- The indigenously developed Cryogenic Upper Stage (CUS) forms the third stage of GSLV Mk II.
- Liftoff mass: 4.14 tones.

GSLV Mk III

- This is a **3-stage heavy-lift rocket** with an **indigenous cryogenic engine** in the 3rd stage.
- GSLV Mk III (ISRO's Fat boy) is designed to carry 4-ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO), which is about twice the capability of the GSLV Mk II.
- Most famous launches: injected Chandrayaan-2, India's second Lunar Mission, into Earth Parking Orbit on July 22, 2019, from Satish Dhawan Space Centre, Sriharikota.
- Further, India's first human space flight Gaganyaan to be launched using GSLV Mk III in 2022.

Small Satellite Launch Vehicle (SSLV)

- Designed by ISRO's Vikram Sarabhai Space Centre, to launch payload capacity of 500 kg to Low Earth orbit & 300 kg to Sun-synchronous orbit for launching small satellites.
- **Objective:** To commercially launch small satellites at a lower price and higher launch rate as compared to PSLV.
- Unlike the PSLV and GSLV, the SSLV can be assembled both vertically and horizontally.
- The first three stages of the vehicle will use a solid propellant, with a fourth stage being a velocity-trimming module.

4.3.4 Rocket Fuel

- The Indian Space Research Organisation **(ISRO) is using the very poisonous and corrosive fuel UDMH (Unsymmetrical Di-Methyl Hydrazine), combined with the oxidiser nitrogen Tetroxide. This is referred to as a "dirty combo."**
- Other space programmes throughout the world have switched to a cleaner and greener fuel, liquid methane or kerosene.
- Changing to liquid methane would need the usage of a cryogenic engine, as any gas must be stored at extremely low temperatures to remain liquefied.

Propellant Used in Rocket

- The propellant is a chemical mixture that comprises a fuel and an oxidizer that is burned to provide thrust in rockets.
- For propulsion, fuel is a substance that burns when mixed with an oxidizer.
  - The oxidizer is a substance that releases oxygen in order to be combined with a fuel. The mixture ratio is the proportion of oxidizer to fuel.
  - The condition of a propellant is **classified as liquid, solid, or hybrid.**
- **Liquid Propellant:** The fuel and oxidizer are stored separately in a liquid propellant rocket and delivered to a combustion chamber by a system of pipes, valves, and turbopumps, where they are mixed and burned to produce thrust.
  - **Cryogenic propellants are liquefied gases** kept at extremely low temperatures, with the most common fuel being liquid hydrogen (LH_2) and the oxidizer being liquid oxygen (LO_2 or LOX).
  - At temperatures of **-253 C** (-423 F), hydrogen remains liquid, while oxygen remains liquid at temperatures of **-183 C.** (-297 F).
- **Solid propellant rockets are the most basic of rocket designs.** They are made of a steel casing loaded with a mixture of solid compounds (fuel and oxidizer) that burn rapidly and produce thrust by ejecting hot gases from a nozzle.
- **Hybrid propellant engines** are a type of engine that falls somewhere between solid and liquid propellant engines. One of the components is solid, which is generally the fuel, and the other is liquid, which is usually the oxidizer.

Cryogenic Engine

- A cryogenic rocket engine uses a cryogenic fuel or oxidizer, which means the fuel or oxidizer (or both) are gases that have been liquefied and kept at extremely low temperatures.
- In comparison to solid and earth-storable liquid propellant rocket stages, cryogenic rocket stages are more efficient and produce greater thrust per kilogramme of propellant burned.

Air Breathing Engines

- In the burning of fuel, air-breathing engines utilise oxygen from the environment. The turbojet, turboprop, ramjet, and pulse-jet are among them.
- Other methods in use are heavier, less efficient, and less cost-effective than this one.
- **Types of Air Breathing Engines**
  - **Ramjet:** A ramjet is a type of air-breathing jet engine that compresses incoming air for combustion without the use of a revolving compressor. At supersonic speeds, ramjets are most efficient, but at hypersonic speeds, they are ineffective.
  - **Scramjet:** A scramjet engine is superior than a ramjet engine because it can run at hypersonic speeds while still allowing supersonic combustion.

- **A dual mode ramjet (DMRJ)** is a kind of jet engine that converts from a ramjet to a scramjet over the Mach 4-8 range, allowing it to function efficiently in both subsonic and supersonic combustion modes.

4.3.5 International Space Station

- The **International Space Station** (ISS) **is a low-Earth- orbiting, habitable artificial satellite.**
- NASA (United States), **Roscosmos** (Russia), **JAXA** (Japan), **ESA** (Europe), and **CSA** (Canada) are among the five space agencies involved in the project.
- The station serves as a microgravity and space environment research laboratory, where astrobiology, astronomy, meteorology, physics, and other fields are studied.
- On board the ISS, the atmosphere is identical to that of Earth.

4.3.6 Exploration of the Sun

- The **Parker Solar Probe is the first spacecraft** to reach the solar corona's lower layers. The structure and dynamics of the Sun's coronal plasma and magnetic field will be studied.
- Parker measured particles and magnetic fields in the Sun's upper atmosphere, known as the corona, according to **NASA**.
- **Aditya L-1 Mission:** The Indian Space Research Organisation (ISRO) is gearing up for Aditya-L1, the country's first scientific mission to study the Sun.
  - It would be positioned in the L1 Lagrange point, which is a location in space.
  - Aditya L1 will be launched with seven payloads (instruments) aboard the Polar Satellite Launch Vehicle (PSLV) XL.
  - It will conduct round-the-clock imaging of the Sun and investigate the corona, photosphere, chromosphere, solar emissions, solar winds and flares, and Coronal Mass Ejections.

4.3.7 Missions to Moon

- Numerous space missions have been launched to explore Earth's natural satellite as part of human exploration of the Moon.
- The **Soviet Union's Luna 2** was the first spacecraft to reach the Moon's surface safely.
- **Luna 9** was the first spacecraft to make a controlled soft landing, while Luna 10 was the first mission to enter orbit, both in **1966**.
- Crewed missions to the Moon were carried out by the **United States** as part of the Apollo programme between **1968** and **1972**. **Apollo 8** was the first crewed mission to enter orbit in **1968**.
- Neil Armstrong became the first person to walk on the Moon during **Apollo 11 in July 1969**.
- So far, **24 humans** have visited this massive landmass, **12** have walked on it.

India' s Missions to Moon
Chandrayaan 1
• India's first mission to the Moon, was launched in 2008 • Chandrayaan 1 reached the lunar orbit 21 days after its launch and after making 3400 orbits around the Moon and transmitting data. • In late November 2008, Chandrayaan 1 began experiencing abnormally high temperatures. • The last contact with Chandrayaan 1 was on August 28, 2009. It still circles around the Moon.
Chandrayaan 2
• The failure of Chandrayaan-2, India's second mission to the Moon, to make a soft-landing on the lunar surface had led to much disappointment. • The lander and rover malfunctioned in the final moments and crash-landed, getting destroyed in the process. • But that did not mean the entire mission had been wasted. The Orbiter part of the mission has been functioning normally.
Recent Developments
• With Artemis missions, NASA will land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface than ever before. • The Chandrayaan-3 mission is expected to be launched in August 2023.

4.3.8 Missions to Mars

- The Soviets sent a series of probes to Mars beginning in **1960**.
- **Mariner 9 became the first space probe to circle another planet** when it entered orbit around Mars on **November 14, 1971**.
- **In 1997, NASA's Mars Global Surveyor** was launched into orbit around Mars. The primary mapping mission was completed in early 2001, and the mission was a perfect success.
- **In 1997, NASA's Mars Pathfinder** landed in the Ares Vallis on Mars, carrying the robotic exploration spacecraft Sojourner.
- In 2001, NASA's Mars Odyssey orbiter was sent into orbit around Mars.

India' s Missions on Mars: Mangalyaan

- ISRO launched the Mars Orbiter Mission, commonly known as Mangalyaan, on November 5, 2013. (ISRO). On September 24, 2014, it was successfully placed into Martian orbit.

Voyager Mission

- The twin spacecraft Voyager 1 and Voyager 2 were launched **by NASA** in separate months in the summer of 1977 from Cape Canaveral, Florida.
- As originally designed, the Voyagers were **to conduct closeup studies of Jupiter and Saturn, Saturn's rings, and the larger moons of the two planets.**
- **During planetary flybys, Voyager 2 is the only probe that has ever studied Neptune and Uranus**. It is the world's second man-made object to orbit the sun.
- **Voyager 2 is the only spacecraft to have visited all four gas giant planets** — Jupiter, Saturn, Uranus, and Neptune — and found 16 moons, as well as phenomena such as Neptune's seemingly ephemeral Great Dark Spot, Europa's ice shell fissures, and ring structures on each planet.

4.3.9 Gaganyaan Mission

- Gaganyaan is an Indian Space Research Organisation mission (**ISRO**).
- Three Gaganyaan flights will be sent into orbit, according to the Gaganyaan programme.
- Two **unmanned missions** and one human spaceflight are planned.
- Three Indian astronauts, including a woman, will be aboard the Gaganyaan system module, dubbed the Orbital Module.
- For **5-7 days**, it will orbit Earth in a low-earth-orbit at a distance of 300-400 kilometres.
- The **three-stage heavy lift launch vehicle GSLV Mk III**, also known as the **LVM-3** (Launch Vehicle Mark-3), will be utilised to launch Gaganyaan because it has the appropriate payload capabilities.
- Gaganyaan's important missions, including as the test vehicle flight to validate the crew escape system's performance and Gaganyaan's first uncrewed mission (G1), are planned for 2023.

4.3.10 Space Debris

- Space debris encompasses both natural meteoroid and artificial (human-made) orbital debris. Meteoroids are in orbit about the sun, while most artificial debris is in orbit about the Earth **(hence the term "orbital" debris).**
- Orbital debris is any human-made object in orbit about the Earth that no longer serves a useful function.
- Such debris includes non-functional spacecraft, abandoned launch vehicle stages, mission-related debris, and fragmentation debris.
- There are approximately **23,000 pieces** of debris larger than a softball orbiting the Earth.
- They travel at speeds up to **17,500 mph**, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft.

Instances of Misfortune

- In **1996,** a **French satellite** was hit and damaged by debris from a French rocket that had exploded a decade earlier.
- On **Feb. 10, 2009**, a defunct Russian spacecraft collided with and destroyed a functioning **U.S. Iridium commercial spacecraft**.
- The collision added more than 2,300 pieces of large, trackable debris and many more smaller debris to the inventory of space junk.
- **China's 2007** anti-satellite test, which used a missile to destroy an old weather satellite, added more than **3,500 pieces** of large, trackable debris and many more smaller debris to the debris problem.

Cause of concern for Space debris

- With the increasing amount of space debris and the advent of mega-constellations of thousands of satellites, there are fears that collisions such as that between **Iridium 33 and Cosmos 2251** could set off a chain reaction.
- This chain reaction is called the **Kessler syndrome**, in which the resulting space debris would destroy other satellites and so on, with low Earth orbit eventually becoming unusable.

4.3.11 IRNSS-NAVIC

- The Navigation with Indian Constellation (NavIC) satellite system is an autonomous regional navigation satellite system that provides location data in the Indian area and 1500 kilometres surrounding the Indian landmass.
- IRNSS would offer two types of services Standard Positioning Services, which would be available to all users, and Restricted Services, which would only be available to permitted users.
- There are seven satellites in all. Three will be geostationary above the Indian Ocean and four will be geosynchronous.
- This setup assures that at any one moment, at least one of fourteen ground stations is tracking each satellite, with a good likelihood that most of them will be visible from anywhere in India.

4.3.12 Space Technology and Disaster Management

- **Gagan Enabled Mariner's Instrument for Navigation and Information** (GEMINI) device.
- GEMINI is a portable satellite receiver connected to ISRO spacecraft. Because the gadget can send signals up to **300 nautical miles**, fishermen beyond the signal range of their phone providers (i.e. 10-12 km) may also obtain warnings and alarms.
- It will make satellite-based communication easier, which will be especially important in the event of storms, strong seas, or tsunamis.
- The **Indian Space Research Organization** (ISRO) and the Airports Authority of India collaborated on GAGAN.
- It is India's first satellite-based global positioning system, relying on the GSAT satellites of ISRO.
- The disadvantage of this technology is that it only permits one-way communication, which means that **fishermen** cannot use it to make calls.

4.4 DEFENCE

Organisation	Important Information
Defence Research and Development Organisation (DRDO)	• DRDO is the R&D wing of the Ministry of Defence, Government of India. • Established in 1958.
Defense Innovation Organisation	• It is a 'not for profit' company registered under Section 8 of the Companies Act 2013. • Its two founding members are Hindustan Aeronautics Limited (HAL) & Bharat Electronics Limited (BEL) - Defence Public Sector Undertakings (DPSUs).

India's Nuclear Doctrine

- India conducted its first nuclear test in **1974** and the second nuclear test in 1998.
- India declared herself a nuclear weapon state in 1998 and came forward with **Nuclear Doctrine in 2003.**
- **India's Nuclear Doctrine consist of the following major points:**
  - Credible Minimum Deterrence.
  - No First Use policy i.e., India will use the weapon only in retaliation to a nuclear attack on Indian territory or against Indian forces anywhere.
  - Nuclear Command Authority-Retaliatory attacks will be authorized only by the civilian political leadership
  - Nuclear weapons will not be used against non-nuclear weapon states.
  - Massive Retaliation.

Nuclear Triad

- A three-sided military-force structure consisting of land- launched nuclear missiles, nuclear-missile-armed submarines, and strategic aircraft with nuclear bombs and missiles.

Land Based	Agni; Agni-I; Agni-II; Agni III; Agni- IV; ICBM - Agni-V; SLBM - Sagarika (K-15); Cruise – Brahmos Supersonic etc.
Sea Based	Arihant class submarine
Air Based	Mig-27 ETC

4.4.1 Indian Missile System

- Integrated Guided Missile Development Programme (IGMDP) was conceived by **Dr. A P J Abdul Kalam to enable India attain self-sufficiency in missile technology**, in response to the Missile Technology Control Regime.
- IGMDP was started in 1983 and completed in March 2012.
- It developed **5 types of missiles** under it

PATNA : is a short trick for remembering 5 missiles' names.

P-Prithvi | **A-Agni** | **A-Trishul** | **N-Nag** | **A-Akash**

Prithvi

- Tactical surface-to-surface short range ballistic missile.
- First missile developed under IGMDP in 1983.
- Uses either liquid or both liquid and solid fuels and are capable of carrying conventional as well as nuclear warheads.
- **Prithvi I**- Army version-150 km range
- **Prithvi II-** Air force version-350 km range
- **Prithvi III**- Naval version-600 km range

Agni

- It is an intercontinental surface-to-surface, nuclear capable ballistic missile developed by DRDO.
- At present, US, China, Russia, UK, France and Israel are known to have ICBMs.
- It has been equipped with very high accuracy.
- Ring Laser Gyro based Inertial Navigation System (RINS) and **Micro Navigation System** (MINS).

Trishul

- Short range surface-to-air missile for Indian Navy used for Immediate combat action.

- Range - 9km.
- Currently not in service.

Nag

- Anti-tank guided missile developed by DRDO
- Range - 4km.

- 3rd generation 'fire and forget' guided missile where the target is identified and designated before the weapon is launched.
- It is an all-weather condition with day and night capabilities.
- Launched from land and air-based platforms.

Akash

- Group of 4 **medium range surface-to-air missiles** with a radar called Rajendra.
- Multi-target engagement capacity. Radar detects incoming objects and missiles are fired.
- Range – 30 km. Altitudes up to 18000 m.
- Already in use.

4.4.2 Other Missiles

Astra	**Prahaar**	**Pralay**	**Nirbhay**	**Dhanush**
Brahmos Missile System	**Pinaka Missile System**	**Rudra M-I**		

Astra

- Astra is an all-weather beyond-visual-range air-to-air missile (BVRAAM)
- **Range** - 80km.
- **Payload capacity**: 15 kg.
- First indigenously developed missile of India
- Uses solid fuel ducted Ramjet and has BVRAAM (beyond visual range air-to-air missile) technology.
- Can destroy enemy aircrafts at supersonic speed.

Prahaar

- Solid-fuel, surface-to-surface tactical ballistic missile
- **Range** - 150 km.
- **Payload capacity** - 200 to 500kg.

Pralay

- Solid fuel surface-to-surface tactical missile.
- Payload - 1 tonne and has a range of 350 km.

Nirbhay

- NIRBHAY is **India's first indigenous Long Range, all-weather, Sub-Sonic Cruise Missile,**
- It can carry a warhead of 200 kg to 300 kg at a speed of 0.6 to 0.7 Mach with a launch weight of about 1500 kg.
- It can avoid detection as it has the ability to cruise at heights as low as 100 m.
- Can be launched from multiple platforms and is capable of carrying conventional and nuclear warheads.
- Two-stage missile powered by Solid rocket motor booster.
- **Range** of 1000 km.

Dhanush

- It is also known as Prithvi-III.
- **Sea-to-sea/surface** short range ballistic missile.
- Range - 350 km.
- Capable of carrying nuclear as well as conventional warheads.

Brahmos Missile System

- BRAHMOS is a **joint venture** between the Defence Research and Development Organisation of **India** (DRDO) and the NPOM of **Russia**.
- Named after the rivers Brahmaputra (India) and Moskva (Russia).
- Two-stage (solid propellant engine in the first stage and liquid ramjet in second) air-to-surface missile.

- Range - around 300 km.
- Speed - Mach 2.8
- India's entry into the **Missile Technology Control Regime** (MTCR) has extended the range of the BRAHMOS missile to reach 450 km-600km.
- Can be launched from land, air, and sea and multi capability missile with pinpoint accuracy that works in both day and night irrespective of the weather conditions.
- Operates on the "Fire and Forgets" principle.
- One of the fastest cruise missiles currently operationally deployed.
- Lower target dispersion and quicker engagement.
- Low radar signature.

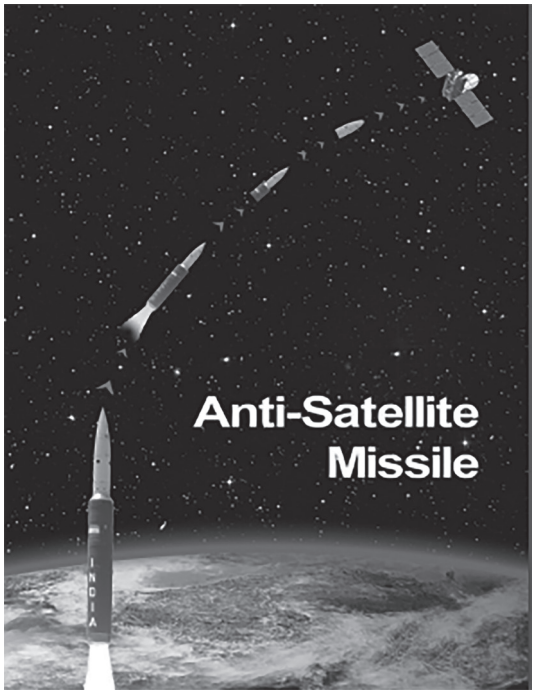
Pinaka Missile System

- **Indigenous multi-barrel rocket launch system**, for the Indian Army by DRDO
- The navigation system - aided by the Indian Regional Navigation Satellite System (IRNSS).
- The range is more than 70 km.

Rudra M-I

- It is the first indigenous anti-radiation missile of the country.
- Range of up to 200 km depending upon the launch conditions.
- Can be launched from altitudes of 500 m to 15 km and speeds of 0.6 to 2 mach.
- Can locate and target any radiation-emitting source like enemy radars, communication sites and other Radio Frequency (RF) emitting targets.

Anti-Satellite Weapons (ASAT) Mission Shakti



- To develop highly potent Anti-satellite weapons (ASAT).
- It is a joint programme of DRDO and the Indian Space Research Organisation (ISRO).
- Anti-satellite (ASAT) System is a missile-based system to attack moving satellites.
- ASAT propels India to the coveted space-superpower league.
- India will now have the power to decimate satellites for pure military and strategic purposes.
- India will have the capability to interfere with satellites or engage in direct attacks.
- ASAT missiles can be air, sea or land based.
- Can also help in creating nuclear missile deterrence.
- In March 2019, India successfully tested its ASAT missile.
- joining a select group of nations – USA, Russia and China with a similar technology.
- India used the **Kinetic Kill space technology**.
- The ASAT missile destroyed a live satellite in Low Earth orbit (283-kilometre).
- As per DRDO, the missile is capable of shooting down targets moving at a speed of 10 km per second at an altitude as high as 1200 km.

4.4.3 Air Defence Systems

Indian Ballistic Missile Defence Programme

- India's BMD development began in 1999, after the Kargil war.
- It is a two-tiered defence system and will be able to intercept any incoming missile launched 5,000 km away.
  1. **Prithvi Air Defence (PAD):** It's designed for High altitude interception (exo-atmospheric interception).
  2. **Advanced Air Defence (AAD):** It's endo-atmospheric interception system (for low altitude interception).

Anti-Ballistic Missile Systems	
S-400 Triumf Missile System	Russia - It is a mobile, surface-to-air missile system.
THAAD-Terminal High Altitude Area Defense system	US- a transportable, ground-based
Iron Dome Aerial Defence System	Israel

4.4.4 Submarines

Nuclear Powered | **Diesel Powered** | **Attack Submarines** | **Ballistic Missile Submarines**

Nuclear-powered

- Gets energy from a nuclear reactor so it can stay submerged in water for months.
- Difficult for the enemy to detect.

- Can float near territorial waters of enemy nations.
- Provide excellent second-striking capability
- **SSN:** submersible ship nuclear-powered-specifically designed for attacking and sinking other submarines/ ships. Generally, do not carry long range missiles.
- **SSBN:** submersible ship Ballistic Nuclear-Powered-have the capability to deploy submarine launched ballistic missiles with nuclear warheads.

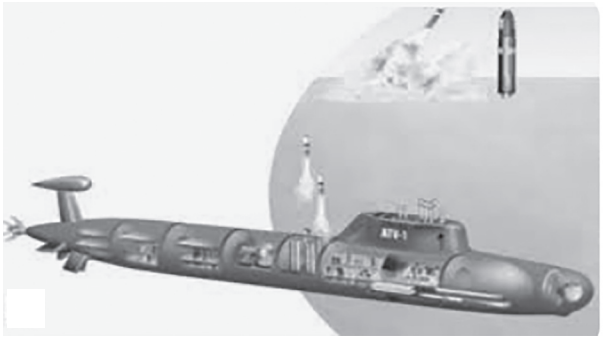
Diesel-Powered

- Come on waterbody surface after regular intervals because burning of diesel needs oxygen
- Easy for enemy to detect
- Can't float near territorial waters of enemy nation
- Don't possess that advantage

Attack Submarines

- Generally small submarines designed for specific tasks, which include attack on the enemy in combat.
- It uses torpedoes and other small range missiles.
- These submarines have limited range and need to come out of the water after some time.

Ballistic Missile Submarines



- Bigger in size and are more destructive for the enemy.
- It is used as a launch platform for ballistic or long-range missiles.
- These can carry nuclear warheads.
- These submarines are nuclear powered submarines. As a result, they have almost unlimited range because of the availability of unlimited power supply.
- These can remain underwater for months and can travel up to thousand miles.

4.4.5 Projects by Navy

Project 75 | **Project 28** | **Project 17A**

Project 75

- Part of a **30-year** submarine building plan from **2007** upto **2030.**
- This project envisages the construction of six conventional submarines with better sensors and weapons and the Air Independent Propulsion System (AIP)- Kalvari, Khanderi, Karanj, Vela, Vagir and Vagsheer.

Project 28

- Under this 4 Anti-Submarine Warships have to be built indigenously in India.
- **Four corvettes-** INS Kamorta, INS Kadmatt, INS Kiltan and INS Kavaratti.
- The warships are named after the islands in the Lakshadweep archipelago.

Project 17A

- Involves the building of seven stealth frigates.

4.4.6 Initiatives to Modernise Defence Industry

Strategic Partnership (SP) Model

It identifies a few Indian private companies who would initially tie up with global Original Equipment Manufacturers (OEMs) to seek technology transfers to set up domestic manufacturing infrastructure and supply chains.

iDEX

- Launched in 2018.
- Aims to promote **innovation and technology development in Defence and Aerospace** by engaging Industries (which includes MSMEs, start-ups, individual innovators, R & D institutes & academia) with funding and other support to carry out Research & Development.
- It will be funded and managed by the **Defence Innovation Organization** (DIO) and will function as the executive arm of DIO.

4.5 ROBOTICS

- Robotics deals with the design, building, operation, structural depositions, manufacturing, and application of robots.
- Robotics is a fast expanding field that continues to research, create, and manufacture new robots that serve a variety of practical uses.

4.5.1 Components of Robots

- **Manipulator:** Just like the human arm, the robot consists of what is called a manipulator having several joints and links.
- **End Effector:** The End Effector is expected to perform tasks normally performed by the palm and finger arrangements of the human arm.
- **The Locomotion Device:** The motors used for providing locomotion in robots are of three types depending on the source of energy: Electric, Hydraulic or Pneumatic.
- **The Controller**: Sensors are nothing but measuring instruments which measure quantities such as position, velocity, force, torque, proximity, temperature, etc.

4.5.2 Applications

- Robots are highly **beneficial for workers, industries and countries**. If introduced properly, industrial robots can augment the quality of life by freeing workers from dirty, boring, hazardous and heavy labour.
- Economic Survey 2017-18 recognised robotics as a focus area (along with blockchain, AI and other futuristic technologies).
- It was speculated that robotics would have a special place under **Make in India 2.0.**

4.5.3. Recent Breakthrough in the Field of Robotics

Artificial Humans –NEON

- Samsung's future factory STAR Labs has developed Neon, AI-powered virtual beings that look and behave like real humans.
- The Neons are still currently in their early development phase, acting mainly as AI chatbots in human-like form.
- They look and behave like real humans, and could one day develop memories and emotions — though from behind a **4K display.**

There are two core technologies behind his virtual humans

- First, there is the proprietary **CORE R3 technology** that drives the "reality, real time and responsiveness" behind NEONs.
- Second technology is **SPECTRA**, which will complement CORE R3 with the "spectrum of intelligence, learning, emotions and memory".

Xenobots

- Scientists in the United States have created the **world's first "living machines"** — tiny robots built from the cells of the African clawed frog that can move around on their own.
- They have named the millimetre-wide robots **xenobots**— after the species of aquatic frog found across sub- **Saharan Africa** from **Nigeria** and **Sudan to South Africa, Xenopus laevis.**
- They discovered that these computer-designed and hand- assembled organisms can swim out into their tiny dish, find single cells, gather hundreds of them together, and assemble **baby** Xenobots.
- The xenobots "can move toward a target, perhaps pick up a payload and heal themselves after being cut".
- AI-designed Xenobots reveal entirely new forms of biological self-replication—promising for regenerative medicine.

4.5.4 Robotics in India

- **Mitra, the first indigenously** built **humanoid robot** is capable of interacting with humans smartly.
- **Robocop** is a police robot that has been deployed in Hyderabad to help with law enforcement and traffic control.
- **Green seeker sensor** This clever equipment assesses the demands of a plant and then applies the exact amount of fertilizer and pesticides required. Green Seeker is a contraption that employs sensors to allow the plant to communicate what it requires.
- **Daksh, a robot developed by the Defense Research and Development Organization** (DRDO), is primarily meant to detect and recover improvised explosive devices (IEDs). It was first used by the Indian Army in 2011. The Indian Army is said to be using **20 Daksh robots** already.

4.6 INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

4.6.1 Network

- A network is a **collection of** computers, servers, mainframes, network devices, peripherals, or other devices connected to allow data sharing. An example of a network is the Internet, which connects millions of people all over the world.
- **Web refers to the World Wide Web (WWW)**, the internet's core information retrieval system.
- **Web 2.0** is the current version of the web with which we are all familiar, while Web 3.0 represents its next phase that will be decentralized, open, and of greater utility.
- **Web 3.0** is built upon the core concepts of decentralization, openness, and greater user utility.

4.6.2 Dark Net And Deep Web

- The darknet is a **computer network with limited access** that is mostly used for **criminal operations** on the internet, such as drug sales and the sale of personal information.
- The darknet is part of the larger "deep web," which is a network of encrypted Internet material that is not searchable through regular search engines.
- The phrases "deep web" and "darknet" are sometimes used interchangeably. This, however, is incorrect.
- The darknet is a subset of the deeper web. All unindexed sites that don't show up when you conduct an Internet search are considered part of the deep web.

- Not all acts related to the deep web are illegal. Most of the time, regular search engines are unable to find these pages.

4.6.3. Metaverse

- **Augmented reality:** "The **real-time usage of information** in the form of text, visuals, audio, or other virtual upgrades merged with real-world objects" is how augmented reality (AR) is described.
- **Virtual reality (VR):** It is a computer-generated simulation in which a person may interact with an artificial three- dimensional world with the use of electronic equipment such as special eyewear with a screen or sensors-equipped gloves. The user can enjoy a realistic-feeling experience in this simulated artificial world.
- **Metaverse:** It is a network of always-on **virtual environments** in which numerous individuals may interact with one another and digital things through virtual representations of themselves. A metaverse is a mixed reality environment that combines augmented and virtual reality.

4.6.4 Basics of Computers

- A computer is a device that transforms data into meaningful information.
- The term hardware refers to the physical components of your computer such as the system unit, mouse etc.
- The software is the instructions that make the computer work. Software is held either on your computer's hard disk or in DVD ROM.

Types of Memory

- **Computer memory is of two basic types – Primary memory** (RAM and ROM) and Secondary memory (hard drive, CD, etc).
- **Random Access Memory (RAM)** is primary-volatile memory and Read-Only Memory (ROM) is primary-non- volatile memory.

How Computer Memory is Measured?

- **Bit:** All computers work on a binary numbering system, i.e. they process data in one's or zero's. This 1 or 0 level of storage is called a bit.
- **Byte:** A byte consists of eight bits.
- **Kilobyte:** A kilobyte (KB) consists of 1024 bytes.
- **Megabyte:** A megabyte (MB) consists of 1024 kilobytes.
- **Gigabyte:** A gigabyte (GB) consists of 1024 megabytes.

Types of Computers

- **Mini and Mainframe** Computers Very powerful, used by large organisations such as banks to control the entire business operation.
- **Personal Computers** Cheap and easy to use. Often used as stand-alone computers or in a network.

4.6.5 Supercomputers

- These are large systems that are specifically designed to solve complex scientific & industrial challenges.
- The performance of a supercomputer is measured in **Floating-Point Operations per Second** (FLOPS).
- The top Five Supercomputers in the world:

Fugaku (Japan)	Sierra (USA)	Tianhe-2 (China)	Summit (USA)	Sunway Taihulight (China)

- **India has 4 supercomputers in the list of world's top 500 supercomputers with Pratyush & Mihir** being the fastest supercomputers in India.
- The first indigenous supercomputer was developed indigenously in 1991 by Centre for Development of Advanced Computing which was called as PARAM 8000.
- **Application areas:** Climate Modeling, Computational Biology, Atomic Energy Simulations, National Defence, Disaster management etc.

National Supercomputing Mission (NSM)

- It was Launched in **2015**
- NSM is jointly steered by the **MeitY and Department of S&T** (DST).
- Implemented by the Centre for Development of Advanced Computing (C-DAC), Pune & the IISc, Bengaluru.
- **Objective:** to connect national academic and R&D institutions with a grid of over 70 high-performance computing facilities.
- These will be networked on the 'National Supercomputing Grid' over the National Knowledge Network (NKN).

4.6.6 Quantum Computing

- Quantum computers are **machines that use the properties of quantum physics to store data and perform computations.**
- A classical computer performs operations using classical bits, which can be either 0 or 1.
- A quantum computer uses quantum bits or Qubits, which can be both 0 and 1 at the same time.
- **'Qubits' are the units of computation in quantum computers** (or quantum bits). They take advantage of quantum mechanics' characteristics, which regulate how matter behaves at the atomic level.
- The laws of quantum physics are used to achieve functioning of quantum computing.
  - **Superimposition:** Each quantum bit (basic unit of information in a quantum computer) can represent both a 1 and a 0 at the same time, which is known as superposition.

- **Quantum entanglement:** Subatomic particles become "entangled" (connected) in quantum entanglement, which means that any change in one upsets the other, even though they are at opposite ends of the universe.

- **Major advantages:** Faster, Accurate, & Energy efficient.
- **SYCAMORE:** it is Google's Quantum Computer, which recently claimed Quantum Supremacy.
- **Quantum Supremacy:** refers to quantum computers being able to solve a problem that a classical computer cannot.

4.6.7 Cloud Computing

- It is the **supply of computer services over the Internet** ("the cloud"), including servers, storage, databases, networking, software, analytics, and intelligence, in order to provide speedier innovation, more flexible resources, and economies of scale.
- The Government of India has launched an ambitious programme called "GI Cloud," which has been dubbed "MeghRaj," in order to utilize and harness the benefits of Cloud Computing.
- The goal of this programme is to implement a variety of components, including governance structures, to enable Cloud adoption in government.

4.6.8 Edge Computing

- Edge computing is a **distributed information technology architecture in which client data is processed at the periphery of the network.**
- Data is analyzed locally.

Cloud Computing	Edge Computing
Computation is not done at the source	Computation is done near-source
Preferred to process normal data	Preferred to process time-sensitive data.
Latency is more	Reduced latency
Less secure	More secure

4.6.9 Big Data & Data Mining

- Big Data constitutes a **large volume of structured or unstructured data**.
- Big data is **so huge** that the traditional data processing system is inadequate to process.
- **Data mining** is a process used to **extract usable data** from a larger set of any raw data
- By analyzing this data, a useful decision can be made in various cases such as:
  - Tracking Customer Spending Habit, Shopping Behavior
  - Smart Traffic System
  - Auto Driving Car
  - Virtual Personal Assistants
  - Internet of Things etc.

4.6.10 Computer Viruses

- A computer virus is a **type of malicious code or program** written to alter the way a computer operates and is designed to spread from one computer to another.
- In the process, a virus has the potential to cause unexpected or damaging effects, such as harming the system software by corrupting or destroying data.

What are the Different Types of Computer Viruses?

Boot sector virus: This type of virus can take control when you start — or boot — your computer. One way it can spread is by plugging an infected USB drive into your computer.

- **Web scripting virus:** This type of virus exploits the code of web browsers and web pages. If you access such a web page, the virus can infect your computer.
- **Browser hijacker:** This type of virus "hijacks" certain web browser functions, and you may be automatically directed to an unintended website.
- **Resident virus:** This is a general term for any virus that inserts itself in a computer system's memory. A resident virus can execute anytime when an operating system loads.
- **Direct action virus:** This type of virus comes into action when you execute a file containing a virus. Otherwise, it remains dormant.
- **Polymorphic virus:** A polymorphic virus changes its code each time an infected file is executed. It does this to evade antivirus programs.
- **File infector virus:** This common virus inserts malicious code into executable files — files used to perform certain functions or operations on a system.
- **Multipartite virus:** This kind of virus infects and spreads in multiple ways. It can infect both program files and system sectors.
- **Macro virus:** Macro viruses are written in the same macro language used for software applications.
- Such viruses spread when you open an infected document, often through email attachments. A computer worm is malware, just like a virus, but a worm takes a copy of itself and propagates it to other users.

4.6.11 Mobile Technology

- Mobile communication involves **transmitting voice or data** using wireless radio transmission.

- Mobile generations refer to change like mobile wireless communication network speed, technology, data capacity, frequency, latency etc.

5G Technology

- 5G is the **next-generation cellular technology** that will provide faster and more reliable communication with **ultra-low latency**.
- Latency is a measure of delay. In a network, latency measures the time it takes for some data to get to its destination across the network.

4G Technology

- 4G mobile technology provides wireless mobile broadband internet access in addition to voice and other services of 3G.
- Applications include improved web access, Internet Protocol (IP) telephony, Video Conferencing, Cloud Computing, Gaming Services, High-Definition Mobile TV etc.
- 4G **uses LTE** (Long Term Evolution) **technology**, which allows **voice & data-communication simultaneously.**

6G Technology

- It will be able to operate at **higher frequencies** than 5G networks, resulting in significantly **increased capacity and lower latency** (delay).
- One of the 6G internet's goals will be to provide communication with a **one-microsecond latency** (a communication delay of one microsecond).
- This is 1,000 times faster than one millisecond throughput – or 1/1000 the latency.
- It aims to make use of the currently underutilized terahertz frequency spectrum.

Do You Know?

Beamforming is the application of multiple radiating elements transmitting the same signal at an identical wavelength and phase, which combine to create a single antenna with a longer, more targeted stream which is formed by reinforcing the waves in a specific direction

4.6.12 Net Neutrality

- **Net neutrality** refers to the fact that governments and internet service providers treat all data on the internet equally and do not charge users more for higher-quality delivery or give some websites preferential treatment.
- **The Telecom Regulatory Authority of India** (TRAI) recently proposed the formation of a multi-stakeholder body (MSB) to guarantee that internet service providers in the nation follow net neutrality principles.
- **All Internet service providers** (ISPs) must provide the same amount of data access and speed to all traffic under network neutrality, and traffic to one service or website cannot be banned or downgraded.

4.7 EMERGING TECHNOLOGIES

4.7.1 Blockchain Technology

- Blockchain technology is a **structure that stores transactional records** (also known as block), of the public in several databases, known as the **chain**, in a network connected through **Peer-to-peer** (P2P) nodes.
- This storage is referred to as a digital ledger.
- Every transaction in this ledger (storage) is authorized by the digital signature of the owner, which authenticates the transaction and saves it from any tampering.
- Blockchain Key characteristic features include decentralization, persistence, and anonymity.
- Blockchain technology discards the need for any third- party or central authority for peer-to-peer transactions.

Cryptocurrency

- Cryptocurrency is a **digital payment system** that doesn't rely on banks to verify transactions. It's a peer-to-peer system that can enable anyone anywhere to send and receive payments.
- In many countries, cryptocurrency is unregulated & they are not a legal tender payment system. For example, Bitcoin.

Central Bank Digital Currency (CBDC)

- **CBDC is a digital version of fiat currency** that may be exchanged using blockchain-based wallets and is controlled by the central bank. It is a digital type of legal money issued by a central bank.
- **An official digital currency would lower the cost of currency administration** while allowing real-time payments to be made without the need for interbank settlement.
- Another advantage of CBDC is that, to the degree that **huge amounts of cash can be replaced by CBDC, the cost of printing, transporting, and keeping paper money** may be significantly decreased.
- The Indian government has declared in its Budget 2022- 23 that its central bank will issue a digital currency as early as **2022-**

4.7.2 Wearable Technology

- These are smart electronic devices designed to be worn on the user's body. **Ex: Smart jewellery, Wristbands, watches etc.**
- These devices detect, analyze, and transmit information.
- Wearable technology is evolving into an important category of the Internet of things, with life-changing applications in medicine and other fields.

4.7.3 Near-Field Communication (NFC)

- NFC is a short-range contactless communication technology based on a Radio Frequency (RF) field using a base frequency of 13.56 MHz
- NFC-enabled devices must be either physically touching or within a few centimeters of each other for data transfer to occur.

4.7.4. Radio Frequency Identification (RFID)

- RFID technology uses radio waves to passively identify a tagged object.
- An RFID tag consists of a tiny radio transponder; a radio receiver and transmitter.
- Unlike a barcode, the tag doesn't need to be within the line of sight of the reader, so it may be embedded in the tracked object.

4.7.5 Fastags

- The FASTag is a **reloadable tag that allows tolls to be deducted automatically without the need to stop for a cash transaction.**
- Once activated, the tag employs radio frequency identification **(RFID) technology** and is attached to the vehicle's windscreen.
- It was first used in **April 2016**, and on **December 1, 2017**, the government made it mandatory for all new automobiles and trucks to be fitted with a FASTag before being sold.
- The **National Highway Authority of India** (NHAI) returns **5%** of total monthly transactions to encourage the usage of **FASTags.**

4.7.6 Internet of Things (IoT)

- IoT is the **interlinking of** digital devices, people, machines, appliances, & other objects with one another **through wireless networks**.
- It allows **machines & people to be connected and communicate as well**.
- IoT Applications are many including works of daily life, Industry, Agriculture, Healthcare, Transportation, Governance etc.

4.7.7 Artificial Intelligence (AI)

- Artificial intelligence (AI) is the **ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans** because they require human intelligence and discernment.
- AI refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions.
- AI is a self, adaptive learning system.
- **Applications:** Industrial automation, Space science, self-driven cars, Healthcare sector, weather forecasting etc.

3 Types of Artificial Intelligence
• Artificial Narrow Intelligence (ANI) • Artificial General Intelligence (AGI) • Artificial Super Intelligence (ASI)

Working Mechanism of Artificial Intelligence

- AI works by combining large amounts of data with fast, iterative processing and intelligent algorithms, allowing the software to learn automatically from patterns or features in the data.
- AI is a broad field of study that includes many theories, methods and technologies, as well as the following major subfields:
  - **Machine learning automates** analytical model building. It uses methods from neural networks, statistics, operations research and physics to find hidden insights in data without explicitly being programmed for where to look or what to conclude.
  - **A neural network is a type of machine learning** that is made up of interconnected units (like neurons) that processes information by responding to external inputs, relaying information between each unit. The the process requires multiple passes at the data to find connections and derive meaning from undefined data.
  - **Deep learning** uses huge neural networks with many layers of processing units, taking advantage of advances in computing power and improved training techniques to learn complex patterns in large amounts of data.
  - **Computer vision** relies on pattern recognition and deep learning to recognize what's in a picture or video. When machines can process, analyze and understand images, they can capture images or videos in real time and interpret their surroundings.
  - **Natural language processing (NLP)** is the ability of computers to analyze, understand and generate human language, including speech.
  - The next stage of NLP is natural language interaction, which allows humans to communicate with computers using normal, everyday language to perform tasks.

4.7.8 Li-Fi

- It is a bidirectional, fully networked **wireless communication technology that transmits data using visible light** rather than radio frequencies**.**
- A router is made out of an adapted LED bulb.
- It can provide more resilient and reliable wireless networks that complement and enhance existing cellular and Wi-Fi networks by providing greater security, data rates, and density.

- It delivers ultra-fast data connections, which are particularly beneficial in metropolitan regions where radio spectrum is congested, as well as in rural locations where Fiber Optic Cables or networks are unavailable.
- A standard LED bulb is linked to a gadget, which is linked to the Internet.
- The Internet data enters the bulb via the gadget and is transported by light waves.
- Light waves delivering Internet data fall on a receiver or a dongle attached to the computer on the other end.

4.7.9 Biometrics

- Biometrics are **biological measurements** — or physical characteristics — that can be **used to identify individuals**.
- **For example**, fingerprint mapping, facial recognition, and retina scans are all forms of biometric technology, but these are just the most recognized options.

Digital Signature Certificates (DSC)

- DSC are the digital equivalent (that is electronic format) of physical or paper certificates.
- Certificates **serve as a proof of identity of an individual**.
- DSCs can be presented electronically to prove identity, to access information or services on the Internet or to sign certain documents digitally.

4.7.10 3D Printing

- 3D printing, also known as **additive manufacturing**, is a method of **creating prototypes** or functional models of products by layering materials such as plastic, resin, thermoplastic, metal, fiber, or ceramic.
- With a market share of more than 35%, the United States is the global leader in 3D printing. China controls almost half of the Asian market, followed by Japan (30%) and South Korea (10%).

Process of 3D Printing

- The process of 3D printing begins with the creation of a virtual model of the thing to be manufactured.
- A 3D modelling application, such as CAD (Computer Aided Design), or 3D scanners can be used to create virtual designs.
- After that, the 3D digital copy is loaded into a 3D modelling application. In order to print the model, it is next cut into hundreds or thousands of horizontal layers.
- This prepared file is then sent to the 3D printer, which reads each slice in 2D format and then builds the item layer by layer, with no apparent layering and a 3 dimensional structure as a result.

3D Bioprinting

- The goal of 3D bioprinting was to provide 3D constructs with autonomous mechanical characteristics so that they could **resemble the body's natural tissue.**
- This method enables for the customization of microstructures for disease models.
- **Scientists have created a 3D printing process that can replicate the complicated geometry of blood vessels**, which might be used to **construct prosthetic arteries and organ tissues** in the future.

5 Miscellaneous

5.1 FUEL

- **Fuel:** A fuel is any material that can be made to react with other substances so that it releases energy as heat energy or to be used for work. Some common fuels are wood, coal, petrol, diesel etc.
- **An ideal fuel** is a fuel which produces an adequate amount of heat and very less amount of pollutants.
- An ideal fuel has following characteristics-
  - It is readily available.
  - It is less expensive.
  - It burns easily in air at a moderate rate.
  - It produces a large amount of heat.
  - It can be transported easily.
  - It has a high calorific value.
  - It does not leave behind any undesirable substances.
- **Heating value of fuel:** Heating value of fuel is the amount of heat produced by a complete combustion of fuel and it is measured as a unit of energy per unit mass or volume of substance (e.g. Kcal/kg. KJ/kg, J/mol and Btu/m).
- The heat energy released by reactions of fuels is converted into mechanical energy by an engine/machine. While at times the heat itself is valued for warmth, cooking, illumination, industrial processes etc.
- **Fossil fuel**: Fossil fuel is a general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to beat and pressure in the earth's crust over hundreds of millions of years.
- *Fossil fuels are non-renewable sources of energy.*

Major Fossil Fuels

- **Coal:** Coal is one of the most important fossil fuels. Coal is a solid carbon rich material. In addition to carbon it contains hydrogen, sulphur, oxygen & nitrogen. Coal is usually brown or black. Coal often occurs in stratified sedimentary deposits on burning in air, coal produces mainly carbon dioxide.
- By processing of coal some beneficial products are obtained such as coke, coal tar and coal gas.

There are 4 Main Types of Coal

1. ***Peat coal*** has an excessive quantity of moisture and impurities. Peat coal is the lowest grade of coal.
2. ***Lignite*** is a soft, brown, combustible, sedimentary rock formed from naturally compressed peat.
3. ***Bituminous coal*** or black coal is a relatively soft coal containing a tar like substance bitumen or asphalt. It is formed usually as the result of high pressure being exerted on lignite.
4. ***Anthracite coal*** often referred to as hard coal, is a hard, compact variety of coal that has a submetallic lasture. It has the highest carbon content, the fewest impurities. It has a low sulphur content, which makes it a good burning fuel.

- **Coke:** Coke is a fuel with few impurities and a high carbon content. It is a solid, hard, porous and black material derived from destructive distillation of low ash, low sulphur bituminous coal in the absence of oxygen. It is used in industrial manufacturing of steel and in extraction of several metals.
- **Coal tar:** Coal tar is a thick dark liquid. It is a by-product of the production of coke and coal gas from coal.
  - ***Industrial uses of coal tar*:** It is used in preparation of synthetic colors, explosive substances, plastics, photographic material and road manufacturing materials etc.
  - ***Medical uses of coal tar*:** It may be applied to the affected area to treat psoriasis and seborrheic dermatitis.
- **Coal gas:** Coal gas is a flammable gaseous fuel made from coal. It is produced when coal is heated strongly in the absence of air. The main components of coal gas are hydrogen, methane and carbon monoxide. It is used as fuel in different industries established near to the coal process plants.
- **Petroleum:** Petroleum is an oily, thick, flammable, usually dark coloured liquid that is a form of bitumen or a mixture of various hydrocarbons, naturally occurring in different parts of the world, beneath the earth surface. It is also known as black gold. It also contains sulphur, oxygen and nitrogen in small quantities. It is also known as traditional oil or light oil.

It can be separated into fractions including natural gas, gasolene, naphtha, kerosene, fuel and lubricating oils, paraffin wax and asphalt.

Petrochemicals are chemical products derived from petroleum such as acetylene, benzene, ethane etc., from which other chemicals, pesticides, plastics, synthetic fibers, paint and medicines are derived.

- **Natural Gas:** Natural gas is a fossil fuel formed like other fossil fuels such as coal and oil, natural gas from the buried plants, animals and micro- organisms that lived millions of years ago. Natural gas is a mixture of gaseous hydrocarbons such as methane, ethane, propane and butane and other gases like nitrogen, carbon dioxide and hydrogen sulphide. Natural gas is used as a source of energy for heating, cooking. and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacturing of plastics and other commercially important organic chemicals.
- **Liquefied Petroleum Gas (LPG):** LPG is made during natural gas processing and oil refining. Propane and butane are separated from the natural gas and liquefied at high pressure and stored in cylinders or tanks. It is used as fuel in houses and hotels. LPG gas is odourless. To detect its leakage, *ethyl mercaptan* is mixed.
- **Compressed Natural Gas (CNG):** In CNG mainly methane is stored at high pressure. It is a fuel which can be used in place of gasoline, diesel fuel and LPG. CNG combustion produces fewer undesirable gases than the fuels mentioned above. So it is an eco-friendly fuel or ideal fuel.

The use of petrol and diesel as fuels in automobiles is being replaced by compressed natural gas (CNG) because It produces very small amount of harmful gas. It burns without smoke, so it is a clean fuel.

Disadvantages of burning wood as fuel are as follows: It produces a lot of smoke which is very harmful for human beings. When trees are cut down to obtain wood for use as fuel, then all the useful substances which are obtained from trees are lost.

LPG (Liquefied petroleum gas) is a better domestic fuel than wood due to higher calorific value, so it produces much more heat on burning than an equal mass of wood. Also, It burns completely without leaving behind any residue but wood leaves behind a lot of ash on burning

5.2 IMPORTANT POINTERS FOR BPSC PRE EXAM

Important Days

National Science Day	28 February
International Yoga Day	21 June
World Cancer Day	4 February
World Malaria Day	25 April
World Tuberculosis Day	24 March
World Environment Day	5 June
World Food Day	16 October
International Ozone Day	16 September
World Animal Day	4 October
World Leprosy Day	Last Sunday of January
World Aids Day	1 December
World Diabetes Day	14 November
World Health Day	7 April
World Polio Day	24 October
World Mental Health Day	10 October
World Water Day	22 March

Different Revolutions Related to Agriculture

Green revolution	Cereal production
White revolution	Milk and dairy products
Yellow revolution	Oilseeds
Blue revolution	Fisheries and aquaculture
Pink revolution	Meat, poultry, onion, prawns
Black revolution	Petroleum
Silver revolution	Eggs
Red revolution	Tomato/meat
Round revolution	Potato
Grey revolution	Fertilisers

Brown revolution	Leather
Golden revolution	Horticulture/honey/fruits
Golden fibre revolution	Jute
Silver fibre revolution	Cotton

Important Institutions in India Related to Science

Institute	Location
National rice research institute	Cuttack
Central potato research institute	Shimla
Central drug research institute	Lucknow
Indian veterinary research institute	Bareilly
Central avian research institute	Izatnagar, U.P.
National sugar institute	Kanpur
Indian institute of sugarcane research	Lucknow
National botanical research institute	Lucknow
National institute for empowerment of persons with intellectual disabilities	Secunderabad
National institute for empowerment of persons with visual disabilities	Dehradun
National institute for locomotor disabilities	Kolkata
National institute of immunology	New Delhi
National center for cell sciences	Pune
Centre for DNA fingerprinting and diagnosis	Hyderabad
National institute for plant genome research	New Delhi
National brain research center	Manesar, Haryana
National academy of medical sciences	New Delhi
Institute for microbial technology	Chandigarh
Institute of life sciences	Bhubaneshwar

5.3 BPSC PYQS

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1. The parts of the skeleton that are not as hard as bones and which can be bent are called as

(*a*) Vertebrae

(*b*) Carpals

(*c*) Cartilage

(*d*) More than one of the above

(*e*) None of the above

2. In lichen, a chlorophyll-containing partner, _____ live together.

(*a*) Algae and a fungus

(*b*) Fungus and a bacterium

(*c*) Alga and a virus

(*d*) More than one of the above

(*e*) None of the above

3. Female Anopheles can be distinguished from female Culex because it sits

(*a*) At right angle to the surface of substratum

(*b*) At an angle with substratum

(*c*) Parallel to the surface of substratum

(*d*) More than one of the above

(*e*) None of the above

4. The most important cell type associated with the immunity of the body is

(*a*) RBCs

(*b*) Platelets

(*c*) Lymphocytes

(*d*) More than one of the above

(*e*) None of the above

5. Which one of the following statements is incorrect about muscles in the human body?

(*a*) Muscles can only push the bone

(*b*) Muscles work in pairs

(*c*) Muscles become shorter, stiffer and thicker when contracted,

(*d*) More than one of the above

(*e*) None of the above

6. Large number of thin strips of black paint are made on the surface of a convex lens of focal length 20 cm to catch the image of a white horse. The image will be

(*a*) A horse of less brightness

(*b*) A zebra of black stripes

(*c*) A horse of black stripes

(*d*) More than one of the above

(*e*) None of the above

7. Shrillness of sound is determined by

(*a*) Velocity of sound

(*b*) Amplitude of sound

(*c*) Wavelength of sound

(*d*) More than one of the above

(*e*) None of the above

8. Which of the following photoelectric devices is most suitable for digital applications?

(*a*) Photodiode

(*b*) Photovoltaic cell

(*c*) Photoemitter

(*d*) More than one of the above

(*e*) None of the above

9. Ball bearings are used to convert static friction into

(*a*) Rolling friction

(*b*) Drag

(*c*) Sliding friction

(*d*) More than one of the above

(*e*) None of the above

10. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. This enables the goalkeeper to

(*a*) Decrease the rate of change of momentum

(*b*) Exert large force on the ball

(*c*) Increase the force exerted by the ball on hands

(*d*) More than one of the above

(*e*) None of the above

11. Which among the following is a positively charged particle emitted by a radioactive element?

(*a*) Cathode ray

(*b*) Beta ray

(*c*) Alpha ray

(*d*) More than one of the above.

(*e*) None of the above

12. Centripetal force is responsible to

(*a*) Independent motion of the object in space

(*b*) Keep the body moving along the circular path

(*c*) Fly the object along a straight line

(*d*) More than one of the above

(*e*) None of the above

13. Which of the following energy changes involves frictional force?

(*a*) Kinetic energy to heat energy

(*b*) Potential energy to sound energy

(*c*) Chemical energy to heat energy

(*d*) More than one of the above

(*e*) None of the above

14. A bus is moving along a straight path and suddenly takes a sharp tum to the right side. The passengers sitting on the bus will

(*a*) Bent towards right side

(*b*) Fall in the forward direction

(*c*) Bent towards left side

(*d*) More than one of the above

(*e*) None of the above

15. Before playing the orchestra in a musical concert a sitarist tries to adjust the tension and pluck the string suitably. By doing so he/she is adjusting

(*a*) Frequency of the sitar string with the frequency of other musical instruments

(*b*) Amplitude of sound

(*c*) Intensity of sound

(*d*) More than one of the above

(*e*) None of the above

16. A form of matter has no fixed shape but it has a fixed volume An example of this form of matter is

(*a*) Carbon steel

(*b*) Krypton

(*c*) Kerosene

(*d*) More than one of the above

(*e*) None of the above

17. Some metal oxides react with acid as well as a base to produce salt and water They are known as amphoteric oxides. Examples of amphoteric oxides are

(*a*) CuO and ZnO

(*b*) AlO, and ZnO

(*c*) AlO, and Cuo

(*d*) More than one of the above

(*e*) None of the above

18. Which gas contributes to global warming through its greenhouse effect?

(*a*) Carbon dioxide

(*b*) Nitrous oxide

(*c*) Methane

(*d*) More than one of the above

(*e*) None of the above

19. Acids react with metal carbonates to liberate _____ gas.

(*a*) H_2

(*b*) CO_2

(*c*) CO

(*d*) More than one of the above

(*e*) None of the above

20. Which acid is described as HOOCCOOH?

(*a*) Carbonic acid

(*b*) Oxalic acid

(*c*) Acetic acid

(*d*) More than one of the above

(*e*) None of the above

21. You have been provided with three test tubes. One of them contains distilled water and the other two contain an acidic solution and a basic solution respectively. Which of them will turn red litmus to blue?

(*a*) Distilled water

(*b*) Acid

(*c*) Base

(*d*) More than one of the above

(*e*) None of the above

22. The odour of acetic acid resembles that of

(*a*) Vinegar

(*b*) Tomato

(*c*) Kerosene

(*d*) More than one of the above

(*e*) None of the above

23. Why does dry HCI gas not change the colour of dry litmus paper?

(*a*) HCI gas acts as a dehydrating agent.

(*b*) Blue litmus becomes dry in the presence of dry HCI gas.

(*c*) No H_3O^+ ions are present. Litmus changes colour only in the presence of H_3O^+ ions.

(*d*) More than one of the above

(*e*) None of the above

24. Detect the odd one

(*a*) Ripening of fruit

(*b*) Setting of cement

(*c*) Burning of coal

(*d*) More than one of the above

(*e*) None of the above

25. Which of the following statements about diamond and graphite is true?

(*a*) They have same electrical conductivity

(*b*) They have same crystal structure

(*c*) They have same degree of hardness

(*d*) More than one of the above

(*e*) None of the above

26. The stomata open or close due to change in the

(*a*) Position of nucleus in cells

(*b*) Protein composition of cells

(*c*) Amount of water in cells

(*d*) More than one of the above

(*e*) None of the above

27. Chlorophyll absorbs _____ wavelengths of the sunlight.

(*a*) Red and blue

(*b*) Green and blue

(*c*) Green and red

(*d*) More than one of the above

(*e*) None of the above

28. Which of the following is not a correct match?

(*a*) Petiole: Attaches leaf to stem

(*b*) Thick, hard stem with branching near base: Tree

(*c*) Weak stem which cannot stand upright: Creeper

(*d*) More than one of the above

(*e*) None of the above

29. Water reaches great heights in trees because of suction pull caused by

(*a*) Evaporation

(*b*) Absorption

(*c*) Transpiration

(*d*) More than one of the above

(*e*) None of the above

30. Which among the following is a character of chloroplast which makes them qualified for self-replication?

(*a*) Presence of both DNA and RNA

(*b*) Presence of DNA only

(*c*) Absence of RNA

(*d*) More than one of the above

(*e*) None of the above

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31. What type of lens is used in magnifying glass?
(*a*) Plano-concave lens
(*b*) Convex lens
(*c*) Convex mirror
(*d*) Concave lens
(*e*) None of the above/More than one of the above

32. Which among the following are constituents of brass?
(*a*) Iron and zinc
(*b*) Copper and nickel
(*c*) Iron and copper
(*d*) Zinc and copper
(*e*) None of the above/More than one of the above

33. The paramagnetic theory of magnetism applies to
(*a*) Mercury
(*b*) Iron
(*c*) Platinum
(*d*) Nickel
(*e*) None of the above/More than one of the above

34. Which among the following is known as quicklime?
(*a*) $CaCO_2$
(*b*) $Ca(OH)_2$
(*c*) $CaCl_2$
(*d*) CaO
(*e*) None of the above/More than one of the above

35. The nucleus of an atom consists of
(*a*) Electrons and protons
(*b*) Protons and neutrons
(*c*) Electrons only
(*d*) Electrons and neutrons
(*e*) None of the above/More than one of the above

36. The metallurgical process in which a metal is obtained in a fused state is called
(*a*) Roasting
(*b*) Calcination
(*c*) Froth floatation
(*d*) Smelting
(*e*) None of the above/More than one of the above

37. What happens to the weight of iron, when it rusts?
(*a*) Decreases then increases
(*b*) Increases then decreases
(*c*) Remains same
(*d*) Increases for long time
(*e*) None of the above/More than one of the above

38. Which among the following is also known as white metal?
(*a*) Rhodium
(*b*) Platinum
(*c*) Palladium
(*d*) Nickel
(*e*) None of the above/More than one of the above

39. Consider the following statements with respect to noble metals:
1. Noble metals are found in pure form in nature.
2. Uranium and lead are examples of noble metal.

Which of the above statements is/are correct?
(*a*) 2 only
(*b*) Both 1 and 2
(*c*) Brass is also noble metal
(*d*) 1 only
(*e*) None of the above/More than one of the above

40. Consider the following statements:
1. Addition of salt to pure water increases the boiling point of water and decreases the freezing point of water.
2. When methyl alcohol is added to water, the boiling point of water decreases.

Which of the above statements is/are correct?
(*a*) I only
(*b*) 2 only
(*c*) Both 1 and 2
(*d*) Salt and methyl alcohol are same in behaviour
(*e*) None of the above/More than one of the

41. Fungi are plants that lack
(*a*) Carbon dioxide
(*b*) Chlorophyll
(*c*) Sunlight
(*d*) Oxygen
(*e*) None of the above/More than one of the above

42. Which among the following would cause the bright red colour due to bursting of crackers?
(*a*) Sodium
(*b*) Sulphur
(*c*) Magnesium
(*d*) Strontium
(*e*) None of the above/More than one of the above

43. What are salt-loving plants called?
(*a*) Mesophytes
(*b*) Glycophytes
(*c*) Halophytes
(*d*) Xerophytes
(*e*) None of the above/More than one of the above

44. Which among the following is the main constituent of biogas?
(*a*) Propane
(*b*) Butane
(*c*) Ethane
(*d*) Methane.
(*e*) None of the above/More than one of the above

45. Pollination is best defined as
(*a*) Germination of pollen grains
(*b*) Growth of pollen tube in ovule
(*c*) Visiting flowers by insects
(*d*) Transfer of pollen grain from anther to stigma
(*e*) None of the above/More than one of the above

46. Plants receive their nutrients mainly from
(*a*) Atmosphere
(*b*) Light
(*c*) Soil
(*d*) Chlorophyll
(*e*) None of the above/More than one of the above

47. The animal without red blood cells is
(*a*) Earthworm
(*b*) Snake
(*c*) Peacock
(*d*) Frog
(*e*) None of the above/More than one of the above

48. The ultimate substance to which the carbohydrates are degraded, is
(*a*) Glycerol
(*b*) Glucose
(*c*) Maltose
(*d*) Amino acid,
(*e*) None of the above/More than one of the above

49. Pine, Fir, Spruce, Cedar, Larch and Cypress are the famous timber-yielding plants of which several also occur widely in the hilly regions of India. All these belong to
(*a*) Gymnosperm
(*b*) Monocotyledons
(*c*) Dicotyledons
(*d*) Angiosperm
(*e*) None of the above/More than one of the above

50. Most of the enzymes are
(*a*) Lipids
(*b*) Acids
(*c*) Alkalis
(*d*) Proteins
(*e*) None of the above/More than one of the above

51. Who was the first scientist/doctor, who attempted vaccination?
(*a*) Robert Koch
(*b*) Elie Metchnikoff
(*c*) Edward Jenner
(*d*) Joseph Lister
(*e*) None of the above/More than one of the above

52. From the following pairs, find the one which is correctly matched.
(*a*) Tuberculosis-ATS
(*b*) Tetanus-BCG
(*c*) Malaria Chloroquine
(*d*) Scurvy-Thiamine
(*e*) None of the above/More than one of the above

53. The working principle of a washing machine in
(*a*) Diffusion
(*b*) Centrifugation
(*c*) Dialysis
(*d*) Reverse osmosis
(*e*) None of the above/More than one of the above

54. Who is the first person to define speed?
(*a*) Newton
(*b*) Kepler
(*c*) Ptolemy
(*d*) Galileo
(*e*) None of the above/More than one of the above

55. The speed of light will be minimum while passing through
(*a*) Vacuum
(*b*) Air
(*c*) Glass
(*d*) Water
(*e*) None of the above/More than one of the above

56. Which of the following is not a vector quantity?

(*a*) Velocity

(*b*) Torque

(*c*) Displacement

(*d*) Speed

(*e*) None of the above/More than one of the above

57. What is the law in which under the same conditions of temperature and pressure, equal volumes of all gases contain equal numbers of molecules?

(*a*) Graham's law

(*b*) Pascal's law

(*c*) Avogadro's law

(*d*) Coriolis effect

(*e*) None of the above/More than one of the above

58. The theory of relativity is presented by which scientist?

(*a*) Isaac Newton

(*b*) Stephen Hawking

(*c*) Marie Curie

(*d*) Albert Einstein

(*e*) None of the above/More than one of the above

59. If the spinning speed of the earth increases, then the weight of the body at the equator will

(*a*) Decrease

(*b*) Remain same

(*c*) Be doubled

(*d*) Increase

(*e*) None of the above/More than one of the above

60. Due to temperature variation along a conductor, potential variation occurs along it. This phenomenon is known as

(*a*) Joule effect

(*b*) Seebeck effect

(*c*) Peltier effect

(*d*) Thomson effect

(*e*) None of the above/More than one of the above