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FOR CIVI[...]MINATION

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

From the beginning, the content team comprising Content Creators, Reviewers, DTP operators, Proofreaders, and others is involved in shaping the material to their best knowledge and experience to produce powerful content for the students.

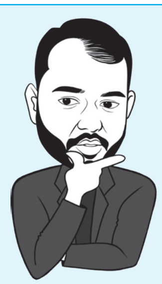
Faculties have adopted a new style of presenting the content in easy-to-understand language and have provided the team with expert guidance and supervision throughout the creation of this book.

PW ONLY IAS strongly believes in conceptual and fun-based learning. PW ONLY IAS provides highly exam-oriented content to bring quality and clarity to the students.

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.

- Holistic Coverage of 50+ NCERT Books
- Thinking Points in and as 'Points to Ponder'
- Intensive use of Maps, Diagrams and Flowcharts
- Subject-Specific Workbooks for Practice



Alakh Pandey

Every chapter consists of 'Points to Ponder,' where our leaders raise thinking points for the students to go beyond the confines of the book. The students are expected to think about and find out possible answers to these points. The Caricatures used are inspired by Alakh Pandey Sir and Sumit Rewri Sir.

Sumit Rewri

CONTENTS

1 Motion and Measurements

Bibliography: The chapter encompasses the summary of **Chapter 7-VI** NCERT (Science), **Chapter 9-VII** NCERT (Science), **Chapters 8 and 9-VIII** NCERT (Science), **Chapters 7, 8, 9 and 10- IX** NCERT (Science).

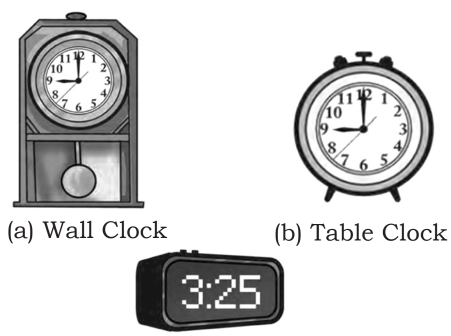
Introduction

In our day-to-day lives, we constantly observe objects in motion for instance, cars travelling on roads, children playing in park, or the simple act of walking. This motion, often governed by the interplay of forces, pressure, and friction, happens in the dimension of time and is measured over distances. From the ease with which a sharp knife cuts a fruit due to shear force, to the atmospheric pressure that surrounds us, or the fundamental understanding of how far one has travelled and how long it took—these concepts intertwine, crafting the tapestry of our physical world. Delving into these principles, we find the core of many phenomena and innovations that make our world functional and comprehensible.

Measurement of Time

Understanding and measuring time accurately is a fundamental human necessity. Before the invention of clocks, our ancestors had ways to measure the approximate time based on natural phenomena, like the position of the sun in the sky.

- **Nature's Clock:** The shadows cast by the sun were among the earliest tools humans used to gauge time. Sundials were made based on this principle.
- **Months and Years:** These were deduced from the lunar cycle and Earth's revolution around the sun.
- **Simple Pendulum:** A very basic time measuring tool, the simple pendulum consists of a metallic ball (or bob) suspended by a thread. The back-and-forth swing of this pendulum, or its oscillation, is periodic. The duration for one complete swing is called its time period. Historically, this principle was used in pendulum clocks. (**Refer to Figure 1.2**)
  - **Experiment with a Pendulum:** Setting up a simple pendulum and measuring its oscillations provides an understanding of periodic motion. Despite slight changes in the initial displacement, a pendulum of a specific length has a nearly constant time period. This property of the pendulum led to its use in timekeeping devices.



(a) Wall Clock (b) Table Clock (c) Digital Clock

Figure 1.1: Some common clocks

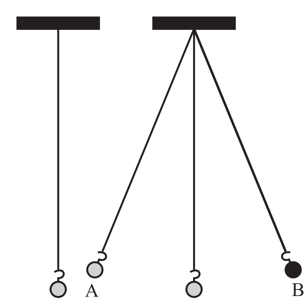
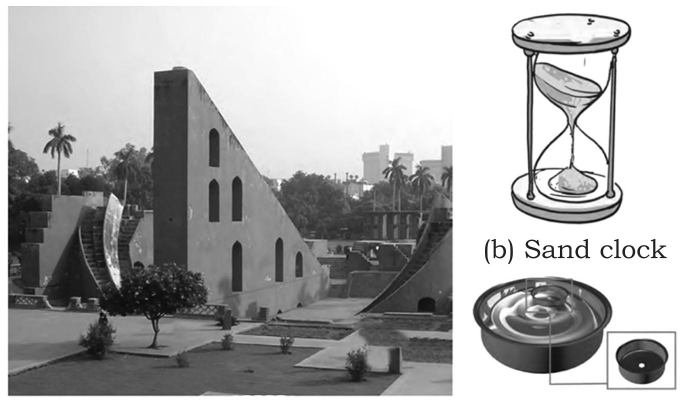


Figure 1.2: (a) A simple pendulum (b) Different position of the bob of an oscillating simple pendulum

- **Quartz Clocks:** More modern and accurate, these clocks utilize the oscillations of quartz crystals in an electric circuit to keep time.
- **Units of Time:**
  - **Time:** Second(s) is considered as the basic unit of time. Other units include minutes (min) and hours(h).
- **Trivia:** Galileo Galilei observed a lamp in a church oscillating back and forth and noticed that it took a constant time for each oscillation. This observation, alongside his other experiments with pendulums, paved the way for the development of pendulum clocks.
- **Comparing Time Intervals:** Time can be expressed in various units based on the context. For instance, while age is conveyed in years, the time to travel a short distance is usually given in minutes or hours.
- **Understanding a Second:** A rough approximation of a second can be gauged by saying "two thousand and one" aloud. An adult's resting heart rate also provides a perspective on time—typically beating around 72 times per minute.
- **Ancient Timekeeping:** Different civilizations used various methods to measure time before pendulum clocks were invented. Sundials, water clocks, and sand clocks are examples. These devices, in their many designs, can be found across different cultures. (**Refer to Figure 1.3**)



(a) Sundial at Janatar Mantar, Delhi (b) Sand clock (c) Water clock

Figure 1.3: Some ancient time-measuring devices

Motion and Measurement of Distances

Story of Transport

- Initially, humans had no means of transport and were dependent on walking. They later used animals for transport and logs as primitive boats. (**Refer to Figure 1.4**)

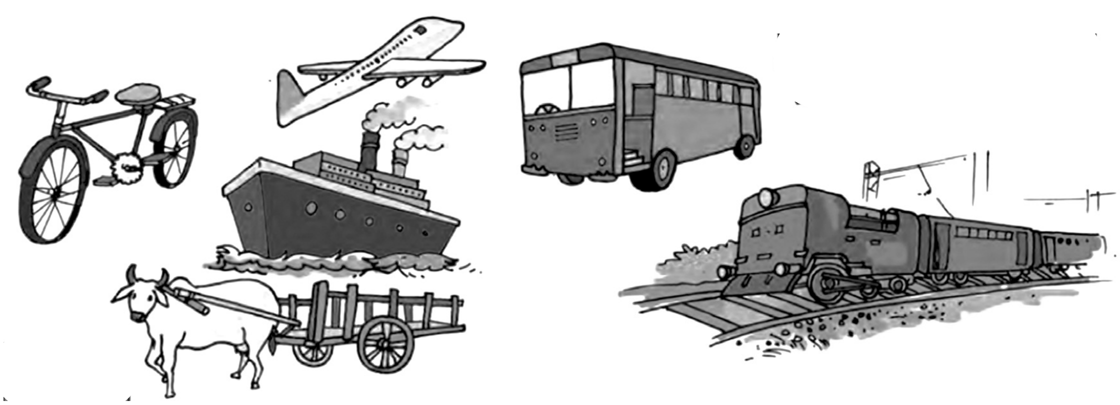


Figure 1.4: Some means of transportation

- The invention of the wheel revolutionized transportation.
- Boats were designed with streamlined shapes inspired by water animals.
- The 19th century saw a significant shift with the invention of the steam engine. This led to the development of steam engine driven wagons and later motor cars, trucks, and buses.
- The 20th century brought advancements like electric trains, monorails, supersonic airplanes, and spacecrafts.

Measurement of Length and its Application

- There are various instances in daily life when measuring distances or lengths becomes essential, such as for tailors, carpenters, and farmers. (**Refer to Figure 1.5**)
- Questions related to distances can range from personal height to the distance between cities or celestial bodies.
- The essence is that measuring distances helps in making informed decisions, be it in daily chores or scientific endeavours.
- **Concept of Measurement:** Measurement is defined as the comparison of an unknown quantity with a known one, which is termed as a unit.
  - The result of a measurement has two components: A number and the unit. The text emphasizes that using non-standard units, like handspans (**Refer to Figure 1.6**) or foot lengths, can yield different measurements for different individuals.
  - This leads to the need for standardized units that are consistent across all individuals.

Figure 1.5: Measuring the length of the desk with string lengths

Figure 1.6: Measuring the witdth of a table with a handspan

Standard Units of Measurement of Length

- **Ancient Units:** Historically, people used various body parts as units of measurements, such as the length of a foot, the width of a finger, and the distance of a step.
  - The Indus valley civilization, ancient Egyptians, Romans, and ancient Indians had their specific units, often based on body parts, which led to variations in measurements across regions.
- **Need for a Standard System:** Due to the inconsistencies in ancient measurements, there was a need for a standardized system. In 1790, the French introduced the metric system.
  - To ensure global consistency, the International System of Units (SI units) was accepted by scientists worldwide.
- **Units of Length:** The primary SI unit for length is the "metre". One metre is subdivided into 100 centimetres, and a centimetre is divided into ten millimetres.
  - For larger distances, the "kilometre" is used, with 1 km equivalent to 1000 m.
  - Using the SI units for all future measurement activities emphasizes the importance of understanding the proper method of measuring lengths and distances.
- **Measuring the Length of a Curved Line:** While straight lines can be measured using a rigid metre scale, curved lines present a challenge. To measure a curved line, one can use a flexible thread, matching it along the curve's path from one end to the other, and then measure the length of the thread on a straight scale. (**Refer to Figure 1.7**)

Figure 1.7: Measuring the length of a curved line with a thread

- **Moving Things Around Us:** Everything around us, either at rest or in motion, can be categorised based on its state. For example, while a table may remain stationary (at rest), a bird might change its position (in motion).
  - By observing an ant's trajectory, (**Refer to Figure 1.8**) one can understand the motion's essence: it is the change in an object's position over time. Interestingly, objects like clocks and fans, though stationary, exhibit movement in their parts.

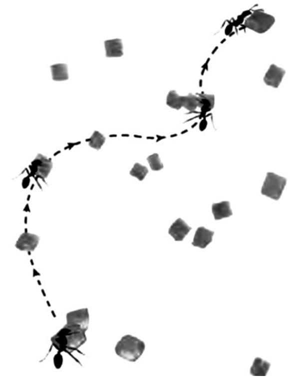


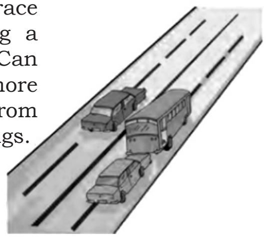
Figure 1.8: Motion of an ant

Types of Motion

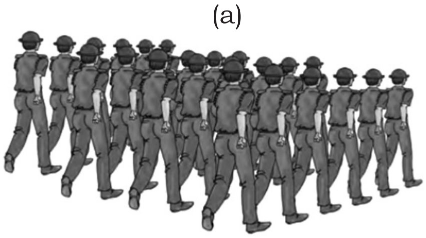
In essence, the study of motion revolves around understanding the change in an object's position over time. From tiny snails to massive planes, and even celestial bodies like the moon orbiting the Earth, everything showcases some form of motion, making the world around us a dynamic tapestry of movement. Some of these motion types include:

- **Rectilinear Motion:** When objects move along a straight path. Examples are vehicles on a straight road or sprinters in a 100-metre race. (**Refer to Figure 1.9**)
- **Circular Motion:** When objects move in a circle, maintaining the same distance from the center throughout. For example, the hands of a clock or a stone tied to a thread and whirled in a circle. (**Refer to Figure 1.10**)
- **Periodic Motion:** When an object repeats its motion after regular intervals. For instance, the to-and-fro motion of a pendulum or a branch of a tree swaying. (**Refer to Figure 1.11**)
- **Combinations of Motions:** Some objects exhibit more than one type of motion. A rolling ball, for instance, simultaneously undergoes rectilinear motion (forward movement) and rotational motion (spinning).

Sprinters in a 100 metre race also move along a straight track. Can you think of more such examples from your surroundings.

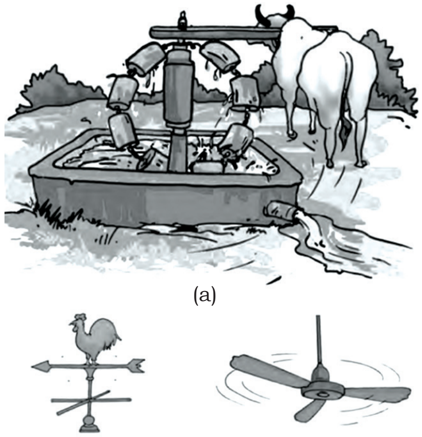


(a)



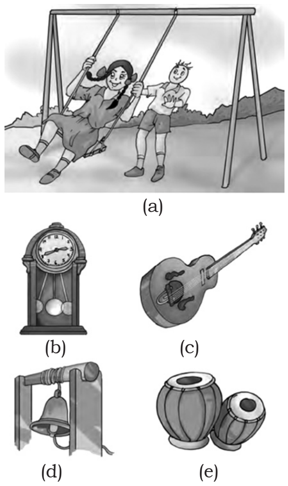
(b)

Figure 1.9: Some examples of rectilinear motion



(a) (b) (c)

Figure 1.10: Some objects in circular motion



(a) (b) (c) (d) (e)

Figure 1.11: Examples of periodic motion

Describing Motion

- Objects can be at rest or in motion in everyday life. Motion is often inferred through indirect evidence, such as the movement of dust indicating air motion.
- The phenomena of sunrise, sunset, and changing of seasons are related to the motion of the Earth, even if we don't directly perceive it.
- An object might appear moving to one observer and stationary to another. Example: Trees appear moving to passengers in a bus but stationary to an observer outside. Motions can be complex-straight, circular, rotating, vibrating, or combinations.
- **Location Description:** An object's location is specified using a reference point or origin. For example, a school's position is described as 2 km north of the railway station, where the railway station serves as the reference point.
- **Motion along a Straight Line:**
  - This is the simplest type of motion. **(Refer to Figure 1.12)**

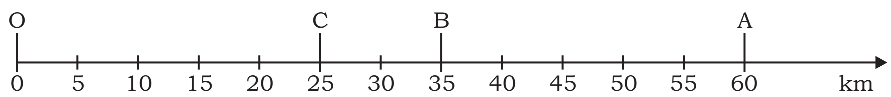


Figure 1.12: Position of an object on a straight line path

  - If an object starts from point O and moves through points C, B, and "A, and then returns back to C" then the path covered is its distance.
  - **Distance:** It is the length of the total path covered. E.g., OA + AC = 95 km. It's a scalar quantity (only magnitude).
  - **Displacement:** It is defined as the shortest distance from initial to final position. It's a vector quantity (magnitude + direction). The difference between the final position and the initial position gives displacement.
    - In some cases, displacement can be equal to the distance travelled, like the motion from O to A (60 km).
    - However, displacement might be less than the total distance covered, like in the journey from O to A to B.
    - Displacement can be zero even if distance is not zero, like if an object returns to its starting point.
- **Uniform Motion and Non-Uniform Motion:**
  - **Uniform Motion:** An object is said to be in uniform motion if it covers equal distances in equal intervals of time. For example, an object moving 5 m every second.
  - **Non-Uniform Motion:** Objects are said to be in non-uniform motion if they cover unequal distances in equal intervals of time. For example, a car in a crowded street or a person jogging in a park.

Measuring the Rate of Motion

The rate of motion can differ between objects; some may move fast while others move slow. Speed measures the rate of motion i.e., distance travelled in unit time.

- **Speed:**
  - **Definition:** Speed is the distance an object travels in a unit of time.
  - **Units:**
    - **SI unit:** Metre per second (m/s).
    - **Others:** Centimetre per second (cm/s), kilometre per hour (km/h).
  - Speed might vary; most objects exhibit non-uniform motion.
  - **Average Speed:** It is defined as the total distance travelled divided by total time taken.
    - **Formula: Average speed = Total distance travelled/Total time taken**
    - For example, a car covering 100 km in 2 hours has an average speed of 50 km/h.

- A **speedometer** is an instrument on vehicles that shows speed in real-time.
- An **odometer** keeps a record of the total distance that the vehicle has travelled.

- **Velocity (Speed with Direction)**: Velocity is the speed of an object moving in a definite direction. It combines speed and direction. The velocity of an object can be uniform or variable.
  - **Average Velocity**: For objects with changing velocity at a uniform rate, the average velocity is the mean of the initial and final velocities.
  - **Formula: Average velocity = initial velocity + final velocity/2**
  - **Units:** m/s (same as speed).

Rate of Change of Velocity

- **Uniform vs. Non-uniform Motion:**
  - **Uniform Motion**: An object moves at a constant velocity. There is no change in velocity over time.
  - **Non-uniform Motion:** Velocity changes with time. It has different values at different instants and at different points of the path.
- **Acceleration**:
  - **Definition:** Acceleration measures how much the velocity of an object changes in a given time period.
  - **Formula**: Acceleration = change in velocity/time taken
    - Given the initial velocity u and final velocity v over time t, acceleration a is: $a = v - u/t$
  - **Accelerated Motion:** Motion in which there is a change in velocity over the change in time.
  - **Direction**:
    - **Positive Acceleration:** Acceleration is in the direction of velocity.
    - **Negative Acceleration (or Deceleration)**: Acceleration is opposite to the direction of velocity.
  - **SI Unit:** ms^{-2}
- **Types of Acceleration:**
  - **Uniform Acceleration:** If an object's velocity changes by the same amount over equal time intervals.
    - **Example:** A freely falling body exhibits uniformly accelerated motion due to gravity.
  - **Non-uniform Acceleration:** If the rate of change in velocity varies over time.
    - **Example:** A car that speeds up by different amounts over equal time intervals.

Graphical Representation of Motion

Graphs are powerful tools for visually representing the motion of objects, enabling clearer understanding and analysis.

Distance–Time Graphs

- These graphs depict how the position of an object changes over a period of time.
  - The x-axis represents time.
  - The y-axis represents distance or displacement.
- **Uniform Speed (Refer to Figure 1.13):** When an object covers equal distances in consistent time intervals, it is said to move with a uniform speed.
  - In such cases, the graph is a straight line. The gradient or slope of this line indicates the speed.

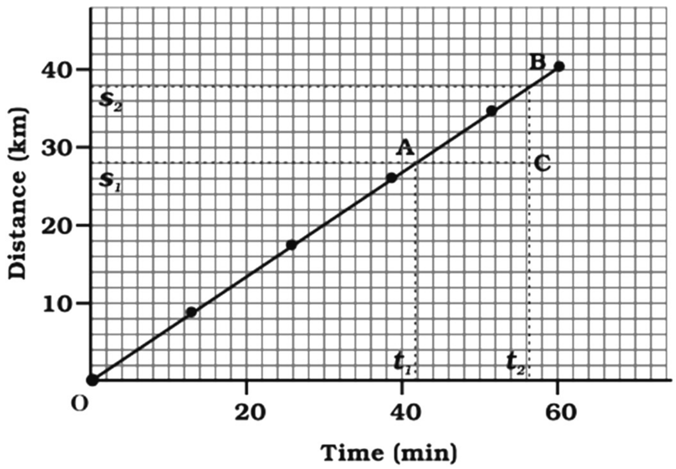


Figure 1.13: Distance-time graph of an object moving with uniform speed

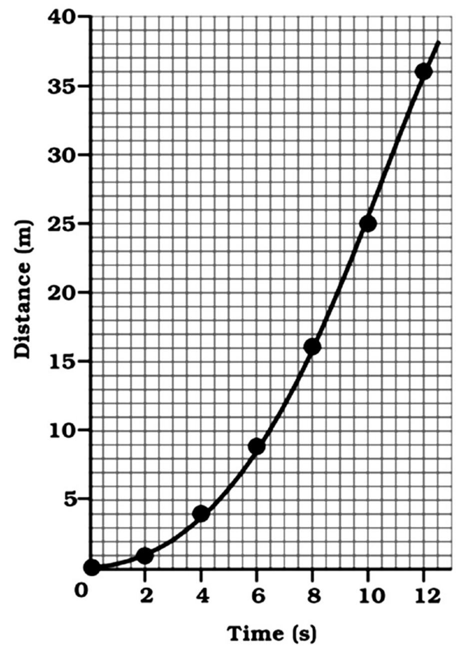


Figure 1.14: Distance-time graph for a car moving with non-uniform speed

- **Non-uniform Speed (Refer to Figure 1.14):**
  - The graph displays non-linear variations when the distance covered varies over time.
  - The specific shape of the curve offers insights into the nature of the non-uniform motion.

For example:

To determine the speed of an object using a distance-time graph, one can take the following steps:

- **Identify Two Points:** Let's consider two points, A and B, on the distance-time graph, as **illustrated in Figure 1.14**.
- **Draw Parallel Lines:** From point A, draw a line parallel to the x-axis, and from point B, draw another line parallel to the y-axis. These lines intersect at a point, C, forming a triangle ABC.
- **Determine Time and Distance:** On the graph:
  - The horizontal line segment AC represents the time interval $(t_2 - t_1)$.
  - The vertical line segment BC indicates the change in distance $(s_2 - s_1)$.

Table 1.1: Distance travelled *b* a car at regular time travels

Time in seconds	Distance in metres
0	0
2	1
4	4
6	9
8	16
10	25
12	36

- **Calculate Speed:** As the object moves from point A to point B, the change in its position is $(s_2 - s_1)$ over the time interval $(t_2 - t_1)$. Therefore, the object's average speed v during this interval is given by:

$$v = s_2 - s_1 / t_2 - t_1$$

Furthermore, distance-time graphs can also represent accelerated motion. For example, **Table 1.1** illustrates distances covered by a car every two seconds, demonstrating an accelerated motion.

Velocity-Time Graphs

- These graphs depict how an object's velocity changes over time.
  - The x-axis represents time.
  - The y-axis represents velocity.
- **Uniform Velocity:**
  - When the velocity of an object remains consistent over time, its graph is a horizontal line (**Refer to Figure 1.15**).
  - The area beneath the graph between two time points indicates the object's displacement.

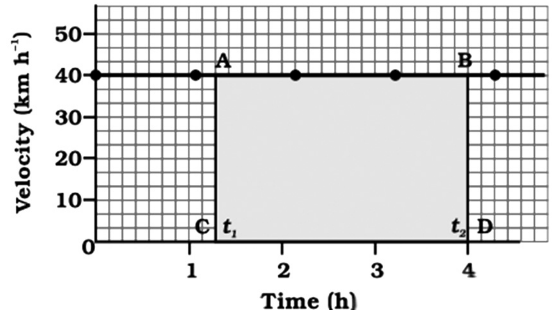


Figure 1.15: Velocity-time graph for uniform motion of a car

Let's look at an example,

Figure 1.15 displays a velocity-time graph for a car moving at a consistent speed of 40 km/h. For objects moving at uniform velocity, the product of their velocity and time yields the displacement. Consequently, the area between the velocity-time graph and the time axis represents the total displacement.

To ascertain the distance covered by the car between the time intervals t_1 and t_2 using the graph in Figure 1.14, one should:

- **Draw Perpendicular Lines:** From the points corresponding to times t_1 and t_2 on the graph, draw perpendicular lines to the opposite axes.
- **Identify Graph Dimensions:** The consistent velocity of 40 km/h is depicted by the vertical height (either AC or BD). Meanwhile, the horizontal distance AB represents the time interval $t_2 - t_1$
- **Calculate Distance:** The distance the car traverses in the duration $t_2 - t$ is given by:

$$s = AC\ CD$$
$$= [(40\ km/h^{-1})\ (t_2 - t_1)h]$$
$$= 40(t_2 - t_1)\ km.$$

Table 1.2: Velocity of a car at regular instants of time

Time in seconds	Velocity of the car (ms^{-1})	(km/h^{-1})
0	0	0
5	2.5	9
10	5.0	18
15	7.5	27
20	10.0	36
25	12.5	45
30	15.0	54

This distance corresponds to the area of the rectangle ABDC (highlighted in Figure 1.4).

Additionally, to understand uniformly accelerated motion, consider a velocity-time graph. Envision a scenario where a car undergoes an engine test on a straight road. An observer in the car logs the vehicle's speed every 5 seconds using its speedometer. Table 1.2 then showcases the car's velocity in both km/h and m/s at various time snapshots.

- **Uniformly Accelerated Motion:**
  - If the velocity of an object changes by consistent amount in equal time intervals, the graph will be a straight line that isn't necessarily horizontal.
  - The total area under the graph **(Refer to Figure 1.16)** represents the distance or magnitude of displacement. This area can be dissected into simpler geometric shapes, like rectangles and triangles, to ascertain the distance.
- **Non-uniformly Accelerated Motion:**
  - The velocity-time graphs for non-uniformly accelerated motion can adopt different shapes and configurations.
  - The exact shape of the graph can be interpreted in different ways (**Refer to Figure 1.17**) depending on the motion's characteristics.

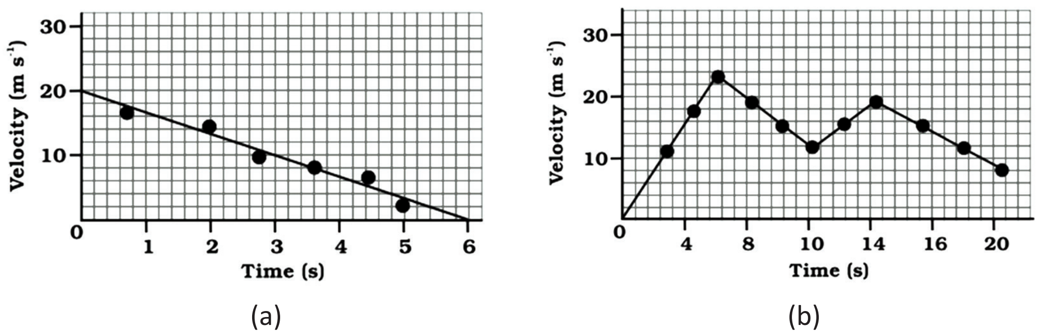


Figure 1.17: Velocity-time graphs of an object in non-uniformly accelerated motion

Equations of Motion

When an object travels in a straight line and experiences uniform acceleration, it abides by certain relationships between its various motion attributes: Velocity, acceleration, and the distance covered. These relationships are captured in a set of equations commonly referred to as the "equations of motion". There are three primary equations of motion:

- **Velocity-Time Relation: v = u + at.** This equation relates the final velocity v of the object to its initial velocity u, the acceleration a, and the time t of motion.
- **Position-Time Relation: s = ut + ½ at^2.** Here, s represents the distance or displacement covered by the object in time t. It relates the distance travelled by the object to its initial velocity, the time of motion, and the uniform acceleration.
- **Position-Velocity Relation: 2 as = v^2 – u^2.** This equation connects the object's displacement to its initial and final velocities, devoid of a direct time reference. It can be derived from the previous two equations by eliminating the time t factor.
- In the above given equations:
  - u stands for the initial velocity.
  - v denotes the final velocity after time t.
  - a is the uniform acceleration.
  - s is the distance or displacement covered during the time *t*.

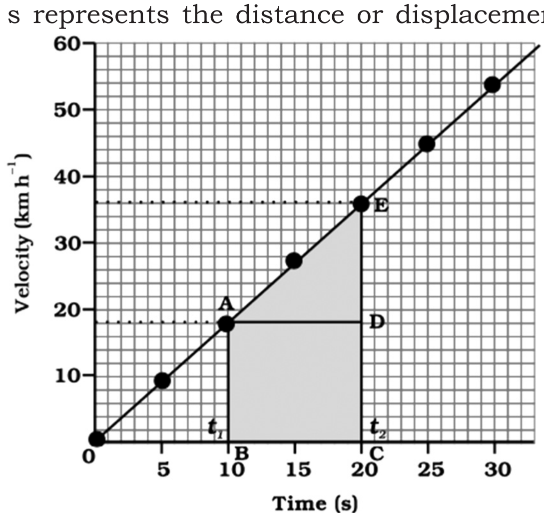


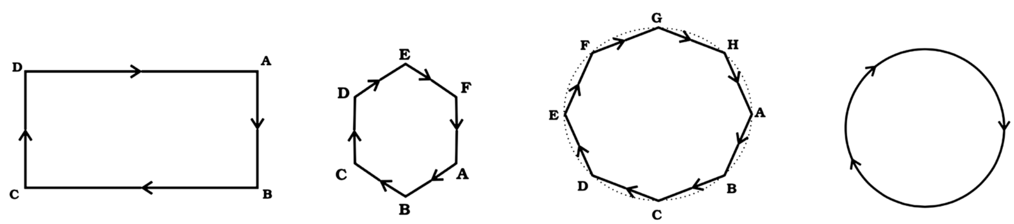
Figure 1.16: Velocity-time graph for a car moving with uniform accelerations

These equations provide a foundational framework for analyzing linear motion with uniform acceleration. Notably, they can be derived using graphical methods, illustrating the power of graphical representations in understanding and deriving physical relationships.

Uniform Circular Motion

- Acceleration is usually associated with a change in the speed of an object. However, it is crucial to understand that even if an object's speed remains constant, a change in the direction of it's motion also constitutes acceleration.
- **Simplifying Circular Motion:** A runner sprinting around a track. On a rectangular track, as illustrated in **Figure 1.18(a)**, if the athlete maintains a constant speed on each straight section (AB, BC, CD, DA), the only time his velocity changes is when he rounds a corner. Here, he alters his direction four times during a single lap.

- Now, let's modify the track's shape. Suppose it's hexagonal, as depicted in **Figure 1.18(b)**. On such a track, the runner adjusts his direction six times in a complete loop. If we shift to an octagonal track, **Figure. 1.18(c)**, the turns become more frequent and the athlete changes his direction eight times in one loop.
- The intriguing part comes when we keep increasing the number of sides on our track. As the number of sides approaches infinity, each side becomes infinitesimally small, and our shape morphs into a circle.
- For an athlete maintaining constant speed on a circular track, the only fluctuation in his velocity stems from the continuous shifts in direction. This movement, despite the speed being unaltered, is termed as accelerated motion due to the constant changes in direction.
- For a circular path (**Refer to Figure 1.18 (d)**) with a radius r, its circumference is given by $2\pi r$. If our runner takes t seconds for one complete round on this track, his speed v is computed as: $v = 2\pi r / t$



(a) Rectangular track (b) Hexagonal track (c) Octagonal shaped track (d) A circular track

Fig. 1.18: The motion of an athlete along closed tracks of different shapes

- **Definition:** Motion, where an object maintains a consistent speed while travelling in a circular path, is termed as uniform circular motion.

A Practical Illustration: Imagine swinging a stone tied to a string in a circular pattern and then releasing it. The stone will dart in a straight line, tangential to its circular route. Why?

- At the release point, the stone preserves the motion direction it possessed at that instant. This behavior affirms that while moving in a circle, the stone's direction altered at every juncture.
- Similarly, during athletic events, when an athlete whirls and then releases a hammer or discuss, it sails in the last direction it had before the release, echoing the behavior of our swung stone.
- Several everyday examples encapsulate the uniform circular motion concept, from:
  - Celestial bodies like the moon orbiting the earth,
  - Satellites revolving in circular trajectories around our planet,
  - To a cyclist racing on a round track at a steady speed.

Force and Laws of Motion

- Historically, rest was believed to be the natural state of an object until **Galileo Galilei and Isaac Newton** challenged this belief, introducing a new perspective on motion.
- In daily life, we observe that a force (push, hit, or pull) is needed to change an object's state of motion, **(Refer to Figure 1.19)** whether to initiate movement, halt it, or modify its velocity.

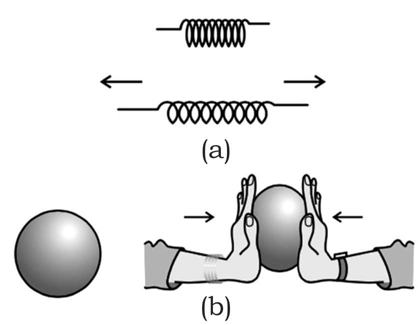


Figure 1.19: (a) A spring expands on application of force; (b) A spherical rubber ball becomes oblong as we apply force on it

Balanced and Unbalanced Forces

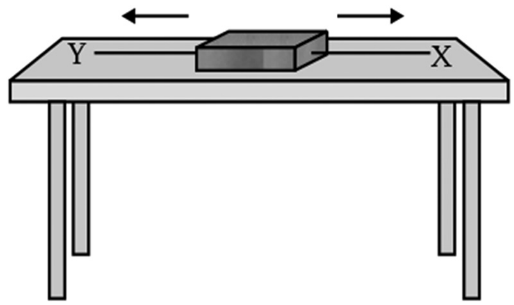


Figure 1.20: Two forces acting on a wooden block

- Forces can be either balanced or unbalanced. When two forces of equal magnitude act on an object from opposite directions, **(Refer to Figure 1.20)** they balance out, resulting in no movement of the object.
- However, if the magnitudes differ, the object will move in the direction of the stronger force. For example, when children try to push a box on a rough floor, (**Refer to Figure 1.21**) the frictional force counters their pushing force. If their force exceeds the frictional force, only then does the box move.
  - Similarly, while riding a bicycle, when we stop pedalling, the bicycle begins to slow down due to frictional forces.

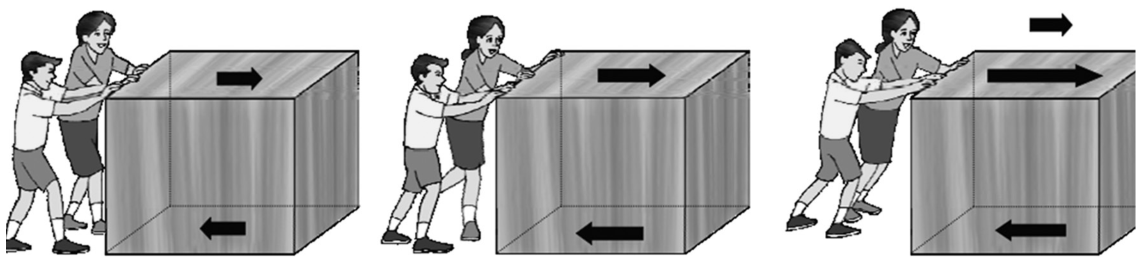


Figure 1.21: Children trying to push a box on a rough floor

- The continuation of an object's motion does not always necessitate a continuous application of unbalanced force. An object moves with uniform velocity when the forces acting on it are balanced. To alter its speed or direction, an unbalanced force must be applied.

First Law of Motion

- Galileo's observations led him to deduce that objects continue to move at a constant speed in the absence of an external force. Newton further evolved this idea, formulating the three fundamental laws governing motion, now known as Newton's laws.
- **Law of Inertia:** The first law, often termed as the law of inertia, states that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force.
- This principle explains various experiences, such as our tendency to move forward when a car suddenly stops or our inclination to fall backwards when a bus starts moving suddenly.

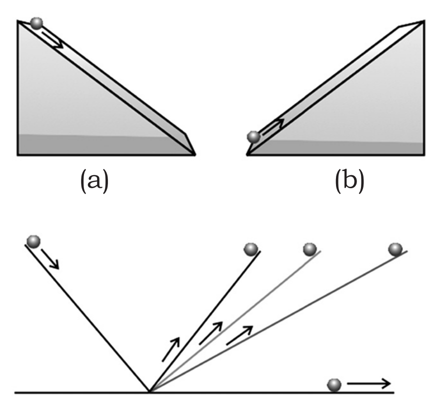
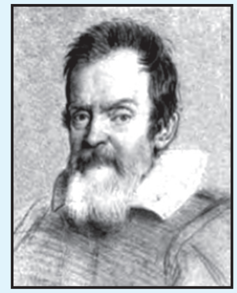


Figure 1.22: (a) the downward motion; (b) the upward motion of a marble on an inclined plane; and (c) on a double inclined plane

About Galileo Galilei:

- ➢ Galileo, born in 1564 in Pisa, Italy, had a profound influence on the understanding of motion. Initially enrolled for a medical degree, he never completed it due to his passion for mathematics.
- ➢ His book, **'The Little Balance'**, introduced Archimedes' method of determining relative densities. In 1589, his essays on motion presented theories about falling objects.
- ➢ Galileo was not only a scientist but also a remarkable craftsman. He developed superior telescopes and even designed the first pendulum clock.
- ➢ His astronomical observations, such as seeing mountains on the moon, the milky way, and bodies orbiting Jupiter, were revolutionary.
- ➢ Through his studies, he countered the then-popular belief, arguing that all planets orbit the Sun and not the Earth.



Galileo Galilei
(1564–1642)

Inertia and Mass

- ✤ All examples and activities discussed emphasize the resistance an object offers to change its state of motion, a property termed as inertia.
- ✤ Objects at rest tend to remain at rest, and those in motion tend to continue moving.
- ✤ Not all bodies have the same level of inertia. For instance, pushing an empty box is easier than pushing a box full of books.
- ✤ If we compare a football and a stone of similar size, kicking the football is easier and less injurious than trying to kick the stone.

POINTS TO PONDER

The Law of Inertia holds that objects tend to be at rest or in uniform motion along a straight line unless acted upon. The mass of the object also influences the inertia. Who do you think will be affected more by a sudden break of a moving bus: a fat person or a thin person?

- ✤ In an activity with coins, a five-rupee coin demands more force to move than a one-rupee coin.
- ✤ Objects with higher mass, like a train, have more inertia than those with less mass, like a cart.
- ✤ The inertia of an object is quantitatively measured by its mass.
- ✤ Inertia is the inherent resistance of an object to change its state of motion or rest. The object's mass quantitatively measures this resistance or inertia.

Second Law of Motion

- ✤ The second law of motion specifies that an unbalanced external force on an object results in a change in its velocity, producing acceleration.
- ✤ **Everyday Observations:** A table tennis ball doesn't hurt a player when hit, but a fast-moving cricket ball can. A stationary truck isn't a threat, but a moving one can be fatal. A bullet, though small in mass, can be deadly when fired.
- ✤ These observations highlight that the impact produced by objects depends on their mass and velocity.

POINTS TO PONDER

What do you think happens if a cricket ball and a bullet both projected at similar speed, which one hurts more? Or do both have similar impacts? What role does mass and velocity play in inducing momentum?

- ✤ To accelerate an object, a greater force is necessary to achieve a higher velocity.
- ✤ **Momentum:** Newton introduced momentum, denoted by p, defined as the product of an object's mass (m) and velocity (v):

$$p = mv$$

- ✧ Momentum has both magnitude and direction. Its direction coincides with the velocity.
- ✧ **Its SI** unit is kilogram-metre per second (kg ms^{-1}).
- ✧ An unbalanced force leads to a change in the object's momentum.

✤ **Using the example of a car with a dead battery:** A sudden push doesn't start it, but a continuous push over time accelerates it to a speed that can start its engine. This implies that momentum change is influenced by both the force magnitude and the duration it's applied.

✤ The second law of motion posits that **the rate of change of momentum of an object is proportional to the applied unbalanced force** and occurs in the direction of this force.

Mathematical Formulation of Second Law of Motion

✤ **Initial Setup:** Consider an object of mass **m** moving in a straight line. It has an initial velocity u and gets uniformly accelerated to velocity v over time t due to a constant force **F**.

- ✧ Initial momentum: $\mathbf{p_1 = mu}$
- ✧ Final momentum: $\mathbf{p_2 = mv}$

✤ **Change in Momentum:**

The change in momentum $(\Delta p) \propto p_2 - p_1$

$$\Delta p \propto mv - mu$$

$$\Delta p \propto m \times (v - u)$$

✤ **Rate of Change in Momentum:** The rate of change is momentum

$$(\Delta p / t) \propto m \times (v - u) / t$$

✤ **Applied Force:**

$$F \propto m \times (v - u) / t$$

$$F = km \times (v - u) / t$$

$$F = kma$$ (**k is the constant of proportionality**)

✤ **SI Units:** Unit of mass is kilogram (kg) and unit of acceleration is m/s^2

- ✧ One unit of force is defined such that k becomes one. Hence, 1 unit of force = k × (1 kg) × (1 ms^{-2}).

✤ Therefore, F = ma (which is the mathematical representation of the second law of motion). Newton (N) is the unit of Force.

✤ **Real-life Observations:**

- ✧ A cricket fielder pulls his hands back **(Refer to Figure 1.23)** while catching a ball to increase the time taken for the ball's velocity to reduce, decreasing the ball's acceleration and impact.
- ✧ In a high jump event, athletes fall on cushioned or sand beds to increase the time taken for their momentum to stop, decreasing the change in momentum and the force of impact.
- ✧ A karate player's ability to break a slab of ice in one blow can also be explained using the second law of motion.

Figure 1.23: A fielder pulls his hands gradually with the moving ball while holding a catch

✤ **Relation with First Law of Motion:**

- ✧ The first law (i.e. objects remain in their state of motion or rest unless acted upon by an external force) can be derived from the second law's mathematical expression.
- ✧ Given F = ma, if F = 0, then v = u for any time t. If the object starts at rest (u = 0), it will remain at rest (v = 0).

Third Law of Motion

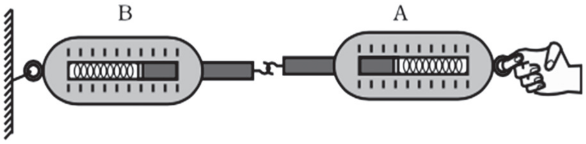


Figure 1.24: Action and reaction forces are equal and opposite

- **Overview:** The third law of motion deals with forces exerted by two objects on each other. When one object exerts a force on a second object, the second object exerts an equal force in the opposite direction on the first object.
  - These forces, termed action and reaction forces, always act on different objects.
- **Football Example:** In football, when players collide, each feels the impact because they exert forces on each other. This interaction results in a pair of forces, not just one.
- **Spring Balance Experiment:** Using two spring balances connected together, (**Refer to Figure 1.24**) if a force is applied to one balance, both show identical readings, but in opposite directions. This illustrates the third law as the force exerted by one balance on the other is equalled by the opposing force of the second balance on the first.
  - This provides an alternative statement for the third law: "**To every action, there is an equal and opposite reaction.**" However, these forces act on two different objects.

POINTS TO PONDER

The third law of motion states that every action has an equal and opposite reaction. By that logic, while it is evident that the earth attracts objects, like an apple falling from a tree, the opposite is also true. Can you think of the variable factor in this case which prevents the earth from moving towards the apple?

- **Walking Example:** When someone tries to walk, they push the ground backwards. In return, the ground exerts an equal and opposite force forwards, propelling the person in the desired direction.
- **Acceleration & Mass:** While action and reaction forces are equal, they may not produce equal accelerations if the objects have different masses.
  - **Gun and Bullet Example:** When firing a gun, the gun exerts a force propelling the bullet forward (**Refer to Figure 1.25**). The bullet exerts an equal force backward on the gun, resulting in the gun's recoil. The gun, being much heavier than the bullet, has less acceleration than the bullet despite the forces being equal.
- **Sailor and Boat Example:** If a sailor jumps forward from a rowing boat, the boat moves backwards. The forward force exerted by the sailor on the water or ground is countered by an equal backward force exerted by the water or ground on the boat. (**Refer to Figure 1.26**).

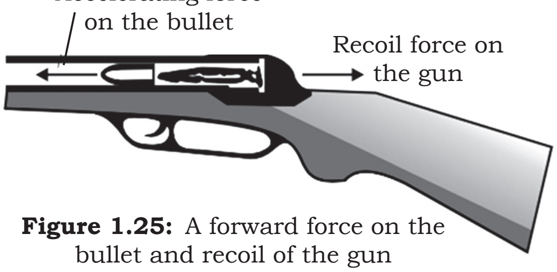


Figure 1.25: A forward force on the bullet and recoil of the gun

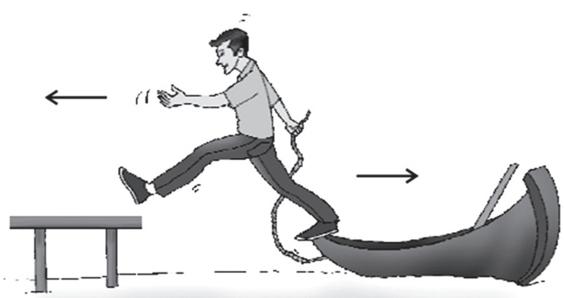


Figure 1.26: As the sailor jumps in forward direction, the boat moves backwards

Gravitation

Gravitation is the force responsible for the attraction between objects with mass. It is responsible for the motion of celestial bodies and objects falling towards the Earth. Sir Isaac Newton established the concept of the gravitational force.

- **Moon's Motion:**
  - The moon revolves around the earth.
  - Newton postulated that the same force that causes an apple to fall to the ground also keeps the moon in its orbit around the Earth.
  - Although the moon seems to orbit the Earth without falling towards it, that is where the concept of centripetal force comes into play.

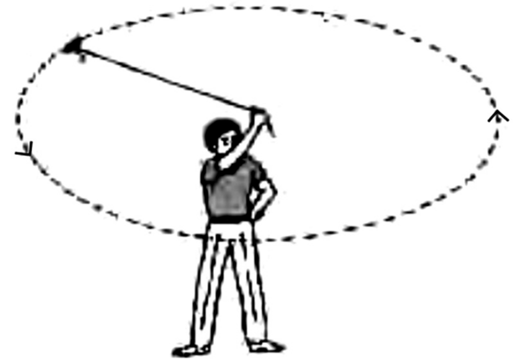


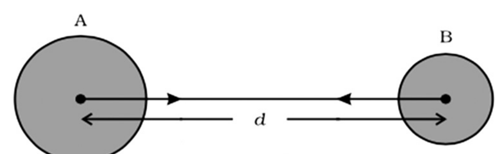
Figure 1.27: A stone describing a circular path with a velocity of constant magnitude

- **Centripetal Force:** When an object moves in a circular path, **(Refer to Figure 1.27)** the force that keeps it moving along that path and prevents it from flying off in a straight line is called the centripetal force.
  - Without this force, an object in motion would continue in a straight line, tangent to the circular path.
  - **Moon and Centripetal Force:** The moon's orbit around the earth can be attributed to centripetal force. This force is a result of the gravitational attraction between the Earth and the moon. If the gravitational force is absent, the moon would not revolve around the Earth but would move in a straight line.
- **Apple & Earth Attraction:** While it is evident that the earth attracts objects, like an apple falling from a tree, the opposite is also true. According to Newton's third law, the apple exerts an equal and opposite gravitational force on the earth.
  - However, due to the enormous mass difference between the earth and an apple, the resulting acceleration of the earth towards the apple is minuscule and imperceptible.
- **Celestial Bodies & Gravitation:** Planets in our solar system revolve around the Sun due to the gravitational pull the Sun exerts on them. Newton deduced from these observations that **all objects in the universe exert gravitational forces on each other, irrespective of their size**.
- **Gravitation is a universal force that attracts objects with mass towards each other**. This force is crucial for the functioning of our universe, governing the movement of celestial bodies and determining how objects behave on the Earth.

Universal Law of Gravitation

- Every object in the universe attracts every other object with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.
- **Mathematical Representation:** For two objects A and B of masses M and m respectively, separated by a distance d **(Refer to Figure 1.28)**:

$$F \propto M \times m$$
$$F \propto 1 / d^2$$



$$F = G\frac{Mm}{d^2}$$

Figure 1.28: The gravitational force between two uniform objects is directed along the line joining their centres

Combining both we get:

$$F \propto M \times m / d^2 \text{ or } F = G\,(M \times m / d^2),$$

where **G is the Universal Gravitational Constant.**

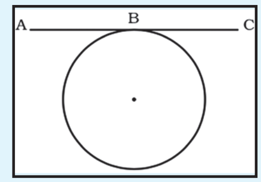
- **Value of G:** The constant *G*, called the universal gravitational constant, has an accepted value of:

$$F \times d^2 = G\,M \times m \text{ or,}$$
$$G = F \times d^2 / M \times m$$

  - This value was determined by **Henry Cavendish** using a sensitive balance.

- **Perceptibility:** While this law means there's a gravitational force between any two objects (like you and your friend), it is usually too much weak to be noticeable unless at least one of the objects has a very large mass, like a planet.
- **Universality:** The law is applicable universally, irrespective of the nature, size, or location of the bodies. For instance, if the distance between two objects is doubled (increases by a factor of 2), the gravitational force between them becomes one-fourth (1/4) of its original value.

> **Tangent to a Circle:** A straight line that touches the circle at only one point without crossing through it is referred to as a tangent.



Importance of The Universal Law of Gravitation

- **Application:** The Universal Law of Gravitation is foundational in understanding the large-scale structure and behaviour of the universe, from why apples fall from trees to the intricate dance of galaxies.
- The Universal Law of Gravitation is crucial because it unifies the understanding of several phenomena. Few of the more common ones are listed as under:
  - **Earthly Attraction:** It explains why things fall towards the Earth.
  - **Moon's Orbit:** The motion of the moon around the Earth is due to the gravitational attraction between them.
  - **Planetary Motion:** Planets orbit the Sun due to gravitational forces.
  - **Tidal Phenomena:** Tides in the oceans are significantly influenced by the gravitational forces exerted by the Moon and, to a lesser extent, the Sun.

Free Fall

- Objects are said to be in free fall when they are only influenced by the gravitational force of the Earth, with no other forces (like air resistance) acting on them.
- **Acceleration due to Gravity (g):** Objects in free fall experience an acceleration towards the Earth due to its gravitational pull. This acceleration is denoted as g (unit: ms^{-2}) and is termed as the "acceleration due to gravity".
- **Gravitational Force on a Falling Object:**

  F = mg

  where:

  m = mass of the object;

  g = acceleration due to gravity

> **POINTS TO PONDER**
>
> The mass of the object influences the free fall of the body. Which do you think falls first to the ground when dropped from similar height: an iron ball or a feather? Can you imagine the result when a similar experiment is conducted in vacuum? Why does the result vary in both these situations?

- **Relation with Universal Gravitational Constant:**

  $mg = G\,(M \times m/d^2)$ or,

  $g = G\,(M/d^2)$,

where:

  G = Universal gravitational constant,

  M = Mass of the Earth,

  R = Radius of the Earth

- **Variation with Latitude:** Earth is not a perfect sphere; it's slightly flattened at the poles and bulges at the equator. Thus, g is slightly greater at the poles than at the equator.

Calculating the Value of g

- Using Known Values:

$$g = G\,(M / R^2)$$

Using values:

$$g = 6.7 \times 10^{-11}\ Nm^2 / kg^{-2} \times 6 \times 10^{24} kg / (6.4 \times 10^6\ m)^2.$$

After calculation, we get

$$g = 9.8\ ms^{-2}$$

Hence, the standard value for the acceleration due to gravity on the surface of Earth is

$$\mathbf{g = 9.8\ ms^{-2}}$$

Motion under Gravitational Influence

- **Galileo's Experiment:**
  - Galileo, in an experiment from the Leaning Tower of Pisa, demonstrated that all objects, irrespective of their mass, fall at the same rate in the absence of air resistance.
- **Equations of Motion in Free Fall:**
  - With gas constant near Earth's surface, equations of uniformly accelerated motion apply. Here, acceleration a is replaced by g:
    - $v = u + gt$
    - $s = ut + \frac{1}{2}gt^2$
    - $v^2 = u^2 + 2gs$
  - Here: u = Initial velocity, v = Final velocity, s = Distance covered in time t
  - The direction of g is taken positive when it's in the direction of motion (downwards) and negative when opposing it (like in case of an object thrown upwards).

Mass

- **Definition:** Mass is a measure of the amount of matter contained in an object.
- **Inertia and Mass:** The more mass an object has, the more inertia it possesses. Inertia is the resistance of any physical object to any change in its state of motion.
- **Constancy:** The mass of an object remains the same regardless of its location. Whether the object is on Earth, the Moon, in outer space, or anywhere else in the universe, its mass will not change. This property makes mass a scalar and universal quantity.

POINTS TO PONDER

Weight of a person varies when he is on the equator and when he is near the poles. Can you tell why this happens? Also does the mass of the person vary in both these locations?

Weight

- **Definition:** Weight is the force exerted on an object due to gravity. It's the force with which an object is attracted towards a massive body, such as a planet.
- **Relation between Weight and Mass:** Weight is dependent on both the mass of an object and the acceleration due to gravity at that particular location.
  - Mathematically, it can be represented as:

    $$W = m \times g$$

  Where

  W = Weight of the object (in newtons)

  m = Mass of the object (in kilograms)

  g = Acceleration due to gravity.
- **Units:** Since weight is a force, its SI unit is the Newton (N).
- **Direction:** Weight is a vector quantity as it has both magnitude (how much force) and direction (towards the center of the massive body, usually downwards towards the center of the Earth).

- **Variability:** Weight of an object can vary depending on where the object is. For instance, an object would weigh less on the Moon than on Earth due to the Moon's lower gravitational acceleration. Conversely, the mass of that object remains constant regardless of location.
- **Measuring Mass via Weight:** In everyday life and many standard conditions on Earth, because g is relatively constant, we often use weight to indirectly measure mass. When we say something "weighs" 10 kilograms, technically it is a misuse of terms, but it is understood colloquially because of the consistent gravity on Earth's surface.
- While mass is a scalar quantity that remains constant regardless of an object's location, weight is a vector quantity that can vary based on local gravitational forces. This distinction is crucial in fields such as physics, astronomy, and space exploration, where objects may be observed or used in various gravitational environments.

Weight of an Object on the Moon

- **Concept:** Just as objects have weight on Earth due to the gravitational force exerted by the Earth, they also have weight on the Moon due to the Moon's gravitational force. However, the Moon's gravitational force is weaker than Earth's because the Moon has less mass.
- **Comparison with Earth:** The weight of an object on the Moon is one-sixth (1/6) of its weight on Earth. This means that if you weigh 60 kg on Earth, you would weigh only 10 kg on the Moon.

Work and Energy

Life Processes and Energy

- All living beings require energy for their life processes and activities. Activities that are more strenuous necessitate more energy. Similarly, animals also need energy for various activities such as running, jumping, or moving away from threats.
- Machines, on the other hand, often require fuel like petrol and diesel to operate.

Work

- **Day-to-day vs. Scientific Definition:**
  - Common parlance treats any physical or mental labor as work. However, by the scientific definition, many activities we consider as "working hard" may involve little to no "work".
  - For example, while we push a huge rock with all our might(power) but fail to move it, or hold a load without being able to move it, it does not qualify as work in science, even if they tire us out.
  - Climbing stairs or a tree involves work because there is displacement against a force.
- **Scientific Conception of Work:**
  - Pushing a pebble, pulling a trolley, and lifting a book are all examples where work is done in the scientific sense.
  - Two conditions must be met for work to be recognized in science:
    - A force should act on an object.
    - The object must undergo displacement.
  - If either condition is unmet, work hasn't been done.
- **Work Done by a Constant Force:**
  - Work is defined as the product of force and the displacement in the direction of the force: $W = F \times s$. (**Refer to Figure 1.29**)
  - Work has only magnitude, not direction.
  - The unit of work is the **newton-meter (N m) or joule (J)**.
  - When force or displacement is zero, the work done is also zero.
  - Work done is positive when force and displacement are in the same direction. Conversely, work is negative when the force acts opposite to the direction of displacement.

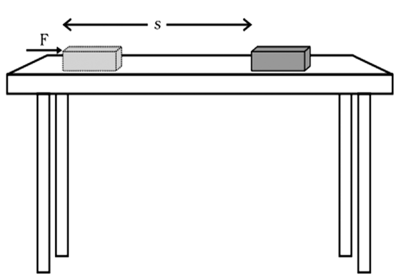


Figure 1.29: The force is acting in the direction of displacement

- **Direction of Force and Work Done:**
  - **Force and Displacement in the Same Direction:**
    - **Example:** A baby pulls a toy car parallel to the ground. (**Refer to Figure 1.30**)
    - The force exerted by the baby is in the direction of the car's displacement. Here, the work done is calculated as the product of force and displacement.
    - In such cases, the work done is taken as positive.

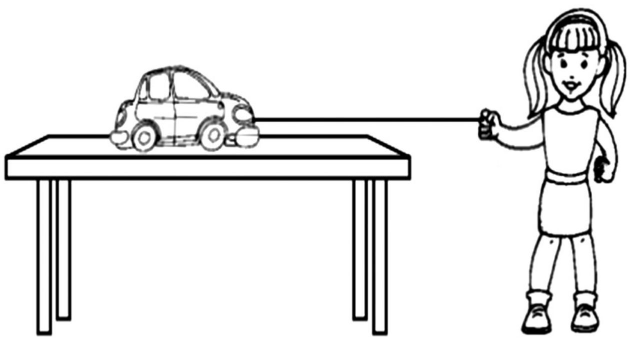


Figure 1.30: A baby pulling a toy car parallel to the ground

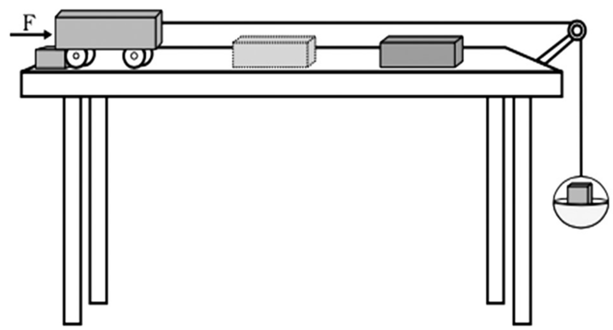


Figure 1.31: A wooden block of known mass in front of the trolley is placed at a convenient fixed distance

  - **Force Opposite to the Direction of Displacement:**
    - Consider an object moving uniformly in one direction. (**Refer to Figure 1.31**)
    - A retarding force, denoted as F, acts opposite to its movement. The angle between the directions of the force and displacement is 180°.
    - If the object stops after displacement 's', the work done by force F is negative. It's represented mathematically as either **F × (–s) or (–F × s)**.

Energy

- Energy is fundamental to life, with the sun being the ultimate source. Other energy sources include atomic nuclei, the Earth's interior, and tides.
- In science, energy is defined as the capability of an object to do work. When an object does work, it loses energy, and the object on which the work is done gains energy.
- Objects with energy can exert a force on another object, transferring energy. Energy is measured in terms of capacity to do work. The unit of Energy is Joule (J). **1 kJ equals 1000 J**.

James Prescott Joule

James Prescott Joule, a British physicist, is renowned for his work on electricity and thermodynamics.
The unit "joule" is named in his honour.

James Prescott Joule (1818–1889)

Forms of Energy

- **Transforamation:** Energy can be converted from one form to another. Numerous instances in nature showcase such conversions.
- Energy exists in various forms: Mechanical (potential + kinetic), heat, chemical, electrical, and light.

- **Kinetic Energy:**
  - Kinetic energy pertains to objects in motion.
  - Examples include a moving bullet, flowing water, or a running athlete.
  - The kinetic energy of an object increases with its speed.
  - The kinetic energy of a body is equivalent to the work done on it to achieve its current velocity.
  - Kinetic energy can be represented by the equation: $E_k = ½\ mv^2$ where E_k is the kinetic energy, m is the mass, and v is the velocity.
- **Potential Energy**
  - Energy stored in an object due to the work done on it, without causing a change in its velocity, is termed as potential energy. (**Refer to Figure 1.32**)
  - **Examples:**
    - Stretching a rubber band stores potential energy within it.
    - Winding the key of a toy car stores potential energy in the spring inside the toy.
  - The potential energy an object possesses is because of its position or configuration.

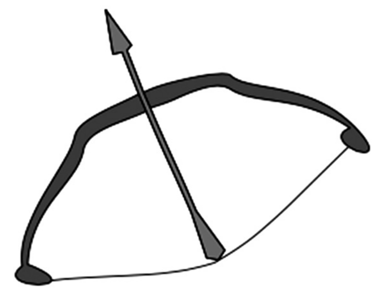


Figure 1.32: An arrow and the stretched string on the bow

- **Potential Energy of an Object at a Height**
  - **Gravitational Potential Energy:** Gravitational potential energy of an object at a height is defined by the amount of work done to raise it from ground level to that height against the gravitational force.
  - **Determining Gravitational Potential Energy:**
    - Consider an object of mass m. Let it be raised through a height h from the ground. (**Refer to Figure 1.33**)
    - The minimum force required to lift the object is its weight, which is mg (where g is the acceleration due to gravity).
    - Work done, W, on the object against gravity is:

$$W = mg \times h = mgh$$

    - The energy gained by the object, which is its potential energy E_p, is then: $E_p = mgh$
  - **Note:** The potential energy of an object at a height is relative to the ground or zero level chosen. An object's potential energy can differ depending on the reference level.
    - The work done by gravity on an object only depends on the difference in its vertical height between initial and final positions, irrespective of the path taken. For instance, if a block is raised from position A to B via two different paths, but the height AB = h, the work done in both cases remains mgh. (**Refer to Figure 1.34**)

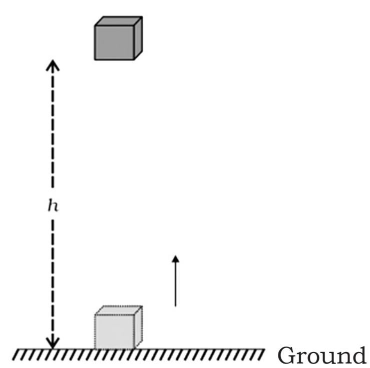


Figure 1.33: An object of mass raised through height

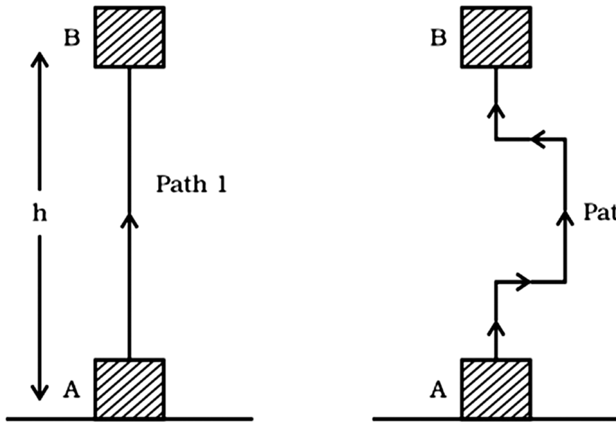


Figure 1.34: A block being raised from position A to B by taking two different paths

Law of Conservation of Energy

- Energy can change from one form to another, yet regardless of how energy transforms, **the total energy of a system remains constant**, this is the law of conservation of energy.
- According to this law, energy can not be created or destroyed but only changed from one form to another. The total energy before and after any transformation remains the same.
- This law holds true across all situations and all types of energy transformations.
- **Example:**
  - When an object with mass, m, falls freely from a height, h, its initial potential energy is mgh while its kinetic energy is zero (since its velocity is zero). As it descends, its potential energy gets converted into kinetic energy.
  - The kinetic energy at any given time during the fall would be $\frac{1}{2} mv^2$, where v is its velocity at that instant.
  - The further it falls, the more its potential energy decreases and its kinetic energy increases.
  - When the object is about to touch the ground, its height h = 0 and velocity v will be at its maximum. Hence, its kinetic energy is maximized while its potential energy is minimized.
  - Throughout the fall, the sum of its potential energy and kinetic energy remains constant, as depicted by the equation: **$mgh + \frac{1}{2} mv^2 = \text{constant}$**
  - The combination of an object's kinetic and potential energy is its total mechanical energy.
  - In the context of the falling object, there's a constant transformation of gravitational potential energy into kinetic energy (assuming we neglect air resistance).

Rate of Doing Work

- Work rate varies among individuals and machines. Different agents transfer energy and perform work at different rates.
- For instance, a stronger individual might complete a task more quickly than someone less strong. Similarly, a more powerful vehicle will cover a distance in a shorter span than a less powerful one.
- The efficiency or capability of machines, like motorbikes and cars, is often described in terms of their power. This essentially indicates the rate at which these machines can perform work or transfer energy.
- **Definition of Power:** Power is a measure of how rapidly work is done or energy is transferred. It can be mathematically represented as:

  Power = Work (W) / Time (t) *i.e.* $P = W/t$

- **Units of Power:**
  - The SI unit of power is the watt (W), named in honor of James Watt.
  - One watt signifies the power exerted when work is done at a rate of 1 joule per second. Thus: 1 watt = 1 joule/second or or 1 W = 1 Js^{-1}
  - For larger energy transfer rates, power is often measured in kilowatts (kW).
    - 1 kilowatt (kW) =1000 watts (W)
    - 1 kW = 1000 W
    - 1 kW = 1000 Js^{-1}
- **Average Power:** Since the power exerted by an agent can fluctuate over time, the notion of average power becomes significant. Average power is computed by dividing the total energy utilized by the overall time spent. It provides a consistent measure of an agent's work rate over a specific time frame.
- Concept of power can be used to distinguish the efficiency of various agents, machines, or individuals.

Force and Pressure

Whenever actions such as kicking, pushing, throwing, or flicking are performed on a ball, a force is applied.

Force – A Push or a Pull:

- **Descriptive Actions:** Activities such as picking, opening, shutting, kicking, hitting, lifting, flicking, pushing, and pulling. (**Refer to figure 1.35**)

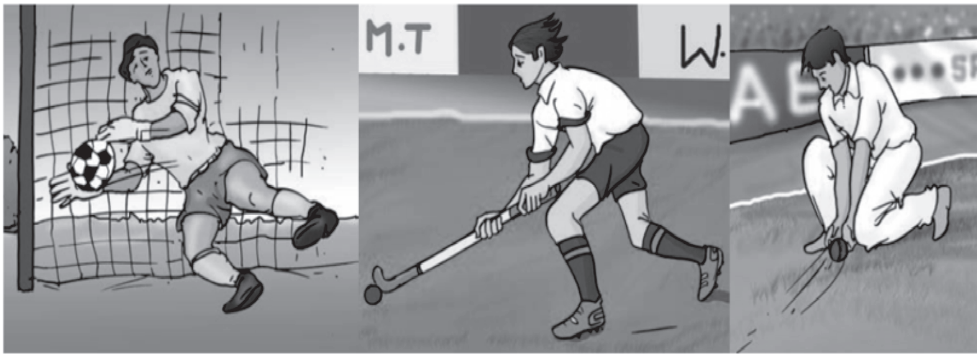


Figure 1.35: (a) A goal keeper saving a goal, (b) A hockey player flicking a ball, and (c) A fielder stopping a ball

- **Impact of Actions:** Each action typically results in an alteration in the object's motion.
- **Grouping Actions:** Most actions can be categorized as either a pull, a push, or sometimes both.
- **Definition of Force:** In scientific terms, a force is described as a push or pull exerted on an object, causing it to move.

Forces Result from Interactions

- **Illustrative Scenario:** A stationary car with a man behind it. Simply being behind the car doesn't cause it to move. On pushing the car, it responds by moving in the direction of the applied force. (**Refer to figure 1.36 (a) and (b)**)
- **Instances of Interactions:**
  - Two girls pushing each other. (**Refer to Figure 1.37 (a)**)
  - Two girls pulling each other. (**Refer to Figure 1.37 (b)**)
  - A man and a cow in a tug-of-war. (**Refer to Figure 1.37 (c)**)

(a) (b)

Figure 1.36: (a) A man standing behind a stationary car, (b) A car being pushed by a man

(a) (b) (c)

Figure 1.37: (a) Who is pushing whom? (b) Who is pulling whom? (c) Who is pulling whom?

- **Insight:** A force emerges from the interaction between two objects at least. Consequently, when one object interacts with another, a force is generated between them.

Delving Deeper into Forces

- **Tug-of-War Example:** Two opposing teams exert force on a rope. (**Refer to Figure 1.38**)
- Occasionally, the rope remains stationary. The team exerting a greater force typically emerges as the winner.
- **Understanding Force:**
  - When forces are applied in the same direction, they accumulate.
  - If forces act in contrasting directions, the resultant force is their difference.
  - In scenarios like a tug-of-war, equal forces from opposing directions mean no movement.

Figure 1.38: The rope may not move if the two teams pull at it with equal force

- **Characteristics of Force:**
  - Force is characterized by its magnitude.
  - The direction of a force is as crucial as its strength.
  - Altering the force's direction or magnitude modifies its effects.

A Force can Change the State of Motion

- **Experiment with a Ball:**
  - When you gently push a stationary rubber ball on a level surface, it begins to move. (Refer to Figure 1.39)

Figure 1.39: A ball at rest begins to move when a force is applied on it

- Pushing the moving ball either increases or decreases its speed based on the direction of the force.
- Placing your palm momentarily in front of the moving ball applies a force. The speed of the ball may change depending on the nature of the contact.

- **Football Analogy**
  - Before a penalty kick, the ball is stationary with zero speed.
  - The player's kick applies force, causing the ball to move towards the goal.
  - A goalkeeper's dive to save the goal applies force to the ball which can stop or deflect it, reducing its speed to zero.
- **Observation:**
  - A force on an object can change its speed.
  - If force direction aligns with the object's motion, its speed increases.
  - Opposite directional force results in decreased speed of the object.
- **Children's Game with Tyre:** Children push a rubber tyre to move it, increasing its speed with every push. (**Refer to Figure 1.40**)

Figure 1.40: To move a tyre faster it has to be pushed repeatedly

- **Change in Direction due to Force:**
  - Pushing a moving ball and placing a ruler in its path can change its direction based on the angle at which the ball strikes the ruler.
  - Volleyball players apply force to the ball to direct it, changing both speed and direction.
  - In cricket, batsmen apply force on the ball with their bat, altering its direction.
  - Both speed and direction of the ball can change due to force application. (**Refer to Figure 1.41**)

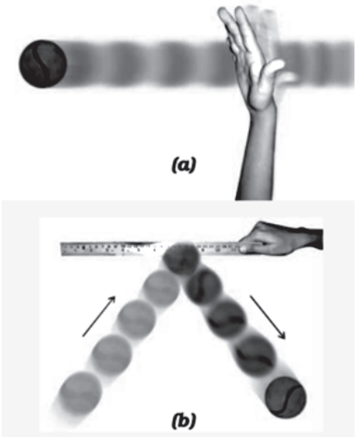


Figure 1.41: (a) A ball set in motion by pushing it along a level surface and (b) the direction of motion of the ball after it strikes the ruler placed in its path

- **Defining State of Motion:** An object's state of motion comprises its speed and direction. Rest represents a state of zero speed. A change in speed, direction, or both, equates to a change in an object's state of motion. Both motion and rest are considered states of motion.
- **Impact of Force on State of Motion:** Force does not necessarily alter the state of motion of an object. For example, a heavy box which does not move regardless of the applied force or a wall which remains unaffected when pushed.

Force can Change the Shape of an Object:

- **Examples of Force Changing Shape:** Inflated balloon changes its shape when pressed, rolling a ball of dough into a chapati changes its form and pressing a rubber ball on a table modifies its shape etc.
- **Conclusion from Observations:** Based on the above observation, we can say that Force can:
  - Initiate motion in a stationary object.
  - Change an object's speed.

- ✧ Alter the direction of motion.
- ✧ Modify the shape of an object.
- ✧ Cause combinations of the above effects.

✤ **Importance of Force:** Actions such as movement, change in speed, direction or shape require the presence of a force. Objects can't initiate these changes by themselves.

Contact Forces:

✤ **Muscular Force:**

- ✧ Actions like pushing a book or lifting a bucket necessitate physical contact to apply force. This interaction often stems from our body's muscles. Hence, termed muscular force.
- ✧ Animals like bullocks, horses, and camels also use muscular force for tasks. (**Refer to Figure 1.42**). As muscular force requires direct contact, it's categorized as a contact force.

Figure 1.42: Muscular force of animals is used to carry out many difficult tasks

✤ **Friction:**

- ✧ **Observations:**
  - ❒ A rolling ball stops eventually.
  - ❒ A bicycle, when not pedaled, slows down and stops.
  - ❒ A vehicle halts when its engine is turned off.
  - ❒ A boat stops moving once rowing ceases.
- ✧ Despite no visible force acting, these objects cease motion due to a contact force known as friction. Friction arises from surface interactions and operates opposite to the motion's direction.

Non-contact Forces

✤ **Magnetic Force:**

- ✧ **Experiment with Bar Magnets:** Using two bar magnets and rollers, it is observed that without touching each other, one magnet influences the movement of the other. (**Refer to Figure 1.43**)
- ✧ **Inference:** Magnets exhibit either attraction or repulsion depending on their poles. This force between magnets occurs even without direct contact. Thus, the force exerted by a magnet, either on another magnet or on iron, exemplifies a non-contact force.

Figure 1.43: Observing attraction and repulsion between two magnets

✤ **Electrostatic Force:**

- ✧ **Experiment with Plastic Straws:** Rubbing one end of a plastic straw with paper charges it. When brought close to another similarly charged straw (without contact), there's a noticeable influence on its behavior. (**Refer to Figure 1.44**)

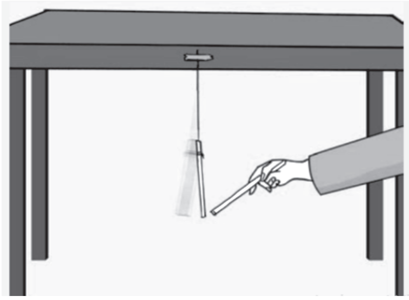


Figure 1.44: A straw rubbed with paper attracts another straw but repels it if it has also been rubbed with a sheet of paper

- **Inference:** Rubbing gives the straw an electrostatic charge. The force exerted by one charged body on another, whether charged or uncharged, is termed electrostatic force, a non-contact force.

- **Gravitational Force:**
  - **Observations:** Objects like coins or pens fall when dropped; fruits and leaves descend when detached from plants.
  - **Inference:** The change in the state of motion indicates the influence of a force. This force, which makes the objects fall towards the Earth, **is called gravitational force or gravity**. All objects experience this constant force.

Thrust and Pressure

- **Thrust:**
  - **Definition:** The force acting on an object perpendicular to the surface is called thrust.
  - **Application:** When you push a pin into a board, you're applying thrust.
- **Pressure:**
  - **Definition:** Pressure measures the amount of force applied per unit area. It is calculated as **Pressure = thrust/area**.
  - **Unit:** The SI unit of pressure is **Pascal (Pa)**, which is equivalent to N/M^2 or Nm^{-2}. It was named after the French mathematician and physicist, Blaise Pascal.
  - **Concept:** Pressure depends on the amount of thrust and the area over which it is distributed. If you exert the same force (or thrust) over a smaller area, the pressure is greater and vice-versa.
  - **Further Interpretations:**
    - **Situation 1:** When fixing a poster using drawing pins, **(Refer to Figure 1.45)** the force applied by your thumb on the pin's head is spread out on its broader end but focuses on a much tinier area at its pointed tip.
    - **Situation 2:** Standing versus lying on loose sand presents different outcomes because of pressure distribution. Standing makes your feet sink due to the force (your weight) acting on the smaller area of your feet. Conversely, when lying down, the same force spreads over a larger contact area, which means less sinking.

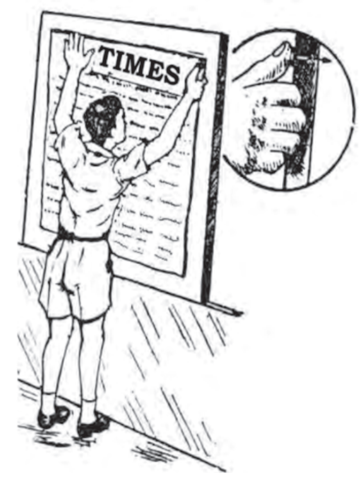


Figure 1.45: To fix a poster, drawing pins are pressed with the thumb perpendicular to the board

  - **Real-life Applications:**
    - **Camel's Feet:** A camel can walk on desert sand without sinking because its feet are wide. This distributes the camel's weight over a larger area, reducing the pressure on the sand.
    - **Tank's Continuous Chain:** A tank uses a continuous chain to distribute its heavy weight over a large surface area, reducing the pressure on the ground and preventing it from sinking in.
    - **Wide Tyres:** Trucks and Buses have wide tyres to distribute their heavy weight over a larger surface area, thereby reducing the pressure on roads.
    - **Sharp Tools:** Cutting tools like knives and needles have sharp edges or points to concentrate the force over a very tiny area, producing a large pressure that can easily cut or pierce materials.

- **Pushing a Nail:** The pointed end of a nail can more easily penetrate a wooden plank than its head, indicating that the same amount of force applied over a smaller area results in a greater effect. **(Refer to Figure 1.46)**
- **Porters Carrying Load:** Porters place a round piece of cloth on their heads, when they have to carry heavy loads. By doing this they increase the area of contact of the load with their head. So, the pressure on their head is reduced and they find it easier to carry the load. **(Refer to Figure 1.47)**

Figure 1.46: Pushing a nail into a wooden plank

Pressure Exerted by Liquids and Gases

- **Pressure Exerted by Liquids:**
  - In experiments involving rubber sheets covering a container, it is observed that as water is poured into the container, the rubber sheet bulges out. The greater the volume or height of the water, the more the rubber bulges, indicating that liquids exert pressure not only on the base but also on the walls of their container. **(Refer to Figure 1.48 and 1.49)**

Figure 1.47: A porter carrying a heavy load

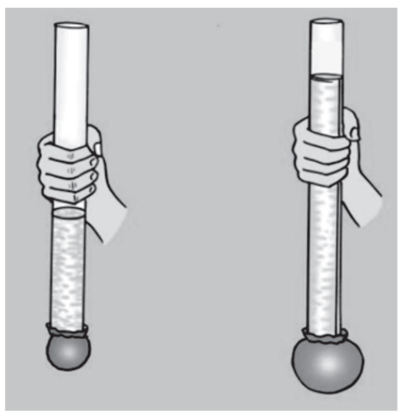


Figure 1.48: Pressure exerted by water at the bottom of the container depends on the height of its column

Figure 1.49: A liquid exerts pressure on the walls of the container

  - By drilling holes into a bottle, we observe that water flows out of all the holes, and if the holes are at the same height, the water will fall at the same distance from the bottle. This experiment indicates that liquids exert uniform pressure at the same depth or height on the walls of their container. **(Refer to figure 1.50)**

Figure 1.50: Liquids exert equal pressure at the same depth

- **Pressure Exerted by Gases:**
  - When inflating a balloon, air fills up the available space. If the balloon's mouth isn't sealed, the air rushes out when released, which demonstrates that the air inside was exerting pressure on the inner walls of the balloon. If the balloon has holes, it won't inflate because the air would escape, further illustrating that gases exert pressure on their container's walls.

- In the context of a bicycle tyre, if there's a puncture, air rushes out. This shows that the air inside exerts pressure on the inner walls of the tube.

Atmospheric Pressure

- **Understanding Atmospheric Pressure:** Earth's atmosphere, which extends for many kilometres above its surface, exerts a pressure on us known as atmospheric pressure. This pressure comes from the weight of the column of air above us and is equivalent to the force of gravity on that column of air. **(Refer to Figure 1.51)**
- **Experiment with Rubber Sucker:** The rubber sucker experiment demonstrates the strength of atmospheric pressure. When the sucker is pressed against a smooth surface, most of the air between the sucker and the surface is forced out. **(Refer to Figure 1.52)**
  - The atmospheric pressure outside then presses the sucker against the surface, making it difficult to pull it off. If no air was trapped between the sucker and the surface, it would be almost impossible for anyone to pull the sucker off, illustrating the magnitude of atmospheric pressure.
- **Magnitude of Atmospheric Pressure:**
  - Consider the weight of air in a column that has a base area of 15cm × 15cm and extends up to the height of the atmosphere. **(Refer to Figure 1.53)**
  - The force exerted by this air is roughly equivalent to the gravitational force on an object weighing 225 kg. This force corresponds to a pressure of approximately 2250N.
  - Our bodies are adapted to this pressure, and the internal pressure within our bodies balances out the atmospheric pressure, preventing us from being crushed.

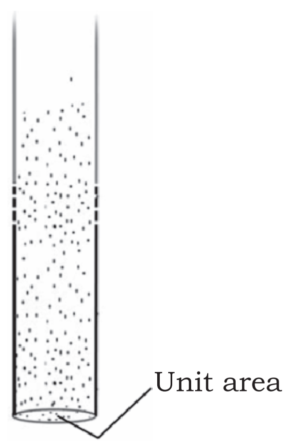


Figure 1.51: Atmospheric pressure is the force of gravity on air in a column of unit area

Figure 1.52: A rubber sucker pressed on a surface

Figure 1.53: Pressure of atmosphere on your head

Otto von Guericke's Experiment

- In the 17th century, Otto von Guericke's experiment with two hollow metallic hemispheres showcased the might of atmospheric pressure.
- After removing the air from the inside of the joined hemispheres using a pump, even 16 horses (eight on each hemisphere) couldn't separate them. (**Refer to figure 1.54**)

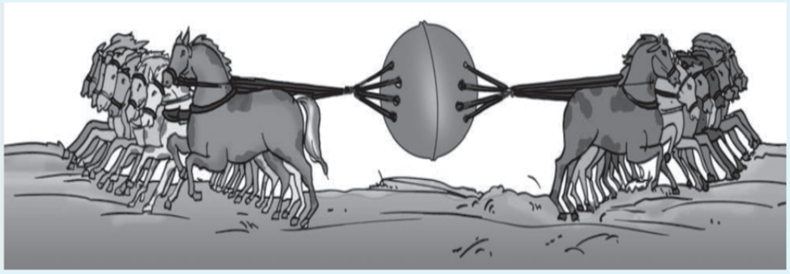


Figure 1.54: Horses pulling the hemispheres

- This is a powerful illustration of the immense force exerted by the atmosphere due to its pressure.

Buoyancy

Buoyancy can explain certain observations, such as feeling lighter while swimming or why a massive iron ship floats while an equivalent amount of iron in a sheet form sinks.

- When an object like a bottle is submerged in water, it experiences gravitational pull downwards. Simultaneously, water pushes it upwards, exerting an opposing force.
- If the upward force exerted by the water (buoyant force) surpasses the object's weight, the object rises upon release.
- To submerge an object entirely in water, the upward force due to water needs to balance out. This balance requires an external force acting downwards to counter the difference between the upward force and the object's weight.
- The force that the water applies upwards on an object is termed as **"upthrust" or "buoyant force"**. Every object experiences this buoyant force when immersed in a fluid. The intensity of this force depends on the fluid's density.

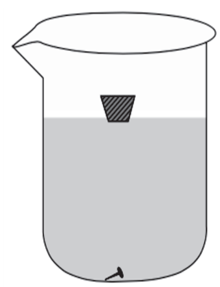


Figure 1.55: An iron nail sinks and a cork floats when placed on the surface of water

Why Do Objects Float or Sink When Placed on the Surface of Water?

The behaviour of objects, whether they float or sink, is closely linked to their density in relation to the fluid they are placed in.

- An experiment with a beaker filled **(Refer to Figure 1.55)** with water reveals that when an iron nail is placed on the water's surface, it sinks. This is because the gravitational force pulling the nail downwards surpasses the upthrust of water on the nail.
- Conversely, a cork floats because its density is lower than that of water. The water's upthrust on the cork exceeds the cork's weight, causing it to remain afloat.
- In contrast, the density of an iron nail exceeds that of water. Hence, the upthrust of water on the nail is insufficient to counterbalance the nail's weight, making it sink.
- Conclusively, objects with a density lower than the liquid will float, while those with a higher density will sink.

POINTS TO PONDER

A small rock of a few kgs sinks in the water while a huge ship of several tonnes of weight doesn't. Can you think why this happens? How does the buoyant force act and what factors influence such a behavior?

Archimedes' Principle

Experiment

- A stone is tied to a rubber string or a spring balance **(Refer to Figure 1.56)**.
- The stone is suspended, causing elongation in the string or a specific reading on the spring balance due to the stone's weight.
- The stone is gradually immersed in water. As it gets submerged, the elongation of the string or the reading on the spring balance decreases.

Observation

- The elongation or the reading decreases as the stone is immersed in water, with no further change once the stone is fully submerged.

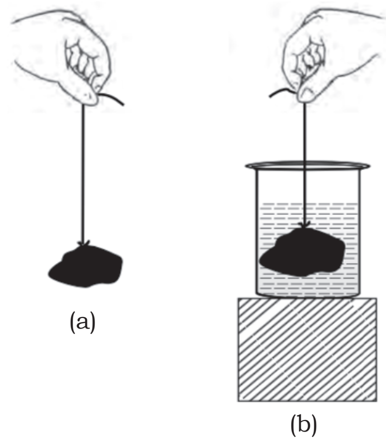


Figure 1.56: (a) Observe the elongation of the rubber string due to the weight of a piece of stone suspended from it in air.
(b) The elongation decreases as the stone is immersed in water

Inference

- The elongation in the string or the spring balance reading is a result of the stone's weight.
- When this elongation or reading decreases upon immersion in water, it suggests that an upward force is acting on the stone.
- This force, which opposes the stone's weight and results in decreased tension on the string or spring balance, is termed as the **buoyant force or force of buoyancy**.

Archimedes' Principle

- Whenever a body is completely or partially submerged in a fluid, it experiences an upward force. This force is equivalent to the weight of the fluid that the body displaces.
- This principle answers why there's no further decrease in elongation once the stone is fully submerged: The amount of displaced fluid remains constant, and thus the buoyant force does not increase further.
- **Applications**
  - Archimedes' principle is fundamental in designing marine structures such as ships and submarines.
  - Instruments like **lactometers** (measuring milk purity) and **hydrometers** (determining liquid densities) also operate based on this principle.

Archimedes:

- Archimedes was a renowned Greek scientist who discovered the principle now named after him. This principle further aided him in verifying the purity of a gold crown meant for the king.
- Apart from this, Archimedes is acclaimed for his contributions to geometry and mechanics. His profound understanding of mechanisms like levers, pulleys, and wheels-and-axle notably benefited the Greek army during their confrontations with the Romans.

Archimedes

Friction

Friction is the reason a car stops when brakes are applied, a ball rolling on the ground eventually stops, and why we might slip on a banana peel or find it challenging to walk on a wet floor. **(Refer to Figure 1.57)**

Force of Friction

- When an object, like a book, is pushed on a surface, it doesn't keep moving indefinitely. It stops after traveling some distance. The force that opposes its motion is called friction. **(Refer to Figure 1.58)**
- For instance, if you push the book to the left, friction acts to the right and vice versa. Friction always opposes the direction of the applied force. It acts between the two surfaces in contact, in this case, the book and the table.

Figure 1.57: A boy falls down when he steps on a banana peel

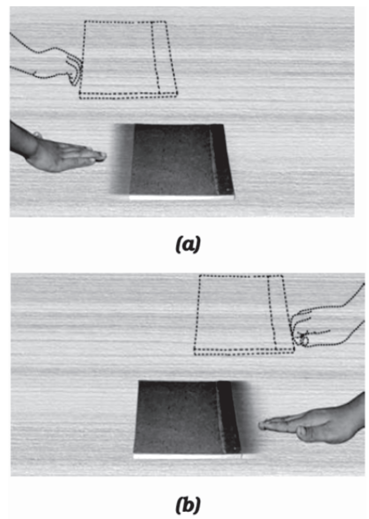


Figure 1.58: (a) (b) Friction opposes relative motion between the surfaces of the book and the table

Factors Affecting Friction

- To understand the factors that influence friction, consider an experiment with a brick. **(Refer to Figure 1.59)** When you pull the brick using a spring balance, the reading just before it starts moving indicates the friction between the brick and the floor.
- Wrapping the brick in different materials, like polythene or jute, and then pulling it will yield different readings, suggesting that the nature of the surfaces in contact affects the amount of friction.

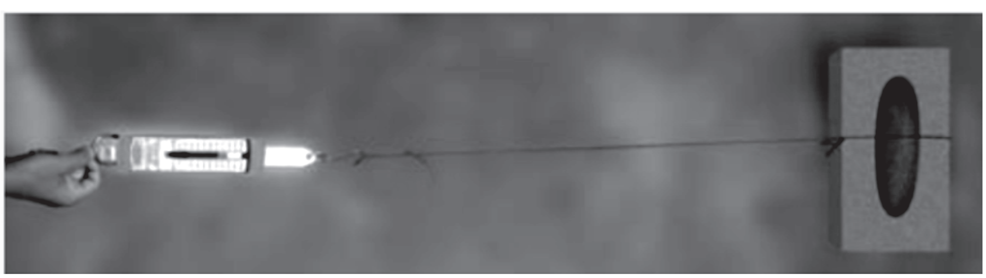


Figure 1.59: A brick is being pulled by spring balance

- **Spring Balance:** This device measures the force acting on an object. It has a spring that stretches proportionally to the force applied.
  - The amount of stretching is indicated by a pointer on a scale, providing a reading of the force. **(Refer to Figure 1.60)**

Figure 1.60: Spring Balance Device

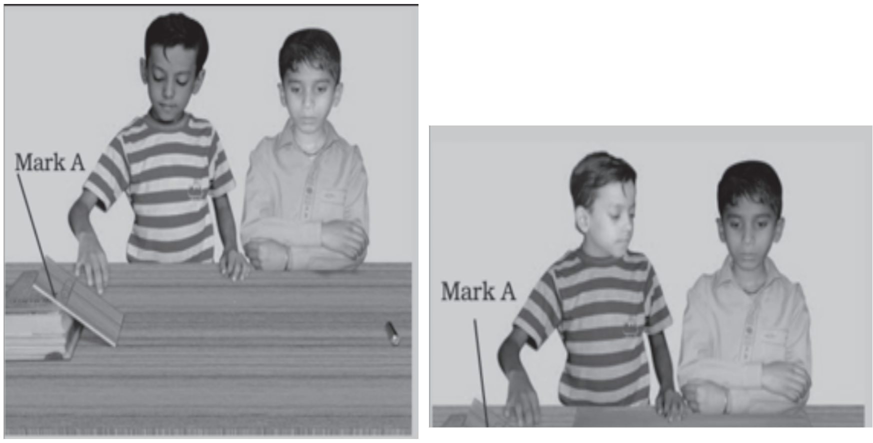


Figure 1.61: (a) (b) The pencil cell covers different distances on different surfaces

- **Experiment with Inclined Plane:** To further understand friction, consider a pencil cell sliding down an inclined plane onto a table. **(Refer to Figure 1.61)**
  - The distance the cell travels before coming to a stop varies based on the surface it encounters after the incline, whether it's a bare table, a table covered in cloth, or one sprinkled with sand. This indicates that the nature of the surface affects the frictional force.
- **Nature of Surfaces and Friction:** While some surfaces may appear smooth, they often have microscopic irregularities. **(Refer to Figure 1.62)** Friction arises because of the interlocking of these irregularities when two surfaces come in contact.
  - Rougher surfaces, with more irregularities, produce higher friction. If the surfaces are pressed harder against each other, the friction also increases, as the interlocking becomes more pronounced.
- **Static and Sliding Friction:**
  - When trying to move a stationary object, the initial force required to start the motion is often higher than the force needed to keep it moving. **(Refer to Figure 1.63)**
  - This initial force counters static friction. Once the object is in motion, the friction encountered is called sliding friction, which is usually a bit less than static friction.

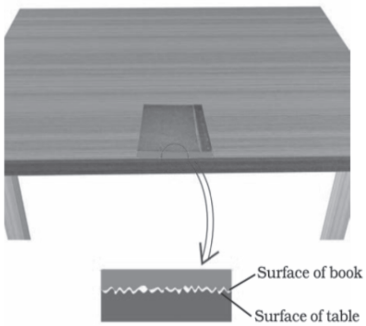


Figure 1.62 Surface irregularities

Figure 1.63: You have to push on the box to keep it moving

✤ This is because, during sliding, the surfaces in contact do not have enough time to lock into each other as firmly as when they were stationary.

Friction: A Necessary Evil

✤ **Positive Aspects of Friction**

- ✧ Friction is essential for many of our daily activities. It allows us to grip objects, like a glass or an earthen pot. If these objects were greasy, it would be harder to hold them because friction would be reduced.
- ✧ Walking would be nearly impossible without friction, as evidenced by the difficulty we face on slippery surfaces.
- ✧ Writing with pen, pencil, or chalk requires friction between the writing instrument and the surface.
- ✧ Friction between the tires of vehicles and the road allows them to start, stop, and turn.
- ✧ Building and construction activities, like fixing a nail on the wall **(Refer to Figure 1.64)** or tying a knot, depend on friction.

Figure 1.64: A nail is fixed in the wall due to friction

✤ **Negative Aspects of Friction**

- ✧ Friction causes wear and tear of materials, such as screws, ball bearings, shoe soles, **(Refer to Figure 1.65)** and even infrastructure like the steps of over-bridges at stations.
- ✧ It can produce heat, leading to energy wastage. For example, when palms are rubbed vigorously, **(Refer to Figure 1.66)** they feel warm. Striking a matchstick produces fire due to frictional heat. **(Refer to Figure 1.67**) Similarly, machines like mixers heat up due to friction, causing energy losses.

Figure 1.65: Soles of shoes wear out due to friction

Figure 1.66: Rubbing of your palms makes you feel warm

Figure 1.67: Stricking a matchstick produces fire by friction

Increasing and Reducing Friction

✤ **Increasing Friction:** In many situations, increased friction is beneficial, such as:

- ✧ Shoe soles and tires are grooved or treaded to provide better grip with the ground. **(Refer to Figure 1.68)**

- Brake systems in vehicles use friction to stop movement.
- Kabaddi players and gymnasts use soil or coarse substances, respectively, to enhance grip by increasing friction.

Figure 1.68: (a) (b) (a) Soles of shoes and (b) tyres are treaded to increase friction

- **Reducing Friction:** There are instances when it is desirable to decrease friction:
  - Fine powder on a carrom board makes the striker and coins move smoothly. **(Refer to Figure 1.69)**
  - Lubricants like oil, grease, and graphite **(Refer to Figure 1.70)** are used to reduce friction between machine parts, forming a layer that prevents direct surface-to-surface contact. This avoids the interlocking of surface irregularities, resulting in smoother movement.
  - In cases where traditional lubricants might not be suitable, other methods like air cushions between moving parts are used to reduce friction.

Figure 1.69: Powder is sprinkled on the carrom board to reduce friction

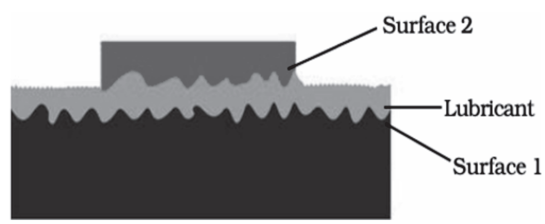


Figure 1.70: Action of lubricant

Wheels Reduce Friction

- Wheels are one of humanity's most impactful inventions, mainly because they significantly reduce friction.
- When an object rolls over another, the resistance is **termed "rolling friction"**, which is usually much less than "sliding friction".
- This is illustrated by the ease with which a book moves over cylindrical pencils placed parallelly under it, rolling them forward. **(Refer to Figure 1.71)** Similarly, heavy machinery is sometimes moved by placing logs underneath, allowing it to roll.
- Luggage with wheels or rollers exemplifies the advantage of rolling over sliding. By reducing friction, rolling makes it much easier to transport even heavy loads. **(Refer to Figure 1.72)**
- This principle is implemented in machines using ball bearings, which replace sliding with rolling, thus reducing friction and wear. Common applications of ball bearings **(Refer to Figure 1.73)** include the hubs and axles of ceiling fans and bicycles.

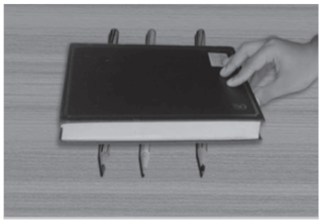


Figure 1.71: Motion of the book on rollers

Figure 1.72: Rolling reduces friction

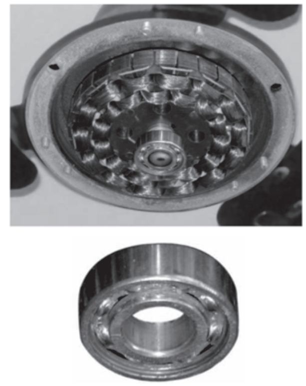


Figure 1.73: Ball bearings reduce friction

Fluid Friction

- Despite being thin and light, fluids, which encompass both gases (like air) and liquids, exert frictional forces on objects moving through them. This frictional force exerted by fluids is termed "drag". The amount of drag an object experiences in a fluid depends on:
  - Its speed relative to the fluid.
  - The shape of the object.
  - The nature of the fluid.
- To ensure efficiency and minimize energy loss due to friction, objects are designed to have streamlined shapes that reduce fluid friction.
- Nature provides numerous examples of optimal shapes to minimize drag. Birds and fishes, which navigate through fluids continuously, have evolved streamlined body shapes to efficiently overcome friction.
- Drawing inspiration from nature, engineers design vehicles, especially aircraft, with shapes that minimize drag, making them more energy-efficient and faster. **(Refer to Figure 1.74)**

POINTS TO PONDER

Suppose there exists a completely friction free carrom board, what do you think happens to a coin sliding on it? Will it be in perpetual motion? Or will it eventually lose energy in some form to come to a halt?

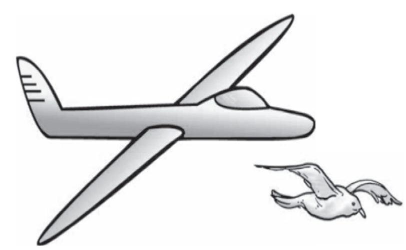


Figure 1.74: Similarity in shapes of an aeroplane and a bird

Conclusion

The physical world operates on a series of interconnected principles. The relationship between force, pressure, and friction provides a foundation that determines how objects move and interact. Time, an ever-forward marching dimension, and the measurement of distances, help quantify and understand this motion, giving us the ability to plan, predict, and innovate. By internalizing these concepts, whether it's appreciating the friction that prevents us from slipping or calculating the time and distance of our commutes, we gain a profound appreciation for the forces that shape our everyday experiences. These principles not only ground us in reality but propel us forward, guiding our innovations and discoveries.

Glossary:

- **Force:** A push or pull upon an object resulting from its interaction with another object.
- **Pressure:** The force applied per unit area.
- **Area:** The size of a surface or the extent of a 2D shape in a plane.
- **Liquid Pressure:** The pressure exerted by liquids on the walls of their container.
- **Gas Pressure:** The pressure exerted by gases on their container's walls.
- **Atmospheric Pressure:** The force exerted onto a surface by the weight of the air above that surface in the atmosphere.
- **Friction:** The force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.
- **Static Friction:** The force between two objects that are not moving relative to each other.
- **Sliding Friction:** Friction that occurs when an object slides over a surface.
- **Rolling Friction:** Friction that occurs when an object rolls over a surface.
- **Motion:** The action or process of moving or being moved.
- **Time:** A continuous, measurable quantity in which events occur in a sequence proceeding from the past through the present to the future.
- **Distance:** A numerical description of how far apart objects are.
- **Measurement:** The action of measuring something.
- **Lubricant:** A substance introduced to reduce friction between surfaces in mutual contact.
- **Fluid Friction:** Resistance to an object's motion through a liquid or gas.
- **Atmosphere:** The envelope of gases surrounding Earth or another planet.
- **Gravity:** The force by which a planet or other body draws objects toward its center.
- **Surface Irregularities:** Microscopic deformities or roughness on a surface that lead to friction.
- **Pressure Exertion:** The act of applying force onto a surface.
- **Uniform Pressure:** Equal force exerted across a surface.
- **Inclined Plane:** A flat surface set at an angle or incline with no moving parts used to raise or lower a load.
- **Spring Balance:** A weighing scale used to measure the weight of an object, especially by the tension of a spring.
- **Bearing:** A machine element that constrains relative motion to only the desired motion.
- **Liquids:** A state of matter with a definite volume but no fixed shape.
- **Gases:** A state of matter without a defined shape or volume.
- **Sharp Edges:** Edges that are thin and fine-tuned, often used to concentrate force.
- **Tread:** The pattern that's sculpted into the flat parts of automobile tires to improve their grip on the road.
- **Groove:** A narrow, linear cut or indentation in a hard material.
- **Air Cushions:** A technique used to reduce friction by allowing objects to glide over a thin layer of air.
- **Ball Bearings:** A type of rolling-element bearing that uses balls to maintain the separation between moving parts.
- **Roller:** A cylinder that rotates around its own axis and aids in motion.
- **Puncture:** A small hole caused by a sharp object.
- **Machines:** Devices that transmit or modify force or motion.

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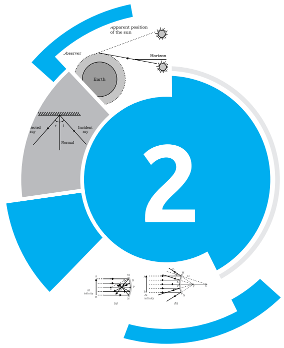


2 Light

Bibliography: This chapter encompasses the summary of **Chapter 8 - Class VI** NCERT (Science), **Chapter 11 - Class VII** NCERT (Science), **Chapter 13 - Class VIII** NCERT (Science) and **Chapters 9 and 10 - Class X** NCERT (Science).

Introduction

An object reflects light that falls on it. This reflected light is received by our eyes and enables us to see things. We are able to see through a transparent medium as light is transmitted through it. Objects like the sun which gives out or emits light of their own are called **luminous** objects. To see a shadow a source of light and an opaque object is needed. The shadow can be seen only on a screen. The ground, walls of a room, a building, or other such surfaces act as a screen for the shadows we observe on a daily basis. There are a number of phenomena associated with light such as image formation by mirrors, the twinkling of stars, the beautiful colours of a rainbow, bending of light by a medium and so on. A study of the properties of light is a prerequisite to understand these phenomena.

Laws of Reflection

- After striking the mirror, the ray of light is reflected in another direction. The light ray, which strikes any surface, is called the **incident ray**. The ray that comes back from the surface after reflection is known as the **reflected ray**.
- **First Law of Reflection:** The **angle of incidence (i)** is equal to the **angle of reflection (r)**. This can be stated as: **i = r**.
  - The angle between the incident ray and the normal is the **angle of incidence**, and the angle between the reflected ray and the normal is the **angle of reflection**. According to the first law of reflection, these two angles are equal. **(Refer to Figure 2.1)**

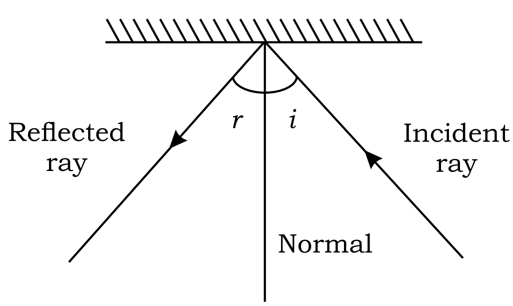


Figure 2.1: Angle of incidence and angle of reflection

- **Second Law of Reflection:** The incident ray, the reflected ray, and the normal all lie in the same plane.

- This law emphasises that reflection occurs in a specific plane. The incident ray and the reflected ray, along with the normal, all exist on the same plane defined by the surface of reflection. **(Refer to Figure 2.1)**

Regular and Diffused Reflection

- **Diffused or irregular reflection:** When all the parallel rays reflected from a rough or irregular surface are not parallel, the reflection is known as diffused or irregular reflection. Diffused reflection is not due to the failure of the laws of reflection. It is caused by the irregularities in the reflecting surface. **(Refer to Figure 2.2 and 2.3)**

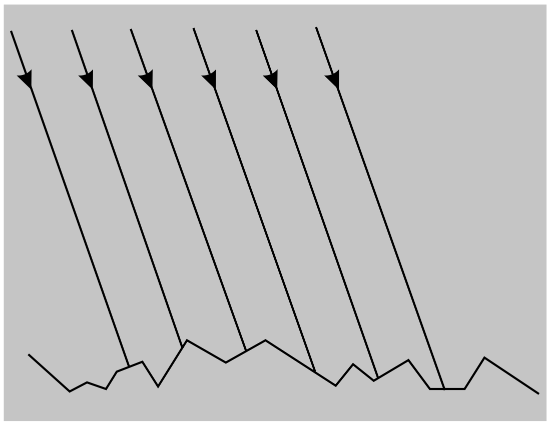


Figure 2.2: Parallel rays incident on an irregular surface

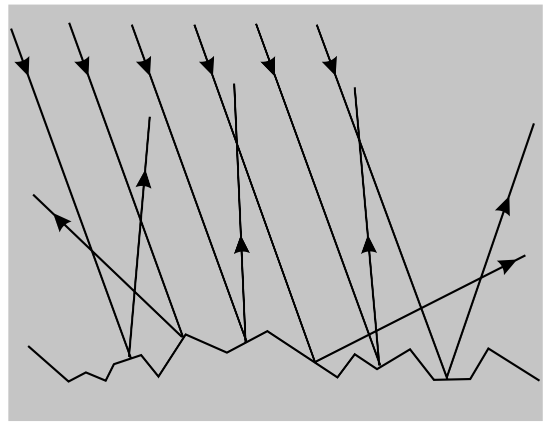


Figure 2.3: Rays reflected from irregular surface

- **Regular reflection:** On the other hand, reflection from a smooth surface like that of a mirror is called regular reflection. Images are formed by regular reflection.

Do We See all Objects due to Reflected Light?

Nearly everything we see around is seen due to reflected light. The Moon, for example, receives light from the Sun and reflects it. The objects which shine in the light of other objects are called **illuminated objects**. There are other objects, which give their own light, such as the Sun, fire, flame of a candle and an electric lamp. Their light falls on our eyes and that is how we see them. The objects which emit their own light are known as **luminous objects**.

Characteristics of Images formed by Different Mirrors and Lens

- In a **plane mirror** the image is formed behind the mirror. It is erect, of the same size and is at the same distance from the mirror as the object is in front of it. An image formed on a screen is called a **real image**. The image formed by a plane mirror that could not be obtained on a screen is called a **virtual image**.
- In an image formed by a mirror, the left side of the object is seen on the right side in the image, and the right side of the object appears to be on the left side in the image.
- A **concave mirror** can form a real and inverted image. When the object is placed very close to the mirror, the image formed is virtual, erect and magnified. Image formed by a **convex mirror** is erect, virtual and smaller in size than the object.
- A **convex lens** can form a real and inverted image. When the object is placed very close to the lens, the image formed is virtual, erect and magnified. When used to see objects magnified, the convex lens is called a magnifying glass.
- A **concave lens** always forms an erect, virtual and smaller image than the object.

Reflection of Light

- Light falling on shiny objects changes the direction of light. For example, a shining stainless steel plate or a shining steel spoon can change the direction of light. The surface of water can also act like a mirror and change the path of light.
- The laws of reflection, as explained earlier, are applicable to all types of reflecting surfaces including spherical surfaces. The most commonly used type of curved mirror is the spherical mirror. The reflecting surface of such mirrors can be considered to form a part of the surface of a sphere. Such mirrors, whose reflecting surfaces are spherical, are called **spherical mirrors**.

POINTS TO PONDER

We are able to see because of the light reflecting back from the object. We can see an apple because light falling on the apple is reflected back which is captured by our eyes. Can you apply the same logic when we are able to see a shadow? How are we able to see the shadow?

Spherical Mirrors

- A spherical mirror, whose reflecting surface is curved inwards, that is, faces towards the centre of the sphere, is called a **concave mirror**. A spherical mirror whose reflecting surface is curved outwards, is called a **convex mirror**.

(a) Concave mirror *(b) Convex mirror*

Figure 2.4: Concave and Convex Mirrors

- **Pole:** The centre of the reflecting surface of a spherical mirror is a point called the **pole**. It lies on the surface of the mirror. The pole is usually represented by the letter P.
- **Centre of curvature:** The reflecting surface of a spherical mirror forms a part of a sphere. This sphere has a centre. This point is called the **centre of curvature** of the spherical mirror. It is represented by the letter C.
- **Radius of curvature:** The centre of curvature is not a part of the mirror because it lies outside its reflecting surface. The centre of curvature of a concave mirror lies in front of it. However, it lies behind the mirror in case of a convex mirror. **(Refer to Figure 2.5)** The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the **radius of curvature** of the mirror. It is represented by the letter R. The distance PC is equal to the radius of curvature.
- **Principal axis:** An imaginary straight line passing through the pole and the centre of curvature of a spherical mirror is called the **principal axis**. The principal axis is normal to the mirror at its pole.
- **Focal length:** By holding a concave mirror in hand and directing its reflecting surface towards the Sun above a paper can make the paper catch fire. This is because the light from the Sun is converged at a point, as a sharp, bright spot by the mirror. The spot of light is the image of the Sun on the sheet of paper. This point is the focus of the concave mirror. The heat produced due to the concentration of sunlight ignites the paper. The distance of this image from the position of the mirror gives the approximate value of **focal length** of the mirror.

- **Principal focus:** A number of rays parallel to the principal axis are falling on a concave mirror. Observe the reflected rays. They are all meeting/intersecting at a point on the principal axis of the mirror. This point is called the **principal focus** of the concave mirror. (Refer to Figure 2.5a)
- The reflected rays appear to come from a point on the principal axis. This point is called the **principal focus** of the convex mirror. The principal focus is represented by the letter F. The distance between the pole and the principal focus of a spherical mirror is called the **focal length**. It is represented by the letter f. **(Refer to Figure 2.5b)**
- **Aperture:** The reflecting surface of a spherical mirror is by-and-large spherical. The surface, then, has a circular outline. The diameter of the reflecting surface of a spherical mirror is called its **aperture**. Distance MN represents the aperture. **(Refer to Figure 2.5)**

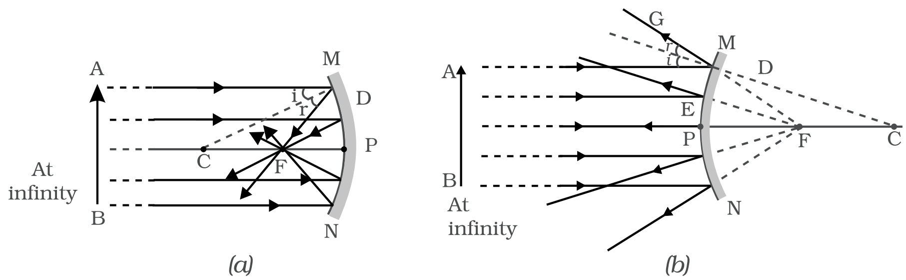


Figure 2.5: (a) Concave Mirror and (b) Convex Mirror

- A **relationship between the radius of curvature R, and focal length f**, of a spherical mirror is represented as **R = 2f**. This is because for spherical mirrors of small apertures, the radius of curvature is found to be equal to twice the focal length. This implies that the principal focus of a spherical mirror lies midway between the pole and centre of curvature.

Representation of Images Formed by Spherical Mirrors Using Ray Diagrams

- To construct the ray diagrams, in order to locate the image of an object, an arbitrarily large number of rays emanating from a point could be considered. The intersection of at least two reflected rays gives the position of the image of the point object. Any two of the following rays can be considered for locating the image.
  (i) A ray parallel to the principal axis, after reflection, will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror. **(Refer to Figure 2.6)**

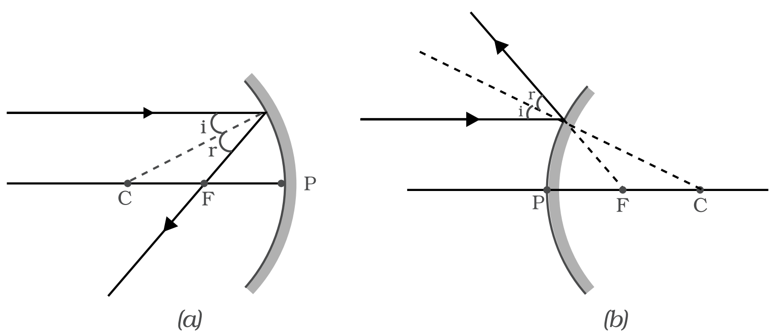
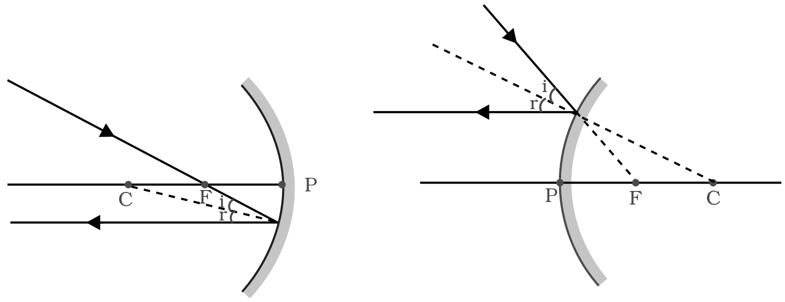


Figure 2.6

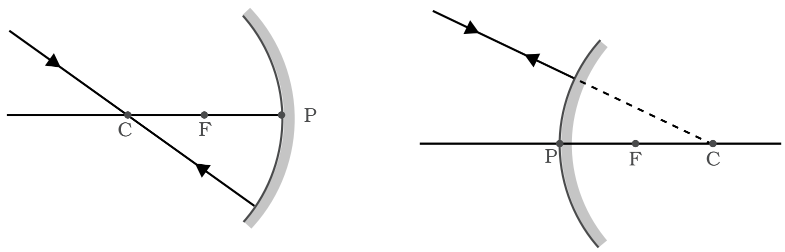
  (ii) A ray passing through the principal focus of a concave mirror or a ray which is directed towards the principal focus of a convex mirror, after reflection, will emerge parallel to the principal axis. **(Refer to Figure 2.7)**



(a) (b)

Figure 2.7

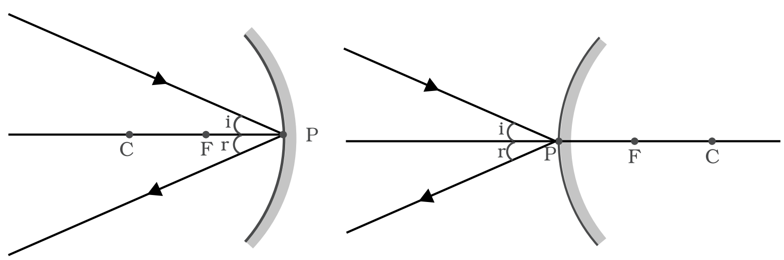
(iii) A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path. **(Refer to Figure 2.8)** The light rays come back along the same path because the incident rays fall on the mirror along the normal to the reflecting surface.



(a) (b)

Figure 2.8

(iv) A ray incident obliquely to the principal axis, towards a point P (pole of the mirror), on the concave mirror or a convex mirror is reflected obliquely. The incident and reflected rays follow the laws of reflection at the point of incidence (point P), making equal angles with the principal axis. **(Refer to Figure 2.9)**



(a) (b)

Figure 2.9

In all the above cases the laws of reflection are followed. At the point of incidence, the incident ray is reflected in such a way that the angle of reflection equals the angle of incidence.

Image Formation by Spherical Mirrors

(a) Image formation by Concave Mirror (Refer to Figure 2.10)

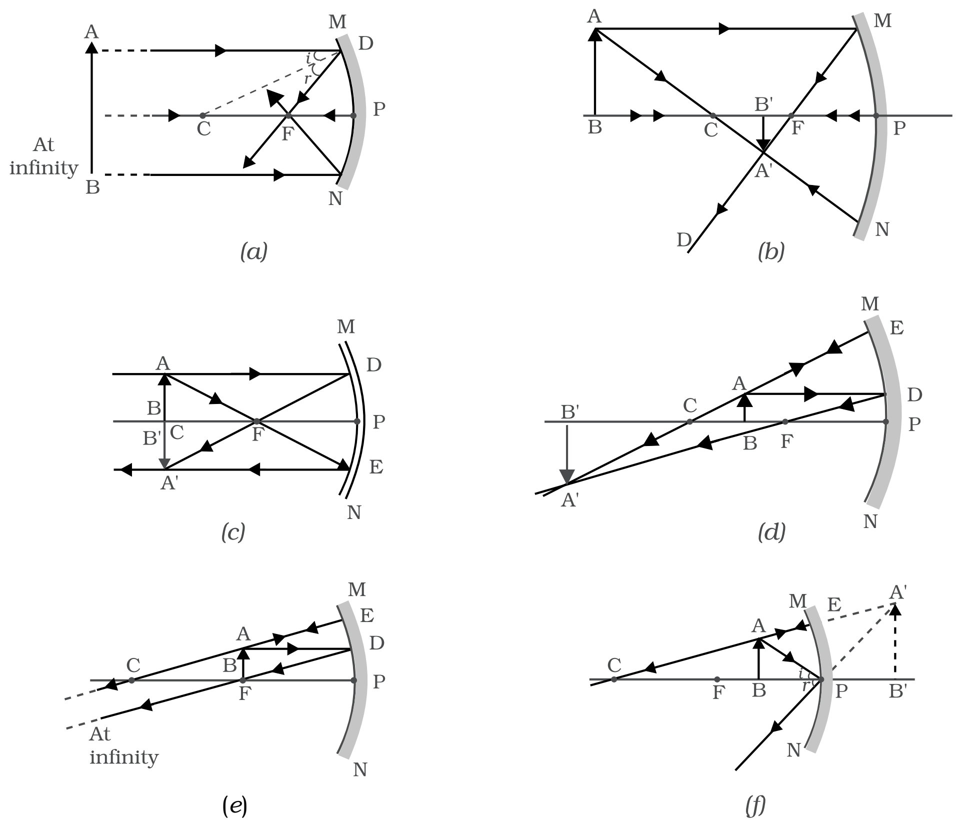


Figure 2.10: Ray diagrams for the image formation by a concave mirror

Table 2.1: Image formation by a concave mirror for different positions of the object

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point-sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

(b) Image formation by a Convex Mirror (Refer to Figure 2.11)

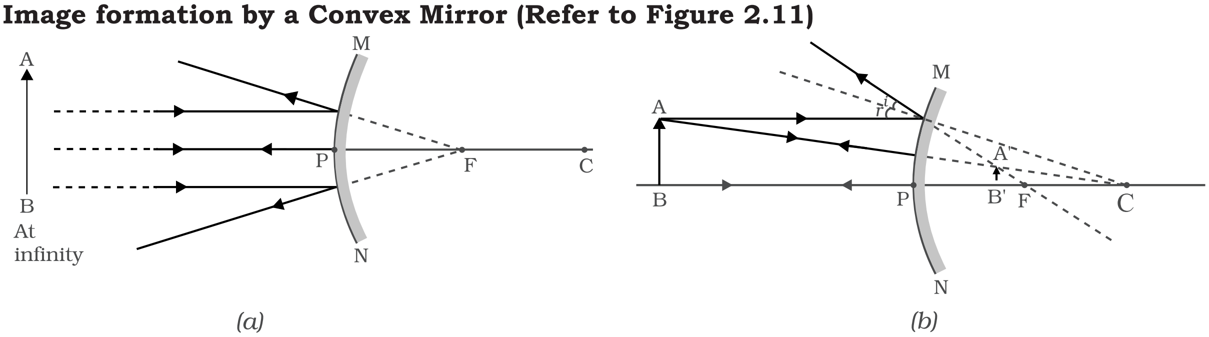


Figure 2.11: Ray diagram for the image formation by a convex mirror

Table 2.2: Nature, position and relative size of the image formed by a convex mirror

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect

Uses of Concave and Convex Mirrors

- **Concave mirrors:** These are commonly used in torches, search-lights and vehicle headlights to get powerful parallel beams of light. They are often used as shaving mirrors to see a larger image of the face. The dentists use concave mirrors to see large images of the teeth of patients. Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.
- **Convex mirrors:** These are commonly used as rear-view (wing) mirrors in vehicles. These mirrors enable the driver to see traffic behind him/her to facilitate safe driving. Convex mirrors are preferred because they always give an erect, though diminished, image. Also, they have a wider field of view as they are curved outwards. Thus, convex mirrors enable the driver to view a much larger area than the one which would be possible with a plane mirror.

Sign Convention for Reflection by Spherical Mirrors

- A set of sign conventions called the **New Cartesian Sign Convention** is used while dealing with the reflection of light. In this convention, the **pole (P)** of the mirror is taken as the origin **(Refer to Figure 2.12**). The **principal axis** of the mirror is taken as the **x-axis (X'X)** of the coordinate system. The conventions are as follows:
  - (i) The object is always placed to the left of the mirror. This implies that the light from the object falls on the mirror from the left-hand side.
  - (ii) All distances parallel to the principal axis are measured from the pole of the mirror.
  - (iii) All the distances measured to the right of the origin (along + x-axis) are taken as positive while those measured to the left of the origin (along – x-axis) are taken as negative.
  - (iv) Distances measured perpendicular to and above the principal axis (along + y-axis) are taken as positive.
  - (v) Distances measured perpendicular to and below the principal axis (along – y-axis) are taken as negative.

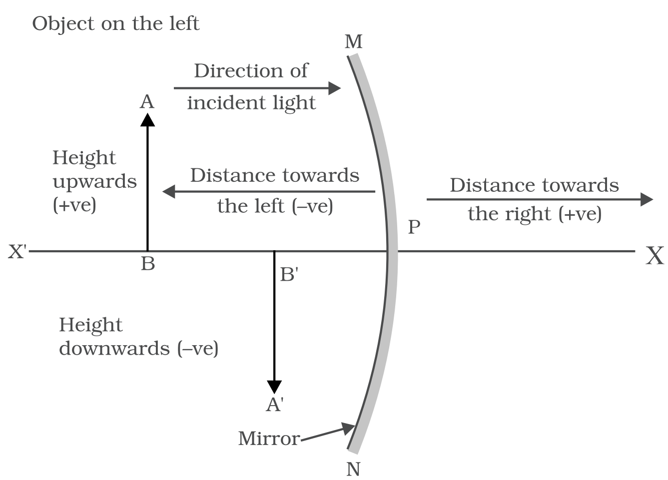


Figure 2.12: The New Cartesian Sign Convention for spherical mirrors

Mirror Formula and Magnification

- **Object distance:** In a spherical mirror, the distance of the object from its pole is called the object distance **(u)**.
- **Image distance:** The distance of the image from the pole of the mirror is called the image distance **(v)**.
- **Focal length:** The distance of the principal focus from the pole is called the focal length (f). There is a relationship between these three quantities given by the mirror formula which is expressed as:

  $$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

  This formula is valid in all situations for all spherical mirrors for all positions of the object.

Magnification

- Magnification produced by a spherical mirror gives the relative extent to which the image of an object is magnified with respect to the object size. It is expressed as the ratio of the height of the image to the height of the object. It is usually represented by the letter m.
- If h is the height of the object and h′ is the height of the image, then the magnification m produced by a spherical mirror is given by:

  $$m = \frac{\text{Height of the image } (h')}{\text{Height of the object } (h)}$$

  $$m = \frac{h'}{h}$$

- The magnification m is also related to the object distance (u) and image distance (v). It can be expressed as: Magnification **(m) = h′/h = –v/u**.
- The height of the object is taken to be positive as the object is usually placed above the principal axis. The height of the image should be taken as positive for virtual images. However, it is to be taken as negative for real images. A negative sign in the value of the magnification indicates that the image is real. A positive sign in the value of the magnification indicates that the image is virtual.

Refraction of Light

- **Light seems to travel along straight-line paths in a transparent medium.** But it is also observed that the bottom of a tank or a pond containing water appears to be raised. Similarly, when a thick glass slab is placed over some printed matter, the letters appear raised when viewed through the glass slab. A pencil partly immersed in water in a glass tumbler appears to be displaced at the interface of air and water.
- This is because the light reaching us from the portion of the pencil inside water seems to come from a different direction, compared to the part above water. This makes the pencil appear to be displaced at the interface. For similar reasons, the letters appear to be raised, when seen through a glass slab placed over it. These observations indicate that **light does not travel in the same direction in all media**. It appears that when travelling obliquely from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as **refraction of light**.

Refraction through a Rectangular Glass Slab

- The rectangular glass slab experiment demonstrates that when light passes from one medium (e.g., air) to another medium with a different refractive index (e.g., glass), it undergoes refraction.

- As the incident ray enters the glass slab, it bends towards the normal line drawn at the point of entry. This is because glass has a higher refractive index compared to air **(Figure 2.13)**.

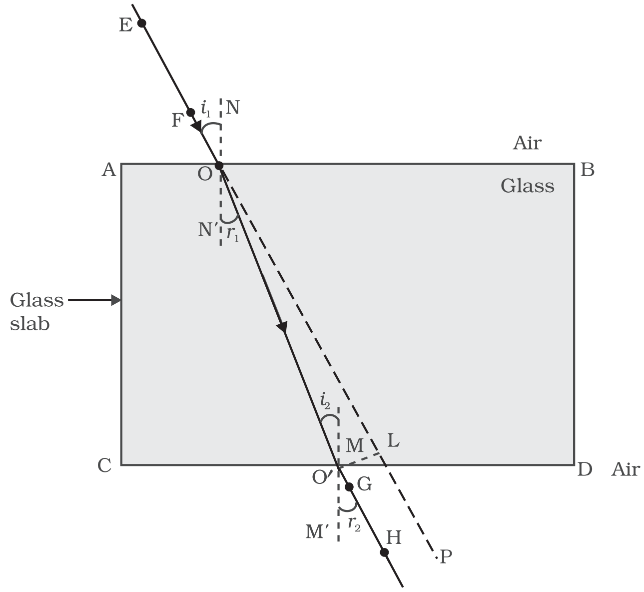


Figure 2.13: Refraction of light through a rectangular glass slab

- **Laws of refraction of light:**
  (i) The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the **same plane**.
  (ii) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is also known as **Snell's Law of Refraction**. (This is true for angle $0 < i < 90°$) If i is the angle of incidence and r is the angle of refraction, then, $\sin i / \sin r$ = constant. This constant value is called the **refractive index of the second medium** with respect to the first.

The Refractive Index

- A ray of light that travels obliquely from one transparent medium into another will change its direction in the second medium. The **extent of the change in direction that takes place in a given pair of media** may be expressed in terms of the refractive index.
- The refractive index can be linked to an important physical quantity, the relative speed of propagation of light in different media.
  - Light propagates with different speeds in different media. Light travels fastest in vacuum with speed of 3×10^8 ms^{-1}. In air, the speed of light is only marginally less, compared to that in vacuum. It reduces considerably in glass or water. The value of the refractive index for a given pair of media depends upon the speed of light in the two media, as given below. **(Refer to Figure 2.14)**

POINTS TO PONDER
The refractive index can cause an object to appear in a position that is different from its actual location. In a similar manner, the Earth's atmosphere possesses a refractive index. Does this imply that the positions of the Sun and the Moon, as observed by us, differ from their true positions?

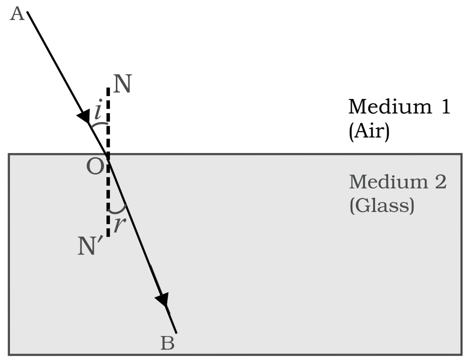


Figure 2.14

- Consider a ray of light travelling from medium 1 into medium 2. Let v_1 be the speed of light in medium 1 and v_2 be the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol n_{21}. It is represented as;

$$\mathbf{n_{21}} = \frac{\textbf{Speed of light in medium 1}}{\textbf{Speed of light in medium 2}} = \frac{\mathbf{v_1}}{\mathbf{v_2}}$$

- By the same argument, the refractive index of medium 1 with respect to medium 2 is represented as n_{12}. It is given by;

$$\mathbf{n_{12}} = \frac{\textbf{Speed of light in medium 2}}{\textbf{Speed of light in medium 1}} = \frac{\mathbf{v_2}}{\mathbf{v_1}}$$

- If medium 1 is vacuum or air, then the refractive index of medium 2 is considered with respect to vacuum. This is called the **absolute refractive index of the medium**. It is simply represented as n_2. If c is the speed of light in air and v is the speed of light in the medium, then, the refractive index of the medium n_m is given by

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \frac{c}{v}$$

- The absolute refractive index of a medium is simply called its refractive index. The refractive index of several media is given in Table 2.3. From the table you can know that the refractive index of water, n_w = 1.33. This means that the ratio of the speed of light in air and the speed of light in water is equal to 1.33. Similarly, the refractive index of crown glass, n_g = 1.52.
- An optically denser medium may not possess greater mass density. For example, kerosene having higher refractive index, is optically denser than water, although its mass density is less than water. (Refer Table 2.3)

Table 2.3: Absolute refractive index of some material media

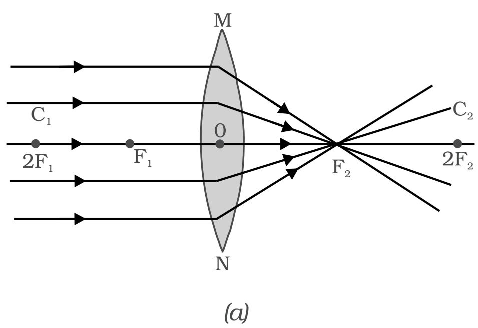
Material medium	Refractive index	Material medium	Refractive index
Air	1.0003	Canada Balsam	1.53
Ice	1.31	Rock salt	1.54
Water	1.33		
Alcohol	1.36		
Kerosene	1.44	Carbon disulphide	1.63
Fused quartz	1.46	Dense flint glass	1.65
Turpentine oil	1.47	Ruby	1.71
Benzene	1.50	Sapphire	1.77
Crown glass	1.52	Diamond	2.42

Optical Density

The ability of a medium to refract light is also expressed in terms of its **optical density**. Optical density has a definite connotation. It is not the same as mass density. In comparing two media, the one with the larger refractive index is optically denser medium than the other. The other medium of lower refractive index is optically rarer. The **speed of light is higher in a rarer medium than a denser medium**. Thus, a ray of light travelling from a rarer medium to a denser medium slows down and bends towards the normal. When it travels from a denser medium to a rarer medium, it speeds up and bends away from the normal.

Refraction by Spherical Lenses

- A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. This means that a lens is bound by at least one spherical surface. In such lenses, the other surface would be plane.
- A lens may have two spherical surfaces, bulging outwards. Such a lens is called a **double convex lens**. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lenses converge light rays. Hence convex lenses are also called **converging lenses**.
- A **double concave lens** is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays **(Refer to Figure 2.15)**. Such lenses are also called **diverging lenses**. A double concave lens is simply called a concave lens. A lens, either a convex lens or a concave lens, has two spherical surfaces. Each of these surfaces form a part of the sphere.



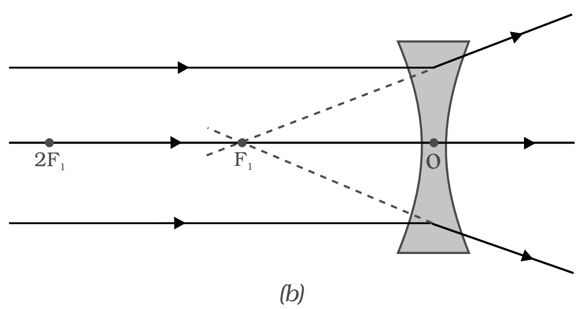


Figure 2.15: (a) Converging action of a convex lens and (b) diverging action of a concave lens

- The centres of these spheres are called centres of curvature of the lens. The centre of **curvature of a lens** is usually represented by the letter C. Since there are two centres of curvature, we may represent them as C_1 and C_2. An imaginary straight line passing through the two centres of curvature of a lens is called its **principal axis**. The central point of a lens is its **optical centre**. It is usually represented by the letter O. A ray of light through the optical centre of a lens passes without suffering any deviation. The effective diameter of the circular outline of a spherical lens is called its **aperture**.
- Several rays of light parallel to the principal axis are falling on a convex lens. These rays, after refraction from the lens, are converging to a point on the principal axis. This point on the principal axis is called the principal focus of the lens. **(Refer to Figure 2.15 (a))**
- Several rays of light parallel to the principal axis are falling on a concave lens. These rays, after refraction from the lens, are appearing to diverge from a point on the principal axis. This point on the principal axis is called the principal focus of the concave lens. **(Refer to Figure 2.15 (b))**
- If parallel rays pass from the opposite surface of the lens, another principal focus on the opposite side is made. Letter F is usually used to represent principal focus. However, a lens

has two principal foci. They are represented by F_1 and F_2. The distance of the principal focus from the optical centre of a lens is called its focal length. The letter f is used to represent the focal length.

Image Formation in Lenses Using Ray Diagrams

For drawing ray diagrams in lenses, alike spherical mirrors, we consider any two of the following rays:

(i) A ray of light from the object, parallel to the principal axis, after refraction from a convex lens, passes through the principal focus on the other side of the lens (Refer to Figure 2.16a). In case of a concave lens, the ray appears to diverge from the principal focus located on the same side of the lens. **(Refer to Figure 2.16b)**

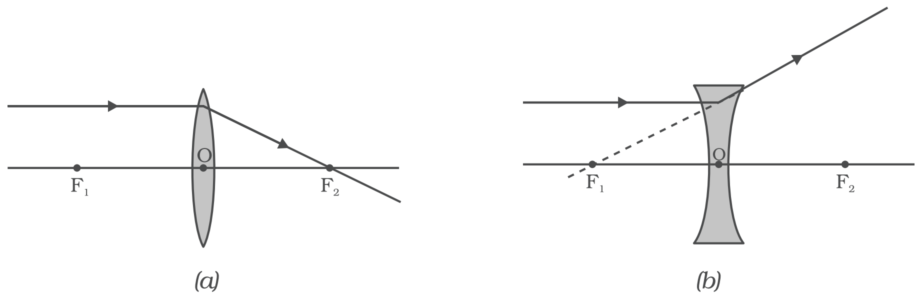


Figure 2.16

(ii) A ray of light passing through a principal focus, after refraction from a convex lens, will emerge parallel to the principal axis. (Refer to Figure 2.17(a)). A ray of light appearing to meet at the principal focus of a concave lens, after refraction, will emerge parallel to the principal axis. **(Refer to Figure 2.17(b))**

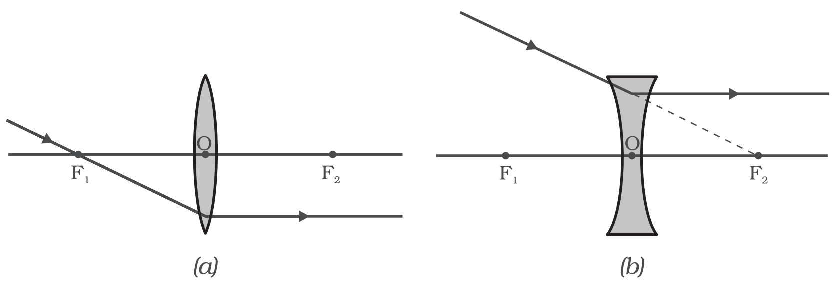


Figure 2.17

(iii) A ray of light passing through the optical centre of a lens will emerge without any deviation. **(Refer to Figure 2.18)**

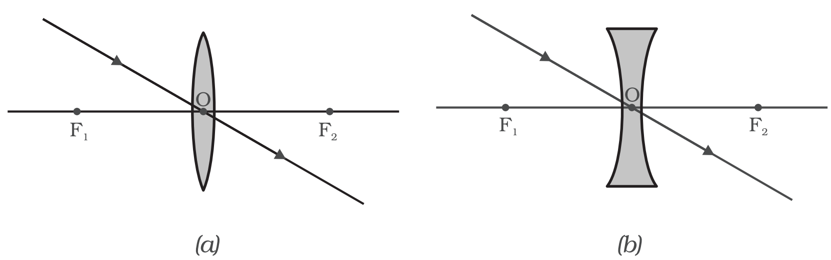


Figure 2.18

The ray diagrams for the image formation in a convex lens for a few positions of the object **(Refer to Figure 2.19)**

Image Formation by Lenses

Lenses form images by refracting light. The nature, position and relative size of the image formed by a convex and concave lens for various position of the object is summarised in table 2.4 and 2.5 **(Refer to Figures 2.19 and 2.20)**

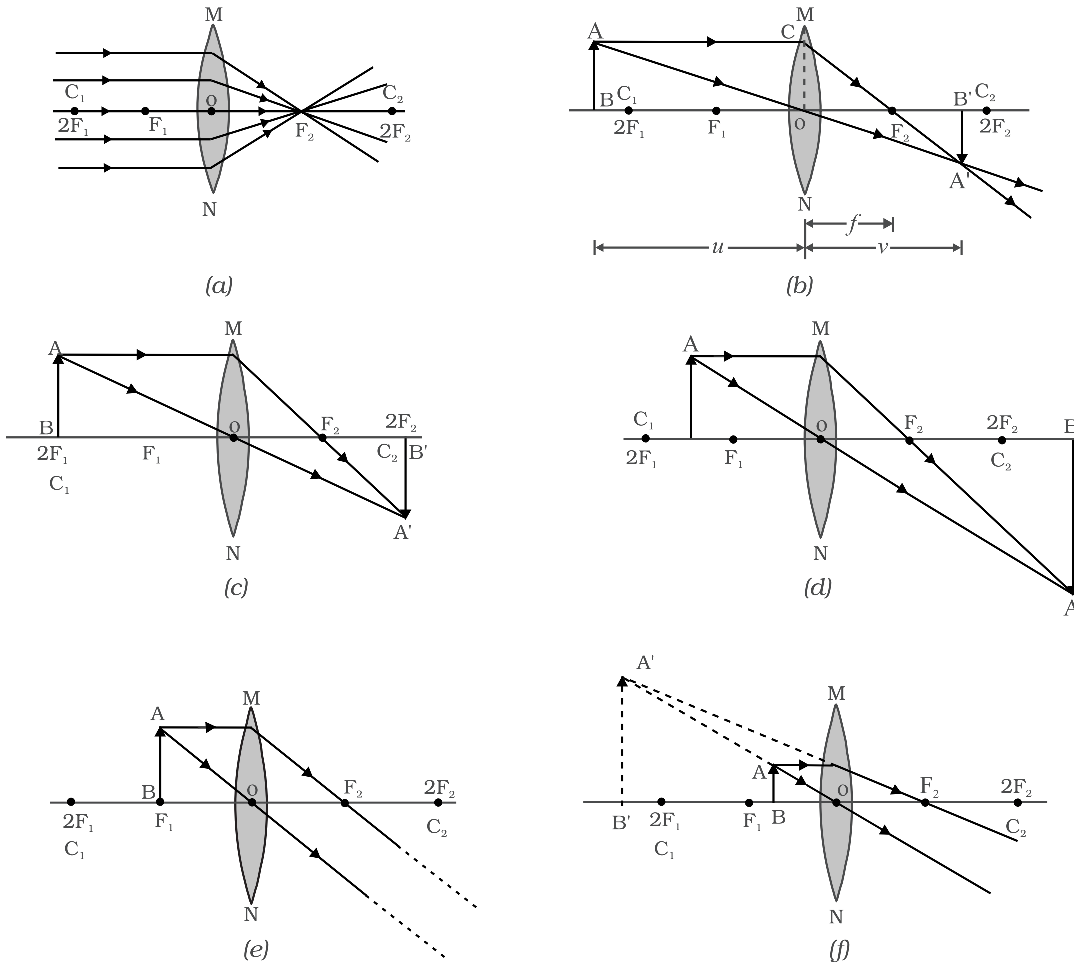


Figure 2.19: The position, size and the nature of the image formed by a convex lens for various positions of the object

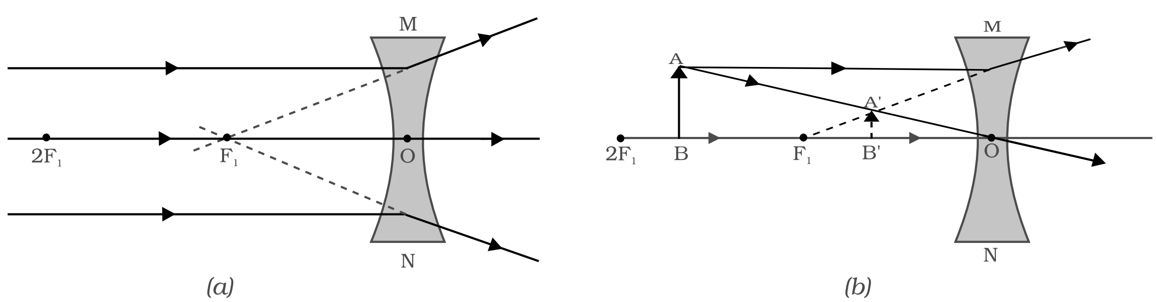


Figure 2.20: Nature, position and relative size of the image formed by a concave lens

Lenses form images by refracting light. convex and concave lens for vario summarised in Table 2.4 a Table 2.5.

Table 2.4: Nature, position and relative size of the image formed by a convex lens for various positions of the object.

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Table 2.5: Nature, position and relative size of the image formed by a concave lens for various positions of the object.

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

In conclusion it can be said that a concave lens will always give a virtual, erect and diminished image, irrespective of the position of the object.

Sign Convention for Spherical Lenses

For lenses, the sign convention is similar to that used for mirrors. All the rules for signs of distances are applied except that all measurements are taken from the optical centre of the lens. According to the convention, the focal length of a convex lens is positive and that of a concave lens is negative.

Lens Formula and Magnification

- This formula gives the relationship between object distance (u), image-distance (v) and the focal length (f). The lens formula is expressed as $\mathbf{1/v - 1/u = 1/f}$
- The lens formula given above is general and is valid in all situations for any spherical lens.

Magnification

- The magnification produced by a lens, similar to that for spherical mirrors, is defined as the ratio of the height of the image and the height of the object. Magnification is represented by the letter m. If h is the height of the object and h′ is the height of the image given by a lens, then the magnification produced by the lens is given by,

$$\mathbf{m} = \frac{\textbf{Height of the image}}{\textbf{Height of the object}} = \frac{\mathbf{h'}}{\mathbf{h}}$$

- Magnification produced by a lens is also related to the object-distance u, and the image-distance v. This relationship is given by: Magnification $\mathbf{(m) = h'/h = v/u}$

Power of a Lens

- The ability of a lens to converge or diverge light rays depends on its focal length. For example, a convex lens of short focal length bends the light rays through large angles, by focusing them closer to the optical centre.

- Similarly, concave lenses of very short focal length cause higher divergence than the one with longer focal length. The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power.
- The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter P. The power P of a lens of focal length f is given by:

$$\mathbf{P = \frac{1}{f}}$$

- The SI unit of power of a lens is '**dioptre**'. It is denoted by the letter **D**. If 'f' is expressed in metres, then, the power is expressed in dioptres. Thus, 1 dioptre is the power of a lens whose focal length is 1 metre. $1D = 1\ m^{-1}$.
- **The power of a convex lens is positive and that of a concave lens is negative.** Opticians prescribe corrective lenses indicating their powers.

Designing a lens

Many optical instruments consist of a number of lenses. They are combined to increase the magnification and sharpness of the image. The net power (P) of the lenses placed in contact is given by the algebraic sum of the individual powers P_1, P_2, P_3, ... as $P = P_1 + P_2 + P_3 + ...$ The use of powers, instead of focal lengths, for lenses is quite convenient for opticians. During eye-testing, an optician puts several different combinations of corrective lenses of known power, in contact, inside the testing spectacles' frame. The optician calculates the power of the lens required by simple algebraic addition. For example, a combination of two lenses of power +2.0 D and +0.25 D is equivalent to a single lens of power +2.25 D. The simple additive property of the powers of lenses can be used to design lens systems to minimise certain defects in images produced by a single lens. Such a lens system, consisting of several lenses in contact, is commonly used in the design of lenses of camera, microscopes and telescopes.

Refraction of Light through a Prism

- A triangular glass prism has two triangular bases and three rectangular lateral surfaces. These surfaces are inclined to each other. The angle between its two lateral faces is called the angle of the prism.

Dispersion of White Light by Glass Prism

- The prism splits white light into a band of colours. The various colours seen are Violet, Indigo, Blue, Green, Yellow, Orange and Red. **(Refer to Figure 2.21)** The band of the coloured components of a light beam is called its **spectrum**. The splitting of light into its component colours is called **dispersion**.

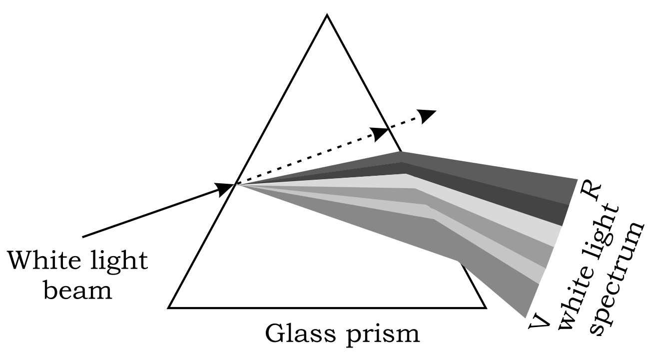


Figure 2.21: Dispersion of white light by the glass prism

- Different colours of light bend through different angles with respect to the incident ray, as they pass through a prism. The red light bends the least while the violet bends the most. Thus the rays of each colour emerge along different paths and thus become distinct. It is the band of distinct colours that we see in a spectrum.

- **Isaac Newton** was the first to use a glass prism to obtain the spectrum of sunlight. He tried to split the colours of the spectrum of white light further by using another similar prism. However, he could not get any more colours. He then placed a second identical prism in an inverted position with respect to the first prism. **(Refer to Figure 2.22)** This allowed all the colours of the spectrum to pass through the second prism. He found a beam of white light emerging from the other side of the second prism. This observation gave Newton the idea that the sunlight is made up of seven colours.

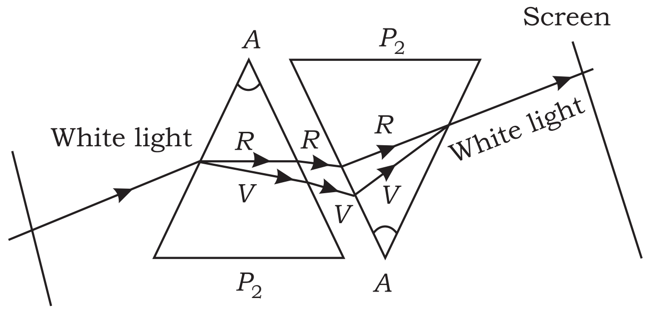


Figure 2.22: Recombination of the spectrum of white light

- Any light that gives a spectrum similar to that of sunlight is often referred to as **white light**.
- A **rainbow** is a natural spectrum appearing in the sky after a rain shower. **(Refer to Figure 2.23)** It is caused by **dispersion of sunlight** by tiny water droplets, present in the atmosphere. A rainbow is always formed in a direction opposite to that of the Sun. The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally, and finally refract it again when it comes out of the raindrop. **(Refer to Figure 2.24)** Due to the dispersion of light and internal reflection, different colours reach the observer's eye.

POINTS TO PONDER

The white light that we receive when passed through prism gives different coloured light. Have you ever wondered why we receive white light and not these different coloured light? And why do we see a more red or orange colour light during sunrise or sunset and not during day time?

Figure 2.23: Rainbow

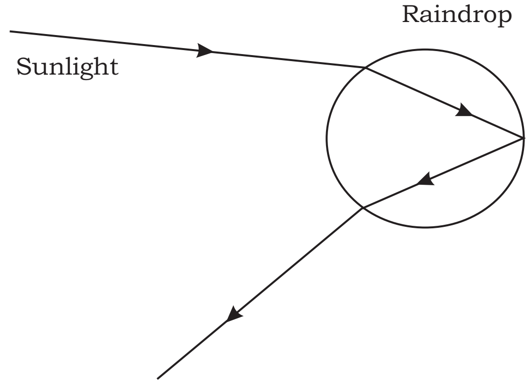


Figure 2.24: Rainbow Formation

Atmospheric Refraction

- Sometimes we notice random wavering or flickering of objects seen through a turbulent stream of hot air rising above a fire or a radiator. The air just above the fire becomes hotter than the air further up.
- The **hotter air is lighter (less dense)** than the cooler air above it, and has a refractive index slightly less than that of the cooler air. Since the physical conditions of the refracting medium (air) are not stationary, the apparent position of the object, as seen through the hot air, fluctuates. This wavering is thus an effect of atmospheric refraction (refraction of light by the earth's atmosphere) on a small scale in our local environment.

Twinkling of Stars

- The twinkling of a star is due to **atmospheric refraction of starlight**. The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth. The atmospheric refraction occurs in a medium of gradually changing refractive index.
- Since the atmosphere bends starlight towards the normal, the apparent position of the star is slightly different from its actual position. The star appears slightly higher (above) than its actual position when viewed near the horizon. **(Refer to Figure 2.25)** Further, this apparent position of the star is not stationary, but keeps on changing slightly, since the physical conditions of the earth's atmosphere are not stationary. Since the stars are very distant, they approximate point-sized sources of light. As the path of rays of light coming from the star goes on varying slightly, the apparent position of the star fluctuates and the amount of starlight entering the eye flickers, the star sometimes appears brighter, and at some other time, fainter, which is the twinkling effect.

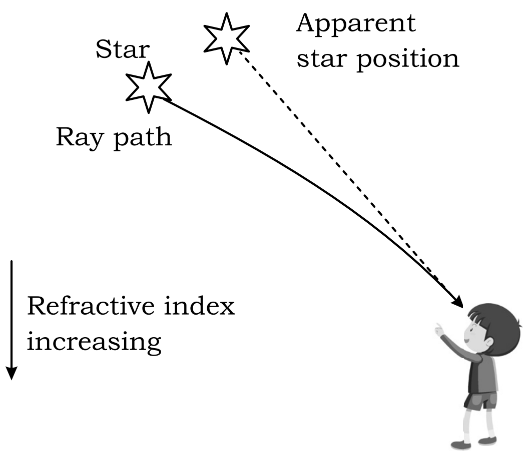


Figure 2.25: Apparent star position due to atmospheric refraction

- The planets are much closer to the earth, and are thus seen as extended sources. Planets in our solar system are relatively close to Earth and appear as extended disks rather than point sources of light. The light from a planet does not come from a single point, so the small changes in direction caused by atmospheric turbulence tend to average out across the planet's visible disk. As a result, the light from planets doesn't twinkle in the same way as stars do, and they appear as steady, non-twinkling points of light in the night sky.

Advance Sunrise and Delayed Sunset

- The Sun is visible to us about two minutes before the actual sunrise, and about two minutes after the actual sunset because of atmospheric refraction. By actual sunrise, we mean the actual crossing of the horizon by the Sun.

- The time difference between actual sunset and the apparent sunset is about two minutes. The apparent flattening of the Sun's disc at sunrise and sunset is also due to the same phenomenon. **(Refer to Figure 2.26)**

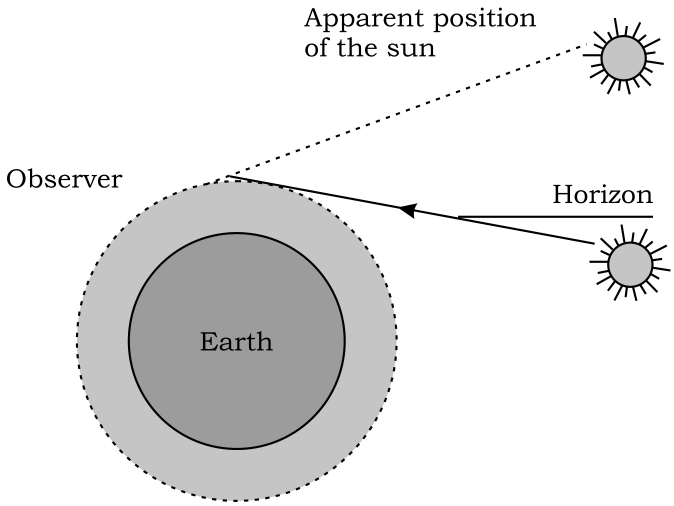


Figure 2.26: Atmospheric refraction effects at sunrise and sunset

Why is the colour of the clear Sky Blue?

The molecules of air and other fine particles in the atmosphere have size smaller than the wavelength of visible light. These are more effective in scattering light of shorter wavelengths at the blue end than light of longer wavelengths at the red end. The red light has a wavelength about 1.8 times greater than blue light. Thus, when sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes. If the earth had no atmosphere, there would not have been any scattering. Then, the sky would have looked dark. The sky appears dark to passengers flying at very high altitudes, as scattering is not prominent at such heights. The 'danger' signal lights are red in colour because the red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance.

Scattering of Light

- The interplay of light with objects around us gives rise to several spectacular phenomena in nature. The blue colour of the sky, colour of water in deep sea, the reddening of the sun at sunrise and the sunset are some of the wonderful phenomena we are familiar with.
- The path of a beam of light passing through a true solution is not visible. However, its path becomes visible through a colloidal solution where the size of the particles is relatively larger.

Tyndall Effect

- The earth's atmosphere is a heterogeneous mixture of minute particles. These particles include smoke, tiny water droplets, suspended particles of dust and molecules of air. When a beam of light strikes such fine particles, the path of the beam becomes visible.
- The light reaches us, after being reflected diffusely by these particles. **The phenomenon of scattering of light by the colloidal particles gives rise to the Tyndall effect.**
- This phenomenon is seen when a fine beam of sunlight enters a smoke-filled room through a small hole. Thus, scattering of light makes the particles visible.
- Tyndall effect can also be observed when sunlight passes through a canopy of a dense forest. Here, tiny water droplets in the mist scatter light.

- The colour of the scattered light depends on the size of the scattering particles. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelengths. If the size of the scattering particles is large enough, then, the scattered light may even appear white.

Human Eye

- The human eye is one of the most valuable and sensitive sense organs. It is like a camera.

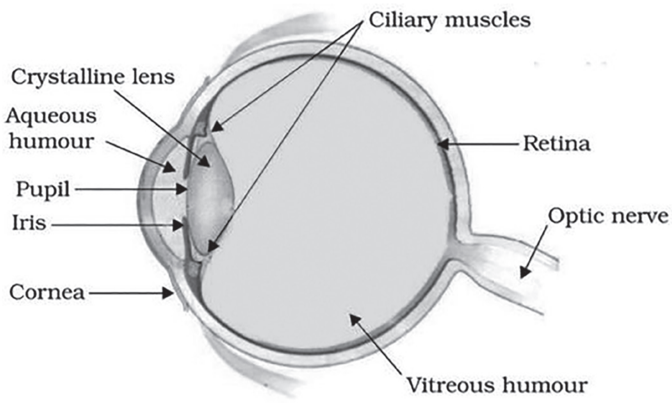


Figure 2.27: The Human Eye

Parts of eyes

- **Retina:** The lens system of eyes forms an image on a light-sensitive screen called the retina. The retina contains several nerve cells.
- **Optical nerve:** Sensations felt by the nerve cells are then transmitted to the brain through the optic nerve.
- There are two kinds of cells– (i) **cones**, which are sensitive to bright light and (ii) **rods**, which are sensitive to dim light. Cones sense colour.
- **Blind spot:** At the junction of the optic nerve and the retina, there are no sensory cells, so no vision is possible at that spot. This is called the **blind spot**. The impression of an image does not vanish immediately from the retina. It persists there for about 1/16th of a second. So, if still images of a moving object are flashed on the eye at a rate faster than 16 per second, then the eye perceives this object as moving.
- **Cornea:** Light enters the eye through a thin membrane called the **cornea**. It forms a transparent bulge on the front surface of the eyeball. The eyeball is approximately spherical in shape with a diameter of about 2.3 cm. Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea.
- **Iris:** It is behind the cornea. It is a dark muscular diaphragm that controls the size of the pupil.
- **Pupil:** It regulates and controls the amount of light entering the eye.
- **Eye lens:** It forms an inverted real image of the object on the retina. The retina is a delicate membrane having an enormous number of light-sensitive cells. The light-sensitive cells get activated upon illumination and generate electrical signals. These signals are sent to the brain via the **optic nerves**. The brain interprets these signals, and finally, processes the information so that we perceive objects as they are.

POINTS TO PONDER

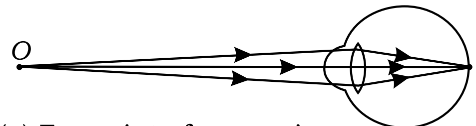
The Eye lens forms an inverted real image of the object on the retina. What do you think is the type of lens we have: concave or convex or double spherical?

Power of Accommodation

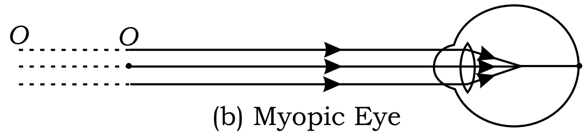
- The eye lens is composed of a fibrous, jelly-like material. Its curvature can be modified to some extent by the ciliary muscles. The change in the curvature of the eye lens can thus change its focal length.
- When the muscles are relaxed, the lens becomes thin. Thus, its focal length increases. This enables us to see distant objects clearly. The **ciliary muscles** contract when objects are closer to the eye. This increases the curvature of the eye lens. The eye lens then becomes thicker. Consequently, the focal length of the eye lens decreases. This enables us to see nearby objects clearly.
- The **ability of the eye lens to adjust its focal length** is called **accommodation**. But the focal length of the eye lens cannot be decreased below a certain minimum limit. To see an object comfortably and distinctly it must be about 25 cm from the eyes. The minimum distance, at which objects can be seen most distinctly without strain, is called the **least distance of distinct vision**. It is also called the **near point of the eye**.
- For a young adult with normal vision, the near point is about 25 cm. The farthest point upto which the eye can see objects clearly is called the far point of the eye. It is infinite for a normal eye.
- When the crystalline lens of people at old age becomes milky and cloudy, it is called **cataract**. This causes partial or complete loss of vision. It is possible to restore vision through a cataract surgery.

Defects of Vision and their Correction

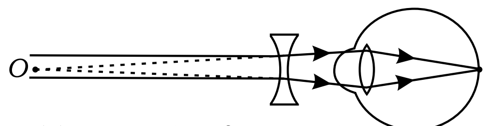
- The eye may gradually lose their power of accommodation. In such conditions, the person cannot see the objects distinctly and comfortably. The vision becomes blurred due to the refractive defects of the eye.
- There are mainly three common refractive defects of vision. These are (i) Myopia or near - sightedness, (ii) Hypermetropia or far - sightedness, and (iii) Presbyopia. These defects can be corrected by the use of suitable spherical lenses.
  - **Myopia:** It is also known as **near-sightedness**. A person with myopia can see nearby objects clearly but cannot see distant objects distinctly. A person with this defect has a far point nearer than infinity. In a myopic eye, the image of a distant object is formed in front of the retina and not at the retina itself. **(Refer to Figure 2.28)** This defect may arise due to (i) Excessive curvature of the eye lens, or (ii) Elongation of the eyeball. This defect **can be corrected by using a concave lens** of suitable power. A concave lens of suitable power will bring the image back onto the retina and thus the defect is corrected.



(a) Far point of a myopic eye



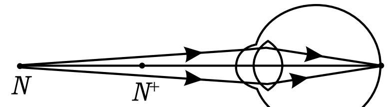
(b) Myopic Eye



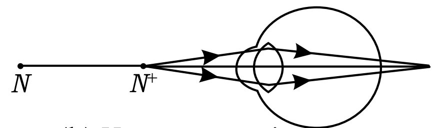
(c) Correction for myopia

Figure 2.28: (a),b) The myopic eye, and (c) correction for myopia with a concave lens

✧ **Hypermetropia:** It is also known as **far-sightedness**. A person with hypermetropia can see distant objects clearly but cannot see nearby objects distinctly. The near point, for the person, is farther away from the normal near point (25 cm). This is because the light rays from a closeby object are focussed at a point behind the retina as **(Refer to Figure 2.29b)**. This defect arises either because (i) the focal length of the eye lens is too long, or (ii) the eyeball has become too small. This defect can be corrected by using a convex lens of appropriate power. **(Refer to Figure 2.29c)** Eye-glasses with converging lenses provide the additional focussing power required for forming the image on the retina.



(a) Near point of a Hypermetropic eye



(b) Hypermetropic eye

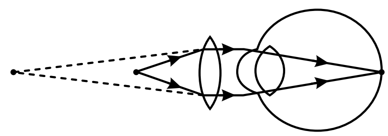

(c) Correction for Hypermetropic eye

Figure 2.29: (a),b) The myop

✧ **Presbyopia:** The power of accommodation of the eye usually decreases with ageing. For most people, the near point gradually recedes away. They find it difficult to see nearby objects comfortably and distinctly without corrective eye-glasses. This defect is called **Presbyopia**. It arises due to the gradual weakening of the ciliary muscles and diminishing flexibility of the eye lens. Sometimes, a person may suffer from **both myopia and hypermetropia**. Such people often require bi-focal lenses. A common type of bi-focal lens consists of both concave and convex lenses. The upper portion consists of a concave lens. It facilitates distant vision. The lower part is a convex lens. It facilitates near vision.

Visually Challenged Persons Can Read and Write

- Some persons, including children, can be visually handicapped. They have very limited vision to see things. Some persons cannot see at all since birth. Some persons may lose their eyesight because of a disease. Such persons try to identify things by touching and listening to voices more carefully. They develop their other senses more sharply.
- However, additional resources can enable them to develop their capabilities further.

Louis Braille, himself a visually challenged person, developed a system for visually challenged persons and published it in 1821. The Braille system has 63 dot patterns or characters. The present system was adopted in 1932. There is Braille code for common languages, mathematics and scientific notation. Many Indian languages can be read using the Braille system.


Louis Braille

EYES DONATION

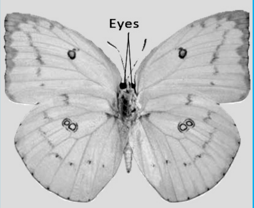
Our eyes can live even after our death. About 35 million people in the developing world are blind and most of them can be cured. About 4.5 million people with corneal blindness can be cured through corneal transplantation of donated eyes. Out of these 4.5 million, 60% are children below the age of 12.

- Eye donors can belong to any age group or sex. People who use spectacles, or those operated for cataract, can still donate the eyes. People who are diabetic, have hypertension, asthma patients and those without communicable diseases can also donate eyes.
- Eyes must be removed within 4-6 hours after death. Inform the nearest eye bank immediately.
- The eye bank team will remove the eyes at the home of the deceased or at a hospital.
- Eye removal takes only 10-15 minutes. It is a simple process and does not lead to any disfigurement.
- Persons who were infected with or died because of AIDS, Hepatitis B or C, rabies, acute leukaemia, tetanus, cholera, meningitis or encephalitis cannot donate eyes.

An eye bank collects, evaluates and distributes the donated eyes. All eyes donated are evaluated using strict medical standards. Those donated eyes found unsuitable for transplantation are used for valuable research and medical education. The identities of both the donor and the recipient remain confidential. One pair of eyes gives vision to up to four corneal blind people.

Did you know?

Animals have eyes shaped in different ways. Eyes of a crab are quite small but they enable the crab to look all around. So, the crab can sense even if the enemy approaches from behind. Butterflies have large eyes that seem to be made up of thousands of little eyes. They can see not only in the front and the sides but the back as well. A night bird (owl) can see very well in the night but not during the day. On the other hand, daylight birds (kite, eagle) can see well during the day but not at night. The owl has a large cornea and a large pupil to allow more light in its eye. Also, it has on its retina a large number of rods and only a few cones. The day birds on the other hand, have more cones and fewer rods.



Eyes of a Butterfly

Care of the Eyes

- If advised, use suitable spectacles.
- Too little or too much light is bad for the eyes. Insufficient light causes eye strain and headache. Too much light, like that of the Sun, a powerful lamp or a laser torch can injure the retina.
- Do not look at the Sun or a powerful light directly.
- Never rub your eyes. If particles of dust go into your eyes, wash your eyes with clean water. If there is no improvement go to a doctor.
- Always read at the normal distance for vision. Do not read by bringing the book too close to your eyes or keeping it too far.
- Lack of vitamin A in foodstuff is responsible for many eye troubles. Most common amongst them is night blindness.

Non-optical and optical aids for visually impaired

Non-optical aids include visual aids, tactual aids (using the sense of touch), auditory aids (using the sense of hearing) and electronic aids. Visual aids, can magnify words, can provide suitable intensity of light and material at proper distances. Tactual aids, including Braille writer slate and stylus, help the visually challenged persons in taking notes, reading and writing. Auditory aids include cassettes, tape recorders, talking books and other such devices. Electronic aids, such as talking calculators and computers, are also available for performing many computational tasks. Closed circuit television, also an electronic aid, enlarges printed material with suitable contrast and illumination. Nowadays, use of audio CDs and voice boxes with computers are also very helpful for listening to and writing the desired text. Optical aids include bifocal lenses, contact lenses, tinted lenses, magnifiers and telescopic aids. While the lens combinations are used to rectify visual limitations, telescopic aids are available to view chalkboard and class demonstrations.

Some visually impaired Indians have great achievements to their credit. Diwakar, a child prodigy has given amazing performances as a singer. Ravindra Jain, born completely visually impaired, obtained his Sangeet Prabhakar degree from Allahabad. He had shown his excellence as a lyricist, singer and music composer. Lal Advani, himself visually impaired, established an Association for special education and rehabilitation of disabled in India. Besides this, he represented India on Braille problems in UNESCO. Helen A. Keller, an American author and lecturer, is perhaps the most well known and inspiring visually challenged person. She lost her sight when she was only 18 months old. But because of her resolve and courage she could complete her graduation from a university. She wrote a number of books including The Story of my Life (1903).


Helen A. Keller

Conclusion

The study of light holds profound significance not only in understanding fundamental principles of physics but also in its myriad applications across various disciplines. Reflection, the phenomenon where light changes its path upon encountering a surface, finds practical utility in designing optical instruments, engineering applications, and even in art. Refraction is pivotal in the functioning of lenses, prisms, and optical fibres, impacting fields ranging from medical imaging to telecommunications. The phenomenon of dispersion, where light splits into its constituent colours, underlies innovations in spectroscopy, telecommunications, and imaging technologies. This knowledge proves vital in modern scientific research, engineering endeavours, and technological advancements. The study of concave and convex mirrors, along with the distinct characteristics of various lenses, plays a crucial role in the operation of telescopes, microscopes, and cameras.

Glossary:

- **Luminous:** Emitting its own light.
- **Opaque:** Not allowing light to pass through.
- **Transparent:** Allowing light to pass through with minimal distortion.
- **Translucent:** Allowing some light to pass through but scattering it.
- **Reflection:** The bouncing back of light when it strikes a surface.
- **Concave lens:** A lens that curves inward and diverges light.
- **Concave mirror:** A mirror that curves inward, reflecting light outward.
- **Convex lens:** A lens that curves outward and converges light.
- **Convex mirror:** A mirror that curves outward, reflecting light outward.
- **Erect image:** An image that appears upright and in the same orientation as the object.
- **Magnified image:** An enlarged representation of an object.
- **Magnifying glass:** A convex lens used to magnify small objects.
- **Prism:** A transparent optical element that disperses light into its component colours.
- **Rainbow:** A natural optical phenomenon featuring a spectrum of colours in the sky.
- **Real image:** An image formed by actual converging or diverging rays of light, capable of being projected onto a screen.
- **Rear view mirror:** A mirror in a vehicle used to view objects behind the vehicle.
- **Side mirror:** A mirror on the side of a vehicle used to view objects in adjacent lanes.
- **Spherical mirror:** A mirror with a curved, spherical surface, which can be either concave or convex.
- **Virtual image:** An image formed by apparent rays of light that do not actually converge or originate from a real point source.

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Electricity

Bibliography: This Chapter encompasses a summary of **Chapter 12 - Class X, Chapter 11 and 12 - Class VIII, Chapter 10 - Class VII, and Chapter 9 - Class VI** of Science NCERT.

Introduction

Electricity has an important place in modern society. It is a controllable and convenient form of energy for a variety of uses in homes, schools, hospitals, industries and so on. Electricity makes it possible to light our homes, roads, offices, markets and factories even after sunset. A power station provides us with electricity which helps us to continue working at night. In this chapter we will find answers to questions like, what constitutes electricity? How does it flow in an electric circuit? What are the factors that control or regulate the current through an electric circuit? We shall also discuss the chemical effect, heating effect as well as magnetic effect of electric current and its applications. At last we shall discuss a destructive natural phenomena which is lightning and steps can be taken to minimise destruction caused by this phenomena.

Electrical Components

Electric Conductors

- The materials which allow electric current to pass through them are good conductors of electricity.
- A component of a given size that offers low resistance is a good conductor.
- Objects made of metals or metal alloys are good conductors of electricity.
  - For example, iron, steel, copper, gold, aluminium, mercury, brass etc.
- Our body is also a conductor of electricity.

Insulators

- The materials which do not allow electric current to pass through them easily are insulators.
  - For example, rubber, wood, plastics, glass, wood, air etc.
- A component that offers a higher resistance is a poor conductor.

POINTS TO PONDER
You studied about conductors and insulators. But have you heard about semiconductors? What are their properties? Do they exhibit any resistance?

Electric Switch

- A switch is a simple device that either breaks the circuit or completes it to stop or start the flow of electricity.
- It can be placed anywhere in the circuit.

- **Switch ON:** When the switch is in the 'ON' position, the circuit from the positive terminal of the battery to the negative terminal is complete and the current flows throughout the circuit instantly. Thus the circuit is then said to be closed **(Refer to Figure 3.1)**.
- **Switch OFF:** When the switch is in the 'OFF' position, the circuit is incomplete. No current flows through any part of the circuit, thus it is said to be open **(Refer to Figure 3.2)**.

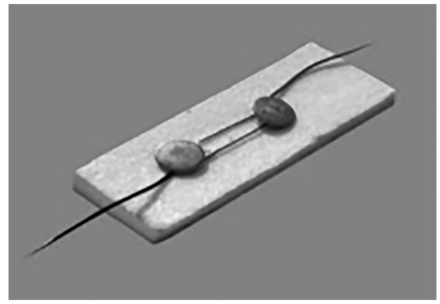


Figure 3.1: A switch in 'on' position

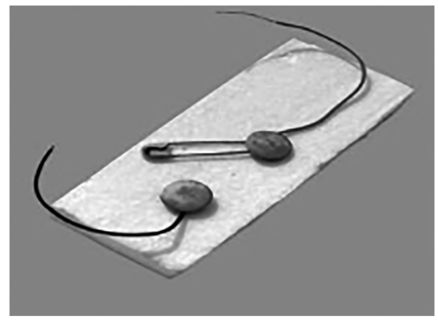


Figure 3.2: A switch in 'off' position

Electric Cell

- It is a device which contains chemicals inside it and converts it into electrical energy.
- They are a common source of electricity and have two terminals namely positive and negative.
- Electric cells are used in a number of devices such as a torch, radio, toys, alarm clocks, wristwatches and so on.

Battery

- Battery is a combination of two or more cells combined together in a series.
- Cells are connected in such a way that the positive terminal of one cell is connected to the negative terminal of the next cell.
- Cells are not always placed one after the other. Sometimes they are placed side by side.
- Many devices such as torches, transistors, toys, TV remote controls, use batteries.

Ammeter

- Ammeter is an instrument which **measures electric current** in a circuit.
- It is always connected in series in a circuit through which the current is to be measured.

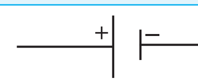
Voltmeter

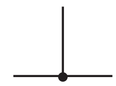
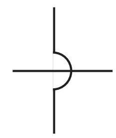
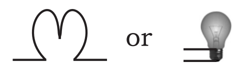
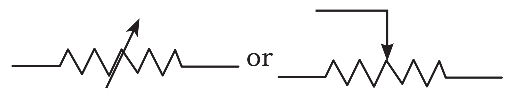
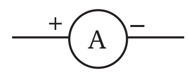
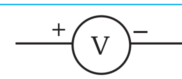
- Voltmeter is an instrument to **measure the potential difference**.
- It is always **connected in parallel** across the points between which the potential difference is to be measured.

Symbols of Electronic Components

- Some common electric components can be represented by symbols. For example, in the symbol of the electric cell, the longer line represents the positive terminal and the thicker, shorter line represents the negative terminal (Refer Table 3.1).

Table 3.1: Symbols for some electric circuit components

Sl. No.	Components	Symbols
1.	An electric cell	
2.	A battery or a combination of cells	

Sl. No.	Components	Symbols
3.	Plug key or switch (open)	
4.	Plug key or switch (closed)	
5.	A wire joint	
6.	Wires crossing without joining	
7.	Electric bulb	
8.	A resistor of resistance R	
9.	Variable resistance or rheostat	
10.	Ammeter	
11.	Voltmeter	

Electric Current

- Electric current is expressed by the amount of charge (electrons) flowing through a particular area in unit time. In other words, it **is the rate of flow of electric charges**.
- The source can be through inverters, a battery, generators etc. and can be used for lighting, heating, cooling and so on.
- Electric current was considered to be the flow of positive charges and the direction of flow of positive charges was taken to be the direction of electric current.

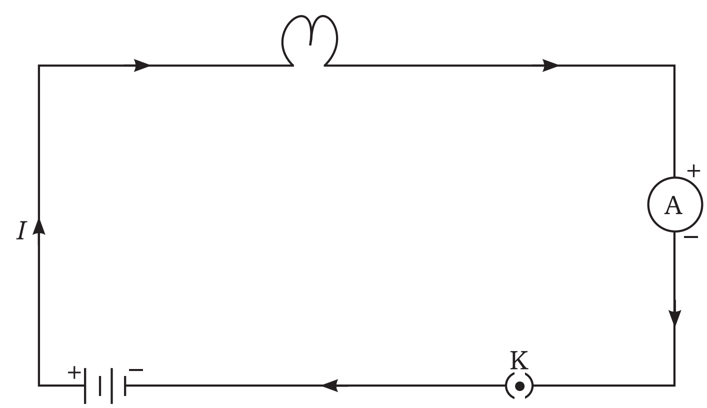


Figure 3.3: A schematic diagram of an electric circuit

- Conventionally, in an electric circuit the direction of electric current is taken as opposite to the direction of the flow of electrons (negative charges). **(Refer to Figure 3.3)**
- Therefore, if a net charge Q, flows across any cross-section of a conductor in time t, then the current I, through the cross-section is,

$$I = \frac{Q}{t}$$

- The SI unit of electric charge is **coulomb (C)**, which is equivalent to the charge contained in nearly **6 × 10^{18} electrons**.

- An electron possesses a negative charge of **1.6×10^{-19} C**.
- The electric current is expressed by a unit called **ampere (A)**, named after the French scientist, **Andre-Marie Ampere** (1775–1836).
  - **One ampere:** It is constituted by the flow of one coulomb of charge per second, i.e.

    $$1A = \frac{1C}{1s}$$

  - Small quantities of current are expressed in milliampere **(1 mA = 10^{-3} A)** or in microampere (**1 μA = 10^{-6} A**).

Flow of charges inside a wire

Inside the solid, the atoms are packed together with very little spacing between them. But the electrons can travel through a perfect solid crystal smoothly and easily, almost as if they were in a vacuum. The 'motion' of electrons in a conductor, however, is very different from that of charges in empty space. When a steady current flows through a conductor, the electrons in it move with a certain average 'drift speed'. One can calculate this drift speed of electrons for a typical copper wire carrying a small current, and it is found to be actually very small, of the order of 1 mm/s. The physical drift of electrons in the conducting wires is a very slow process. The exact mechanism of the current flow, which takes place with a speed close to the speed of light, is fascinating.

Electric Circuit

- A continuous and closed path of an electric current is called an electric circuit.
- Electric circuit is the complete path for electricity to pass, from one terminal of the electric cell through the bulb and back to the other terminal of the electric cell. The bulb glows only when current flows through the circuit **(Refer to Figure 3.4)**.

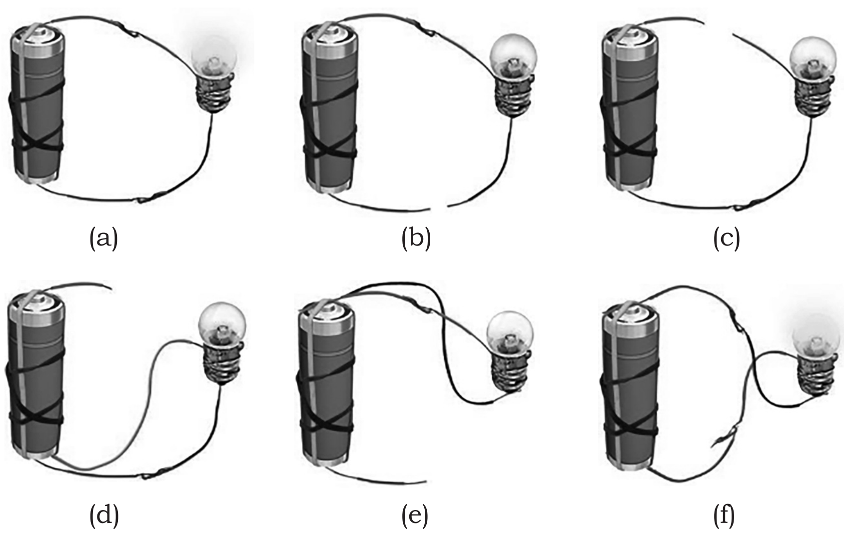


Figure 3.4: Different arrangements of electric cell and bulb

- Sometimes an electric bulb does not glow even if it is connected to the cell. This may happen if the bulb has fused.
- One reason for a bulb to fuse is a break in its filament. If the filament of the bulb is broken, the path of the current between the terminals of the electric cell is not completed and hence the current cannot flow.

Circuit Diagram

- It is a diagram, in which different components of the circuit are represented by the symbols.
- Circuit diagrams are much easier to draw using symbols **(Refer to Figure 3.5)**.

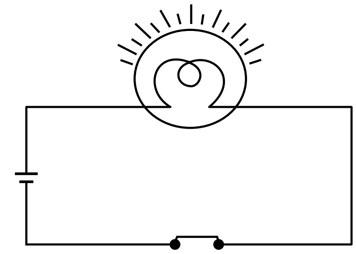


Figure 3.5: A Circuit diagram when switch is ON

Electric Potential and Potential Difference

- For flow of charges in a conducting metallic wire, gravity has no role to play; the electrons move only if there is a difference of electric pressure called the **potential difference** along the conductor.
- This difference of potential may be produced by a battery, consisting of electric cells. The chemical action within a cell generates the potential difference across the terminals of the cell, even when no current is drawn from it. When the cell is connected to a conducting circuit element, the potential difference sets the charges in motion in the conductor and produces an electric current. In order to maintain the current in a given electric circuit, the cell has to expend its chemical energy stored in it.
- Thus, the electric potential difference between two points in an electric circuit carrying some current as the work done to move a unit charge from one point to the other

  Potential difference (V) between two points = Work done (W)/Charge (Q)

  V = W/Q
- The SI unit of electric potential difference is volt (V), named after **Alessandro Volta** (1745 –1827), an Italian physicist.
  - **One volt:** One volt is the potential difference between two points in a current carrying conductor when 1 joule of work is done to move a charge of 1 coulomb from one point to the other. Therefore,

    1 volt = 1 joule/1 coulomb

    1 V = 1 J C^{-1}

Ohm's Law

- In 1827, a German physicist Georg Simon Ohm (1787–1854) found out that the potential difference, **V**, across the ends of a given metallic wire in an electric circuit is directly proportional to the current **'I'** flowing through it, provided its temperature remains the same **(Refer to Figure 3.6)**. This is called Ohm's law and can understood as,

  $V \propto I$

  Or, V/I = constant

  = R (Resistance)

  Or, **V = IR**

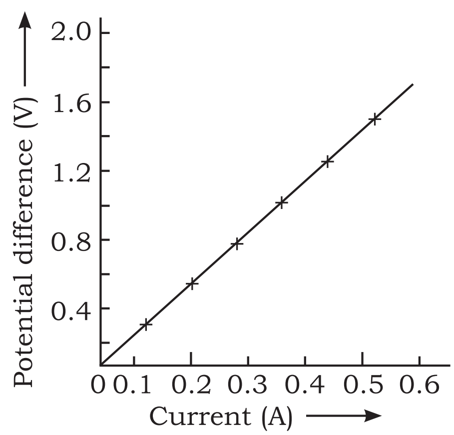


Figure 3.6: V–I graph showing Ohm's law

- **Resistance (R):** It is the property of a conductor to resist the flow of charges through it. R is a constant for the given metallic wire at a given temperature. Its SI unit is **ohm**, represented by the Greek letter Ω. Thus, the current through a resistor is inversely proportional to its resistance. If the resistance is doubled the current gets halved. According to Ohm's law

  R = V/I

- **One ohm:** If the potential difference across the two ends of a conductor is 1 V and the current through it is 1 A, then the resistance R, of the conductor is 1 Ω.

  1 ohm = 1 volt/ 1 ampere

  Or, I = V/R

- **Variable resistance:** A component used to regulate current without changing the voltage source is called variable resistance. In an electric circuit, a device called **rheostat** is often used to change the resistance in the circuit.
- **Resistor:** The electrons are not completely free to move within a conductor. They are restrained by the attraction of the atoms among which they move. Thus, motion of electrons through a conductor is retarded by its resistance. A conductor having some appreciable resistance is called a resistor.

POINTS TO PONDER

Resistance to the electric current is one of the major reasons for the transmission losses in the national power grids. Also this resistance causes the heating of devices and reduced efficiency in computing. Have you heard of Superconductors? Can you look for the status of research on superconductors?

Factors on which the Resistance of a Conductor Depends

- On applying Ohm's law, it is clear that the resistance of the conductor depends on:
  i. Its length,
  ii. Its area of cross-section, and
  iii. The nature of its material.
- Resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A).

  $R \propto l$ and

  $R \propto 1/A$

  Combining both we get

  $R \propto l/A$

  Or, $R = \rho \frac{l}{A}$ (ρ is electrical resistivity)

- **Electrical resistivity (ρ):** ρ (rho) is a constant of proportionality and is called the electrical resistivity of the material of the conductor. The SI unit is Ω m. It is a characteristic property of the material.
  - The metals and some alloys have very low resistivity in the range of 10^{-8} Ω m to 10^{-6} Ω m. They are good conductors of electricity. The resistivity of an alloy is generally higher than that of its constituent metals (Refer Table 3.2). Alloys do not oxidise (burn) readily at high temperatures. For this reason, they are commonly used in electrical heating devices, like electric iron, toasters etc. Tungsten is used almost exclusively for filaments of electric bulbs, whereas copper and aluminium are generally used for electrical transmission lines.
  - Insulators like rubber and glass have resistivity of the order of 10^{12} to 10^{17} Ω m.
- Both the resistance and resistivity of a material vary with temperature.

Table 3.2: Electrical resistivity of some substances at 20°C

	Material	**Resistivity (Ω m)**
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}

	Material	Resistivity (Ω m)
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Magnanin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Resistance of a System of Resistors

- Ohm's law can be applied to combinations of resistors. There are two methods of joining the resistors together.

Resistors in Series

- An electric circuit in which resistors having resistances R_1, R_2 and R_3, respectively, are joined end to end are said to be resistors in series **(Refer to Figure 3.7)**.
- In a series combination of resistors the current is the same in every part of the circuit or the same current through each resistor.
- The total potential difference across a combination of resistors in series is equal to the sum of potential difference across the individual resistors.

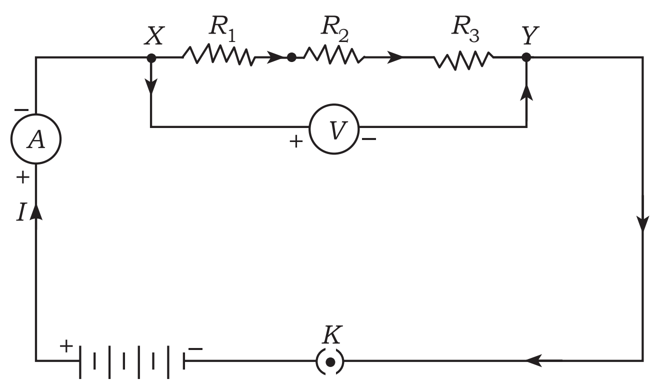


Figure 3.7: Resistors in series

$V = V_1 + V_2 + V_3$

Let I be the current through the circuit. The current through each resistor is also I.

By applying the Ohm's law to the entire circuit, we have

$V = I R$

On applying Ohm's law to the three resistors separately, we further have

$V_1 = I R_1$

$V_2 = I R_2$ and

$V_3 = I R_3$

Since, $V = V_1 + V_2 + V_3$

So, $I R = I R_1 + I R_2 + I R_3$

Or $\mathbf{R_s = R_1 + R_2 + R_3}$

- Thus, when several resistors are joined in series, the resistance of the combination Rs equals the sum of their individual resistances, R_1, R_2, R_3 and is thus greater than any individual resistance.
- **Disadvantage of a series circuit:** In a series circuit, the current is constant throughout the electric circuit. Thus it is impracticable to connect an electric bulb and an electric heater in series, because they need currents of widely different values to operate properly. Another major disadvantage of a series circuit is that when one component fails the entire circuit is broken and none of the components works.

Resistors in Parallel

- When the arrangement of three resistors are joined in parallel with a battery, it is observed that the total current I, is equal to the sum of the separate currents through each branch of the combination **(Refer to Figure 3.8)**.

  $I = I_1 + I_2 + I_3$

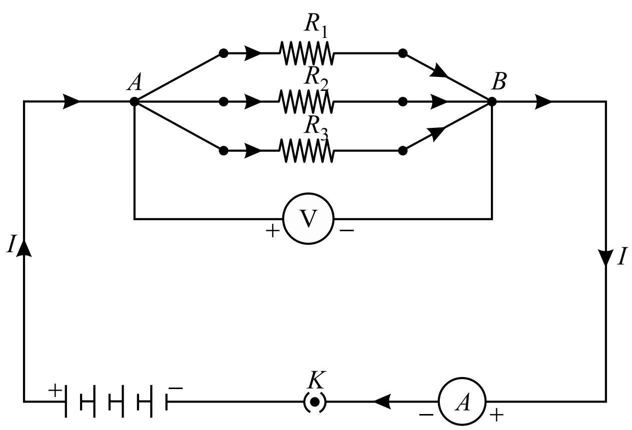


Figure 3.8: Resistors in parallel

- Let R_p be the equivalent resistance of the parallel combination of resistors.
- By applying Ohm's law to the parallel combination of resistors, we have

  $I = V/Rp$

  On applying Ohm's law to each resistor, we have

  $I_1 = V/R_1$

  $I_2 = V/R_2$ and

  $I_3 = V/R_3$

  Since $I = I_1 + I_2 + I_3$

  So, $V/R_P = V/R_1 + V/R_2 + V/R_3$

  Or, $\mathbf{1/R_P = 1/R_1 + 1/R_2 + 1/R_3}$
- Thus, the reciprocal of the equivalent resistance of a group of resistances joined in parallel is equal to the sum of the reciprocals of the individual resistances.
- **Advantage:** A parallel circuit divides the current through the electrical gadgets. The total resistance in a parallel circuit is decreased. This is helpful particularly when each gadget has different resistance and requires different current to operate properly.

Electric Power

- The **rate of doing work** is power. This is also the rate of consumption of energy.
- The power P is given by,

  $P = VI$

  Or $\mathbf{P = I^2R = V^2/R}$
- The SI unit of electric power is watt (W).
- One Watt is the power consumed by a device that carries 1 A of current when operated at a potential difference of 1 V. Thus,

  1 W = 1 volt × 1 ampere = 1 V A
- The unit 'watt' is very small to use. Therefore, we use a much larger unit called **'kilowatt' (= 1000 watts).**

- Since electrical energy is the product of power and time, the unit of electric energy is, therefore, **watt hour (W h)**.
- **One watt hour** is the energy consumed when 1 watt of power is used for 1 hour.
- The commercial unit of electric energy is **kilowatt hour (kW h)**, commonly known as 'unit'.

  1 kW h = 1000 watt × 3600 second

  $= 3.6 \times 10^6$ watt second

  $= 3.6 \times 10^6$ joule (J)

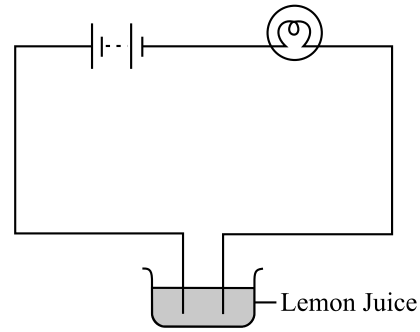


Figure 3.9: Testing conduction of electricity

Conduction of Electricity in Liquids

- Some liquids are good conductors of electricity and some are poor conductors. Under certain conditions, most materials can conduct.
- For example, dipping the ends of the tester into lemon juice or vinegar shows, when the liquid between the two ends of the tester allows the electric current to pass, the circuit of the tester becomes complete **(Refer to Figure 3.9)**. The current flows in the circuit and the bulb glows. When the liquid does not allow the electric current to pass, the circuit of the tester is not complete and the bulb does not glow. In some situations even though the liquid is conducting, the bulb may not glow. As a result, the circuit of the tester may be complete and yet the current through it may be too weak to make the bulb glow.
- The water from sources such as taps, hand pumps, wells and ponds is not pure. It may contain several salts dissolved in it. This water is thus a good conductor of electricity. On the other hand, distilled water is free of salts and is a poor conductor, but when salt is dissolved in distilled water, it becomes a conductor of electricity.
- Most liquids that conduct electricity are solutions of acids, bases and salts.

Do You Know?

Small amounts of mineral salts present naturally in water are beneficial for human health. However, these salts make water a good conductor. So, we should never handle electrical appliances with wet hands or while standing on a wet floor.

In 1800, a British chemist, **William Nicholson** (1753–1815), had shown that if electrodes were immersed in water, and a current was passed, bubbles of oxygen and hydrogen were produced. Oxygen bubbles formed on the electrode connected to the positive terminal of the battery and hydrogen bubbles formed on the other electrode.

Chemical Effects of Electric Current

- The passage of an electric current through a conducting solution causes chemical reactions. The resulting effects are called the chemical effects of the electric current.
- For example, two carbon rods/iron nails (electrodes), wrapped with copper wires, connected to a battery and immersed in salt water show some of the chemical effects of the electric current such as formation of bubbles of a gas on the electrodes, deposits of metal may be seen on electrodes or changes of colour of solutions may occur **(Refer to Figure 3.10)**. The reaction would depend on what solution and electrodes are used.

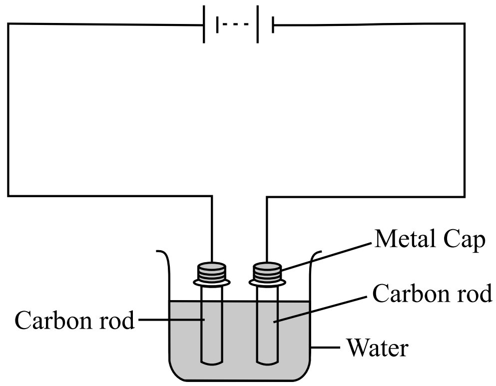


Figure 3.10: Passing current through water

Electroplating

- The process of depositing a layer of any desired metal on another material by means of electricity is called 'electroplating'. It is one of the most common applications of chemical effects of electric current.

- **For example**, When electric current is passed through the copper sulphate solution, copper sulphate dissociates into copper and sulphate. The free copper gets drawn to the electrode connected to the negative terminal of the battery and gets deposited on it. From the other electrode, a copper plate, an equal amount of copper gets dissolved in the solution. Thus, the loss of copper from the solution is restored and the process continues. This means that copper gets transferred from one electrode to the other.
- **Electroplating** is widely used in industry **for coating metal objects** with a thin layer of a different metal. For example, chromium plating is done on many objects such as car parts, bath taps, kitchen gas burners, bicycle handlebars, wheel rims and many others.
  - Chromium has a shiny appearance and does not corrode. It resists scratches. However, chromium is expensive and it may not be economical to make the whole object out of chromium. So the object is made from a cheaper metal and only a coating of chromium over it is deposited.
- **Jewellery makers** electroplate silver and gold on less expensive metals. These ornaments have the appearance of silver or gold but are much less expensive.
- Tin cans, used for storing food, are made by **electroplating tin on iron**. Tin is less reactive than iron. Thus, food does not come into contact with iron and does not spoil.
- Iron is used in bridges and automobiles to provide strength. However, iron tends to corrode and rust. So, a **coating of zinc is deposited on iron** to protect it from corrosion and formation of rust.

Note: In the electroplating factories the disposal of the used conducting solution is a major concern. It is a polluting waste and there are specific disposal guidelines to protect the environment.

Heating Effect of Electric Current

- Flow of electric current in an electric device/wire produces heat. This is the heating effect of the electric current. Electric heater used for cooking, electric iron, an electric bulb or room heater are some appliances which show heating effects when electric current flows.
- If a current is flowing through a resistor of resistance R and potential difference across it be V; t is the time during which a charge Q flows across and the work done in moving the charge Q through a potential difference V is VQ. Then the power input to the circuit by the source is

$$P = V\frac{Q}{t} = VI$$

Or the energy supplied to the circuit by the source in time t is P × t, that is, V × I × t. This energy is dissipated in the resistor as heat. Thus for a steady current I, the amount of heat H produced in time t is

$$\mathbf{H = VIt}$$

By Applying Ohm's law, we get

$$\mathbf{H = I^2Rt}$$

Do You Know?

Incandescent electric bulbs are often used for lighting but a part of electricity consumed is used in producing heat. This is not desirable as it results in the wastage of electricity.

The **fluorescent tube-lights and compact fluorescent lamps (CFLs)** are better electricity efficient lighting sources. Fluorescent tubes and CFLs contain mercury vapour which is toxic in nature. Therefore, damaged fluorescent tubes or CFLs need to be disposed off safely.

Short Circuit: When the insulation on the wires has come off due to wear and tear, the direct touching of wires cause excessive currents in electrical circuits. This situation cause short circuit.

Overload: Connection of many devices to a single socket can be a reason for excessive current. This may cause overload in the circuit.

This is known as Joule's law of heating.

- **Joule's law of heating:** The law implies that heat produced in a resistor is:
  - (i) Directly proportional to the square of current for a given resistance,
  - (ii) Directly proportional to resistance for a given current, and
  - (iii) Directly proportional to the time for which the current flows through the resistor.

Element

- All electrical heating devices consist of a coil of wire called an element. Electrical appliances, such as immersion heaters, hotplates, irons, geysers, electric kettles, hair dryers, have elements inside them. When these appliances are connected to the electric supply, their elements become red hot and give out heat.
- The amount of heat produced in a wire depends on its material, length and thickness. Thus, for different requirements, the wires of different materials, lengths and thicknesses are used.

Filament

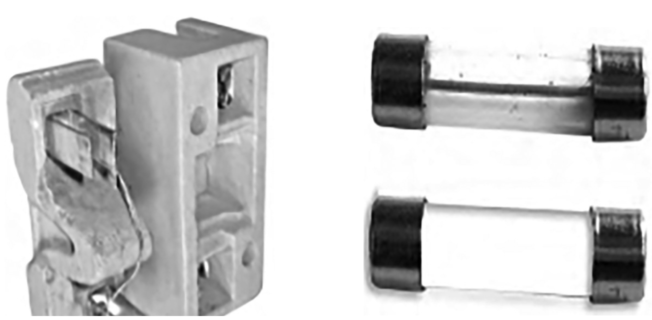
- A conducting thin wire that gives off light is called the filament of the bulb.
- When an electric current passes through it the filament gets heated to such a high temperature that it starts glowing.
- If a large current passes through a wire, the wire may become so hot that it may even melt and break.
- When the bulb gets fused, its filament is broken.

ISI Mark

Bureau of Indian Standards, New Delhi assigns a Standard Mark on products, called ISI mark which is an assurance of conformity to the specifications given on the products. In fact, before buying any electrical appliance, look for this mark. The ISI mark ensures that the appliance is safe and wastage of energy is minimum. It is advised to use electrical appliances and gadgets, which are electricity efficient.

Practical Applications of Heating Effect of Electric Current

- The generation of heat in a conductor is an inevitable consequence of electric current but in many cases, it is undesirable as it converts useful electrical energy into heat.
- In electric circuits, the unavoidable heating can increase the temperature of the components and alter their properties. However, the heating effect of electric current has many useful applications.
- The electric laundry iron, electric toaster, electric oven, electric kettle and electric heater are some of the familiar devices based on Joule's heating.
- The electric heating is also used to produce light, as in an electric bulb. Here, the filament must retain as much of the heat generated as is possible, so that it gets very hot without melting and emits light. A strong metal with a high melting point such as tungsten (melting point 3380°C) is used for making bulb filaments.
  - The filament should be thermally isolated as much as possible, using insulating support, etc.
  - The bulbs are usually filled with chemically inactive nitrogen and argon gases to prolong the life of filament.
  - Most of the power consumed by the filament appears as heat, but a small part of it is in the form of light radiated.
- Another application of Joule's heating is the fuse used in electric circuits.



(a) (b)

Figure 3.11: (a) Fuse used in buildings and (b) Fuses used in electrical appliances

Fuse

- It is a safety device that **protects circuits and appliances** by stopping the flow of any unduly high electric current and prevents electric fires. The fuse is placed in series with the device. It consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc.
  - Wires used for making electric fuses are made from some special materials which melt quickly and break when large electric currents are passed through them.
  - The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends.
  - The fuses used for **domestic purposes** are rated as 1 A, 2 A, 3 A, 5 A, 10 A, etc.
  - In all buildings fuses are inserted in all electrical circuits.
  - Also, there is a maximum limit on the current which can safely flow through a circuit. If, by accident the current exceeds this safe limit, the wires may become overheated and may cause fire. If a proper fuse is there in the circuit, it will blow off and break the circuit.
  - Fuses of different kinds are used for different purposes **(Refer to Figure 3.11)**. One must always use proper fuses specified for particular applications, and which carry an ISI mark.
  - One disadvantage of a fuse is that once the filament of the fuse is broken, it needs to be replaced. This is a time consuming process. This challenge can be overcome by **Miniature Circuit Breaker (MCB)**. **(Refer to Figure 3.12)**

Figure 3.12: Miniature Circuit Breakers (MCB)

These days Miniature circuit breakers (MCBs) are increasingly being used in place of fuses. These are switches which automatically turn off when current in a circuit exceeds the safe limit. If turned them on then the circuit is once again complete.

Light Emitting Diode (LED)

The LED bulbs are much electricity efficient and therefore being preferred. For producing a given intensity of light, LED bulbs consume less electricity and have longer lifetime as compared to incandescent bulbs or fluorescent tubes or CFLs. LED glows even when a weak electric current flows through it. There are two wires (called leads) attached to an LED. One lead is slightly longer than the other. While connecting to a circuit, the longer lead is always connected to the positive terminal of the battery and the shorter lead is connected to the negative terminal of the battery.

LEDs are available in many colours such as red, green, yellow, blue, white and are increasingly being used for many applications, for example in traffic signal lights. LEDs are increasingly being used for lighting. A cluster of white LEDs grouped together forms a LED light source. But LED light sources are expensive, so CFLs are currently the best choice. Once the technological advances reduce the cost of LEDs, they will become the preferred lighting source.

Magnetic Effect of Electric Current

- If the electric current passes through a wire, then the current carrying wire behaves like a magnet.
- **Hans Christian Oersted (A.D. 1777-1851)** was the first person who noticed every time when the current was passed through the wire the compass needle placed near it got deflected from its usual North-South position.

Electromagnet

- It is a magnet made by passing electric current through it.
- Electromagnet consists of a coil of insulated wire wrapped around a piece of iron which is magnetised only when an electric current is passed through the coil. The magnetism of an electromagnet remains as long as the current is flowing in its coil.

- **Uses**
  - The electromagnets can be made very strong and can lift very heavy loads.
  - The electromagnets are also used to separate magnetic material from the junk.
  - Doctors use tiny electromagnets to take out small pieces of magnetic material that have accidentally fallen in the eye.

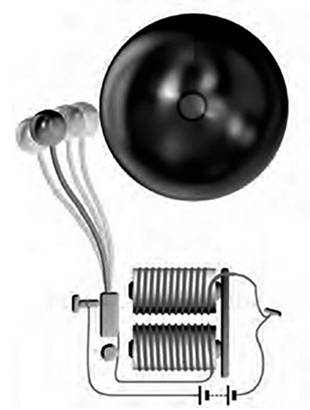


Figure 3.13: Circuit of an electric bell

Electric Bell

- Electric bell consists of a coil of wire wound on an iron piece. The coil acts as an electromagnet.
- **Working:** An iron strip with a hammer at one end is kept close to the electromagnet. There is a contact screw near the iron strip. When the iron strip is in contact with the screw, the current flows through the coil which becomes an electromagnet. It, then, pulls the iron strip and the hammer strikes the gong of the bell to produce a sound. However, when the electromagnet pulls the iron strip, it also breaks the circuit and the current through the coil stops flowing. The iron strip comes back to its original position and touches the contact screw again. This completes the circuit. The current flows in the coil and the hammer strikes the gong again. This process is repeated in quick succession **(Refer to Figure 3.13)**.

Conclusion

Some materials allow electric current to pass through them and some resist the flow of current. Various electronic components are arranged in a manner through which they can form a closed circuit to conduct electricity. These electric components can be represented by their symbols in circuit diagrams. However, the electrons are not completely free to move within a conductor and is retarded by its resistance. When an electric current passes through a conductor it shows heating effect, magnetic effect and so on. Electricity is not only limited to power our home appliances. In fact some natural phenomena are visible in our surroundings also.

Do You Know?

The credit for the invention of the electric bulb is usually given to **Thomas Alva Edison (A.D. 1847 – 1931)**, though others before him had worked on it. He was a remarkable man. He made some 1300 inventions including the **electric bulb, gramophone, the motion picture camera and the carbon transmitter**, which facilitated the invention of the telephone.

***Glossary*:**

- **Switch:** Switch is a simple device that is used to either break the electric circuit or to complete it.
- **Conductors:** Materials that allow electric current to pass through them are called conductors.
- **Insulators:** Materials that do not allow electric current to pass through them are called insulators.
- **Electric Current:** A stream of electrons moving through a conductor constitutes an electric current. Conventionally, the direction of current is taken opposite to the direction of flow of electrons.
- **Resistance:** Resistance is a property that resists the flow of electrons in a conductor. It controls the magnitude of the current. The SI unit of resistance is ohm (Ω).
- **Ohm's law:** The potential difference across the ends of a resistor is directly proportional to the current through it, provided its temperature remains the same.
- **One Watt:** The unit of power is watt (W). One watt of power is consumed when 1 A of current flows at a potential difference of 1 V.
- **Electroplating:** The process of depositing a layer of any desired metal on another material, by means of electricity, is called electroplating.
- **Electromagnet:** A current carrying coil of an insulated wire wrapped around a piece of iron is called an electromagnet.
- **Static Charges:** The electrical charges produced by rubbing are called static charges.
- **Earthing:** The process of transfer of charge from a charged object to the earth is called earthing.

❐❐❐

Magnetism

Bibliography: The chapter encompasses the summary of **Chapter 10 - CLASS VI** NCERT (Science), **Chapter 12 - CLASS X** NCERT (Science).

Introduction

Magnetism, a natural phenomenon that has intrigued mankind since ancient times, is a vital element in many modern technologies and applications. This chapter delves deep into the mysterious world of magnets, their discovery, and their varied uses. From the basic principles of magnetic effects on electric current to their application in medicine and everyday life, the nuances of magnetism are meticulously dissected to provide a comprehensive understanding.

Figure 4.1: Picking up pieces of iron from waste

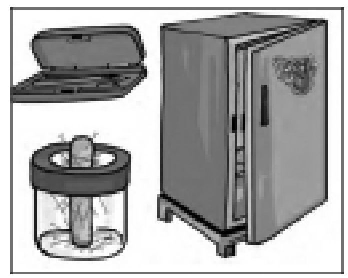


Figure 4.2: Some common items that have magnets inside them

Fun with Magnets

- Figure 4.1 shows a crane at junkyard which seems to attract and pick up iron pieces. A magnet is being used by the crane to sort out iron from the junk.
- Many everyday items, like stickers on refrigerators or pin holders, use magnets. **(Refer to Figure 4.2**) These items often conceal their magnets, making them appear "magical" in their ability to stick or attract metal.

Discovery of Magnets

Figure 4.3: A natural magnet on a hillside!

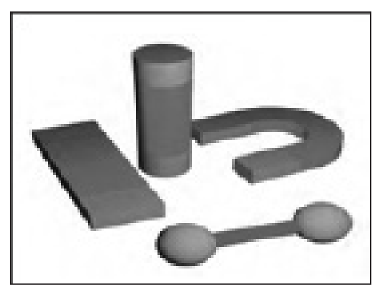


Figure 4.4: Magnets of different shapes

- Legends suggest that magnets were **discovered by a shepherd named Magnes** in ancient Greece. His stick, with an iron tip, got attracted to a rock, which turned out to be a natural magnet called magnetite. **(Refer to Figure 4.3).** The name might have originated either from the shepherd or a place called Magnesia.
- Such rocks, which attracted iron, were later termed magnets. Over time, humans realized that they could create their own magnets, leading to the development of artificial magnets.

- Today, artificial magnets come in various shapes like bar magnets, horseshoe magnets, and cylindrical magnets. **(Refer to Figure 4.4)**

Magnetic Experiment

- An experiment can demonstrate the invisible force of magnets.
- By placing a magnet inside a cup and hanging an iron clip on a short thread near the cup, the magnet, unseen inside the cup, can attract the clip, making it seem like the clip hovers in the air by some unseen force. **(Refer to Figure 4.5)**

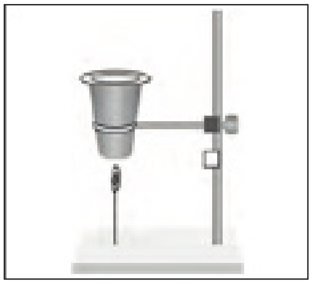


Figure 4.5: Effect of Magnet - a paper clip hanging in air!

Magnetic and Non-Magnetic Materials

- By retracing the steps of Magnes, one can explore the magnetic nature of objects around them. A simple way to do this is by attaching a magnet to a stick, termed as the "**Magnes stick**", and using it to determine which objects it attracts in various environments like a school playground or a classroom.
- Objects attracted by the magnet are made of **magnetic materials** like iron, nickel, or cobalt. On the other hand, materials that aren't attracted by the magnet are termed **non-magnetic**.
- An interesting experiment involves rubbing a magnet in sand or soil. Upon extraction, one might notice particles sticking to the magnet. While many of these particles can be shaken off, some stubborn ones remain. These particles are typically iron filings present in the soil. This activity helps deduce the presence of iron in different soil or sand samples. **(Refer to Figure 4.6)**

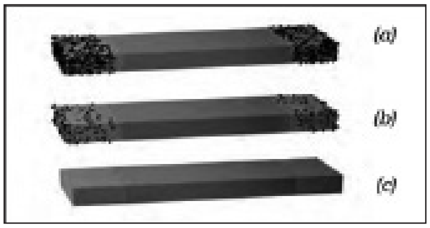


Figure 4.6: Magnet with (a) many iron filings (b) few iron filings and (c) no iron filings sticking to it.

- By documenting the amount of iron filings found in various soil samples, one can compare the iron content from different regions. Sharing this information can provide insights into the varying magnetic properties of soils from different parts of the country.

Poles of a Magnet

- When a magnet is rubbed in soil, it attracts iron filings, if present. Interestingly, these filings do not stick uniformly all over the magnet. An activity using a sheet of paper and some iron filings demonstrates this behavior. Placing a bar magnet on the paper reveals that certain areas of the magnet attract more iron filings than others. Repetition of this activity confirms a consistent pattern in the distribution of the iron filings. **(Refer to Figure 4.7)**

Figure 4.7: Iron filings sticking to a bar magnet

- This distinct attraction is more pronounced near the two ends of the bar magnet. These specific regions are termed as the "poles" of the magnet. Magnets of different shapes also have poles, which can be identified using the same method with iron filings. By observing and experimenting with various magnets, one can deduce and mark the location of poles for different magnet **shapes**.

Finding Directions with Magnets

- From ancient times, the unique properties of magnets have been harnessed to find directions. A famous anecdote revolves around Emperor Hoang Ti of China, who used a rotating statue on his

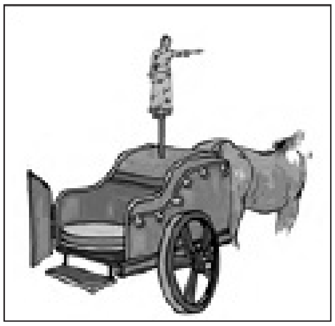


Figure 4.8: The chariot with direction finding statue

chariot that always pointed south, helping him navigate unfamiliar territories. **(Refer to Figure 4.8)**

Figure 4.9: A freely suspended bar magnet always comes to rest in the same direction

- You can replicate this directional attribute of magnets by suspending a bar magnet, allowing it to rotate freely. When left undisturbed, the magnet consistently aligns itself in the North-South direction. When you push the magnet in different directions and let it settle, it will invariably return to this North-South orientation. **(Refer to Figure 4.9)**
- Using the rising sun as a general indicator of the east direction, you can determine the North. With this method, the magnet's end pointing North is termed the North pole or North seeking end, while the other end pointing South is termed the South pole or South seeking end. This inherent quality of magnets has been invaluable for travelers over centuries.
- This magnetic property eventually led to the invention of the compass. **(Refer to Figure 4.10)** A compass consists of a magnetized needle that can pivot freely inside a marked dial. When settled, the needle indicates the North-South direction. The needle's north pole is typically differentiated by a distinct color. By using a compass, navigators and explorers have been finding their way for ages, proving the indispensable nature of this magnetic tool.

Figure 4.10: A Compass

Creating Your Own Magnet and Compass

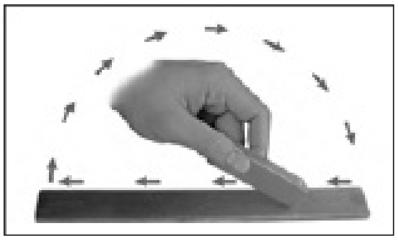


Figure 4.11: Making our own magnet

- You can easily transform a regular iron piece into a magnet. To do this, take an iron bar and stroke it with a bar magnet from one end to the other, ensuring you use the same pole and move in the same direction consistently. **(Refer to Figure 4.11)**
- After about 30-40 strokes, the iron bar will become magnetized, which can be tested by bringing it close to a pin or iron filings.
- Once you've made a magnet, you can create a simple compass. Magnetize an iron needle with your new magnet. Then, insert this needle through a small piece of cork or foam, ensuring it doesn't touch the base. Place this setup on water in a bowl, allowing the cork to float freely. **(Refer to Figure 4.12)**
- The magnetized needle will align itself with the Earth's magnetic field, pointing towards the North-South direction. No matter how you rotate the floating cork, once it stabilizes, the needle will consistently point in the same direction, giving you a rudimentary compass.

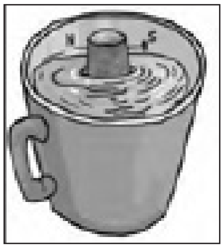


Figure 4.12: A compass in a cup

Attraction and Repulsion between Magnets

- When experimenting with magnets placed on toy cars, we observe some intriguing behaviors. If a car with the south pole of a magnet facing forward (Car A) is placed near another car with its north pole facing forward (Car B), the two cars attract each other. If the opposite poles of the magnets face each other, they attract. However, when similar poles face each other, they repel. **(Refer to Figure 4.13** and **Figure 4.14)**

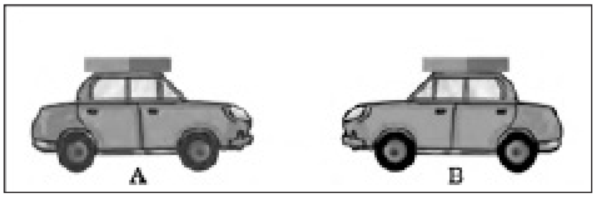


Figure 4.13: Do opposite poles attract each other?

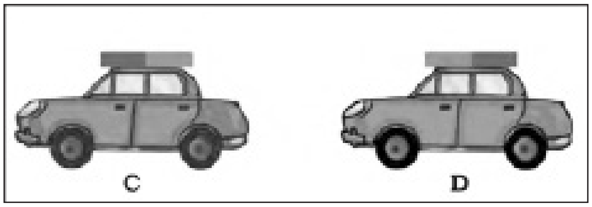


Figure 4.14: Repulsion between similar poles

- This property can also be observed by suspending a magnet and bringing the poles of another magnet near it. Like poles repel, and unlike poles attract each other.
- It is important to handle magnets with care. Their magnetic properties can diminish if subjected to heat, impact, or if they're mishandled. **(Refer to Figure 4.15)** For storage, bar magnets should be paired with unlike poles together, separated by wood, and capped with soft iron pieces at their ends.
- Horse-shoe magnets should have an iron piece across their poles. Also, magnets should be kept away from electronic devices like televisions, mobile phones, cassettes, CDs, and computers to prevent potential damage. **(Refer to Figure 4.16)**

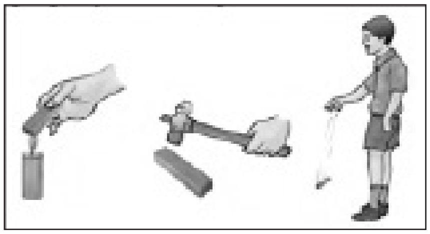


Figure 4.15: Magnets lose their property on heating, hammering and droping

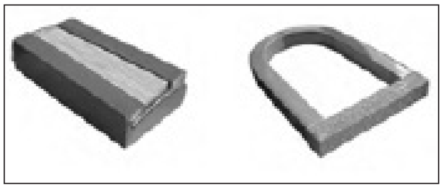


Figure 4.16: Store your magnets safely

Magnetic Effects of Electric Current

When an electric current flows through a wire, it displays magnetic characteristics.

- **Activity Description:**
  - A straight copper wire is placed perpendicularly on an electric circuit between points X and Y. **(Refer to Figure 4.17)**
  - A compass placed horizontally near this wire shows needle movement.
  - When current is passed through the circuit, the compass needle deflects.
  - The deflection of the compass needle indicates that the current-carrying copper wire has a magnetic effect, suggesting a connection between electricity and magnetism.

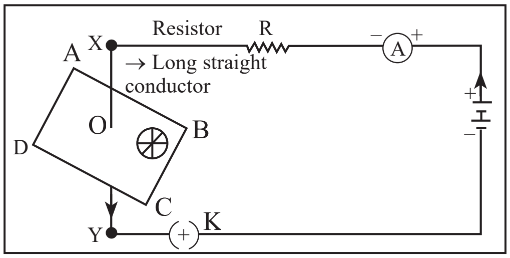
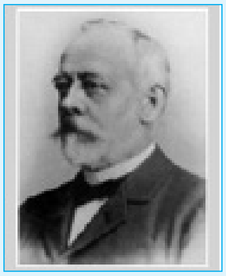


Figure 4.17: Compass needle is deflected on passing an electric current through a metallic conductor

Hans Christian Oersted (1777–1851)

- Oersted, a prominent 19th-century scientist, made significant contributions to the understanding of electromagnetism.
- In 1820, he observed that a compass needle deflected when placed near a current-carrying metallic wire, highlighting the relationship between electricity and magnetism.
- Oersted's insights paved the way for technologies such as radio, television, and fiber optics.
- In recognition of his contributions, the unit of magnetic field strength is termed "oersted."



Magnetic Field And Field Lines

Compass and Bar Magnet Interaction

- A compass needle, essentially a small bar magnet, deflects near a bar magnet.
- The compass needle has two ends pointing north (north seeking or north pole) and south (south seeking or south pole).
- Observations show that like poles of magnets repel each other, while unlike poles attract.

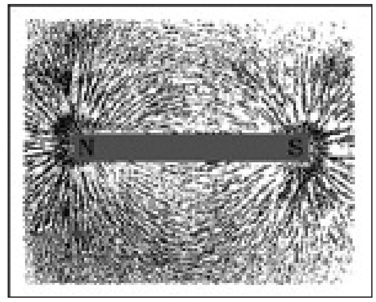


Figure 4.18: Iron filings near the bar magnet align themselves along the field lines

Visualization of Magnetic Field with Iron Filings

- When a bar magnet is placed on a paper and surrounded by iron filings, tapping the board leads to the iron filings forming a specific pattern. **(Refer to Figure 4.18)**
- This pattern is due to the magnet's influence, indicating the presence of a magnetic field around it.
- The paths that the iron filings take are called **magnetic field lines**.

Mapping Magnetic Field Lines with a Compass

- Using a compass and a bar magnet on paper, one can map the magnetic field. **(Refer to Figure 4.19)**
- The compass needle, when placed near the north pole of the bar magnet, will have its south pole pointing towards the magnet's north.
- By moving the compass and marking the positions, the field lines can be drawn, showing the magnetic field around the magnet.

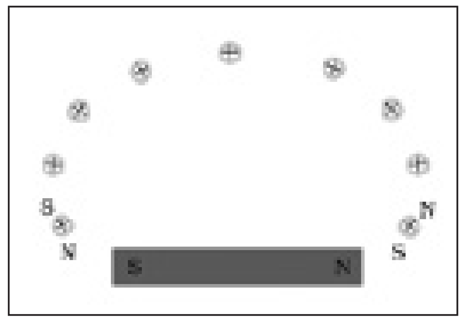


Figure 4.19: Drawing a magnetic field line with the help of a compass needle

Characteristics of Magnetic Fields

- Magnetic fields possess both direction and magnitude.
- Conventionally, field lines emerge from the north pole and converge at the south pole of a magnet.
- Within the magnet, the direction is from the south pole to the north pole, making the magnetic field lines closed curves. **(Refer to Figure 4.20)**
- The field's strength is indicated by the proximity of the field lines. **Closer lines signify a stronger field.**
- Field lines never intersect, as a compass needle can't point in two directions simultaneously.

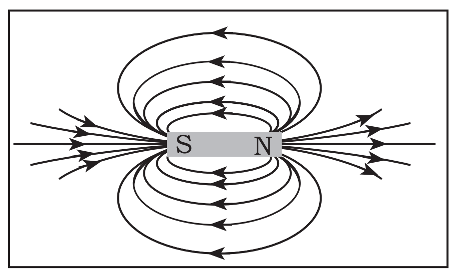


Figure 4.20: Field lines around a bar magnet

Magnetic Field Due To A Current-Carrying Conductor

Understanding Magnetic Fields

- An electric current flowing through a metallic conductor induces a magnetic field around it.
- This was observed using a simple setup involving a copper wire and a compass. **(Refer to Figure 4.21)**

✤ Changing the direction of the current also reverses the direction of the magnetic field.

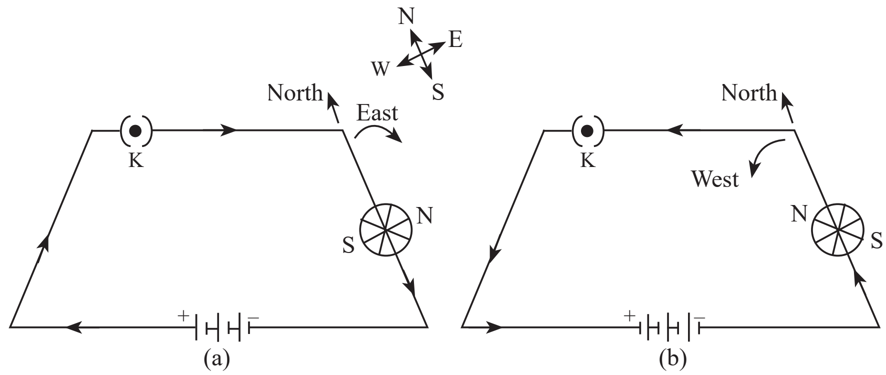


Figure 4.21: A simple electric circuit in which a straight copper wire is placed parallel to and over a compass needle. The deflection in the needle becomes opposite when the direction of the current is reversed.

Field Pattern around a Straight Conductor

✤ When a straight copper wire carries current, it produces a magnetic field around it. Using iron filings, this field can be visualized as concentric circles around the wire. **(Refer to Figure 4.22)**

✤ The closer the compass to the wire, the stronger the deflection, indicating the strength of the magnetic field decreases with distance from the conductor.

POINTS TO PONDER

Since each current carrying conductor generates its own magnetic field, do all the electronic devices that we use in our daily lives like TV, mobile, laptops etc generate their own magnetic fields? Find out if these magnetic fields have any effect on our health.

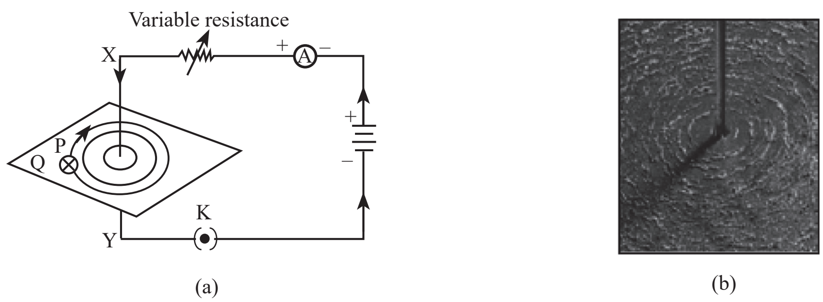


Figure 4.22: (a) A pattern of concentric circles indicating the field lines of a magnetic field around a straight conducting wire. The arrows in the circles show the direction of the field lines. (b) A close up of the pattern obtained.

Right-Hand Thumb Rule

✤ It is a method to determine the direction of the magnetic field around a current-carrying conductor.

✤ When the thumb of the right hand points in the direction of the current, the curled fingers indicate the direction of the magnetic field. **(Refer to Figure 4.23)**

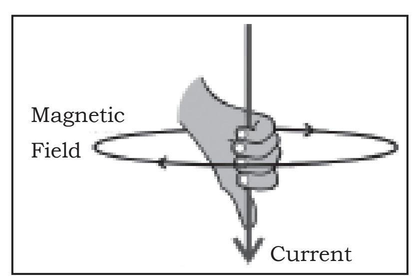


Figure 4.23: Right-hand thumb rule

Field due to Current in a Circular Loop

✤ When a straight wire carrying current is shaped into a circular loop, the magnetic field lines look different. At the center of the loop, these field lines appear as straight lines. All sections of the wire contribute to the field lines in the same direction inside the loop. **(Refer to Figure 4.24 and 4.25)**

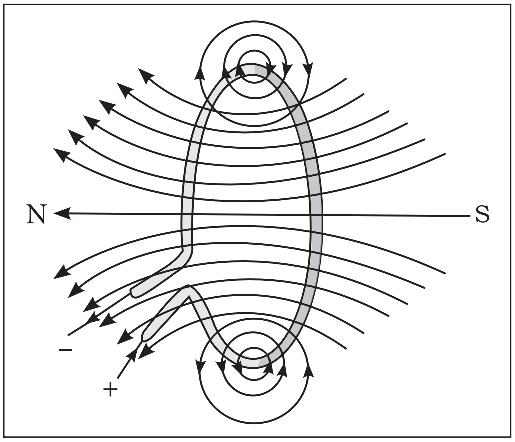


Figure 4.24: Magnetic field lines of the field produced by a current-carrying circular loop

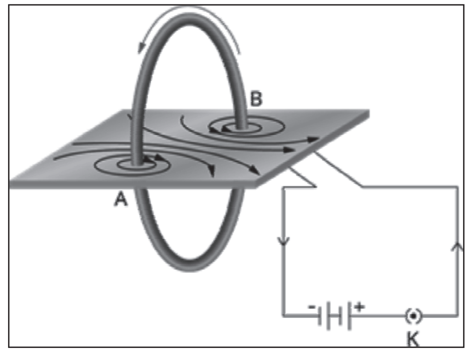


Figure 4.25: Magnetic field produced by a current- carrying circular coil

- ✤ The **strength of the magnetic field is directly proportional to the current** and the number of turns in the coil.

Magnetic Field in a Solenoid

- ✤ A solenoid is a coil of insulated copper wire wrapped in a cylindrical shape. The magnetic field around a current-carrying solenoid is similar to that around a bar magnet. **(Refer to Figure 4.26 and 4.27)**

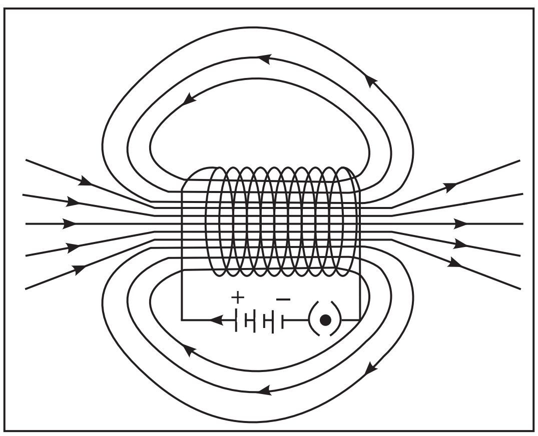


Figure 4.26: Field lines of the magnetic field through and around a current carrying solenoid

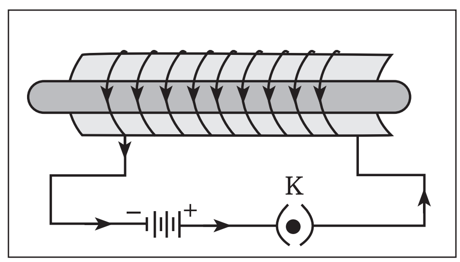


Figure 4.27: A current-carrying solenoid coil is used to magnetise steel rod inside it – an electromagnet

- ✤ Inside the solenoid, the magnetic field is uniform and strong, which can magnetize magnetic materials placed inside. Such a solenoid acts as an electromagnet when powered.

Force On A Current-Carrying Conductor In A Magnetic Field

An electric current flowing through a conductor generates a magnetic field. This field can influence a magnet near the conductor. **Andre Marie Ampere** suggested that a magnet and a current-carrying conductor exert mutual forces on each other.

Demonstrative Activity

- ✤ An aluminum rod was suspended and placed between the poles of a horseshoe magnet. **(Refer to Figure 4.28)**

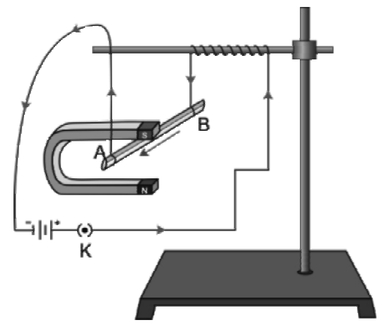


Figure 4.28: A current-carrying rod, AB, experiences a force perpendicular to its length and the magnetic field. Support for the magnet is not shown here, for simplicity.

- When current was passed through the rod, it displaced. Reversing the current reversed the rod's displacement direction.
- This showed that the current-carrying rod experienced a force in a magnetic field, and the direction of this force depended on the current's direction and the magnetic field.

Fleming's Left-Hand Rule

- To find the force's direction on a conductor, the thumb, forefinger, and middle finger of the left hand are stretched perpendicular to each other. **(Refer to Figure 4.29)**
- The first finger indicates the magnetic field, the second the current, and the thumb shows the force's direction or motion.

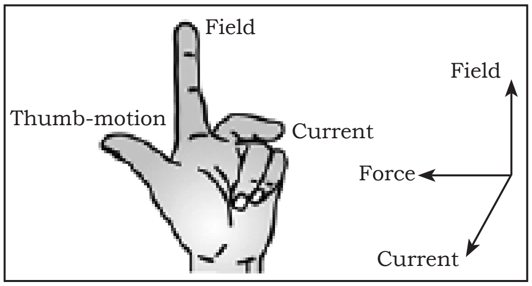


Figure 4.29: Fleming's left-hand rule

Applications

- Devices like electric motors, generators, loudspeakers, microphones, and measuring instruments utilize the interplay between current-carrying conductors and magnetic fields.

Magnetism in Medicine

- Our body's nerve currents produce weak magnetic fields, especially in the heart and brain.
- Magnetic Resonance Imaging (MRI) leverages these fields to generate images for medical diagnosis, highlighting magnetism's crucial role in modern medicine.

Conclusion

Magnetism, with its ubiquitous presence in the natural world and its pivotal role in modern technology, remains an essential topic of study. Through an exploration of its historical discovery to its application in compasses, medical devices, and domestic circuits, we've seen that the realm of magnetism is vast and its potential applications are endless.

Glossary:

- **Magnetic Field:** The region around a magnet where a force can be experienced.
- **Electromagnetic Effects:** Phenomenon where electric currents produce magnetic fields.
- **Oersted:** Scientist who discovered the relationship between electricity and magnetism.
- **Field Lines:** Paths indicating the strength and direction of a magnetic field.
- **Solenoid:** A coil of wire exhibiting magnetic properties when carrying an electric current.
- **Fleming's Left-Hand Rule:** A rule to determine the direction of force on a current-carrying conductor in a magnetic field.

- **MRI (Magnetic Resonance Imaging):** A diagnostic technique that uses magnetism to produce images of internal structures.
- **Live Wire:** The main wire in electrical systems, usually red, carrying the current to a device.
- **Neutral Wire:** Typically black, this wire completes the electrical circuit, returning current to its source.
- **Earth Wire:** A safety wire, typically green, providing a direct route for electrical current to the ground.
- **Magnetite:** A naturally occurring magnet, discovered according to legend by a shepherd named Magnes.
- **Bar Magnet:** A rectangular piece of magnetized material.
- **Compass:** A navigational instrument with a magnetized needle showing direction relative to Earth's magnetic poles.
- **North Pole (of magnet):** The end of a magnet that, when freely suspended, points towards the Earth's North Pole.
- **South Pole (of magnet):** The end of a magnet that, when freely suspended, points towards the Earth's South Pole.
- **Attraction:** The force that draws two objects together, observed in unlike poles of magnets.
- **Repulsion:** The force that pushes two objects apart, observed in like poles of magnets.
- **Fuse:** A safety device in electric circuits, preventing damage from overloading or short-circuits.
- **Overloading:** A situation where too much current flows in a circuit, often due to too many devices connected or a fault.
- **Short-Circuit:** A situation where current flows along an unintended path, often causing overloading.
- **Hoang Ti:** Ancient Chinese emperor known for his chariot's direction-finding statue, an early compass application.
- **Magnes Stick:** A tool resembling a shepherd's stick with a magnet on its end, used for experimentation.
- **Current:** The flow of electricity around a circuit.
- **Right-Hand Thumb Rule:** A method to determine the direction of the magnetic field around a current-carrying conductor.
- **Electromagnet:** A type of magnet whose magnetic field is produced by an electric current.

❐❐❐

5 Sound

Bibliography: This chapter encompasses the summary of **Chapter 10 - VIII** NCERT (Science) and **Chapter 11 - IX** NCERT (Science).

Introduction

Everyday we hear sounds from various sources like humans, birds, bells, machines, vehicles, televisions, radios etc. Sound is a **form of energy** that produces the sensation of hearing in our ears. Sound is produced by vibrating objects. When an object vibrates, it creates a disturbance in the surrounding air molecules, generating a sound wave.

Production of Sound

Sound is produced by striking the tuning fork, by plucking, scratching, rubbing, blowing or shaking different objects. We set the objects vibrating and produce sound. **Vibration** means a kind of rapid to and fro motion of an object. The sound of the human voice is produced due to vibrations in the vocal cords. Sound is produced by the vibration of objects. When an object vibrates, it creates a disturbance in the surrounding medium (usually air) which propagates in the form of waves, ultimately reaching our ears.

Production of Sound by Humans

- In humans, the sound is produced by the **voice box or the larynx (Refer to Figure 5.1)**. Voice box in humans is at the upper end of the windpipe. Two vocal cords are stretched across the voice box or larynx in such a way that it leaves a narrow slit between them for the passage of air.
- When the lungs force air through the slit, the vocal cords vibrate, producing sound. When the vocal cords are tight and thin, the type or quality of voice is different from the one when they are loose and thick.

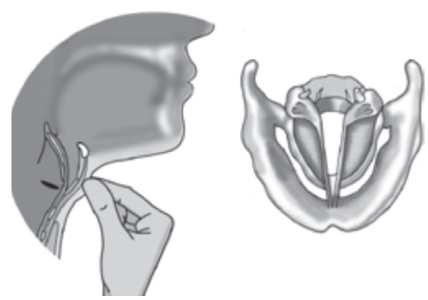


Figure 5.1: Voice box in humans

Propagation of Sound

- Sound is produced by vibrating objects. The matter or substance through which sound is transmitted is called a **medium**. It can be solid, liquid or gas. Sound moves through a medium from the point of generation to the listener.
- When an object vibrates, it sets the particles of the medium around it vibrating. The particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is first

POINTS TO PONDER

Sound needs a medium to travel. But recently NASA was able to record how black hole sounds like. How is that possible since there is no medium to carry sound in space?

displaced from its equilibrium position. It then exerts a force on the adjacent particle. As a result, the adjacent particle gets displaced from its position of rest.

- After displacing the adjacent particle, the first particle comes back to its original position. This process continues in the medium till the sound reaches our ear. The disturbance created by a source of sound in the medium travels through the medium.
- A **wave** is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion.
- Sound waves are characterised by the motion of particles in the medium and are called **mechanical waves.** Air is the most common medium through which sound travels. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure. This region is called a **compression (C)**. This compression starts to move away from the vibrating object.

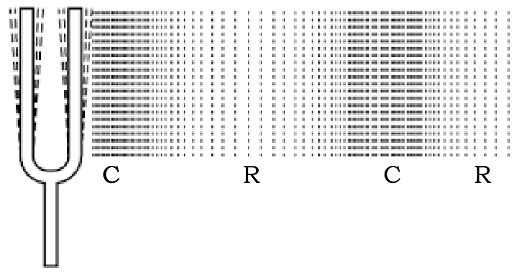


Figure. 5.2: A vibrating object creating a series of compressions (C) and rarefactions (R) in the medium.

- When the vibrating object moves backwards, it creates a region of low pressure called **rarefaction (R)**. As the object moves back and forth rapidly, a series of compressions and rarefactions is created in the air. These make the sound wave that propagates through the medium (Refer Figure 5.2).

Sound Waves are Longitudinal waves

- **Longitudinal Waves:** In a longitudinal wave, the particles of the medium (such as air, water, or solids) vibrate in the direction of the wave's propagation. This means that the motion of the particles is parallel to the direction of the wave itself.
  - In the case of sound waves, air molecules move back and forth parallel to the direction in which the sound is travelling. The compressions and rarefactions alternate, creating a series of high-pressure (compression) and low-pressure (rarefaction) regions.
- **Transverse Waves:** In a transverse wave, the particles of the medium oscillate perpendicular to the direction of the wave's motion. This creates crests (high points) and troughs (low points) in the wave.
  - Examples of transverse waves include light waves and waves on a string. In light waves, the electric and magnetic fields oscillate perpendicular to the direction of propagation.
- While sound waves are longitudinal, some waves in other mediums (like water waves on the surface of a pond) can exhibit both longitudinal and transverse characteristics. These are known as **surface waves**, as they have components that move both parallel and perpendicular to the direction of wave motion. Sound waves, specifically which travel through air or other mediums, are longitudinal waves and do not exhibit transverse motion.

POINTS TO PONDER

Human ear can hear up to 20,000 Hz. We can't perceive the sound over that frequency. What do you think what will be the effect if we are continuously exposed to frequencies higher than 20,000 Hz?

Characteristics of Sound Wave

- Sound waves can be described by it's **a)** Frequency, **b)** Amplitude and **c)** Speed.
- **Frequency:** It refers to the number of oscillations or vibrations per unit of time. In the context of sound, it determines the pitch of the sound. If we can count the number of the compressions or rarefactions that cross us per unit time, we will get the frequency of the sound wave.

- **Unit:** Hertz (Hz) is used to measure frequency, which represents one cycle per second.
- **High frequency** sounds have a high pitch, like a whistle or a bird's chirp. **Low frequency sounds** have a low pitch, like the rumble of thunder.
- **Example:** The frequency of a typical conversation is about 300 to 3,000 Hz.

Heinrich Rudolph **Hertz** was born on 22 February 1857 in Hamburg, Germany and educated at the University of Berlin. He confirmed J.C. Maxwell's electromagnetic theory by his experiments. He laid the foundation for future development of radio, telephone, telegraph and even television. He also discovered the photoelectric effect which was later explained by Albert Einstein. The SI unit of frequency was named as hertz in his honour.

- **Amplitude:** It refers to the maximum displacement or distance moved by a point on a vibrating body or wave from its equilibrium position during one complete vibration. In the context of sound, it determines the loudness or intensity of the sound.
  - **Unit:** The unit of amplitude is usually measured in decibels (dB) in acoustics.
  - Greater amplitude results in a louder sound and Smaller amplitude results in a quieter sound.
  - **Example:** A loud shout will have a greater amplitude compared to a soft whisper.
- **Speed:** Speed of sound is the distance travelled per unit time by a sound wave as it propagates through a medium.
  - **Unit:** The speed of sound is typically measured in metres per second (m/s).
  - The speed of sound varies depending on the medium. In air, at a temperature of about 22°C, it's approximately 344 metres per second.
  - **Example:** In dry air at 20°C, sound travels at around 343 metres per second.

Various Elements associated with Sound

- A sound wave in graphic form represents how density and pressure change when the sound wave moves in the medium. (Refer Figure 5.3(c))
- Figure 5.3(a) and Figure 5.3(b) represent the density and pressure variations, respectively, as a sound wave propagates in the medium. **Compressions** are the regions where particles are crowded together and are represented by the upper portion of the curve **(Refer to Figure 5.3(c))**. Thus, compressions are regions where density as well as pressure is high.

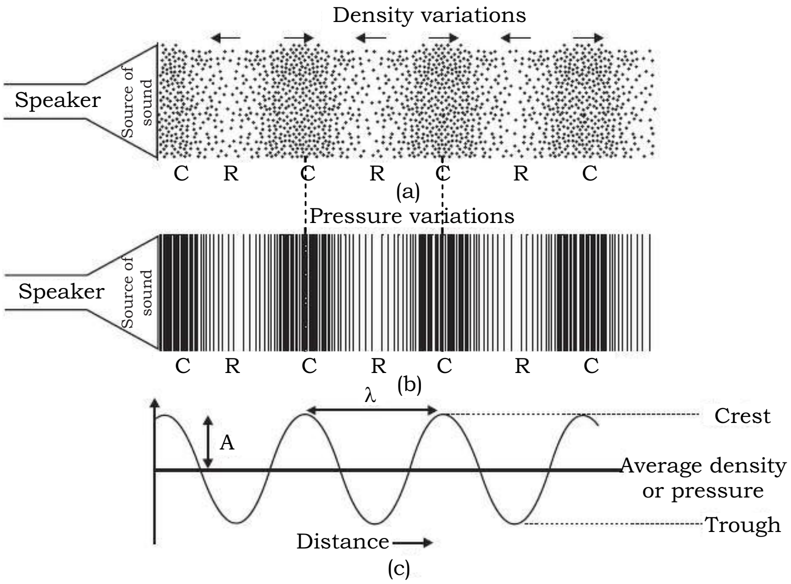
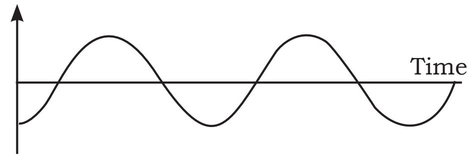
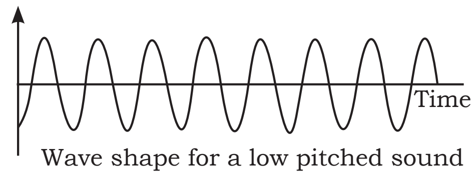


Figure 5.3: Sound propagates as density or pressure variations as shown in (a) and (b), (c) represents graphically the density and pressure variations.

- **Rarefactions** are the regions of low pressure where particles are spread apart and are represented by the valley, that is, the lower portion of the curve in Figure 5.3(c).
- The distance between two consecutive compressions (C) or two consecutive rarefactions (R) is called the **wavelength (Refer to Figure 5.3(c))**. The wavelength is usually represented by λ (Greek letter lambda). Its SI unit is metre (m).
- **Frequency:** The number of the compressions or rarefactions that cross per unit time indicate the **frequency** of the sound wave. It is usually represented by ν (Greek letter, nu). Its SI unit is hertz (symbol, Hz).
- **Time Period:** The time taken by two consecutive compressions or rarefactions to cross a fixed point is called the **time period of the wave**. It is represented by the symbol T. Its SI unit is second (s).
- Frequency and time period are related as follows: = Time period = 1/frequency



Wave shape for a low pitched sound



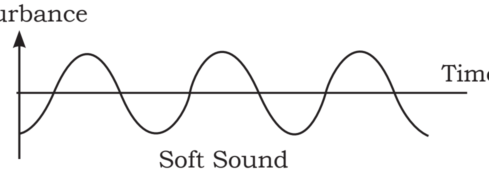
Wave shape for a low pitched sound

Figure 5.4: Low pitch sound has low frequency and high pitch of sound has high frequency.

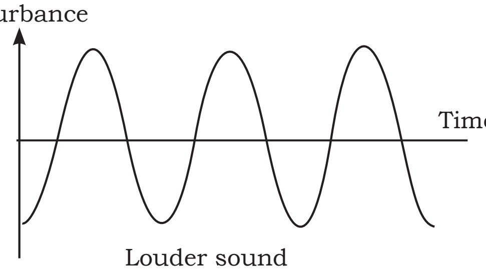
- **Pitch:** How our brain interprets the frequency of an emitted sound is called its **pitch**. The faster the vibration of the source, the higher the frequency, the higher is the pitch **(Refer to Figure 5.4)**. A high pitch sound corresponds to a greater number of compressions and rarefactions passing a fixed point per unit time. Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.

Amplitude

- The magnitude of the maximum disturbance in the medium on either side of the mean value is called the **amplitude** of the wave. It is usually represented by the letter A **(Refer to Figure 5.3(c))**. For sound its unit will be that of density or pressure.
- The **loudness or softness of a sound** is determined basically by its amplitude. The amplitude of the sound wave depends upon the force with which an object is made to vibrate. A sound wave spreads out from its source. As it moves away from the source its amplitude as well as its loudness decreases. Louder sound can travel a larger distance as it is associated with higher energy. **(Refer to Figure 5.5)**
- The **quality or timber of sound** is that characteristic which enables us to distinguish one sound from another having the same pitch and loudness. The sound which is more pleasant is said to be of a rich quality. A sound of a single frequency is called a **tone**. The sound which is produced due to a mixture of several frequencies is called a **note** and is pleasant to listen to.



Soft Sound



Louder sound

Figure 5.5: Soft sound has small amplitude and louder sound has large amplitude

- **Noise** is unpleasant to the ear whereas music is pleasant to hear and is of rich quality. The speed of sound is defined as the distance at which a point on a wave, such as a compression or a rarefaction, travels per unit time. We know, speed, v = distance / time = λ/T.

Here λ is the wavelength of the sound wave. It is the distance travelled by the sound wave in one time period (T) of the wave. Thus, v = λ ν (1/T = ν) or v = λ ν

That is, **speed = wavelength × frequency**. The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Sonic boom: When the speed of any object exceeds the speed of sound it is said to be travelling at supersonic speed. Bullets, jet aircrafts etc. often travel at supersonic speeds. When a sound producing source moves with a speed higher than that of sound, it produces shock waves in air. These shock waves carry a large amount of energy. The air pressure variation associated with this type of shock waves produces a very sharp and loud sound called the **"sonic boom"**. The shock waves produced by a supersonic aircraft have enough energy to shatter glass and even damage buildings.

- The amount of sound energy which passes each second through the unit area is called the intensity of sound. We sometimes use the terms "loudness" and "intensity" interchangeably, but they are not the same. Loudness is a measure of the response of the ear to the sound.

Speed of Sound in Different Media

- Sound propagates through a medium at a finite speed. The sound of a thunder is heard a little later than the flash of light is seen. Hence, sound travels at a speed which is much less than the speed of light. The **speed of sound depends on the properties of the medium** through which it travels.
- The speed of sound in a medium depends on the **temperature of the medium**. The speed of sound decreases when we go from solid to gaseous state. In any medium as we increase the temperature, the speed of sound increases.
- **Example:** The speed of sound in air is 331 m s^{-1} at 0°C and 344 m s^{-1} at 22°C. (Refer Table 5.1).

Table 5.1: Speed of sound in different media at 25 degree celsius

State	Substance	Speed in m/s
Solids	Aluminum	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

Reflection of Sound

- Sound bounces off a solid or a liquid like a rubber ball bounces off a wall. Like light, sound gets reflected at the surface of a solid or liquid and follows the laws of reflection.
- The directions in which the sound is incident and is reflected make equal angles with the normal to the reflecting surface at the point of incidence, and the three are in the same plane. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves.

Echo

- An echo is a phenomenon that occurs when **sound waves bounce off a surface** and return to the listener after travelling a certain distance. It is essentially the reflection of sound. The minimum distance required for a distinct echo to be heard is approximately 17.2 metres. This is because sound travels at about 343 metres per second in air, and it takes some time for the sound wave to travel to the surface and back. To hear a distinct echo the **time interval between the original sound and the reflected one must be at least 0.1s**.
- Echoes may be heard more than once due to **successive or multiple reflections**. The rolling of thunder is heard due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land. Sonar (Sound Navigation and Ranging technology is based on the principle of echo.

Did You Know?

Golconda fort, near Hyderabad, is one of the most magnificent forts in India. It is famous for many engineering and architectural marvels. One of the marvels is the water supply system. But, perhaps, more astonishing is a dome near the entrance to the fort. A hand-clap at a particular point under the dome reverberates and can be heard at the highest point of the fort, about a kilometre away. This was devised as a warning system. If a guard saw a suspicious movement outside the fort, he clapped at the particular point under the dome, and the army inside the fort was alerted to the danger of the approaching enemy.

Reverberation

- Reverberation is the persistence of sound in an enclosed space after the original sound source has stopped producing sound. It occurs due to multiple reflections of sound waves from the walls, floor, and ceiling of a room.
- A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation.
- To reduce unwanted reverberation, the roof and walls of the auditorium or halls are generally covered with sound-absorbent materials like compressed fibreboard, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Loudness of sound is proportional to the square of the amplitude of the vibration producing the sound. For example, if the amplitude becomes twice, the loudness increases by a factor of 4. The loudness is expressed in a unit called decibel (dB). The following table gives some idea of the loudness of sound coming from various sources.

Normal breathing	10 dB
Soft whisper (at 5m)	30 dB
Normal conversation	60 dB
Busy traffic	70 dB
Average factory	80 dB

Above 80 dB the noise becomes physically painful.

Uses of Multiple Reflection of Sound

- **Megaphones** or loudhailers, horns, musical instruments such as trumpets and shehnai, are all designed to send sound in a particular direction without spreading it in all directions **(Refer to figure 5.6)**.

Figure 5.6: A Megaphone and Horn

- **Stethoscope** is a medical instrument used for listening to sounds produced inside the body, mostly in the heart or lungs. The sound of the patient's heartbeat reaches the doctor's ears by multiple reflections of sound **(Refer to Figure 5.7)**.
- The **ceilings of concert halls**, conference halls and cinema halls are mostly curved so that sound after reflection reaches all corners of the hall **(Refer to Figure 5.8)**.


Figure 5.7: A Stethoscope

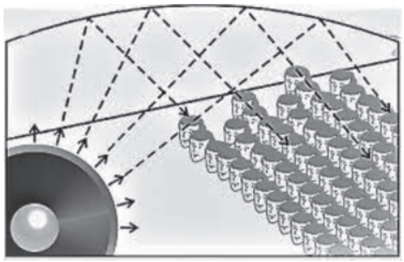


Figure 5.8: Curved ceiling of a Conference Hall

Inaudible and Audible Sounds

- Sounds of frequencies less than about 20 vibrations per second (20 Hz) cannot be detected by the human ear. Such sounds are called inaudible. On the higher side, sounds of frequencies higher than 20,000 vibrations per second (20 kHz) are also not audible to the human ear. Thus, for the human ear, the **range of audible frequencies is roughly from 20 to 20,000 Hz**.
- Children under the age of five and some animals, such as dogs can hear up to 25 kHz (1 kHz = 1000 Hz). As people grow older their ears become less sensitive to higher frequencies.

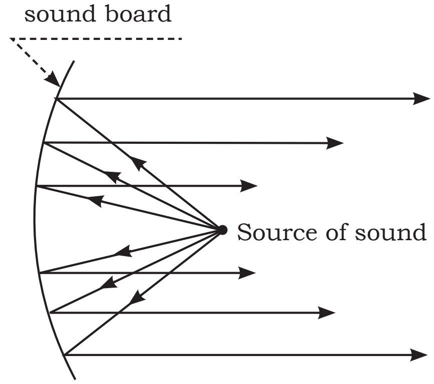


Figure 5.9: Sound board used in a big hall.

- Sounds of frequencies below 20 Hz are called **infrasonic sound or infrasound**. Rhinoceroses communicate using infrasound of frequency as low as 5 Hz. Whales and elephants produce sound in the infrasound range.
- Frequencies higher than 20 kHz are called **ultrasonic sound or ultrasound**. Ultrasound is produced by animals such as dolphins, bats and porpoises.

POINTS TO PONDER
Can you find out how Dolphins, whales and Bats navigate? What physical adaptations do they have that facilitate their navigation and orientation in water and air?

Ultrasound and its applications

- Ultrasounds are **high frequency waves**. They are able to travel along well defined paths even in the presence of obstacles. Ultrasounds are used extensively in industries and for medical purposes.
- It is **used to clean parts** located in hard-to-reach places, for example, spiral tubes, odd shaped parts, electronic components, etc. Objects to be cleaned are placed in a cleaning solution and

ultrasonic waves are sent into the solution. Due to the high frequency, the particles of dust, grease and dirt get detached and drop out.

- It can be used to **detect cracks and flaws in metal blocks** in construction of big structures like buildings, bridges, machines and also scientific equipment. Ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. If there is even a small defect, the ultrasound gets reflected back indicating the presence of the flaw or defect **(Refer to Figure 5.10)**.

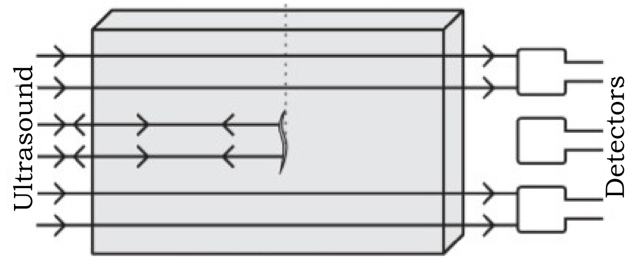


Figure 5.10: Ultrasound is reflected back from the defective locations inside a metal block

- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called **'echocardiography'**.
- Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs of the human body. It helps the doctor to detect abnormalities, such as stones in the gall bladder and kidney or tumours in different organs. In this technique the ultrasonic waves travel through the tissues of the body and get reflected from a region where there is a change of tissue density. Ultrasonography is then used to generate images of the organ.
- **Ultrasonography** is also used for examination of the foetus during pregnancy to detect congenital defects and growth abnormalities.
- Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains. These grains later get flushed out with urine.

Sonar

- The acronym **SONAR stands for Sound Navigation And Ranging.** Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. It consists of a transmitter and a detector and is installed in a boat or a ship **(Refer to Figure 5.11)**.
- The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound. Let the time interval between transmission and reception of ultrasound signal be, **t** and the speed of sound

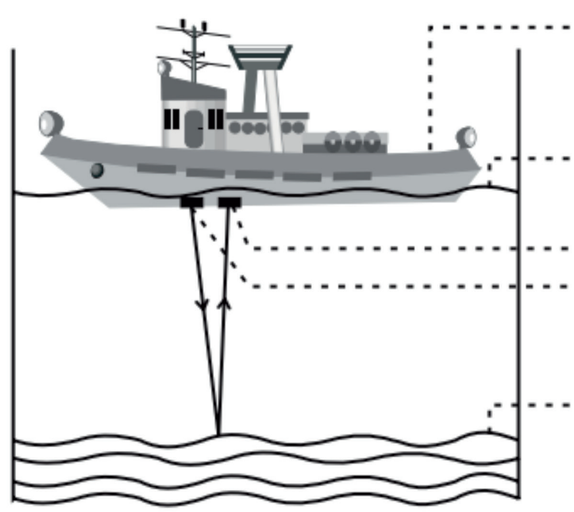


Figure 5.11: Ultrasound sent by the transmitter and received by the detector

through seawater be **v**. The total distance, 2d travelled by the ultrasound is then, $\mathbf{2d = v \times t}$. The above method is called echo-ranging.

- The sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarines, icebergs, sunken ships etc.

Noise Pollution

- Presence of excessive or unwanted sounds in the environment is called noise pollution. Major **causes of noise pollution** are sounds of vehicles, explosions including bursting of crackers, machines, loudspeakers etc. Television and transistor radio at high volumes, some kitchen appliances, desert coolers, air conditioners, all contribute to noise pollution.
- **Lack of sleep, hypertension (high blood pressure), anxiety** and many more health disorders may be caused by noise pollution. Temporary or even permanent impairment of hearing can be caused due to continuous hearing of loud noise.

Measures to Mitigate Noise Pollution

- The sources of noise must be controlled to control noise pollution. For this, silencing devices must be installed in aircraft engines, transport vehicles, industrial machines and home appliances.
- All noisy operations must be conducted away from any residential area. Noise producing industries should be set up away from such areas. Use of automobile horns should be minimised. TV and music systems should be run at low volumes.
- Trees must be planted along the roads and around buildings to cut down on the sounds reaching the residents, thus reducing the harmful effects of noise pollution.

Ears

- The shape of the outer part of the ear is like a funnel. When sound enters it, it travels down a canal at the end of which, there is a thin stretched membrane. It is called the **eardrum**. It performs an important function.
- The eardrum is like a stretched rubber sheet. Sound vibrations make the eardrum vibrate. The eardrum sends vibrations to the inner ear. From there, the signal goes to the brain, and this is how we hear. **(Refer to Figure 5.12)**

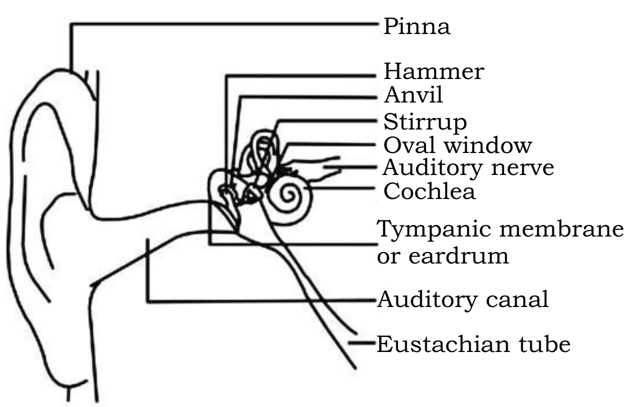


Figure 5.12: Auditory parts of Human Ear

Hearing Impairment

Total hearing impairment, which is rare, is usually from birth itself. Partial disability is generally the result of a disease, injury or age. Children with impaired hearing need special care. By learning sign language, such children can communicate effectively. Because speech develops as the direct result of hearing, a child with a hearing loss may have defective speech also. Technological devices for the hearing-impaired have made it possible for such persons to improve their quality of life. Society can do much to improve the living environment for the hearing-impaired and help them live normal lives.

Hearing Aid: People with hearing loss may need a hearing aid. A hearing aid is an electronic, battery operated device. The hearing aid receives sound through a microphone. The microphone converts the sound waves to electrical signals. These electrical signals are amplified by an amplifier. The amplified electrical signals are given to a speaker of the hearing aid. The speaker converts the amplified electrical signal to sound and sends it to the ear for clear hearing.

Conclusion

The study of sound is crucial in understanding the nature of the auditory world that surrounds us. The intricacies of sound waves, their propagation, and the factors influencing their speed are important to understand Sound. The characteristics of sound, such as frequency, amplitude, and wavelength, which play a vital role in determining how we perceive different sounds. Sound waves find extensive applications in our daily lives, from communication systems to medical imaging techniques like ultrasound. Understanding the principles of sound is not only essential for scientists and engineers but also for artists, musicians, and anyone interested in acoustics.

Glossary:

- **Amplitude:** The extent or magnitude of a wave's displacement from its resting position.
- **Eardrum:** A thin membrane in the ear that vibrates in response to sound waves, transmitting them to the inner ear.
- **Frequency:** The number of oscillations or cycles of a wave that occur in one second.
- **Hertz (Hz):** The unit of measurement for frequency, representing one cycle per second.
- **Larynx:** Also known as the voice box, it is a part of the throat that houses the vocal cords and is crucial for speech production.
- **Loudness:** The perceptual quality of sound that relates to its intensity or amplitude.
- **Noise:** Any unwanted or disruptive sound that interferes with the intended communication of a message.
- **Oscillation:** A repetitive back-and-forth movement or vibration around a central point.
- **Pitch:** The perceived highness or lowness of a sound, determined by its frequency.
- **Time Period:** The duration of one complete cycle of a wave, measured in seconds.
- **Vibration:** Rapid oscillating movements or oscillations around a central point.
- **Voice Box:** Another term for the larynx, a structure in the throat essential for producing vocal sounds.
- **Windpipe:** Also known as the trachea, it is a tube-like structure that connects the larynx to the bronchi and allows air to pass into the lungs.

❐❐❐

6 Matter

Bibliography: This chapter encompasses the summary of **Chapter 3 - VI** NCERT (Science) and **Chapters 1 and 2 - IX** NCERT (Science).

Introduction

Matter, the fundamental substance composing the universe, is the cornerstone of our understanding of the physical world. Anything in the universe, that occupies space and has mass is called 'Matter'. According to the ancient Indian and Greek philosophers every living or non-living entity is made up of five basic elements known as the "Panch Tatva" which includes the air, earth, fire, sky and water. Today, modern science delves deeper into the intricate nature of matter, examining its physical properties and chemical behaviour.

Matter

- The matter is made up of very tiny particles and these particles are so small that we cannot see them with naked eyes.

Particle Nature of Matter

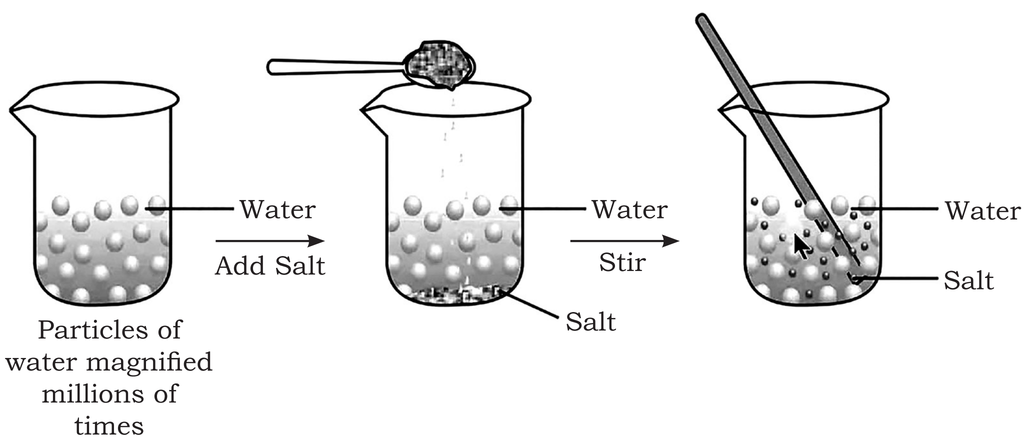


Figure 6.1: When we dissolve salt in water, the particles of salt get into the spaces between particles of water

- **(Figure 6.1)** shows how the nature of matter is in particulate form.
- The particles of the matter are really small as there are millions of tiny particles in just one crystal, any particle, which keep on dividing themselves into smaller and smaller particles.
- This can be visually seen when a drop of dettol is added to water.

Characteristics of Particles of Matter

- **Space between Particles:** The particles of one type of matter get into the spaces between particles of the other, proving that there is enough space between particles of matter. For example, when we make tea, coffee or lemonade (nimbu paani), particles of one type of matter get into the spaces between particles of the other.
- **Constant Motion of Particles:** Particles of the matter are in constant motion and this movement is due to the kinetic energy they possess, which depends on the temperature.
- **Attractive Force:** Particles of matter have force acting between them, which keeps them together. The strength of this force of attraction varies from one kind of matter to another.

> **Schools of thought**
> Two schools of thought emerged regarding the nature of matter, one school believed matter to be continuous like a block of wood (continuous) and the other believed that matter to be made up of particles like sand (particulate).

States of Matter

- Variation in the characteristics of the particles of matter creates variation in states of matter. There are three different states of matter i.e. solid, liquid and gas.

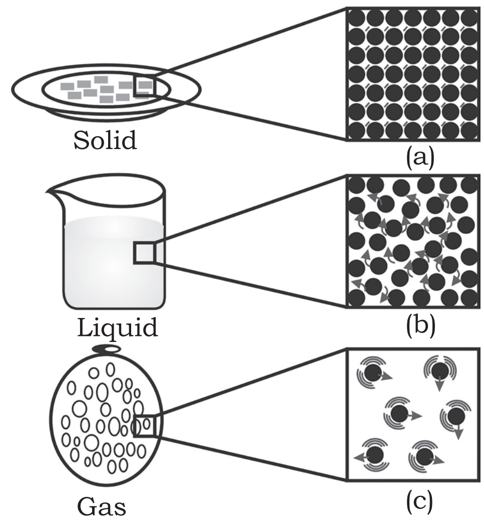


Figure 6.2: (a), (b) and (c) show the magnified schematic pictures of the three states of matter. The motion of the particles can be seen and compared in the three states of matter

The Solid State

- **Matter occurs in solid state.** Solids maintain their state with strong intermolecular forces **(Figure 6.2)**, which keeps the particles in a fixed position.
- Characteristics of solid state include definite shape and volume, distinct boundaries and negligible compressibility.

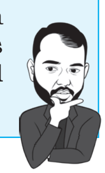
The Liquid State

- The liquids have no fixed shape but have a **fixed volume**.
- Liquids have **weaker intermolecular forces (Figure 6.2)** compared to solids, allowing them to flow and take the shape of their container.
- Their rate of diffusion is higher than that of solids because liquid particles move freely and have greater space between each other than the solids.

The Gaseous State

- Gases have **neither a definite shape nor a definite volume**, they have very weak intermolecular forces **(Figure 6.2)**, allowing them to expand to fill the entire volume of their container.
- Due to their high compressibility, large volumes of a gas can be compressed into a smaller volumes (eg CNG, LPG cylinder).
- The particles in gases are widely spaced and move randomly at high speeds exerting pressure.

> **POINTS TO PONDER**
> Plasma is considered as the fourth state of matter which can be observed in everyday life. Think about what makes plasma different from gas in terms of physical and chemical properties.



Factors Affecting Change in State of Matter

Temperature:

- **Fusion/Melting:** When the temperature of solids increases, the kinetic energy of particles rises causing them to vibrate more rapidly. Heat energy provided overcomes interparticle forces, enabling particles to move freely and transition from solid to liquid, this change of state from solid to liquid is called fusion or melting.
- **Melting Point:** The minimum temperature at which a solid melts to become a liquid at the atmospheric pressure is called its **melting point.** The melting point of a solid is an indication of the strength of the force of attraction between its particles.
- **Latent Heat of Fusion:** When a solid melts, its temperature remains the same because the heat energy is being used to **overcome the particle attraction** hence showing no change in temperature. This is the latent heat of fusion which is defined as the heat energy required to change 1 kg of solid into liquid at its melting point. This shows that particles in water at 0°C (273 K) have more energy as compared to particles in ice at the same temperature.
- **Latent Heat of Vaporization:** When heat is supplied to water, particles gain energy and eventually reach a point where they can break free, causing the liquid to change into a gas. During this transition the temperature change remains hidden, the excess energy is absorbed by the particles and is called as **latent heat of vaporization**.
- **Sublimation:** It involves change directly from solid to gas, this process of change directly, without an intermediate liquid state, from solid to gas is called as **sublimation. (Refer to Figure 6.4)**.
- **Deposition:** When a substance changes directly from gas to solid, the process is called deposition.

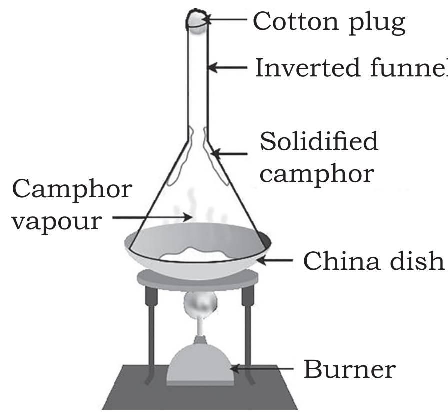


Figure 6.4: Sublimation of camphor

> **Boiling Point**
> The temperature at which a liquid starts to change into gas at the atmospheric pressure is known as its **boiling point**.

> **POINTS TO PONDER**
> Sublimation is direct conversion of matter from solid state to gaseous state, skipping liquid state in transition. Think about conditions when this process of change of state is observed.

Effect of Change of Pressure

- Applying pressure and reducing temperature can liquefy gases **(Refer to Figure 6.5)**. For example, solid carbon dioxide (known as Dry ice) gets converted directly into gaseous state at atmospheric pressure without coming into liquid state.

  Hence, we can conclude that pressure and temperature determine the state of a substance, whether it will be solid, liquid or gas.

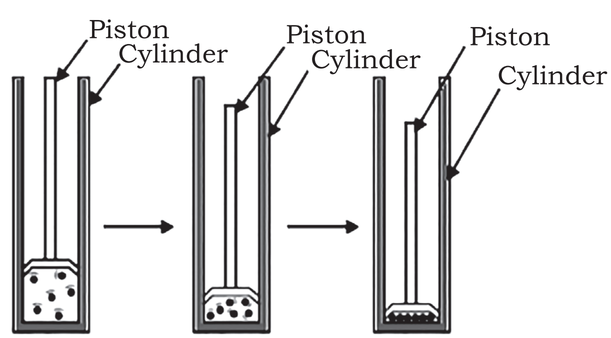


Figure 6.5: By applying pressure particles of matter can be brought close together

Evaluation

✤ The process of change of liquid into vapour at any temperature **below its boiling point** is called evaporation. This happens when a small fraction of particles at the surface, having higher kinetic energy, is able to break away from the forces of attraction of other particles and get converted into vapour.

Factors Affecting Evaporation

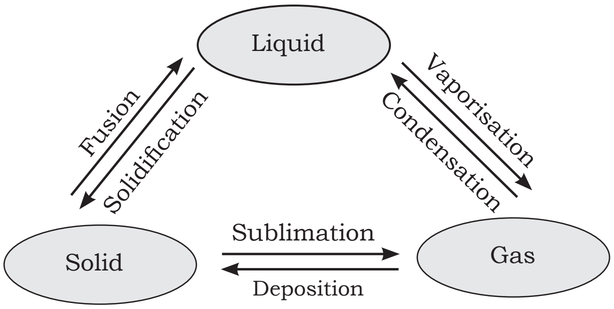


Figure 6.6: Interconversion of the three states of matter

1. **Surface Area:** Rate of evaporation is directly proportional to surface area. For example, to dry the clothes quickly we spread them out.
2. **Temperature:** With the increase of temperature, more particles get enough kinetic energy to go into the vapour state.
3. **Humidity:** The amount of water vapour present in air at a particular temperature is called humidity. If this humidity is high then the rate of evaporation decreases.
4. **Wind Speed:** Wind speed impacts the particles of water vapor present in air, impacting the rate of evaporation.

Cooling Effect Due to Evaporation

✤ During evaporation, the particles of liquid absorb energy from the surrounding to compensate for the energy lost while evaporating, which causes the temperature of surrounding to reduce inturn giving the cooling effect.

Some of the examples of this cooling effect are as follows

✤ **Sprinkling of water** on rooftops or open areas on scorching hot days cools the surface down. This is because water has a high latent heat of vaporization, and as it evaporates, it effectively cools down the heated surface.

✤ **Pouring acetone** (nail polish remover) on the palm makes the palm feel cooler. Acetone absorbs energy from the palm, leading to their evaporation, which in turn makes the palm feel cooler.

✤ **Wearing cotton clothes during summer:** Cotton, known for its excellent water absorption properties, aids in soaking up sweat and facilitating its exposure to the air, promoting rapid evaporation and enhancing the cooling effect during summer.

✤ **Water droplets** on the outer surface of a glass containing ice-cold water is due to loss of energy of water vapour coming in contact with glass.

Condensation

✤ The transformation of water vapour into water is called condensation. Condensation is caused by the loss of heat. When moist air is cooled, it may reach a level when its capacity to hold water vapour ceases. Then, the excess water vapour condenses into liquid form.

Purity of Matter around Us

✤ In assessing the purity of consumables like milk, ghee, butter, salt, spices, mineral water, or juice, we often encounter the term 'pure' on their packaging, but scientifically nothing is pure rather, it is just a mixture. For instance, milk is a blend of water, fat, proteins, and more.

Mixture

✤ Mixtures consist of multiple types of pure substances; whereas pure substances, regardless of their source, exhibit consistent characteristic properties.

- For example, sodium chloride and sugar cannot be separated by physical process into its chemical constituents but soft drink and soil being mixtures can be separated into its constituents.

Types of Mixture

- Depending upon the nature of the components that form a mixture, we can have different types of mixtures.
- **Homogeneous Mixtures:** It refers to a mixture in which the components mixed are uniformly distributed throughout the mixture. For Example, salt in water etc.
- **Heterogeneous Mixtures:** This is a type of mixture in which all the components are completely mixed and all the particles can be seen under a microscope. For example, mixture of sodium chloride and iron filings etc.

Solution

- A solution is a homogeneous mixture consisting of two or more substances. For example, lemonade and soda water.
- It is not just a liquid that contains either a solid, liquid or a gas dissolved in it, but we can also have solid solutions (alloys) and gaseous solutions (air).
- Homogeneity exists at the particle level in a solution, meaning the components are evenly distributed. For example lemonade tastes the same throughout.

Composition of Solution

- A solution has a solvent and a solute as its component.
- **Solvent:** Usually present is larger quantities, it is the component that dissolves the other substance;
- **Solute**: Usually present in lesser quantities, it is the component that is dissolved in the solvent.

POINTS TO PONDER

Water is considered a universal solvent, making it key to natural as well as human processes. Think about what properties of water make it such a good solvent?

Properties of a Solution

- It is a homogeneous mixture, in which the particles are smaller in size (< 1 nm), making them invisible to naked eyes.
- Because of the very small particle size, they do not scatter a beam of light passing through the solution, hence the path of light is not visible.
- As the solute particles do not settle down when left undisturbed, they cannot be separated from the mixture by the process of filtration.

More to know

Alloys: Alloys are mixtures of two or more metals or a metal and a non-metal and cannot be separated into their components by physical methods. But still, an alloy is considered as a mixture because it shows the properties of its constituents and can have variable composition. For example, brass is a mixture of approximately 30% zinc and 70% copper.

Examples of Solution

- Sugar solution has sugar as the solute and water as the solvent.
- 'Tincture of iodine', has iodine (solid) as the solute and alcohol (liquid) as the solvent.
- Aerated drinks like soda water, etc., are gas in liquid solutions. These contain carbon dioxide (gas) as solute and water (liquid) as solvent.
- Air is a mixture of gas in gas, containing oxygen (21%) and nitrogen (78%) as major constituents.

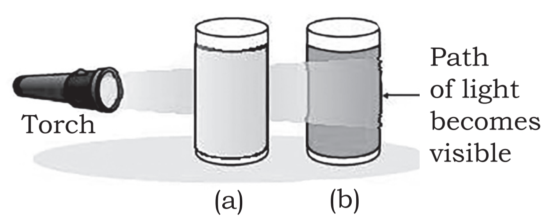


Figure 6.7: (a) Solution of copper sulphate does not show Tyndall effect, (b) mixture of water and milk shows Tyndall effect.

Concentration of a Solution

- As the solution is made of solute and solvent, their proportions can be varied to get different concentrations of solutions. The concentration of a solution is the amount (mass or volume) of solute present in a given amount (mass or volume) of solution.

  Concentration of Solution = Amount of solute/Amount of Solution
- **Saturated Solution:** At any particular temperature, a solution that has dissolved as much solute as it is capable of dissolving, is said to be a **saturated solution** and the amount of the solute present in the saturated solution is called its **solubility**.
- **Unsaturated Solution:** If the amount of solute contained in a solution is less than the saturation level, it is called an unsaturated solution.

Suspension

- A suspension is an example of a **heterogeneous mixture** where solute particles do not dissolve but instead remain suspended evenly within the medium. Unlike solutions, particles in suspensions are visible to the naked eye.

Properties of a Suspension

- It is a heterogeneous mixture in which the particles of a suspension can be seen by the naked eye.
- The particles of a suspension scatter a beam of light passing through it, making its path visible.
- As the solute particles settle down when left undisturbed, they can be separated from the mixture by the process of filtration.
- When the particles settle down, the suspension brakes and it does not scatter light any more.

Colloidal Solution

- Colloidal solution is a **heterogeneous mixture**, consisting of smaller particles that are uniformly spread throughout the solution.
- A colloidal solution consists of two main components: the dispersed phase (the solute-like component, comprising the dispersed particles) and the dispersion medium (the component in which the dispersed phase is suspended).

Tyndall Effect

- Though the particles are invisible to naked eyes, they are big enough to scatter a beam of light passing through them, this phenomenon is called the Tyndall effect.
- The Tyndall effect can also be witnessed In everyday situations, such as when a beam of light enters a room through a small opening and scatters off dust and smoke particles in the air; and when sunlight passes through the canopy of a dense forest, where mist containing tiny droplets of water acts as particles of colloid dispersed in air **(Refer to Figure 6.8)**.

Figure 6.8: The Tyndall effect

Properties of a Colloid

- It is a heterogeneous mixture in which the size of particles is too small to be individually seen with naked eyes.
- Colloids are big enough to scatter a beam of light passing through it and make its path visible.

- They do not settle down when left undisturbed, that is, a colloid is quite stable.
- They cannot be separated from the mixture by the process of filtration, but can be separated through centrifugation.

Table 6.1: Common Examples of Colloids

Dispersed phase	Dispersing medium	Type	Example
Liquid	Gas	Aerosol	Fog, clouds, mist
Solid	Gas	Aerosol	Smoke, automobile exhaust
Gas	Liquid	Foam	Shaving cream
Liquid		Emulsion	Milk, face cream
Solid	Liquid	Sol	Milk of magnesia, mud
Gas	Solid	Foam	Foam, rubber, sponge, pumice
Liquid	Solid	Gel	Jelly, cheese, butter
Solid	Solid	Solid sol	Coloured gemstone, milky glass

Physical and Chemical Changes

Physical Change

- It refers that changing the state of a pure substance between solid, liquid, or gas phase. For example, physical properties change during tempering steel, crystallization, and melting.

Chemical Change

- Any change that brings change in the chemical properties of matter and results in new substances is called chemical change. Burning candle is an example.

Pure Substance

- Pure substances are the substance that are made up of only one kind of particle and have a fixed or constant structure.

Types of Pure Substance

- On the basis of their chemical composition, substances can be classified either as elements or compounds as follows.

Elements

- Robert Boyle, First Scientist to use the term element in 1661, was defined by Antoine Laurent Lavoisier, in the 18th century, as a fundamental form of matter that cannot be further decomposed into simpler substances through chemical reactions.
- Elements can be normally divided into metals, nonmetals and metalloids.

Properties of Metals

- They have a lustre (shine).
- They have a silvery-grey or golden-yellow colour.

More to know

- The number of elements known at present are more than 100. Ninety-two elements are naturally occurring and the rest are man-made.
- Majority of the elements are solid.
- Eleven elements are in gaseous state at room temperature.
- Two elements which remains as liquid at room temperature are mercury and bromine.
- Elements, gallium and cesium become liquid at a temperature slightly above room temperature (303 K).

Metalloids: These are elements showing properties between those of metals and nonmetals, examples are boron, silicon, germanium.

- They conduct heat and electricity.
- They are ductile (can be drawn into wires).
- They are malleable (can be hammered into thin sheets).
- They are sonorous (make a ringing sound when hit).
- Examples of metals include gold, silver, copper, iron, sodium, potassium etc. Mercury is the only metal that is liquid at room temperature.

Properties of Non-metals

- They display a variety of colours.
- They are poor conductors of heat and electricity.
- They are not lustrous, sonorous or malleable.
- Examples of non-metals are hydrogen, oxygen, iodine, carbon (coal, coke), bromine,chlorine etc

Table 6.2: Mixtures and Compounds

Mixtures	Compounds
Elements or compounds just mix together to form a mixture and no new compound is formed.	Elements react to form new compounds.
A mixture has a variable composition.	The composition of each new substance is always fixed.
A mixture shows the properties of the constituent substances.	The new substance has totally different properties.
The constituents can be separated fairly easily by physical methods.	The constituents can be separated only by chemical or electrochemical reactions.

Compounds

A compound is a substance composed of two or more elements, chemically combined with one another in a fixed proportion.

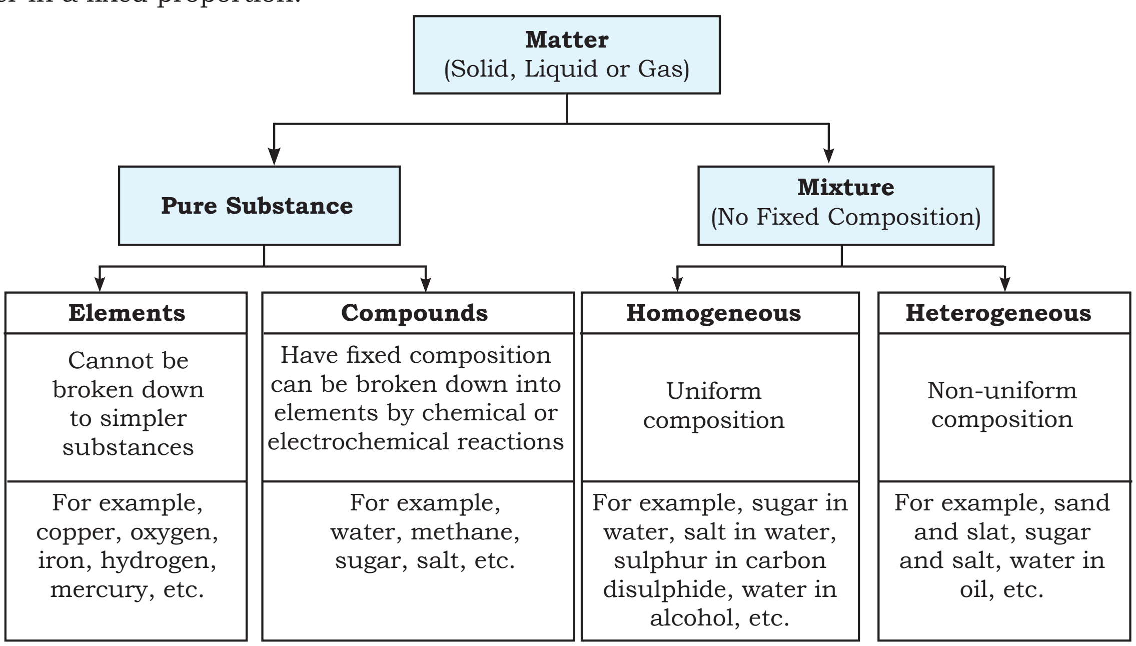


Figure 6.9: Schematic classification of matter

Separation of Substances

- Separation refers to the processes and techniques used to isolate or remove specific components or substances from a mixture.
- These techniques are employed to extract, purify, or obtain pure substances from mixtures of different substances. The choice of a particular separation method depends on the nature of the mixture and the objectives of the separation process as follows.

Figure 6.10: Threshing

Methods of Separation

- **Handpicking:** Handpicking is a separation method suitable for removing relatively larger-sized impurities such as dirt, stones, and husks from grains like wheat, rice, or pulses. It involves manually selecting and removing the unwanted substances from the mixture by hand.
- **Threshing:** Threshing is the process employed to separate grains from stalks and other parts of plants, where the stalks are beaten or agitated to release the grain seeds from them. This process can be carried out manually or with the assistance of bullocks.
- **Winnowing:** Winnowing is a method for separating lighter and heavier elements in a mixture by utilising the force of wind to carry away the lighter components, leaving behind the heavier ones.
- **Sieving:** Sieving is used when components of a mixture have different sizes. This process involves passing a mixture through a sieve, which is a device or tool consisting of a mesh or perforated surface. The mesh or perforations in the sieve allow smaller particles to pass through while retaining larger particles.

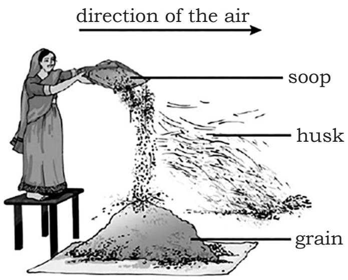


Figure 6.11: Winnowing

Figure 6.12: Sieving

Sedimentation, Decantation and Filtration

- Sometimes, it's challenging to separate components from a mixture through methods like winnowing or handpicking, especially when dealing with lighter impurities like dust or soil particles mixed with rice or pulses.
- **Sedimentation:** It is a process of settling down of heavier components within a mixture when a liquid is added is called **sedimentation**.

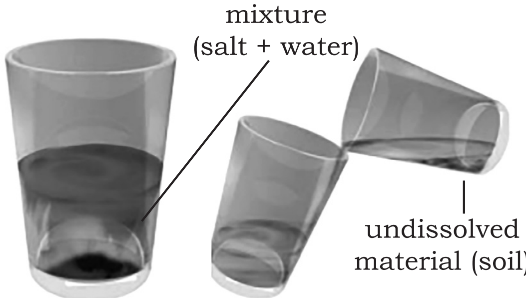


Figure 6.13: Separating two components of a mixture by sedimentation and decantation

- **Decantation:** Decantation is the subsequent step that follows sedimentation, which involves pouring off the clear liquid (supernatant) from a container, leaving behind the heavier component.
- The same principle is used for separating a mixture of two liquids that do not mix with each other, for eg. mixture of oil and water.
- **Filtration:** Sedimentation is not an effective method where insoluble impurities like soil is present, filtration is more effective in such cases which involves passing the mixture through a porous material, known as a filter paper.

Conclusion

The study of the states of matter reveals the fascinating intricacies of our physical world. Matter exists in three primary states: Solid, liquid, and gas, each defined by the arrangement and behavior of particles. Changes in temperature and pressure can trigger transitions between these states, exemplifying the profound influence of energy on matter. Evaporation, condensation, melting, and boiling are fundamental processes that underscore these transitions. Additionally, other phenomena like sublimation and deposition exist, showcasing matter's versatility. The comprehension of these states of matter not only enriches our scientific knowledge but also finds practical applications in diverse fields, from chemistry to daily life.

Glossary:

- **Sublimation:** It is the change of solid state directly to gaseous state without going through liquid state.
- **Deposition:** It is the change of gaseous state directly to solid state without going through liquid state.
- **Boiling:** It is a bulk phenomenon, where particles from the bulk (whole) of the liquid change into vapour state.
- **Evaporation:** It is a surface phenomenon, in which particles from the surface gain enough energy to overcome the forces of attraction present in the liquid and change into the vapour state.
- **Solution:** It is a homogeneous mixture of two or more substances. The major component of a solution is called the solvent, and the minor, the solute.
- **Element:** It is a form of matter that cannot be broken down by chemical reactions into simpler substances.
- **Compound:** It is a substance composed of two or more different types of elements, chemically combined in a fixed proportion.
- **Suspension:** Materials that are insoluble in a solvent and have particles that are visible to naked eyes, form a suspension.
- **Latent Heat of Vaporisation:** It is the heat energy required to change 1 kg of a liquid to gas at atmospheric pressure at its boiling point.
- **Latent Heat of Fusion:** It is the amount of heat energy required to change 1 kg of solid into liquid at its melting point.

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7 Atoms and Molecules

Bibliography: This Chapter encompasses a summary of **Chapter 3 and 4 - IX** NCERT (Science)

Introduction

In ancient times, Indian and Greek philosophers have always wondered about the unknown and unseen form of matter. Around 500 BC, the idea of divisibility of matter was considered in India. Atoms and molecules are the fundamental building blocks of matter. In this chapter you will find out the answers of questions like what makes the atom of one element different from the atom of another element and are atoms really indivisible? Further we will look into various models that have been proposed to explain how these particles are arranged within the atom and structure of atoms.

Laws of Chemical Combination

- An Indian philosopher **Maharishi Kanad**, postulated that if we go on dividing matter **(Padarth**), a stage will come when further division will not be possible. He named these smallest particles **Parmanu.**
- Another Indian philosopher, **Pakudha Katyayama**, elaborated this doctrine and said that these particles normally exist in a combined form which gives us various forms of matter.
- Greek philosophers, **Democritus and Leucippus** suggested that if we go on dividing matter, a stage will come when particles obtained cannot be divided further and Democritus called these indivisible particles **Atoms (meaning indivisible)**.
- All this was just based on philosophical considerations.
- By the end of the 18th century, scientists recognised the difference between elements and compounds and started finding out how and why elements combine and what happens when they combine.
- **Antoine L. Lavoisier** laid the foundation of chemical sciences by establishing **two important laws of chemical combination**. The following two laws were established after much experimentation by **Lavoisier and Joseph L. Proust.**
- **Law of Conservation of Mass**
  - It states that mass can neither be created nor destroyed in a chemical reaction.
- Law of **Constant Proportions or the law of definite proportions**
  - Lavoisier, along with other scientists, noted that many compounds were composed of two or more elements and each such compound had the same elements in the same proportions, irrespective of where the compound came from or who prepared it.
  - This law was stated by **Proust** as "In a chemical substance the elements are always present in definite proportions by mass". For example, in a compound such as water, if 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained i.e the ratio of the mass of hydrogen to the mass of oxygen is always 1 : 8. Similarly in ammonia, nitrogen and hydrogen are always present in the ratio 14 : 3 by mass.

- To explain this British chemist **John Dalton** provided the basic theory about the nature of matter **(Refer to Figure 7.1)**.

Dalton's Atomic Theory

- Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportions. According to the theory, **all matter, whether an element, a compound or a mixture is composed of small particles called atoms.**
- **The postulates of this theory stated as follows:**
  - All matter is made of very tiny particles called atoms, which participate in chemical reactions.
  - Atoms are indivisible particles, which can neither be created nor be destroyed in a chemical reaction.
  - Atoms of a given element are identical in mass and chemical properties.
  - Atoms of different elements have different masses and chemical properties.
  - Atoms combine in the ratio of small whole numbers to form compounds.
  - The relative number and kinds of atoms are constant in a given compound.

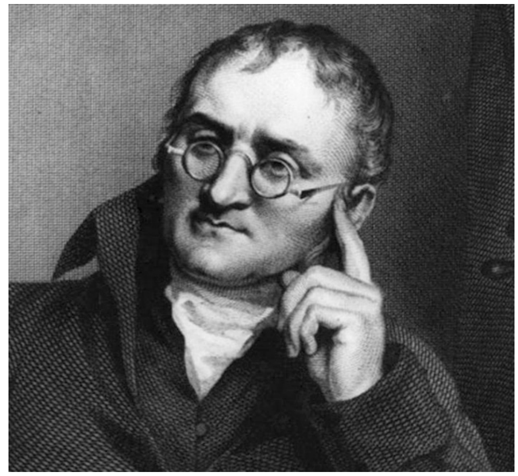


Figure 7.1: John Dalton

John Dalton was born in a poor weaver's family in 1766 in England. He began his career as a teacher at the age of 12 and after seven years he became a school principal. In 1793, he left for Manchester to teach mathematics, physics and chemistry in a college. He spent most of his life there teaching and researching. In 1808, he presented his atomic theory which was a turning point in the study of matter.

Charged Particles in Matter

- At the end of the 19th century the major challenge was to reveal the structure and the properties of the atom.
- One of the first indications that atoms are not indivisible, comes from studying static electricity and the condition under which electricity is conducted by different substances. Many scientists contributed in revealing the presence of charged particles in an atom.
- In **1900, J.J. Thomson** identified that the atom was an indivisible particle but contained at least one subatomic particle which is the electron (represented as 'e^-').
- Even before the electron was identified, **E. Goldstein** in 1886 discovered the presence of new radiations in a gas discharge and called them **canal rays**. These rays were positively charged radiations which ultimately led to the discovery of another subatomic particle named **proton** (represented as p^+) which had a charge, equal in magnitude but opposite in sign to that of the electron. Its mass was approximately 2000 times that of the electron.
- The mass of a proton is taken as one unit and its charge as plus one whereas the mass of an electron is considered to be negligible and its charge is minus one.
- It seemed that an atom was composed of protons and electrons, mutually balancing their charges.

Atom

- Atoms are the fundamental building blocks of all matter. The existence of different kinds of matter is due to different atoms constituting them. Our entire world is made up of atoms.

Size of Atom

- Atoms are very small, they are smaller than anything that we can imagine or compare with (Refer to Table 7.1).
- Atomic radius is measured in **nanometres.**

  $1/10^9$ nm = 1 nm; 1 m = 10^9 nm

Table 7.1: Relative Size of Atom

Relative Sizes	
Radii (in m)	**Example**
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of sand
10^{-2}	Ant
10^{-1}	Apple

The Structure of an Atom

- The discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of Dalton's atomic theory.
- Many scientists proposed various atomic models to explain how electrons and protons are arranged within an atom.

Thomson's Model of an Atom

- Thomson proposed the model of an atom to be similar to that of a Christmas pudding. The electrons, in a sphere of positive charge, were like currants (dry fruits) in a spherical Christmas pudding **(Refer to Figure 7.2)**.
- **Thomson (Refer to Figure 7.3) proposed that:**
  - An atom consists of a positively charged sphere and the electrons are embedded in it.
  - The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.

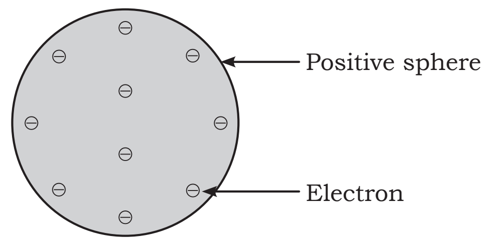


Figure 7.2: Thomson's model of an atom

Figure 7.3: J.J. Thomson (1856-1940)

A British physicist, was born in Cheetham Hill, a suburb of Manchester, on 18 December 1856. He was awarded the Nobel prize in Physics in 1906 for his work on the discovery of electrons. He directed the Cavendish Laboratory at Cambridge for 35 years and seven of his research assistants subsequently won Nobel prizes.

Rutherford's Model of an Atom

- Ernest Rutherford designed an experiment to know the arrangement of electrons within the atom.
- In this experiment, fast moving alpha (α)-particles were made to fall on a thin gold foil.
  - He selected a gold foil because he wanted as thin a layer as possible and this gold foil was about 1000 atoms thick.
  - α-particles are doubly-charged helium ions (He^{2+}). Since they have a mass of 4u, the fast-moving α-particles have a considerable amount of energy.
  - It was expected that α-particles would be deflected by the subatomic particles in the gold atoms. Since the α-particles were much heavier than the protons.
- But, the α-particle scattering experiment gave totally unexpected results **(Refer to Figure 7.4)**.
  - Most of the fast moving α-particles passed straight through the gold foil.

- ✧ Some of the α-particles were deflected by the foil by small angles.
- ✧ One out of every 12000 particles appeared to rebound.

✤ **Rutherford (Refer to Figure 7.5) concluded from the α-particle scattering experiment that:**

- ✧ Most of the space inside the atom is empty because most of the α-particles passed through the gold foil without getting deflected.
- ✧ Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.
- ✧ A very small fraction of α-particles were deflected by 180°, indicating that all the positive charge and mass of the gold atom were concentrated in a very small volume within the atom.

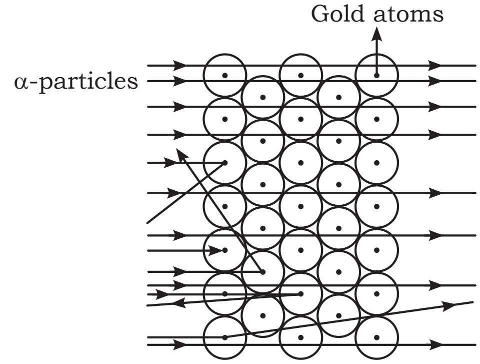


Figure 7.4: Scattering of α-particles by a gold foil

✤ He also calculated that the radius of the nucleus is about 10^5 times less than the radius of the atom.

✤ On the basis of his experiment, he put forward the Nuclear Model of an Atom.

- ✧ There is a positively charged centre in an atom called the **nucleus**. Nearly all the mass of an atom resides in the nucleus.
- ✧ The electrons revolve around the nucleus in circular paths.
- ✧ The size of the nucleus is very small as compared to the size of the atom.

✤ **Drawbacks of Rutherford's model:** The revolution of the electron in a circular orbit is not expected to be stable. Any particle in a circular orbit would undergo acceleration and would radiate energy. Thus, the revolving electron would lose energy and finally fall into the nucleus. If this were so, the atom should be highly unstable and hence matter would not exist in the form that we know. Atoms are quite stable.

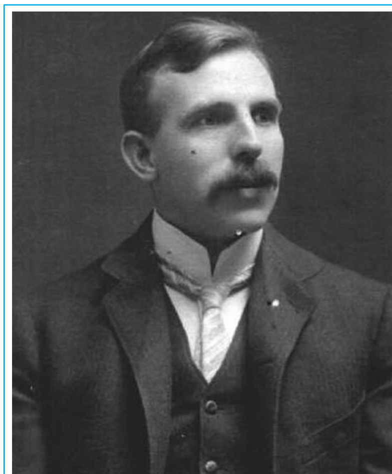


Figure 7.5: E. Rutherford (1871-1937)

He was born at Spring Grove on 30 August 1871. He was known as the **'Father' of nuclear physics**. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment. He got the Nobel prize in chemistry in 1908.

Bohr's Model of Atom

✤ In order to overcome the objections raised against Rutherford's model of the atom, Neils Bohr **(Refer to Figure 7.7)** put forward the following postulates:

- ✧ Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.
- ✧ While revolving in discrete orbits the electrons do not radiate energy.

✤ These orbits or shells are called **energy levels (Refer to Figure 7.6)**.

✤ These orbits or shells are represented by the letters K, L, M, N, … or the numbers, n = 1, 2, 3, 4, ….

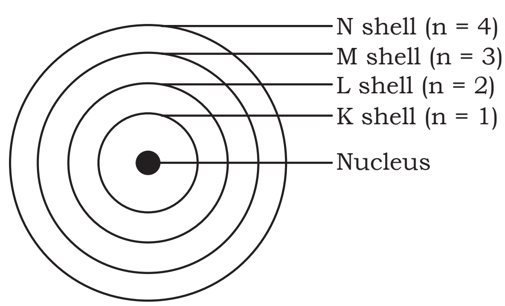


Figure 7.6: A few energy levels in an atom

J. Chadwick

- In 1932, J. Chadwick discovered another subatomic particle which had no charge and a mass nearly equal to that of a proton named as **neutron** (represented as 'n')
- Neutrons are present in the nucleus of all atoms, **except hydrogen.**
- The mass of an atom is therefore given by the sum of the masses of protons and neutrons present in the nucleus.

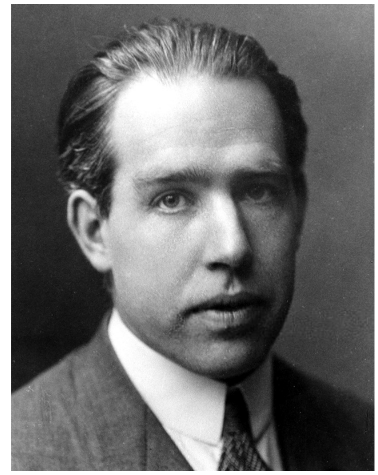


Figure 7.7: Neils Bohr (1885-1962)

He was born in Copenhagen on 7 October 1885. He was appointed professor of physics at Copenhagen University in 1916 and got the Nobel prize for his work on the structure of atom in 1922. Among Professor Bohr's numerous writings, three appearing as books are:

(i) The Theory of Spectra and Atomic Constitution,

(ii) Atomic Theory and,

(iii) The Description of Nature.

Distribution of Electrons Into Different Orbits

- Bohr and Bury suggested the distribution of electrons into different orbits of an atom.
- The following rules are followed for writing the number of electrons in different energy levels or shells:
  - The maximum number of electrons present in a shell is given by the formula $2n^2$, where 'n' is the orbit number or energy level index, 1, 2, 3,….

    Hence the maximum number of electrons in different shells are as follows:

    first orbit or K-shell = $2 \times 1^2 = 2$, second orbit or L-shell will be = $2 \times 2^2 = 8$, third orbit or M-shell will be = $2 \times 3^2 = 18$, fourth orbit or N-shell will be = $2 \times 4^2 = 32$, and so on.
- The maximum number of electrons that can be accommodated in the outermost orbit is 8.
- Electrons are not accommodated in a given shell, unless the inner shells are filled **(Refer to Figure 7.8)**.

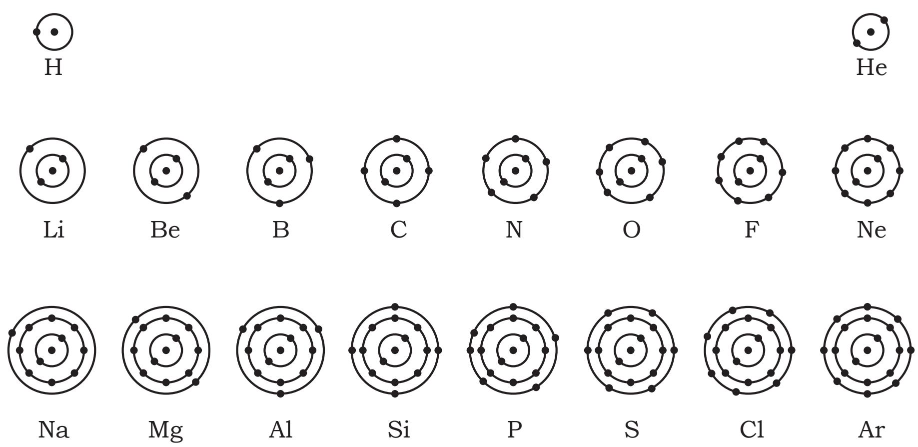


Figure 7.8: Schematic atomic structure of the first eighteen elements

Valency

- The electrons present in the outermost shell of an atom are known as the **valence electrons**.
- It was observed that the atoms of elements, completely filled with 8 electrons in the outermost shell show little chemical activity i.e their combining capacity or valency is zero. Of these inert

elements, the helium atom has two electrons in its outermost shell and all other elements have atoms with eight electrons in the outermost shell.

- The combining capacity of the atoms of elements, i.e their tendency to react and form molecules with atoms of the same or different elements, was thus explained as an attempt to attain a fully-filled outermost shell.
- An outermost-shell, which had 8 electrons was said to possess an **octet**. Atoms would thus react, so as to achieve an octet in the outermost shell by sharing, gaining or losing electrons.
- The number of electrons gained, lost or shared so as to make the octet of electrons in the outermost shell, gives the combining capacity of the element, that is, the valency. For Ex: Hydrogen, Lithium and Sodium atoms contain 1 electron each in their outermost shell, therefore each one of them can lose one electron. So, they are said to have a valency of 1. Similarly valency of magnesium and aluminium is 2 and 3, respectively.
- If the number of electrons in the outermost shell of an atom is close to its full capacity, then valency is determined in a different way. For example the fluorine atom has 7 electrons in the outermost shell and it is easier to gain one electron instead of losing seven electrons. Hence valency of fluorine is 1 (Refer to Table 7.2).

POINTS TO PONDER

Noble gases are a group of elements who have very low reactivity and exist as independent atoms. Think about what property of their structure makes them inert and state their uses.

Table 7.2: Composition of Atoms of the First 18 Elements with Electron Distribution in Various Shells

Name of Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution Electrons				Valency
						K	L	M	N	
Hydrogen	H	1	1	-	1	1	-	-	-	1
Helium	He	2	2	2	2	2	-	-	-	0
Lithium	Li	3	3	4	3	2	1	-	-	1
Beryllium	Be	4	4	5	4	2	2	-	-	2
Boron	B	5	5	6	5	2	3	-	-	3
Carbon	C	6	6	6	6	2	4	-	-	4
Nitrogen	N	7	7	7	7	2	5	-	-	3
Oxygen	O	8	8	8	8	2	6	-	-	2
Fluorine	F	9	9	10	9	2	7	-	-	1
Neon	Ne	10	10	10	10	2	8	-	-	0
Sodium	Na	11	11	12	11	2	8	1	-	1
Magnesium	Mg	12	12	12	12	2	8	2	-	2
Aluminium	Al	13	13	14	13	2	8	3	-	3
Silicon	Si	14	14	14	14	2	8	4	-	4
Phosphorus	P	15	15	16	15	2	8	5	-	3, 5
Sulphur	S	16	16	16	16	2	8	6	-	2
Chlorine	Cl	17	17	18	17	2	8	7	-	1
Argon	Ar	18	18	22	18	2	8	8	-	0

Symbols of Atoms of Different Elements

- **Dalton** was the first scientist to use the symbols for elements **(Refer to Figure 7.9)**.
- When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element.

- **Berzilius** suggested that the symbols be made from one or two letters of the name of the element.
- In the beginning, the names of elements were derived from the name of the place where they were found for the first time. For example, the name **copper was taken from Cyprus.**
- Some names were taken from specific colours. For example, gold was taken from the English word meaning yellow.

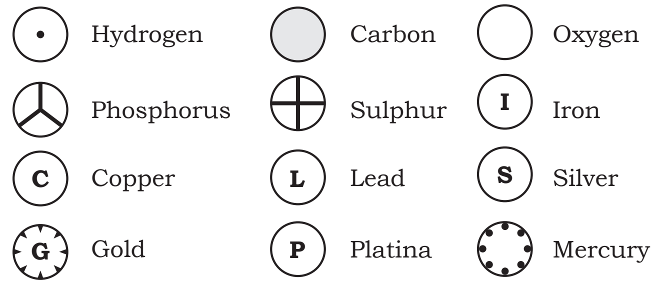


Figure 7.9: Symbols proposed by Dalton

- Now-a-days, **IUPAC (International Union of Pure and Applied Chemistry)** is an international scientific organisation which approves names of elements, symbols and units.
- Many of the symbols are the first one or two letters of the element's name in English. For example, hydrogen- H; aluminium - Al; cobalt - Co.
- Symbols of some elements are formed from the first letter of the name and a letter, appearing later in the name. For example, chlorine - Cl; zinc - Zn etc.
- Other symbols have been taken from the names of elements in Latin, German or Greek. For example, the symbol of iron is Fe from its Latin name ferrum, sodium is Na from natrium, potassium is K from kalium (Refer to Table 7.3).

Table 7.3: Symbols for some elements

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

Atomic Number

- It is defined as the **number of protons present in the nucleus** of an atom.
- All atoms of an element have the same atomic number, denoted by 'Z'.
- In fact, elements are defined by the number of protons they possess. For hydrogen, Z = 1, because in a hydrogen atom, only 1 proton is present in the nucleus. Similarly, for carbon, Z = 6.

Mass Number

- The mass number is defined as the **sum of the total number of protons and neutrons** present in the nucleus of an atom and it is denoted by 'A'.
- Since protons and neutrons are present in the nucleus they are also called **nucleons**.

- Mass of carbon is 12 u because it has 6 protons and 6 neutrons. Similarly, the mass of aluminium is 27 u (13 protons + 14 neutrons).
- In the notation for an atom, the atomic number, mass number and symbol of the element are to be written as:

Mass Number

Symbol of element

Atomic Number

Isotopes

- Isotopes are defined as the atoms of the same element, having the **same atomic number but different mass numbers**. For example, hydrogen atoms have three atomic species, namely protium ($_1H^1$), deuterium ($_1H^2$or D) and tritium ($_1H^3$ or T). The atomic number of each one is 1, but the mass number is 1, 2 and 3, respectively. Similarly (i) carbon, $_6C^{12}$ and $_6C^{14}$, (ii) chlorine, $_{17}Cl^{35}$ and $_{17}Cl^{37}$, etc.
- Many elements consist of a mixture of isotopes. Each isotope of an element is a pure substance.
- The chemical properties of isotopes are similar but their physical properties are different. Chlorine occurs in nature in two isotopic forms, with masses 35 u and 37 u in the ratio of 3:1.
- The mass of an atom of any natural element is taken as the average mass of all the naturally occurring atoms of that element. For example, the average mass of Cl will be 35.5u and if an element has no isotopes, then the mass of its atom would be the same as the sum of protons and neutrons in it.
- **Applications**: Some isotopes have special properties such as:
  - An isotope of uranium is used as a fuel in nuclear reactors.
  - An isotope of cobalt is used in the treatment of cancer.
  - An isotope of iodine is used in the treatment of goitre.

POINTS TO PONDER

Carbon isotopes **C-12** and **C-14** are used in carbon dating techniques especially for fossils. Can you think about how radioactive dating works based on isotopes in general and carbon dating in particular?

Isobars

- Atoms of **different elements with different atomic numbers but same mass number**, are known as isobars.
- For example, Calcium (atomic number 20) and Argon (atomic number 18) are isobars. The number of protons in these atoms is different, but the mass number of both these elements is 40 i.e. the total number of nucleons is the same in the atoms of this pair of elements.

Atomic Mass

- According to Dalton's atomic theory, each element had a characteristic atomic mass.
- Since determining the mass of an individual atom was a relatively difficult task, relative atomic masses were determined using the laws of chemical combinations and the compounds formed.
- While searching for various atomic mass units, scientists initially took 1/16 of the mass of an atom of naturally occurring oxygen as the unit due to two reasons:
  - (i) Oxygen reacted with a large number of elements and formed compounds.
  - (ii) This atomic mass unit gave masses of most of the elements as whole numbers.

Table 7.4: Atomic Masses of a few elements

Element	Atomic Mass (u)
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

- However, in 1961, carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass unit (earlier abbreviated as 'amu', but according to the latest IUPAC, it is now written as 'u' – unified mass) is a mass unit equal to exactly one-twelfth (1/12th) the mass of one atom of carbon-12.
- The relative atomic masses of all elements have been found with respect to an atom of carbon-12 (Refer to Table 7.4).

Existence of Atom

Atoms of most elements are not able to exist independently. They form molecules and ions. These molecules or ions aggregate in large numbers to form the matter that we can see, feel or touch.

Molecule

- A molecule is in general a group of two or more atoms that are chemically bonded together, i.e, tightly held together by attractive forces.
- A molecule can be defined as the smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of that substance.
- Atoms of the same element or of different elements can join together to form molecules.

Table 7.5: Atomicity of some elements

Types of Element	Name	Atomicity
Non-Metal	Argon	Monoatomic
	Helium	Monoatomic
	Oxygen	Diatomic
	Hydrogen	Diatomic
	Nitrogen	Diatomic
	Chlorine	Diatomic
	Phosphorus	Tetra-atomic
	Sulphur	Poly-atomic
Metal	Sodium	Monoatomic
	Iron	Monoatomic
	Aluminium	Monoatomic
	Copper	Monoatomic

Molecules of Elements

- The molecules of an element are constituted by the same type of atoms.
- Molecules of many elements, such as argon (Ar), helium (He) etc. are made up of only one atom of that element.
- In the case of non-metals such as a molecule of oxygen consists of two atoms of oxygen and hence it is known as a diatomic molecule, O_2. If 3 atoms of oxygen unite into a molecule, we get ozone, O_3.
- The number of atoms constituting a molecule is known as its **atomicity** (Refer to Table 7.5).
- Metals and some other elements, like carbon, do not have a simple structure but consist of a very large and indefinite number of atoms bonded together.

Molecules of Compounds

Atoms of different elements join together in definite proportions to form molecules of compounds (Refer to Table 7.6).

Table 7.6: Molecules of some compounds

Compound	Combining Elements	Ratio by Mass
Water	Hydrogen, Oxygen	1 : 8
Ammonia	Nitrogen, Hydrogen	14 : 3
Carbon Dioxide	Carbon, Oxygen	3 : 8

An Ion

- Compounds composed of metals and non-metals contain charged species known as ions. (Refer to Table 7.7)
- Ions may consist of a single charged atom or a group of atoms that have a net charge on them.
- It can be negatively or positively charged. A negatively charged ion is called an '**anion**' and the positively charged ion, a '**cation**'. For example, Sodium Chloride (NaCl) contains positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).

Table 7.7: Some Ionic Compounds

Ionic Compound	Constituting Elements	Ratio by Mass
Calcium oxide	Calcium and oxygen	5 : 2
Magnetism sulphide	Magnesium and sulphur	3 : 4
Sodium chloride	Sodium and chlorine	23 : 35.5

- A group of atoms carrying a charge is known as a **polyatomic ion** (Refer to Table 7.8).

Table 7.8: Some common, simple and polyatomic ions

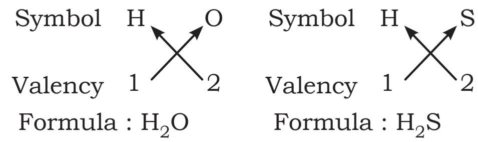
Valency	Name of ion	Symbol	Non-metallic element	Symbol	Polyatomic ions	Symbol
1.	Sodium	Na^+	Hydrogen	H^+	Ammonium	NH_4^+
	Potassium	K^+	Hydride	H^-	Hydroxide	OH^-
	Silver	Ag^+	Chloride	Cl^-	Nitrate	NO_3^-
	Copper (I)*	Cu^+	Bromide	Br^-		
			Iodide	I^-	Hydrogen Carbonate	HCO_3^-
2.	Magnesium	Mg^{2+}	Oxide	O^{2-}	Carbonate	CO_3^{2-}
	Calcium	Ca^{2+}	Sulphide	S^{2-}	Sulphite	SO_3^{2-}
	Zinc	Zn^{2+}			Sulphate	SO_4^{2-}
	Iron (II)*	Fe^{2+}				
	Copper (II)*	Cu^{2+}				
3.	Aluminium	Al^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}
	Iron (III)*	Fe^{3+}				

Writing Chemical Formulae

- The chemical formula of a compound is **a symbolic representation of its composition**.
- Valency or combining capacity can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound (Refer to Table 7.8).
- **The rules that have to follow while writing a chemical formula are as follows:**
  - The valencies or charges on the ion must balance.
  - When a compound consists of a metal and a nonmetal, the name or symbol of the metal is written first. For example, calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO) etc., where oxygen, chlorine, sulphur are nonmetals whereas calcium, sodium, iron and copper are metals.
  - In compounds formed with polyatomic ions, the number of ions present in the compound is indicated by enclosing the formula of ions in a bracket and writing the number of ions outside the bracket. For Example: $Mg(OH)_2$.

Formulae of Simple Compounds

- The simplest compounds, which are made up of two different elements, are called **binary compounds**.
- While writing the chemical formulae for compounds, we write the constituent elements and their valencies. Then we must cross over the valencies of the combining atoms.



Molecular Mass and Mole Concept

Molecular Mass

- The molecular mass of a substance is the **sum of the atomic masses of all the atoms in a molecule of the substance**. It is therefore the relative mass of a molecule expressed in atomic mass units (u).
  - For example, The molecular mass of HNO_3 = the atomic mass of H + the atomic mass of N + 3 × the atomic mass of O

    = 1 + 14 + 3 × 16 = 63 u

Formula Unit Mass

- The formula unit mass of a substance is a **sum of the atomic masses of all atoms in a formula unit of a compound**.
- It is calculated in the same manner as we calculate the molecular mass. The only difference is that the word formula unit is used for those substances whose constituent particles are ions.
  - For example, Formula unit mass of sodium chloride (NaCl) can be calculated as:

    1 × 23 + 1 × 35.5 = 58.5 u

Mole Concept

- The mole, symbol mol, is the **SI unit of amount of substance**.
- One mole of any species (atoms, molecules, ions or particles) is that quantity in number having a mass equal to its atomic or molecular mass in grams **(Refer to Figure 7.10)**.
- The number of particles (atoms, molecules or ions) present in 1 mole of any substance is fixed, with a value of $6.02214076 \times 10^{23}$. This number is called the **Avogadro Constant or Avogadro Number** (represented by N_0), named in honour of the Italian scientist, Amedeo Avogadro.
- 1 mole (of anything) = $6.02214076 \times 10^{23}$ in number

  = Relative mass in grams.

POINTS TO PONDER

The International Bureau of Weights and Measures in 2019 adopted new definitions of four fundamental quantities i.e., kilogram, current, mole and temperature. Think about the reason for this redefinition of 4 out of 7 base quantities and what is the difference between the old and new definition of Mole.

- The mass of 1 mole of a substance is equal to its relative atomic or molecular mass in grams.
- The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u).
- Mass of 1 mole of an atom of that element, that is, molar mass is also known as **gram atomic mass.**
  - For Example: atomic mass of oxygen = 16 u. So, gram atomic mass of oxygen = 16 g. 16 u oxygen has only 1 atom of oxygen, 16 g oxygen has 1 mole atom, that is, 6.022 x atoms of oxygen.
- The word "mole" was introduced around 1896 by **Wilhelm Ostwald** who derived the term from the Latin word moles meaning a 'heap' or 'pile'. A substance may be considered as a heap of

atoms or molecules. In 1967, the unit mole was accepted to provide a simple way of reporting a large number that is the massive heap of atoms and molecules in a sample.

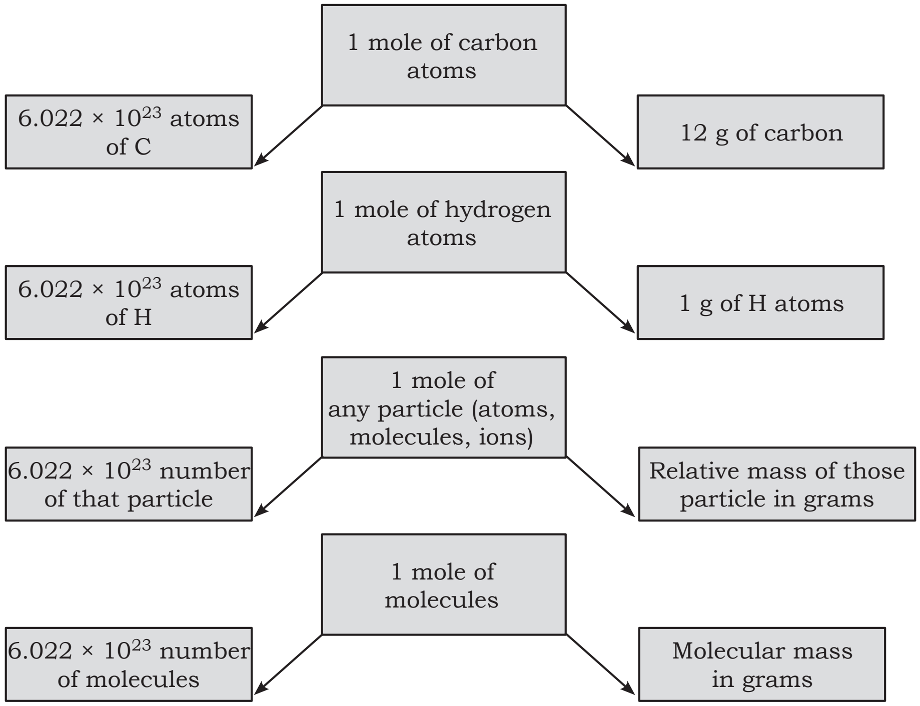


Figure 7.10: Relationship between mole, Avogadro number and mass

Conclusion

Thus, an atom is the smallest unit of any substance that can exist independently and retain all its chemical properties. Various models proposed by scientists unveil the structure of the atom. They have a tendency to react and form molecules with atoms of the same or different elements. Also, atoms of different elements join together in definite proportions to form molecules of compounds.

Glossary:

- **Atom:** Atoms are the fundamental building blocks of all matter.
- **Valency:** The combining power (or capacity) of an element is known as its valency.
- **Binary compounds:** Compounds which are made up of two different elements.
- **Atomic Number:** The atomic number of an element is the same as the number of protons in the nucleus of its atom.
- **Mass Number:** The mass number of an atom is equal to the number of nucleons in its nucleus.
- **Isotopes:** Isotopes are atoms of the same element, which have different mass numbers.
- **Isobars:** Isobars are atoms having the same mass number but different atomic numbers.
- **Molecule:** A molecule is the smallest particle of an element or a compound capable of independent existence under ordinary conditions.
- **Polyatomic Ions:** Clusters of atoms that act as an ion are called polyatomic ions.
- **Avogadro constant:** The Avogadro constant 6.022×10^{23} is defined as the number of atoms in exactly 12 g of carbon-12.
- **Mole:** The mole is the amount of substance that contains the same number of particles (atoms/ ions/ molecules/ formula units etc.) as there are atoms in exactly 12 g of carbon-12.
- **Molar mass:** Mass of 1 mole of a substance is called its molar mass.

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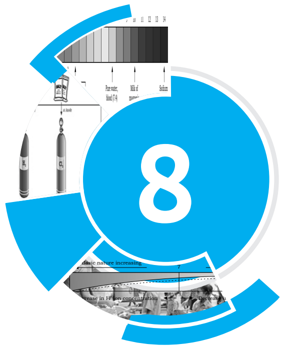


8 Chemical Reactions and Equations

Bibliography: This chapter encompasses a summary of **Chapters 1 and 2 - X** NCERT (Science) and **Chapter 4 and 5 - VII** NCERT (Science)

Introduction

We use a large number of substances in our daily life such as lemon, curd, sugar, salt, tamarind etc. Some of these substances taste sour, some taste bitter, some taste sweet and some taste salty. Some of these substances change. In this chapter we will study the nature of these changes. Also we will study the chemical properties of acids, bases and salt, how acids and bases cancel out each other's effects, how to write chemical equations and many more interesting things that we use and see in our day-to-day life.

Acids

- The word acid comes from the 'Latin' word **acere - means sour**.
- Curd, lemon juice, orange juice and vinegar taste sour because they contain acids (Refer to Table 8.1).
- The chemical nature of such substances is acidic.

Acids

Caution: Acids and bases are corrosive in nature. They are also irritating and harmful to skin.

Acids in other planets: The atmosphere of venus is made up of thick white and yellowish clouds of sulphuric acid.

Bases

- Substances which are bitter in taste and feel soapy on touching are known as bases. For example, Baking Soda.
- The nature of such substances is said to be basic.

Table 8.1: Acid and Base and their Sources

Name of Acid	Found in
Acetic acid	Vinegar
Formic acid	Ant's sting
Citric acid	Citrus fruits such as oranges, lemons, etc.
Lactic acid	Curd
Oxalic acid	Spinach, Tomato
Ascorbic acid	Amla, Citrus fruits (Vitamin C)
Tartaric acid	Tamarind, grapes, unripe mangoes, etc.
Methanoic acid	Nettle Sting and Ant Sting

Name of Base	Found in
Calcium hydroxide	Limewater
Ammonium hydroxide	Window cleaner
Sodium hydroxide/Potassium hydroxide	Soap
Magnesium hydroxide	Milk of Magnesia

Indicators

- Substances used to test whether a substance is acidic or basic are known as indicators.
- The indicators change their colour when added to a solution containing an acidic or a basic substance.

Litmus solution is a purple dye, which is extracted from lichen, a plant belonging to the division Thallophyta. When the litmus solution is neither acidic nor basic, its colour is purple. There are many other natural materials like **red cabbage leaves, turmeric,** coloured petals of some flowers such as **Hydrangea, Petunia and Geranium,** which indicate the presence of acid or base in a solution. These are called **acid-base indicators** or sometimes simply indicators.

- Indicators can be both natural and synthetic.

Natural Indicators

- Turmeric, litmus, Hibiscus or China Rose petals (Gudhal), etc., are some of the naturally occurring indicators.

To prepare limewater, dissolve some lime (chuna) in water. Stir the solution and keep it for some time. Pour a little from the top. This is lime water.

Litmus: A Natural Dye

- The most commonly used natural indicator is **litmus extracted from lichens**.
- It has a mauve (purple) colour in distilled water. When added to an acidic solution, it turns red and when added to a basic solution, it turns blue.
- It is available in the form of a solution, or in the form of strips of paper, known as litmus paper (red and blue litmus paper).
  - **Neutral Solution:** The solutions which do not change the colour of either red or blue litmus are known as neutral solutions. These substances are neither acidic nor basic.

Turmeric

- Turmeric stain on white shirt turns to red when it is washed with soap. It is because the soap solution is basic.

China Rose (Gudhal)

- China rose (Gudhal) indicator turns acidic solutions to dark pink (magenta) and basic solutions to green.

Acid rain
As the name indicates the rain containing excess of acids is called an acid rain. The rain becomes acidic because carbon dioxide, sulphur dioxide and nitrogen dioxide (which are released into the air as pollutants) dissolve in rain drops to form carbonic acid, sulphuric acid and nitric acid respectively. Acid rain can cause damage to buildings, historical monuments, plants and animals.

Synthetic Indicators

- Synthetic indicators such as methyl orange and phenolphthalein are used to test for acids and bases.
- When the solution is basic, phenolphthalein gives a pink colour and when the solution is acidic, it remains colourless.

Olfactory

- There are some substances whose odour changes in acidic or basic media. These are called olfactory indicators.

Strength of Acid or Base Solutions

- To judge how strong a given acid or base is, we use a **universal indicator**, which is a mixture of several indicators.
- The universal indicator shows different colours at different concentrations of hydrogen ions in a solution.
- A scale for measuring hydrogen ion concentration in a solution, called **pH scale** has been developed.
- The p in pH stands for **'potenz'** in German, meaning **power**.
- pH scale can measure **pH generally from 0 (very acidic) to 14 (very alkaline)**.
- Higher the hydronium ion concentration, lower is the pH value.
- The pH of a **neutral solution** is 7 whereas values less than 7 on the pH scale represent an acidic solution.
- As the pH value increases from 7 to 14, it represents an increase in OH^- ion concentration in the solution, i.e, increase in the strength of alkali. Generally paper impregnated with the universal indicator is used for measuring pH (Refer to Figure 8.1).
- Acids that give rise to more H^+ ions are said to be strong acids, and acids that give less H^+ ions are said to be weak acids.

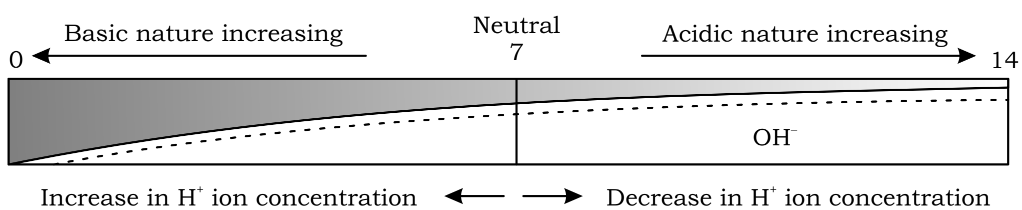


Figure 8.1: Variation of pH with the change in concentration of H+ (aq) and OH– (aq) ions

Importance of pH in Everyday Life

- **Plants and animals:** Our body works within the pH range of 7.0 to 7.8. Living organisms can survive only in a narrow range of pH change. When pH of rain water is less than 5.6, it is called **acid rain**. When acid rain flows into the rivers, it lowers the pH of the river water. Thus, the survival of aquatic life in such rivers becomes difficult (Refer to Figure 8.2).
- **pH of the soil:** Plants require a specific pH range for their healthy growth.
- **pH in our digestive system:** Our stomach produces hydrochloric acid. It helps in the digestion of food without harming the stomach.
- **pH change as the cause of tooth decay:** Tooth enamel, made up of calcium phosphate is the hardest substance in our body. It does not dissolve in water, but is corroded when the pH in the mouth is below 5.5. The bacteria present in the mouth produce acids by degradation of sugar and food particles remaining in the mouth after eating. Using toothpastes, which are generally basic, for cleaning the teeth can neutralise the excess acid and prevent tooth decay.
- **Self defence by animals and plants through chemical warfare:** Bee-sting leaves an acid which causes pain and irritation. Use of a mild base like baking soda on the stung area gives relief. Stinging hair of nettle leaves inject methanoic acid causing burning pain.

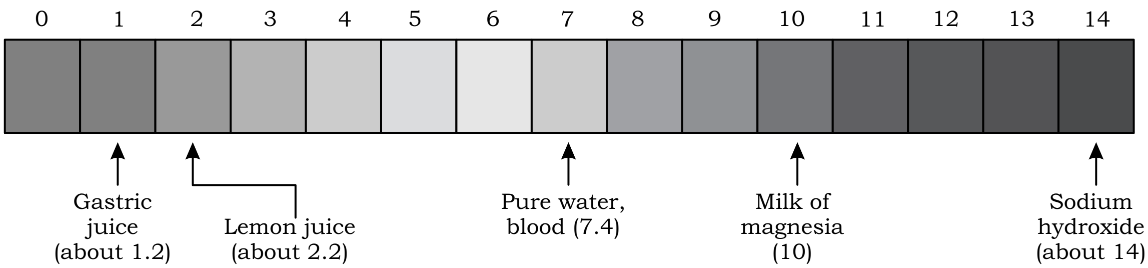


Figure 8.2: pH of some common substances shown on a pH paper (colours are only a rough guide)

Neutralisation

- When an acidic solution is mixed with a basic solution, both the solutions neutralise the effect of each other. The resulting solution is neither acidic nor basic.
- In a neutralisation reaction a new substance is formed called salt. Salt may be acidic, basic or neutral in nature.
- Thus, the reaction between an acid and a base is known as neutralisation. Salt and water are produced in this process with the evolution of heat.

Acid + Base → Salt + Water (Heat is evolved)

- For example, Hydrochloric acid (HCl) + Sodium hydroxide (NaOH) → Sodium Chloride (NaCl) + Water (H_2O)

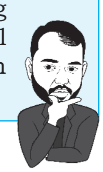
Neutralisation in Everyday Life

Indigestion

- Our stomach contains hydrochloric acid which helps us in digesting food. But too much acid in the stomach causes indigestion. During indigestion the stomach produces too much acid and this causes pain and irritation. To get rid of this pain, people use bases called antacids such as milk of magnesia, which contains magnesium hydroxide which neutralises the effect of excessive acid.

POINTS TO PONDER

Parietal cells in our stomach produce HCL acid whose excess leads to acidity. But the stomach produces it for a vital function. Think about the role of acid in digestion and what lifestyle habits like timing and type of food help in optimal health of the digestive system in context of acidity.



Ant bite

- Ant bites inject the acidic liquid **(formic acid)** into the skin.
- It can be neutralised by the rubbing moist baking soda (sodium hydrogen carbonate) or calamine solution, which contains zinc carbonate.

Soil treatment

- Plants do not grow well when the soil is either too acidic or too basic.
- Excessive use of chemical fertilisers makes the soil acidic. When the soil is too acidic, it is treated with bases like quicklime (calcium oxide) or slaked lime (calcium hydroxide).
- When the soil is basic, organic matter (compost) is added to it which releases acids and thus neutralises the basic nature of the soil.

Nature provides neutralisation options

Nettle is a herbaceous plant which grows in the wild. Its leaves have stinging hair, which cause painful stings when touched accidentally. This is due to the methanoic acid secreted by them. A traditional remedy is rubbing the area with the leaf of the dock plant, which often grows beside the nettle in the wild.

Factory wastes

- The wastes of many factories contain acids and the flow of these waste into the water bodies can kill fish and other organisms.
- The factory wastes are, therefore, neutralised by adding basic substances.

Physical and Chemical Changes

- Every day we witness many changes in our surroundings. These changes may involve one or more substances. For example, making a sugar solution is a change, setting curd from milk.
- Broadly these changes are of two kinds: **Physical and Chemical.**

Physical Changes

- Properties such as shape, size, colour and state of a substance are called its physical properties.
- A change in which a substance undergoes a change in its physical properties is called a physical change.
- A physical change is generally reversible and no new substance is formed. For example, melting of ice, cutting a piece of paper.

Chemical Changes

- A change in which one or more new substances are formed is called a chemical change. It is also called a chemical reaction.
- **For example,**
  1. Burning of thin strip or ribbon of magnesium leaves a powdery ash of magnesium oxide
     Magnesium (Mg) + Oxygen (O_2) → Magnesium Oxide (MgO)
     On dissolving the ash of MgO in water it forms a new substance called Magnesium hydroxide which is a **base**.
     Magnesium oxide (MgO) + Water (H_2O) → Magnesium hydroxide [$Mg(OH)_2$]
  2. Copper sulphate solution (blue) + Iron → Iron sulphate solution (green) + Copper (brown deposit).
  3. Vinegar (Acetic acid) + Baking soda (Sodium hydrogen carbonate) → Carbon dioxide + other substances.
  4. When carbon dioxide is passed through lime water, calcium carbonate is formed, which makes lime water milky. The turning of lime water into milky is a standard test of carbon dioxide.
     Carbon dioxide (CO_2) + Lime water [$Ca(OH)_2$] → Calcium Carbonate ($CaCO_3$) + Water (H_2O)
- Chemical changes are very important in our lives because all new substances are formed as a result of chemical changes. For example, extraction of metal from an ore, a medicine, plastics and detergents, are produced by chemical reactions.
- In addition to new products, the following may accompany a chemical change:
  - Heat, light or any other radiation (ultraviolet, for example) may be given off or absorbed.
  - Sound may be produced.
  - A change in smell may take place or a new smell may be given off.
  - A colour change.
  - A gas may be formed.

A protective shield

The ozone layer in our atmosphere protects us from the harmful ultraviolet radiation which come from the sun. Ozone absorbs this radiation and breaks down to oxygen. Oxygen is different from ozone. If ultraviolet radiation were not absorbed by ozone, it would reach the earth's surface and cause harm to us and other life forms. It acts as a natural shield against this radiation.

Rusting of Iron

- A piece of iron in the open for some time, acquires a film of brownish substance. This substance is called **rust** and the process is called **rusting**. Rust is not iron. It is different from iron on which it gets deposited.

> **Other tit-bits**
>
> Stainless steel is made by mixing iron with carbon and metals like chromium, nickel and manganese. It does not rust.

- Since iron is used in making bridges, ships, cars, truck bodies and many other articles, the monetary loss due to rusting is huge.
- For rusting, the presence of both oxygen and water/water vapour is essential. Rusting becomes faster if the content of moisture in air is high (humid).
- The salt water of the sea makes the process of rust formation faster. Therefore, ships suffer a lot of damage from rusting in spite of being painted.
- **The process of rusting can be represented by:**

  Iron (Fe) + Oxygen (O_2, from the air) + water (H_2O) → rust (iron oxide Fe_2O_3)

Prevention of rusting

- By applying a coat of paint or grease regularly.
- **Galvanisation:** Depositing a layer of a metal like **chromium or zinc** on iron is called "galvanisation". The iron pipes used in homes to carry water are galvanised to prevent rusting.

> **Did You Know?**
>
> Near the Qutub Minar in Delhi stands an iron pillar which is more than 7 metres high and weighs more than 6000 kg. After such a long period it has not rusted. For its quality of rust resistance it has been examined by scientists from all parts of the world. It tells something about the advances India had made in metal technology as back as 1600 years ago.

Crystallisation

- The salt obtained by the evaporation of seawater is not pure and the shape of its crystals cannot be seen clearly. However, large crystals of pure substances can be formed from their solutions.
- Thus, the process of deriving large crystals of pure substances from their solution is called **"crystallisation"**. It is an example of a physical change.

Chemical Reaction

- When the nature and the identity of the initial substance have somewhat changed it is said to be a chemical change and whenever a chemical change occurs, a chemical reaction takes place.
- These chemical reactions can be represented as chemical equations.

Chemical Equations

- The description of a chemical reaction in sentence form is quite long. It can be written in a shorter form. The simplest way to do this is to write it in the form of a word-equation.
- When a magnesium ribbon is burnt in oxygen, it gets converted to magnesium oxide. It can be written in words as:

  Magnesium + Oxygen → Magnesium oxide

  (Reactants) (Product)

  - **Reactants:** The substances that undergo chemical change in the reaction are the reactants.
  - **Product:** The new substance formed during the reaction is a product.
  - A word-equation shows change of reactants to products through an arrow placed between them. The reactants are written on the left-hand side (LHS) with a plus sign (+) between them and products are written on the right-hand side (RHS) with a plus sign (+) between them. The arrowhead points towards the products, and shows the direction of the reaction.

Writing a Chemical Equation

- Chemical equations can be made more concise and useful if we use chemical formulae instead of words.
- A chemical equation represents a chemical reaction. Burning of magnesium ribbon in oxygen can be written as,

$$Mg + O_2 \rightarrow MgO$$

Balanced Chemical Equations

- **Law of conservation of mass** states that mass can neither be created nor destroyed in a chemical reaction i.e the total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants.
- In other words, the number of atoms of each element remains the same, before and after a chemical reaction.
- Hence, we need to balance a skeletal chemical equation. For example,

1. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ **(Refer to Table 8.2)**

Table 8.2: Number of atoms of different elements on both sides of the arrow

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Zn	1	1
H	2	2
S	1	1
O	4	4

As the number of atoms of each element is the same on both sides of the arrow, the equation is a balanced chemical equation.

2. $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Step I: List the number of atoms of different elements present in the unbalanced equation (Refer to Table 8.3).

Table 8.3: Number of atoms of different elements present in the unbalanced equation

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1	3
H	2	2
O	1	4

Step II: Start balancing with the compound that contains the maximum number of atoms. It may be a reactant or a product. In that compound, select the element which has the maximum number of atoms. i.e. the compound is Fe_3O_4 and the element oxygen in it. To balance the oxygen atoms (Refer to Table 8.4).

Table 8.4: Atoms of Oxygen

Atoms of Oxygen	In reactants	In products
Initial	1 (in H_2O)	4 (in Fe_3O_4)
To balance	1 × 4	4

Now the partly balanced equation becomes:

$Fe + 4\ H_2O \rightarrow Fe_3O_4 + H_2$

Step III: Now to equalise the number of H atoms, make the number of molecules of hydrogen as four on the RHS (Refer to Table 8.5).

Table 8.5: Atoms of Hydrogen

Atoms of Hydrogen	In reactants	In products
Initial	8 (in $4H_2O$)	2 (in H_2)
To balance	8	2 × 4

The equation would be:

$Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2$

Step IV: To equalise Fe, we take three atoms of Fe on the LHS (Refer to Table 8.6).

Table 8.6: Atoms of Iron

Atoms of Iron	In reactants	In products
Initial	1 (in Fe)	3 (in Fe_3O_4)
To balance	1 × 3	3

The equation would be:

$3\ Fe + 4\ H_2O \rightarrow Fe_3O_4 + 4\ H_2$

Step V: Finally, the numbers of atoms of elements on both sides of equations are equal. This equation is now balanced. This method of balancing chemical equations is called the **hit-and-trial method.**

$\mathbf{3Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2}$

Step VI: To make a chemical equation more informative, the physical states of the reactants and products are mentioned. The gaseous, liquid, aqueous and solid states of reactants and products are represented by the notations (g), (l), (aq) and (s), respectively.

Note: The word aqueous (aq) is written if the reactant or product is present as a solution in water.

Thus, the balanced Equation becomes

$3Fe\ (s) + 4H_2O\ (g) \rightarrow Fe_3O_4\ (s) + 4H_2\ (g)$

Sometimes the reaction conditions, such as temperature, pressure, catalyst, etc., for the reaction indicated above and/or below the arrow in the equation. For example,

$$CO(g) + 2H_2(g) \xrightarrow{340\ atm} CH_3OH(I)$$

$$6CO_2(aq) + 6H_2O(I) \xrightarrow[chlorophyll]{sunlight} \underset{(Glucose)}{C_6H_{12}(aq)} + 6O_2(aq)$$

Types of chemical reactions

- During a chemical reaction, neither atoms of one element change into those of another element nor do atoms disappear from the mixture or appear from elsewhere.
- In fact, chemical reactions involve the breaking and making of bonds between atoms to produce new substances.

Combination Reaction

- When two or more substances (elements or compounds) combine to **form a single product,** the reactions are called combination reactions. For example,
  1. Calcium oxide reacts vigorously with water to produce slaked lime (calcium hydroxide) releasing a large amount of heat.

     $CaO\ (s) + H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) + Heat$

     (Quick lime) (Slaked lime)

     In this reaction, calcium oxide and water combine to form a single product, calcium hydroxide.

DID YOU KNOW?

A solution of slaked lime is used for white washing walls. Calcium hydroxide reacts slowly with the carbon dioxide in air to form a thin layer of calcium carbonate on the walls and gives a shiny finish to the walls. The chemical formula for marble is also $CaCO_3$.

$Ca(OH)_2\ (aq) + CO_2\ (g) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

(Calcium Hydroxide) (Calcium Carbonate)

2. Burning of coal

$$C(s) + O_2\ (g) \rightarrow CO_2\ (g)$$

3. Formation of water from H_2 (g) and O_2 (g)

$$2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (l)$$

✤ **Exothermic chemical reaction:** Reactions in which heat is released along with the formation of products are called exothermic chemical reactions. For example,

1. Burning of natural gas:

   $CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$

2. Respiration:

   During digestion, food is broken down into simpler substances. For example, rice, potatoes and bread contain carbohydrates. These carbohydrates are broken down to form glucose. This glucose combines with oxygen in the cells of our body and provides energy.

   $C_6H_{12}O_6\ (aq) + 6O_2\ (aq) \rightarrow 6CO_2\ (aq) + 6H_2O\ (l) + \text{energy}$
   (Glucose)

3. The decomposition of vegetable matter into compost.

POINTS TO PONDER

Reactions can be endothermic and exothermic and overall energy is neither created nor destroyed which is the first law of thermodynamics. Can you think of what is the source of energy for endothermic reactions to occur? And in exothermic reactions, what type of energy is released, and what is the significance of this energy release

Decomposition Reaction

✤ In this reaction a single reactant breaks down to give simpler products. For example,

1. $2FeSO_4\ (s) \xrightarrow{heat} Fe_2O_3\ (s) + SO_2\ (g) + SO_3\ (g)$
   Ferrous sulphate crystals ($FeSO_4$, $7H_2O$) lose water when heated and the green colour of the crystals changes. It then decomposes to ferric oxide (Fe_2O_3), Sulphur dioxide (SO_2) and Sulphur trioxide (SO_3).
2. Decomposition of Calcium Carbonate **(Limestone)** to calcium oxide (called **lime or quicklime**) and carbon dioxide on heating is an important decomposition reaction used in various industries. It has many uses such as in the manufacture of cement. When a decomposition reaction is carried out by heating, it is called **thermal decomposition**.

   $CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$
   (Limestone) (Quicklime)

3. $2Pb(NO_3)_2\ (s) \xrightarrow{heat} 2PbO(s) + 4NO_2\ (g) + O_2\ (g)$
   (Lead nitrate) (Lead oxide) (Brown fumes of Nitrogen dioxide) (Oxygen)
4. $2AgCl(s) \xrightarrow{sunlight} 2Ag(s) + Cl_2\ (g)$
   White silver chloride turns grey in sunlight.
5. $2AgBr(s) \xrightarrow{sunlight} 2Ag(s) + Br_2\ (g)$
   The above reactions of silver chloride and silver bromide are used in black and **white photography.**

✤ **Endothermic Reactions:** The decomposition reactions require energy either in the form of heat, light or electricity for breaking down the reactants. Thus, the reactions in which energy is absorbed are known as endothermic reactions.

Displacement Reaction

✤ A reaction in which a more reactive element displaces a less reactive element from a compound is known as displacement reaction. For example,

1. $Fe(s) + CuSO_4\ (aq) \rightarrow FeSO_4\ (aq) + Cu(s)$

(Iron sulphate)

The iron nail becomes brownish in colour and the blue colour of copper sulphate solution fades. In this reaction, iron has displaced or removed another element, copper, from copper sulphate solution.

2. $Zn(s) + CuSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Cu(s)$

(Copper sulphate) (Zinc sulphate)

3. $Pb(s) + CuCl_2\ (aq) \rightarrow PbCl_2\ (aq) + Cu(s)$

(Copper chloride) (Lead chloride)

Zinc and lead are more reactive elements than copper.

Double Displacement Reaction

- Reactions in which there is an exchange of ions between the reactants are called double displacement reactions. For example,

$$Na_2SO_4\ (aq) + BaCl_2\ (aq) \rightarrow BaSO_4\ (s) + 2NaCl\ (aq)$$

(Sodium sulphate) (Barium chloride) (Barium sulphate) (Sodium chloride)

- The white precipitate of BaSO4 is formed by the reaction of SO^{-2}_4 and Ba^{2+} which is insoluble in water) is formed. This insoluble substance formed is known as a precipitate. Any reaction that produces a precipitate can be called a **precipitation reaction.**
- The other product formed is sodium chloride which remains in the solution.

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**. For example;

1. When copper powder is heated, the surface of copper powder becomes coated with black copper (II) oxide. This is because oxygen is added to copper and copper oxide is formed.

$$2Cu + O_2 \xrightarrow{heat} 2CuO$$

- If hydrogen gas is passed over this heated material (CuO), the black coating on the surface turns brown as the reverse reaction takes place and copper is obtained.

$$CuO + H_2 \xrightarrow{heat} Cu + H_2O$$

- If a substance gains oxygen or loses hydrogen during a reaction, it **is oxidised**. If a substance loses oxygen or gains hydrogen during a reaction, it is **reduced**. During this reaction, the copper(II) oxide is losing oxygen and is being reduced. The hydrogen is gaining oxygen and is being oxidised $2CuO + H_2 \xrightarrow{heat} Cu + H_2O$.

2. $ZnO + C \rightarrow Zn + CO$

In this reaction carbon is oxidised to CO and ZnO is reduced to Zn.

3. $MnO_2 + 4\ HCl \rightarrow MnCl_2 + 2\ H_2O + Cl_2$

In this reaction HCl is oxidised to Cl_2 whereas MnO_2 is reduced to $MnCl_2$.

- **The effects of oxidation reactions in everyday life -**
  - **Corrosion:** When a metal is attacked by substances around it such as moisture, acids, etc., it is said to corrode and this process is called corrosion. For example, Iron articles get coated with a reddish brown powder when left for some time by the process known as rusting of iron. The black coating on silver and the green coating on copper are other examples of corrosion.
  - **Rancidity:** When fats and oils are oxidised, they become rancid and their smell and taste change. Usually substances which prevent oxidation **(antioxidants)** are added to foods

containing fats and oil. Keeping food in air tight containers helps to slow down oxidation. For example, chips manufacturers usually flush bags of chips with gas such as nitrogen to prevent the chips from getting oxidized.

Understanding the Chemical Properties of Acids and Bases

Reaction of Acids and Bases with Metals

- When metal reacts with the acids it forms a compound called **a salt and hydrogen gas.**

  Acid + Metal → Salt + Hydrogen gas

  $2NaOH\ (aq) + Zn\ (s) \rightarrow Na_2ZnO_2\ (s) + H_2\ (g)$

  (Sodium zincate)

- **Reactions of metal with the bases are not possible.**

Reaction of Metal Carbonates and Metal Hydrogencarbonates with Acids

- All metal carbonates and hydrogencarbonates react with acids to give a corresponding salt, carbon dioxide and water.

  Metal carbonate/Metal hydrogencarbonate + Acid → Salt + Carbon dioxide + Water

- **For example,**
  1. $Na_2CO_3\ (s) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + H_2O\ (l) + CO_2\ (g)$
  2. $NaHCO_3\ (s) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l) + CO_2\ (g)$
  3. On passing the carbon dioxide gas evolved through lime water,

     $Ca(OH)_2\ (aq) + CO_2\ (g) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

     (Lime water) (White precipitate)

     On passing excess carbon dioxide

     $CaCO_3\ (s) + H_2O\ (l) + CO_2\ (g) \rightarrow Ca(HCO_3)_2\ (aq)$

     Limestone, chalk and marble are different forms of calcium carbonate.

Reaction of Metallic Oxides with Acids

- The general reaction between a metal oxide and an acid can be written as;

  Metal oxide + Acid → Salt + Water

  $CuO\ (s) + 2\ HCl\ (l) \rightarrow CuCl_2\ (l) + H_2O\ (l)$

- Since metallic oxides react with acids to give salts and water, similar to the reaction of a base with an acid, metallic oxides are said to be basic oxides.

Reaction of a Non-metallic Oxide with Base

- The general reaction between a non-metallic oxide and a base can be written as

  Nonmetallic oxide + base → Salt + Water

- **For example,** Calcium hydroxide, which is a base, reacts with carbon dioxide to produce salt and water.

  $Ca(OH)_2\ (aq) + CO_2\ (g) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

Since this is similar to the reaction between a base and an acid, it can be concluded that non-metallic oxides are acidic in nature.

What Do All Acids and All Bases Have in Common

Table 8.7: Difference between Acids and Bases

Acids	Bases
All acids generate hydrogen gas by reacting with metals.	Base dissociates hydroxide ions in water.
The electric current is carried through the acidic solution by ions.	The electric current is carried through the basic solution by ions.
Acids contain H^+ ion as cation and anion such as in HCl, in HNO_3, in H_2SO_4, CH_3COO^- in CH_3COOH. Since the cation present in acids is H^+, this suggests that acids produce hydrogen ions, H^+ (aq), in solution, which are responsible for their acidic properties.	Bases contain OH^- ions.
Examples are HCl, H_2SO_4, CH_3COOH etc.	Examples are NaOH, KOH, $Mg(OH)_2$ etc.

An Acid or a Base in a Water Solution

- The separation of H+ ion from HCl molecules cannot occur in the absence of water.

  $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

> **Did you know?**
>
> All bases do not dissolve in water. Bases which are soluble in water are called **alkalis.** They are soapy to touch, bitter and corrosive.)

- Hydrogen ions cannot exist alone, but they exist after combining with water molecules. Thus hydrogen ions must always be shown as H^+ (aq) or hydronium ion (H_3O^+).

  $H^+ + H_2O \rightarrow H_3O^+$

- Bases dissolved in water generate hydroxide (OH–) ions. For example,

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

  $KOH\ (s) \rightarrow K^+\ (aq) + OH^-\ (aq)$

  $Mg(OH)_2\ (s) \rightarrow Mg^{2+}\ (aq) + 2OH^-\ (aq)$

- The process of dissolving an acid or a base in water is highly exothermic.
- Mixing an acid or base with water results in a decrease in the concentration of ions (H_3O^+/OH^-) per unit volume. Such a process is called **dilution** and the acid or the base is said to be diluted.

Salts

Family of Salts

- Salts having the same positive or negative radicals are said to belong to a family. For example, NaCl and Na_2SO_4 belong to the family of sodium salts. Similarly, NaCl and KCl belong to the family of chloride salts.

pH of Salts

- Salts of a strong acid and a strong base are neutral with a pH value of 7.
- Salts of a strong acid and weak base are acidic with pH value less than 7 and
- Salts of a strong base and weak acid are basic in nature, with pH value more than 7.

Chemicals from Common Salt

- The salt formed by the combination of hydrochloric acid and sodium hydroxide solution is called sodium chloride.
- Deposits of solid salt are also found in several parts of the world and are often brown due to impurities. This is called **rock salt**.

- Beds of rock salt were formed when seas of bygone ages dried up. Rock salt is mined like coal.
- **Common salt - A raw material for chemicals:** The common salt is an important raw material for various materials of daily use, such as sodium hydroxide, baking soda, washing soda, bleaching powder and many more.
- **Sodium Hydroxide:** When electricity is passed through an aqueous solution of sodium chloride (called brine), it decomposes to form sodium hydroxide. The process is called the chlor-alkali process because of the products formed which include chlor for chlorine and alkali for sodium hydroxide (Refer to Figure 8.3). Chlorine gas is given off at the anode, and hydrogen gas at the cathode. Sodium hydroxide solution is formed near the cathode.

$$2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2\ (g) + H_2\ (g)$$

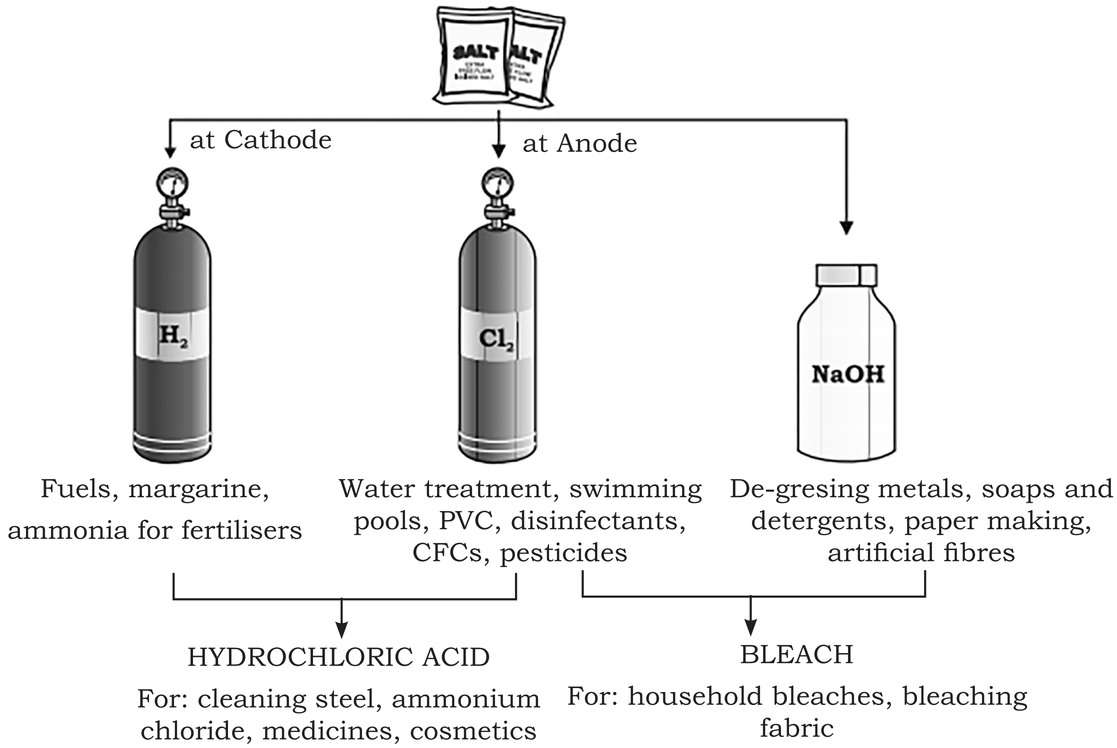


Figure 8.3: Important products from the chlor-alkali process

Bleaching Powder: Chlorine is produced during the electrolysis of aqueous sodium chloride (brine) and is used for the manufacture of bleaching powder. Bleaching powder **($CaOCl_2$)** is produced by the action of chlorine on dry slaked lime [$Ca(OH)_2$].

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

Uses of bleaching powder:

1. For bleaching cotton and linen in the textile industry, for bleaching wood pulp in paper factories and for bleaching washed clothes in laundry;
2. As an oxidising agent in many chemical industries; and
3. To make drinking water free from germs.

Baking Soda: The baking soda is commonly used in the kitchen for making tasty crispy pakoras, etc. Sometimes it is added for faster cooking. The chemical name of the compound is **sodium hydrogencarbonate ($NaHCO_3$).** It is produced using sodium chloride as one of the raw materials.
$NaCl + H_2O + CO_2 + NH_3 \rightarrow NH_4Cl$ (Ammonium chloride) + $NaHCO_3$ (Sodium hydrogencarbonate)
When it is heated during cooking the following reaction takes place;

$$2NaHCO_3 \rightarrow Na_2CO_3 \text{ (Sodium carbonate)} + H_2O + CO_2$$

Uses of baking soda:

1. For making baking powder, which is a mixture of baking soda (sodium hydrogencarbonate) and a mild edible acid such as tartaric acid. When baking powder is heated or mixed in water the following reaction takes place:

   $NaHCO_3$ + H+ (From any acid) $\rightarrow$ CO_2 + H_2O + Sodium salt of acid

   Carbon dioxide produced during the reaction can cause bread or cake to rise making them soft and spongy.
2. It is also an ingredient in antacids. Being alkaline, it neutralises excess acid in the stomach and provides relief.
3. It is also used in soda-acid fire extinguishers.

   Washing Soda: Another chemical that can be obtained from sodium chloride is Sodium carbonate – $\mathbf{Na_2CO_3.10H_2O}$ (washing soda). Recrystallisation of sodium carbonate gives washing soda. It is also a basic salt.

$$Na_2CO_3 + 10\ H_2O \rightarrow Na_2CO_3.10H_2O$$

Uses of washing soda:

1. Sodium carbonate is used in glass, soap and paper industries.
2. It is used in the manufacture of sodium compounds such as borax.
3. Sodium carbonate can be used as a cleaning agent for domestic purposes.
4. It is used for removing permanent hardness of water.

Are the Crystals of Salts really Dry

- Copper sulphate crystals which seem to be dry contain water of crystallisation. When the crystals are heated, this water is removed and the salt turns white. If we moisten the crystals again with water, then the blue colour of the crystals reappears.
- Water of crystallisation is the fixed number of water molecules present in one formula unit of a salt.
- Five water molecules are present in one formula unit of copper sulphate. Chemical formula for hydrated copper sulphate is $CuSO_4.5H_2O$.
- **Gypsum** has two water molecules as water of crystallisation. It has the chemical formula $\mathbf{CaSO_4.2H_2O}$.
- On heating gypsum at 373 K, it loses water molecules and becomes calcium sulphate hemihydrate $\mathbf{(CaSO_4.\frac{1}{2}H_2O)}$. This is called **Plaster of Paris**, the substance which doctors use as plaster for supporting fractured bones in the right position.
  - Plaster of Paris is a white powder and on mixing with water, it changes to gypsum once again giving a hard solid mass.

    $$CaSO_4.\frac{1}{2}H_2O + 1\frac{1}{2}H_2O \rightarrow CaSO_4.2H_2O$$
  - Plaster of Paris is used for making toys, materials for decoration and for making surfaces smooth.

Conclusion

Substances that we use can be acids or bases. These substances show changes which can be reversible or irreversible. Chemical changes are very important in our lives as all new substances are formed as a result of chemical changes. The chemical changes can be represented by a chemical equation. Also, the chemical properties of these substances play an important part in our daily life in many ways.

Glossary:

- **Acids:** Acids are sour in taste. Acid turns blue litmus red.
- **Bases:** Bases are bitter in taste and soapy to touch. Bases turn red litmus blue.
- **Neutral:** Substances which are neither acidic nor basic are called neutral.
- **Indicators:** Solutions of substances that show different colour in acidic, basic and neutral solutions are called indicators.
- **Acid-base indicators:** Acid-base indicators are dyes or mixtures of dyes which are used to indicate the presence of acids and bases.
- **Salt:** An acid and a base neutralise each other and form a salt. A salt may be acidic, basic or neutral in nature.
- **Physical Changes:** Physical changes are changes in the physical properties of substances. No new substances are formed in these changes. These changes may be reversible.
- **Chemical Changes:** In chemical changes new substances are produced.
- **Crystallisation:** Some substances can be obtained in pure state from their solutions by crystallisation.
- **Chemical Equation:** A chemical equation is balanced so that the numbers of atoms of each type involved in a chemical reaction are the same on the reactant and product sides of the equation. Equations must always be balanced.
- **Combination reactions:** In a combination reaction two or more substances combine to form a new single substance.
- **Decomposition reactions:** Decomposition reactions are opposite to combination reactions. In a decomposition reaction, a single substance decomposes to give two or more substances.
- **Exothermic reactions:** Reactions in which heat is given out along with the products are called exothermic reactions.
- **Endothermic reactions:** Reactions in which energy is absorbed are known as endothermic reactions.
- **Displacement reactions:** When an element displaces another element from its compound, a displacement reaction occurs.
- **Double displacement reactions:** Two different atoms or groups of atoms (ions) are exchanged in double displacement reactions.
- **Oxidation and Reduction:** Reactions also involve the gain or loss of oxygen or hydrogen by substances. Oxidation is the gain of oxygen or loss of hydrogen. Reduction is the loss of oxygen or gain of hydrogen.

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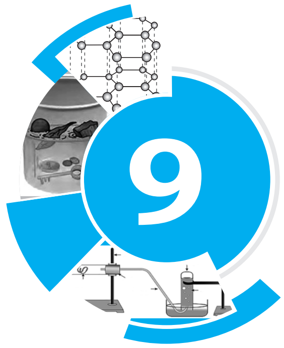


Metals and Non-metals

Bibliography: The chapter encompasses the summary of **Chapter 2 - VI** NCERT (Science), **Chapters - 3 and 4 - X** NCERT (Science).

Introduction

The things which we all use in our daily life are made up of different types of materials. All these materials have mass, shape and are classified based on many criteria, including their physical states, properties of materials, etc.

Properties of Materials

- Based on the different properties, materials can be differentiated into their respective groups. Listed below are the properties of materials.
  - **State of Matter:** At first, the materials can be sorted into their groups based on the 3 states of matter which are, Solids, liquids and gases.
  - **Appearance:** The second criteria used for sorting the materials is based on their appearance. The appearance of materials varies in colour, texture, hardness, softness and lustre.
  - **Solubility:** The third criteria used to sort the materials are based on their solubility. The solubility depends on soluble and insoluble materials in water. For example, Salt and sugar are soluble in water. Chalk and sand are insoluble in water.
  - **Metal/Non-metal:** The fourth criteria used to sort the materials is based on the metal and non-metals. Iron, copper, and gold are examples of metals and coal, chalk, and rubber are examples of non-metals.
  - **Degree of Transparency:** The fifth criteria used to sort the materials is based on the light transmission through objects, which includes Opaque, Translucent and Transparent.

Criteria and Need of Classification

- Materials can be classified based on several properties:
  - Transparency
  - Hardness
  - Soluble and Insoluble
  - Float and Sink
- Classification makes everything easier and orderly for better understanding.

Materials and Their Classification

Materials are classified based on similarities in their properties, such as appearance, hardness, transparency, solubility or density.

Appearance

- **Polishing:** Materials can be differentiated from each other based on their appearance.
  - Some, like diamond and gold, are shiny and are termed lustrous materials.(**Refer to Figure 9.1)** Some other materials, like graphite and wood, do not appear shiny and are generally known as non-lustrous materials.
  - **Metal Polishing:** Metal Polishing is a method of improving the durability and texture of metal surfaces as they are much less likely to wear or corrode. It acts as a protective shield against metal surfaces because it stops oxidation.

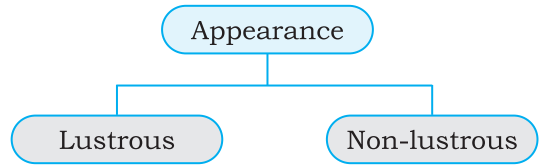


Figure 9.1

Hardness

- **Toughness:** The property of material to withstand stress without breaking is termed as toughness.
  - **Strength and Ductility:** A material with high strength and high ductility will have more toughness than a material with low strength and high ductility.
  - **Soft/Hard Substances:** Materials that can be compressed or deformed easily are referred to as soft substances. Whereas materials that are difficult to bend or compress are termed hard substances.

Solubility

- Some substances completely disappear or dissolve in water. These substances are soluble in water.
- Other substances do not mix with water and do not disappear even after we stir for a long time. These substances are insoluble in water.

Floatation

- **Buoyancy**
  - The upward force applied by the fluid on the object or the body when an object is put in or submerged in the fluid is termed as Buoyancy.
  - Materials can be classified based on the sinking or floating in water: A leaf floats on water, on other hand a metal spoon will sink into the water.

Density

- Density is defined as mass per unit volume of a given object. One can think of it as the amount of particles of a substance packed into a certain amount of space.
  - If the particles are packed tightly together, the density would be greater than if they are loosely packed with a lot of empty space around them.
  - Density is the reason some objects sink, and other objects float.
  - The SI unit is **kg/m^3**.

Figure 9.2: Some objects float in water while others sink in it.

Transparency:

- Materials can be grouped into three main categories based on their ability to transmit light.
  - **Transparent:** An object which allows visible light to pass through it, is called a transparent object. We can clearly see through a transparent object. E.g:- glass, fish tank.

- **Translucent:** An object, which allows partial passage to light is called a translucent object. E.g.: Plastic bottle, paper cup.
- **Opaque:** An object which does not allow passage to light is called an opaque object. We cannot see through an opaque object. E.g.: Wood, metals.

In the earlier sections we have seen the elements that can be classified as metals or nonmetals on the basis of their properties. Now, we will be focussing on properties that differentiate them. Based on their physical and chemical properties, these elements can be divided into three groups: Metalloids, Metals, and Nonmetals.

Properties of Metals

Physical Properties of Metals

- Metals are hard and have a high tensile strength.
  - Carbon is the only non-metal with very high tensile strength.
- Metals are generally in a solid state at room temperature. But Mercury is a metal which remains in liquid form at room temperature.
- **Sonorous:** Metals produce a typical ringing sound when hit by something.
- Metals are good conductors of heat and electricity.
  - **Exception:** Graphite (a non-metal) is a good conductor of heat and electricity.
- **Malleable**: Metals can be beaten into thin sheets.
- **Ductile**: Metals can be drawn into thin wires.
- **Melting and Boiling Points:** Metals have high melting and boiling points (except Caesium (Cs) and Gallium (Ga)).
  - Graphite, a form of carbon (a non-metal), has a high boiling point and exists in a solid state at room temperature.

POINTS TO PONDER
Metals though being hard are ductile and malleable. Think about how its structure which gives it rigidness also imparts these properties to metals.

- **Dense:** Density of metals is high (except alkali metals). Osmium has the highest density, and lithium has least density
- **Lustrous:** Metals have the quality of reflecting light from their surface and can be polished, e.g., gold, silver and copper. Iodine and carbon are non-metals which are lustrous.
  - Note that carbon is lustrous only in certain forms like diamond and graphite.
- **Colour:** Metals are silver-grey in colour (except gold and copper).

Chemical Properties of Metals

- Reaction of Metals with Oxygen (Burnt in Air):
  - A metal oxide is formed when metals are burned in the air and react with oxygen in the air. Metal oxides are a type of basic material found in nature.
  - Metal + Oxygen → Metal oxide (basic). For example, when copper is heated in air, it combines with oxygen to form copper(II) oxide, a black oxide.

$$\underset{\text{(Copper)}}{2Cu} + O_2 \longrightarrow \underset{\text{(Copper (II) oxide)}}{2CuO}$$

- Similarly, aluminium forms aluminium oxide:

$$\underset{\text{(Aluminium)}}{4Al} + 3O_2 \longrightarrow \underset{\text{(Aluminium oxide)}}{2Al_2O_3}$$

Basic Oxides of Metals:

- Metal oxides are crystalline solids that contain a metal cation and an oxide anion. They typically react with water to form bases or with acids to form salts. Thus, these compounds are often called basic oxides.
- Some metallic oxides get dissolved in water and form alkalis. Their aqueous solution turns red litmus blue.
  - $Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$
  - $K_2O(s) + H_2O(l) \longrightarrow 2KOH(aq)$

Amphoteric Oxides of Metals:

- Amphoteric oxides are metal oxides which react with both acids as well as bases to form salt and water.
  - $Al_2O_3(s) + 6HCl \longrightarrow 2AlCl_3 + 3H_2O(l)$
  - $Al_2O_3(s) + 2NaOH \longrightarrow 2NaAlO_2 + H_2O(l)$

Reaction of Metals with Water or Steam (Refer to Figure 9.3)

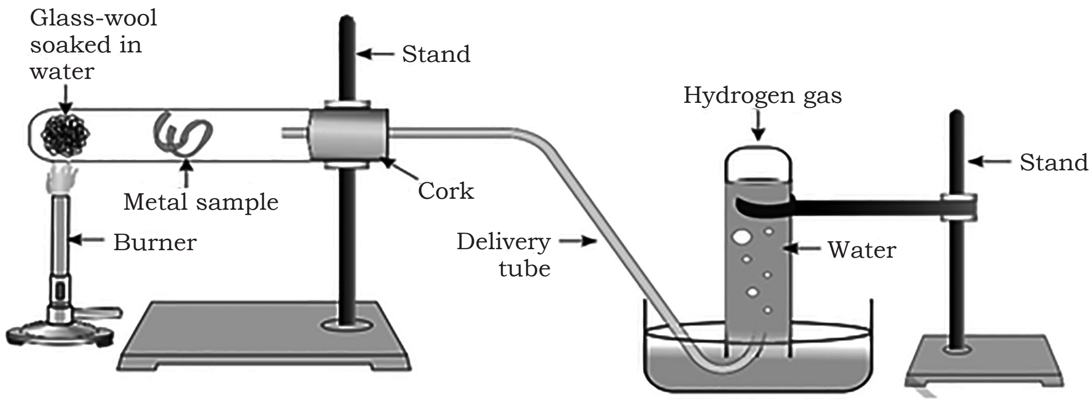


Figure 9.3: Action of Steam into Metal

- Aluminium, iron, and zinc are metals that do not react with either cold or hot water. However, when they come into contact with steam, they produce metal oxide and hydrogen.
- Lead, copper, silver, and gold are metals that do not react with water.
- Calcium starts floating in water because it has hydrogen bubbles sticking to its surface.
- Metal + Water → Metal Hydroxide or Metal oxide + Hydrogen
  - $2Na(s) + 2H_2O(l)$ (cold) $\longrightarrow 2NaOH(aq) + H_2(g)$ + heat
  - $2K(s) + 2H_2O(l) \longrightarrow 2KOH + H_2(g)$ + heat energy
  - $Ca + 2H_2O$ (cold) $\longrightarrow Ca\ (OH)_2(aq) + H_2(g)$
  - $2Al(s) + 3H_2O$ (steam) $\longrightarrow Al_2O_3(s) + 3H_2(g)$
  - $3Fe(s) + 4H_2O$ (steam) $\longrightarrow Fe_3O_4(s) + 4H_2(g)$

Reaction of Metals with Acid:

- When a metal is immersed in acid, it becomes smaller and smaller as the chemical process consumes it. During this moment, gas bubbles can also be detected. Hydrogen gas bubbles are formed as a result of the reaction. Because hydrogen is combustible, this can be demonstrated with a burning splint.

- Metal + dilute acid ⟶ Salt + Hydrogen Gas

- Hydrogen gas is not evolved when a metal reacts with nitric acid. It is because HNO_3 is a strong oxidising agent. It oxidises the H_2 produced to water and itself gets reduced to any of the nitrogen oxides (N_2O, NO, NO_2).
- But magnesium (Mg) and manganese (Mn) react with very dilute HNO_3 to evolve H_2 gas.
- The rate of formation of bubbles is the fastest in the case of magnesium.
- The reactivity decreases in the order Mg > Al > Zn > Fe.
- In the case of copper, no bubbles were seen and the temperature also remained unchanged. This shows that copper does not react with dilute HCl.

Reaction of Metals with solutions of other Metal Salts

- **Metal Displacement Reaction:** A more reactive metal can displace a less reactive metal from its salt solution in a displacement reaction. Metal displacement reaction is a common name for this reaction.
- The reactivity of certain regularly used metals has been ordered in decreasing order. This is referred to as the reactivity or activity series.
  - Metal A + Salt Solution of Metal B ⟶ Salt Solution of Metal A + Metal B

Reaction of Metals with Bases:

- The base has a bitter taste and a slippery texture. A base dissolved in water is called an alkali. When chemically reacting with acids, such compounds produce salts. Bases are known to turn **blue on red litmus paper**.
  - Base + metal ⟶ Salt + Hydrogen

The Reactivity Series:

- The reactivity series is a list of metals arranged in the order of their decreasing activities.
- The reactivity series of metals, also known as the activity series, refers to the arrangement of metals in the descending order of their reactivities. **(Refer Table 9.1)**

Table 9.1: Activity Series: Relative Reactivities of Metals

K	Potassium	Most reactive
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
Al	Aluminium	
Zn	Zinc	Reactivity decreases
Fe	Iron	
Pb	Lead	
[H]	[Hydrogen]	
Cu	Copper	
Hg	Mercury	
Ag	Silver	
Au	Gold	Least Reactive

- Metals such as **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, aluminium, zinc, lead, etc., are covered with a thin layer of oxide.
- The protective oxide layer prevents the metal from further oxidation.
- Iron does not burn on heating but iron filings burn vigorously when sprinkled in the flame of the burner.
- Copper does not burn, but the hot metal is coated with a black coloured layer of copper(II) oxide.
- Silver and gold do not react with oxygen even at high temperatures.

Reaction of Metals and Non-Metals

- Sodium atom has one electron in its outermost shell. If it loses the electron from its M shell then its L shell now becomes the outermost shell and that has a stable octet.
  - The nucleus of this atom still has 11 protons but the number of electrons has become 10, so there is a net positive charge giving us a sodium cation Na^+.
- Chlorine has seven electrons in its outermost shell and it requires one more electron to complete its octet.
- If sodium and chlorine were to react, the electron lost by sodium could be taken up by chlorine. **(Refer Table 9.2)**

Table 9.2: Electronic Configuration of some elements

Type of element	Element	Atomic number	Number of electrons in shells			
			K	L	M	N
Noble gases	Helium (He)	2	2			
	Neon (Ne)	10	2	8		
	Argon (Ar)	18	2	8	8	
Metals	Sodium (Na)	11	2	8	1	
	Magnesium (Mg)	12	2	8	2	
	Aluminium (Al)	13	2	8	3	
	Potassium (K)	19	2	8	8	1
	Calcium (Ca)	20	2	8	8	2
Non-metals	Nitrogen (N)	7	2	5		
	Oxygen (O)	8	2	6		
	Fluorine (F)	9	2	7		
	Phosphorus (P)	15	2	8	5	
	Sulphur (S)	16	2	8	6	
	Chlorine (CI)	17	2	8	7	

- After gaining an electron, the chlorine atom gets a unit negative charge, because its nucleus has 17 protons and there are 18 electrons in its K, L and M shells. This gives us a chloride anion Cl^-. So both these elements can have a give-and-take relation between them.
  - $Na \longrightarrow Na^+ + e^-$

- $Cl + e^- \longrightarrow Cl^-$
- $Na + Cl \longrightarrow NaCl$ (Formation of Sodium Chloride)

 - Sodium and chloride ions, being oppositely charged, attract each other and are held by strong electrostatic forces of attraction to exist as sodium chloride (NaCl).

- It should be noted that sodium chloride does not exist as molecules but aggregates of oppositely charged ions.

Properties of Ionic Compounds

Physical Nature of Ionic Compounds

- **State of Matter and Hardness:** Ionic compounds are solids and are somewhat hard because of the strong force of attraction between the positive and negative ions. These compounds are generally brittle and break into pieces when pressure is applied.
- **Melting and Boiling points:** Ionic compounds have high melting and boiling points. This is because a considerable amount of energy is required to break the strong inter-ionic attraction.
- **Solubility:** Electrovalent compounds are generally soluble in water and insoluble in solvents such as kerosene, petrol, etc.
- **Conduction of Electricity:** The conduction of electricity through a solution involves the movement of charged particles. A solution of an ionic compound in water contains ions, which move to the opposite electrodes when electricity is passed through the solution.

Occurrence of Metals

Most elements, especially metals, occur in nature in a combined state with other elements. All these compounds of metals are known as **minerals**. But out of them, only a few are viable sources of that metal. Such sources are called **ores**.

Extraction of Metals

- **Mining:** The process of extracting metal ores buried deep underground is called Mining. The metal ores are found in the earth's crust in varying abundance.
- The extraction of metals from ores is what allows us to use the minerals in the ground. The ores are very different from the finished metals that we see in buildings and bridges.
- Ores consist of the desired metal compound and the impurities and earthly substances called **Gangue.**
  - Metals of high reactivity – Na, K, Mg, Al.
  - Metals of medium reactivity – Fe, Zn, Pb, Sn.
  - Metals of low reactivity – Cu, Ag, Hg
- **Enrichment of Ores:** It means the **removal of impurities or gangue from ore** through various physical and chemical processes. The technique used for a particular ore depends on the difference in the properties of the ore and the gangue.

Extracting Metals Low in Reactivity Series

- **By self-reduction**- When the sulphide ores of less electropositive metals like Hg, Pb, Cu etc., are heated in air, a part of the ore gets converted to oxide, which then reacts with the remaining sulphide ore to give the crude metal and sulphur dioxide. In this process, no external reducing agent is used.
  - $2HgS$(Cinnabar) + $3O_2(g)$ + heat $\longrightarrow$ $2HgO$(crude metal) + $2SO_2(g)$
  - $2HgO(s)$ + heat $\longrightarrow$ $2Hg(l) + O_2(g)$

- $2Cu_2S$(Copper pyrite) + $3O_2(g)$ + heat ⟶ $2Cu_2O(s) + 2SO_2(g)$
- $2Cu_2O(s) + Cu_2S(s)$ + heat ⟶ 6Cu(crude metal) + $SO_2(g)$

Extracting Metals in the Middle of Reactivity Series

- **Calcination:** Calcination is a process in which ore is heated in the absence of air, or air might be supplied in limited quantities. Roasting involves heating of ore lower than its melting point in the presence of air or oxygen. Calcination involves the thermal decomposition of carbonate ores.
- **Smelting:** It involves heating the roasted or calcined ore (metal oxide) to a high temperature with a suitable reducing agent. The crude metal is obtained in its molten state.
  - Fe_2O_3 + 3C(coke) ⟶ $2Fe + 3CO_2$
- **Aluminothermic Reaction:** It is also known as the **Goldschmidt reaction** and is a highly **exothermic reaction** in which metal oxides, usually of Fe and Cr, are heated to a high temperature with aluminium.
  - $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$ + Heat
  - $Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr$ + Heat

Extraction of Metals Towards the Top of the Reactivity Series

- The metals high up in the reactivity series are very reactive. They cannot be obtained from their compounds by heating with carbon. For example, carbon cannot reduce the oxides of sodium, magnesium, calcium, aluminium, etc., to the respective metals.
- This is because these metals have more affinity for oxygen than carbon. These metals are obtained by **electrolytic reduction**. For example, sodium, magnesium and calcium are obtained by the electrolysis of their molten chlorides.
- The metals are deposited at the cathode (the negatively charged electrode), whereas chlorine is liberated at the anode (the positively charged electrode).
- The reactions are:
  - At cathode $Na^+ + e^- \longrightarrow Na$
  - At anode $2Cl^- \longrightarrow Cl_2 + 2e^-$
- Similarly, aluminium is obtained by the electrolytic reduction of aluminium oxide.

Refining of Metals

- It is the process of removing impurities or gangue from crude metal. It is the last step in metallurgy and is based on the difference between the properties of metal and gangue.
- **Electrolytic Refining:**
  - Metals like copper, zinc, nickel, silver, tin, gold etc., are refined electrolytically.
    - **Anode:** Impure or crude metal
    - **Cathode:** A thin strip of pure metal
  - **Electrolyte:** It is the aqueous solution of metal salt
    - **From anode (oxidation):** Metal ions are released into the solution from anode.
    - **At cathode (reduction):** The equivalent amount of metal from the solution is deposited at the cathode.
  - Impurities deposit at the bottom of the anode.

Corrosion

- Gradual deterioration of a material, usually a metal, by the action of moisture, air or chemicals in the surrounding environment. **(Refer to Figure 9.4)**

Rusting:

- During the corrosion of iron, iron metal is oxidised by the oxygen of air in the presence of water (moisture) to form hydrated iron (III) oxide called rust.

  $4Fe(s) + 3O_2$ (from air) $+ xH_2O$ (moisture) $\longrightarrow 2Fe_2O_3 . xH_2O$(rust)

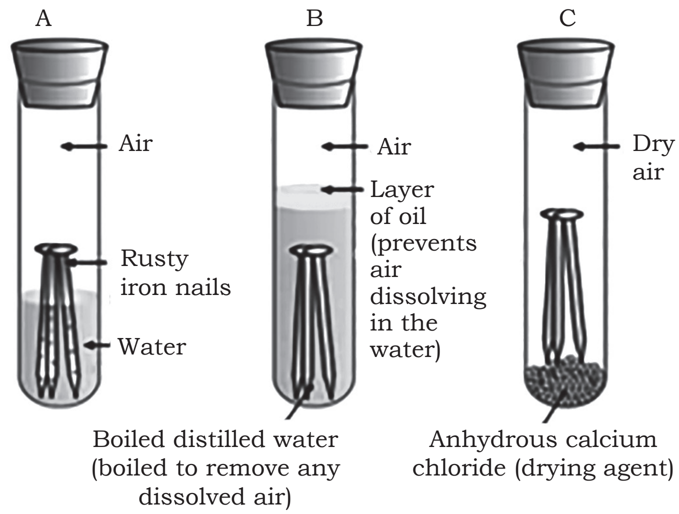


Figure 9.4 Investigating the conditions under which iron rusts. In tube A, both air and water are present. In tube B, there is no air dissolved in the water. In tube C, the air is dry.

Corrosion of Copper

- Copper metal when exposed to air turns green in colour due to corrosion. When a copper vessel is exposed to air in the rainy season, the metal reacts with gases and moisture and atmospheric gases to form a mixture of copper carbonate and copper hydroxide. This gives a green colour to the surface of copper metal.

$$Cu(s) + H_2O \text{ (moisture)} + CO_2 \text{ (from air)} \longrightarrow CuCO_3.Cu(OH)_2 \text{ (green)}$$

Corrosion of Silver

- When placed in air the Silver object turns black. This is due to the presence of Hydrogen sulphide in the air, the Silver object reacts with the Hydrogen sulphide present in the air. This whole process is actually known as corrosion which is basically the degradation or the destruction of the article when present in the excess moisture and air. In the case of Silver element, corrosion is known as Silver tarnishing. And so after this corrosion, the black substance formed is known as Silver sulphide.

$$Ag(s) + H_2S\text{(from air)} \longrightarrow Ag_2S\text{(black)} + H_2(g)$$

Prevention of Corrosion

- **Coating with paints or oil or grease:** The application of paint or oil or grease on metal surfaces keeps out air and moisture.
- **Alloying:** Alloyed metal is more resistant to corrosion. Example: stainless steel.
- **Galvanization:** This is a process of coating molten zinc on iron articles. Zinc forms a protective layer and prevents corrosion.
- **Electroplating:** It is a method of coating one metal with another by the use of an electric current. This method not only lends protection but also enhances the metallic appearance. Examples: silver plating, and nickel plating.

> The iron pillar near the Qutub Minar in Delhi was built more than 1600 years ago by the iron workers of India. They had developed a process which prevented iron from rusting. For its quality of rust resistance, it has been examined by scientists from all parts of the world. The iron pillar is 8 m high and weighs 6 tonnes (6000 kg).

- **Sacrificial Protection:** Magnesium is more reactive than iron. When it is coated on articles made of iron or steel, it acts as the cathode undergoes a reaction (sacrifice) instead of iron and protects the articles.

Properties of Non-Metals

Non-metals are those elements which do not exhibit the properties of metals.

Physical Properties of Nonmetals	Exceptions in Physical Properties
• They occur as solids, liquids and gases at room temperature.	• Alkali metals (Na, K, Li) can be cut using a knife.
• Brittle	• Mercury is a liquid metal.
• Non-malleable	• Lead and Mercury are poor conductors of heat.
• Non-ductile	• Mercury expands significantly for the slightest change in temperature.
• Non-sonorous	• Gallium and Caesium have very low melting points.
• Bad conductors of heat and electricity.	• Iodine is non-metal, but it has lustre.
• Most non-metals produce acidic oxides when dissolved in water. On the other hand, most metals give rise to basic oxides.	• Graphite conducts electricity. • Diamond conducts heat and has a very high melting point.

Carbon and Its Compounds

- Food, clothes, medicines, books, or many other things are all based on this versatile element carbon. In addition, all living structures are carbon based. Carbon is available in nature, the importance of carbon seems to be immense.
- Carbon is a chemical element with the atomic number 6 and the symbol C.

Bonding: The Covalent Bond

- Forces of attraction between the molecules are not very strong.
- Carbon compounds are largely non-conductors of electricity, it can be concluded that the bonding in the carbon compounds does not give rise to any ions.
- To achieve the electronic configuration of the nearest noble gas, "He", Carbon has to loose four of its valence electrons, which involves a huge amount of energy.
- C^{4+} ions, hence formed, will be highly unstable due to the presence of six protons and two electrons.
- If the carbon atom gains four electrons to achieve the nearest electronic configuration of the noble gas, Ne, C^{4-} ions will be formed.
- But again, a huge amount of energy is required. Moreover, in C^{4+} ions it is difficult for 6 protons to hold 10 electrons. Hence, to satisfy its tetravalency, carbon shares all four of its valence electrons and forms covalent bonds.
- The simplest molecule formed in this manner is that of hydrogen. As you have learnt earlier, the atomic number of hydrogen is 1. Hence hydrogen has one

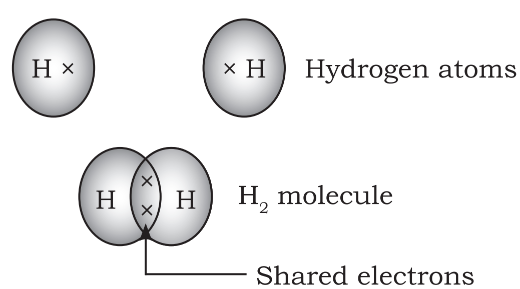


Figure 9.5: (a) A Molecule of Hydrogen

electron in its K shell and it requires one more electron to fill the K shell. So two hydrogen atoms share their electrons to form a molecule of hydrogen, H_2. This allows each hydrogen atom to attain the electronic configuration of the nearest noble gas, helium, which has two electrons in its K shell. We can depict this using dots or crosses to represent valence electrons

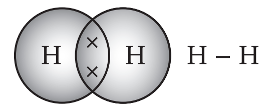


Figure 9.5: (b) Single bond between two hydrogen atoms.

- The shared pair of electrons is said to constitute a single covalent bond between the two hydrogen atoms. A single covalent bond is also represented by a line between the two atoms, **(Refer to Figure 9.5 (a) and (b).**
- In the case of oxygen, we see the formation of a double bond between two oxygen atoms.
- This is because an atom of oxygen has six electrons in its L shell (the atomic number of oxygen is eight) and it requires two more electrons to complete its octet.
- So each atom of oxygen shares two electrons with another atom of oxygen to give us the structure shown in **Figure 9.6**.
- The two electrons contributed by each oxygen atom give rise to two shared pairs of electrons. This is said to constitute a double bond between the two atoms.
- Each nitrogen atom has five electrons in the valence shell (2,5). It requires three electrons to acquire the nearest noble gas configuration (Ne). **(Figure 9.7)**
- Therefore, both atoms share three electrons each and form a triple bond.

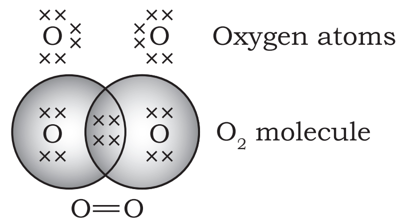


Figure 9.6: Double Bond between two Oxygen atoms

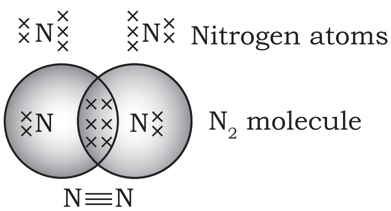


Figure 9.7: Triple bond between two Nitrogen atoms

Allotropes of Carbon

- The phenomenon of the existence of the same element in different physical forms with similar chemical properties is known as allotropy.
- Some elements like carbon, sulphur, phosphorus, etc., exhibit this phenomenon.
- Crystalline allotropes of carbon include diamond, graphite and fullerene.
- Amorphous allotropes of carbon include coal, coke, charcoal, lamp black and gas carbon.
- **Diamond:** Diamond has a regular tetrahedral geometry. This is because each carbon is connected to four neighbouring carbon atoms via single covalent bonds, resulting in a single unit of a crystal.
  - These crystal units lie in different planes and are connected to each other, resulting in a rigid three-dimensional cubic pattern of the diamond. **(Refer to Figure 9.8(a))**
  - Is a good conductor of heat but a poor conductor of electricity.
- **Graphite:** Graphite has a soft and slippery feel and it is a good conductor of electricity. **(Refer to Figure 9.8(b))**
- **C60:** C60, also known as *Buckminsterfullerene*, is the very popular and stable form of the known fullerenes. **(Refer to Figure 9.8(c))**

POINTS TO PONDER

Diamond and Graphite both are allotropes of carbon. Think about why graphite is a good conductor of electricity while diamond is not. Also why tetrahedral structure of carbon makes it so strong while hexagonal layered structure of graphite makes it relatively weak.

✧ It is the most common naturally occurring fullerene and can be found in small quantities in soot.

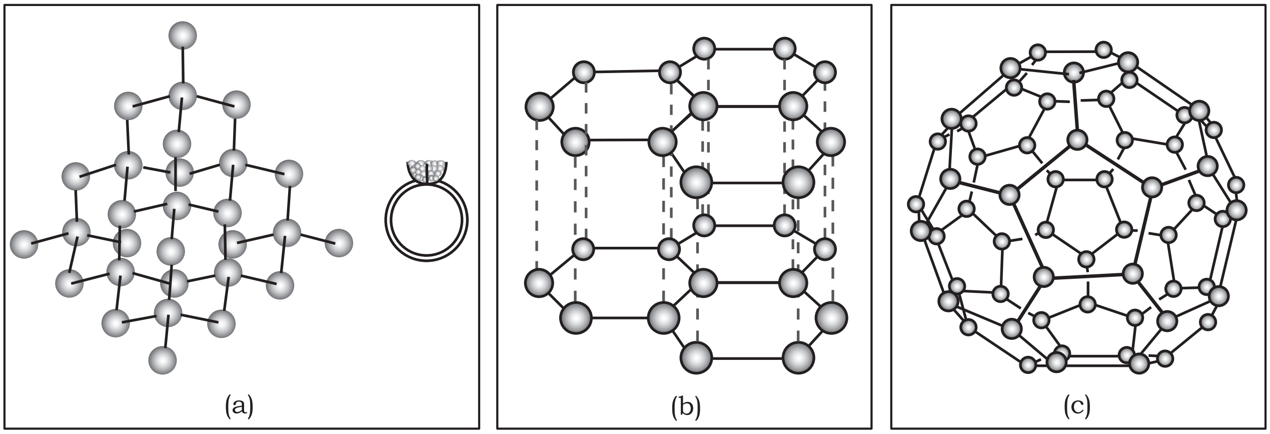


Figure 9.8: (a) Diamond, (b) Graphite, (c) C60

✧ It consists of 60 carbon atoms arranged in 12 pentagons and 20 hexagons, like in a soccer ball.

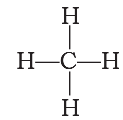
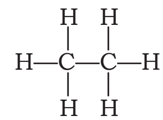
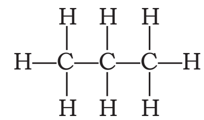
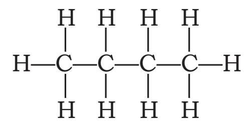
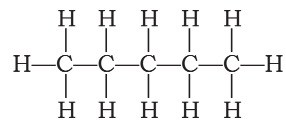
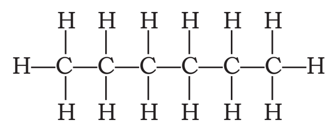
Versatile Nature of Carbon

- **Tetravalency and Catenation:** The fact that carbon can form single, double, and triple bonds demonstrate its versatility. It can also form chains, branching chains, and rings when joined to other carbon atoms.
- It's a versatile element that can be found in a wide variety of chemical combinations. Carbon's versatility is best appreciated through properties like tetravalency and catenation.
  - **Tetravalency:** Carbon has a valency of four, so it is capable of bonding with four other atoms of carbon or atoms of some other mono-valent element.
  - **Catenation:** The property of a carbon element due to which its atom can join one another to form long carbon chains is called catenation.
    - **S8:** In its native state, sulphur shows catenation of up to 8 atoms in the form of S8 molecule. It has a puckered ring structure.

Saturated and Unsaturated Carbon Compounds

- The compound formed between carbon and hydrogen is ethane with a formula of C_2H_6. In order to arrive at the structure of simple carbon compounds, the first step is to link the carbon atoms together with a single bond C—C.
- Using the hydrogen atoms to satisfy the remaining valencies of carbon is the next step.
- **Chains, Branches and Rings:** In the earlier section, we have seen the carbon compounds methane, ethane and propane, containing respectively 1, 2 and 3 carbon atoms.
- Such 'chains' of carbon atoms can contain many more carbon atoms.
- The names and structures of six of these are given in **Table 9.3.**

Table 9.3: Formulae and structures of saturated compounds of carbon and hydrogen

No. of C atoms	Name	Formula	Structure
1.	Methane	CH_4	
2.	Ethane	C_2H_6	
3.	Propane	C_3H_8	
4.	Butane	C_4H_{10}	
5.	Pentane	C_5H_{12}	
6.	Hexane	C_6H_{14}	

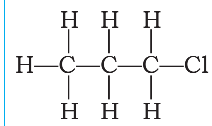
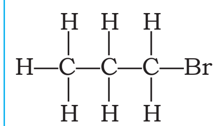
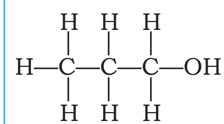
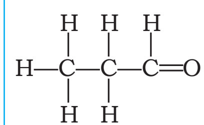
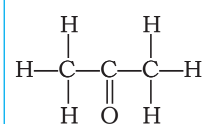
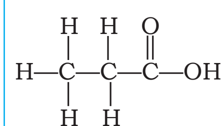
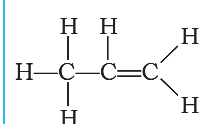
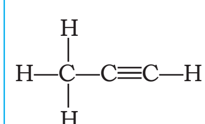
Main Functional Groups in Carbon Compounds

- **Hydroxyl Group (–OH):** All organic compounds containing –OH group are known as **alcohols**. For example, Methanol (CH_3OH), Ethanol ($CH_3–CH_2–OH$), etc.
- **Aldehyde Group (–CHO):** All organic compounds containing –CHO group are known as **aldehydes**. For example, Methanal (HCHO), Ethanal (CH_3CHO), etc.
- **Ketone Group (–C=O):** All organic compounds containing (–C=O) groups flanked by two alkyl groups are known as **ketones**. For example, Propanone (CH_3COCH_3), Butanone ($CH_3COCH_2CH_3$), etc.
- **Carboxyl Group (–COOH):** All organic acids contain a carboxyl group (–COOH). Hence, they are also called **carboxylic acids**. For example, Ethanoic acid (CH_3COOH), Propanoic acid (CH_3CH_2COOH), etc.
- **Halogen Group (F, CI, Br, I):** The alkanes in which one or more than one hydrogen atom is substituted by- X (F, Cl, Br or I) are known as **haloalkanes**. For example, Chloromethane (CH_3Cl), Bromomethane (CH_3Br), etc.

Nomenclature of Carbon Compounds

- The International Union of Pure and Applied Chemistry (IUPAC) decided on some rules for naming carbon compounds. This was done to maintain uniformity throughout the world. **(Table 9.4)**

Table 9.4: Nomenclature of Organic Compound

Class of compounds	Prefix/Suffix	Example
1. Halo alkane	Prefix-chloro, bromo, etc.	 Chloropropane
		 Bromopropane
2. Alcohol	Suffix - ol	 Propanol
3. Aldehyde	Suffix - al	 Propanol
4. Ketone	Suffix - one	 Propanone
5. Carboxylic acid	Suffix - oic acid	 Propanoic acid
6. Alkenes	Suffix - ene	 Propene
7. Alkynes	Suffix - yne	 Propyne

Homologous Series

- Homologous series constitutes organic compounds with the same general formula, and similar chemical characteristics but different physical properties. The adjacent members differ in their molecular formula by $-CH_2$. Eg: Methane, ethane, propane, butane, etc. are all part of the alkane homologous series.
  - The general formula of this series is C_nH_{2n+2}.
  - Methane (CH_4), Ethane (CH_3CH_3), Propane ($CH_3CH_2CH_3$), Butane ($CH_3CH_2CH_2CH_3$).
- It can be noticed that there is a difference of $-CH_2$ units between each successive compound.

Formation of coal and petroleum

- Coal and petroleum have been formed from biomass which has been subjected to various biological and geological processes. Coal is the remains of trees, ferns, and other plants that lived millions of years ago.
- These were crushed into the earth, perhaps by earthquakes or volcanic eruptions. They were pressed down by layers of earth and rock. They slowly decayed into coal.
- Oil and gas are the remains of millions of tiny plants and animals that lived in the sea. When they died, their bodies sank to the sea bed and were covered by silt Bacteria attacked the dead remains, turning them into oil and gas under the high pressures they were being subjected to.
- Meanwhile, the silt was slowly compressed into rock. The oil and gas seeped into the porous parts of the rock, and got trapped like water in a sponge.

Chemical Properties of Carbon Compounds

- **Combustion Reactions:** Combustion means the burning of carbon or carbon-containing compounds in the presence of air or oxygen to produce carbon dioxide, heat and light.
  - $2CH_3OH + 3O_2 \rightarrow 4H_2O + 2CO_2$
- Saturated hydrocarbons give a clean flame, while unsaturated hydrocarbons give a smoky flame. In the presence of limited oxygen, even saturated hydrocarbons give smoky flame.
- **Soot:** It is a black substance formed by combustion or separated from fuel during combustion, rising in fine particles and adhering to the sides of the chimney or pipe conveying the smoke especially, i.e., the fine powder consisting chiefly of carbon that colours smoke.

Why do substances burn with or without a flame?

This is because a flame is only produced when gaseous substances burn. When wood or charcoal is ignited, the volatile substances present evaporate and burn with a flame in the beginning.

A luminous flame is seen when the atoms of the gaseous substance are heated and start to glow. The color produced by each element is a characteristic property of that element.

- **Oxidation:** Oxidation is a chemical reaction that occurs in an atom or compound and results in the loss of one or more electrons. (**Refer to Figure 9.9**)

$$CH_3—CH_2OH \xrightarrow[\text{Or acidified } K_2Cr_2O_7 \text{ + Heat}]{\text{Alkaline } KMnO_4 \text{ + Heat}} CH_3COOH$$

Figure 9.9: Oxidation

- **Addition:** The reactions in which two molecules react to form a single product having all the atoms of the combining molecules are called addition reactions.
  - The hydrogenation reaction is an example of the addition reaction. In this reaction, hydrogen is added to a double bond or a triple bond in the presence of a catalyst like nickel, palladium or platinum. (**Refer to Figure 9.10**)

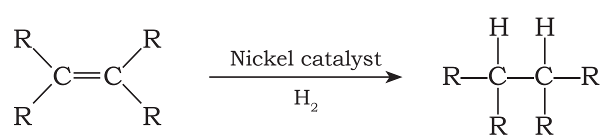


Figure 9.10: Addition

- **Substitution:** The reaction in which an atom or group of atoms in a molecule is replaced or substituted by different atoms or groups of atoms is called a substitution reaction. In alkanes, hydrogen atoms are replaced by other elements. (**Refer to Figure 9.11**)

$$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl \text{ (in the presence of sunlight)}$$

Figure 9.11: Substitution

Ethanol and Ethanoic Acid

- **Ethanol:** Ethanol or C_2H_5OH is a colourless liquid having a pleasant smell.
- It boils at 351 K.

How do alcohols affect living beings?

- When large quantities of ethanol are consumed, it tends to slow metabolic processes and to depress the central nervous system. This results in lack of coordination, mental confusion, drowsiness, lowering of the normal inhibitions, and finally stupor.
- The individual may feel relaxed without realizing that his sense of judgment, sense of timing, and muscular coordination have been seriously impaired.
- Unlike ethanol, intake of methanol in very small quantities can cause death. Methanol is oxidized to methanal in the liver.
- Methanal reacts rapidly with the components of cells. It coagulates the protoplasm, in much the same way an egg is coagulated by cooking.
- Methanol also affects the optic nerve, causing blindness. Ethanol is an important industrial solvent.
- To prevent the misuse of ethanol produced for industrial use, it is made unfit for drinking by adding poisonous substances like methanol to it.
- Dyes are also added to color the alcohol blue so that it can be identified easily. This is called denatured alcohol.

Alcohol as a fuel

- Sugarcane plants are one of the most efficient convertors of sunlight into chemical energy. Sugarcane juice can be used to prepare molasses which is fermented to give alcohol (ethanol).

- It is miscible with water in all proportions.
- It is a nonconductor of electricity (it does not contain ions)
- It is neutral to litmus.
- **Uses:** Ethanol is used as an antifreeze in radiators of vehicles in cold countries.
  - It is also used as a solvent in the manufacture of paints, dyes, medicines, soaps and synthetic rubber. It is also used as a solvent to prepare the tincture of iodine.
- **Reactions of Ethanol with Sodium:** Ethanol reacts with sodium to produce hydrogen gas and sodium ethoxide. This reaction supports the acidic character of ethanol.

$$2C_2H_5OH + 2Na \longrightarrow 2C_2H_5ONa + H_2(\uparrow)$$

- **Reactions to give Unsaturated Hydrocarbon (Dehydration of Ethanol):** Ethanol reacts with concentrated sulphuric acid at 443 K to produce **ethylene**. This reaction is known as dehydration of ethanol because, in this reaction, a water molecule is removed from the ethanol molecule.

$$CH_3CH_2OH \longrightarrow CH_2 = CH_2 + H_2O$$

- **Ethanoic Acid:** With molecular formula given as CH_3COOH, it dissolves in water, alcohol and ether.
  - It often freezes during winter in a cold climate, and therefore, it is named glacial acetic acid.

Reactions of Ethanoic Acid

- **Esterification:** When a carboxylic acid is refluxed with alcohol in the presence of a small quantity of concentrated H_2SO_4, a sweet-smelling ester is formed. This reaction of ester formation is called esterification.
- **Saponification:** On treatment with sodium hydroxide, which is an alkali, the ester is converted back to alcohol and sodium salt of carboxylic acid. This reaction is known as saponification

because it is used in the preparation of soap. Soaps are sodium or potassium salts of long chain carboxylic acid. **(Refer Figure 9.12)**

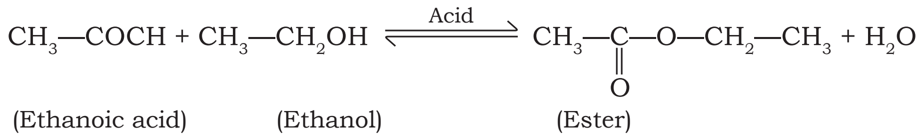


Figure 9.12: Esterification

- **Reaction with a Base:** Like mineral acids, ethanoic acid reacts with a base such as sodium hydroxide to give a salt (sodium ethanoate or commonly called sodium acetate) and water:

$$NaOH + CH_3COOH \longrightarrow CH_3COONa + H_2O$$

- **Reaction with Carbonates and Hydrogen Carbonates:** Ethanoic acid reacts with carbonates and hydrogen carbonates to give rise to salt, carbon dioxide and water. The salt produced is commonly called **sodium acetate.**

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + H_2O + CO_2$$
$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

- **Soaps and Detergents:** Most dirt is oily in nature and oil does not dissolve in water. The molecules of soap are sodium or potassium salts of long-chain carboxylic acids. The ionic-end of soap interacts with water while the carbon chain interacts with oil.
  - The soap molecules, thus form structures called **micelles (Refer Figure 9.13)** where one end of the molecules is towards the oil droplet while the ionic-end faces outside.
  - This forms an emulsion in water. The soap micelle thus helps in pulling out the dirt in water and we can wash our clothes clean

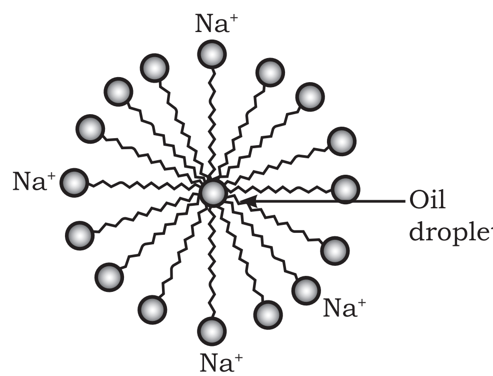


Figure 9.13: Formation of Micelles

  - Soaps are molecules in which the two ends have differing properties, one is hydrophilic, that is, it interacts with water, while the other end is hydrophobic, that is, it interacts with hydrocarbons. When soap is at the surface of water, the hydrophobic 'tail' of soap will not be soluble in water and the soap will align along the surface of water with the ionic end in water and the hydrocarbon 'tail' protruding out of water.
  - Inside water, these molecules have a unique orientation that keeps the hydrocarbon portion out of the water. Thus, clusters of molecules in which the hydrophobic tails are in the interior of the cluster and the ionic ends are on the surface of the cluster.
  - This formation is called a **micelle**. Soap in the form of a micelle is able to clean, since the oily dirt will be collected in the centre of the micelle. The micelles stay in solution as a colloid and will not come together to precipitate because of ion-ion repulsion.
  - Thus, the dirt suspended in the micelles is also easily rinsed away. The soap micelles are large enough to scatter light. Hence a soap solution appears cloudy.

POINTS TO PONDER

Soaps and detergent when added to water make bubbles and help in cleansing. Think about how this mechanism occurs and what is surface tension ?

Conclusion

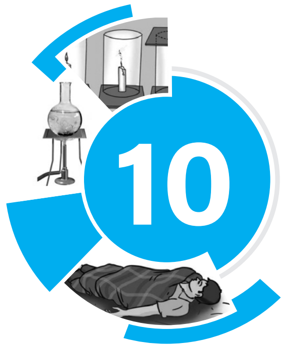
From the above notes, we can conclude that elements can be classified as metals and non-metals. They are solids at room temperature, except mercury which is a liquid. Different metals have different reactivities with water and dilute acids. An alloy is a homogeneous mixture of two or more metals, or a metal and a nonmetal. Non-metals form negatively charged ions by gaining electrons when reacting with metals. Non-metals form oxides which are either acidic or neutral. Non-metals do not displace hydrogen from dilute acids. They react with hydrogen to form hydrides.

Carbon is a versatile element that forms the basis for all living organisms and many of the things we use. Carbon forms covalent bonds with itself and other elements such as hydrogen, oxygen, sulphur, nitrogen and chlorine. Carbon and its compounds are some of our major sources of fuels. Ethanol and ethanoic acid are carbon compounds of importance in our daily lives. The action of soaps and detergents is based on the presence of both hydrophobic and hydrophilic groups in the molecule and this helps to emulsify the oily dirt and hence its removal.

Glossary:

- **Anodising:** Anodising is a process of forming a thick oxide layer of aluminium. During anodising, a clean aluminium article is made the anode and is electrolysed with dilute sulphuric acid. The oxygen gas evolved at the anode reacts with aluminium to make a thicker protective oxide layer. This oxide layer can be dyed easily to give aluminium articles an attractive finish.
- **Aqua Regia:** (Latin for 'royal water') 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.
- **Mineral:** Solid homogeneous inorganic substances occurring in nature having a definite chemical composition.
- **Ore:** A mineral that contains metal that is valuable enough to be mined.
- **Gangue:** Worthless mineral or earthy substance associated with metallic ore.
- **Pure gold:** Also known as 24 carat gold, is very soft therefore, not suitable for making jewellery. 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 is alloyed with 2 parts of either copper or silver.
- **Organic Compounds:** Any of a large class of chemical compounds in which one or more atoms of carbon are covalently bonded to atoms of other elements, most commonly hydrogen, oxygen, or nitrogen.

❐❐❐



Energy

Bibliography: The chapter encompasses the summary of **Chapter 3 - VII** NCERT (Science) and **Chapters 3- and 4 - VIII** NCERT (Science).

Introduction

Understanding the principles and dynamics of energy is fundamental to various aspects of daily life, technological advancements, and environmental consciousness. Energy sources are the life-blood of modern civilization, powering our homes, industries, and transportation systems. This comprehensive overview, spanning coal and petroleum, limited natural resources, combustion, and flame, to the intricacies of heat transfer and the science behind our clothing choices, provides a detailed insight into the multifaceted realm of energy.

Heat and Its Perception

Our clothing preferences, such as woollen garments during winter and cotton ones in summer, are influenced by how these fabrics interact with varying temperatures, keeping us comfortable.

Everyday Temperature Variations:

- Objects around us possess different temperatures, some feeling warm, others cold.
- **The Reliability of Touch:** Identification of temperature solely by touch can be deceptive. An experiment involving the immersion of hands in hot and cold water and then in lukewarm water illustrates this. Our sense of touch is not always an accurate indicator of an object's temperature. **(Refer to Figure 10.1)**

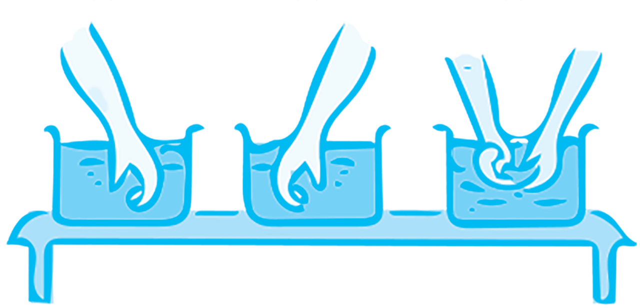


Figure 10.1: Feeling water in three containers

The Science of Measuring Temperature

Laboratory Thermometer

- **Introduction to Thermometers:** A thermometer is a pivotal tool for measuring temperature.
- A laboratory thermometer is an instrument used to measure the temperature of various objects, differing from the clinical thermometer, which is used specifically for measuring human body temperature.
- **Features and Range:** The laboratory thermometer typically has a range from –10°C to 110°C. Understanding how much a small division on this thermometer represents for accurate readings is essential.

- **Usage:** To measure the temperature using a laboratory thermometer, immerse its bulb in the substance (e.g., water) ensuring it doesn't touch the container's sides or bottom. **(Refer to Figure 10.2)**
  - Hold the thermometer vertically and wait for the mercury level to stabilise.
  - Read the temperature while the thermometer is still immersed. The reason is that the mercury level starts to change once removed from the substance.
  - This characteristic makes the laboratory thermometer inconvenient for measuring body temperature since, unlike the clinical thermometer, you can't read it once removed from the source.

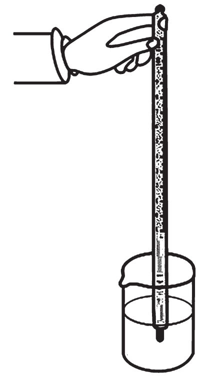


Figure 10.2: Measuring temperature of water with a laboratory thermometer

- **Comparison with Clinical Thermometer:** Clinical thermometers have a unique feature – a kink near the bulb. **(Refer to Figure 10.3)** This kink prevents the mercury level from falling on its own, allowing the temperature to be read even after removing it from the mouth.
  - This is why clinical thermometers are more suitable for measuring body temperature, whereas laboratory thermometers are not.

Figure 10.3: A clinical thermometer has a kink in it

- **Environmental Concerns:** Given the environmental hazards associated with mercury, which is toxic and challenging to dispose of, there are concerns about its use in thermometers.
  - Consequently, digital thermometers that don't use mercury are becoming increasingly popular.

Clinical Thermometer

- The clinical thermometer is designed specifically to gauge body temperature.
- **Structure and Reading:** This thermometer comprises a glass tube with a mercury-filled bulb at one end. **(Refer to Figure 10.4)**

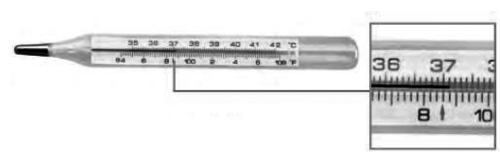


Figure 10.4: A clinical thermometer

- The readings are taken on the Celsius scale (°C). Its measurement range is restricted between 35°C and 42°C, corresponding to the typical human body temperature spectrum.
- **Procedure to Measure Body Temperature:** To ascertain body temperature, place the thermometer's bulb under the tongue for a minute and then observe the mercury level. **(Refer to Figure 10.5)**
  - The average body temperature hovers around 37°C. However, individual temperatures might have minor deviations.

Figure 10.5: Correct method of reading a clinical thermometer

- **Usage Limitations:** A clinical thermometer's design is specialised for human body temperature measurements. Using it for other purposes, like gauging the temperature of boiling liquids, is inadvisable.
  - Additionally, to prevent damage, avoid exposing the thermometer to excessive heat or direct sunlight.

Transfer of Heat

Heat Flow

- Objects when heated, transfer heat from a hotter region to a colder one. For example, a frying pan becomes hot when exposed to a flame, heat is transferred from the flame to the pan. When removed, the pan cools as it transfers heat to the cooler surroundings.
- In essence, heat transfer occurs through three primary modes: Conduction (through solids), convection (through fluids), and radiation (through a vacuum or medium). The nature of the material and its environment determines which method dominates.
- **Conduction:** Heat can flow through an object by conduction, where heat is transferred from a hotter part to a cooler part. A metal rod, when heated at one end, will eventually have its other end heated, showcasing conduction.
  - Not all substances conduct heat equally. Materials like aluminium, iron, and copper are good heat conductors, while plastics and wood are poor conductors, known as insulators. **(Refer to Figure 10.6 and 10.7)**

Figure 10.6: Flow of heat through a metal strip

Figure 10.7: Conduction of heat by different materials Figure

- **Convection:** Fluids, like water and air, transfer heat mainly through convection. When a fluid is heated, the portion near the heat source becomes less dense and rises, and the cooler, denser portion descends. This circulation transfers heat throughout the fluid. **(Refer to Figure 10.8 and 10.9)**

Figure 10.8: Convection of heat in water

Figure 10.9: Transfer of heat by convection in air

- In coastal areas, sea breezes (during the day) and land breezes (at night) are examples of convection in the air, caused by temperature differences between the land and the sea.
- The air from the sea is called the **sea breeze**. At night it is exactly the reverse. The water cools down more slowly than the land. So, the cool air from the land moves towards the sea. This is called the **land breeze. (Refer to Figure 10.10)**

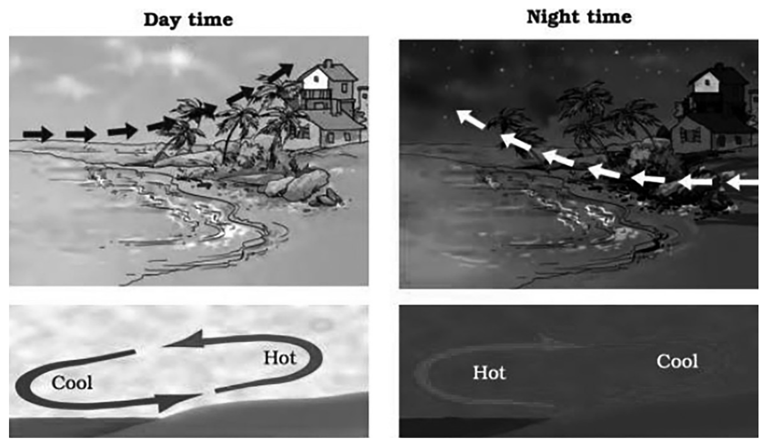


Figure 10.10: Sea breeze and Land breeze

- **Radiation:** The Sun's heat reaches Earth via radiation. Unlike conduction and convection, radiation doesn't require a medium; it can happen in a vacuum. All hot bodies emit radiation.
  - Upon receiving heat radiation, objects can reflect, absorb, or transmit it. The absorbed heat raises the object's temperature. Using umbrellas in the sun, for instance, is an example of protection against heat radiation.

Temperatures in Summer and Winter

Our clothing choices for different seasons are influenced by the heat absorption and reflection properties of colours and materials. Proper insulation, either through clothing or building materials, ensures comfort by regulating heat transfer.

Colour and Heat Absorption

- In summer, we generally prefer wearing light-coloured clothes, while in winter, we lean towards dark-coloured ones.
- To understand why, an experiment with two identical tin cans painted in contrasting colours (one black and the other white) is conducted. **(Refer to Figure 10.11)**

Figure 10.11: Containers with black and white surface

- When filled with water and exposed to the sun, the container painted black heats up faster. This illustrates that dark surfaces absorb more heat, making dark clothes preferable in winter to keep us warm.
- Conversely, light-coloured clothes reflect most heat, making them more comfortable for summer.

Warmth of Wool

- During winter, woollen clothes are preferred as they offer warmth. Wool, being a poor conductor of heat, and having trapped air between its fibres, provides insulation.
- This prevents the loss of body heat to the cold environment.

Blanket Choice

- When given an option between a single thick blanket or two thin blankets joined together during winter, the latter is preferable.
- The reason lies in the trapped layer of air between the two blankets, which provides added insulation.

Building Insulation

- Optimising heat in homes can be achieved through design choices, such as constructing outer walls that trap layers of air.
- One such method involves using hollow bricks, which prevent excessive heating or cooling inside the building.

Coal and Petroleum

Materials used for basic needs come from nature or are made by human efforts. Air, water, soil, and minerals are natural resources. Natural resources are classified into the following two groups:

- **Inexhaustible Natural Resources:** These are unlimited in nature, and not to be exhausted by human activities. Their examples include sunlight, air, etc.
- **Exhaustible Natural Resources:** These are limited in nature and can be exhausted by human activities. Forests, wildlife, minerals, coal, petroleum, natural gas, etc. are examples.

Fossil Fuels: Consumption of Limited Resources

- Containers filled with eatables represent exhaustible natural resources.
- Different generations consume these resources differently.
- Some generations may leave resources for future generations.
- The concept underscores the limited availability of certain resources.
- Exhaustible natural resources like coal, petroleum, and natural gas are formed from dead remains of living organisms and are termed fossil fuels.

Coal

Coal is hard, stone-like, black in colour. Used for cooking, in railway engines, in thermal power plants, and various industries. **(Refer to Figure 10.12)**

Figure 10.12: Coal

- **Formation:**
  - About 300 million years ago, the earth had dense forests in low-lying wetland areas. Forests got buried under the soil due to natural processes.
  - **Carbonisation:** Over time, with increased pressure and temperature, dead plants are converted to coal. This process of conversion is called carbonization.
  - Since it was formed from vegetation remains, coal is a fossil fuel. **(Refer to Figure 10.13)**

Figure 10.13: A Coal Mine

- **Combustion of Coal:** When coal is heated in air, it produces mainly carbon dioxide gas.
- **Products from Coal:**
  - **Coke:** It is a tough, porous, black substance, considered an almost pure form of carbon. It is used in steel manufacture and metal extraction.
  - **Coal Tar:** It is a black, thick liquid with an unpleasant smell. **(Refer to Figure 10.14)**

Figure 10.14: Coal tar

    - It comprises a mixture of around 200 substances.
    - Coal tar is used for **synthetic dyes**, **drugs**, **explosives**, **perfumes**, **plastics**, **paints**, **photographic materials**, and **roofing materials**.
    - **Naphthalene balls**, which repel moths and other insects, are derived from coal tar.
    - **Bitumen**, which is a petroleum product, is now used for road metalling instead of coal tar.
  - **Coal Gas:** Coal gas is obtained during processing of coal to get coke. It is used as a fuel in industries near coal processing plants. Historically it was used for street lighting, now more for heating.

POINTS TO PONDER
Coal, natural gas, petroleum all are derived from fossils yet have different properties. Think about differences in their formation process that give these distinct types of energy sources from the same fossils.

Petroleum and Natural Gas:

- **Petroleum:**
  - The term "petroleum" originates from "petra" (rock) and "oleum" (oil), highlighting its extraction from beneath the Earth's rocks. **(Refer to Figure 10.15)**

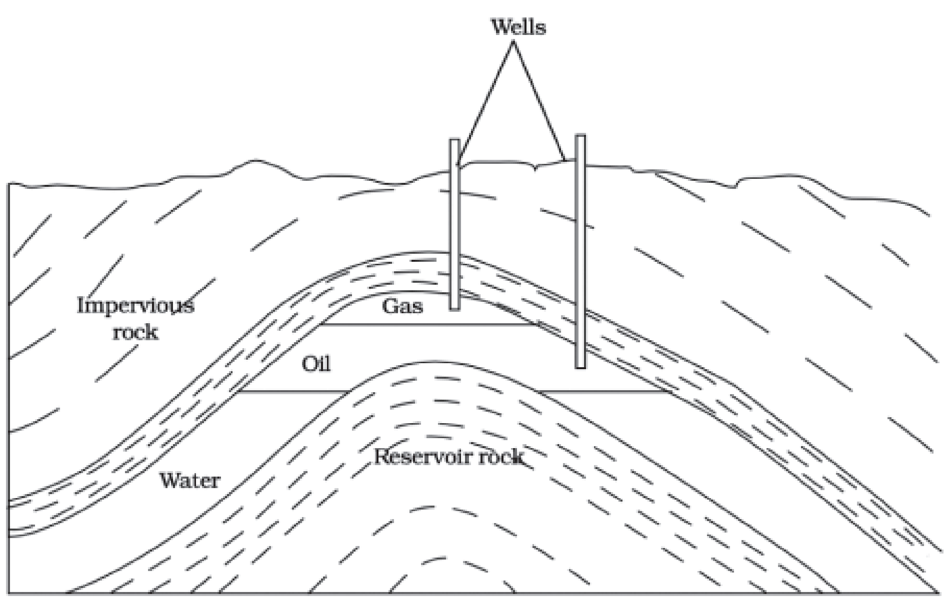


Figure 10.15: Petroleum and natural gas deposits

  - Light automobiles such as motorcycles, scooters, and cars use petrol as fuel. Heavy motor vehicles like trucks and tractors are powered by diesel.

- **Formation:**
  - Petroleum originates from organisms that once lived in the sea. Over millions of years, these dead organisms transformed into petroleum and natural gas due to high temperature, high pressure, and absence of air.
  - Since oil and gas are lighter than water, their layer is situated above water.
- **Discovery and Location:** The world's first oil well was drilled in Pennsylvania, USA, in 1859.
  - In India, oil was first discovered in **Assam (Makum) in 1867**. Other locations include Gujarat, Mumbai High, and the river basins of Godavari and Krishna.
- **Refining:** Petroleum, characterised by its dark and oily appearance, possesses an unpleasant odour. It comprises various constituents including petroleum gas, petrol, diesel, lubricating oil, and paraffin wax. Refining involves the process of separating these constituents. **(Refer to Figure 10.16)**
- **Products and Petrochemicals:** The substances derived from petroleum and natural gas are termed as 'Petrochemicals'.
  - They are instrumental in producing detergents, fibres such as polyester, nylon, and acrylic, as well as polythene and plastics.
  - Hydrogen gas, sourced from natural gas, is pivotal in the production of fertilisers like urea.
  - **Black Gold:** Due to its significant commercial value, petroleum is often dubbed 'black gold'.
  - **Various Constituents of Petroleum and their Uses:**

POINTS TO PONDER
Petroleum is refined to get various products like petrol, diesel, kerosene etc which we use extensively in everyday life. Think about at least five differences between petrol, diesel and kerosene. Why does diesel create more pollution? Why petrol gives better acceleration but diesel is used more to move heavy duty vehicles, locomotives, submarines?

Figure 10.16: A petroleum refinery

S.No.	Constituents of Petroleum	Uses
1.	Petroleum Gas in Liquid form (LPG)	Fuel for home and industry
2.	Petrol	Motor fuel, aviation fuel, dry cleaning solvent
3.	Kerosene	Fuel for stoves, lamps, and jet aircraft
4.	Diesel	Fuel for heavy motor vehicles and electric generators
5.	Lubricating oil	Lubrication
6.	Paraffin wax	Used in ointments, candles, and vaseline
7.	Bitumen	Utilised in paints and road surfacing

- **Natural Gas:**
  - Natural gas stands as an essential fossil fuel, mainly because of the ease with which it can be transported through pipes.
  - It is stored under high pressure to form compressed natural gas (CNG), which is utilised for power generation.

POINTS TO PONDER
Natural gas use in the energy mix is increasing because of its less polluting nature. Think about differences in different types of natural gas like Shale gas, Town gas, methane clathrate.

- ✧ It is preferred as a fuel for transport vehicles due to its less polluting nature, marking it as a cleaner fuel.
- ✧ **Direct Usage:** Natural gas can be directly burned in homes and factories.
- ✧ A network of pipelines facilitates its supply in locations like Vadodara (Gujarat) and certain parts of Delhi.
- ✧ **Applications:** Natural gas also serves as a foundational material for producing several chemicals and fertilisers.
- ✧ **Indian Reserves:** Natural gas reserves in India are abundant, with significant deposits in Tripura, Rajasthan, Maharashtra, and the Krishna Godavari delta.

Limited Natural Resources

- As established earlier, some natural resources like fossil fuels, forests, and minerals are exhaustible. While it took millions of years for dead organisms to transform into fuels like coal and petroleum, the known reserves might only last a few more centuries.
- The combustion of these fuels is a primary contributor to air pollution and is associated with global warming.
- It is imperative to use these resources judiciously to ensure a healthier environment, mitigate the risks of global warming, and prolong their availability.
- In India, the **Petroleum Conservation Research Association (PCRA)** offers conservation suggestions such as:
  - ✧ Maintaining a consistent speed while driving,
  - ✧ Turning off the engine during prolonged stops,
  - ✧ Ensuring correct tyre pressure, and
  - ✧ Undertaking regular vehicle maintenance.

Combustion and Flame

- Fuels are used in homes, industries, and automobiles. Examples include cow dung, wood, coal, charcoal, petrol, diesel, and compressed natural gas (CNG).
- The burning of different substances like a candle and coal differs, with some producing a flame and others not.

Figure 10.17: Burning of magnesium

What is Combustion?

- Combustion is a chemical process where a substance reacts with oxygen to produce heat. The burning substance is termed combustible or a fuel, which can be solid, liquid, or gas.
- During combustion, light may also be emitted either as a flame or a glow.
- Magnesium, when burned, forms magnesium oxide while releasing heat and light. **(Refer to 10.17)**
- Charcoal, like coal, burns in air producing carbon dioxide, heat, and light.
- In our bodies, food reacts with oxygen to produce heat, serving as a fuel.
- **Conditions for Combustion:**
  - ✧ Air is essential for combustion.

    (Refer to Figure 10.18)

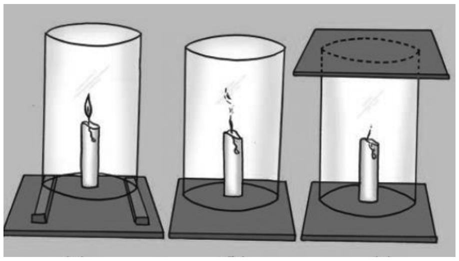


Figure 10.18: Experiment to show that air is essential for burning

- A candle burns freely when there's a flow of air but flickers and produces smoke or goes off entirely when the air supply is restricted.
- Fire can be extinguished by cutting off the air supply, as seen when a burning person is covered with a blanket. **(Refer to Figure 10.19)**

Figure 10.19: Blanket wrapped around a person whose clothes caught fire

- **Ignition Temperature:**
  - Different substances have distinct temperatures at which they catch fire, known as their ignition temperature.
  - For instance, a matchstick doesn't ignite at room temperature but does when friction is applied by striking it against the matchbox.
  - The design of the matchstick has evolved, with the current safety matches containing safer chemicals than their earlier counterparts, which had dangerous white phosphorus.
  - A combustible substance won't burn if its temperature remains below its ignition temperature. This is why cooking oil might catch fire on prolonged heating but wood doesn't. **(Refer to Figure 10.20)**

Figure 10.20: Forest fire

  - Ignition temperature ensures substances only burn when they reach a certain temperature.
  - An example of this concept is a paper cup not burning when it contains water since the water prevents the paper from reaching its ignition temperature. **(Refer to Figure 10.21)**

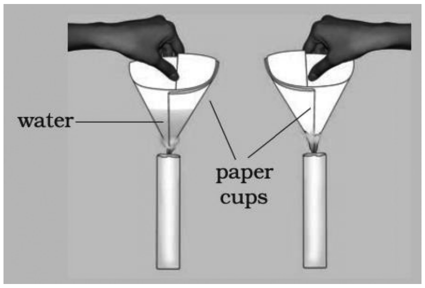


Figure 10.21: Heating water in a paper cup

- **Inflammable Substances:**
  - These are substances with very low ignition temperatures, making them easily catch fire.
  - Examples include petrol, alcohol, and Liquified Petroleum Gas (LPG).

Types of Combustion

- **Rapid Combustion:** When substances burn swiftly and produce heat and light. For instance, when a burning matchstick or gas lighter is brought near a gas stove, the gas burns rapidly, exemplifying rapid combustion.

- **Spontaneous Combustion:** This refers to a type of combustion where a material spontaneously bursts into flames without any apparent external cause.
  - Substances like phosphorus can ignite in air at room temperature.
  - Instances include **coal dust causing fires in coal mines** due to spontaneous combustion.
  - Natural causes like sunlight or lightning can lead to spontaneous forest fires. However, human negligence, such as leaving campfires unextinguished, is often the major cause of forest fires.
- **Explosion:** An explosive combustion occurs when a sudden reaction results in the rapid release of heat, light, sound, and gas. Fireworks during festivals provide an example. When a cracker is ignited, it leads to an explosion.
  - External pressure applied to a cracker can also trigger an explosive reaction.

Flame Characteristics

- LPG flame and candle flame have distinctive colours. **(Refer to Figures 10.22 and 10.23)**

Figure 10.22: Colours of a candle flame and the flame of a kitchen stove

Figure 10.23: Flames of kerosene lamp, candle and Bunsen burner

- Substances that evaporate during burning will form flames. E.g., kerosene and molten wax.
- Charcoal doesn't produce a flame as it doesn't vaporise.
- The luminous zone of a flame indicates the presence of unburnt carbon particles. **(Refer to Figures 10.24 and 10.25)**
- The non-luminous zone is the hottest part of the flame, often used by goldsmiths for melting precious metals due to its high temperature. **(Refer to Figures 10.26 and 10.27)**

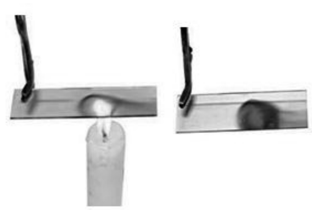


Figure 10.24

Figure 10.25

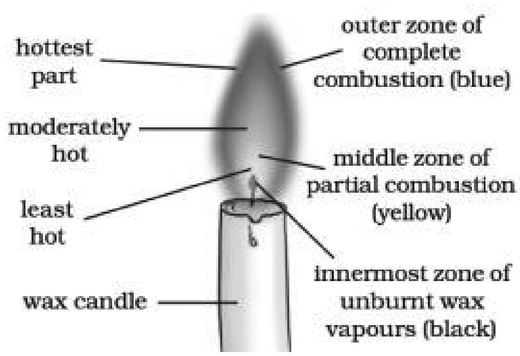


Figure 10.26: Different zones of candle flame

Figure 10.27: Goldsmith blowing through a metallic pipe

Control of Fire

Fire Brigade's Response

- Upon arrival, a fire brigade typically pours water on the fire. **(Refer to Figure 10.28)**

Figure 10.28: Firemen extinguish the fire by throwing water under pressure

- Water serves two purposes:
  - It cools the combustible material, reducing its temperature below the ignition point, thus preventing the fire from spreading.
  - The water vapours surround the combustible material, restricting the supply of air, and effectively extinguishing the fire.

Essential Requirements for Fire

- Three critical elements are needed to produce fire:
  - Fuel
  - Air (supplying oxygen)
  - Heat (to elevate the fuel's temperature beyond its ignition point).
- Controlling fire involves eliminating one or more of these components.
- Fire extinguishers work by either restricting the air supply, reducing the fuel's temperature, or both. In many situations, the fuel itself (like a building) cannot be removed.

Types of Fire Extinguishers (Refer to Figure 10.29)

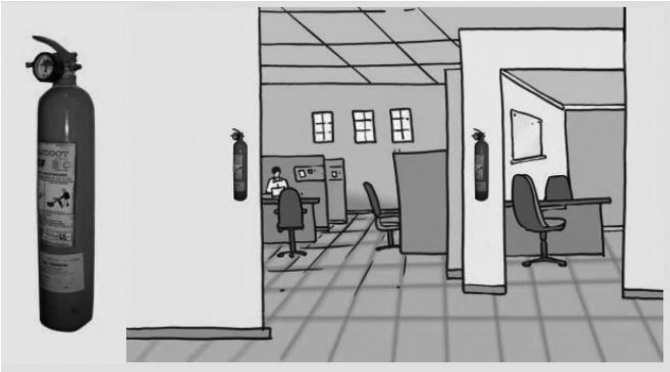


Figure 10.29: Fire extinguisher

- **Water:**
  - Water is the most common extinguisher. It is effective for fires involving materials like wood and paper.
  - Water is not suitable for electrical fires (due to conductivity) or oil and petrol fires (since water is denser than oil and sinks beneath it).
- **Carbon Dioxide (CO_2):**
  - It is ideal for fires involving electrical equipment and flammable materials like petrol.
  - It is heavier than oxygen, CO_2 forms a blanket over the fire, cutting off the oxygen supply.
  - CO_2 doesn't typically damage electrical equipment.
  - It can be stored as a high-pressure liquid in cylinders. Upon release, CO_2 expands and cools, providing a dual benefit of suffocating and cooling the fire.
- **Dry Powdered Chemicals:**
  - Chemicals like sodium bicarbonate (baking soda) or potassium bicarbonate can be used.
  - These chemicals, when near fire, release CO_2, which then acts as a fire suppressant.

Fuel

- Sources of heat energy include wood, charcoal, petrol, and kerosene, these are termed as fuels.
- A good fuel is one which:
  - Is readily available and economical.
  - Burns at a moderate rate in air.
  - Produces ample heat and minimal undesirable residues.
- Different fuels come in solid, liquid, and gaseous forms.

Fuel Efficiency

- Efficiency varies among fuels like cow dung, coal, and LPG.
- **Calorific Value:** The calorific value denotes the heat energy produced upon the complete combustion of 1 kg of fuel, expressed in kJ/kg.

Calorific Values of Different Fuels	
Fuel	**Calorific Value (kJ/kg)**
Cow dung cake	6,000 - 8,000
Wood	17,000 - 22,000
Coal	25,000 - 33,000
Petrol	45,000
Kerosene	45,000
Diesel	45,000
Methane	50,000
CNG	50,000
LPG	55,000
Biogas	35,000 - 40,000
Hydrogen	150,000

- **Environmental Impact of Fuels:**
  - **Burning of Wood:** Produces significant smoke, causing respiratory issues. Using wood as fuel leads to the loss of essential substances from trees and contributes to deforestation.
  - **Carbon Fuels:** They release unburnt carbon particles, leading to pollutants causing respiratory ailments.

- ✧ **Carbon Monoxide:** It is a hazardous gas produced from incomplete combustion, especially dangerous in closed rooms.
- ✧ **Carbon Dioxide:** Its increased concentration due to fuel combustion may lead to global warming.
- ✧ **Sulphur Dioxide and Nitrogen Oxides:** Released from burning coal, diesel, and petrol, these gases form acid rain, detrimental to crops, buildings, and soil.
- ✧ **Transition to CNG:** Diesel and petrol are being replaced by CNG in vehicles, as it's a cleaner fuel emitting fewer harmful products.

✤ **Global Warming:** It is characterised by an increase in Earth's atmospheric temperature, leading to polar glacier melting. Global warming results in sea-level rise, causing floods in coastal areas, with potential permanent submersion of low-lying regions.

Conclusion

The intricate balance of energy, its sources, utilisation, and impact, weave a complex web that influences both our immediate environment and the larger global ecosystem. From the fossil fuels that power our industries to the very clothes we wear, understanding the science of energy is paramount.

Glossary:

- **Exhaustible Natural Resources:** These are the limited resources that can be depleted by human activities.
- **Fossil Fuels:** Fuels formed from the decay of organic matter over millions of years, e.g., coal and petroleum are called fossil fuels.
- **Carbonisation:** It is the process of transformation of dead vegetation into coal under pressure over time.
- **Petrochemicals:** These are the chemicals derived from petroleum or natural gas.
- **Combustion:** It is a chemical process wherein a substance reacts with oxygen producing heat.
- **Ignition Temperature:** This is the minimum temperature at which a substance catches fire.
- **Inflammable Substances:** These are the materials with very low ignition temperatures.
- **Conduction:** It is the mode of transfer of heat within a body without any movement of the body itself.
- **Convection:** This is the mode of transfer of heat involving the movement of fluid molecules from a hotter region to a cooler one.
- **Radiation:** Transfer of heat in the form of rays or waves.
- **Conductor:** A substance, body, or device that readily conducts heat, electricity, sound, etc.
- **Insulator:** These are materials or devices that prevent or reduce the passage of heat, electricity, or sound.
- **Sea Breeze:** Cool air moving from sea to land.
- **Land Breeze:** Cool air moving from land to sea.
- **Global Warming:** A gradual increase in the overall temperature of the Earth's atmosphere.
- **Calorific Value:** The amount of heat released on complete combustion of a unit mass or volume of a substance.
- **Laboratory Thermometer:** Instrument used for measuring temperature outside of human bodies.
- **Clinical Thermometer:** Instrument specifically designed to measure human body temperature.
- **Kerosene:** A hydrocarbon liquid often used as fuel.
- **Biogas:** A type of biofuel produced from the decomposition of organic matter.
- **CNG (Compressed Natural Gas):** Natural gas stored at high pressure.
- **LPG (Liquified Petroleum Gas):** Hydrocarbon gas stored as a liquid.
- **Bitumen:** A viscous black liquid used primarily for road surfacing.
- **Coal Tar:** A thick black liquid produced during coal processing.
- **Convection Current:** The transfer of heat in a fluid through the movement of the heated particles.
- **Explosive Combustion:** Combustion that occurs rapidly with the release of gas and heat.
- **Spontaneous Combustion:** Ignition of a substance without any external source of ignition.

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11

Cells and Tissues

Bibliography: This chapter encompasses the summary of **Chapters 5 and 6 - IX** NCERT **(Science).**

Introduction

A cell has a basic structural organization. This helps the cells to perform functions like respiration, obtaining nutrition, and clearing of waste material, or forming new proteins. This means that a particular function is carried out by a cluster of cells at a definite place in the body. This cluster of cells, called a tissue, is arranged and designed so as to give the highest possible efficiency of function.

Information about Cell

- **Discovery:** Cells were first discovered by **Robert Hooke** in **1665**. Cell is a *Latin* word for **'a little room'**. He observed the cells in a cork slice with the help of a primitive microscope.
- In 1674, **Leeuwenhoek** used an advanced microscope to unveil free-living cells in pond water. Then, in 1831, **Robert Brown** identified the cell's nucleus, while in 1839, **Purkinje** introduced the term **'protoplasm' for the cell's fluid component**.
- **The Cell Theory (Schleiden (1838) and Schwann (1839)):**
  - All the plants and animals are composed of cells and the cell is the basic unit of life.
  - All cells arise from **pre-existing cells**, given by **Virchow (1855)**.
- **Unicellular Organisms:** The discovery of magnifying lenses revealed the microscopic world, where a single cell can form an entire organism (e.g., Amoeba, Chlamydomonas, bacteria), known as unicellular organisms.
- **Multicellular Organisms:** Organisms such as fungi, plants, and animals, consist of cells working together in various body parts. All life begins as a single cell that divides to produce more cells, demonstrating that every cell comes from pre-existing cells.
- **Shape and Size:** Cell shape and size relate to their functions; some, like Amoeba, exhibit changing shapes, while others have fixed, distinct shapes (e.g., nerve cells).
- **Functions:** All living cells share fundamental functions. Cells function efficiently due to division of labor, akin to multicellular organisms.
- **Organelles:** They contain specialized components called cell organelles, each performing specific tasks such as material synthesis and waste removal.
  - These organelles collectively form the cell's basic unit, and intriguingly, all cells, regardless of their function or organism, possess the same organelles.

Cells: The Structural and Functional Unit of Life

- Each living cell has the capacity to perform certain basic functions that are characteristic of all living forms. The Cellular component is called **Cell Organelles**. Examples: **plasma membrane**, **nucleus and cytoplasm**.

- A cell is able to live and perform all its functions because of these organelles.
- These organelles together constitute the basic unit called **the cell**.
- If we study a cell under a microscope, we would find three features in almost every cell; **plasma membrane, nucleus and cytoplasm**.
- All activities inside the cell and interactions of the cell with its environment are possible due to these features.

Did You Know?
During the 1950s, scientists postulated the concept of prokaryotic cells and eukaryotic cells, with earlier groundwork being laid by Edouard Chatton, a French Biologist in 1925.

Components of the Cell

Plasma Membrane Or Cell Membrane

- This is the outermost covering of the cell that separates the contents of the cell from its external environment. The cell membrane is an **active part** of the cell.
- **Selectively Permeable Membrane:** The plasma membrane allows or permits the entry and exit of some materials in and out of the cell. It also prevents movement of some other materials. The cell membrane, therefore, is called a **selectively permeable membrane**.
- The plasma membrane is flexible and is made up of organic molecules called **lipids and proteins**.

Cell Wall

- Plant cells have another rigid outer covering called the **cell wall**. The cell wall lies outside the plasma membrane.
- The plant cell wall is mainly composed of **cellulose**. Cellulose is a complex substance and provides **structural strength** to plants.
- Cell walls permit the cells of plants, fungi and bacteria to withstand very dilute **(hypotonic)** external media without bursting.

Nucleus

- In 1831, **Robert Brown** discovered the nucleus in the cell. The nucleus has a double layered covering called **a nuclear membrane.**
- **Chromosomes:** The nucleus contains **chromosomes**; chromosomes contain information for inheritance of characters from parents to the next generation in the form of DNA (DeoxyriboNucleic Acid) molecules.
  - Chromosomes are composed of **DNA and protein**. DNA molecules contain the information necessary for constructing and organizing cells.
  - Functional segments of DNA are called genes.
- The nucleus plays a **central role** in cellular reproduction.
- Eventual advancements in science and technology shed more light into the cell, with new findings and discoveries about its structure and cellular components.

Prokaryotic Cells	Eukaryotic Cells
Size: Generally small (1-10µm)	**Size:** Generally large (5- 100µm)
Nuclear Region: Undefined nuclear region containing only nucleic acids is called a nucleoid and cells lack a nuclear membrane	**Nuclear Region:** Well defined and surrounded by nuclear membrane
Chromosomes: Single	**Chromosomes:** More than one chromosomes

✤ Membranes-bound cell organelles absent	✤ Membranes-bound cell organelles present
✤ Examples include Escherichia coli, Streptococcus, Nostoc, Anabaena, Cyanobacteria.	✤ Examples include protists, fungi, plants, and animals(everything except Prokaryotes)

Cytoplasm

- ✤ The cytoplasm is the **fluid content** inside the plasma membrane.
- ✤ It also contains many specialized cell organelles.
- ✤ Each of these organelles performs a specific function for the cell.

Did You Know?

Viruses lack any membranes and hence do not show characteristics of life until they enter a living body and use its cell machinery to multiply.

Cell Organelles

- ✤ Large and complex cells need many chemical activities to support their structure and function. To keep these activities separate from each other, these cells use membrane-bound organelles within themselves.
- ✤ Important example of cell organelles are: **Endoplasmic Reticulum, Golgi apparatus, Lysosomes, mitochondria and plastids.**

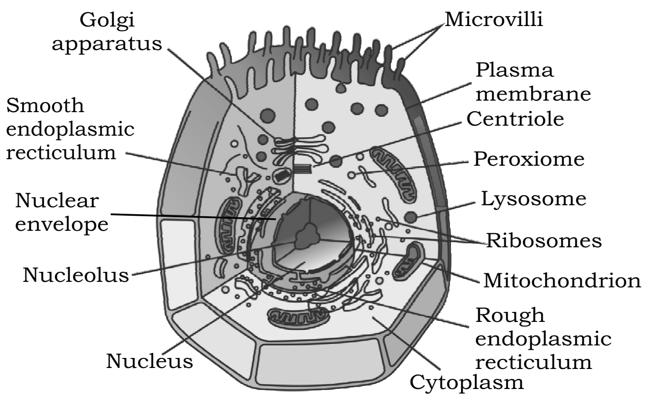

Figure 11.1: Animal Cell

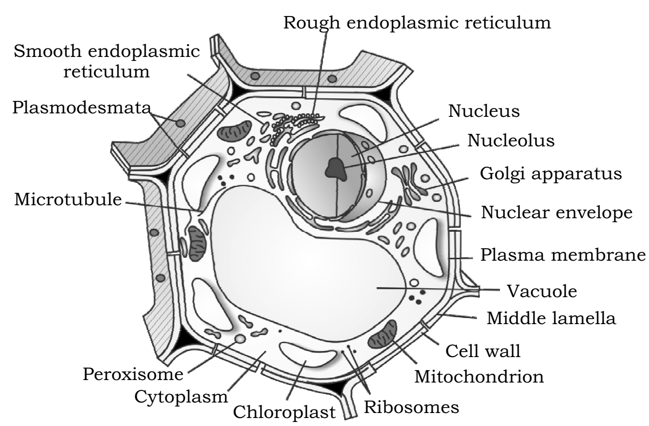

Figure 11.2: Plant Cell

Comparison of Plant and Animal cells

Component	Plant cell	Animal Cell
Cell wall	Provides protection, support	Absent (some cells have extracellular matrix of protein)
Nucleus	Site of most of cell's genetic information	Site of most of cell's genetic information
Endoplasmic reticulum	Protein synthesis, processing and storage, lipid synthesis	Protein synthesis, processing, and storage, lipid synthesis
Golgi apparatus	Protein processing, secretion	Protein processing, secretion
Vacuole	Provides turgor storage	Small sized
Mitochondrion	Cellular respiration	Cellular respiration
Plastid	Photosynthesis, color, starch or lipid storage	Absent
Peroxisome	Oxidizes fatty acids, photorespiration in green tissues	Oxidizes fatty acids
Cytoskeleton	Regulates cell shape, moves chromosomes, cytoplasmic streaming	Regulates cell shape, moves chromosomes, cytoplasmic streaming
Centriole	Absent	Required for nuclear division

Endoplasmic Reticulum (ER)

- The endoplasmic reticulum (ER) is a large network of membrane-bound tubes and sheets. It looks like **long tubules** or round or oblong bags (vesicles). The ER membrane is similar in structure to the plasma membrane.
- There are two types of **ER– rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER).**
- **Functions:**
  - The **SER** helps in the manufacture of **fat molecules, or lipids.**
  - **The function of the ER** is to serve as channels for the transport of materials (especially proteins) between various regions of the cytoplasm or between the cytoplasm and the nucleus.
  - The **ribosomes are** the **sites of protein manufacture**. The manufactured proteins are then sent to various places in the cell depending on need, using the **ER.**
  - In the **liver cells** of the group of animals called vertebrates, **SER** plays a crucial role in detoxifying many poisons and drugs.
  - The ER also functions as a **cytoplasmic framework** providing a surface for some of the biochemical activities of the cell.

Golgi Apparatus

- It is a system of membrane-bound vesicles (flattened sacs) arranged approximately parallel to each other in stacks called cisterns.
- These membranes often have connections with the membranes of ER and therefore constitute another portion of a complex cellular membrane system.
- **Function:**
  - Its **functions** include the **storage**, **modification and packaging of products** in vesicles.
  - In some cases, complex sugars may be made from simple sugars in the Golgi apparatus.
  - The Golgi apparatus is also involved in the formation of **Lysosomes**.

Lysosomes

- **Lysosomes** are membrane-bound sacs filled with **digestive enzymes**. These enzymes are made by **RER**. Lysosomes are a kind of **waste disposal system** of the **cell**.
- Lysosomes are also known as the **'suicide bags'** of a cell.

Mitochondria

- Mitochondria are known as the **powerhouses of the cell**. The energy required for various chemical activities needed for life is released by mitochondria in the form of **ATP (Adenosine triphosphate)** molecules.
  - **ATP** is known as the energy currency of the cell. The body uses energy stored in ATP for making new chemical compounds and for mechanical work.
  - Mitochondria have their own **DNA and ribosomes**. Therefore, mitochondria are able to make some of their **own proteins**.

POINTS TO PONDER

Mitochondria contains a small amount of DNA which is also the source of some genetic diseases. Can you think of such genetic diseases and what modern biotechnology solution has been used to eliminate them from the fetus? (Hint: Three parent baby)

Plastids

- Plastids are present **only in plant cells**. There are two types of plastids which are, **Chromoplasts** (coloured plastids) and **Leucoplasts** (white or colorless plastids). Plastids too have their own **DNA and ribosomes**.
    - **Chromoplasts** containing the pigment chlorophyll are known as chloroplasts.
        - **Chloroplasts** are important for photosynthesis in plants.
    - **Leucoplasts** are primarily organelles in which materials such as **starch, oils and protein granules are stored.**

Vacuoles

- Vacuoles are **storage sacs** for solid or liquid contents. Vacuoles are **small sized in animal cells** while **plant cells** have very **large vacuoles**.
- The central vacuole of some plant cells may occupy **50-90%** of the cell volume.
- In **plant cells vacuoles** are full of cell sap and provide **turgidity and rigidity** to the cell.
- In some **unicellular organisms**, specialized vacuoles also play important roles in expelling excess water and some wastes from the cell.

Cell Divisions

- New cells are formed in organisms in order to grow, to replace old, dead and injured cells, and to form gametes required for reproduction. The process by which new cells are made is called cell division.
- There are **two main types** of **cell division**: **mitosis** and **meiosis**.
- **Mitosis:** This is the process of cell division by which most of the cells divide for growth. In this process, each cell, **called as the mother cell**, divides to form two identical daughter cells (Fig. 11.3). The daughter cells have the same number of chromosomes as the mother cell. It helps in growth and repair of tissues in organisms.
- **Meiosis:** "It involves two consecutive divisions". When a cell divides by meiosis it produces four new cells instead of just two (Fig.11.3). The new cells only have half the number of chromosomes than that of the mother cells.

POINTS TO PONDER

Mitosis and Meiosis are two processes of cell division in humans and also in other organisms. Can you think of how anomalies in these processes lead to genetic abnormalities like downs syndrome, turner Syndrome etc. in humans?

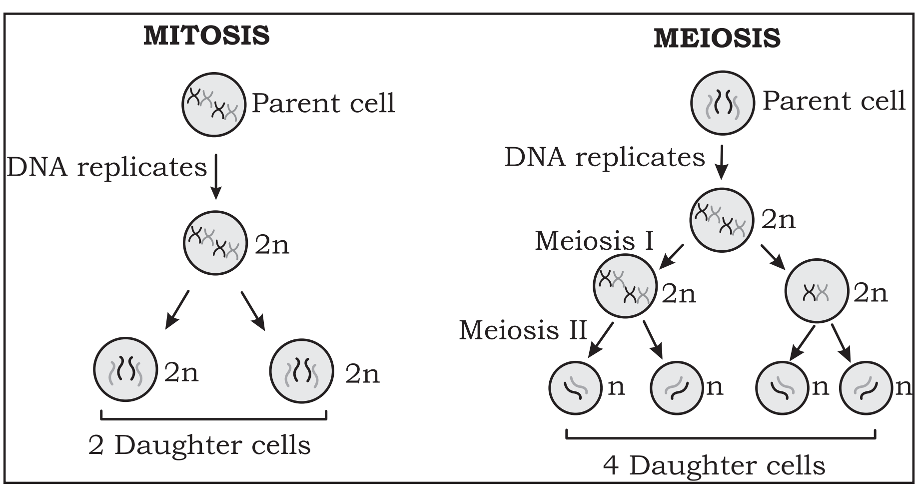

Figure 11.3: Mitosis and Meiosis

Tissues

- **Definition:** A group of cells that are similar in structure and/or work together to achieve a particular function forms a tissue. Tissues are of two types i.e., plant and animal tissues.

Plant Tissue

- **Plant Tissue:** Plants are stationary or fixed, and their supporting tissue is generally made up of dead cells.
- Based on their ability to divide, plant tissues can be divided into two categories: **Dividing and non-dividing**.
- **Meristematic Tissue:** The growth of plants occurs only in certain specific regions. This is because the dividing tissue, also known as **meristematic tissue**, is located only at these points. Meristematic tissues are classified as **apical, lateral and intercalary**. (Refer Figure 11.4)
- Cells of meristematic tissue are very **active**, they have **dense cytoplasm**, **thin cellulose walls** and prominent nuclei. **They lack vacuoles**.
- **Differentiation and Permanent Tissue:** Differentiation of meristematic tissue leads to the development of various types of **permanent tissues**. This process of taking up a permanent shape, size, and a function is called **differentiation**.

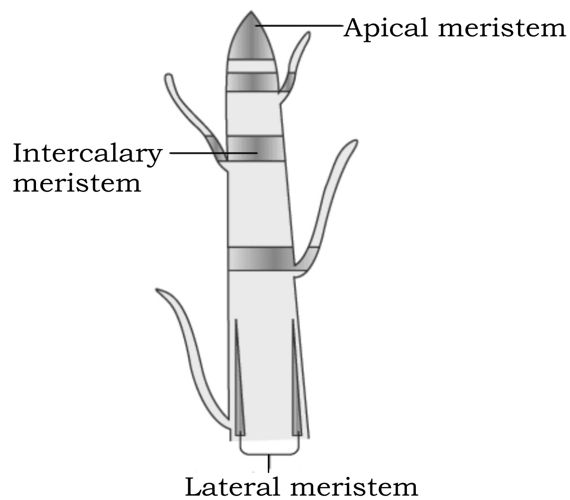

Figure 11.4: Location of meristematic tissue in plant

Simple Permanent Tissue	Complex Permanent Tissue
✤ A few layers of cells beneath the epidermis are generally simple permanent tissue. ✤ All made of **one type of cells**, which look **like each other**. Such tissues are called simple permanent tissue. ✤ Various types of simple tissues: **(a) Parenchyma (b) Collenchyma (c) Sclerenchyma** ✤ **Parenchyma:** It is the most common simple permanent tissue. It consists of relatively unspecialised cells with thin cell walls. They are living cells. ✤ **Collenchyma:** The flexibility in plants is due to **collenchyma**. ✤ It allows **bending** of various parts of a plant like tendrils and stems of climbers without breaking. It also provides mechanical support.	✤ Complex tissues are made of more than one type of cells. All these cells coordinate to perform a common function. ✤ **Xylem and phloem** are examples of such complex tissues. ✤ They are both conducting tissues and constitute a vascular bundle. ✤ **Xylem** consists of tracheids, vessels, xylem parenchyma, Xylem fibers. Tracheids and vessels are tubular structures. This allows them to **transport water and minerals** vertically. The parenchyma stores food. ✤ **Phloem** is made up of five types of cells: sieve cells, sieve tubes, companion cells, phloem fibres and Phloem parenchyma. ✤ **Phloem** transports food from leaves to other parts of the plant.

✤ **Sclerenchyma:** It is the tissue which makes the plant hard and stiff. For example, the **husk of a coconut**. It is made of sclerenchymatous tissue. The cells of this tissue are **dead**. ✤ **Epidermal cells** is the **outermost layer of cells**, Epidermal cells on the aerial parts of the plant often secrete a waxy, water resistant layer on their outer surface. ✤ It has a **protective role to play**, cells of epidermal tissue form a continuous layer without intercellular spaces. ✤ **Epidermal cells** of the roots, whose function is water absorption, commonly bear long hairlike parts that greatly increase the total absorptive surface area. ✤ In some plants like **desert plants**, epidermis has **a thick waxy** coating of cutin (chemical substance with waterproof quality) on its outer surface.	

Animal Tissue

- Animal tissue is moving tissue and most cells are living. On the basis of the functions there are different types of animal tissues, such as **epithelial tissue, connective tissue, muscular tissue and nervous tissue**.

Epithelial Tissue

- The covering or **protective tissues** in the animal body are epithelial tissues. Epithelium covers most organs and cavities within the body.
- The skin, the lining of the mouth, the lining of blood vessels, lung alveoli and kidney tubules are all made of epithelial tissue.
- Different types of epithelial tissues as listed as under:
  - **Squamous:** Simple squamous epithelial cells are extremely thin and flat and form a delicate lining. The esophagus and the lining of the mouth are also covered with squamous epithelium.
  - **Stratified Squamous:** Stratified squamous epithelium is skin epithelial cells arranged in many layers to prevent wear and tear.
  - **Cuboidal:** Cuboidal epithelium (with cube-shaped cells) forms the lining of kidney tubules and ducts of salivary glands, where it provides mechanical support.
  - **Columnar (Ciliated):** Columnar epithelium where absorption and secretion occur, as in the inner lining of the intestine, tall epithelial cells.

Connective Tissue

- The cells of connective tissue are loosely spaced and embedded in an intercellular matrix. The matrix may be jelly-like, fluid, dense or rigid.
- **Blood** is a type of connective tissue. **Blood** has a fluid (liquid) matrix called **plasma**, in which **red blood corpuscles** (RBCs), **white blood corpuscles** (WBCs) and **platelets** are suspended.
  - The plasma contains proteins, salts and hormones.

- ✧ Blood flows and transports gasses, digested food, hormones and waste materials to different parts of the body.

- ✤ **Bone** is another example of a connective tissue. It forms the framework that supports the body. It also anchors the muscles and supports the main organs of the body.
  - ✧ It is a strong and nonflexible tissue.
  - ✧ Bone cells are composed of **calcium** and **phosphorus** compounds.
- ✤ **Ligaments:** Two bones can be connected to each other by another type of connective tissue called the **Ligament**. This tissue is very elastic. It has considerable strength.

Types of Muscles Fibers

- ➢ **Striated Muscle:** voluntary muscles or skeletal muscles are also called **striated muscles.** are mostly attached to bones and help in body movement.
- ➢ **Smooth Muscles:** Also known as **involuntary muscles** control the movement of food in the alimentary canal or the cantraction and relaxation of blood. They are also found in the iris of the eye, in ureters and in the bronchi of the lungs.
- ➢ **Cardiac Muscles:** The muscles of the hear show rhythmic contraction and relaxation throughout life.
These are **involuntary muscles.**

- ✤ **Tendons** connect muscles to bones and are another **type of connective tissue.**
- ✤ **Cartilage** is a type of connective tissue, Cartilage smoothens bone surfaces at joints and is also present in the nose, ear, trachea and larynx.
- ✤ **Areolar connective tissue** is found between the skin and muscles, around blood vessels and nerves and in the bone marrow. It fills the space inside the organs, supports internal organs and helps in repair of tissues.

Muscular Tissue

- ✤ Muscular tissue consists of elongated cells known as muscle fibers and is primarily responsible for body movement.
- ✤ Types of Muscular Tissue:

A. Voluntary Muscles (Skeletal Muscles)

- ❒ Under conscious control.
- ❒ Attached to bones for body movement.
- ❒ Exhibits striations, characterized by long, cylindrical, unbranched, and multinucleate cells.

B. Involuntary Muscles (Smooth Muscles)

- ❒ Control involuntary movements like digestion and blood vessel contractions.
- ❒ Spindle-shaped cells with a single nucleus, referred to as unstriated muscles.

C. Cardiac Muscles

- ❒ Unique to the heart, creating rhythmic contractions.
- ❒ Cardiomyocytes are striated, uninucleate, and interconnected via intercalated discs.
- ❒ Properties of Muscular Tissue: Contractibility, extensibility, elasticity, and excitability.
- ❒ Structure of Muscular Tissue: Epimysium, perimysium, and endomysium facilitate muscle contraction.
- ❒ Muscular Tissue Function: Muscles contract upon receiving signals from nerve bundles.
- ❒ Actin and myosin interactions drive muscle contractions, contributing to body movement, organ compression, and sound production.
- ❒ Muscles serve as storage sites for glycogen and contain myoglobin for oxygen transport. Skeletal muscles make up about 40% of body mass.

Nervous Tissue

- The brain, spinal cord and nerves are all composed of the nervous tissue.
- The cells of this tissue are called nerve cells or **neurons**.
- A neuron consists of a cell body with a nucleus and cytoplasm, from which long thin hair-like parts arise. Each neuron has a single long part (process), called the **axon**, and many short, branched parts (processes) called **dendrites**. (Refer figure 11.5)
- An individual nerve cell may be up to a meter long.
- The signal that passes along the nerve fiber is called a **nerve impulse**.

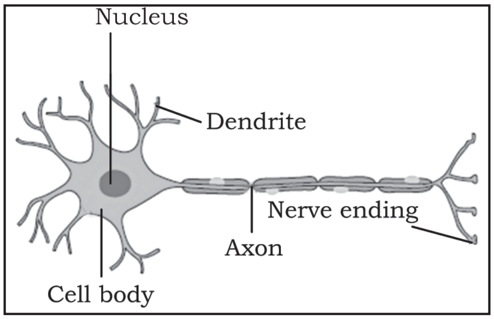

Figure 11.5: Neuron-unit of nervous tissue

The **functional combination** of nerve and muscle tissue is **fundamental** to most animals. This combination enables animals to move rapidly in **response to stimuli**.

Conclusion

- Understanding cells and tissues is pivotal in grasping the foundation of life and disease. It offers insights into our biological essence and holds the key to advancements in healthcare and biotechnology. Comprehensive knowledge of cells and tissues is indispensable for unraveling the intricacies of life, health, and disease. It forms the cornerstone of medical research, biotechnology, and regenerative medicine, driving progress in diagnostics and therapeutics, and ultimately, improving the quality of human life.

Glossary:

- **Diffusion:** It is the movement of substance across cell membranes. Some substances like carbon dioxide or oxygen can move across the cell membrane.
- **Osmosis:** The movement of water molecules through a selectively permeable membrane.
- **Hypotonic Solution:** If the medium surrounding the cell has a higher water concentration than the cell, meaning that the outside solution is very dilute, the cell will gain water by osmosis.
- **Isotonic solution:** If the medium has exactly the same water concentration as the cell, there will be no net movement of water across the cell membrane.
- **Hypertonic solution:** If the medium has a lower concentration of water than the cell, meaning that it is a very concentrated solution, the cell will lose water by osmosis.

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12

Plant Organisms

Bibliography: This chapter encompasses the summary of **Chapters 4 and 6-Class VI** NCERT (Science), **Chapters 1, 6, 7 and 8-Class VII** NCERT (Science), **Chapter 5-Class VIII** NCERT (Science) and **Chapter 7-Class 10** NCERT (Science).

Introduction

There is a diversity of plants around us. All living beings directly or indirectly depend on plants for their nutrition. There are vegetative and reproductive parts of the plant and each is responsible for performing different functions. Seed dispersal plays an important role in maintaining the kind of diversity in plants that we notice around ourselves. Furthermore, it is the reproduction in plants that helps the plant kingdom proliferate. But serious conservation efforts are needed in order to maintain the diversity in the plant kingdom, which is soon depleting.

Kinds of Plants

- **Herbs:** Plants with green and tender stems are called herbs. They are usually short and may not have many branches. **(Refer to Figure 12.1)**
- **Shrubs:** They are plants that develop branches near their base. Their stem is hard but not very thick. **(Refer to Figure 12.1)**
- **Trees:** Plants with hard and thick stems, are very tall and their stems have branches in the upper part are called trees. **(Refer to Figure 12.1)**
- **Creepers:** Plants with weak stems that cannot stand upright but spread on the ground are called creepers. **(Refer to Figure 12.2)**
- **Climbers:** Plants which take support and climb up are called climbers. **(Refer to Figure 12.2)**

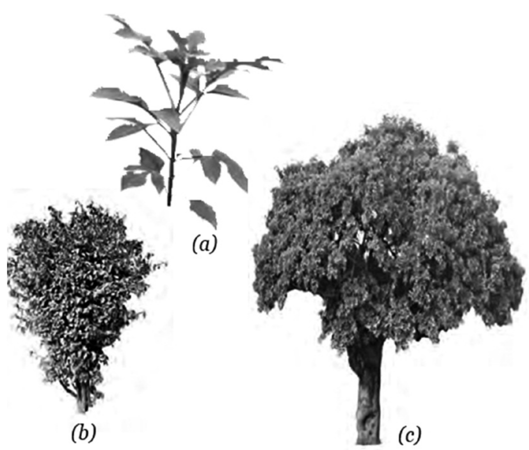


Figure 12.1: (a) Herb (b) Shrub (c) Tree

Figure 12.2: Creeper and Climber

Parts of a Plant (Refer to Figure 12.3)

- **Stem:** It carries water and minerals upwards to other parts of the plant attached with it.
- **Leaf:** It is a thin, flat, usually green structure attached to the stem or branch of a plant.
  - The part of the leaf by which it is attached to the stem is called **petiole**. The broad, green part of the leaf is called **lamina**. **(Refer to Figure 12.5)**
  - The lines on the leaf are called **veins**. A prominent line in the middle of the leaf is called the midrib. The design made by veins in a leaf is called the **leaf venation. Reticulate venation** has net like design on both sides of **midrib**. Some other leaves like grass have parallel veins running through it. This is called **parallel venation**. **(Refer to Figure 12.4)**
  - Leaves prepare their food in the presence of sunlight, using water, carbon dioxide and a green coloured substance (chlorophyll) present in them. This process is called **photosynthesis**. Oxygen is given out in this process. The food prepared by leaves ultimately gets stored in different parts of the plant. The leaves also lose water through transpiration.

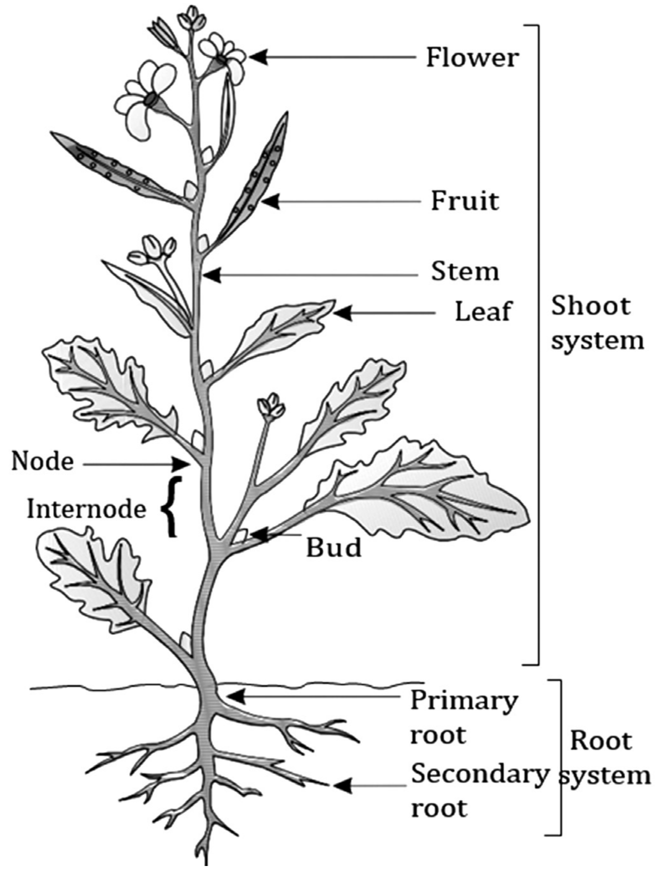


Figure 12.3: Parts of a Plant

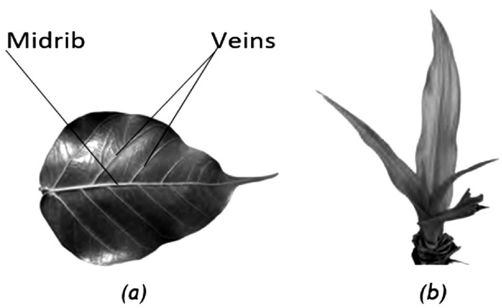


Figure 12.4: Reticulate and Parallel Leaf Venation

Figure 12.5: A Leaf

- **Roots:** They help in holding the plant firmly to the soil and anchor the plant to the soil.
  - The main root is called **tap root** and the smaller roots are called **lateral roots**.
  - Some plants do not have a main root. All their roots seem similar and these are called **fibrous roots**.

- **Leaf venation and root type are related** in most plants. Taproots have net like venation while fibrous roots have parallel venation. **(Refer to Figure 12.6)**
- Roots absorb water and minerals from the soil and the stem conducts these to leaves and other parts of the plant. The leaves prepare food. This food travels through the stem and is stored in different parts of the plant. Some food is eaten as root like carrot, radish, sweet potato, turnip and tapioca.

Figure 12.6: (a) Taproot (b) Fibrous Roots

- **Flower: Petals** are the prominent parts of an open flower. Different flowers have petals of different colours. The parts made of small leaf-like structures are called **sepals**. **(Refer to Figure 12.7)**
  - The innermost part of the flower is called the **pistil**. The pistil is the female reproductive organ of a flower. **It contains stigma, style and ovary**. **(Refer to Figure 12.10)**
  - Ovary is the lowermost and swollen part of the pistil. Small bead-like structures inside the ovary are called **ovules**.
  - The **stamen** is the male reproductive organ of a flower. **It contains the anther and filament**. **(Refer to Figure 12.9)**
  - The anther is the top part of the stamen, where **pollen** is produced and stored. The **filament** is the slender stalk that supports the anther.

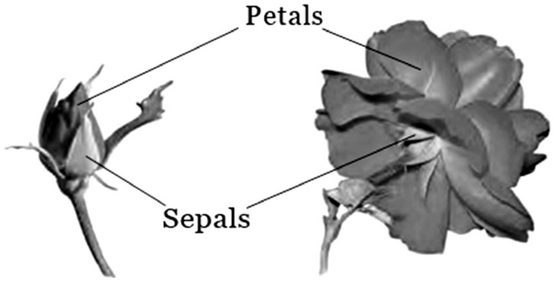


Figure 12.7: Bud and Flower

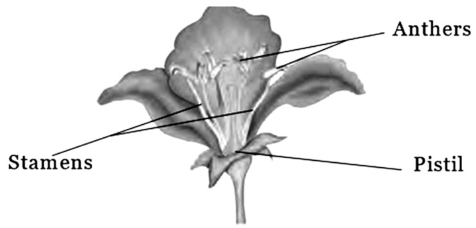


Figure 12.8: Parts of a Flower

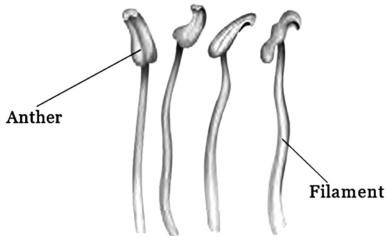


Figure 12.9: Parts of a Stamen

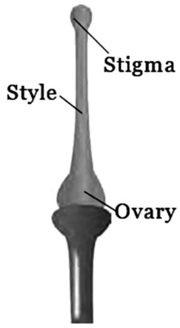


Figure 12.10: Parts of a Pistil

Plants: Habitats and Adaptations

- The organisms, both plants and animals, living in a habitat are its **biotic components**. The non-living things such as rocks, soil, air and water in the habitat constitute its **abiotic components**.
- There are certain features which help organisms to live in their surroundings better. The presence of specific features or certain habits, which enable an organism to live naturally in a place is called adaptation. It differs in every habitat.
  - **Adaptation** is the method by which organisms get well adjusted to the climate. It takes a long time because the abiotic factors of a region also change very slowly. Only the adapted organisms survive in case of calamities or sudden changes in surroundings.
  - Organisms adapt to different abiotic factors in different ways and this results in a wide variety of organisms in different **habitats**.
- The place where organisms live is called habitat. Habitat means a dwelling place (a home).
- **Terrestrial Habitat:** The plants and animals that live on land are said to live in terrestrial habitats. Examples of terrestrial habitats are forests, grasslands, deserts, coastal and mountain regions.
  - **Desert:** Desert plants lose very little water through transpiration. The leaves in desert plants are either absent, very small, or they are in the form of spines. This helps in reducing loss of water from the leaves through transpiration. The leaf-like structure in a cactus is its stem. Photosynthesis in these plants is usually carried out by the stems. Desert plant stem is covered with a thick waxy layer, which helps to retain water in the tissues of the plant. Most desert plants have roots that go very deep into the soil for absorbing maximum water. **(Refer to Figure 12.11)**

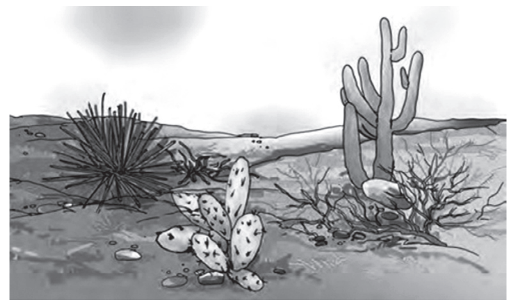


Figure 12.11: Some typical plants that grow in desert

  - **Mountains:** These habitats are normally very cold, windy and also snowy. The trees here are mostly cone shaped and have sloping branches. **(Refer to Figure 12.12)** The leaves of some of these trees are needle-like. This helps the rainwater and snow to slide off easily.

Figure 12.12: Trees of a Mountain Habitat

- **Aquatic Habitats:** The habitats of plants and animals that live in water are called aquatic habitats. Examples are lakes, rivers and oceans.
  - **Oceans and Seas:** Seagrasses have a dense network of roots that anchor them in the sandy or muddy ocean floor. These roots help stabilise the plants.
  - **Ponds and Lakes:** Some aquatic plants have their roots fixed in the soil below the water, the roots are much

POINTS TO PONDER

How do the unique habitats in which plants grow, from arid deserts to lush rainforests, challenge our understanding of adaptation and showcase the remarkable strategies that plants employ to thrive in their specific environments?

reduced in size and their main function is to hold the plant in place. The stems of these plants are long, hollow and light. The stems grow up to the surface of water while the leaves and flowers float on the surface of water. Some aquatic plants are submerged in water. These plants have narrow and thin ribbon-like leaves which can bend in the flowing water. (Refer to Figure 12.13)

Figure 12.13: Some aquatic plants float on water. Some have their roots fixed in the soil at the bottom. Some aquatic plants are submerged in water.

Characteristics of Plant Organisms

- **Food requirement:** All living organisms, including plants and animals, depend on food for energy. Food is also required for carrying on other life processes that go inside all organisms.
- **Growth:** All plant organisms show growth and mature with time.
- **Respiration:** It is necessary for all living organisms. Exchange of gases in plants mainly takes place through leaves. The leaves take in air through tiny pores in them and use the oxygen. They give out carbon dioxide in the air. The amount of oxygen released in the process of food preparation by plants is much more than the oxygen they use in respiration. Respiration in plants takes place day and night.
- **Stimuli response:** Changes in our surroundings that make us respond to them, are called stimuli. Flowers of some plants bloom only at night. In some plants flowers close after sunset, in some plants like Mimosa (touch-me-not) leaves close or fold when someone touches them. **(Refer to Figure 12.14)**

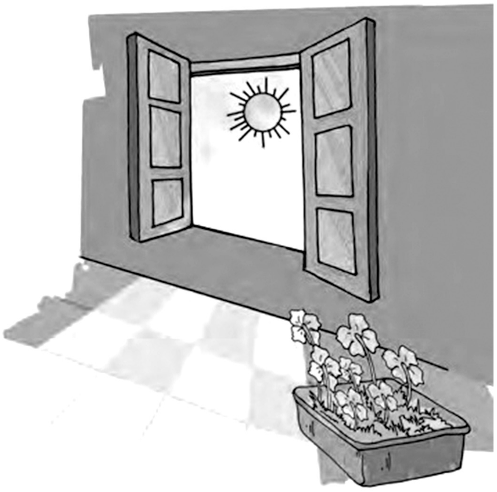


Figure 12.14: Plants respond to light (Stimuli)

- **Excretion:** This is another characteristic common to all organisms. Some plants remove waste products as secretions while other plants store the waste products within their parts in a way that they do not harm the plant as a whole.
- **Reproduction:** Many plants reproduce through seeds, which can germinate and grow into new plants. Some plants also reproduce through parts other than seeds. For example, a part of a potato with a bud, grows into a new plant. **(Refer to Figure 12.15)**

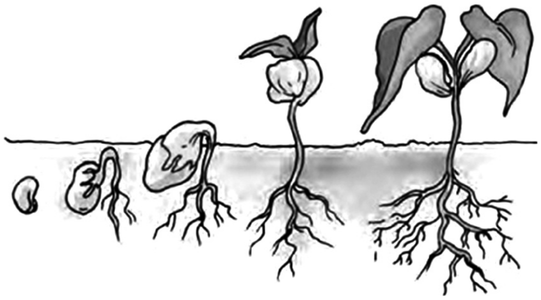


Figure 12.15: A seed from a plant germinates into a new plant

- **Movement:** Plants are generally anchored in soil so they do not move from one place to another. However, various substances like water, minerals and the food synthesised by them move from one part to another part of the plant.

- **Death:** Like all living beings, even plants die. Because organisms (plants and animals) die, particular types of organisms can survive over thousands of years only if they reproduce their own kind.

Mode of Nutrition in Plants

- Carbohydrates, proteins, fats, vitamins and minerals are called **nutrients** present in food and are vital for the body. The nutrients enable living organisms to build their bodies, to grow, to repair damaged parts of their bodies and provide the energy to carry out life processes.
- These nutrients can be synthesised by plants as food but can not be synthesised by animals including humans. Humans and animals are directly or indirectly dependent on plants for food and nutrition. Plants are the only organisms that can prepare food for themselves by using water, carbon dioxide and minerals.
- **Nutrition** is the mode of taking food by an organism and its utilisation by the body. The mode of nutrition in which organisms make food themselves from simple substances is called autotrophic (*auto = self; trophos = nourishment*) nutrition. Therefore, plants are called **autotrophs**. Animals and most other organisms take in food prepared by plants. They are called **heterotrophs** (heteros = other).

Photosynthesis (by Autotrophs)

- Leaves are the food factories of plants. Water and minerals present in the soil are absorbed by the roots and transported to the leaves. Carbon dioxide from air is taken in through the tiny pores present on the surface of leaves called **stomata**. These pores are surrounded by **guard cells**. **(Refer to Figure 12.16)**
- Water and minerals are transported to the leaves by the **vessels** which run throughout the root, the stem, the branches and the leaves. They form a continuous path or passage for the nutrients to reach the leaf.
- The leaves have a green pigment called chlorophyll. It helps leaves to capture the energy of the sunlight. This energy is used to synthesise (prepare) food from carbon dioxide and water.
- The leaves other than green leaves also have **chlorophyll**, they also undergo photosynthesis. Algae can also prepare their own food by photosynthesis.
- The synthesis of food occurs in the presence of sunlight, it is called **photosynthesis** (Photo: light; synthesis: to combine). Chlorophyll, sunlight, carbon dioxide and water are necessary to carry out the process of photosynthesis. It is a unique process on the earth. In the absence of photosynthesis, life would be impossible on the earth.

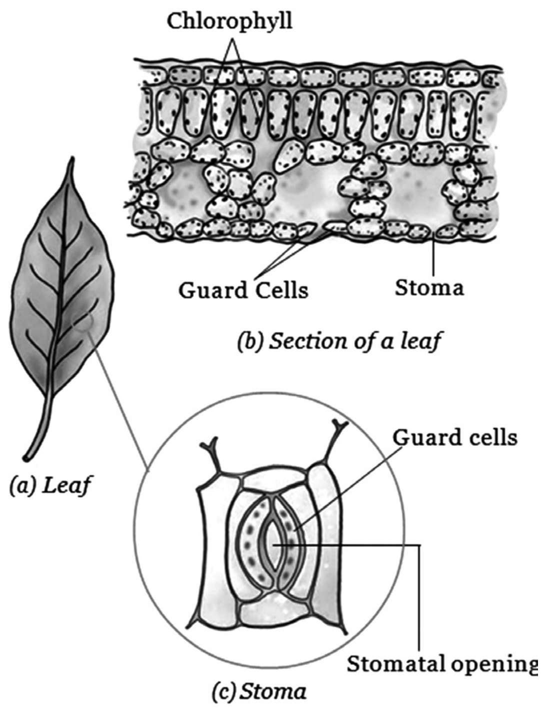


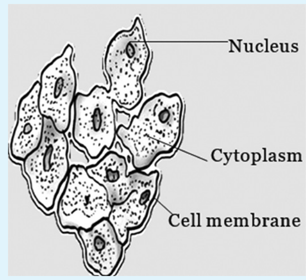
Figure 12.16: Photosynthesis

- The **solar energy is captured by the leaves and stored in the plant in the form of food**. Thus, the sun is the ultimate source of energy for all living organisms.
- Oxygen is produced during photosynthesis. During photosynthesis, chlorophyll containing cells of leaves in the presence of sunlight, use carbon dioxide and water to synthesise carbohydrates. This process can be represented in an equation:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{carbohydrate} + \text{oxygen}$$

- During this process, oxygen is released. The presence of starch in leaves indicates the occurrence of photosynthesis. Starch is also a carbohydrate.
- **Carbohydrates** are made of carbon, hydrogen and oxygen. These are used to synthesise other components of food such as proteins and fats. **Proteins** are nitrogenous substances and contain nitrogen.
- The nitrogen is present in abundance in gaseous form in the air but plants cannot absorb nitrogen in this form. Soil has certain bacteria which converts gaseous nitrogen into a usable form and releases it into the soil **(Nitrogen Fixation).** These are absorbed by the plants along with water. Fertilisers are also rich in nitrogen, which is added to the soil by farmers.

CELLS: The bodies of living organisms are made of tiny units called cells. Cells can be seen only under the microscope. Some organisms are made of only one cell. The cell is enclosed by a thin outer boundary, called the cell membrane. Most cells have a distinct, centrally located spherical structure called the nucleus. The nucleus is surrounded by a jelly-like substance called cytoplasm.



Other Modes of Nutrition (by Heterotrophs)

- Plants that do not have chlorophyll cannot synthesise their own food. They depend on the food produced by other plants. They use the heterotrophic mode of nutrition.
- **Cuscuta (Amarbel)** does not have chlorophyll. It takes ready-made food from the plant on which it is climbing. The plant on which it climbs is called the **host**. Since it deprives the host of valuable nutrients, Cuscuta is called the **parasite**. **(Refer to Figure 12.17)**
- A few plants can trap insects and digest them. One example is the **pitcher plant**. **(Refer to Figure 12.18)** The pitcher-like or jug-like structure is the modified part of the leaf. The apex of the leaf forms a lid which can open and close the mouth of the pitcher. Inside the pitcher there is hair. When an insect lands in the pitcher, the lid closes and the trapped insect gets entangled into the hair. The lid closes and the insect is trapped. The insect is digested by the digestive juices secreted in the pitcher and its nutrients are absorbed. Such insect-eating plants are called insectivorous plants.

Figure 12.17: Cuscuta (Amarbel) on host plant

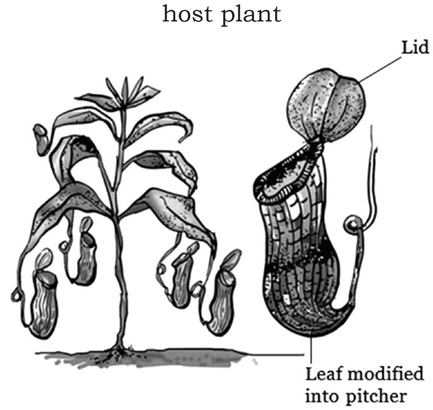


Figure 12.18: Pitcher plant showing lid and pitcher

Saprotrophs

- **Fungi** have a different mode of nutrition. They absorb the **nutrients from dead and decaying matter**. This mode of nutrition is called saprotrophic nutrition. Such organisms with saprotrophic mode of nutrition are called saprotrophs. **(Refer to Figure 12.19)**
- Fungi also grow on pickles, leather, clothes and other articles that are left in hot and humid weather for a long time.

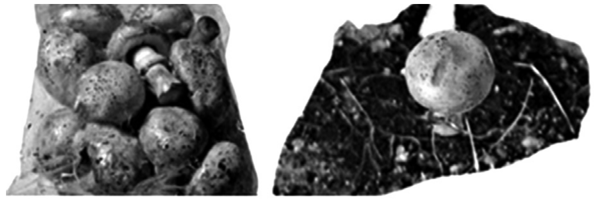


Figure 12.19: Packet of mushrooms, a mushroom growing on decayed material.

Symbiotic Relationship

- Some organisms live together and share both shelter and nutrients. This relationship is called symbiosis.
- For example, certain fungi live inside the roots of plants. The plants provide nutrients to the fungus and, in return, the fungus provides water and certain nutrients.
- In **lichens**, a chlorophyll-containing partner, which is an **alga,** and a **fungus** live together. The fungus provides shelter, water and minerals to the alga and, in return, the alga prepares and provides food to the fungus.

Replenishment of Nutrients in Soil

- The amount of minerals and nutrients from the soil decline as plants absorb these from the soil. These nutrients need to be added from time-to-time to enrich the soil. Farmers add fertilisers to replenish the soil with lacking nutrients.
- Crop plants also absorb a lot of nitrogen and the soil becomes deficient in nitrogen. They need nitrogen in a soluble form. The bacterium called **rhizobium** can take atmospheric nitrogen and convert it into a usable form. But Rhizobium cannot make its own food. So it often lives in the roots of gram, peas, moong, beans and other legumes and provides them with nitrogen. In return, the plants provide food and shelter to the bacteria.
- **Rhizobium and leguminous plants** have a **symbiotic relationship**. This association is of great significance for the farmers. They can reduce the use of nitrogenous fertilisers where leguminous plants are grown. Most of the pulses (dals) are obtained from leguminous plants.

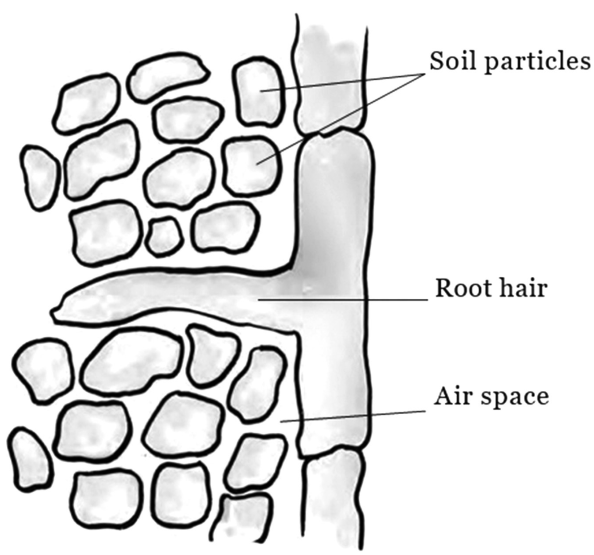


Figure 12.20: Roots absorb air from the soil

Respiration

- Respiration is a vital biological process. All living organisms need to respire to get the energy needed for their survival. Like other living organisms, plants also respire for their survival. They also **take in oxygen from the air and give out carbon.**

- In plants, each part can independently take in oxygen from the air and give out carbon dioxide. Plants have **tiny pores called stomata** for exchange of oxygen and carbon dioxide. Like all other living cells of the plants, the root cells also need oxygen to generate energy. Roots take up air from the air spaces present between the soil particles. **(Refer to Figure 12.20)**

What happens when potted plants are overwatered?

When potted plants are overwatered, it means they are receiving more water than they can effectively absorb or utilise. This can lead to several negative consequences:

- Root rot
- Reduced Nutrient uptake
- Wilting and yellowing of leaves
- Stunted growth
- Fungal and Bacterial diseases
- Leaching of Nutrients
- Molds and algae growth

Transportation of Substances in Plants

- Plants take water, minerals and nutrients from the soil through the roots and transport it to the leaves. The leaves prepare food for the plant, using water and carbon dioxide during photosynthesis.
- Food is the source of energy and every cell of an organism gets energy by the breakdown of glucose. The cells use this energy to carry out vital activities of life. Therefore food must be made available to every cell of an organism.

Transport of Water and Minerals

- Plants absorb water and minerals by the roots. The roots have **root hair** which increase the surface area of the roots for the absorption of water and mineral nutrients dissolved in water. The root hair is in contact with the water present between the soil particles.
- Plants have pipe-like vessels to transport water and nutrients from the soil. The vessels are made of special cells, forming the **vascular tissue.** A tissue is a group of cells that perform specialised function in an organism.
- **Xylem:** The vascular tissue for the transport of water and nutrients in the plant is called the xylem. The xylem forms a continuous network of channels that connects roots to the leaves through the stem and branches and thus transports water to the entire plant. **(Refer to Figure 12.21)**
- **Phloem:** Food is synthesised in leaves and it has to be transported to all parts of the plant. This is done by the vascular tissue called the phloem. Thus, xylem and phloem transport substances in plants.

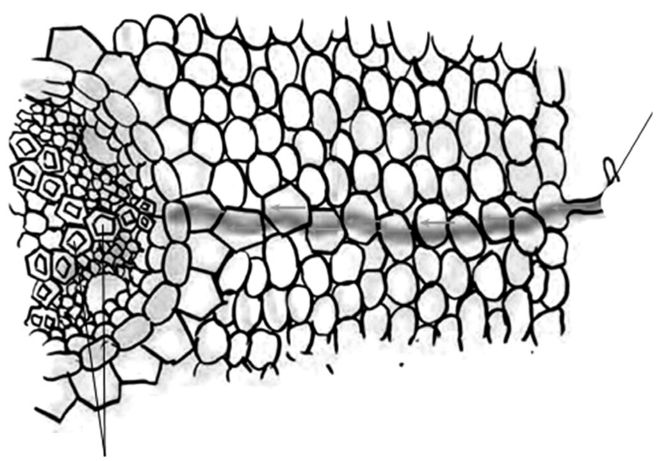


Figure 12.21: Transport of water and minerals in a section of root.

Transpiration

- When plants absorb minerals, nutrients and water from the soil, not all water is utilised by the plant. The **excess water evaporates** through stomata present on leaves by the process of transpiration.
- The evaporation of water from leaves generates a suction pull which can pull water to great heights in the tall trees. Transpiration also cools the plant.

Reproduction in Plants

- The production of new individuals from their parents is known as reproduction. It is because of reproduction that we notice the existence of so many organisms. Reproduction at its most basic level involves making copies of the blueprints of body design.
- **Chromosomes** in the nucleus of a cell contain information for inheritance of features from parents to the next generation in the form of **DNA (DeoxyriboNucleic Acid)** molecules. The DNA in the cell nucleus is the information source for making proteins.
- Cells use chemical reactions to build copies of their DNA. This creates two copies of the DNA in a reproducing cell, and they have to be separated from each other. DNA copying is accompanied by the creation of an additional cellular apparatus, and then the DNA copies separate, each with its own cellular apparatus. Effectively, a cell divides to give rise to two cells.
- Copying the DNA has some variations each time. As a result, the DNA copies generated are similar, but not identical to the original hence the surviving cells are similar to, but subtly different from each other. This inbuilt tendency for variation during reproduction is the **basis for evolution**.

The Importance of Variation

- Reproduction is linked to the stability of population of species because DNA copying during reproduction maintains the body design features of the parents. It allows the new organism to use a particular **niche or habitat** in the ecosystem.
- But these niches can change because of reasons beyond the control of the organisms. Temperatures on earth can go up or down, water levels can vary, etc. If the niche were drastically altered, the entire population could be wiped out. However, if some variations were to be present in a few individuals in these populations, there would be some chance for them to survive. **Variation is thus useful for the survival of species over time.**

Modes of Reproduction in Plants

- Most plants have roots, stems and leaves. These are called the **vegetative parts** of a plant. After a certain period of growth, most plants bear flowers. Seeds germinate and form new plants.
- Flowers perform the function of reproduction in plants. Flowers are the **reproductive parts**. There are several ways by which plants produce their offspring. These are categorised into two types: **(i) Asexual:** In asexual reproduction plants can give rise to new plants without seeds, and **(ii) Sexual reproduction:** In sexual reproduction, new plants are obtained from seeds.

POINTS TO PONDER

How does the practice of vegetative propagation impact genetic diversity within plant populations, and what are the potential ecological consequences of this method of plant reproduction?

Asexual Reproduction

- **Vegetative propagation:** It is a type of asexual reproduction in which new plants are produced from roots, stems, leaves and buds. As reproduction is through the vegetative parts of the plant, it is known as Vegetative Propagation.
  - Flower buds develop into flowers. Apart from flower buds, there are buds in the **axil** (point of attachment of the leaf at the node) of leaves which develop into shoots. These buds are called **vegetative buds**. A bud consists of a short stem around which immature overlapping leaves are present. Vegetative buds can also give rise to new plants. **(Refer to Figure 12.22)**

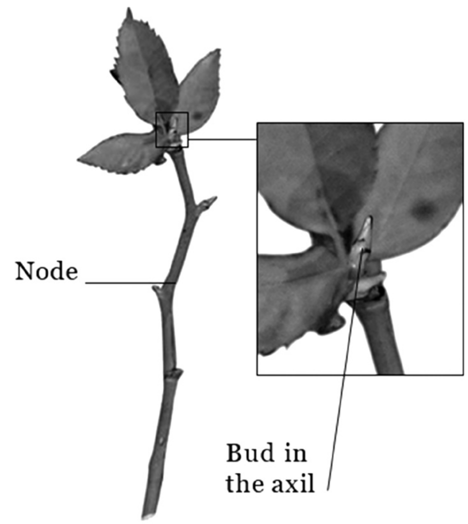


Figure 12.22: Stem cutting of Rose

  - **Bryophyllum** (sprout leaf plant) has buds in the margins of leaves. **(Refer to Figure 12.23)** If a leaf of this plant falls on a moist soil, each bud can give rise to a new plant.
  - **Roots** of some plants can also give rise to new plants. **Example:** Sweet potato and dahlia. Plants such as cacti produce new plants when their parts get detached from the main plant body. Each detached part can grow into a new plant.

Figure 12.23: Leaf of Bryophyllum with buds in the margin

  - Vegetative propagation is used in methods such as **layering or grafting** to grow many plants like sugarcane, roses, or grapes for agricultural purposes. Plants raised by vegetative propagation can bear flowers and fruits earlier than those produced from seeds.
  - Such methods also make possible the propagation of plants such as banana, orange, rose and jasmine that have lost the capacity to produce seeds. Another advantage of vegetative propagation is that **all plants produced are genetically similar** enough to the parent plant to have all its characteristics.
- **Budding:** A new organism develops as an outgrowth from the body of the parent organism.
  - **Example: Yeast** is a single-celled organism and can only be observed under a microscope. **(Refer to Figure 12.24)**

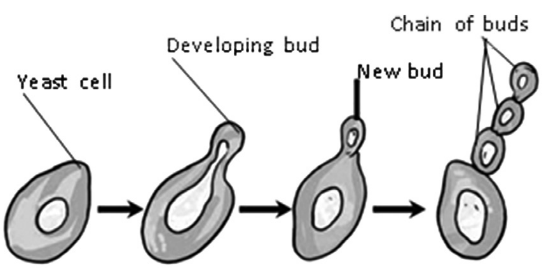


Figure 12.24: Reproduction in yeast by budding

  - It is observed that the **small bulb-like projection** coming out from the yeast cell is called a **bud**. The bud gradually grows and gets detached from the parent cell and forms a new yeast cell. The new yeast cell grows, matures and produces more yeast cells. Sometimes, another bud arises from the bud forming a chain of buds. If this process continues, a large number of yeast cells are produced in a short time.

- **Fragmentation:** In multicellular organisms with relatively simple body organisation, simple reproductive methods can work. Example: **Spirogyra** simply breaks up into smaller pieces upon maturation. These pieces or fragments grow into new individuals. **(Refer to Figure 12.25)**
  - But not all multicellular organisms can simply divide cell-by-cell. It is because they are not simply a random collection of cells. Specialised cells are organised as tissues, and tissues are organised into organs, which then have to be placed at definite positions in the body.
  - In such a carefully organised situation, cell-by-cell division would be impractical. Multicellular organisms, therefore, need to use more complex ways of reproduction. A basic strategy used in multicellular organisms is that different cell types perform different specialised functions.

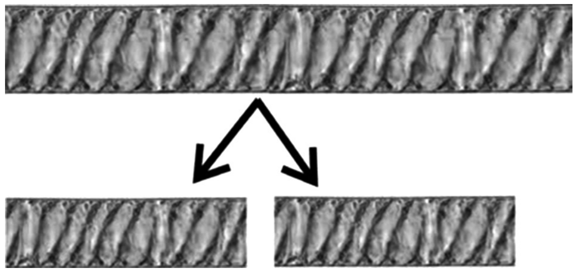


Figure 12.25: Fragmentation in spirogyra (an alga)

  - **Reproduction** in such organisms is also the **function of a specific cell type**. A single cell type in the organism that is capable of growing, proliferating and making other cell types under the right circumstances.
  - **Example:** In **algae**, when water and nutrients are available, it grows and multiplies rapidly by fragmentation. An alga breaks up into two or more fragments. These fragments or pieces grow into new individuals. This process continues and they cover a large area in a short period of time.
- **Spore Formation:** Spores are asexual reproductive bodies. Each spore is covered by a hard protective coat to withstand unfavourable conditions such as high temperature and low humidity.
  - Under favourable conditions, a spore germinates and develops into a new individual. Plants such as **moss and ferns** reproduce by means of spores. **(Refer to Figure 12.26)**
  - **Example:** In **bread mould (Rhizopus)**, the thread-like structures are not reproductive parts. The tiny blob-on-a-stick structures are involved in reproduction. The blobs are **sporangia**, which contain cells, or spores, that can eventually develop into new Rhizopus individuals. The spores are covered by thick walls that protect them until they come into contact with another moist surface and can begin to grow. **(Refer to Figure 12.27)**

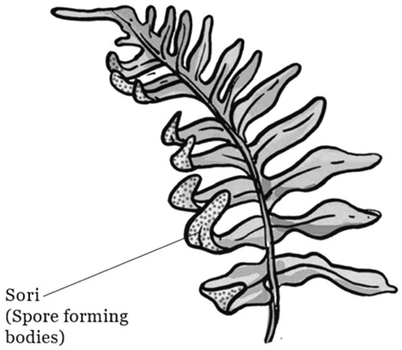


Figure 12.26: Reproduction through spore formation in fern.

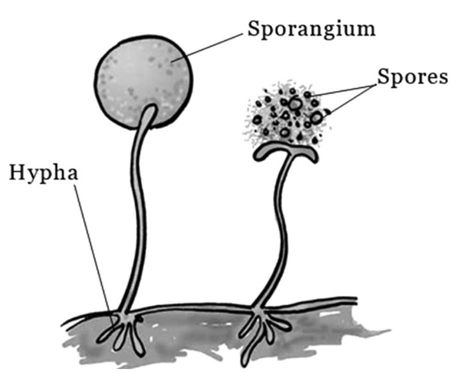


Figure 12.27: Reproduction through spore formation in fungus.

Sexual Reproduction

- The sexual mode of reproduction incorporates a process of combining DNA from two different individuals during reproduction. But this creates a major difficulty of the new generation having twice the amount of DNA that the previous generation had. This is likely to mess up the control of the cellular apparatus by the DNA.
- But as organisms become more complex, the specialisation of tissue increases. Special lineages of cells in specialised organs have only half the number of chromosomes and half the amount of DNA as compared to the non-reproductive body cells. This is achieved by a process of cell division called **meiosis**.
- Thus, when these **germ-cells** from two individuals combine during sexual reproduction to form a new individual, it results in re-establishment of the number of chromosomes and the DNA content in the new generation.
- As the body designs become more complex, the germ-cells also specialise. One germ-cell is large and contains the food-stores while the other is smaller and likely to be motile. Conventionally, the motile germ cell is called the **male gamete** and the germ-cell containing the stored food is called the **female gamete.**
- **Sexual Reproduction in Flowering Plants:** The reproductive parts of angiosperms are located in the flower. Different parts of a flower are sepals, petals, stamens and pistils. Stamens and pistils are the reproductive parts of a flower which contain the germ-cells.
  - The flower may be **unisexual (corn, cucumber, papaya, watermelon)** when it contains either stamens or pistil or **bisexual (hibiscus, mustard, rose, petunia)** when it contains both stamens and pistil. **Stamen is the male reproductive part** and it produces pollen grains that are yellowish in colour. **Pistil** is present in the centre of a flower and **is the female reproductive part**. It is made of three parts: **ovary**, **style** and **stigma**. **(Refer to Figure 12.28)**
  - The swollen bottom part is the ovary, the middle elongated part is the style and the terminal part which may be sticky is the stigma. The ovary contains ovules and each ovule has an egg cell.

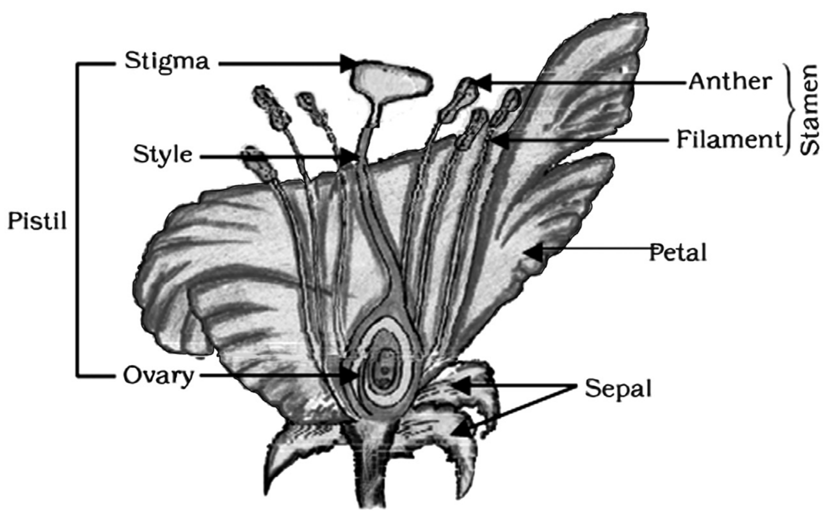


Figure 12.28: Longitudinal section of flower

✤ **Pollination:** The transfer of pollen from the stamen to the stigma is called pollination. **(Refer to Figure 12.29)**

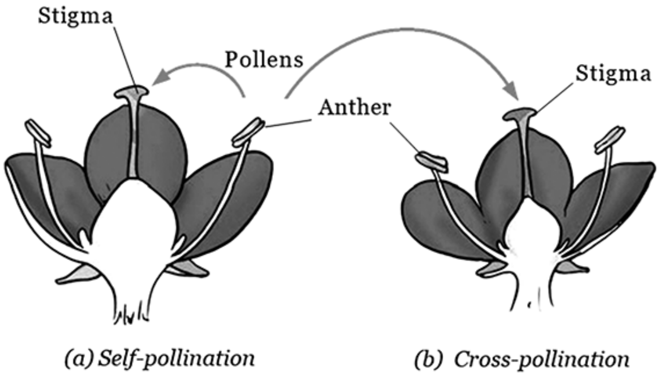


Figure 12.29: Pollination in flower

✧ If this transfer of pollen occurs in the same flower, it is referred to as **self-pollination**.

✧ If the pollen is transferred from one flower to another, it is known as **cross-pollination**. This transfer of pollen from one flower to another is achieved by agents like wind, water or animals.

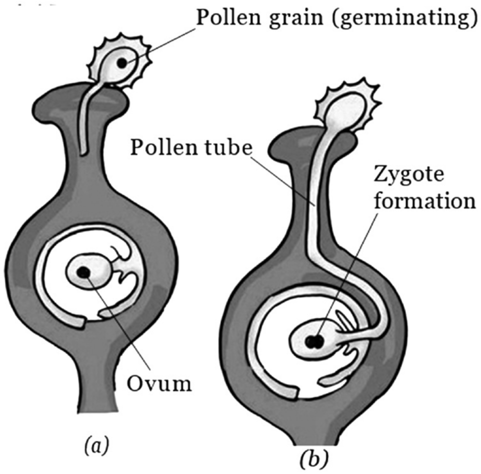


Figure 12.30: Fertilisation (Zygote formation)

✤ **Fertilisation:** The cell which results after fusion of the gametes is called a **zygote**. The process of fusion of male and female gametes (to form a zygote) is called fertilisation. The zygote develops into an **embryo**. **(Refer to Figure 12.30)**

✤ **Germination:** After the pollen lands on a suitable stigma, it has to reach the female germ-cells which are in the ovary. For this, a tube grows out of the pollen grain and travels through the style to reach the ovary.

✧ After fertilisation, the zygote divides several times to form an embryo within the ovule. The ovule develops a tough coat and is gradually converted into a seed. The ovary grows rapidly and ripens to form a fruit. Meanwhile, the petals, sepals, stamens, style and stigma may shrivel and fall off.

✧ The seed contains the future plant or embryo which develops into a seedling under appropriate conditions. This process is known as **germination**. (Refer to Figure 12.31)

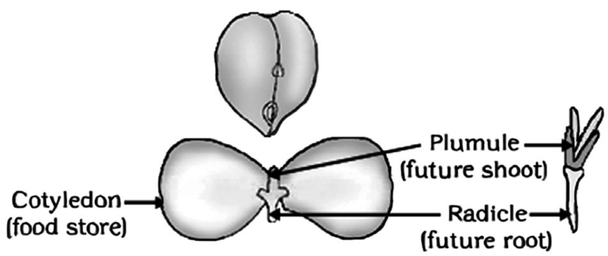


Figure 12.31: Germination

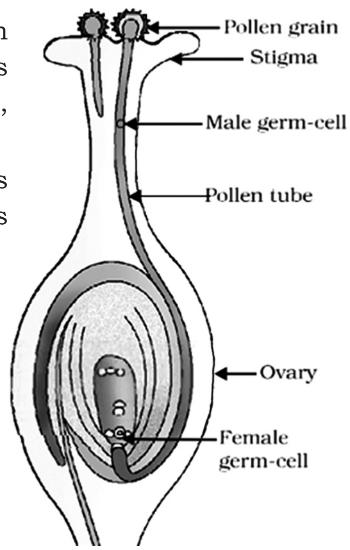


Figure 12.32: Germination of pollen on stigma

- **Fruits and Seed Formation:** After fertilisation, the ovary grows into a fruit and other parts of the flower fall off. The fruit is the ripened ovary. The seeds develop from the ovules. The seed contains an embryo enclosed in a protective seed coat. Some fruits are fleshy and juicy such as mango and orange. Some fruits are hard like almonds and walnuts.

Seed Dispersal and its Importance

- Seed dispersal is important because if seeds fall and grow in the same place, there would be severe competition for sunlight, water, minerals and space. As a result, the seeds would not grow into healthy plants.
- **Plants benefit by seed dispersal**. It **prevents competition** between the plant and its own seedlings for sunlight, water and minerals. It also enables the plants to invade new habitats for **wider distribution**.
- Seeds and fruits of plants are carried away by wind, water and animals. Winged seeds such as those of drumstick and maple **(Refer to Figure 12.33)**, light seeds of grasses or hairy seeds of aak (Madar) and hairy fruit of sunflowers get blown off with the wind to far away places. **(Refer to Figure 12.34)**
- Some seeds are dispersed by water. These fruits or seeds usually develop floating ability in the form of spongy or fibrous outer coat as in coconut. Some seeds are dispersed by animals, especially spiny seeds with hooks which get attached to the bodies of animals and are carried to distant places. Examples are **Xanthium** and **Urena**.
- Some seeds are dispersed when the fruits burst with sudden jerks. The seeds are scattered far from the parent plant. This happens in the case of **castor** and **balsam**.

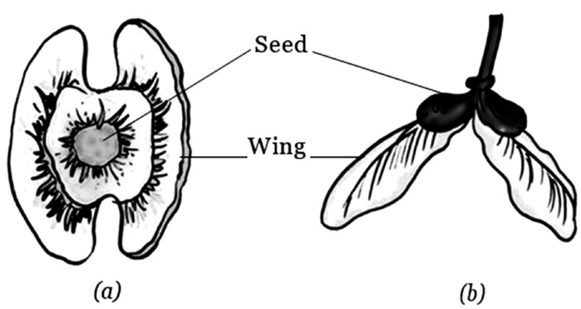


Figure 12.33: Seeds of (a) drumstick and (b) maple

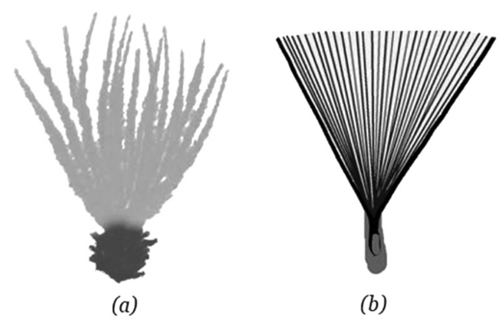


Figure 12.34: (a) The hairy fruit of sunflower and (b) hairy seed of madar (aak)

Conservation of Plants

A great variety of plants and animals exist on earth. They are essential for the well-being and survival of mankind. Plants play a foundational role, providing sustenance, shelter, and oxygen to an intricate web of organisms. However, in recent times, the harmonious balance between organisms has been threatened.

Deforestation

- Deforestation means clearing of forests and using that land for other purposes. Trees in the forest are cut for: Procuring land for cultivation, building houses and factories, making furniture or using wood as fuel.
- **Consequences of Deforestation**
  - It increases the temperature and pollution level on the earth. **Ground water level** also gets lowered.

- **Rainfall and the fertility** of the soil also decrease with increased chances of natural calamities such as floods and droughts. This depreciates the soil quality.
- Fewer trees results in increased levels of carbon-dioxide in the atmosphere. This can lead to **global warming** and increase in temperature on the earth.
- Fewer trees result in more soil erosion. Removal of the top layer of the soil exposes the lower, hard and rocky layers. This soil has less humus and is less fertile. Gradually the fertile land gets converted into deserts. It is called **desertification**.
- Deforestation also leads to a decrease in the **water holding capacity** of the soil. The movement of water from the soil surface into the ground (infiltration rate) is reduced. It increases the chances of floods and lesser flood resistance.

Reforestation

- Reforestation is restocking of the destroyed forests by planting new trees. The planted trees should generally be of the same species which were found in that forest.
- It can take place naturally also. If the deforested area is left undisturbed, it re-establishes itself. In natural reforestation there is no role of human beings.
- **The Forest (Conservation) Act, 1980**, is aimed at preservation and conservation of natural forests and meeting the basic needs of the people living in or near the forests.

Natural Causes of Deforestation

- Natural Fires caused by lightning strikes.
- Droughts
- Insect infestations (e.g., bark beetles) and diseases (e.g., Dutch Elm disease) can devastate large areas of forest.

Human-made Causes of Deforestation

- Agriculture
- Logging and timber production
- Infrastructure development
- Mining
- Urbanisation

Recycling of Paper

- It takes seventeen fully grown trees to make one tonne of paper. Therefore, paper must be saved and recycled atleast five to seven times before discarding it.
- Recycling paper not only saves trees but also saves energy and water needed for manufacturing paper. Moreover, the amount of harmful chemicals used in paper making will also be reduced.

Biosphere is that part of the earth in which living organisms exist or which supports life. Biological diversity or biodiversity, refers to the variety of organisms existing on the earth, their interrelationships and their relationship with the environment.

Conservation of Forest and Wildlife

- Apart from our personal efforts and efforts of the society, government agencies should also take care of the forests and animals. The government lays down rules, methods and policies to protect and conserve them. Wildlife sanctuaries, national parks, biosphere reserves etc., are protected areas for conservation of plants and animals present in that area. Killing (poaching) or capturing animals in general is strictly prohibited and punishable by law in all such places.
- **Biosphere Reserve:** These are the areas meant for conservation of biodiversity. Biosphere reserves help to maintain the biodiversity and culture of that area. A biosphere reserve may also contain other protected areas in it. Pachmarhi comprises three protection sites: the Bori Sanctuary, Satpura National Park and Pachmarhi Sanctuary – otherwise known as the Satpura Tiger Reserve. **(Refer to Figure 12.35)**

Figure 12.35: Pachmarhi Biosphere Reserve

- **Wildlife Sanctuary:** Wildlife Sanctuaries like reserve forests provide protection and suitable living conditions to wild animals. In wildlife sanctuaries, people living there are allowed to do certain activities such as grazing by their livestock, collecting medicinal plants, firewood, etc.
- **National Park:** These reserves are large and diverse enough to protect whole sets of ecosystems. They preserve flora, fauna, landscape and historic objects of an area. **Satpura National Park is the first Reserve Forest of India**. The finest Indian teak is found in this forest. Strict rules are imposed in all National Parks. Human activities such as grazing, poaching, hunting, capturing of animals or collection of firewood, medicinal plants, etc. are not allowed.

> **Rock shelters** are also found inside the **Satpura National Park**. These are evidence of prehistoric human life in these jungles. These give us an idea of the life of primitive people.
>
> Rock paintings are found in these shelters. A total of 55 rock shelters have been identified in Pachmarhi Biosphere Reserve. Figures of animals and men fighting, hunting, dancing and playing musical instruments are depicted in these paintings. Many tribes still live in the area.

Red Data Book

- It is the source book which keeps a record of all the endangered animals and plants. The Red Data Book is maintained internationally by **IUCN**. India also maintains a Red Data Book for plants and animals found in India. Animals whose numbers are diminishing to a level that they might face extinction are known as the **endangered animals**.
- Small animals are much more in danger of becoming extinct than the bigger animals. At times, snakes, frogs, lizards, bats and owls are killed without realising their importance in the ecosystem. They might be small in size but their role in the ecosystem cannot be ignored. They form part of **food chains and food webs**.

> **Endemic Species:** These are those species of plants and animals which are found exclusively in a particular area. They are not naturally found anywhere else. Example: Sal and Wild mango are endemic to Pachmarhi Biosphere reserve.

Conclusion

The world of plant organisms is diverse, filled with a wide array of species that play vital roles in our ecosystem. From providing us with oxygen, food, and medicine to supporting countless other organisms in their habitats, plants are essential for life on Earth. The study of plant organisms is vital for us to comprehend the world of flora around us and the processes that plants undergo to provide humans with nutrition, which is the bedrock of existence. Lately, human activities, such as deforestation, habitat destruction, and pollution, have posed significant threats to plant life and biodiversity. To ensure the continued existence of these valuable organisms, it is our responsibility to protect plant organisms from further destruction.

Some of the **threatened wild animals** like black buck, white eyed buck, elephant, golden cat, pink headed duck, gharial, marsh crocodile, python, rhinoceros, etc., are protected and preserved in wildlife sanctuaries.

Indian sanctuaries have unique landscapes — broad leaved forests, mountain forests and bush lands in deltas of big rivers.

Glossary:

- **Asexual reproduction:** Reproduction without the involvement of gametes, resulting in genetically identical offspring.
- **Budding:** A form of asexual reproduction where a new organism develops as an outgrowth or "bud" from the parent.
- **Embryo:** The early stage of development in a multicellular organism.
- **Fertilisation:** The process of combining male and female gametes (sperm and egg) to form a zygote.
- **Fragmentation:** A method of asexual reproduction where an organism splits into smaller pieces, each of which can grow into a new individual.
- **Gametes:** Specialised cells (sperm and egg) that fuse during fertilisation to form a zygote.
- **Hypha:** A thread-like structure in fungi that makes up the body of the organism.
- **Ovule:** The structure in plants that contains the female gamete (egg) and develops into a seed after fertilisation.
- **Pollen grain:** The male reproductive structure in plants that carries the male gamete (sperm).
- **Pollen tube:** A tube that grows from a pollen grain to deliver sperm to the female reproductive structures in plants.
- **Pollination:** The transfer of pollen from the male reproductive organ to the female reproductive organ in plants.
- **Seed dispersal:** The process by which seeds are spread away from the parent plant to facilitate germination and growth.
- **Sexual reproduction:** Reproduction involving the fusion of gametes, resulting in genetically diverse offspring.
- **Spore:** A small, usually single-celled reproductive structure capable of developing into a new individual.
- **Sporangium:** A structure that produces and contains spores in many fungi and some plants.
- **Vegetative propagation:** A method of asexual reproduction where new plants grow from vegetative structures like stems, roots, or leaves.
- **Zygote:** The cell formed by the fusion of male and female gametes during fertilisation.
- **Autotrophic:** Organisms capable of producing their own food through photosynthesis or chemosynthesis.
- **Chlorophyll:** The green pigment in plant cells that plays a central role in photosynthesis.
- **Heterotrophs:** Organisms that obtain their food by consuming other organisms or organic matter.
- **Host:** An organism that provides a habitat or nourishment to another organism, often a parasite.
- **Insectivorous:** Organisms that primarily feed on insects.
- **Nutrient:** Substances necessary for the growth, development, and maintenance of living organisms.
- **Nutrition:** The process by which organisms obtain and use nutrients from their environment.
- **Parasite:** An organism that lives in or on another organism (the host) and derives nutrients at the host's expense.
- **Saprotrophic:** Organisms that obtain nutrients by decomposing and absorbing organic matter from dead or decaying organisms.
- **Stomata:** Small openings or pores on the surface of plant leaves and stems that regulate gas exchange and water loss.

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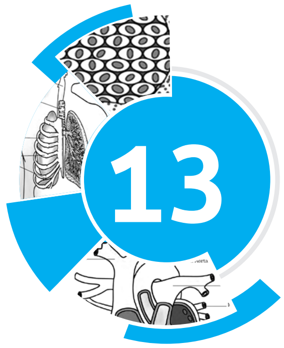


Animal Organisms

Bibliography: This chapter encompasses the summary of **Chapter 7 - Class X** (Science), **Chapters 2, 5, and 6 - Class VIII** (Science), **Chapters 2, 6, and 7 - Class VII** (Science) and **Chapter 6 - Class VI** (Science).

Introduction

This chapter encompasses the intricate details of organisms and their adaptability to diverse habitats. It explores human bodily functions, such as breathing and circulation, and examines various animal habitats from deserts to oceans. Each environment presents its own unique challenges, and the resident organisms have evolved specific adaptations to thrive. Additionally, defining characteristics that differentiate living from non-living entities are discussed, providing a comprehensive understanding of life on Earth.

Organisms

An organism is a living thing that can function on its own. It has an organised structure and can react to stimuli, reproduce, grow, and adapt to various environmental conditions.

Characteristics of Organisms

- **Living:** Humans, animals, and plants are living. The ability to talk, move, or grow does not solely define living things.
- **Growth:** Living organisms like plants and animals grow in size over time. While clouds may appear to grow.
- **Movement:** Many living organisms, especially animals, exhibit movement. However, not all living things move in an observable manner, such as plants. Movement alone does not define life, as non-living entities like cars also move.

Habitat and Adaptation

- A habitat is the natural environment of an organism.
- Adaptation refers to the specific features or habits that allow an organism to live naturally in a particular environment.
- **Variety in Habitats:** Diverse habitats range from the cold of the Himalayas to the hot deserts of Rajasthan and the humid beaches of coastal regions. Each habitat, despite its unique conditions, is home to a myriad of life forms, showcasing the adaptability of organisms.

Organisms and their Surroundings

- Different locations are populated by distinct organisms that have adapted to their unique conditions. For instance, deserts are home to camels, while seas are dominated by a variety of fish species.

- The immediate environmental conditions, like air and water availability, determine the organisms present.

Components of Habitats

- **Biotic Components:** These are the living organisms in a habitat.
- **Abiotic Components:** These include non-living elements like rocks, soil, air, and water. Sunlight and heat are examples of abiotic components.

Types of Habitats

Terrestrial Habitats

These are land-based environments like forests, grasslands, deserts, coastal areas, and mountain regions. They are as follows:

1. Deserts

- It is an area where there is an intense amount of heat and scarcity of water.
- Animals like rats and snakes avoid the heat by staying in burrows during the day and are active at night.

> **Camel Adaptations for Desert Conditions:** They have long legs to keep away from sand's heat. The Desert Survivor possesses long legs to keep its body away from the heat of the sand. Camels have efficient water retention abilities, which are evident as they excrete minimal urine, produce dry dung, and rarely sweat.

2. Mountain Regions

- Cold, windy, possible snowfall during winters.
- Animals have thick skin or fur for insulation in these regions.
- Species like Yaks possess long hair for warmth in low temperature. Snow leopards have thick fur, even on their feet.
- On the other hand, Mountain goats possess strong hooves for navigating rocky terrain.

3. Grasslands

- Grassland Ecosystem is an area where the vegetation is dominated by grasses and other herbaceous (non-woody) plants.
- **Lion's Features:** The light brown colour aids in camouflage. Eyes in front for accurate prey location. They have retractable claws on their front legs for hunting.
- **Deer's Features:** They have strong teeth for chewing hard plant stems. Long ears for detecting predators. Eyes on the sides of the head for a panoramic view of potential threats. They have speed for escaping from predators.

Aquatic Habitats

- Environments such as lakes, rivers, and oceans where organisms thrive in water.
- **Fish adaptations:** They have a streamlined body for efficient movement; and gills for extracting oxygen from water. They have a streamlined body shape for efficient movement in water. Their bodies are covered in slippery scales that offer protection and aid in mobility. Gills allow them to utilise the oxygen dissolved in water.
- **Squids and Octopuses:** They lack a streamlined shape but can make their bodies streamlined when moving. They Primarily reside near the seabed. Equipped with gills for using dissolved oxygen.
- **Dolphins and Whales:** They lack gills; instead, they have nostrils or blowholes on their heads. Breathe in air when near the surface, but can remain submerged for extended periods.

Microorganisms

- Microorganisms are living things that are too small to be seen with the naked eye. They can only be viewed under a microscope.
- Some, like bread fungus, can be viewed with a magnifying glass, while others need a microscope for observation.
- Water and soil are abundant with tiny organisms, many of which are microorganisms.
- Microorganisms are classified into four major groups. These groups are bacteria, fungi, protozoa, and some algae. **(Refer to Figure 13.1)**

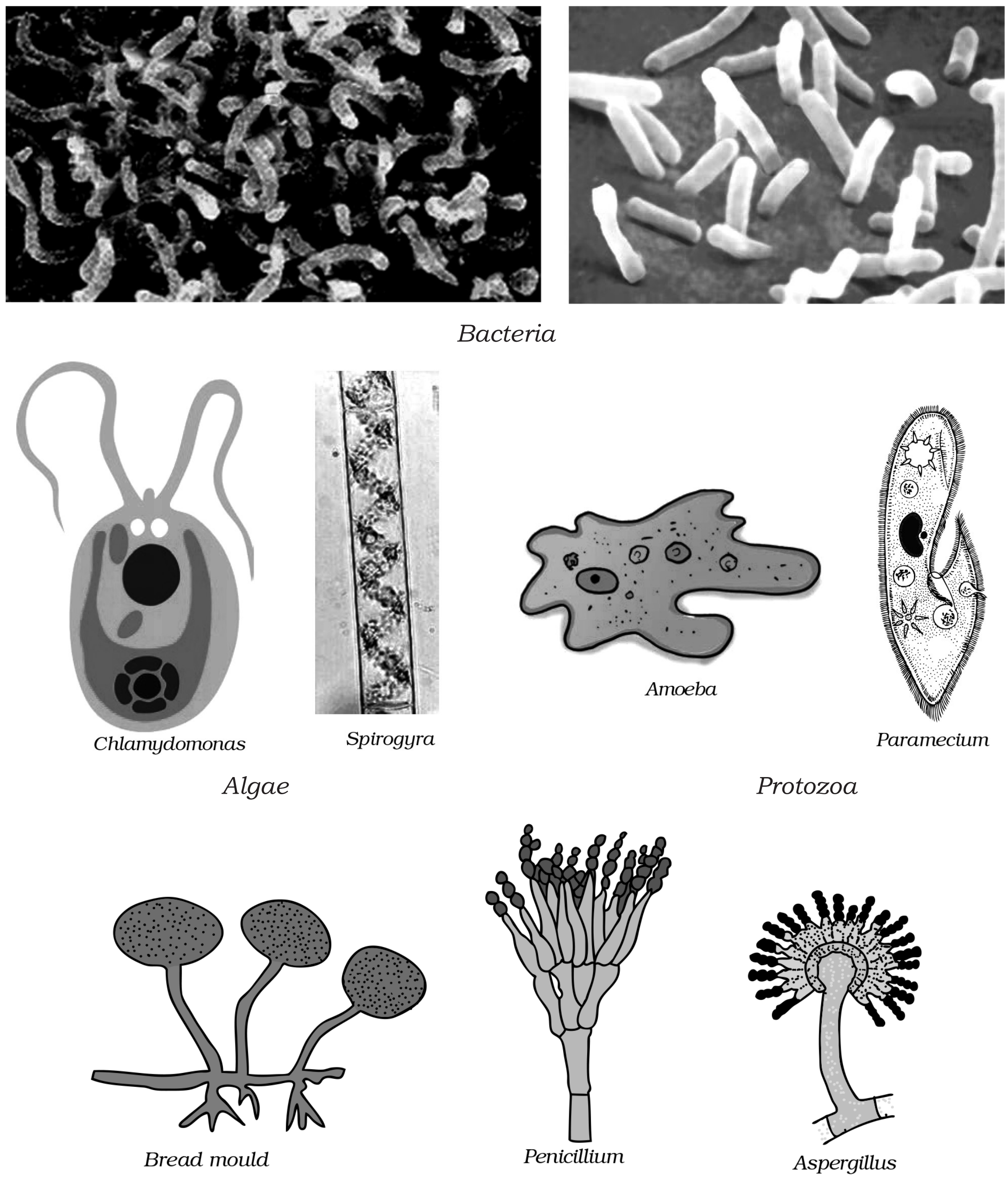


Fig. 13.1: Types of Microorganisms

Habitat of Microorganisms

- Extremely cold regions like ice.
- Hot environments, such as hot springs.
- Dry areas like deserts.
- Wet regions, such as marshlands.
- They are also present inside animal bodies, including humans.
- Some microorganisms live on host organisms.
- Others live independently, without relying on a host.

Viruses

- While viruses are microscopic, they differ from other microorganisms.
- They reproduce exclusively within the host organism's cells, which could be a bacterium, plant, or animal.
- They cause various diseases, ranging from common colds and influenza to severe conditions like polio and chicken pox. **(Refer to Figure 13.2)**

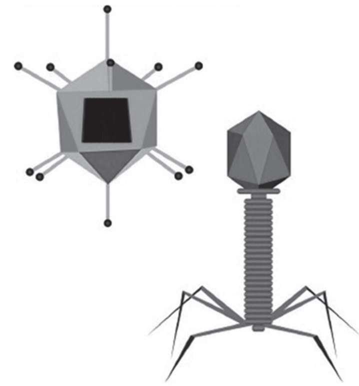


Figure 13.2: Virus

Reproduction in Microorganisms

Importance of DNA in Reproduction:

- Organisms look similar due to similar body designs. For similar body designs, the blueprints (or genetic information) must also be similar.
- Chromosomes in the nucleus contain inheritance information in the form of DNA. DNA serves as the information source for protein synthesis.
- Changes in DNA information lead to the creation of different proteins, which can result in altered body designs.
- Therefore, a basic event in reproduction is the creation of a DNA copy.

> Diseases like dysentery and malaria are caused by protozoa (protozoans) whereas typhoid and tuberculosis (TB) are bacterial diseases.

DNA Copying Mechanism:

- Cells reproduce by creating a copy of their DNA through chemical reactions. This results in two DNA copies in a reproducing cell.
- Both DNA copies need to be separated. Simply pushing one DNA copy out is not feasible as it lacks the cellular structure to sustain life.
- Hence, DNA copying is followed by the creation of an additional cellular structure. The cell then divides, resulting in two new cells.

> **POINTS TO PONDER**
> Viruses have been said to be living at the edge of life transitioning between living and non living . Think about why that is and the role of Virus in the evolution of life.

Accuracy and Variation in DNA Replication:

- Cells arising from reproduction are similar but not necessarily identical. The accuracy of the DNA copying process determines the similarity between the original and new cells.
- Bio-chemical reactions, including DNA copying, are not 100% accurate. Variations can occur during DNA copying, leading to subtle differences between the original and new DNA.
- Some variations can be so drastic that the new cell might not survive. However, many variations are subtle and do not impact the cell's survival.

The Importance of Variation and Reproduction and its Significance:

- Variation refers to the differences in characteristics among individuals within a population. Organisms occupy specific niches in ecosystems due to their reproductive abilities.
- Consistency in DNA copying during reproduction ensures the maintenance of body design features, which allow organisms to thrive in their specific niches. Reproduction contributes to the stability of species populations.
- Niches can undergo changes due to various external factors like fluctuations in temperatures, variations in water levels, and meteorite impacts, among others. If a niche changes drastically and organisms are only suited for the original niche, the entire population could be at risk.
- **Importance of Variation for Survival:**
  - Variation within a population increases the chances of survival when facing environmental changes.
  - For instance, in a population of bacteria living in temperate waters, if the temperature increases due to global warming, most bacteria might die. However, bacteria variants resistant to heat would survive and proliferate.
  - Thus, variation acts as a protective mechanism, ensuring the survival of species over time.
  - The ways organisms reproduce are determined by their body designs. We will discuss types of reproduction simultaneously in this chapter.

Modes of Reproduction in Microorganisms

- Depending on the number of parents involved, there are different modes of reproduction. Every living organism reproduces by either of the two modes i.e., sexual reproduction or asexual reproduction. Microorganisms can reproduce asexually or sexually.
- In asexual reproduction, a single microbe produces two identical offspring without the help of a partner. In sexual reproduction, two microbes mix their genetic information and so their offspring are genetically different. In this chapter, we'll discuss the asexual mode of reproduction by microorganisms.

Asexual Reproduction

- It is the mode of production that involves only one organism. The offspring that is produced is genetically identical to the mother and almost always has the same number of chromosomes, which are called clones.
- Asexual reproduction can happen in various ways, which are explained below:

Fission

- Fission is a form of asexual reproduction where a single cell divides to produce two or more separate daughter cells.

Patterns of Fission in Unicellular Organisms

- For unicellular organisms, fission results in the creation of new individuals. Different patterns of fission have been observed among various organisms:
- **Binary Fission:** It is common in many bacteria and protozoa. The organism splits into two roughly

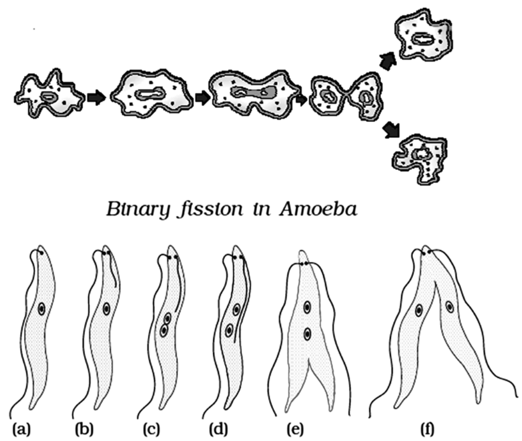


Figure 13.3: Binary fission in Amoeba and Binary fission in Leishmania

equal halves. In organisms like the Amoeba, the split can occur in any plane. In more organized unicellular organisms, such as Leishmania (which causes kala-azar), the division occurs in a specific orientation due to the presence of structures like a whip-like tail. **(Refer to figure 13.3)**

- **Multiple Fission:** It is observed in organisms like the malarial parasite Plasmodium. The organism divides into many daughter cells simultaneously. **(Refer to figure 13.4)**

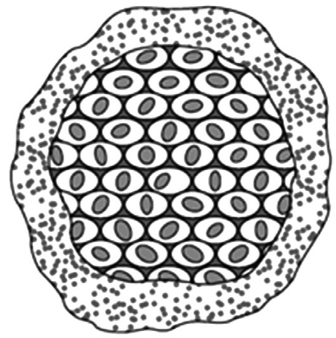


Figure 13.4: Multiple fission in Plasmodium

Fragmentation

- Fragmentation is a form of asexual reproduction where an organism breaks into fragments, and each fragment develops into a mature, fully-grown individual.

Fragmentation in Simple Multicellular Organisms

- In multicellular organisms with basic body organisation, like Spirogyra, simple reproductive methods such as fragmentation are effective.
- Upon maturation, Spirogyra breaks into smaller fragments. These fragments then grow into new individual organisms.

Complexities in Multicellular Organisms

- Not all multicellular organisms can reproduce through simple cell-by-cell division.
- Many multicellular organisms have specialized cells organized into tissues, which in turn form organs.
- These organs have specific positions in the body, making cell-by-cell division impractical.
- Hence, complex multicellular organisms require more intricate reproductive methods.

Specialised Reproduction in Multicellular Organisms

- Multicellular organisms exhibit specialisation, where different cell types perform distinct functions.
- Reproduction in these organisms is typically the role of a specific cell type.
- For successful reproduction, there must be a unique cell type within the organism capable of growing, proliferating, and producing other cell types when conditions are favourable.

Regeneration

- Regeneration is the ability of fully differentiated organisms to develop into new individuals from their body parts.

Regenerative Abilities of Organisms

- Many organisms can regenerate or grow into complete beings from their body fragments.
- For instance, simple animals like Hydra and Planaria exhibit this ability. **(Refer to figure 13.5)**
- If these animals are cut or broken into multiple pieces, each fragment has the potential to grow into a complete organism.

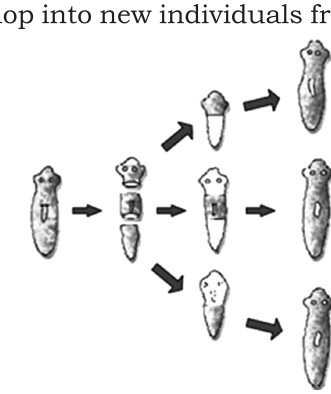


Figure 13.5: Regeneration in Planaria

Mechanism of Regeneration

- Regeneration is facilitated by specialised cells.
- These cells undergo proliferation, creating a large number of cells.
- From this collective cell mass, differentiation occurs, where cells transform into various cell types and tissues.
- This transformation process, where cells follow an organized sequence to form different tissues, is termed development. A basic difference between regeneration and reproduction is shown in Table 13.1.

Table 13.1: Difference between Regeneration and Reproduction

Criteria	Regeneration	Reproduction
Definition	Growth of an organism from a fragment of its body.	Natural process of producing offspring.
Dependence of Fragmentation	Yes (organisms can grow from their body fragments).	No (organisms typically don't rely on being fragmented).

Budding

- Budding is a form of asexual reproduction in which a new organism develops from an outgrowth, or bud, due to cell division at one particular site on a parent organism.

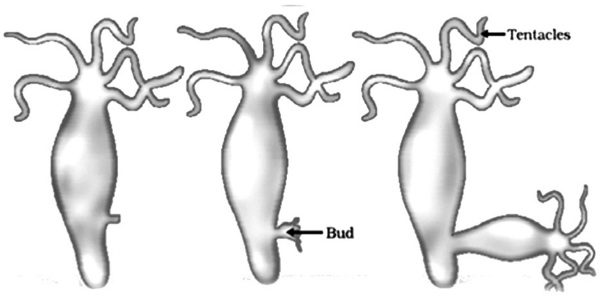


Figure 13.6: Budding in Hydra

Budding Process in Hydra

- Hydra is an organism that utilizes regenerative cells for reproduction through budding.
- A bud emerges as an outgrowth on the hydra due to consistent cell division at a specific location **(Refer to Figure 13.6).**
- These buds grow and evolve into small, individual organisms.
- Upon reaching maturity, these buds detach from the parent organism and transform into new, independent individuals.

Story of Dolly, the First Cloned Mammal

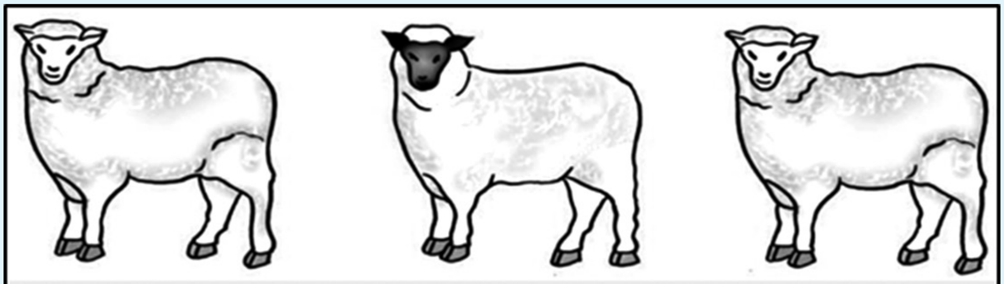
Cloning refers to the production of an exact replica of a cell, a specific living part, or an entire organism.

Dolly's Historic Birth

- Dolly, a sheep, holds the distinction of being the first mammal to be cloned.
- She was born on 5th July 1996, a significant achievement by Ian Wilmut and his team at the Roslin Institute in Edinburgh, Scotland.

Process of Cloning Dolly

- A cell was extracted from the mammary gland of a Finn Dorsett sheep.
- Concurrently, an egg was taken from a Scottish blackface ewe.
- The nucleus of this egg was removed and replaced with the nucleus from the Finn Dorsett sheep's mammary gland cell.
- This modified egg was then implanted into the Scottish blackface ewe.
- Dolly developed from this egg, and although she was born by the Scottish blackface ewe, she was genetically identical to the Finn Dorsett sheep.



(a) Finn Dorsett sheep (b) Scottish blackface ewe (c) Dolly

Significance and Legacy of Dolly

- Dolly did not exhibit any traits of the Scottish blackface ewe, demonstrating the complete genetic influence of the Finn Dorsett sheep.
- Dolly lived a relatively normal life, producing offspring through regular reproductive means.
- Unfortunately, she passed away on 14th February 2003 due to a specific lung ailment.

Cloning Post-Dolly

- Following the success of Dolly, numerous efforts have been undertaken to clone other mammals.
- However, many of these cloned animals either perish before reaching full term or shortly after birth.
- Notably, many clones have manifested severe abnormalities, indicating the challenges and complexities inherent in the cloning process.

Uses of Microorganisms

- Microorganisms have significant roles in our lives, both beneficial and harmful. Friendly microorganisms are used in food preparations like curd, bread, and cake. They are important in environmental clean-up as they break down organic waste into harmless substances. They are utilised in medicine preparation. They enhance soil fertility through nitrogen fixation.

> Microorganisms have been used for the production of alcohol since ages.

Making of Curd and Bread

- Bacterium, Lactobacillus, promotes curd formation by converting milk.
- Bacteria and yeast aid in food fermentation, such as in idlis and dosa batter.
- Yeast's carbon dioxide production during respiration is used in the baking industry.

Louis Pasteur discovered fermentation in 1857.

Commercial Use of Microorganisms

- Microorganisms, especially yeast, aid in producing alcohol, wine, and acetic acid.
- The process of converting sugar into alcohol using yeast is termed as fermentation.

Edward Jenner discovered the vaccine for small-pox in 1798.

Medicinal Use of Microorganisms

- Antibiotics, sourced from microorganisms, combat disease-causing microbes.
- **Examples:** Streptomycin, tetracycline, erythromycin.
- Antibiotics are also added to livestock feed to prevent microbial infections and control plant diseases.

Vaccination

- Introducing dead or weakened microbes into a healthy body makes it produce antibodies against those microbes.
- These antibodies provide protection against certain diseases.
- Vaccination can prevent diseases like cholera, tuberculosis, smallpox, and hepatitis.

In 1929, Alexander Fleming was working on a culture of disease-causing bacteria. Suddenly he found the spores of a little green mould in one of his culture plates. He observed that the presence of mould prevented the growth of bacteria. In fact, it also killed many of these bacteria. From this the mould penicillin was prepared.

Increasing Soil Fertility and Cleaning the Environment

- Certain bacteria can fix atmospheric nitrogen, enriching the soil and enhancing its fertility; these bacteria are known as biological nitrogen fixers.
- Microorganisms assist in converting plant and food wastes into manure.

Harmful Microorganisms

While many microorganisms are beneficial, several are harmful and cause diseases in humans, plants, and animals. These disease-causing entities are termed as **pathogens**. Refer to Table 13.2

Table 13.2: Some Common Human Diseases caused by Microorganisms

Human Disease	Causative Microorganism	Mode of Transmission	Preventive Measures (General)
Tuberculosis Measles Chicken Pox Polio	Bacteria Virus Virus Virus	Air Air Air/Contact Air/Water	Keep the patient in complete isolation. Keep the personal belongings of the patient away from those of the others. Vaccination to be given at suitable age.
Cholera Typhoid	Bacteria Bacteria	Water/Food Water	Maintain personal hygiene and good sanitary habits. Consume properly cooked food and boiled drinking water. Vaccination.
Hepatitis A	Virus	Water	Drink boiled drinking water. Vaccination.
Malaria	Protozoa	Mosquito	Use mosquito net and repellents. Spray insecticides and control breeding of mosquitoes by not allowing water to collect in the surroundings.

Diseases in Humans

- Pathogens can invade our systems via the air, water, food, or direct contact.
- Diseases that spread from an infected individual to a healthy one are termed communicable diseases.
- **For Examples:** Cholera, common cold, chicken pox, and tuberculosis.
- The common cold, for instance, spreads when an infected person sneezes, releasing virus-laden droplets into the air.

Certain insects and animals act as carriers for these pathogens

- Houseflies, which frequent garbage and excreta, can transfer pathogens to uncovered food.
- Female **Anopheles mosquito** carries the malaria parasite.
- Female **Aedes mosquito** is a carrier of the dengue virus.

Preventive Measures

- Always cover food and avoid consuming exposed food items.
- Prevent water accumulation to stop mosquito breeding.
- Maintain clean and dry surroundings.

Robert Köch (1876) discovered the bacterium (*Bacillus anthracis*) which causes anthrax disease.

Diseases in Animals

- Microorganisms also inflict diseases on animals.
- **Anthrax** affects both humans and cattle and is caused by a bacterium.
- The foot and mouth disease in cattle is due to a virus.

Reproduction: Viviparous and Oviparous Animals

- **Viviparous Animals:** Animals that give birth to live young ones. Animals such as dogs, cows, and cats do not lay eggs. Instead, they give birth to live offspring.
- **Oviparous Animals:** Animals that reproduce by laying eggs. Some animals, like certain birds and reptiles, lay eggs outside their bodies. These eggs can be easily observed and collected.

From Young Ones to Adults

- New individuals, whether born or hatched from eggs, continue to grow until they reach adulthood.
- In some species, young ones may appear drastically different from their adult counterparts.

Case Study: Life Cycle of a Frog

- **Distinct stages:** Egg → Tadpole (larva) → Adult. **(Refer to figure 13.7)**
- Tadpoles, which are in the larval stage, look significantly different from adult frogs.
- Tadpoles undergo a transformation process to become adult frogs. This transformation is termed **metamorphosis**.

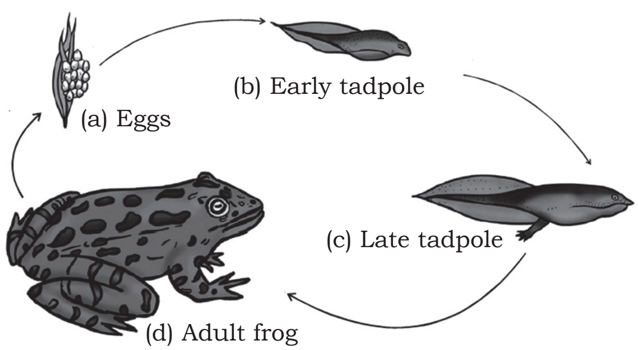


Figure 13.7: Life cycle of frog

Metamorphosis in Humans

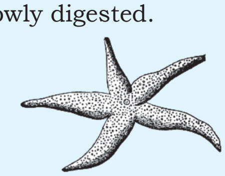
- Unlike certain animals, humans do not undergo drastic metamorphosis.
- Human body parts present at birth are similar to those in adulthood, and they grow and develop as the individual matures.

Nutrition in Animals

- Animal nutrition encompasses the nutrient requirements, the method of food intake, and how the body utilises it.
- **Digestion:** It refers to the conversion of complex food components into simpler substances. The components of food such as carbohydrates are complex substances. These complex substances cannot be utilized as such. So they are broken down into simpler substances. The breakdown of complex components of food into simpler substances.

AMAZING FACTS

Starfish feeds on animals covered by hard shells of calcium carbonate. After opening the shell, the starfish pops out its stomach through its mouth to eat the soft animal inside the shell. The stomach then goes back into the body and the food is slowly digested.



Diverse Modes of Food Intake

Different organisms have varied ways of consuming food:

- Bees and hummingbirds extract nectar from plants.
- Human infants and many other animals rely on the mother's milk.
- Predators like the python consume by swallowing their prey whole.
- Certain aquatic species filter and consume minuscule food particles from the water around them.

Human Digestive System

- Human nutrition encompasses the intake, breakdown, and utilisation of food, which involves the process of breaking down complex food components into simpler substances. **(Refer to figure 13.8)**
- Inside the body, the food passes through a continuous canal which begins at the buccal cavity and ends at the anus.
- **Canal or Alimentary Canal:**
  - **The canal can be divided into various compartments:** (1) the buccal cavity, (2) the food pipe or oesophagus, (3) the stomach, (4) the small intestine, (5) the large intestine ending in the rectum and (6) the anus.

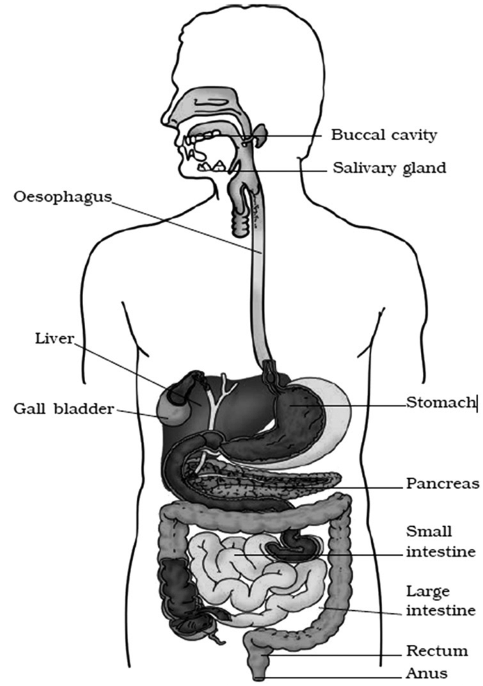


Figure 13.8: Human Digestive System

Let's discuss all these parts in detail

- **Buccal Cavity (mouth):** Ingestion is the process of taking in food. Food is chewed by teeth and broken down mechanically. The tongue assists in mixing, tasting, and swallowing the food. **(Refer to figure 13.9)**
- **Oesophagus (food pipe):** Swallowed food travels down the oesophagus, which connects the mouth to the stomach. **(Refer to figure 13.10)**
- **Stomach:** It is a J-shaped bag that receives food from the oesophagus. The inner lining secretes mucus, hydrochloric acid, and digestive juices. These secretions help in the breakdown of proteins.

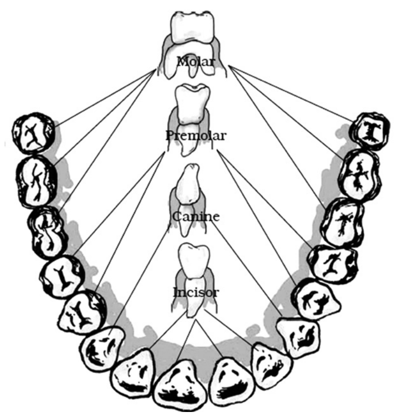


Figure 13.9: Arrangement of teeth and different type of teeth

Diarrhoea

Diarrhoea, characterized by frequent watery stools, can arise from infections, food poisoning, or indigestion. It's a prevalent ailment in India, especially among children, and can be life-threatening due to the substantial loss of water and salts. Immediate attention is crucial. Before seeking medical advice, the affected individual should consume an Oral Rehydration Solution (ORS), which consists of boiled and cooled water with a pinch of salt and sugar.

Discovery of Stomach Function

Accidental Revelation:

- In 1822, Alexis St. Martin suffered a severe gunshot wound which left a hole in his chest and stomach.
- He was treated by an American army doctor, William Beaumont, who managed to save him but couldn't completely close the stomach hole.

Beaumont's Observations:

- Using this unintentional opening as an opportunity, Beaumont conducted studies on the working of the human stomach.
- He noticed the stomach churned food.
- He observed the stomach wall secreted a digestive fluid.
- He identified that the stomach only transferred its contents to the intestine after the digestion process was complete.

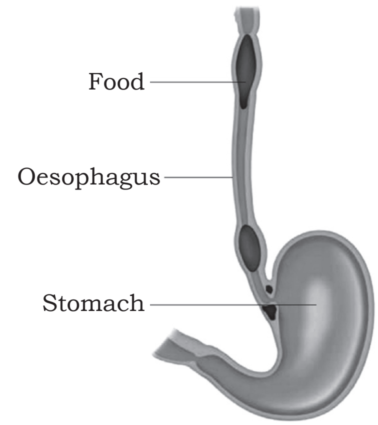


Figure 13.10: Movement of the food in the oesophagus of the alimentary canal

- **Small Intestine:** It is a coiled, 7.5-meter-long structure, and receives secretions from the liver and pancreas. It secretes bile juice that is stored in a sac called the gallbladder, which aids in fat digestion. The pancreas produces pancreatic juice that acts on carbohydrates, fats, and proteins. Final digestion occurs here, breaking down carbohydrates, fats, and proteins into simpler forms. The digested food is absorbed by villi present on the walls of the small intestine. This process is called absorption. The absorbed nutrients are then used by the body, a process called assimilation.
- **Large Intestine:** It is shorter (1.5 metres) but wider than the small intestine. Its main function is to absorb water and salts from the undigested food. The waste is stored as semi-solid faeces in the rectum and is periodically excreted through the anus, a process known as egestion.

Yeasts are single-celled organisms. They respire anaerobically and during this process yield alcohol. They are therefore, used to make wine and beer.

Respiration

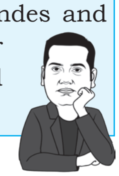
Respiration is a chemical process that living organisms use to release energy from food.

The Need for Respiration

- All organisms consist of cells that perform functions requiring energy.
- This energy is derived from food, which releases its stored energy during respiration.
- Breathing provides oxygen, which aids in the breakdown of food in cells. This is termed cellular respiration.

POINTS TO PONDER

Cellular respiration is key to producing ATP molecules which gives energy to cells. In higher altitudes where the amount of oxygen available declines, humans have gone through various Genetic and Physiological adaptation. Think about such adaptations making habitation of areas like Andes and Himalayas possible for humans who have evolved in grasslands of Africa.



Types of Respirations

- **Cellular Respiration:** The process of breakdown of food in the cell with the release of energy is called cellular respiration. Cellular respiration takes place in the cells of all organisms.
- **Aerobic Respiration:** It involves the breakdown of food (glucose) into carbon dioxide and water by using oxygen. When the breakdown of glucose occurs with the use of oxygen it is called aerobic respiration. **(Refer to figure 13.11)**

$$\text{Glucose} \xrightarrow[\text{of oxygen}]{\text{in the presence}} \text{carbon dioxide + water + energy}$$

Figure 13.11: Aerobic Respiration

- **Anaerobic Respiration:** Food can also be broken down, without using oxygen. This is called anaerobic respiration. Breakdown of food releases energy. Some organisms, like yeast, can function without oxygen through anaerobic respiration. In this process, glucose breaks down into alcohol and carbon dioxide. **(Refer to figure 13.12)**

$$\text{Glucose} \xrightarrow[\text{of oxygen}]{\text{in the absence}} \text{alcohol + carbon dioxide + energy}$$

Figure 13.12: Anaerobic respiration

Examples of Anaerobic Respiration

- Organisms like yeast that can survive without air are termed Anaerobes.
- Muscle cells in humans can also perform anaerobic respiration temporarily during activities like heavy exercise when oxygen supply is limited.
- Heavy exercises lead muscle cells to respire anaerobically, producing lactic acid. **(Refer to Figure 13.13)**

$$\underset{\text{(in muscle)}}{\text{Glucose}} \xrightarrow[\text{of oxygen}]{\text{in the absence}} \text{lactic acid + energy}$$

Figure 13.13: Production of lactic acide inside muscle

- The accumulation of lactic acid in muscles results in cramps. Relief from cramps can be achieved through hot water baths or massages, as they increase blood circulation, ensuring more oxygen supply to muscles. This facilitates the breakdown of lactic acid into carbon dioxide and water.

Human Breathing

- Breathing is the act of taking in oxygen-rich air and expelling carbon dioxide-rich air using respiratory organs. **(Refer to Figure 13.14)**
- The process of inhaling Oxygen rich air is called inhalation, while exhaling carbon dioxide rich air is termed **Exhalation**.
- Breathing is continuous and vital for an organism's life.
- A single breath consists of one inhalation followed by one exhalation.
- The breathing rate refers to the number of breaths taken in a minute.

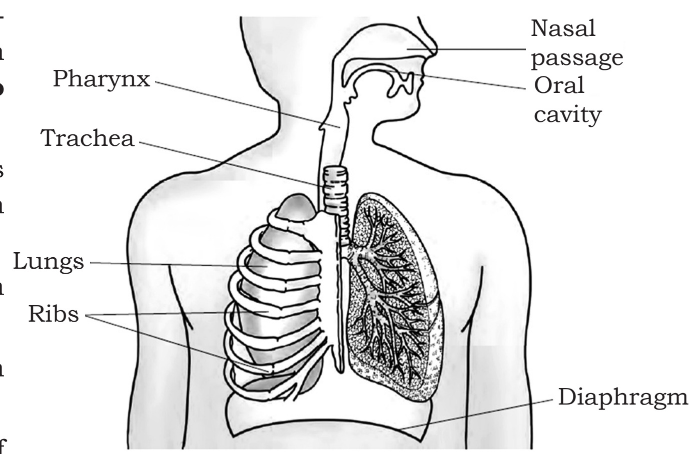


Figure 13.14: Human respiratory system

> The air around us has various types of unwanted particles, such as smoke, dust. pollens, etc. When we inhale, the particles get trapped in the hair present in our nasal cavity. However, sometimes these particles may get past the hair in the nasal cavity. This may irritate the lining of the cavity, as a result of which we sneeze. Sneezing expels these foreign particles from the inhaled air and a dust- free, clean air enters our body.

Mechanism of Breathing

- Breathing starts when air is inhaled through the nostrils.
- This air travels from the nostrils to the nasal cavity, then to the lungs via the windpipe.
- Lungs are located in the chest cavity, which is bounded by ribs and underlaid by the diaphragm muscle.
- **Inhalation** involves the ribs moving upwards and outwards, with the diaphragm descending, leading to the chest cavity expanding and air filling the lungs.
- During exhalation, the opposite happens: ribs move downward and inward, and the diaphragm rises, causing the chest cavity to contract and push air out of the lungs. **(Refer to Figure 13.15)**

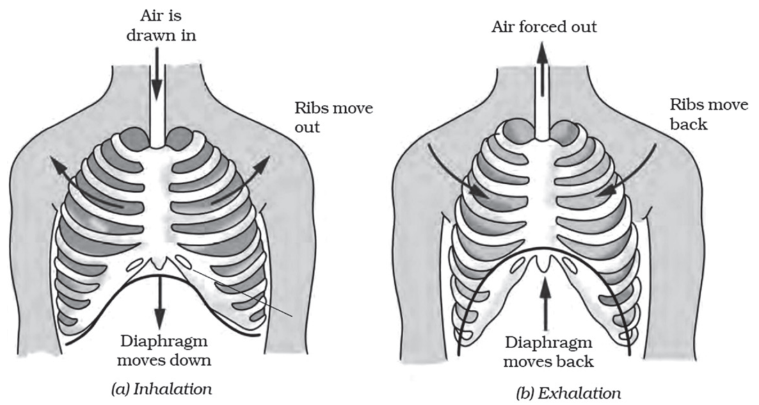


Figure 13.15: Mechanism of breathing in human beings

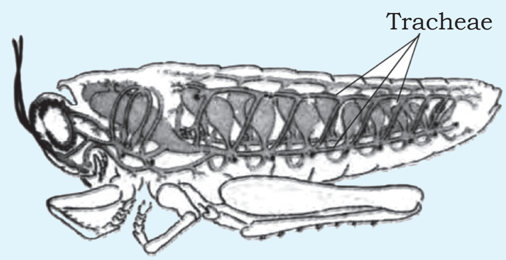
Breathing Mechanisms in Different Animals

Breathing in Terrestrial Animals

- Like humans, animals such as elephants, lions, cows, goats, frogs, lizards, snakes, and birds possess lungs in their chest cavities for respiration.

Insect Respiration: Cockroach

- Cockroaches, like many insects, possess small side openings termed **"spiracles".**
- Inside, they have a network of air tubes named tracheae, which are exclusive to insects.
- Oxygen-rich air enters through the spiracles, travels through the tracheal tubes, diffuses into the body tissue, and reaches each cell.
- Conversely, carbon dioxide from the cells travels into the tracheal tubes and exits via the spiracles.



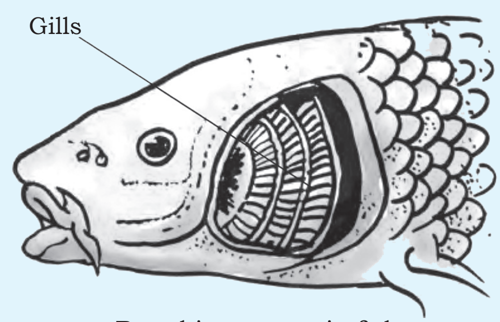
Cockroach Tracheal system

Earthworm Respiration

- Earthworms respire through their skin.
- Their skin is moist and slimy, facilitating gas exchange.
- Similarly, while frogs have lungs for respiration, their moist and slippery skin also allows them to breathe.

Aquatic Respiration: Breathing Underwater

- While humans cannot breathe underwater, many aquatic organisms have adapted mechanisms to do so.
- Fish, for example, use gills to extract oxygen dissolved in water.
- Gills, which are skin projections, are rich in blood vessels to assist in gas exchange



Breathing organs in fish

Human Circulatory System

- The human circulatory system is a network of blood vessels that move blood, nutrients, and oxygen throughout the body. **(Refer to figure 13.16)**

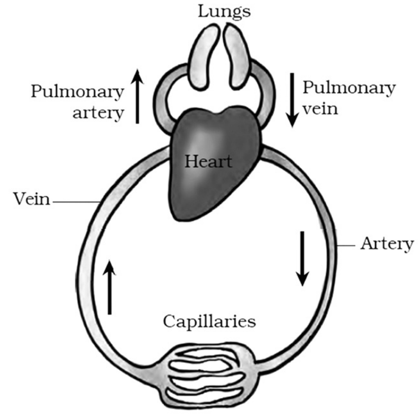


Figure 13.16: Schematic diagram of circulation

Blood

- Blood is the vital fluid flowing in vessels, responsible for transporting.
- Digested food from the small intestine.
- Oxygen from the lungs to cells.
- Waste from the body for excretion.

Components of Blood

- **Plasma:** The fluid where cells are suspended.
- **Red Blood Cells (RBC):** RBCs contain **haemoglobin** which binds and transports oxygen. Haemoglobin binds with oxygen and transports it to all the parts of the body and ultimately to all the cells. Gives blood its red colour.
- **White Blood Cells (WBC):** WBCs defend the body against germs.
- **Platelets:** The platelets play a key role in clotting, preventing excessive bleeding from injuries.
- **Blood Vessels:** There are different types of blood vessels in the body. They are pathways of Blood
- **Arteries:** They carry oxygen-rich blood from the heart to the body. They have thick, elastic walls due to high-pressure flow
- **Veins:** They transport carbon dioxide-rich blood back to the heart. They have thin walls and valves to ensure one-directional flow.
- **Capillaries:** These are tiny vessels where arteries and veins connect, facilitating the exchange of substances with cells.

Heart

- It is located in the chest cavity and is roughly the size of a fist.
- It comprises four chambers: two arteries (upper) and two ventricles (lower) to prevent the mixing of oxygen-rich and carbon dioxide-rich blood. **(Refer to Figure 13.17)**
- The heart's muscular walls contract and relax rhythmically, producing a heartbeat.
- The heart's function is to ensure continuous blood circulation throughout the body, carrying vital substances.

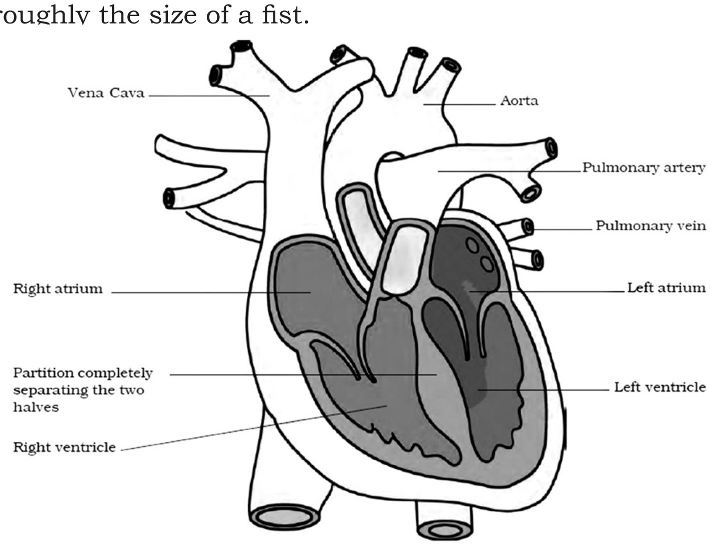


Figure 13.17: Sections of human heart

Heartbeat and Pulse

- A heartbeat is the rhythmic contraction and relaxation of the heart's chambers.
- A heartbeat can be felt on the left side

of the chest and heard using instruments like a stethoscope.

- Each heartbeat creates a pulse in the arteries, and the pulse rate indicates the heart rate. The two are directly related.

Excretion

- Excretion is the process of removing waste products produced in the cells of living organisms.
- These wastes are toxic and need to be eliminated from the body.
- The organs and parts involved in excretion collectively form the excretory system.

The Human Excretory System

- The human body, a complex and intricate system, constantly produces waste.
- Managing this waste efficiently is crucial for maintaining health, and that is where the excretory system comes into play. **(Refer to figure 13.18)**
- **The Kidneys:** The body possesses two bean-shaped kidneys that filter waste from the blood. These organs discerningly ensure that only waste is filtered out, retaining essential elements. Each capillary cluster in the kidney is associated with the cup-shaped end of a coiled tube called **Bowman's capsule** that collects the filtrate. Each kidney has large numbers of these filtration units called **nephrons (Refer to Figure 13.19)** packed close together. Some substances in the initial filtrate, such as glucose, amino acids, salts and a major amount of water, are selectively re-absorbed as the urine flows along the tube. The amount of water re-absorbed depends on how much excess water there is in the body, and on how much dissolved waste there is to be excreted.

> Sometimes a person's kidneys may stop working due to infection or injury. As a result of kidney failure, waste products start accumulating in the blood. Such persons cannot survive unless their blood is filtered periodically through an artificial kidney. This process is called **dialysis**.

- **Ureters:** Ureters serve as transport channels, directing the filtered waste, now termed urine, from the kidneys to the bladder.
- **Urinary Bladder:** The bladder functions as a reservoir, storing urine and signaling when evacuation is necessary.

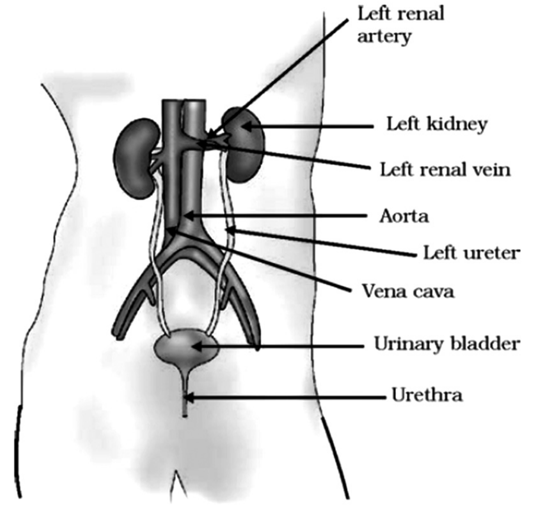


Figure 13.18: Human excretory system

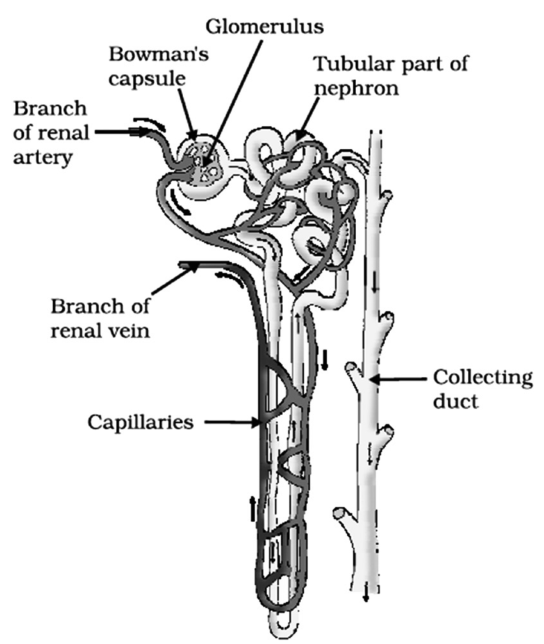


Figure 13.19: Structure of a Nephron

> The way in which waste chemicals are removed from the body of the animal depends on the availability of water. Aquatic animals like fishes, excrete cell waste as ammonia which directly dissolves in water. Some land animals like birds, lizards, snakes excrete a semi-solid, white coloured compound (uric acid). The major excretory product in humans is Urea.

- **Urethra:** The urethra signifies the final path through which urine exits the body.
- **Waste Composition:** Predominantly, urine comprises water, amounting to 95%. The residual 5% consists of urea and other waste materials. It's noteworthy that an average adult expels about 1–1.8 L of urine daily.
- **Additional Excretory Mechanism:** Beyond urine, the body also dispels waste via sweat, a concoction of water and salts. White marks on clothing after sweating can be attributed to these salts.

Sexual Reproduction

- Sexual reproduction is a mode of reproduction that requires the involvement of two individuals (male and female) to create a new generation, populations, enhancing the survival chances of species.
- Asexual reproduction has limitations in generating variations.

Generation of Variations

- DNA copying is not always accurate, leading to variations.
- Despite their precision, DNA-copying mechanisms result in slow variation generation.
- Combining variations from two different individuals creates novel combinations.
- Sexual reproduction merges DNA from two individuals, facilitating variation.

Challenges and Solutions in Sexual Reproduction

- A challenge in sexual reproduction is the potential doubling of DNA with each generation. This can disrupt cellular control by the DNA.
- **Solution:** Many multi-cellular organisms have special cell lineages in certain organs with half the chromosomes and DNA compared to non-reproductive cells. Achieved through a cell division process called meiosis. When germ cells from two individuals combine, they re-establish the chromosome and DNA content for the new generation.

Germ-cell Specialisation

- In simple organisms, germ cells might be similar or slightly different.
- **In complex organisms**, the germ-cells specialise. One germ cell is large and contains food stores (female gametes). The other is smaller and motile (male gamete). These specialisations lead to differences in male and female reproductive organs and, at times, in the bodies of male and female organisms.

Reproduction in Human Beings

- Sexual reproduction in humans is a mode where two individuals (male and female) participate to produce a new generation.

Growth and Changes During Puberty

- Humans undergo various growth phases, from an increase in height to changes in body features.
- However, during early teenage years, changes occur that are not just related to body enlargement.
- Both boys and girls experience the growth of thick hair in new body regions like armpits and genital areas, the appearance of thin hair on legs, arms, and face, oily skin and potential pimples, and heightened self-awareness and awareness of others.
- Gender-specific changes include an increase in breast size, darkening of nipple skin, and onset of menstruation for girls, while boys experience facial hair growth, voice cracking, and periodic erection of the penis.
- The changes during puberty vary in terms of timing and pace among individuals.

Purpose and Process of Sexual Maturation

- Sexual maturation prepares the body for reproduction. The creation of germ cells for sexual reproduction is a specialised function.
- While the body grows to adult size, its resources focus on growth. Once growth slows, reproductive tissues mature.
- The period of adolescence when reproductive tissues mature is termed puberty.

Significance of Sexual Maturity in Reproduction

- For sexual reproduction, germ cells from two individuals must unite. Sexual maturity signals, like hair growth patterns, indicate readiness for reproduction.
- The transfer of germ cells requires mature sexual organs, like an erect penis. In mammals, including humans, the baby is nurtured inside the mother's body and is breast-fed later, necessitating the maturity of female reproductive organs and breasts.

Have you heard of test tube babies?

In some women oviducts are blocked. These women are unable to bear babies because sperms cannot reach the egg for fertilisation. In such cases, doctors collect freshly released egg and sperms and keep them together for a few hours for **IVF or in vitro fertilisation (fertilisation outside the body)**. In case fertilisation occurs, the zygote is allowed to develop for about a week and then it is placed in the mother's uterus. Complete development takes place in the uterus the baby is born like any other baby. Babies born through this technique are called **test- tube babies**. The term is actually misleading because babies cannot grow in test tubes.

Male Reproductive System

- The male reproductive system is designed to produce and deliver germ cells (sperms) for the process of fertilization. **(Refer to figure 13.20)**

Parts of Male Reproductive System and Its Functions

- **Testes:** It is the primary organ for the production of germ cells or sperms. They are located outside the abdominal cavity within the scrotum. It requires a lower temperature than the body's normal temperature for effective sperm formation. It plays a role in secreting the hormone testosterone. Testosterone regulates sperm formation and induces appearance changes in boys during puberty. **(Refer to Figure 13.20)**
- **Vas Deferens:** It is responsible for delivering the formed sperms. It merges with a tube from the urinary bladder, leading to the formation of the urethra. The urethra serves as a common passage for both sperm and urine.
- **Prostate and Seminal Vesicles:** These are the glands situated along the vas deferens pathway. It contributes secretions to assist sperm transport and provide nutrition. The combined fluid aids in sperm mobility and sustenance.
- **Sperms:** They are minute entities primarily composed of genetic material. They are equipped with a long tail to facilitate movement towards the female germ cell. **(Refer to Figure 13.21)**

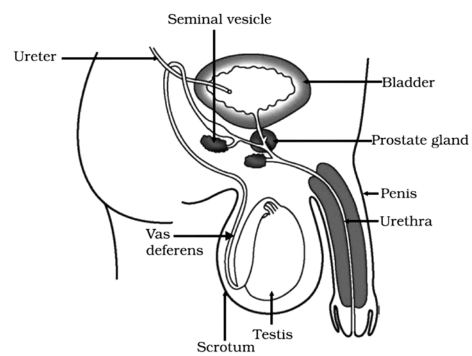


Figure 13.20: Human–male reproductive system

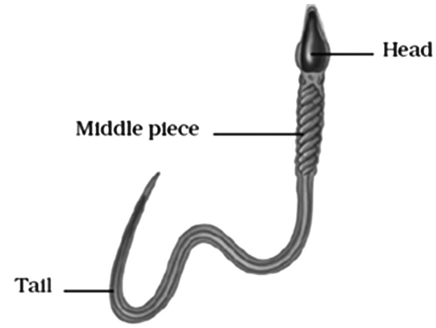


Figure 13.21: A Human Sperm

Female Reproductive System

- ✤ The female reproductive system is designed to produce germ cells (eggs) and facilitate their fertilisation, nurturing the embryo and foetus until childbirth. **(Refer to Figure 13.22)**

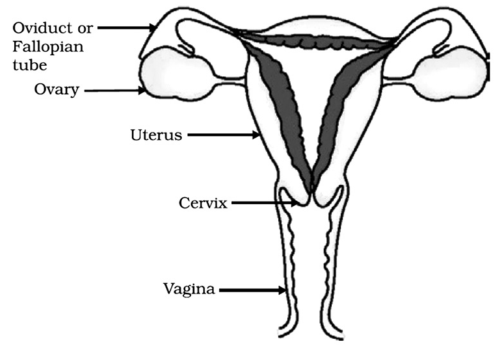


Figure 13.22: Human –female reproductive system

Components and Functions

- ✤ **Ovaries:** They are primary organs responsible for the production of female germ cells or eggs they also produce certain hormones. At birth, ovaries contain numerous immature eggs, with some maturing upon reaching puberty. One egg is produced monthly by an ovary. **(Refer to Figure 13.22)**
- ✤ **Oviduct or Fallopian Tube:** It transports the egg from the ovary to the uterus.
- ✤ **Uterus:** It is an elastic bag-like structure where the fertilised egg or embryo gets implanted and grows. It prepares its lining every month to receive and nurture the embryo, thickening it and ensuring it is rich in blood supply.
- ✤ **Vagina and Cervix:** The uterus opens into the vagina through the cervix. Sperm enter the body through the vaginal passage during sexual intercourse.
- ✤ **Fertilisation and Development:** Sperms may encounter the egg in the oviduct, leading to fertilisation. The fertilised egg (zygote) divides, forming an embryo that implants in the uterus lining. The embryo evolves into a foetus, getting its nutrition from the mother via the placenta. **(Refer to figure 13.23)**

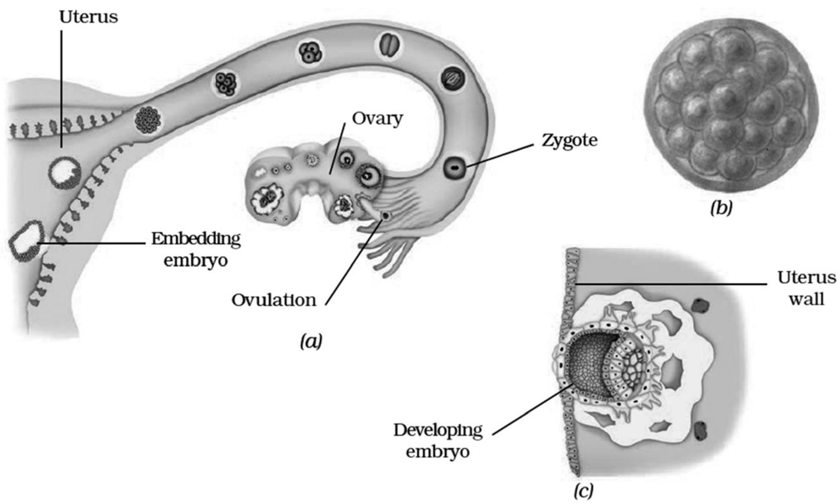


Figure 13.23: (a) Zygote formation and development of an embryo from the zygote; (b) Ball of cells (enlarged); (c) Embedding of the embryo in the uterus (enlarged)

- ✤ **Inheritance Through Fertilisation:** Fertilisation facilitates the union of an egg cell from the mother and a sperm cell from the father. The resulting offspring inherits characteristics from both parents. This can be observed by comparing siblings and noting similarities to either parent.
- ✤ **Placenta:** It is a special tissue embedded in the uterine wall. It facilitates the transfer of glucose, oxygen, and waste between the mother and the embryo. It contains villi on the embryo's side and blood spaces on the mother's side, providing a large surface area for nutrient and waste exchange.

Types of Fertilisation

Internal Fertilisation

- Occurs inside the female body.
- Common in various animals such as humans, cows, dogs, and hens.

External Fertilisation

- The male deposits sperms over the laid eggs. Sperms use their tails to swim and come into contact with the eggs, leading to fertilisation.
- This fusion of male and female gametes outside the female body is termed external fertilisation.
- Predominantly seen in aquatic animals like fish and starfish.

- **Embryo Development and Birth:** After fertilisation, a zygote is formed, which begins to develop into an embryo. This zygote undergoes multiple divisions to produce a ball of cells. As these cells progress, they group together to form different tissues and organs. When this developing structure embeds itself in the wall of the uterus, it is termed as an embryo. As development continues, distinct body parts like limbs, heads, eyes, and ears emerge. When all these body parts are identifiable, the embryo evolves into what is known as a foetus. Following the complete development of the foetus, the mother gives birth. **(Refer to Figure 13.24)**

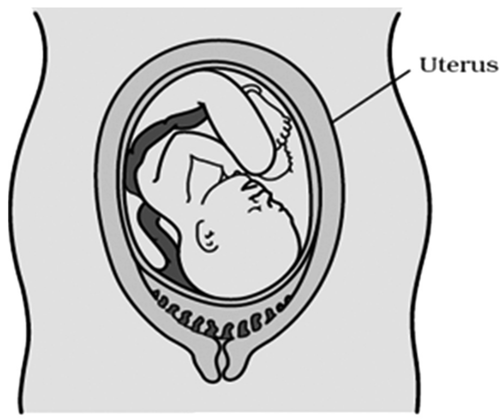


Figure 13.24: Foetus in the uterus

Process After Egg Is Not Fertilised

- Menstruation is a monthly cycle where the uterus sheds its lining in the absence of a fertilised egg.

Process and Implications

- If not fertilised, an egg survives for about a day.
- The uterus prepares its lining every month in anticipation of a fertilised egg.
- The lining becomes thick and spongy to potentially nourish an embryo.
- In the absence of fertilisation, the thickened uterine lining is no longer required.
- The lining breaks down and is expelled through the vagina as a combination of blood and mucous.
- This shedding process, termed as **Menstruation**, occurs roughly every month.
- The menstruation duration typically ranges from two to eight days.

Embryo Development in Hens: In hens, the process is slightly different. While they too undergo internal fertilisation, the zygote divides while travelling down the oviduct, gaining protective layers around it. One of these layers is the hard eggshell we commonly see. Once this shell forms, the hen lays the egg. Inside this eggshell, the embryo takes about 3 weeks to develop into a chick. To ensure the chick's development, hens often sit on their eggs to provide the necessary warmth. Upon full development, chicks break open the eggshell to come out.

External Fertilisation and Development: For animals that practice external fertilisation, the development of the embryo occurs outside the female's body. These embryos grow within their protective egg casings and, upon maturity, hatch. This is commonly seen in organisms like tadpoles that are found in ponds and streams.

Reproductive Health

Sexual Maturation and its Implications:

- Sexual maturation is a gradual process co-occurring with general body growth.
- Sexual maturation doesn't necessarily equate to readiness for sexual activities or child-rearing.
- Individuals face pressures from friends, family, and the government regarding sexual activities and procreation.

Sexual Health and Disease Transmission:

- Sexual intimacy can lead to the transmission of diseases.
- Diseases like gonorrhoea, syphilis, warts, and HIV-AIDS can be sexually transmitted.
- Condom usage during sex can prevent many such infections.

Contraception and Pregnancy Prevention:

- Pregnancy demands physical and mental preparation; hence, contraception is crucial. Following are some contraceptive methods:
- **Mechanical barriers:** Like condoms, prevent sperm from reaching the egg.
- **Hormonal methods:** Pills alter the hormonal balance to prevent egg release and fertilisation but may cause side effects.
- **Intrauterine devices:** Like loops or copper-T, can cause irritation in the uterus.
- **Surgical methods:** Blocking vas deferens in males or fallopian tubes in females prevents fertilisation. While safe long-term, surgical methods can cause immediate complications.
- **Abortion:** It is the surgical removal of unwanted pregnancies. It is misused in cases like illegal sex-selective abortions of female foetuses.

Concerns of Population Size:

- Expanding the human population affects the standard of living.
- Inequalities in society majorly contribute to poor living standards, making population size less significant.

Conclusion

Organisms demonstrate remarkable adaptability and resilience when faced with environmental challenges. Through a study of various habitats, from arid deserts to expansive oceans, it becomes evident that evolution has tailored each species to its surroundings. Whether it's the human circulatory system or the specific adaptations of a camel, nature finds a way to persevere. The distinction between living and non-living entities further underscores the complexity and beauty of life.

***Glossary*:**

- **Organism:** A living thing that can function independently. It possesses an organized structure and can react to stimuli, reproduce, grow, and adapt.
- **Habitat:** The natural environment of an organism.
- **Adaptation:** The specific features or habits that allow an organism to live naturally in a particular environment.
- **Breathing:** The act of taking in oxygen-rich air and expelling carbon dioxide-rich air using respiratory organs.
- **Heartbeat:** The rhythmic contraction and relaxation of the heart's chambers.
- **Pulse:** Created by each heartbeat, it can be felt in the arteries and indicates the heart rate.
- **Excretion:** The process of removing waste products produced in the cells of living organisms.
- **Plasma:** The fluid in which cells are suspended in the blood.
- **Red Blood Cells (RBC):** Cells that contain haemoglobin, which binds and transports oxygen throughout the body.
- **White Blood Cells (WBC):** Cells that defend the body against germs/pathogens.
- **Platelets:** Play a crucial role in clotting, preventing excessive bleeding from injuries.
- **Blood Vessels:** Pathways of blood, including arteries, veins, and capillaries.
- **Arteries:** Vessels that carry oxygen-rich blood from the heart to the body.
- **Veins:** Vessels that transport carbon dioxide-rich blood back to the heart.
- **Capillaries:** Tiny vessels where arteries and veins connect, facilitating the exchange of substances with cells.
- **Heart:** A muscular organ located in the chest cavity, responsible for ensuring continuous blood circulation throughout the body.

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Life Processes

Bibliography: This Chapter encompasses the summary of **Chapter 5 - Class VI**, **Chapter 7 - Class VIII** and **Chapters 5, 6, 7 and 8 - Class X** of Science NCERT.

Introduction

Exploring the intricate tapestry of life processes, this chapter encapsulates the essence of growth, movement, reproduction, and co-ordination. From the microscopic world of cells to the grandeur of human anatomy, each page unfolds the wonders of life. This chapter delves into the mechanisms that sustain living organisms, showcasing the harmonious interplay of biology's fundamental elements. Join this journey through a study of bones and cartilage, hormonal symphonies, and the dance of genetic inheritance, unlocking the secrets of life's exquisite choreography.

Human Body and Its Movements

Body parts which we can bend or rotate and where two parts meet, like the elbow, shoulder, or neck, are called joints. Joints bring our body parts together.

Types of Joints

- Our body has different types of joints for various movements.

Ball and socket joints

- A joint where the rounded end of one bone fits into the cavity (hollow space) of another, allowing movements in all directions (Refer Figure 14.1).

Pivotal Joint

- The pivotal joint (Refer Figure 14.2) **facilitates bending the head forward and backwards**, as well as **turning the head to the right or left**.
- Unlike the ball and socket joint where the arm can perform **circular rotations**, the pivotal joint involves a **cylindrical bone rotating within a ring**, showcasing the diversity in joint mechanics.

Hinge Joints

- **The elbow and knee, acting as a hinge joint**, showcases a back-and-forth motion (Refer Figure. 14.3).

Fixed joints

- Joints in the head that differ from movable joints, are known as fixed joints.
- In these joints, **bones do not have the ability to move**.
- An example is the joint between the upper jaw and the rest of the head, which is fixed.

- Contrasting the movement of the lower and upper jaws highlights the nature of fixed joints.

Skeleton as a Framework

All the bones in our body also form a framework to give shape to our body. This framework is called the skeleton (refer Figure 14.4).

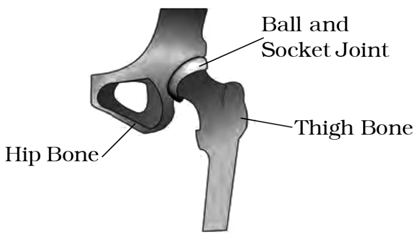


Figure 14.1: A ball and socket joint

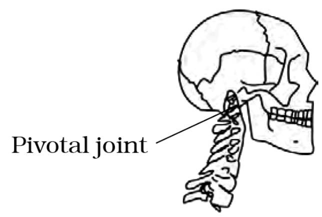


Figure 14.2: A pivotal joint

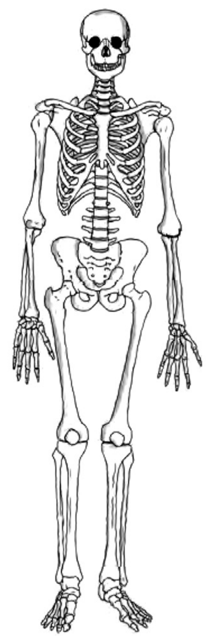


Figure 14.4: The Human Skeleton

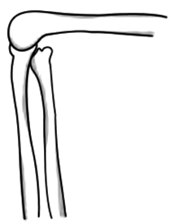


Figure 14.3: Hinge joints of the knee

The **human skeleton** is composed of around **305 bones at birth**. The number of bones in the skeleton changes with age. It **decreases to 206 bones by adulthood** after **some bones have fused** together.

Shape and Bones

- The palm is made up of several small bones called **carpels**. (Refer Figure 14.5).
- Ribs **(bones of the chest)** are curiously bent which **join the chest bone and the backbone together to form a box**. This is called the **rib cage** (Refer Figure 14.6).
- There are **12 ribs on each side of the chest** and these protect some important internal parts of our body.
- The **backbone** is made up of many small bones called **vertebrae**. The backbone consists of **33 vertebrae** (Refer Figure 14.7). The rib cage is joined to these bones.
- Two **bones on the back are prominent** where the **shoulders** are. They are called shoulder bones (Refer Figure 14.8).
- Observe Figure 14.9 carefully. This structure is made of **pelvic bones.** They enclose the **portion of your body below the stomach**. This is the part **you sit on**.
- The skull is made up of many bones joined together (Refer Figure 14.10). It encloses and protects a very important part of the body, **the brain**.
- There are some additional parts of the skeleton that are not as hard as the bones and which can be bent. These are called **cartilage**.

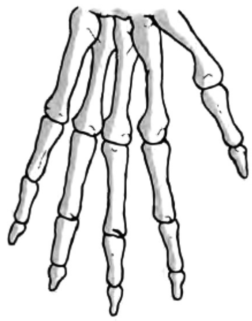


Figure 14.5: Bones of the hand

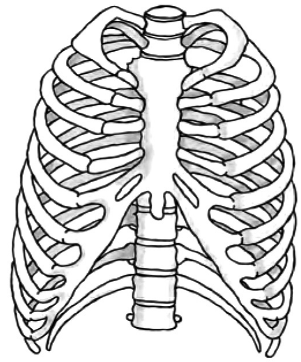


Figure 14.6: The Rib Cage

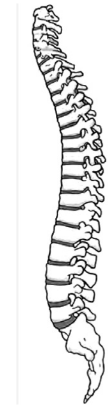


Figure 14.7: The backbone

Figure 14.8: The shoulder bones

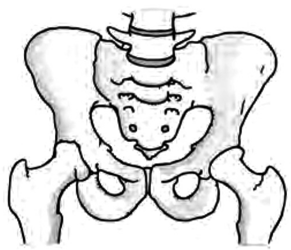


Figure 14.9: Pelvic bones

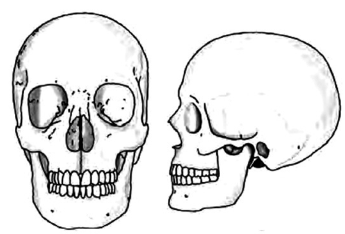


Figure 14.10: The skull

- The upper part of the ear that is **not as soft as the ear lobe but, not as hard as a bone**, is cartilage. (Refer Figure 14.11)
- Cartilage is also **found in the joints of the body**.

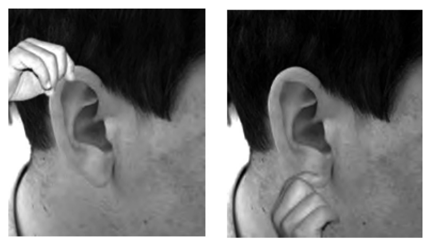


Figure 14.11: Upper part of the ear and lobe ear has cartilage

Muscles: Contraction and Movement

- The muscle of the human arm bulges due to contraction (it becomes smaller in length) (refer Figure 14.12).
- A **contracted muscle** is shorter, stiffer, and thicker.
- **Muscles work in pairs**. When one of them contracts, the bone is pulled in that direction. The other muscle of the pair relaxes. (refer Figure 14.12)
- The **muscles can only pull, not push**, necessitating the coordination of two muscles to move a bone.

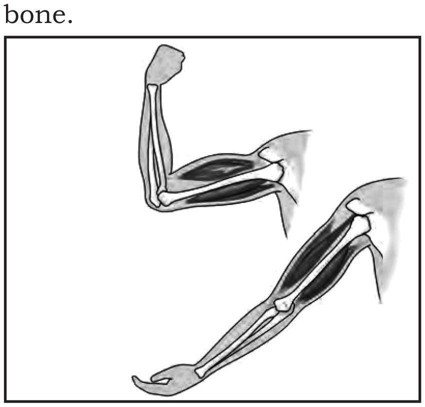


Figure 14.12: Two muscles work together to move a bone

Additional Information

Yoga — For Better Health

Yoga is an invaluable gift of the ancient Indian tradition. The **United Nations declared 21 June as International Day of Yoga**. Yoga keeps a person healthy. It helps in keeping the **backbone erect**, enabling you to sit straight and not slouch. Many postures in yoga require you to lift your own weight, which help in making the bones strong and help ward off **osteoporosis**. It also helps in **relieving joint pain**, which is mostly observed in elderly people. It tunes all muscles in the body and keeps them active.

Gait of Animals

Let us study the manner of movement, that is, the gait of some animals.

Earthworm

- **Movement:** Extends and shortens the body using muscles, secretes slimy substance for movement. (refer Figure 14.13)
- **Body structure:** Rings joined end to end, no bones, tiny bristles for grip.
- **Activity:** Eats soil, improves it for plants, throws away undigested material.

Snail

- **Shell:** Outer skeleton, not made of bones, doesn't aid in movement. (refer Figure 14.14)
- **Body structure:** Thick foot made of muscles for crawling.
- **Motion:** Wavy motion of the foot.

Cockroach

- **Movement:** Walks, climbs, and flies. (refer Figure 14.15)
- **Body structure:** Hard outer skeleton made of plates, three pairs of legs, two pairs of wings.
- **Muscles:** Leg muscles for walking, body muscles for wing movement during flight.

Birds

- **Flight:** Hollow and light bones, wings for flying, modified breastbones for flight muscles. (refer Figure 14.16)
- **Locomotion:** Walks on the ground, some swim in water.

Fish

- **Shape:** Streamlined body for easy water flow. (refer Figure 14.17)
- **Movement:** Muscles make the body curve from side to side, fins help in balance and direction.
- **Swimming:** Series of jerks propel the fish forward.

Snake Movement

- **Snake Movement**—long backbone, thin muscles, loops for forward propulsion.
- Muscles also interconnect the backbone, ribs and skin. (refer Figure 14.18)
- **Motion:** Moves forward very fast and not in a straight line.

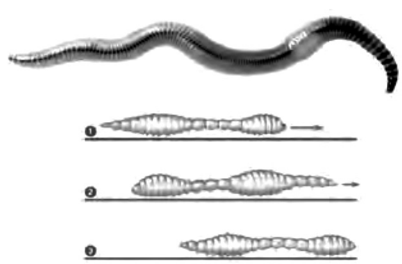


Figure 14.13: Movement of Earthworm

Figure 14.14: A Snail

Figure 14.15: A Cockroach

Figure 14.16: Skeleton of a bird

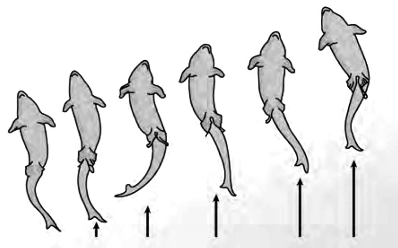


Figure 14.17: Movement in Fish

Figure 14.18: Movement in a snake

We have seen in earlier pages that living organisms are well-organized structures; they can have bones and muscles and how adolescence makes changes to the body of a growing person. Because of the effects of the environment, this organized, ordered nature of living structures is very likely to keep breaking down over time. Determining if something is alive involves more than visible movement, as growth or breath may not always be apparent. Molecular movement, even at an invisible scale, is crucial for life, as living organisms require constant maintenance and repair of their organized structures, which are composed of molecules. Maintenance of life requires processes like nutrition, respiration, transport of materials within the body and excretion of waste products. So, let's understand the maintenance processes in living organisms.

Life Processes

- Even during inactivity, living organisms must undergo **maintenance processes** known as **life processes**.
- These processes require energy, obtained from external sources through the nutrition.
- Nutrition involves **transferring energy from external sources** (food) to the organism's interior.
- Organisms may also require additional raw materials for growth, which are often **carbon-based**.
- Chemical reactions in the body, often **oxidizing-reducing reactions**, break down or build up energy sources.
- **Respiration** involves acquiring oxygen from the environment and using it to break down food sources for **cellular needs**.
- Single-celled organisms can exchange substances directly with the environment through diffusion. In multicellular organisms, specialized tissues handle functions like food and oxygen uptake, creating a need for a transportation system.
- A **transportation system** is necessary **to carry food and oxygen** from uptake points to various parts of the body.
- **Waste/by-products** generated during chemical reactions need to be removed from the body through excretion.
- Specialized tissues for excretion may develop in accordance with the body's design principles in multicellular organisms.
- The transportation system is responsible for carrying **waste away from cells to the excretory tissues**.

Nutrition

- All living organisms share a common need for energy and materials, but they fulfill these requirements in diverse ways.
- Energy is obtained from external sources, and food serves as a crucial source for this purpose.
- **Autotrophs**, such as green plants and certain bacteria, use **simple food materials like carbon dioxide and water** obtained from inorganic sources. In contrast, **heterotrophs**, including animals and fungi, rely on **complex substances for their energy needs**.
- These complex substances must be broken down into simpler ones for utilization in the body's maintenance and growth. **Enzymes**, acting as **biocatalysts**, facilitate this breakdown process.
- The survival of heterotrophs is directly or indirectly dependent on the activities of autotrophs.

Autotrophic Nutrition

- Autotrophs, such as green plants and some bacteria, use **photosynthesis** to fulfill their **carbon and energy requirements**.
- Carbohydrates not immediately used are stored as starch for future energy needs.

Additional Information
The steps of photosynthesis need not occur immediately in sequence. For example, desert plants take up carbon dioxide at night and prepare an intermediate, which is then acted upon by the energy absorbed by chlorophyll during the day.

Photosynthesis Process

- The process involves the **absorption of light energy by chlorophyll**.
- **Light energy is converted to chemical energy**, leading to the **splitting of water molecules** into hydrogen and oxygen.
- **Carbon dioxide** is subsequently reduced to form **carbohydrates**.
- Chloroplasts, which contain chlorophyll, play a crucial role in photosynthesis.

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

- If you carefully observe a cross-section of a leaf under the microscope (shown in Figure 14.19), you will notice that some cells contain green dots. These green dots are cell organelles called chloroplasts which contain chlorophyll.

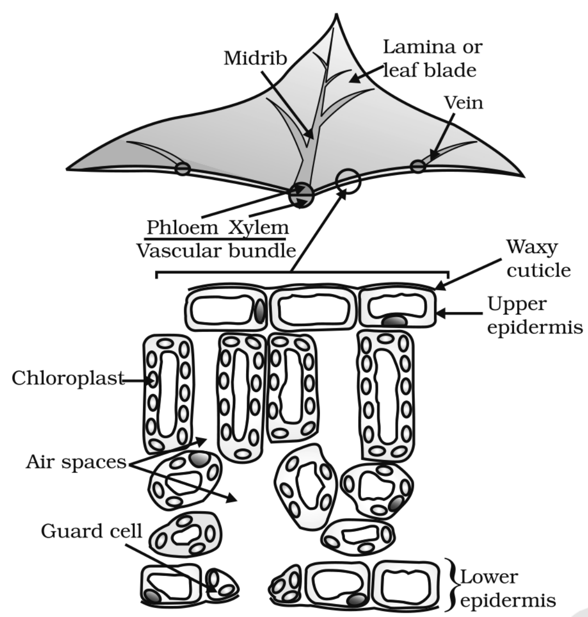


Figure 14.19: Cross-section of a leaf

Carbon Dioxide Uptake

- **Stomata**, small pores located on leaves, facilitate gaseous exchange during photosynthesis. (Refer to Figure 14.20)
- The exchange of gases also occurs on stems, roots, and leaves.
- Control of stomatal pores is governed by **guard cells**, which swell to open and shrink to close.
- Pores close when the plant does not require carbon dioxide.

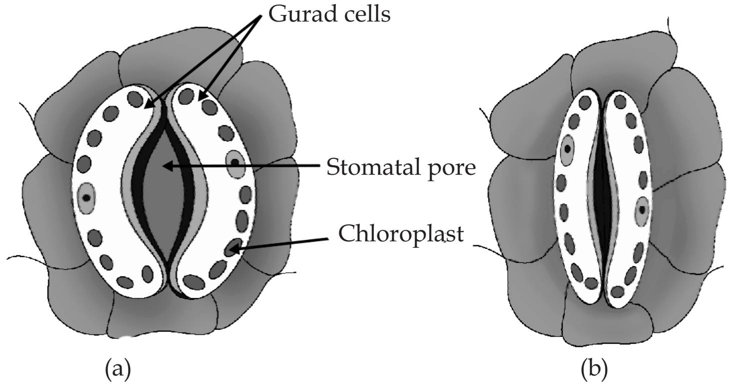


Figure 14.20: (a) Open and (b) closed stomatal pore

Raw Materials for Autotrophs

- The water necessary for photosynthesis is absorbed by roots from the soil.
- Essential elements such as **nitrogen, phosphorus, iron, and magnesium** are taken up from the soil.
- Nitrogen, a critical component for **protein synthesis**, is obtained in the form of inorganic nitrates or nitrites, or as organic compounds produced by bacteria.

Heterotrophic Nutrition

- Organisms adapt their nutritional strategies based on the type and availability of food, as well as the method of obtaining it.
- The distinction between **stationary** (e.g., grass) and **mobile** (e.g., deer) **food sources** leads to variations in how organisms access and process their nutrition.
- The nutritive apparatus differs between species, exemplified by variations between a cow and a lion.
- **Various strategies exist for taking in and utilizing food**; some organisms break down food externally for absorption, like fungi such as bread molds and yeast, while others internally process whole material.
- The ability to take in and break down substances relies on an organism's body design and functioning.
- Additionally, certain organisms adopt a **parasitic nutritive strategy**, obtaining nutrition from plants or animals without causing harm, seen in examples like **cuscuta (amar-bel)**, ticks, lice, leeches, and tape-worms.
- This diversity highlights the adaptability of organisms to their environments in the realm of nutrition.

Organisms Obtaining Nutrition

- Organisms employ diverse methods to obtain nutrition, and their digestive systems vary accordingly.
- In single-celled organisms, such as **Amoeba**, the **entire surface** may serve for food intake (Refer Figure 14.21).

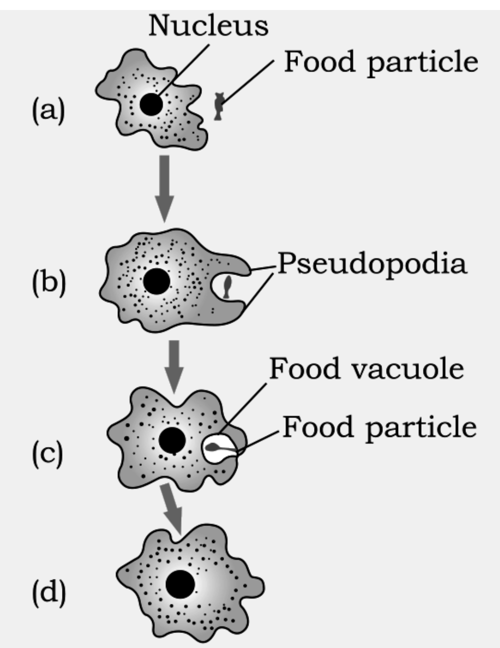


Figure 14.21: Nutrition in Amoeba

- As organisms become more complex, specialized parts emerge to carry out distinct functions. For instance, Amoeba utilizes temporary extensions of the cell surface to form a **food-vacuole**, where complex substances are broken down into simpler ones. The nutrients then diffuse into the **cytoplasm**, while undigested material is expelled from the cell surface.
- In **Paramoecium**, another unicellular organism, a specific spot on the cell is designated for food intake.
- **Cilia**, covering the cell surface, facilitate the movement of food to this spot, showcasing the adaptability of organisms in their nutritional strategies.

Nutrition in Human Beings

Alimentary Canal and Food Processing

- The alimentary canal, a lengthy tube **from the mouth to the anus** (refer Figure 14.22), is specialized into various regions for distinct functions.

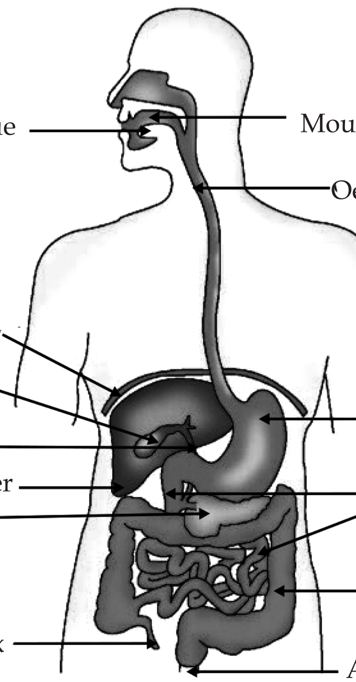


Figure 14.22: Human Alimentary Canal

- Food undergoes processing to create small, uniform particles, initiated by crushing with teeth. **Saliva**, containing the **enzyme salivary amylase**, breaks down **complex starch into simple sugar**.

Peristaltic Movements and Gastric Digestion

- Peristaltic movements, rhythmic contractions along the digestive tube, propel the food forward.
- The food travels from the mouth through the **Oesophagus** to the stomach.
- In the stomach, **gastric glands** release **hydrochloric acid, pepsin, and mucus**. Hydrochloric acid aids pepsin in protein digestion, and mucus protects the stomach lining.

Stomach to Small Intestine Transition

- The **sphincter muscle** regulates the release of food from the stomach into the small intestine.

- The **small intestine**, characterized by extensive coiling, varies in length among animals based on their diets.
- **Herbivores have longer intestines** for cellulose digestion, while **carnivores** like tigers **have shorter ones**.

Small Intestine Digestion and Absorption

- The small intestine is the primary site for complete digestion of carbohydrates, proteins, and fats.
- Secretions from the liver and pancreas neutralize acidic stomach contents.
- **Bile** from the liver emulsifies fats, facilitating enzyme action. The pancreas secretes digestive enzymes like **trypsin and lipase**.
- **Villi** in the small intestine increase the absorption surface, supplying absorbed nutrients to the entire body.

Large Intestine and Waste Elimination

- Unabsorbed food moves to the large intestine, where **water absorption occurs**.
- Waste material is **expelled through the anus**, regulated by the anal sphincter.

Additional Information

Dental caries or **tooth decay** causes gradual softening of **enamel and dentine**. It begins when bacteria acting on sugars produce acids that softens or demineralises the enamel. Masses of bacterial cells together with food particles stick to the teeth to form **dental plaque**. Saliva cannot reach the tooth surface to neutralise the acid as plaque covers the teeth. Brushing the teeth after eating removes the plaque before the bacteria produce acids. If untreated, microorganisms may invade the pulp, causing **inflammation and infection.**

Respiration

Cellular Respiration and Energy Synthesis

- Organisms employ various pathways for cellular respiration **to derive energy from food material**.
- Glucose breakdown into **pyruvate (a three-carbon molecule)** is the common initial step, occurring in the cytoplasm.
- Further, the pyruvate may be converted into ethanol and carbon dioxide. This process takes place in yeast during fermentation. Since this process takes place in the **absence of air (oxygen)**, it is called **anaerobic respiration**.

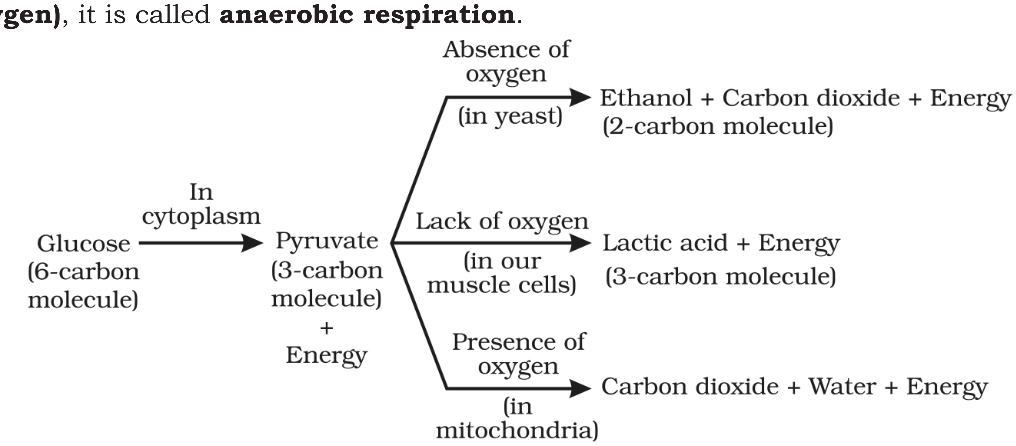


Figure 14.23: Break-down of glucose by various pathways

- Breakdown of pyruvate using oxygen takes place in the **mitochondria** (refer Figure 14.23).
- This process breaks up the three-carbon pyruvate molecule to give three molecules of carbon dioxide. The other product is water. Since this process takes place in the **presence of air (oxygen)**, it is called **aerobic respiration**, yielding higher energy.

Anaerobic Respiration and Lactic Acid Buildup

- In anaerobic respiration, pyruvate may convert into **lactic acid**, causing **muscle cramps** when oxygen is scarce.
- Energy released during cellular respiration immediately synthesizes **ATP**, a crucial molecule for fueling cellular activities.

Aerobic Respiration and Oxygen Dependency

- Aerobic organisms require sufficient oxygen intake for the efficient aerobic respiration process, yielding greater energy release.
- Plants exchange gases through stomata, ensuring contact with air for diffusion of carbon dioxide and oxygen.

Oxygen Uptake and Carbon Dioxide Elimination in Animals

- Animals exhibit diverse adaptations for oxygen uptake and carbon dioxide elimination.
- Terrestrial animals breathe atmospheric oxygen, while aquatic organisms, like fishes, rely on extracting dissolved oxygen from water.
- Different organs in animals absorb oxygen, often protected within the body to preserve delicate surfaces.

Additional Information

ATP

ATP is the energy currency for most cellular processes. The energy released during the process of respiration is used to make an ATP molecule from ADP and inorganic phosphate.

$$ADP + \text{Ⓟ} \xrightarrow{\text{Energy}} ADP \sim \text{Ⓟ} = ATP$$

Ⓟ : Phosphate

Endothermic processes in the cell then use this ATP to drive the reactions. When the terminal phosphate linkage in ATP is broken using water, the energy equivalent to 30.5 kJ/mol is released. Think of how a battery can provide energy for many different kinds of uses. It can be used to obtain mechanical energy, light energy, electrical energy and so on. Similarly, ATP can be used in the cells for the contraction of muscles, protein synthesis, conduction of nervous impulses and many other activities.

Human Respiratory System

- The human respiratory system (refer Figure 14.24) facilitates oxygen intake and carbon dioxide release.
- Nostrils filter and moisten incoming air, which passes through the throat into the lungs.
- Rings of cartilage prevent the collapse of air passages.
- The lungs consist of **alveoli (singular–alveolus)**, where exchange of gases occurs with blood vessels.

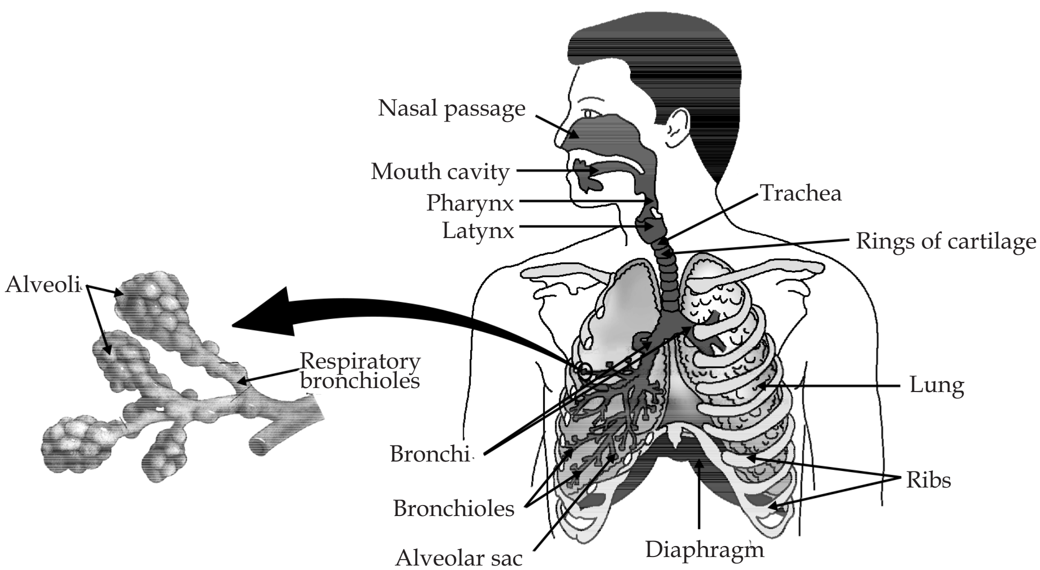


Figure 14.24: Human respiratory system

Breathing Mechanism and Gas Exchange

- In humans, breathing expands the chest cavity, drawing air into the lungs and filling alveoli.
- During the breathing cycle, a residual volume of air ensures sufficient time for gas exchange.
- Hemoglobin in red blood cells serves as the respiratory pigment, aiding oxygen transport.
- Carbon dioxide, more soluble in water, is mainly transported in dissolved form in the blood.

Additional Information

Cilia

Lung cancer is one of common causes of deaths in the world. The upper part of respiratory tract is provided with small hair-like structures called cilia. These cilia help to remove germs, dust and other harmful particles from inhaled air. Smoking destroys these hair due to which germs, dust, smoke and other harmful chemicals enter lungs and cause infection, cough and even lung cancer.

Transportation

Transportation in Human Beings

- Blood, a fluid connective tissue, consists of plasma and cells.
- Plasma transports dissolved food, carbon dioxide, and nitrogenous wastes.
- Red blood cells carry oxygen.
- White blood cells are involved in immune responses.

DO YOU KNOW?

If the alveolar surface were spread out, it would cover about 80 square meters. Consider how efficient exchange of gases becomes because of the large surface available for the exchange to take place.

If diffusion were to move oxygen in our body, it is estimated that it would take 3 years for a molecule of oxygen to get to our toes from our lungs.

The Heart

- The heart is a muscular organ with **four chambers: left atrium, left ventricle, right atrium, and right ventricle**. (refer Figure 14.25)
- The **carbon dioxide-rich blood** has to **reach the lungs** for the carbon dioxide to be removed, and the **oxygenated blood** from the lungs has to be brought **back to the heart**. This oxygen-rich blood is then pumped to the rest of the body. (refer Figure 14.26)
- **Atria** and **ventricles** contract and relax in a co-ordinated manner, facilitated by valves.
- **Oxygen-rich blood** from the lungs comes to the thin-walled upper chamber of the heart on the left, the left atrium. The left atrium relaxes when it is collecting this blood. It then contracts, while the next chamber, the left ventricle, relaxes, so that the blood is transferred to it. When the muscular left ventricle contracts in its turn, the blood is pumped out to the body.

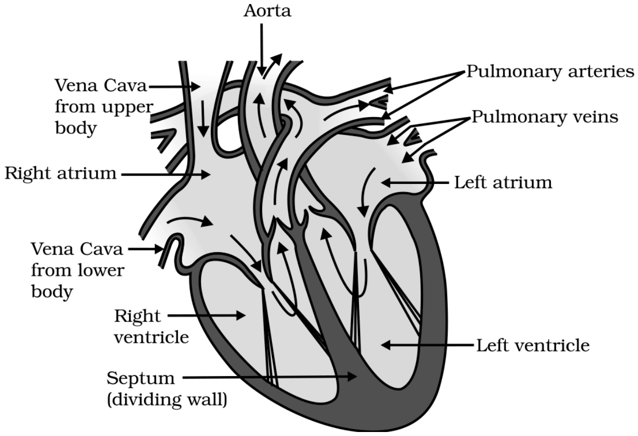


Figure 14.25: Schematic sectional view of the human heart

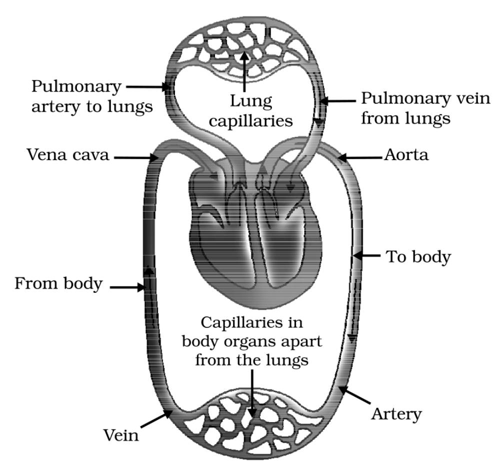


Figure 14.26: Schematic representation of transport and exchange of oxygen and carbon dioxide

- Deoxygenated blood comes from the body to the upper chamber on the right, the right atrium, as it relaxes. As the right atrium contracts, the corresponding lower chamber, the right ventricle, dilates. This transfers blood to the right ventricle, which in turn pumps it to the lungs for oxygenation.

Circulation in Animals

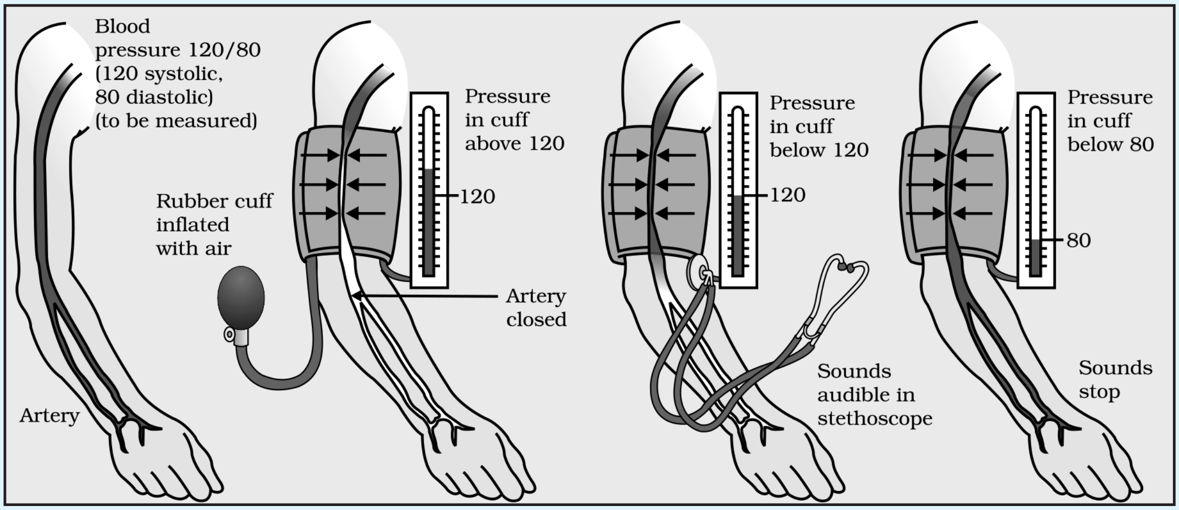
- **Separation** of the **right and left sides of the heart** prevents the mixing of oxygenated and deoxygenated blood.
- **Birds and mammals** have four-chambered hearts for efficient oxygen supply, while **amphibians and reptiles** have three-chambered hearts.
- **Fish** have two-chambered hearts with single circulation.

Blood Vessels

- **Arteries** carry blood away from the heart under high pressure with thick, elastic walls.
- **Veins collect blood** from organs and return it to the heart, equipped with valves.
- **Capillaries**, one-cell thick vessels, facilitate the exchange of materials between blood and cells.
- Maintenance of blood pressure is crucial for efficient circulation.

Blood pressure

The force that blood exerts against the wall of a vessel is called blood pressure. This pressure is much greater in arteries than in veins. The pressure of blood inside the artery during **ventricular systole (contraction)** is called systolic pressure and pressure in artery during **ventricular diastole (relaxation) is called diastolic pressure**. The **normal systolic pressure is about 120 mm of Hg and diastolic pressure is 80 mm of Hg**. Blood pressure is measured with an instrument called **sphygmomanometer**. High blood pressure is also called **hypertension** and is caused by the constriction of arterioles, which results in increased resistance to blood flow. It can lead to the rupture of an artery and internal bleeding.



Platelets and Clotting

- **Platelet cells** in the blood help clotting at points of injury to **prevent excessive bleeding**.
- **Clotting** is essential for minimizing blood loss and maintaining pressure in the **circulatory system**.

Lymphatic System

- **Lymph** is a colourless fluid formed from plasma, proteins, and blood cells escaping into tissues through capillary pores.
- Lymph drains into **lymphatic capillaries**, carrying digested fats and draining excess fluid back into the blood.
- **Lymph nodes** filter and remove impurities from lymph.

Transportation in Plants

- Plants take in simple compounds like CO_2 and perform **photosynthesis in chlorophyll-containing organs, mainly leaves**.
- Soil is a rich source of raw materials such as **nitrogen, phosphorus, and minerals**.
- **Roots**, in contact with the soil, absorb these substances for plant growth.
- **Efficient transportation** is crucial when distances between soil-contacting organs and chlorophyll-containing organs are large.
- Plants, having low energy needs, can afford relatively slow transport systems.
- **Xylem and phloem** are independently organized conducting tubes for moving water, minerals, and products of photosynthesis.

Xylem - Water Transport

- **Vessels and tracheids** in roots, stems, and leaves form interconnected channels for water transport.
- Active uptake of ions in root cells creates a concentration difference, causing water to move into the roots.
- **Transpiration**, the loss of water vapour from leaves, creates suction, pulling water from roots to leaves. (refer Figure 14.27)
- Transpiration also aids in temperature regulation.

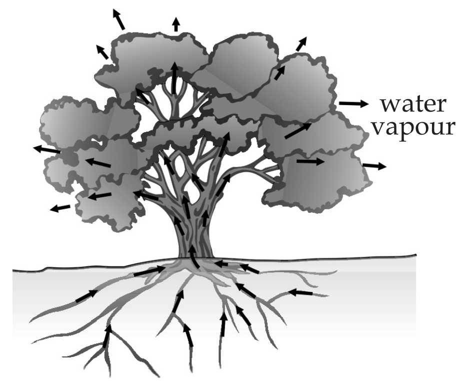


Figure 14.27: Movement of water during transpiration in a tree

Phloem - Food and Substance Transport

- **Translocation** in phloem involves the movement of soluble products of photosynthesis, amino acids, and other substances.
- **Sieve tubes**, with the help of companion cells, facilitate upward and downward translocation.
- Unlike the xylem, translocation in the phloem requires energy from ATP to transfer material and increase **osmotic pressure**.
- This pressure helps move materials according to the plant's needs, such as transporting stored sugar to growing buds in spring.

Excretion

- Excretion is the biological process of **removing harmful metabolic wastes** from the body.
- Different organisms use varied strategies for excretion.
- **Unicellular** organisms often use **simple diffusion** from the body surface.
- **Multicellular** organisms, like humans and plants, use **specialized organs or structures for excretion**.

Excretion in Human Beings

- **Human excretory system** (refer Figure 14.28) includes kidneys, ureters, urinary bladder, and urethra.
- **Kidneys** filter waste products like urea or uric acid from the blood through nephrons.
- **Nephrons** consist of thin-walled blood capillaries associated with **Bowman's capsule**. (refer Figure 14.29)
- Filtrate undergoes selective reabsorption of substances like glucose, amino acids, salts, and water.
- **Ureter** connects kidneys to the urinary bladder where urine is stored.
- **Bladder**, under nervous control, releases urine through the urethra.

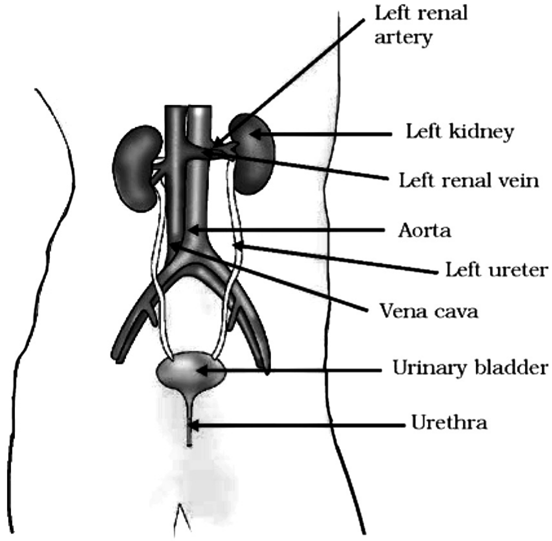


Figure 14.28: Excretory system in human beings

Excretion in Plants

- Plants use different strategies for excretion.
- **Oxygen, a byproduct of photosynthesis**, is released during respiration.
- Excess water is eliminated through transpiration.
- Waste products may be stored in **cellular vacuoles** or in parts such as leaves that fall off.
- **Resins, gums,** and other waste substances are stored, especially in old xylem.
- Some waste substances are excreted into the soil surrounding the plant.

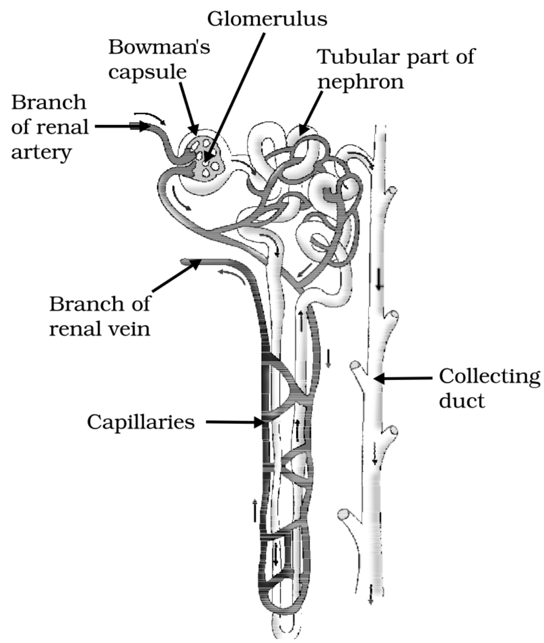


Figure 14.29: Structure of a nephron

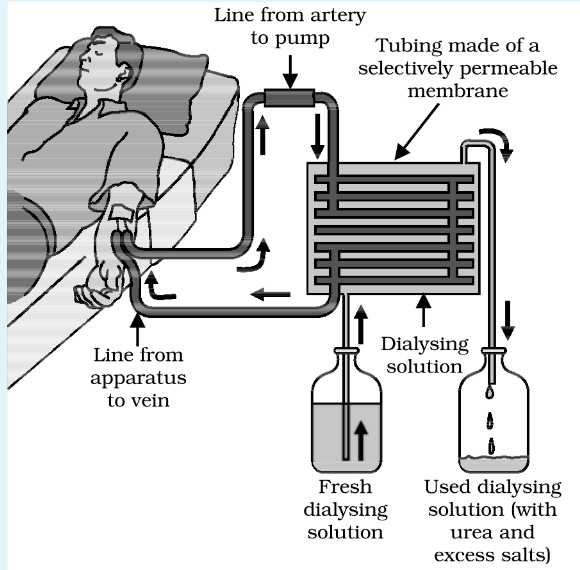
Comparison of Animal and Plant Excretion

- **Animals,** including humans, have specialized excretory organs for efficient waste removal.
- **Plants** utilize various structures, storage mechanisms, and shedding of parts for waste management.
- Both organisms employ strategies based on their physiological characteristics and environmental interactions.

Artificial kidney (Hemodialysis)

In case of kidney failure, an artificial kidney can be used. An artificial kidney is **a device to remove nitrogenous waste products from the blood through dialysis.**

Artificial kidneys contain a number of tubes with a semi-permeable lining, suspended in a tank filled with **dialysing fluid**. This fluid has the same **osmotic pressure** as blood, except that it is devoid of nitrogenous wastes. The patient's blood is passed through these tubes. During this passage, the waste products from the blood pass into dialysing fluid by diffusion. The purified blood is pumped back into the patient. This is similar to the function of the kidney, but it is different since there is no reabsorption involved. Normally, in a healthy adult, the initial filtrate in the kidneys is about 180 L daily. However, the volume actually excreted is only a litre or two a day, because the remaining filtrate is reabsorbed in the kidney tubules.



Organ donation

Organ donation is a generous act of **donating an organ to a person who suffers from non-function of organ(s)**. Donation of an organ may be done by the consent of the donor and his/her family. Anyone **regardless of age or gender can become an organ and tissue donor.** Organ transplants can save or transform the life of a person. Transplantation is required because recipient's organ has been damaged or has failed by disease or injury. In organ transplantation the organ is **surgically removed** from one person (organ donor) and transplanted to another person (the recipient). Common transplantations include **corneas, kidneys, heart, liver, pancreas, lungs, intestines and bone marrow**. Most organ and tissue donations occur just after the donor has died or when the doctor declares a person **brain dead**. But some organs such as **kidney, part of a liver, lung, etc.**, and tissues can be donated while the **donor is alive**.

We looked at life processes involved in the maintenance functions of living organisms. The movement in living organisms is not solely linked to growth but is also a response to the environment. This controlled movement is crucial for survival and is connected to the organism's ability to recognize and respond to events in its surroundings. To achieve this, living organisms employ specialized tissues for control and coordination, aligning with the overall principles of body organization in multicellular organisms.

Control and Coordination in Animals – Nervous System

- Control and coordination in animals are facilitated by **nervous and muscular tissues.**
- Detection and response to environmental **stimuli** involve specialized nerve cells with receptors located in sense organs.
- Information acquired at the tips of nerve cell dendrites triggers a chemical reaction, generating an electrical impulse.

Nervous Impulse Transmission

Nervous impulses follow a **general scheme**:

- Information is acquired at the **dendritic tip**.
- Chemical reaction creates an **electrical impulse**.

- Impulse travels from **dendrite to the cell body**, then along the **axon** to its end.
- At the axon end, chemicals are released, crossing the **synapse** to initiate a similar impulse in the next neuron.
- Synapse allows the transmission of impulses to other cells, such as **muscle cells or glands**.

Nervous Tissue Structure

- Nervous tissue is an **organized network of nerve cells or neurons**.
- Neurons are specialized for conducting information via electrical impulses.
- Figure 14.30 (a) shows a **neuron with identifiable parts:**
  a. Information acquisition at the dendritic tip.
  b. Transmission of information as an electrical impulse along the axon.
  c. Conversion of the impulse into a chemical signal for onward transmission at the synapse.

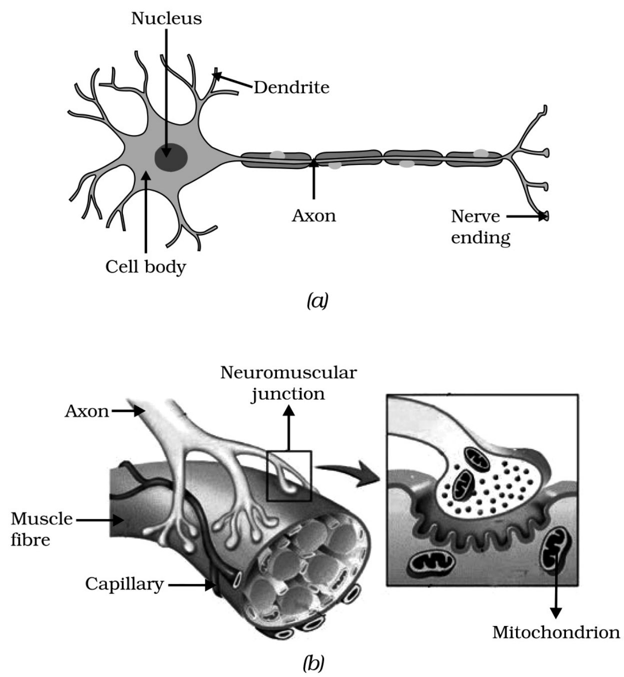


Figure 14.30: (a) Structure of neuron, (b) Neuromuscular junction

Overall Function

- Nervous tissue enables the transmission of information in the form of electrical impulses.
- These impulses travel through neurons, from the information acquisition site to the site of response (e.g., muscle cells or glands).
- The coordinated action of nervous tissue allows animals to detect and respond to stimuli rapidly.

Reflex Actions

- Reflex actions are **sudden, automatic responses** to stimuli in the environment.
- They occur without conscious thought or feeling of control overreactions.
- **Examples include:** Jumping away from danger or pulling back from pain.
- In reflex situations, **responses are quick and do not involve conscious thinking**.
- Touching a flame is an urgent and dangerous situation requiring a rapid response.
- Thinking involves complex interactions of nerve impulses from many **neurons**.
- The thinking tissue in the body consists of dense networks of neurons located in the skull.

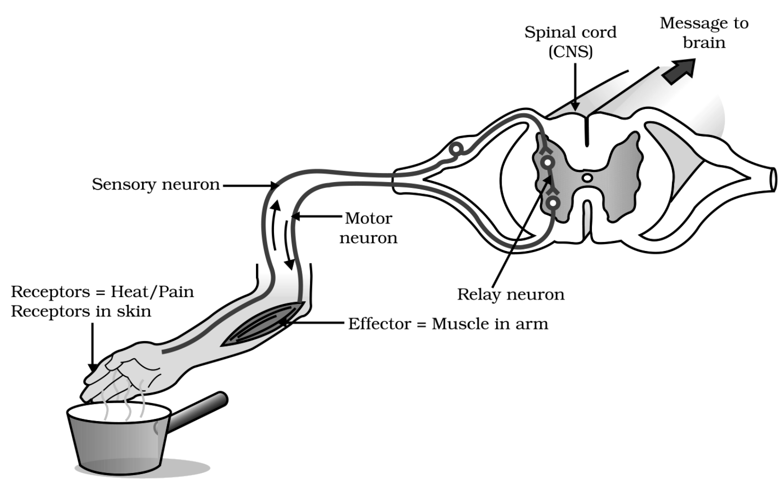


Figure 14.31: Reflex Arc

- The brain receives signals from various parts of the body, thinks about them, and responds accordingly.
- The brain needs to be connected to nerves from different body parts for signal reception and muscle movement instruction.
- If thinking involves complex interactions, it may take too long for a response when touching a hot object, leading to burns.
- Reflex arcs (refer Figure 14.31) are a design solution to the delay problem in complex thinking.
- A reflex arc is a direct connection between nerves detecting a stimulus and nerves controlling muscle movement.
- Connections are made at the **spinal cord**, where nerves from various body parts meet on their way to the brain.
- The **spinal cord forms reflex arcs**, allowing quick input detection and output response without the need for complex thinking.
- Reflex arcs have evolved in animals as efficient mechanisms for quick responses.
- Many animals, lacking complex neuron networks for thinking, rely on reflex arcs.
- Even with complex **neuron networks**, reflex arcs remain more efficient for rapid responses to stimuli.

Human Brain

- Reflex action is not the only function of the spinal cord.
- The **spinal cord is composed of nerves** that supply information for thinking.
- Complex thinking and neural connections primarily occur in the **brain**.
- The brain and spinal cord form the **central nervous system (CNS)**.
- CNS integrates information from all body parts.
- **Peripheral nervous system** includes **cranial nerves** from the brain and spinal nerves from the spinal cord. It facilitates communication between the central nervous system and other parts of the body.

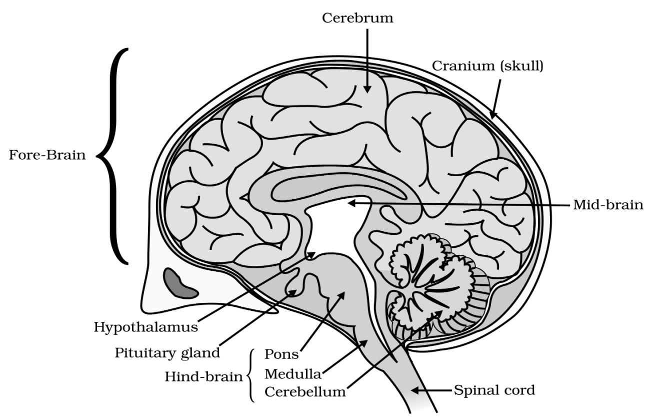


Figure 14.32: Human Brain

- The brain has three major regions: **fore-brain, mid-brain, and hind-brain**. (refer Figure 14.32)
- Functioning as the primary thinking center, the fore-brain receives **sensory impulses**.
- Specialized areas for hearing, smell, sight, etc., exist within the fore-brain.
- Regions of association interpret sensory information and make decisions.
- Motor areas control **voluntary muscle movements.**
- Between reflex actions and thought-out actions, there are **involuntary muscle movements.**
- Involuntary actions, like salivation or heartbeat, are controlled by the mid-brain and hind-brain.
- The **medulla** in the hindbrain controls many involuntary actions, including blood pressure, salivation, and vomiting.
- A part of the hindbrain, the **cerebellum** is responsible for precision in voluntary actions.

- Cerebellum **maintains the posture and balance** of the body.
- The cerebellum is crucial for activities like walking, riding a bicycle, and picking up objects.
- The brain allows for thinking and voluntary actions.
- Involuntary actions are controlled by the **mid-brain and hind-brain**.
- The complex design of different brain regions is responsible for integrating inputs and outputs, enabling various bodily functions without conscious control.

Protection of Delicate Organs

- The brain, a delicate organ crucial for various activities, is protected by a **bony box**.
- Inside this box, the brain is contained in a **fluid-filled balloon**, providing additional shock absorption.
- The **vertebral column** or backbone protects the spinal cord.

Function of Nervous Tissue in Causing Action

- **Nervous tissue** collects, processes, and conveys information to muscles for action.
- When the action or movement is to be performed, **muscle tissue** executes the final task.
- Muscle cells move by changing their shape, causing them to shorten.
- Special proteins in muscle cells undergo changes in shape and arrangement in response to **nervous electrical impulses**.
- These changes in protein arrangement result in the muscle cells adopting a shorter form.
- There are different types of muscles, including **voluntary muscles and involuntary muscles.**
- The variations in muscle types, voluntary and involuntary, stem from their different responses to nervous signals and functions in the body.

Coordination In Plants

- Plants lack a nervous system and muscles, yet they exhibit responses to stimuli.
- **Two types of plant movement** are observed: immediate response to stimuli and movement due to growth.

Immediate Response to Stimulus

- Plants like the **sensitive plants** demonstrate rapid movement in response to touch (refer Figure 14.33).
- Electrical-chemical means are used for communication between cells, even though there is no specialized tissue for information conduction.
- Unlike animals, plant cells change shape by altering water content, leading to swelling or shrinking and subsequent movement.

Figure 14.33: The Sensitive Plant

Movement Due to Growth

- Plants exhibit **tropic movements**, such as **phototropism and geotropism**, in response to environmental stimuli like light and gravity.

- **Phototropic movements involve shoots bending towards the light**, while roots bend away from it (refer Figure 14.34).
- **Geotropism dictates the upward growth of shoots and the downward growth of roots in response to the Earth's gravitational pull.** (refer Figure 14.35)
- Additionally, plants display **hydrotropism** and **chemotropism,** responding to water and chemicals, respectively. For example, pollen tubes exhibit chemotropism as they grow towards ovules during reproduction.
- The communication of information in multicellular organisms involves **quick responses**, like the sensitive plant's rapid touch-induced movement, and **slower responses**, such as sunflowers adjusting to day and night.
- In both plant and animal bodies, controlled directional growth occurs, emphasizing the need for rapid information transfer for swift responses to stimuli.

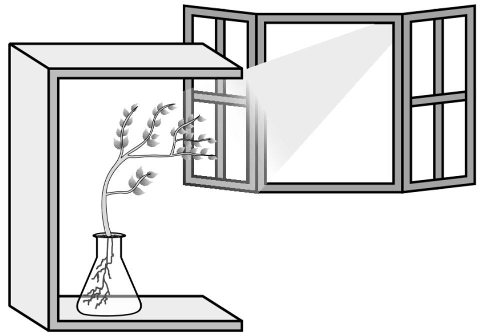


Figure 14.34: Phototropism

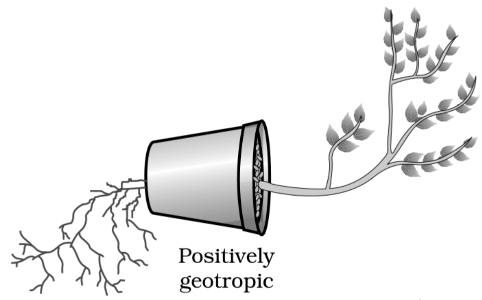


Figure 14.35: Geotropism

Chemical Communication in Plants

- Multicellular organisms, including plants, use **chemical communication** for coordination.
- Hormones, diverse compounds, are released by stimulated cells and diffuse to reach other cells, coordinating growth, development, and responses to the environment.
- Examples of plant hormones include **auxins, gibberellins, cytokinins, and abscisic acid.**
- **Auxins** promote cell elongation and bending towards light in growing shoots.
- **Gibberellins** aid in stem growth.
- **Cytokinins** stimulate cell division, particularly in areas of rapid growth like fruits and seeds.
- **Abscisic acid** inhibits growth and is associated with effects like leaf wilting.
- Plant hormones play a vital role in regulating various physiological processes in plants, ensuring a balanced response to stimuli and environmental conditions.

Hormones In Animals

Immediate Responses to Stimuli in Animals

- In situations requiring immediate action, such as facing a threat, animals like squirrels employ **hormonal responses**.
- For instance, **adrenaline**, secreted from the adrenal glands, is released into the bloodstream, reaching various tissues and organs. (refer Figure 14.36) This hormone prepares the body for either fighting or fleeing by increasing the heart rate, redirecting blood flow, and accelerating breathing.
- This **chemical signalling**, facilitated by hormones, is a crucial aspect of the endocrine system, serving as a secondary mode of control and coordination in animal bodies.

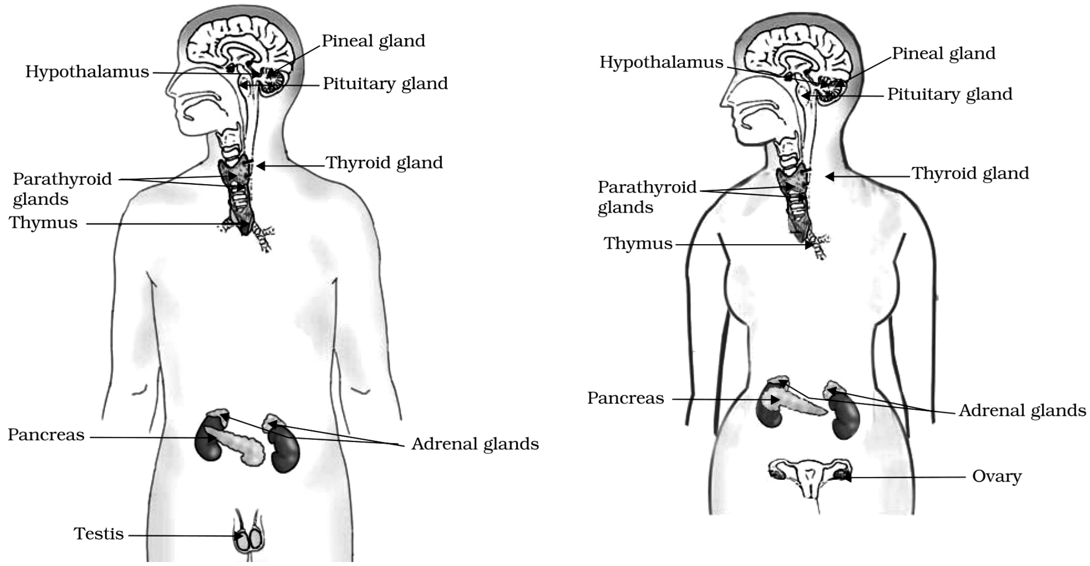


Figure 14.36: Endocrine glands in human beings (a) male, (b) female

Hormonal Regulation of Growth and Development

- Animal hormones also play a pivotal role in growth and development.
- Other endocrine glands (refer Figure 14.36) in the body include the **thyroid, pancreas, and adrenals**.
- **Thyroxin hormone**, synthesized in the thyroid gland with the aid of iodine, regulates carbohydrate, protein, and fat metabolism, contributing to **balanced growth**.
- **Example of thyroid-related disease:** Goitre, caused by insufficient production of **thyroxine**.
- **Example of pancreas-related disease:** Diabetes, resulting from inadequate insulin production.
- **Adrenal glands** secrete hormones to maintain the **correct salt balance** in the blood.
- Adrenal glands also produce **adrenaline**, aiding the body's response to stress (anger, embarrassment, or worry).
- Thyroid and Adrenal glands release hormones in response to orders from the pituitary gland.
- The **pituitary gland** secretes growth hormone, which governs overall growth and development. Deficiency in growth hormone during childhood can lead to **dwarfism**.
- Puberty-related changes are attributed to the secretion of **testosterone** in males and **estrogen** in females.

Table 14.1: Some important hormones and their functions

S.No.	Hormone	Endocrine Gland	Functions
1.	Growth hormone	Pituitary gland	Stimulates growth in all organs
2.	Thyroxine	Thyroid gland	Regulates metabolism for body growth
3.	Insulin	Pancreas	Regulates blood sugar level
4.	Testosterone	Testes	Regulate libido, muscle mass and strength
5.	Estrogen and Progesterone	Ovaries	Development of female sex organs, regulates menstrual cycle, etc.
6.	Adrenaline	Adrenal gland	Regulate your metabolism, immune system, BP
7.	Releasing hormones	Hypothalamus	Stimulates pituitary gland to release hormones

Hormones and Blood Sugar Regulation

- Hormones are integral to maintaining physiological balance, as exemplified by insulin.
- The pancreas produces **insulin** to regulate blood sugar levels. Individuals with diabetes may require insulin injections to manage blood sugar.
- **Feedback mechanisms** ensure precise timing and quantities of hormone release. For instance, the pancreas detects changes in blood sugar levels and adjusts insulin secretion to maintain **equilibrium**.
- Hormones, therefore, serve diverse roles in animal physiology, contributing to both **immediate responses and long-term growth and development**.

> **Additional Information**
>
> **Hypothalamus** plays an important role in the release of many hormones. For example, when the level of **growth hormone** is low, the hypothalamus releases growth hormone releasing factor which stimulates the **pituitary gland** to release growth hormone.

Role of Hormones in Completing the Life History of Insects and Frogs

- The Life cycle of a frog involves **metamorphosis** from tadpole to adult.
- Metamorphosis is the transition from **larva to adult**.
- In insects, **metamorphosis is controlled by insect hormones**.
- In frogs, metamorphosis is controlled by **thyroxine**, a hormone produced by the **thyroid gland**.
- Thyroxine production in frogs requires iodine present in water.
- If the water lacks sufficient iodine, tadpoles cannot undergo metamorphosis to become adults.

Organisms reproduce, despite the fact that it is not essential to maintain the life of an individual organism. While reproduction requires energy, the sheer abundance of individuals in a species is what draws our attention. Without reproduction, the existence of a single non-reproducing organism might go unnoticed. The similarity between individuals in a species allows us to identify and classify them. Reproduction contributes to the overall life processes and organization of living organisms. So, in essence, reproduction ensures the continuation of a species and the perpetuation of recognizable traits.

Reproduction and Genetic Variation

- Organisms exhibit similarity in appearance due to shared body designs, rooted in similar blueprints. Reproduction, fundamentally, involves **copying** these **blueprints stored in DNA**.
- In the cell nucleus, **chromosomes carry DNA**, the molecule containing information for inheritance.
- DNA serves as the informational source for **protein synthesis**, and variations in DNA lead to diverse protein production, influencing body designs.
- Reproduction initiates with the creation of a DNA copy through chemical reactions.
- Cells undergo division, necessitating the separation of DNA copies into individual cells, each equipped with its **cellular apparatus**.
- The accuracy of DNA copying reactions dictates the similarity between the original and copied DNA.
- **Bio-chemical reactions** inherently possess variations, resulting in subtle differences in the generated DNA copies.
- Surviving cells are akin but not necessarily identical, as some variations may be significant enough to render a cell nonfunctional, leading to its demise.
- The inbuilt tendency for variation during reproduction forms the **foundation for evolution.**

- These subtle genetic differences contribute to the diversity within species over successive generations.
- Understanding the variability in DNA copies sheds light on the dynamic process of evolution, shaping the intricate tapestry of life.

The Significance of Genetic Variation in Evolution

- Organisms within populations occupy specific **ecological niches**, utilizing their reproductive capabilities.
- Consistency in DNA copying during reproduction is crucial for preserving the features that adapt organisms to their niches, ensuring stability in populations.
- Despite the link between reproduction and population stability, external factors beyond organisms' control can alter niches.
- **Environmental shifts**, such as temperature fluctuations, changes in water levels, or unforeseen events like meteorite impacts, can impact the suitability of a niche.
- However, the presence of genetic variations within a population offers a survival advantage. Individuals with variations better suited to the altered conditions have a higher likelihood of persevering.
- For instance, consider a population of **bacteria** accustomed to temperate waters. If a rise in water temperature occurs due to global warming, the majority of the bacteria may perish.
- Nevertheless, the existence of heat-resistant variants within the population provides a lifeline. These variants can withstand the changing conditions, ensuring the survival and further growth of the population.

Sexual Reproduction in Humans

- Human sexual reproduction also involves the participation of both male and female individuals. We will study the human reproduction system in detail in the latter part of the Chapter.
- Let us first analyze changes in adolescence and puberty
- The growth of a human being begins from the day one is born. But upon crossing the age of 10 or 11, there is a sudden spurt in growth which becomes noticeable. The changes taking place in the body are part of growing up. They indicate that you are on the way to becoming an adult. It is a strange period of life when you are neither a child nor an adult. So let's understand adolescence.

Adolescence and Puberty

- **Adolescence** is a natural phase from around **11 to 18 or 19 years**. Since this period covers the **'teens'** (13 to 18 or 19 years of age), adolescents are also called **'teenagers'**. It's marked by **physical changes** leading to **reproductive maturity**, referred to as **puberty**. Puberty's main sign is the ability for reproduction, concluding when reproductive maturity is reached.

Changes at Puberty

Increase in Height

- Puberty triggers sudden height increase through the elongation of long bones.
- Growth rates vary, with girls initially growing faster than boys.

Table 14.2: Average rate of growth in height of boys and girls with age

Age in Years	% of full height	
8	72%	77%
9	75%	81%
10	78%	84%
11	81%	88%
12	84%	91%
13	88%	95%
14	92%	98%
15	95%	99%
16	98%	99.5%
17	99%	100%
18	100%	100%

- Genetic factors influence height, and proper nutrition is crucial for growth.
- Table 14.2 gives the average rate of growth in height of boys and girls with age.
- Calculation of full height:

$$\frac{\text{Present height (cm)}}{\text{\% of full height at this age}} \times 100$$

Change in Body Shape

- Puberty induces distinct body changes, such as broader shoulders in boys and widened hips in girls.
- Muscle growth is more prominent in boys, leading to differing body shapes between genders.

Voice Change

- Boys experience **voice box growth** during puberty, resulting in **deeper voices**.
- Girls' larynx remains smaller, contributing to a **higher-pitched voice**.
- **Temporary hoarseness** in boys can occur due to uncontrolled muscle growth in the voice box.
- The growing voice box in boys can be seen as a protruding part of the throat called **Adam's apple** (Fig. 14.37). In girls, the larynx is hardly visible from the outside because of its small size.

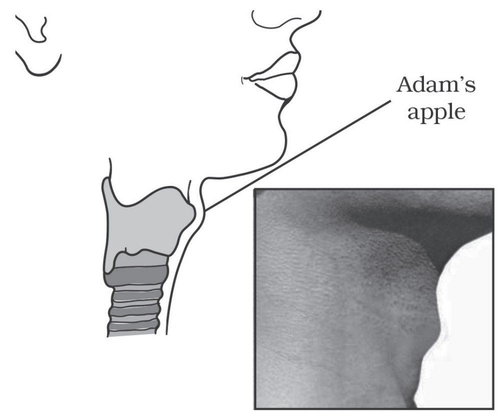


Figure 14.37: Adam's apple in a grown up boy

Increased Activity of Glands

- Puberty leads to heightened activity of **sweat and sebaceous glands.**
- Increased gland activity often causes **acne and pimples on the face**.

A few glands such as sweat glands, oil glands and salivary glands release their secretions through ducts. Endocrine glands release hormones directly into the bloodstream. So, they are also termed ductless glands.

Development of Sex Organs

- Male sex organs, including testes and penis, fully develop during puberty.
- Testes begin sperm production.
- In girls, **ovaries enlarge, eggs mature, and ovulation begins.**

Reaching Mental, Intellectual, and Emotional Maturity

- Adolescence signifies a shift in thinking, marked by **increased independence** and **self-consciousness**.
- **Intellectual development** is notable, with **heightened learning capacity**.
- **Emotional adjustments** may occur, but these changes are natural aspects of growing up.

POINTS TO PONDER

In recent years an increasing number of girls are achieving puberty earlier than long term averages . Think about what are the factors underlying responsible for puberty onset and how the modern socio-economic system is causing early onset of puberty in girls.

Secondary Sexual Characters

- Reproductive organs, testes, and ovaries produce gametes **(sperms and ova)**.

- **Secondary sexual characters** develop breasts in girls, facial hair (moustaches and beards) in boys, and chest hair.
- Hair growth occurs under the arms and in the pubic region, distinguishing gender.
- **Hormones**, and chemical substances, **control adolescent changes.** These are secretions from endocrine glands, or the endocrine system.
- **Testosterone, the male hormone**, released by testes in boys, triggers changes like facial hair growth.
- **Estrogen, the female hormone**, produced by ovaries in girls, leads to breast development.
- Hormone production is **regulated by the pituitary gland.**

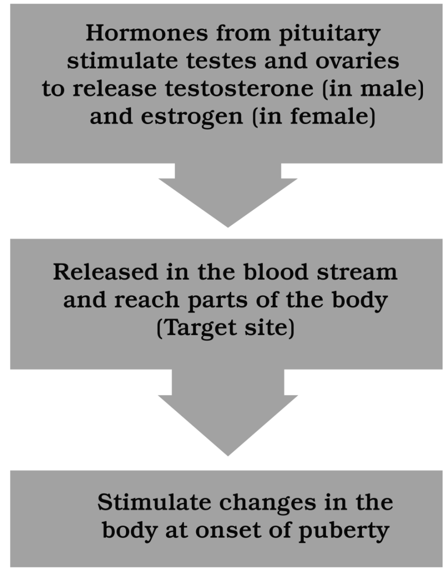


Figure 14.38: The onset of puberty is controlled by hormones

Role of Hormones in Initiating Reproductive Function

- Endocrine glands release hormones into the bloodstream.
- Hormones travel to **specific target** sites in the body.
- Testes and ovaries, endocrine glands, secrete **sex hormones**.
- Sex hormones **influence the development of male and female** secondary sexual characters.
- Hormones from the pituitary gland regulate sex hormones.
- **The pituitary gland** releases various hormones, including those that stimulate ovum maturation in the ovaries and sperm formation in the testes. (refer Figure 14.38)

Female Reproductive Phase

- Females enter the reproductive phase around puberty (10 to 12 years) lasting until approximately 45 to 50 years.
- Ova begins maturing at puberty, with one released every 28 to 30 days.
- The uterine wall thickens for potential egg reception, leading to pregnancy if fertilized.
- Unfertilized egg and thickened uterine lining shed during **menstruation**, occurring every 28 to 30 days.
- The first menstrual flow at puberty is termed **menarche**.
- The menstrual cycle stops at 45 to 50 years, termed **menopause**.

Menstrual Cycle and Hormonal Control

- Menstrual cycle, controlled by hormones, involves egg maturation, release, uterine wall thickening, and breakdown if no pregnancy occurs.
- Initially irregular, the menstrual cycle becomes regular over time.

Accumulation Of Variation During Reproduction

- Inheritance from the previous generation provides a common basic body design for the next generation.
- The **new generation inherits both a common body design and subtle changes from the previous generation**.
- In **asexual reproduction**, where a single individual reproduces, the generated offspring are very similar with minor differences due to DNA copying inaccuracies.
- **Sexual reproduction** introduces even greater **diversity in the offspring.**

- **Variations in a species** are not equal, and different individuals have varying advantages based on the nature of their variations.
- Environmental factors play a crucial role in selecting variants, and the survival of individuals is influenced by their ability to adapt to specific conditions.
- Selection of variants by environmental factors is foundational to evolutionary processes, shaping the characteristics of populations over time.

Creation of diversity over Succeeding Generations

The original organism at the top will give rise to, say, two individuals, similar in body design, but with subtle differences.

Each of them, in turn, will give rise to two individuals in the next generation.

Each of the four individuals in the bottom row will be different from each other. While some of these differences will be unique, others will be inherited from their respective parents, who were different from each other.

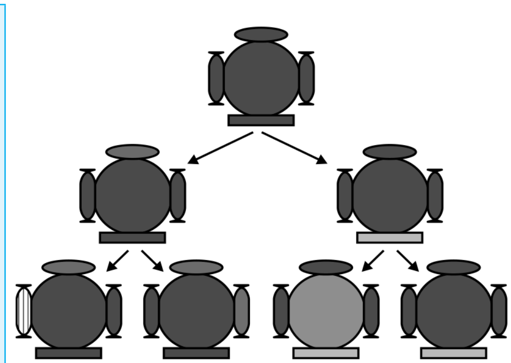


Figure 14.39: Creation of diversity over Succeeding Generations

Heredity

Inherited Traits

- The reproductive process leads to individuals with both common basic body designs and subtle changes.
- Inheritance from the previous generation provides a common basic body design and introduces subtle changes for the next generation.

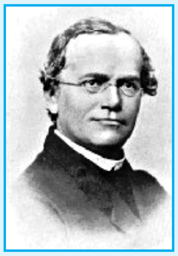
Rules for the Inheritance of Traits – Mendel's Contributions

- **Inheritance** involves contributions from both parents, shaping traits in offspring.
- Mendel's experiments with **garden peas** demonstrated dominant and recessive traits.
- Dominant traits express themselves even in the presence of one copy, while recessive traits require two copies for expression.
- Traits are independently inherited, leading to various combinations in the offspring.

How these Traits get Expressed

- **Genes** control characteristics and each trait is associated with specific genes.
- **The mechanism of heredity** involves the contribution of genetic material from both parents.
- Germ cells have one set of genes, ensuring diversity in offspring during sexual reproduction.

Gregor Johann Mendel (1822–1884)



Mendel was educated in a monastery and went on to study science and mathematics at the University of Vienna. Failure in the examinations for a teaching certificate did not suppress his zeal for scientific quest. He went back to his monastery and started growing peas. Many others had studied the inheritance of traits in peas and other organisms earlier, but Mendel blended his knowledge of science and mathematics and was the first one to keep count of individuals exhibiting a particular trait in each generation. This helped him to arrive at the laws of inheritance.

- **Chromosomes**, present as separate pieces, are inherited from each parent, contributing to trait inheritance.
- **Mendelian experiments tested** with pea plants showing two different characteristics. It illustrated the **concept of dominance and recessiveness** with examples.

Sex Determination (refer Figure 14.40)

- Genetic determination largely influences the **sex of newborn individuals in humans**.
- Instructions for determining a baby's sex are within the **fertilized egg or zygote.**
- Chromosomes carry these instructions and reside in the cell nucleus.
- Humans have 23 pairs of chromosomes, with two being **sex chromosomes: X and Y.**
- Females have two X chromosomes, while males have one X and one Y chromosome.
- **Gametes (egg and sperm)** carry only one set of chromosomes.

Role of Sex Chromosomes in Determining Sex

- Unfertilized eggs always have one X chromosome.
- Sperms come in two types: X-carrying and Y-carrying.
- Fertilization by X-carrying sperm results in a female child, while Y-carrying sperm leads to a male child. (refer FIgure 14.40)
- Sex chromosomes from the father determine the unborn baby's sex.
- The notion that the mother determines the baby's sex is inaccurate and unjustified.
- For species other than humans, environmental cues and different strategies are used for sex determination as environmental factors play a role in the selection of variants and evolutionary processes.

The mechanism of heredity ensures the **stability of the DNA** of the species.

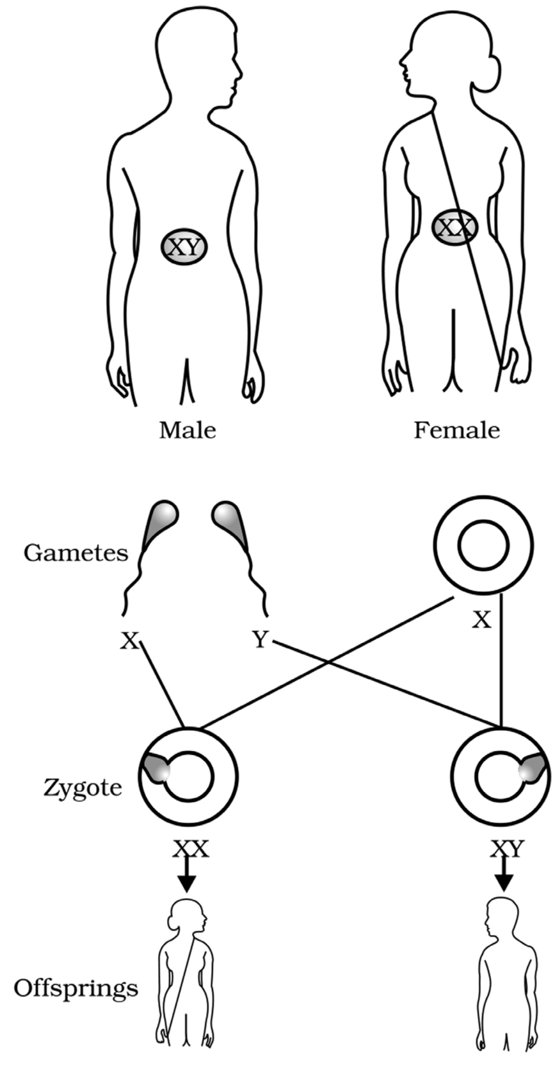


Figure 14.40: Sex determination in human beings

Asexually reproducing organisms follow similar rules of inheritance, ensuring variation and adaptation. Hence, variations are important for the survival and evolution of species.

Conclusion

In the mosaic of existence, this chapter paints a vivid portrait of life's diverse expressions. From the pulsating energy of cells to the orchestration of hormones, they traverse the landscapes of reproduction, respiration, and coordination. The importance of unity and variation in life's symphony becomes clear. Whether in the rhythmic beats of a heart or the delicate dance of chromosomes, life persists, thriving in its myriad forms. With each page turned, a deeper understanding of life's intricate dance emerges—a dance where every cell, every hormone, and every moment is a testament to the enduring beauty of existence.

Glossary:

- **Pituitary Gland:** An endocrine gland located at the base of the brain that regulates various bodily functions and controls other endocrine glands.
- **Thyroid Gland:** An endocrine gland in the neck that produces hormones responsible for regulating metabolism.
- **Pancreas:** An organ that functions as both an endocrine and exocrine gland, producing insulin and digestive enzymes.
- **Adrenal Glands:** Paired glands situated on top of each kidney that produce hormones like cortisol and adrenaline, playing a role in stress response.
- **Reproductive Glands:** Glands such as ovaries in females and testes in males, are responsible for producing sex hormones and gametes.
- **Heredity:** The passing of genetic traits from one generation to the next.
- **Genes:** Units of heredity, segments of DNA that determine specific traits.
- **Chromosomes:** Thread-like structures in the cell nucleus that carry genetic information.
- **DNA:** Deoxyribonucleic acid, a molecule containing genetic instructions for the development and functioning of living organisms.
- **Cell Nucleus:** The central part of a cell that contains genetic material.
- **Muscles:** Tissues responsible for body movement and maintaining posture.
- **Skeletal System:** The framework of bones and cartilage that provides support and protection for the body.
- **Circulatory System:** The system that transports blood, oxygen, and nutrients throughout the body, including the heart and blood vessels.
- **Respiratory System:** The system responsible for breathing and gas exchange, including the lungs and airways.
- **Digestive System:** The system that processes and absorbs nutrients from food, including organs like the stomach and intestines.
- **Nervous System:** The complex network of nerves and cells that transmit signals between different parts of the body.
- **Joint:** The connection between two or more bones, facilitating movement.
- **Flexion:** Bending movement that decreases the angle between body parts.
- **Extension:** Straightening movement that increases the angle between body parts.
- **Synovial Fluid:** Fluid present in joint cavities that lubricates and nourishes the joints.
- **Bristles:** Short, stiff hairs or projections, often found on the surface of certain animals or brushes.
- **Cartilage:** A flexible and elastic connective tissue found in various parts of the body, such as the joints, nose, and ears.
- **Outer Skeleton:** Also known as the exoskeleton, it is a rigid external covering that provides support and protection to some animals, such as insects and crustaceans.
- **Pelvic Bones:** The bones forming the pelvis, including the ilium, ischium, and pubis, which together support the spine and connect the vertebral column to the lower limbs.
- **Pivotal Joint:** A joint that allows rotational movement around a central axis, such as the pivot joint found in the neck, allowing the head to turn.

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Food and Crops

Bibliography: This chapter encompasses the summary of Chapter 1- VI NCERT (Science), Chapter 1- VIII NCERT (Science) and Chapter 12- IX NCERT (Science).

Introduction

Crops are of paramount importance for food production, serving as the primary source of sustenance for humanity. They provide essential nutrients, including carbohydrates, proteins, and vital vitamins, in our daily diets. Effective crop management is central to addressing global food security and ensuring a stable supply of nourishing food. Our body needs different kinds of food according to our special needs. For example, when we are travelling, we may eat whatever is available on the way and similarly when we are at our home, our plate consists of different items according to the region we live in.

Nutrients

- Food is generally made of many ingredients. Ingredients contain some components that are needed by our body. These components are called nutrients.
- **Major nutrients are listed as follows:**
  - Carbohydrates
  - Proteins
  - Fats
  - Vitamins
  - Minerals
  - Dietary fibre
  - Water
- **There are generally two types of carbohydrates in food:**
  - Starch
  - Sugar
- **Test to see if the food contains carbohydrates:**
  - If the colour of (Food + Dilute Iodine solution) changes to blue black then it indicates that the tested food has Starch or Carbohydrates.
- **Test to see if the food contains fats:**
  - Take a food item and crush it, if an oily patch is found in the crushed food, then it indicates food has fats.
- **Test to see if the food contains Protein:**
  - If the colour of (food item + solution of copper sulphate + caustic soda) changes to violet, then it indicates tested food has Protein.

Need of Nutrients

- **Sources of Energy:**
  - Carbohydrates and fats mainly provide us with energy. Some sources of carbohydrates are Sweet Potato, Potato, Sugarcane, Papaya, Melon, Mango, Maize, Bajra, Rice, Wheat.
  - Fat has much more energy than carbohydrates. We get fats from both plants and animals. Plant sources of fats are Sunflower Oil, Groundnut Oil, Mustard Oil, Coconut Oil, Soybean Oil and the animal sources are Meat, Fish, Eggs, Ghee, Butter and Cream.
  - Foods containing fats and carbohydrates are generally called 'energy giving foods'.
- **Growth and Repair:**
  - Proteins are needed for the growth and repair of our body. These foods are called body building foods.
  - Some sources are Peas, Gram, Moong, Soybeans, Tur Dal, Beans, Meat, Fish, Paneer and Eggs.
- **Defence against Disease:**
  - Vitamins help in protecting our body against diseases. Vitamins also help in keeping our eyes, bones, teeth and gums healthy.
  - Vitamins are of different kinds known by different names. Some of these are Vitamin A, Vitamin C, Vitamin D, Vitamin E and K. There is also a group of vitamins called Vitamin B-complex.
  - Our body needs all types of vitamins in small quantities.

Table 15.1: Functions and Sources of Vitamins and Minerals

Vitamins and Minerals	Functions	Sources
Vitamin A	Keeps our skin and eyes healthy.	Papaya, Mango, Carrot
Vitamin B Complex	Gives strong muscles.	Rice, wheat, liver
Vitamin C	Helps in the fight against diseases.	Orange, Guava, Tomato, lemon, Amla, Green Chilli
Vitamin D	Keeps our bones and teeth strong.	Sunlight, milk, Butter, Fish, Egg, Liver
Vitamin E	It is antioxidant, it slows down the process that damages the cell. It also helps to the proper function of many cells.	Vegetable oils, cereals, meat, egg, vegetable
Vitamin K	Helps in the blood clot, preventing excess bleeding.	Leafy greens, meat, egg
Iodine	Iodine is needed to make thyroid hormones and these hormones control the body's metabolism.	Fish, milk, vegetables
Calcium	Builds and Keeps bones healthy.	Milk, egg
Iron	Iron is part of Haemoglobin and many proteins.	Apple, chocolate, leafy vegetables.
Phosphorous	Phosphorus works with calcium to build the bones.	Fish Milk, green chilli

Dietary fibres or Roughage	Not a nutrient but helps in the size of stool and softness. It also helps to decrease the cholesterol level.	Whole grain, pulse, fresh fruits, potato
Water	Helps to throw out waste via urine and sweat and helps our body to absorb nutrients from food.	Drinking water, milk, tea, fruits and vegetables

Balanced Diet

- For the growth and maintenance of good health, our diet should have all the nutrients that our body needs, in the right quantity, not too much of one nor too little of other.
- Balance diet= Roughage + water + right quantities of all nutrients.
- Too much fat leads to obesity.

Deficiency Diseases

- Diseases that occur due to lack of nutrients over a long period are called deficiency disease.
  - For example, Lack of protein leads to Stunted growth, swelling face, discoloration of hairs, skin disease, etc.
  - If an individual experiences a prolonged lack of both carbohydrates and proteins in their diet, it can lead to a complete halt in growth. This can result in significant emaciation, extreme thinness, and such a severe weakness that mobility may be greatly impaired.

The following are Deficiency Diseases

Vitamins and Minerals	Deficiency Disease	Symptoms
Vitamin A	Loss of Vision	Poor vision, loss of vision in dark night
Vitamin B1	Beriberi	Weak muscles and little energy to do work.
Vitamin C	Scurvy	Bleeding gums, wounds take longer time to heal
Vitamin D	Rickets	Bones become soft & bent
Calcium	Bones and teeth decay	Weak bones and tooth decay
Iodine	Goitre	Glant in the neck, mental disability in children
Iron	Anaemia	Weakness

Fortification

- Fortification of food is the addition of key vitamins and minerals to staple foods such as rice, wheat, oil, milk and salt to improve their nutritional content.
  - There is a logo for the fortified items as per the standards of FSSAI. **(For logo Refer Figure 15.1).**

FORTIFIED
SAMPOORNA POSHAN
SWASTH JEEVAN

Figure. 15.1: Fortification Logo by FSSAI

Production, Improvement and Management of Crops

- After learning that all living organisms require food, now let us see how these foods are being produced. In order to provide food for a large population— regular production, proper management and distribution is necessary.

- In India, there has been a four-fold increase in the production of food grains from 1952 to 2010 with only a 25% increase in the cultivable land area. The practices of farming can be divided into three stages:
  - Basic agricultural practices and crop production management,
  - Crop variety improvement,
  - Crop protection management.

POINTS TO PONDER

Can you find out how food can be Fortified? Also try to find out how much proportion of fortification is made available in the food grains distributed through PDS?

Basic Agricultural Practices and Crop Production Management

- **Crops and their Type**
  - Plants of the same kind that are grown and cultivated as a source of food in a large cultivable land is called a crop.
  - **Rabi Crops:** Crops, which are grown in the winter season (from October to March) are called Rabi crops.
  - **Kharif Crops:** The crops, which are sown in the rainy season (from July to October) are called Kharif crops.
- **Basic Practices of Crop Production:** Following are the basic practices involved in crop production:
  - Preparation of soil
  - Sowing
  - Adding manure and fertilisers
  - Irrigation
  - Protecting from weeds
  - Harvesting
  - Storage
- **Crop production management** refers to the growing of crops and providing all the nutrients to the crop plant that are needed and also properly storing them. It includes the following:
  - Nutrition Management,
  - Irrigation,
  - Cropping Patterns

POINTS TO PONDER

Deficiency of nutrients affects physiological processes in plants including reproduction, growth, and susceptibility to diseases. Hence a proper nutrient management of the crops is required. Can you list out the important nutrients that the crops require for healthy growth?

Preparation of Soil

- The preparation of soil is the first step before growing a crop. One of the most important tasks in agriculture is to turn the soil and loosen it. The loose soil allows the roots to breathe easily even when they go deep into the soil.
- The loosened soil helps in the growth of earthworms and microbes present in the soil. These organisms are friends of the farmer since they further turn and loosen the soil and add humus to it.
- Since only a few centimetres of the top layer of soil supports plant growth, turning and loosening of soil brings the nutrient-rich soil to the top so that plants can use these nutrients.
- Loosening of soil is carried out using various processes and tools.

Tilling or Ploughing

- The process of loosening and turning of the soil is called tilling or ploughing and is done by using a plough.
- **Plough:** A plough is a device that is used by farmers for different purposes, such as adding fertilisers, tilling and loosening the soil. (**Refer Figure 15.2**)

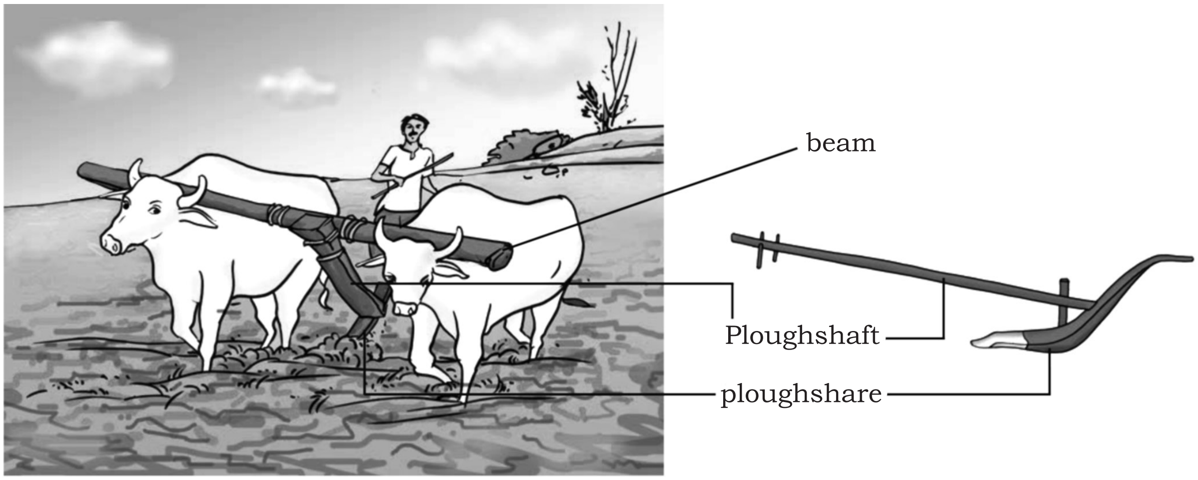

Figure 15.2: Plough

  - It is also used for adding fertilisers to the soil, removing weeds, scraping of soil, etc.
  - The ploughshare is the triangular iron strip. A wooden, traditional plough can be operated by a pair of oxen and a man.
  - Nowadays, these wooden ploughs are mostly replaced by iron ploughs.
- **Hoe:** A hoe is a tool that is used to dig up soil to remove weeds and also loosen up the soil before planting a sapling. (**Refer Figure 15.3**)
- **Cultivator:** A cultivator is attached to the tractor and helps in loosening soil. Cultivators are used instead of ploughs since they are faster.

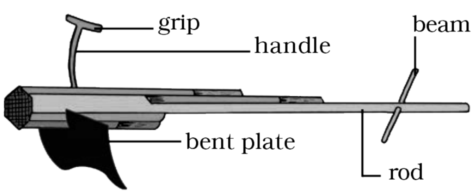

Figure 15.3: Hoe

Sowing

- Sowing is the process of planting seeds in the soil.
- The seeds are sowed in the soil that is loosened by a cultivator or plough.
- **Traditional Tools of Sowing:** Before the advent of modern agricultural machinery, traditional tools were used by farmers. These include ploughs, shovels, scythes and pickaxes.
  - The traditional tool used to sow the seeds was like a funnel.
  - Once seeds were put into this funnel, they would go into 2-3 tubes having sharp ends. The ends will pierce into the soil and place the seeds there.
  - **Seed Drill:** Seed drills are used for sowing with the help of tractors. **(Refer Figure 15.4)**. It ensures that seeds are sown uniformly, at a particular depth and are covered by soil after sowing.

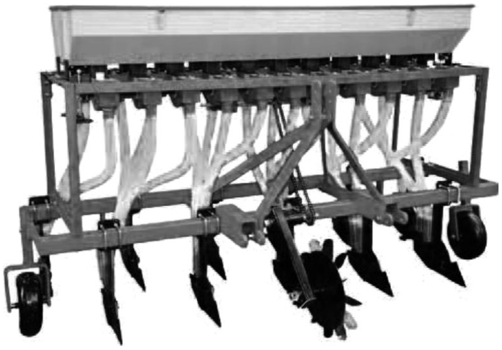

Figure 15.4: Seed Drill

Selection of Quality Seeds

- The quality of the seed is an important factor that determines the crop yield.
- The selection of good seeds is done by putting the seeds into water.
- The dead and damaged seeds become hollow and float on water, whereas the good seeds sink.

Nursery

- A nursery is a place where young plants and trees are grown for planting elsewhere.
- Nursery acts as a **repository of saplings**.

Germination of Seeds

- Germination of the seed happens when the seed is sown in the land and watered.
- A plant starts to emerge from the seed and starts to grow.
- Adding Manure and Fertilisers.

Nutrition Management

- Deficiency of nutrients affects physiological processes in plants including reproduction, growth, and susceptibility to diseases.
- To increase the yield, the soil can be enriched by supplying these nutrients in the form of manure and fertilisers. To see the nutrients supplied by air, please **refer to table 15.2**

Table 15.2: Nutrients supplied by air, water and soil

Source	Nutrients
Air	carbon, oxygen
Water	hydrogen, oxygen
Soil	**(i) Macronutrients:** *nitrogen, phosphorus, potassium, calcium, magnesium, sulphur* **(ii) Micronutrients:** *iron, manganese, boron, zinc, copper, molybdenum, chlorine*

- **Manure/Fertilisers:** Manures and fertilisers are substances that are added to the soil to increase its fertility.
  - Manures are made by decomposition of organic substances, and fertilisers are made of inorganic chemicals.
  - Manure is prepared by the decomposition of animal excreta and plant waste. Manure helps in enriching the soil with nutrients and organic matter and increases soil fertility.
  - Based on the kind of biological material used, manure can be classified as **Compost and vermicompost, Green Manure**.

Difference between Manure and Fertilisers

Fertiliser	Manure
Fertiliser is a manmade both organic and inorganic salt.	Manure is a natural substance obtained by the decomposition of cattle dung and plant residues.
Fertiliser is prepared in factories.	Manure can be prepared in the fields.
Fertiliser does not provide any humus to the soil.	Manures provide a lot of humus to the soil.
They are very rich in plant nutrients like nitrogen, potassium and phosphorus.	They are relatively less rich in plant nutrients.

- **Disadvantages of Using Fertilisers:** Excessive use of fertilisers can cause pollution. It can also change the pH of the soil in certain rare cases.
- **Leaving the Land Fallow:** When land is left fallow for a certain period of time, the land replenishes its nutrients by itself. This land can be used for agriculture again.
- **Advantages of Manure**
  - Organic manure is considered better than fertiliser. This is because it enhances the water holding capacity of the soil.
  - It makes the soil porous due to which exchange of gases becomes easy.
  - It increases the number of friendly microbes. It improves the texture of the soil.

> Droughts occur because of scarcity or irregular distribution of rains. Drought poses a threat to rain-fed farming areas, where farmers do not use irrigation for crop production and depend only on rain. Light soils have less water retention capacity. In areas with light soils, crops get adversely affected by drought conditions.

Irrigation

- **Definition:** The supply of water to crops at regular intervals is called irrigation. The time and frequency of irrigation varies from crop to crop, soil to soil and season to season. In summer, the frequency of watering is higher.
- **Importance of Irrigation:** Water is absorbed by the plant roots. Along with water, minerals and fertilisers are also absorbed. Plants contain nearly 90% water.
  - Water is essential because germination of seeds does not take place under dry conditions.
  - Nutrients dissolved in water are transported to each part of the plant.
  - Water protects the crop from both frost and hot air currents.
- **Sources of Irrigation:** The sources of water for irrigation are— wells, tube wells, ponds, lakes, rivers, dams and canals.
  - **Wells:** These are of two types of wells, namely, dug wells and tube wells. In a dug well, water is collected from water-bearing strata. Tube wells can tap water from the deeper strata. From these wells, water is lifted by pumps for irrigation.
  - **Canals:** Canals receive water from one or more reservoirs or from rivers. The main canal is divided into branch canals having further distributaries to irrigate fields.
  - **River Lift System:** In areas where canal flow is insufficient or irregular due to inadequate reservoir release, the lift system is more rational. Water is directly drawn from the rivers for supplementing irrigation in areas close to rivers.
  - **Tanks:** These are small storage reservoirs, which intercept and store the run-off of smaller catchment areas.

Methods of Irrigation

- **Traditional Methods:** The various traditional ways are the moat (pulley-system), chain pump, dhekli, and rahat (Lever system). Pumps are commonly used for lifting water. Diesel, biogas, electricity and solar energy is used to run these pumps. **(Refer Figure 15.5)**
- **Modern Methods:** They help us to use water economically. The main modern methods used are as follows:
  - **Sprinkler System:** This system is more useful on the uneven land where sufficient water is not available (**Refer Figure 15.6**). Water gets sprinkled on the crop as if it is raining. Sprinkler is very useful for lawns, coffee plantations and several other crops.

- **Drip System:** In this system, the water falls drop by drop directly near the roots. So it is called a drip system. It is the best technique for watering fruit plants, gardens and trees (**Refer Figure 15.7**). Water is not wasted at all. It is a boon in regions where availability of water is poor.

Figure. 15.5: Moat Method

Figure 15.6: Sprinkler Method of Irrigation

Figure 15.7: Drip Method of Irrigation

Cropping Patterns

- **Crop Rotation:** Growing different crops on a piece of land in a pre planned succession is known as crop rotation. If crop rotation is done properly then two or three crops can be grown in a year with a good harvest. These include different ways of growing crops so as to get the maximum benefit. These different ways include the following:
  - **Mixed Cropping:** Mixed cropping is growing two or more crops simultaneously on the same piece of land.
  - **Inter-cropping:** It involves growing two or more crops simultaneously on the same field in a definite proportion or pattern. The crops are selected such that their nutrient requirements are different. This ensures maximum utilisation of the nutrients supplied and also prevents pests and diseases from spreading to all the plants belonging to one crop in a field. (**Refer Figure 15.7(a)**).

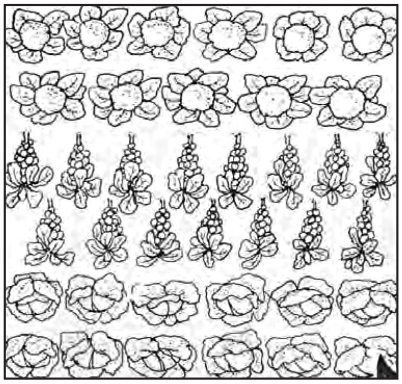

Figure 15.7: (a) Intercropping pattern

Harvesting, Threshing and Winnowing

- **Harvesting:** It is the **process of cutting the crop after it is mature**.
  - **Methods of Harvesting:** Harvesting is done by two methods. First is the manual method, where a sickle is used. Second is the mechanical method, where a huge machine called a harvester is used.
- **Threshing:** Threshing is the process of loosening the grains from the chaff. While it can be done manually, this is carried out with the help of a machine called 'combine' which is in fact a harvester as well as a thresher. (**Refer Figure 15.8**)

Harvesting Festival

After three or four months of hard work there comes the day of the harvest. The period of harvest is, thus, of great joy and happiness in all parts of India.

Men and women celebrate it with great enthusiasm. Special festivals associated with the harvest season are **Pongal, Baisakhi, Holi, Diwali, Nabanya and Bihu.**

- **Winnowing:** Winnowing is the process that separates grain seeds from the chaff using the help of the wind. (**Refer Figure 15.9**) Due to the wind, the lighter chaff flies away, and the heavier grains fall down.

Figure. 15.8: Combine

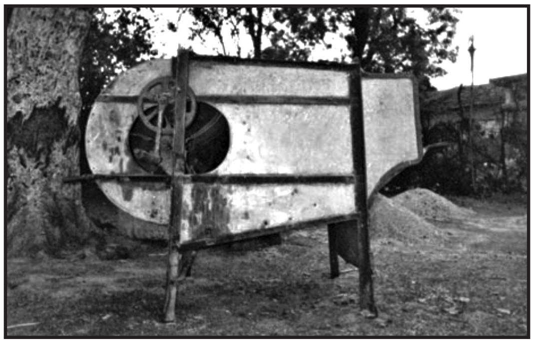

Figure 15.9: Winnowing Machine

Storage

- Storage of the grains is an important step in agriculture. After harvesting, the ready grains are stored in granaries or silos.
- The grains have to be stored in a dry place that does not have a rodent or fungal infestation.
- **Fumigation** of storage places is carried out to make it free from microbes.
- **Granaries:** Granaries are the place where freshly obtained food grains are stored.

Crop Variety Improvement

The crop variety improvement approach depends on finding a crop variety that can give a good yield. It can be done in the following two ways:

- **Higher Yield:** To increase the productivity of the crop per acre.
- **Improved Quality:** The quality of crop products varies from crop to crop. e.g., protein quality is important in pulses, oil quality in oilseeds, and preserving quality in fruits and vegetables.
- **Biotic and Abiotic Resistance:** Crop production can go down due to biotic (diseases, insects, and nematodes) and abiotic (drought, salinity, water logging, heat, cold, and frost) stresses under different situations. Varieties resistant to these stresses can improve crop production.
- **Change in Maturity Duration:** Shorter maturity period of a crop reduces the cost of crop production and makes the variety economical. Uniform maturity makes the harvesting process easy and reduces losses during harvesting.
- **Wider Adaptability:** It allows the crops to be grown under different climatic conditions in different areas.
- **Desirable Agronomic Characteristics:** It increases productivity, for example, tallness and profuse branching are desirable characteristics for fodder crops; while dwarfness is desired in cereals so that less nutrients are consumed by these crops.

Crop Protection Management

- Field crops are infested by a large number of weeds, insect pests, and diseases. Weeds, insects, and diseases can be controlled by various methods.
  - One method can be the use of pesticides. It includes herbicides, insecticides, and fungicides. These chemicals are sprayed on crop plants or used for treating seeds and soil.
  - However, excessive use of these chemicals creates problems, since they can be poisonous to many plant and animal species and cause environmental pollution.
  - Another is mechanical removal of weeds using human labour or machineries.

- **Weeds and Protection against Weeds:** Weeds are undesirable plants that may grow naturally along with the crop. Weeds compete with the crops by absorbing all the water, nutrients, space and light. **Following are the ways in which crops are protected against weed:**
  - **Tilling:** Tilling is a process done before sowing of crops that helps in uprooting and killing weeds.
  - **Manual Removal:** Manual removal includes physical removal of weeds by uprooting them from the soil or chopping them off to ground level periodically.
  - **Weedicides:** Chemicals used to kill the weeds are known as weedicides. They usually don't damage the crop.

Animal Husbandry

Animal husbandry is the management and care of farm animals for milk, egg or meat.

Cattle Farming

- Cattle husbandry is done for two purposes, namely, for milk and for draught labour for agricultural work such as tilling, irrigation, and carting.
- Milk production depends on the duration of the lactation period. So, milk production can be increased by increasing the lactation period.
- Exotic or foreign breeds are selected for long lactation periods, while local breeds show excellent resistance to diseases.
- **Food Requirements of Dairy Animals:** The animal feed includes **roughage**, which is largely fibre, and **concentrates**, which are low in fibre and contain relatively high levels of proteins and other nutrients. The food requirements of dairy animals are of two types:
  - **Maintenance requirement**, which is the food required to support the animal to live a healthy life;
  - **Milk-production requirement**, which is the type of food required during the lactation period.

Poultry Farming

- Poultry farming is undertaken to raise domestic fowl for egg production and chicken meat. The cross-breeding programs between Indian and foreign breeds for variety improvement are focused on developing new varieties. (**Refer Figure 15.10**)
- Broiler chickens are fed with vitamin-rich supplementary feed for a good growth rate and better feed efficiency.
- Care is taken to avoid mortality and to maintain feathering and carcass quality. For good production, there should be maintenance of temperature and hygienic conditions in housing and poultry feed, as well as prevention and control of diseases and pests.

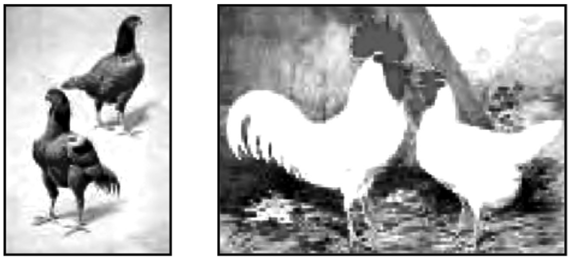

Figure 15.10: (a) Aseel (b) Leghorn

Fish Production

- Fish production includes the finned true fish as well as shellfish such as prawns and mollusks. There are two ways of obtaining fish.
- One is from natural resources, which is called **capture fishing**.
- The other way is by fish farming, which is called **culture fishery**.
- Fishing can be done both by capturing and culture of fish in marine and freshwater ecosystems.

Marine Fisheries

- Popular marine fish varieties include pomfret, mackerel, tuna, sardines, and Bombay duck. Marine fish are caught using many kinds of fishing nets from fishing boats.
- Yields are increased by locating large schools of fish in the open sea using satellites and echo sounders.

POINTS TO PONDER

Just like there is crop protection management, there must exist an animal protection management to protect their health. Why do you think such protection is important? In case of marine farming how is quality ensured?

Inland Fisheries

- Freshwater resources include canals, ponds, reservoirs, and rivers. Brackish water resources, where seawater and freshwater mix together, such as estuaries and lagoons are also important fish reservoirs.
- While capture fishing is also done in such inland water bodies, the yield is not high.
- Most fish production from these resources is through **aquaculture**.

Bee-Keeping

- Bee-keeping needs low investments, farmers use it as an additional income-generating activity. In addition to honey, the beehives are a source of wax which is used in various medicinal preparations.
- The Italian bees have a high honey collection capacity.
- They sting significantly less than other types of bees.
- They stay in a given beehive for long periods and breed very well. For commercial honey production, bee farms or apiaries are established.

Conclusion

The importance of a balanced diet lies in its ability to provide the necessary nutrients for overall health and well-being. Effective food and crop management is crucial for ensuring sustainable agriculture and food security. It involves optimising nutrient supply to crops through the balanced use of macro and micronutrients, with manure and fertilisers as key resources. Proper animal husbandry, such as in poultry farming, ensures a stable source of protein. Efficient fish farming, guided by technology like echo-sounders and satellites, provides diverse dietary options. Additionally, bee-keeping contributes to honey and wax production. These practices collectively contribute to a more resilient and sustainable food production system, addressing the growing global demand for nutritious and safe food.

Glossary:

- **Balanced diet:** Balanced diet provides all the nutrients that our body needs, in right quantities, along with adequate amounts of roughage and water.
- **Beriberi:** A deficiency disease caused by lack of Vitamin B1 (Thiamine)
- **Carbohydrates:** An essential structural component of living cells and source of energy for animals
- **Granaries:** A storehouse for threshed grain or animal feed
- **Harvesting:** The gathering of a ripened crop
- **Intercropping:** A multiple cropping practice that involves the cultivation of two or more crops simultaneously on the same field.
- **Irrigation:** Supplying dry land with water by different means such as wells, tanks etc.
- **Kharif:** Crops usually sown at the beginning of the first rains during the advent of the south-west monsoon season, and harvested at the end of monsoon season (October–November).
- **Manure:** Any animal or plant material used to fertilise land especially animal excreta usually with litter material
- **Plough:** A farm tool having one or more heavy blades to break the soil and cut a furrow prior to sowing.
- **Rabi:** Crops sown around mid-November, preferably after the monsoon rains are over, and harvesting begins in April/May.
- **Roughage:** Coarse, indigestible plant food low in nutrients.
- **Scurvy:** A condition caused by deficiency of Vitamin C (Ascorbic acid).
- **Silo:** A cylindrical tower used for storing silage or grains.
- **Threshing:** The separation of grain or seeds from the husks and straw.
- **Winnowing:** The act of separating grain from their coverings.

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16 Natural Phenomenon

Bibliography: This chapter encompasses the summary of **Chapter 12 - VIII** NCERT (Science).

Introduction

In this chapter of natural phenomenon, we will look at lightning and earthquakes. Lightning is like a quick, bright spark of electricity, and earthquakes are like the Earth's deep sighs. These things bring problems that people have to face. However we can protect ourselves using smart ideas inspired by nature to avoid lightning, and using strong materials to stay safe during earthquakes.

Lightning

- Lightning is an electric spark caused by charge imbalance between clouds and the ground, due to accumulation of charge in the cloud.
- In ancient times, people feared lightning, thinking it was the wrath of gods.

The Sparks that the Greeks Knew About

- In 600 BC, the Greeks discovered the phenomenon of static electricity, noticing that amber, when rubbed with fur, attracted light objects due to electric charges.
- In **1752, Benjamin Franklin** scientifically proved the correlation between lightning and sparks from clothing, a realization that took the world 2000 years to acknowledge.

Charging by Rubbing

- When objects are rubbed together, the movement of electrons occurs, resulting in the positive charging of one object and the negative charging of the other, a fundamental phenomenon in static electricity.
- The rubbing of a plastic refill with polythene results in **charge transfer**, leading to the formation of **charged objects.**
- This phenomenon can be observed in various materials, including **balloons, erasers, and steel spoons.**
- Electric charges produced by rubbing remain static until they are set in motion, forming an electric current.

Types of Charges and their Interaction

- During the rubbing process, electrons move from one object to another, causing an excess of electrons in one and a deficiency in the other, resulting in the creation of charged objects.
- For example, when a glass rod is rubbed with silk cloth, the glass becomes positively charged, and the silk cloth becomes negatively charged, showcasing the **transfer of electric charges** between them.
- **Negatively Charged:** Objects having an excess of electrons are called negatively charged.
- **Positively Charged:** Objects having a shortage of electrons are called positively charged.

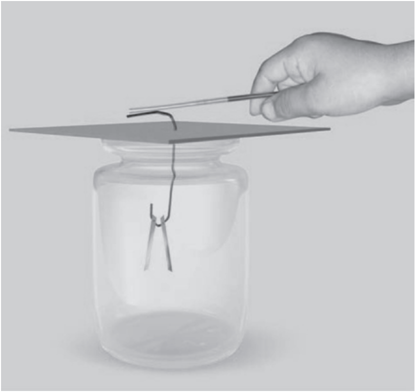
- The electrical charges generated by rubbing are **static**. They do not move by themselves. When charges move, they constitute an **electric current.**
- The current in a circuit which makes a bulb glow, or the current that makes a wire hot, is nothing but a **motion of charges.**
- Like charges repel, whereas, Unlike charges attract each other.

Transfer of Charges

- When we touch charged aluminum foil, charges flow through our body since human body is a good conductor, grounding the charges to the earth.
- **Earthing:** The process of transferring charges from a charged object to the earth is called earthing.
  - Earthing is provided in buildings to protect us from electrical shocks due to any leakage of electrical current.

Electroscope

- **Gold leaf electroscope:** It is used to find whether the body is charged or uncharged.
- Electroscopes consist of two closely placed metallic aluminum foils or strips.
- The ends of aluminum foils are affixed to a metallic wire or rod, enclosed within a glass bottle due to glass's low conductivity.
- When a charged body touches the metallic wire, the charges migrate smoothly, distributing themselves uniformly over the surface of the aluminum foils, creating a balanced charge distribution.
- When aluminum foils are charged with similar charges, they repel each other, widening apart and providing clear evidence of the body's charge.



Did you know?
Lightning is around **27000 degree celsius.**
When the lightning strikes, it makes a hole in the air called a **channel**. After the lightning is gone, the hole collapses. The sound you hear when the hole collapses is **thunder**.

Occurrence of Lightning

- In rain or thunderstorms, air rises while water droplets fall.
- During rain, **charges segregate,** positive charges accumulate near the upper edges of clouds, and negative charges accumulate near the lower edges.
- Additionally, positive charges accumulate on the ground.
- Between the clouds and the ground, the air is present which typically exhibits poor conductivity for charges. However, when its resistance diminishes, it begins to conduct charges.
- Negative and positive charges collide, resulting in bright light and sound, visible to us as **lightning**, known as **electric discharge.**
- Electric discharge can happen between clouds and the earth's surface or between two clouds in the atmosphere. **(Refer Figure 16.1)**

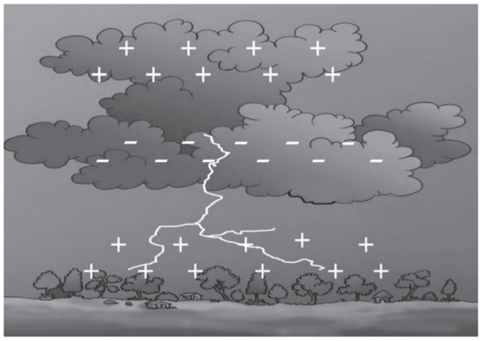


Figure 16.1: Accumulation of charges leading to lightning

Lightning Safety Guidelines to Follow

Outdoors

- Seek refuge in a secure location, like a small grove of trees.
- If you are inside a vehicle, remain inside with closed doors and windows.
- Keep a safe distance from metal poles.
- Avoid lying on the ground; instead, crouch down with your head protected by your hands.

POINTS TO PONDER

Lightning is essentially an electrical discharge through the atmosphere, representing a natural energy resource. Do you believe it's possible to capture electric energy from lightning, and are there any ongoing research initiatives in this field?

Indoors

- Refrain from touching telephone and electrical wires.
- Avoid taking a bath during a lightning storm.
- Unplug electrical appliances as a precautionary measure.

Lightning Conductors

- A lightning conductor is a device used to used to protect buildings from lightning.
- In the construction phase, a metallic rod is meticulously placed along the building's upper edge. One end extends into the air, creating a lightning-attracting point, while the other end is firmly grounded below the surface, ensuring a secure path for lightning discharge.
- When lightning strikes the rod, charges transfer to the earth, leaving the building unharmed and protected. **(Refer Figure 16.2)**

Figure 16.2: Lightning Conductor

Earthquakes

- A sudden shake or trembling of the earth which lasts for a very short time is referred to as an **earthquake**.
- **Focus:** The point inside the earth where the earthquake starts is the focus point.
- **Epicentre:** It is the point on the surface of the earth above the focus point. **(Refer Figure 16.3)**
- They may also cause floods, landslides, tsunamis, and loss of lives.

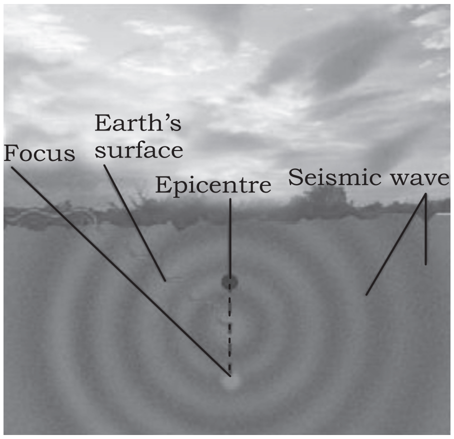


Figure 16.3: Epicenter of the Earthquake

Causes of Earthquakes

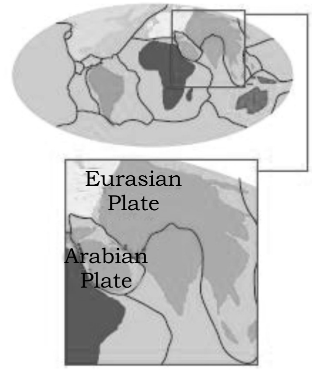


Figure 16.4: Earth Plates

- It is caused by a disturbance deep inside the earth's crust.
- The outer layer of the earth is fragmented.
- **Plate:** Each fragment is called a plate. **(Refer Figure 16.4)**
- These plates are in continual motion, so when they brush past one another, or a plate goes under another due to collision, they cause disturbance in the earth's crust.
- It is this disturbance that shows up as an earthquake on the surface of the earth.
- The **other causes** of earthquakes are volcanic eruptions, meteor hits, and nuclear explosions.

Seismic or Fault Zones

- The boundaries of the plates are the weak zones where earthquakes are more likely to occur. The weak zones are also known as seismic or fault zones. **(Refer Figure 16.5)**

Figure 16.5: Seismic or Fault Zones

Seismic or Fault Zones of India

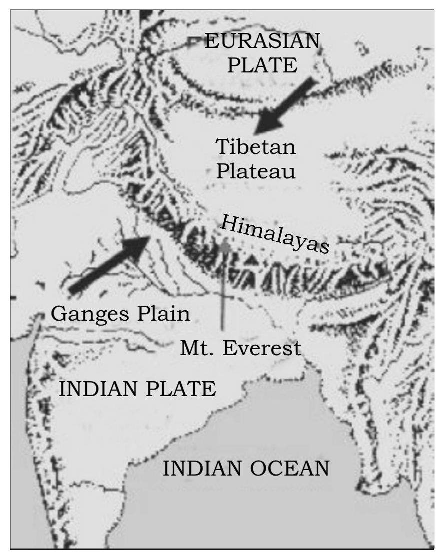


Figure 16.6: Movements of Indian Earth's Plate

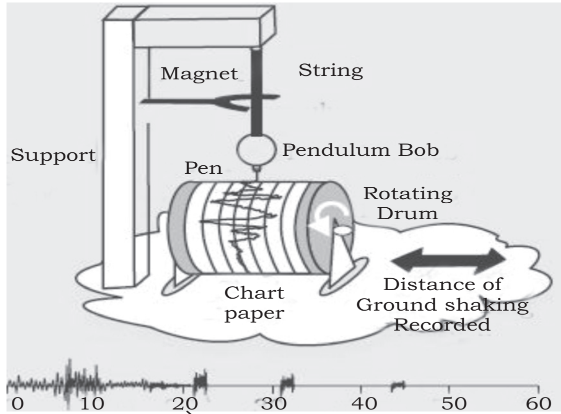
In India, the most threatened areas are as follows:

- Kashmir
- Western and Central Himalayas
- Rann of Kutch
- The whole of North-East
- Rajasthan and the Indo-Gangetic Plain
- Some areas of South India **(Refer Figure 16.6)**

Measurement of Earthquake

- **Seismograph:** It is an instrument used to detect and record earthquakes. **(Refer Figure 16.7)**
  - It consists of a metal rod attached to a fixed base.
  - During an earthquake, the base moves, but the rod does not move. The movement of the base to the rod is commonly transformed into an **electrical voltage.**
  - This record is proportional to the motion of the metal rod relative to the earth, but one can convert it to a record of the absolute motion of the ground.
- **Richter scale:** The power of an earthquake is expressed in terms of a **magnitude** on a scale called **Richter scale.**
  - Destructive earthquakes have magnitudes **higher than 7** on the Richter scale.

✧ Both Bhuj and Kashmir earthquakes had magnitudes greater than 7.5.



A typical seismograph record

Figure 16.7: A Seismograph

Protection Against Earthquake

- Since we know that earthquakes cannot be predicted and are highly destructive, therefore, it is important that we take necessary precautions to protect ourselves all the time.
- People living in seismic zones, where the earthquakes are more likely to occur, have to be specially prepared. First of all, the buildings in these zones should be designed so that they can withstand major tremors. Modern building technology can make it possible.
- It is advisable to make the structure simple so that it is **'Quake Safe'**.
- In highly seismic areas, the use of mud or timber is better than the heavy construction material.
- Since some buildings may catch fire due to an earthquake, it is necessary that all buildings, especially tall buildings, have fire fighting equipment in working order.
- The **Central Building Research Institute, Roorkee**, has developed know how to make quake proof houses.

POINTS TO PONDER

Japan is one of the most seismic sensitive countries. They have developed earthquake resistant construction technology. Do you know how earthquake resistance works and what type of foundation will provide the best support against ground shaking in India ?

Conclusion

The study of this chapter not only unravels the complexities of lightning and earthquakes but also offers practical guidelines to protect yourself and mitigate potential damages. Moreover, it provides a comprehensive exploration of static electricity and its intriguing connection to lightning, offering readers a thorough understanding of these captivating topics.

Glossary:

- **Earthing:** The process of transferring charges from a charged object to the earth.
- **Earthquake:** A sudden shake or trembling of the earth which lasts for a very short time.
- **Electroscope:** It is used to find whether the body is charged or uncharged.
- **Richter scale:** It is a numerical scale for expressing the magnitude of an earthquake on the basis of seismograph oscillations.
- **Seismograph:** An instrument is used to detect and record earthquakes.

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17

Our Environment

Bibliography: This chapter encompasses the summary of **Chapter 11 - VI** NCERT (Science), **Chapters 12 and 13 - VII** NCERT (Science) and **Chapter 13 - X** NCERT (Science).

Introduction

Earth's environment encompasses the interconnected systems of air, water, and land, supporting life and ecosystems. It sustains biodiversity, regulates climate, and provides resources vital for human survival and well-being. Air, water, and land are essential elements of Earth's environment. Air sustains life with oxygen, water supports ecosystems and human needs, and land provides habitats and resources for diverse species.

Composition of Air

- Our earth is surrounded by a thin layer of air. This layer extends up to many kilometres above the surface of the earth and is called the atmosphere. As we move higher in the atmosphere, the air gets rarer.
- Air is a mixture of many gases. Few of its components **(Refer to Figure: 17.1)** are listed as under:
  - **Water Vapour**
  - **Oxygen:** Oxygen in the atmosphere is replaced through photosynthesis. The balance of oxygen and carbon dioxide in the atmosphere is maintained through respiration in plants and animals and by the photosynthesis in plants.
  - **Nitrogen:** The major part of air (which does not support burning candles) is nitrogen.
  - **Carbon Dioxide:** Carbon dioxide makes up a small component of the air around us. Plants and animals consume oxygen for respiration and produce carbon dioxide. Plant and animal matter also consumes oxygen on burning and produces mainly carbon dioxide and a few other gases.
  - **Dust and Smoke:** The burning of fuel also produces smoke. Smoke contains a few gases and fine dust

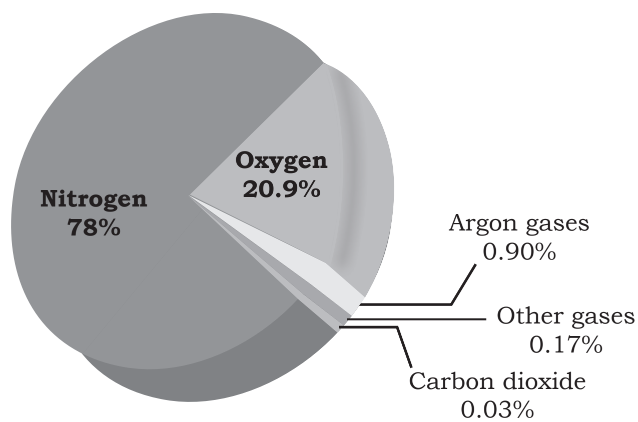
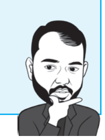


Figure 17.1: Composition of Air

POINTS TO PONDER

Our planet is enveloped by a tenuous expanse of air known as the atmosphere, extending several kilometers above the Earth's surface. What are your thoughts on the consequences of a scenario in which we lacked an atmosphere? How might this impact the existence of life, or would life even be viable in such conditions?



particles and is often harmful. Dust particles are always present in the air. The presence of dust particles in air varies from time to time, and from place to place.

Oxygen in Water and Soil

- When someone heats up water, the air dissolved in it escapes first. Then, the water itself turns into vapour and begins to boil. The bubbles you see in boiling water are made of water vapour.
- A lot of burrows and holes are formed in deep soil by the animals living in the soil. These burrows also make spaces available for air to move in and out of the soil.

Our Environment

- **Environment:** The sum total of all **biotic** (related to living beings) and **abiotic** (related to non-living) factors, substances and conditions that surround and potentially influence organisms without becoming their constituent part.
- **Ecosystem:** It is **a structural and functional unit** of the **biosphere** consisting of living beings and their physical environment and the interaction among them. Term '**Ecosystem**' was coined by **A.G. Tansley** in 1935.

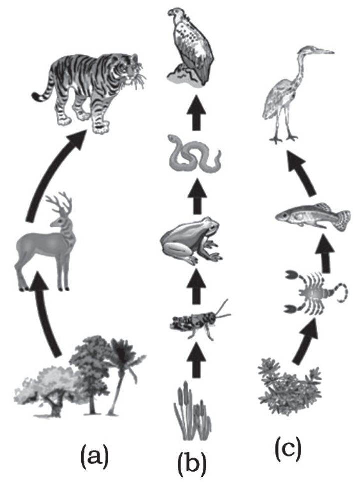


Figure 17.2: (a) In Forest; (b) In Grassland; (c) In Pond

Food Chains and Food Webs

- **Food Chains: A food chain** refers to the order of events in an ecosystem, where one living organism eats another organism, and later that organism is consumed by another larger organism.
- **Consumers:** Organisms depend on the producers for their nourishment. The organisms, whether consuming food directly from producers or indirectly by preying on other consumers, are referred to as consumers. Various organisms at different biotic levels come together to form a food chain.
- **Trophic Levels:** Each level within the food chain is termed a trophic level.
  - **Autotrophs:** The initial trophic level consists of autotrophs or producers, responsible for harnessing solar energy and making it accessible for heterotrophs, or consumers.
  - **Primary and Secondary Consumers:** Herbivores, or primary consumers, occupy the second trophic level, while smaller carnivores, or secondary consumers, are found at the third level.
  - **Tertiary Consumers:** Larger carnivores, or tertiary consumers, constitute the fourth trophic level.

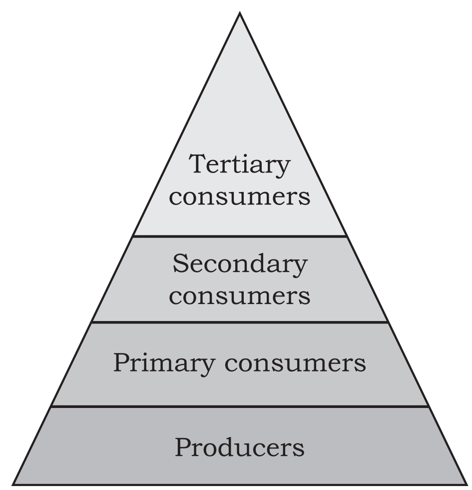


Figure 17.3: Trophic Levels

- The **Flow of Nutrients** and **Energy** from one organism to another at different trophic levels forms a food chain.

  Grass → insects → frog → snake → eagle
- **Interconnected Chain:** Forests contain numerous interconnected food chains, and these chains are interdependent. Every aspect of the forest relies on other components. Disrupting one food chain has repercussions on others within the ecosystem.

- **Unidirectional Flow of Energy:** Interactions among environmental components involve the transfer of energy from one part of the system to another. This energy flow is unidirectional.

> **POINTS TO PONDER**
> What would happen if all the bees on Earth were to go extinct? Can you draw the food chain involved in this scenario?

- In terrestrial ecosystems, green plants capture approximately 1% of the sunlight's energy falling on their leaves and convert it into food energy. As energy progresses through trophic levels, it steadily diminishes due to losses at each level. Much energy is dissipated as heat to the environment, some is expended on digestion and work, and the remainder goes towards growth and reproduction.
- **10% Rule:** Typically, only 10% of the food an organism consumes is transformed into its own body mass and becomes available for the subsequent level of consumers in the food chain. Because so little energy is available for the next level of consumers, food chains usually consist of just three or four steps. The substantial energy loss at each step means that very little usable energy remains after four trophic levels.
- At the lower trophic levels of an ecosystem, there are generally more individuals, with the largest population being the producers.
- **Food Webs:** Food webs exhibit significant variations in terms of length and complexity. Instead of a linear food chain, each organism is typically consumed by multiple other species, which, in turn, are prey for several other organisms. This complex relationship is often depicted as a network of branching lines rather than a straight line food chain.

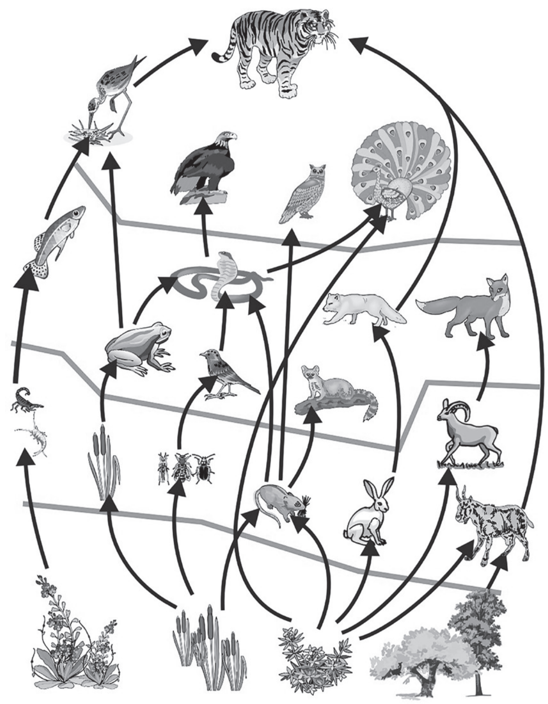


Figure 17.4: Food Web, Consisting of Many Food Chains

Forests: Our Lifeline

- **Forests** serve as **green lungs** and water **purifying systems** in nature. There are several trees, shrubs, herbs and grasses in the forest. The forest floor and the trees are covered with different types of creepers and climbers.
- **Parts of Forest**
  - **Trees:** In a forest, **trees** form the **uppermost layer**, followed by shrubs. The **herbs** form the **lowest layer** of vegetation. Branchy part of a tree above the stem is known as the **crown** of the tree.
  - **Canopy:** The branches of the tall trees look like a roof over the other plants in the forest. These are called a **canopy**.
- **Forest Produce:** Gum, Honey, Sealing wax, oils, spices, fodder for animals and medicinal plants are also some of the products which get from the forest.

> **POINTS TO PONDER**
> Do you know what is the minimum forest cover needed? Which law states it? And why is the minimum forest cover important?

The Nutrients Cycle of Forests:

- There is **an inter-relationship between plant, soil** and **decomposers** in a forest
- **Humus:** Humus is the **dark organic matter** in soil that is formed by the decomposition of plant and animal matter. It is rich in nutrients and retains moisture in the soil. Humus is essential for plant growth and soil health.
- The micro-organisms which convert the dead plants and animals to humus are known as **decomposers**.
- The presence of humus ensures that the nutrients of the dead plants and animals are released into the soil. From there, these nutrients are **again absorbed** by the roots of the living plants.

Roles of Forests in Environment

Forest: A Dynamic Living Entity

- By harbouring a greater variety of plants, the forest provides greater opportunities for food and habitat for the herbivores. Larger number of herbivores means increased availability of food for a variety of carnivores.
- The wide variety of animals helps the forest to regenerate and grow. Decomposers help in maintaining the supply of nutrients to the growing plants in the forest.

Do You Know?

- According to ISFR 2021 India's forest cover has increased from 19.53% in the 1980s to 21.71% in 2021, and its total green cover, including tree cover, now stands at 24.62%.
- **India State of Forests Reports (ISFR):** It is biennial report released by Forest Survey of India (Under **MoEFCC**)

Forests: Protection against Soil Erosion and Flood

- When there are no trees in an area, rainfall directly impacts the ground, potentially leading to flooding in the surrounding area. Tree roots serve to bind the soil, but in their absence, the soil is susceptible to being washed away or eroded.
- Soil plays a vital role in supporting the growth and renewal of forests. Moreover, forests serve as natural sponges for rainwater, allowing it to gradually permeate the ground. This process aids in sustaining the water table consistently throughout the year.
- Forests serve a dual purpose by not only mitigating floods but also regulating the flow of water in streams, ensuring a continuous and reliable water supply.

Water : Our Lifeline

- Clean water is a basic need of human beings. It has been reported that more than one billion **people have no access** to safe drinking water. This accounts for a large number of water-related diseases and even deaths.
- People, even children, walk for several kilometres to collect clean water. It is a serious matter that affects human **dignity**.
- There is increasing scarcity of fresh-water due to **population growth, pollution, industrial development, mismanagement** and other factors.
- On **22 March 2005,** the General Assembly of the United Nations (UNGA) proclaimed the period **2005–2015** as the **International Decade for action on "Water for Life".** All efforts made during this decade aim to **reduce by half the number of people who do not have access to safe drinking water.**

POINTS TO PONDER

Water is nothing but two hydrogen and an oxygen atom. Since there is huge scarcity of water why can't we just chemically create water in labs? Can you think about the issues with such an experiment?

Wastewater:

- **Wastewater** is dirty water that is rich in lather, mixed with oil, and black or brown in colour. It flows down the drains from sinks, showers, toilets, and laundries.
- **Reusing wastewater can save on water-use** and reduce the use of clean drinking water for uses such as gardens and toilets.

Sewage Treatment:

- This is the process of wastewater treatment. Cleaning of wastewater involves removing pollutants before it enters a water body or is reused.
- Sewage is wastewater released by homes, industries, hospitals, offices and other users. It also includes rainwater that has run down the street during a storm or heavy rain.
- Sewage is a liquid waste. Most of it is water, which has a complex mixture of suspended solids, organic and inorganic impurities, nutrients, saprophytes and disease causing bacteria and other microbes.
- These include the following:
  - **Organic Impurities –**Human faeces, animal waste, oil, urea (urine), pesticides, herbicides, fruit and vegetable waste, etc.
  - **Inorganic Impurities –** Nitrates, Phosphates, metals.
  - **Nutrients –** Phosphorus and Nitrogen.
  - **Bacteria –** Such as **vibrio cholera** which causes cholera and **salmonella paratyphi** which causes typhoid.
  - **Other Microbes –** Such as protozoans which cause dysentery.

Processes involved in Wastewater Treatment:

- Treatment of wastewater involves physical, chemical, and biological processes, which remove physical, chemical and biological matter that contaminate the water.
- Wastewater is passed through **bar screens.** By doing so large objects like rags, sticks, cans, plastic packets, and napkins are removed .
- Water then goes to **a grit and sand removal tank.** The speed of the incoming wastewater is decreased to allow sand, grit and pebbles to settle down.
- The water is then allowed to settle in a large tank which is sloped towards the middle. Solids like faeces settle at the bottom and are removed with a scraper. This is the **sludge**.
- A **skimmer** removes the floatable solids like oil and grease. Water that is cleared is called clarified water. **Air is pumped** into the clarified water to help aerobic bacteria to grow. Bacteria consume human waste, food waste, soaps and other unwanted matter still remaining in clarified water.
- After several hours, the suspended microbes settle at the bottom of the tank as activated sludge. The water is then removed from the top.
- The **activated sludge** is about 97% water. The water is removed by sand drying beds or machines. Dried sludge is used as manure, returning organic matter and nutrients to the soil.
- **The treated water** has a very **low level of organic material** and **suspended matter**. It is discharged into a sea, a river or into the ground.
- By-products of wastewater treatment are **sludge** and **biogas**.

> **Do You Know?**
> **Eucalyptus trees** are grown along sewage ponds. These **trees absorb all surplus wastewater** rapidly and **release pure water vapour** into the atmosphere.

Sanitation and Disease

- Poor sanitation and contaminated drinking water is the cause of a large number of diseases.
- The **WHO-UNICEF** data shows **at least one-sixth** of India's rural population still defecates in the open and **a quarter** doesn't have even basic sanitation access.
- Open defecation is an important issue because untreated human excreta is a health hazard. It may cause water pollution and soil pollution. Both the surface water and groundwater get polluted.
- It becomes the most common route for **water borne** diseases. They include **cholera, typhoid, polio, meningitis, hepatitis and dysentery.**

Classification of Waste

Biodegradable Waste

- Biodegradable means that a substance can be broken down into simpler, non-toxic substances by microorganisms such as bacteria and fungi. This process is called Biodegradation. Biodegradable waste is generally composed of kitchen waste (fruit/ vegetable peels, leftover food) and animal waste, crop residues and market waste.
- **Non-Biodegradable Waste:** Non-biodegradable materials are those that cannot be broken down into simpler, non-toxic substances by microorganisms.
- These substances may be inert and simply persist in the environment for a long time or may harm the various members of the ecosystem. Examples include Plastic, Glass and Metal.
- The disposal of the waste we generate is causing serious environmental problems, such as Land Pollution, Water pollution, Air pollution, Diseases.

Alternative Arrangement for Sewage Disposal

- Waste generation is a natural part of human activity. But we can limit the type of waste and quantity of waste produced.
- To improve sanitation, low cost onsite sewage disposal systems, such as **septic tanks, chemical toilets, composting pits.**
  - **Septic tanks** are suitable for places where there is no sewerage system.
- Some organisations offer hygienic on-site human waste disposal technology. These toilets do not require scavenging. Excreta from the toilet seats flow through covered drains into a **Biogas plant**. The biogas produced is used as a source of energy.

Sanitation at Public Places

- Thousands of people visit the public space daily and a large amount of waste is generated there.
- Cleanliness and hygiene should be maintained in these facilities. **Adequate number of toilets** equipped with **handwashing facilities** and soap is a must.
- **Role of Behavioural Change:** We all have a role to play in keeping our environment clean and healthy. **Adopting good sanitation practices** should be our way of life.
  - **As an agent of change** your individual initiative will make a great difference. Influence others with your energy, ideas and optimism. A lot can be done if people work together. There is great power in **collective action.**
  - There should be an adequate number of dustbins.
  - Posters, hoardings, and other forms of advertising in public places should promote health and hygiene in an appealing and simple manner.

Swachh Bharat Mission

- It is a country-wide campaign initiated by the Government of India in 2014 to eliminate open defecation and improve solid waste management.
- It is a restructured version of the Nirmal Bharat Abhiyan launched in 2009.
- Phase 1 of the Swachh Bharat Mission lasted till October 2019.
- Phase 2 is being implemented between 2020–21 and 2024–25.
- The mission is aimed at achieving an "open-defecation free" (ODF) India by 2 October 2019, the 150th anniversary of the birth of Mahatma Gandhi through construction of toilets.

Depletion of the Ozone Layer

- Ozone (O_3) is a molecule formed by three atoms of oxygen. It is a deadly poison at **ground level;** at the **higher levels of the atmosphere,** ozone performs an essential function.
- Ozone shields the surface of the earth from ultraviolet (UV) radiation from the Sun. UV radiation is known to cause **skin cancer** in human beings.
- The amount of ozone in the atmosphere began to drop sharply in the 1980s. This decrease has been linked to synthetic chemicals like **chlorofluorocarbons (CFCs)** which are used as refrigerants and in fire extinguishers.
- **Montreal Protocol:** In 1987, the **United Nations Environment Programme (UNEP)** succeeded in forging an agreement to freeze CFC production at 1986 levels. It is now mandatory for all the manufacturing companies to make **CFC-free refrigerators** throughout the world. It is also Known as Montreal Protocol.
- India has successfully achieved the complete phase out of Hydrochlorofluorocarbon **(HCFC)-141 b**, which is a chemical used by foam manufacturing enterprises and one of the most potent ozone depleting chemicals after Chlorofluorocarbons (CFCs).
  - **(HCFC)-141 b** is used mainly as a blowing agent in the production of rigid polyurethane (PU) foams.
- The Indian government has approved **Ratification of the Kigali Amendment to the Montreal Protocol** on Substances that Deplete the Ozone Layer for phase down of **Hydrofluorocarbons**.

Conclusion

Every living entity, whether plants, animals, microorganisms, humans, or the natural environment, they all engage in interactions that uphold the equilibrium in the natural world. Factors like a healthy environment, proper sanitation, unpolluted air, forests, and sustainable progress are interconnected. To attain sustainable development, safeguarding the environment and its resources is imperative. Sustainable development plays a vital role in safeguarding the environment and ensuring universal access to fundamental life essentials.

Glossary:

- **Saprophytes:** Any organisms that depend on or consume other dead, rotting, or degraded organic substances.
- **Anaerobic Bacteria:** The word anaerobic indicates "without oxygen". Anaerobic bacteria are bacteria that can survive and grow in absence of oxygen.
- **Aerobic Bacteria:** It is the bacteria that grows in the presence of oxygen.
- **Vermicomposting:** A process of conversion of biodegradable waste into compost using earthworms
- **Biological Magnification:** This is a phenomenon where chemicals which are not degradable get accumulated progressively at each trophic level in the food chain. As human beings occupy the top level in any food chain, the maximum concentration of these chemicals get accumulated in our bodies or top predators in respective food chains.
- **Bioaccumulation:** This is a process of accumulation of chemicals in an organism that takes place if the rate of intake exceeds the rate of excretion.
- **Sanitation:** It is about more than just toilets. **Behaviours, facilities** and **services** together provide the **hygienic environment** that is needed to fight diseases and grow up healthy.
- **The Kigali Amendment to Montreal Protocol:** It was adopted in 2016, aims to phase down **hydrofluorocarbons (HFCs),** potent greenhouse gases that contribute to global warming.

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18 Biotechnology

Bibliography: This chapter encompasses the summary of **Chapter 9 (Biotechnology Principles and Processes) and Chapter 10 (Biotechnology and its Applications) of Class XII** - NCERT (SCIENCE).

Introduction

Biotechnology deals with techniques of using **live organisms or enzymes** from organisms to produce products and processes useful to humans. For example, from making curd, bread or wine, to today's restricted sense, **genetically modified organisms (GMOs) and in vitro fertilization (IVF)** are all part of biotechnology. As per the European Federation of Biotechnology (EFB), biotechnology is 'the integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services'.

Biotechnology and Its Various Aspects

- Biotechnology is the stream of study that integrates biology and technology to develop products and systems that can improve our lives and benefit the health of our planet as a whole.
- The most significant contribution of biotechnology is the production of therapeutic proteins and other drugs through genetic engineering.

Principles of Biotechnology

There are two core techniques that enabled the birth of modern biotechnology:

- **Genetic engineering:** These techniques are used 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:** This technique is used for the maintenance of **sterile (microbial contamination-free)** ambience in chemical engineering processes to enable the growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc.

Advantages of Sexual Reproduction over Asexual Reproduction:

Sexual reproduction provides opportunities for **variations and formulation of unique combinations** of genetic setup, some of which may be beneficial to the organism as well as the population.

Asexual reproduction preserves the genetic information, while sexual reproduction permits variation.

Traditional hybridisation procedures used in plant and animal breeding, very often lead to inclusion and multiplication of **undesirable genes** along with the desired genes.

Development of the Principles of Genetic Engineering

- The techniques of **genetic engineering** include the creation of recombinant DNA, the use of gene cloning and gene transfer, **overcoming the limitations** mentioned in traditional hybridisation and allowing us to isolate and introduce only one or a set of desirable genes without introducing undesirable genes into the target organism.

Changes in DNA when transferred into an alien organism

- When a piece of DNA is transferred into an alien organism, that piece of DNA would not be able to multiply itself in the **progeny cells** of the organism.
- But, when it gets integrated into the **genome** of the recipient, it may multiply and be inherited along with the host DNA.
- This is because the alien piece of DNA has become part of a **chromosome**, which has the ability to replicate.
- In a chromosome, there is a specific DNA sequence called the **origin of replication**, which is responsible for initiating replication.
- Therefore, for the multiplication of any alien piece of DNA in an organism it needs to be a part of a chromosome(s) which has a specific sequence known as **'origin of replication'**.

DNA (deoxyribonucleic acid): It is a molecule that carries the genetic instructions necessary for the growth, development, functioning, and reproduction of all known living organisms. It is a long, double-stranded helical structure made up of repeating units called nucleotides.

Genome: Genome represents the complete hereditary information of an organism encoded in its DNA, organised within its chromosome. Genome comprises both the genes and the non-coding sequences of the DNA.

Chromosome: A chromosome is a thread-like structure located in the nucleus of cells such as plant, animal and human cells. Each chromosome is made of a molecule of DNA and histone proteins.

- Thus, an alien DNA is linked with the origin of replication, so that this alien piece of DNA can replicate and multiply itself in the host organism. This can also be called **cloning or making multiple identical copies** of any template DNA.

The First Recombinant DNA

- It emerged from the possibility of linking a gene encoding antibiotic resistance with a native plasmid (autonomously replicating circular extra-chromosomal DNA) of **Salmonella typhimurium.**
  - Stanley Cohen and Herbert Boyer accomplished this in 1972 by isolating the antibiotic resistance gene by cutting out a piece of DNA from a plasmid which was responsible for conferring antibiotic resistance.
- The cutting of DNA at specific locations became possible with the discovery of the so-called **'molecular scissors'– restriction enzymes.** The cut piece of DNA was then linked with the plasmid DNA. These plasmid DNA act as vectors to transfer the piece of DNA attached to it.
- A plasmid can be used as a vector to deliver an alien piece of DNA into the host organism. The linking of antibiotic-resistance genes with the plasmid vector became possible with the enzyme **DNA ligase**, which acts on cut DNA molecules and joins their ends. This makes a new combination of circular autonomously replicating DNA created in vitro and is known as **recombinant DNA.**
- When this DNA is transferred into **Escherichia coli**, a bacterium closely related to Salmonella, it could replicate using the new host's DNA polymerase enzyme and make multiple copies.
- The ability to multiply copies of antibiotic resistance genes in E. coli was called **cloning of antibiotic resistance** genes in E. coli.

  Hence, there are **three basic steps** in genetically modifying an organism:
  - Identification of DNA with desirable genes;
  - Introduction of the identified DNA into the host;
  - Maintenance of introduced DNA in the host and transfer of the DNA to its progeny.

Tools of Recombinant DNA Technology

Genetic engineering or recombinant DNA technology can be accomplished only if we have the key tools, i.e., restriction enzymes, polymerase enzymes, ligases, vectors and the host organism.

Restriction Enzymes

> **DO YOU KNOW?**
>
> The first restriction endonuclease–Hind II, whose functioning depended on a specific DNA nucleotide sequence was isolated and characterized in 1968. It was found that Hind II always cut DNA molecules at a particular point by recognising a specific sequence of six base pairs. This specific base sequence is known as the recognition sequence for Hind II.
>
> **Naming of enzymes:** The first letter of the name comes from the genus and the second two letters come from the species of the prokaryotic cell from which they were isolated. For example, EcoRI comes from Escherichia coli RY

- In 1963, the two enzymes responsible for restricting the growth of bacteriophage in **Escherichia coli** were isolated.
- One of these added methyl groups to DNA, while the other cut DNA. The latter was called **restriction endonuclease.**
- Restriction enzymes belong to a larger class of enzymes called **nucleases.** These are of two kinds; **exonucleases and endonucleases.**
- Exonucleases remove nucleotides from the ends of the DNA whereas endonucleases make cuts at specific positions within the DNA.
- Each restriction endonuclease functions by 'inspecting' the length of a DNA sequence. Once it finds its specific recognition sequence, it will bind to the DNA and cut each of the two strands of the double helix at specific points in their **sugar-phosphate backbones (Refer to figure 18.1).**
- Restriction enzymes cut the strand of DNA a little away from the center of the palindrome sites but between the same two bases on the opposite strands. This leaves single-stranded portions at the ends. There are overhanging stretches called **sticky ends** on each strand **(Refer Figure 18.1).** These are named so because they form hydrogen bonds with their complementary cut counterparts. This stickiness of the ends facilitates the action of the enzyme DNA ligase.
- Restriction endonucleases are used in genetic engineering to form 'recombinant' molecules of DNA, which are composed of DNA from different source
- When cut by the same restriction enzyme, the resultant DNA fragments have the same kind of 'sticky-ends' and these can be joined together **(end-to-end) using DNA ligases (Refer to figure 18.2).**

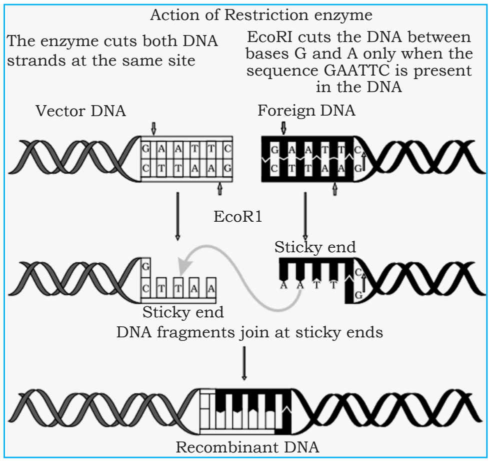

Figure 18.1: Steps in formation of recombinant DNA by action of restriction endonuclease enzyme - EcoRI

Separation and Isolation of DNA Fragments

- The cutting of DNA by restriction endonucleases results in fragments of DNA. These fragments can be separated by a technique known as **gel electrophoresis.**
- Since DNA fragments are negatively charged molecules they can be separated by forcing them to move towards the anode under an electric field through a medium/matrix. Nowadays the most commonly used matrix is **agarose** which is a natural polymer extracted **from seaweeds.**

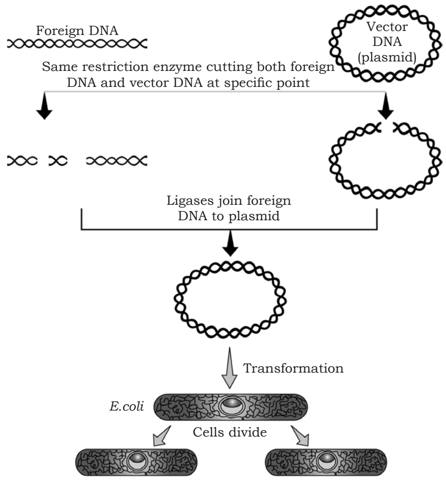

Figure 18.2: Diagrammatic representation of recombinant DNA technology

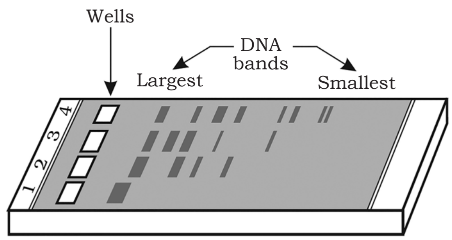

Figure 18.3: A typical agarose gel electrophoresis showing migration of undigested (lane 1) and digested set of DNA fragments (lane 2 to 4)

- The DNA fragments separate according to their size through the **sieving effect** provided by the agarose gel. Hence, the smaller the fragment size, the farther it moves. **(Refer to Figure 18.3).**
- The separated bands of DNA are cut out from the agarose gel and extracted from the gel piece. This step is known as **elution.** The DNA fragments purified in this way are used in constructing recombinant DNA by joining them with cloning vectors.

> **Palindromes:** These are groups of letters that form the same words when read both forward and backward, e.g., "MALAYALAM".
> The palindrome in DNA is a sequence of base pairs that reads the same on the two strands when orientation of reading is kept the same.

Cloning Vectors

- Plasmids and **bacteriophages** have the ability to replicate within bacterial cells independent of the control of chromosomal DNA. Bacteriophages, because of their high number per cell, have very high copy numbers of their genome within the bacterial cells.
- If we are able to link an alien piece of DNA with bacteriophage or plasmid DNA, we can multiply its numbers equal to the copy number of the plasmid or bacteriophage.

Mechanism to facilitate cloning into a vector:

- **Origin of replication (ori):** This is a sequence from where replication starts and any piece of DNA when linked to this sequence can be made to replicate within the host cells. This sequence is also responsible for controlling the copy number of the linked DNA.
- **Selectable marker:** In addition to 'ori', the vector requires a selectable marker, which helps in identifying and eliminating non-transformants and selectively permitting the growth of the transformants.

> **Additional Information**
> **Transformation** is a procedure through which a piece of DNA is introduced in a host bacterium. For example, ampicillin, chloramphenicol, tetracycline or kanamycin, etc., are considered useful selectable markers for E. coli. The normal E. coli cells do not carry resistance against any of these antibiotics.

- **Cloning sites:** The recognition sites on plasmids are known as cloning sites.
  - In order to link the alien DNA, the vector needs to have very few, preferably single, recognition sites for the commonly used restriction enzymes. The presence of more than one recognition site within the vector will generate several fragments, which will complicate gene cloning.

- In the case of two antibiotic resistance genes, one antibiotic resistance gene helps in selecting the transformants, whereas the other antibiotic resistance gene gets 'inactivated due to insertion' of alien DNA, and helps in the selection of recombinants.
- The selection of recombinants due to the inactivation of antibiotics is a cumbersome procedure because it requires simultaneous plating on two plates having different antibiotics.
- Therefore, alternative selectable markers have been developed which differentiate recombinants from non-recombinants on the basis of their ability to produce colour in the presence of a chromogenic substrate.
- In this, a recombinant DNA is inserted within the coding sequence of an enzyme, β-galactosidase. This results in the inactivation of the gene for the synthesis of this enzyme, which is referred to as **insertional inactivation.**

- **Vectors for cloning genes in plants and animals:**
  - Agrobacterium tumefacient, a pathogen of several dicot plants is able to deliver a piece of DNA known as **'T-DNA'** to transform normal plant cells into a tumour and direct these tumour cells to produce the chemicals required by the pathogen.
  - Similarly, **retroviruses** in animals have the ability to transform normal cells into cancerous cells. Retroviruses have also been disarmed and are now used to deliver desirable genes into animal cells. So, once a gene or a DNA fragment has been ligated into a suitable vector it is transferred into a bacterial, plant or animal host (where it multiplies).

Competent Host (For Transformation with Recombinant DNA)

- DNA is a **hydrophilic molecule** and cannot pass through cell membranes. In order to force bacteria to take up the plasmid, the bacterial cells must first be made 'competent' to take up DNA.

Mechanism of introducing alien DNA into host cells:

- Treating them with a specific concentration of a **divalent cation,** such as calcium, increases the efficiency with which DNA enters the bacterium through pores in its cell wall.
- Recombinant DNA can be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 42°C (heat shock) and then putting them back on ice. This enables the bacteria to take up the recombinant DNA.
- In **micro-injection,** recombinant DNA is directly injected into the nucleus of an animal cell.
- In another method, suitable for plants, cells are bombarded with high-velocity micro-particles of gold or tungsten coated with DNA in a method known as **biolistics or gene gun.**
- The last method uses **'disarmed pathogen' vectors**, which when allowed to infect the cell, transfer the recombinant DNA into the host.

Processes Involved in Recombinant DNA Technology

There are the following processes facilitating recombinant DNA technology:

Isolation of the Genetic Material (DNA)

- In the majority of organisms, deoxyribonucleic acid or DNA is the genetic material. In order to cut the DNA with restriction enzymes, it needs to be in pure form, free from other macromolecules.

> Genes are located on long molecules of DNA interwined with proteins such as histones.

- To release DNA along with other macromolecules such as RNA, proteins, polysaccharides and lipids, treating the bacterial cells/plant or animal tissue with enzymes such as **lysozyme (bacteria), cellulase (plant cells), chitinase (fungus)** is required.

- The RNA can be removed by treatment with ribonuclease whereas proteins can be removed by treatment with protease.
- Other molecules can be removed by appropriate treatments and purified DNA ultimately precipitates out after the addition of chilled ethanol. This can be seen as a collection of fine threads in the **suspension (Refer to Figure 18.4).**

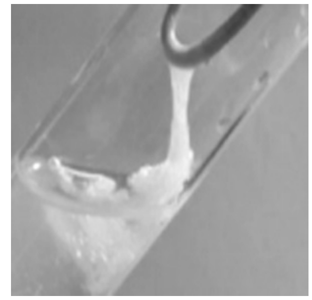

Figure 18.4: DNA that separates out can be removed by spooling

Cutting of DNA at Specific Locations

- **Restriction enzyme digestions** are performed by incubating purified DNA molecules with the **restriction enzyme**, at the optimal conditions for that specific enzyme.
- Agarose gel electrophoresis is employed to check the progression of a restriction enzyme digestion.
- DNA is a negatively charged molecule, hence it moves towards the positive electrode (anode). The process is repeated with the **vector DNA**.
- **Joining of DNA:** After having cut the source DNA as well as the vector DNA with a specific restriction enzyme, the cut-out 'gene of interest' from the source DNA and the cut vector with space are mixed and ligase is added. This results in the preparation of recombinant DNA.

POINTS TO PONDER

Recently a Chinese scientist used gene editing tool CRISPR-Cas9 to eliminate HIV from the foetus of twins whose mother had HIV. Think about how CRISPR- Cas9 tool is significant improvement over previous genetic editing tools and ethical issues involved in editing human embryos.

Polymerase Chain Reaction for Amplification of Gene of Interest

- **Polymerase Chain Reaction:** It refers to a reaction in which multiple copies of the gene (or DNA) of interest are synthesised in vitro using two sets of primers (small chemically synthesised oligonucleotides that are complementary to the regions of DNA) and the enzyme DNA polymerase. The enzyme extends the primers using the nucleotides provided in the reaction and the genomic DNA as a template.
- If the process of replication of DNA is repeated many times, the segment of DNA can be amplified to approximately a billion times, i.e., 1 billion copies are made. Such repeated amplification is achieved with the use of a thermostable DNA polymerase (isolated from a bacterium, Thermus aquaticus), which remains active during the high temperature-induced denaturation of double-stranded DNA. The amplified fragment if desired can now be used to ligate with a vector for further cloning **(Refer to Figure 18.5).**

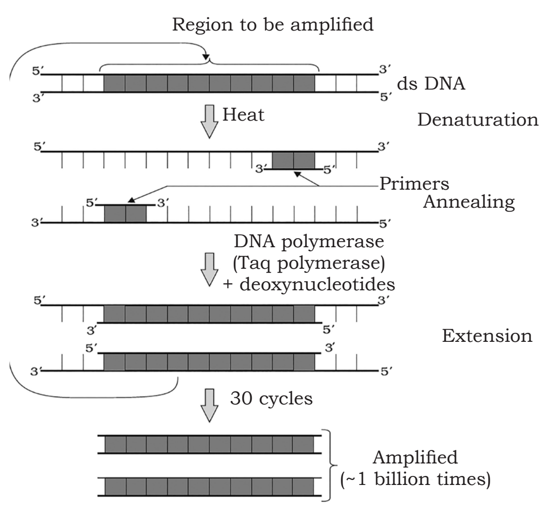

Figure 18.5: Polymerase chain reaction (PCR) : Each cycle has three steps: (i) Denaturation; (ii) Primer annealing; and (iii) Extension of primers

Insertion of Recombinant DNA into the Host Cell/Organism

There are several methods of introducing the ligated DNA into recipient cells.

- Recipient cells, after making themselves 'competent' to receive, take up DNA present in its surroundings. So, if a recombinant DNA-bearing gene for resistance to an antibiotic (e.g., ampicillin) is transferred into E. coli cells, the host cells become transformed into **ampicillin-resistant cells**.

- If we spread the transformed cells on agar plates containing ampicillin, only transformants will grow, and untransformed recipient cells will die.
- Since, due to the ampicillin resistance gene, one is able to select a transformed cell in the presence of ampicillin. The ampicillin resistance gene in this case is called a **selectable marker**.

Obtaining the Foreign Gene Product

- When you insert a piece of alien DNA into a cloning vector and transfer it into a bacterial, plant or animal cell, the alien DNA gets multiplied.
- In almost all recombinant technologies, the ultimate aim is to produce a desirable protein. Hence, there is a need for the recombinant DNA to be expressed. When a protein-encoding gene is expressed in a heterologous host, it is called a **recombinant protein.**
- The cells can also be multiplied in a continuous culture system wherein the used medium is drained out from one side while the fresh medium is added from the other to maintain the cells in their physiologically most active log/exponential phase. This type of culturing method produces a larger biomass leading to higher yields of desired protein.
- To produce in large quantities, the development of **bioreactors,** where large volumes (100-1000 litres) of culture can be processed is required.
- A bioreactor provides the optimal conditions for achieving the desired product by providing optimum growth conditions (temperature, pH, substrate, salts, vitamins, oxygen). A stirred-tank reactor is usually cylindrical or with a **curved base** to facilitate the mixing of the reactor contents. **(Refer to figure 18.6).**

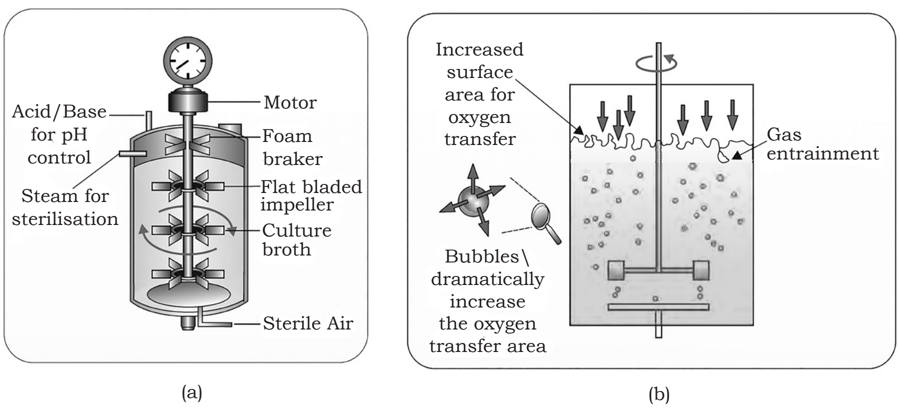

Figure 18.6: (a) Simple stirred-tank bioreactor; (b) Sparged stirred-tank bioreactor through which sterile air bubbles are sparged

Downstream Processing

- After completion of the biosynthetic stage, the product goes through a series of processes before it is ready for marketing as a finished product. The processes include **separation and purification,** which are collectively referred to as **downstream processing.**
- The product has to be formulated with suitable preservatives. Such formulation has to undergo thorough clinical trials as in the case of drugs. Strict quality control testing for each product is also required. The downstream processing and quality control testing vary from product to product.

Applications of Biotechnology

The applications of biotechnology include therapeutics, diagnostics, genetically modified crops for agriculture, processed food, bioremediation, waste treatment, and energy production. Three critical research areas of biotechnology are:

- Providing the best catalyst in the form of an improved organism, usually a microbe or pure enzyme.
- Creating optimal conditions through engineering for a catalyst to act, and
- Downstream processing technologies to purify the protein/organic compound.

Applications of Biotechnology in Agriculture

- **Green Revolution:** The **Green Revolution** succeeded in **tripling the food supply** but it was not enough to feed the growing human population.
- **Tissue Culture Technique:** When a whole plant could be regenerated from explants, i.e., any part of a plant taken out and grown in a test tube, under sterile conditions in special nutrient media. This capacity to generate a whole plant from any cell/explant is called **totipotency.**
- By application of these methods, it is possible to achieve the propagation of a large number of plants in a very short duration. This method of producing thousands of plants through tissue culture is called **micro-propagation.**
- Each of these plants will be genetically identical to the original plant from which they were grown, i.e., they are **some clones.**
- **Recovery of healthy plants** from diseased plants. Even if the plant is infected with a virus, the **meristem** (apical and axillary) is free of virus. Hence, one can remove the meristem and grow it in vitro to obtain **virus-free plants.**
- **Somatic hybridisation:** When single cells from plants and after digesting their cell walls have been able to isolate naked protoplasts (surrounded by plasma membranes). Isolated protoplasts from two different varieties of plants - each having a desirable character - can be fused to get hybrid protoplasts, which can be further grown to form a new plant. These hybrids are called somatic hybrids while the process is called **somatic hybridisation.** For Example, When a protoplast of tomato is fused with that of potato and forms new hybrid plants combining tomato and potato characteristics.

Genetically Modified Organisms (GMO)

- Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called **Genetically Modified Organisms (GMOs).**
- **Advantages of GM plants:**
  - More tolerant to abiotic stresses (cold, drought, salt, heat).
  - Reduced reliance on chemical pesticides (pest-resistant crops).
  - Help to reduce post-harvest losses.
  - Increased efficiency of mineral usage by plants (this prevents early exhaustion of fertility of soil).
  - Enhanced nutritional value of food, e.g., golden rice (Vitamin 'A' enriched rice).
  - It is also used to create tailor-made plants to supply alternative resources to industries, in the form of starches, fuels and pharmaceuticals.

Examples of Genetically Modified Organism

- **BT toxin**: It is produced by a bacterium called **Bacillus thuringiensis (Bt).** It has been cloned from the bacteria and been expressed in plants to provide resistance to insects without the need for insecticides; in effect creating a bio-pesticide. Examples are Bt cotton, Bt corn, rice, tomato, potato soybean etc.

- **BT Cotton:** Some strains of Bacillus thuringiensis produce proteins that kill certain insects such as lepidopterans (tobacco budworm, armyworm), coleopterans (beetles) and dipterans (flies, mosquitoes) protecting the crops. Specific Bt toxin genes were isolated from Bacillus thuringiensis and incorporated into several crop plants such as cotton.
- **Pest Resistant Plants:** Several nematodes parasitise a wide variety of plants and animals including human beings. For example, A Nematode Meloidogyne incognitia infects the roots of tobacco plants and causes a great reduction in yield.

RNA interference (RNAi)

RNAi takes place in all eukaryotic organisms as a method of cellular defense. This method involves silencing of a specific mRNA due to a complementary dsRNA molecule that binds to and prevents translation of the **mRNA (silencing).**

It is used to silence the specific mRNA of the nematode. The consequence is that the parasite could not survive in a transgenic host expressing specific interfering RNA. The transgenic plant therefore got itself protected from the parasite.

Biotechnological Applications In Medicine

The recombinant DNA technological processes have made an immense impact in the area of healthcare by enabling the mass production of safe and more effective **therapeutic drugs** which do not induce unwanted immunological responses as is common in the case of similar products isolated from non-human sources.

Genetically Engineered Insulin

- Insulin consists of two short polypeptide chains: Chain A and Chain B, that are linked together by disulphide bridges **(Refer to figure 18.7).** In mammals, including humans, insulin is synthesised as a pro-hormone which contains an extra stretch called the **C peptide.** This C peptide is not present in the mature insulin and is removed during maturation into insulin.
- In 1983, Eli Lilly prepared two DNA sequences (using the rDNA technique) corresponding to A and B, chains of human insulin and introduced them in plasmids of E. coli to produce insulin chains.

Gene Therapy

- Gene therapy is an attempt to treat a hereditary disease which uses methods that allow correction of a gene defect that persists in a child/embryo.
- Here genes are inserted into a person's cells and tissues to treat a disease. Correction of a genetic defect involves the delivery of a normal gene into the individual or embryo to take over the function of and compensate for the non-functional gene.

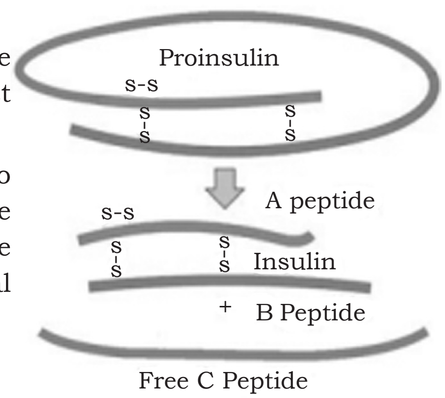

Figure 18.7: Maturation of pro-insulin into insulin (simplified)

Molecular Diagnosis

- Using conventional methods of diagnosis (serum and urine analysis, etc.) early detection is not possible. Recombinant DNA technology, Polymerase Chain Reaction (PCR) and **Enzyme-Linked Immuno-sorbent Assay (ELISA)** are some of the techniques that serve the purpose of early diagnosis.

Transgenic Animals

Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as **transgenic animals**. For example, transgenic rats, rabbits, pigs, sheep, cows and fish. Benefits of such modifications:

- **Physiology and development:** Transgenic animals can be specifically designed to allow the study of how genes are regulated, and how they affect the normal functions of the body and its development, e.g., the study of complex factors involved in growth such as insulin-like growth factors.
- **Study of disease:** Many transgenic animals are designed to increase our understanding of how genes contribute to the development of disease. Ex: Study of human diseases such as cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's.
- **Biological products:** Transgenic animals that produce useful biological products to treat certain human diseases can be created by the introduction of a portion of DNA (or genes).
- **Vaccine safety:** Transgenic mice are being developed for use in testing the safety of vaccines before they are used on humans.
- **Chemical safety testing:** This is known as toxicity/safety testing. The procedure is the same as that used for testing the toxicity of drugs.

Enzyme Linked Immuno-sorbent Assay (ELISA)

ELISA is based on the principle of antigen-antibody interaction. Infection by pathogen can be detected by the presence of antigens (proteins, glycoproteins, etc.) or by detecting the antibodies synthesised against the pathogen.

POINTS TO PONDER

ELISA test is used for identification of various diseases like HIV, COVID-19, LYME disease, Syphilis etc. Can you think of which principle is ELISA based and how it works ?

Ethical Issues

Some ethical standards are required to evaluate the morality of all human activities that might help or harm living organisms. The Indian Government has set up organisations such as **GEAC (Genetic Engineering Approval Committee),** which will make decisions regarding the validity of GM research and the safety of introducing GM organisms for public services.

Some of the issues involved with GMOs are:

- **Monopoly over technology and seeds:** The patents extend to functional equivalents, implying that other people selling the modified crops (after manipulation of traditional varieties) and their seeds (Ex - Basmati rice) could be restricted by the patent.
- **Biopiracy:** It is a term used to refer to the use of bio-resources by multinational companies and other organisations without proper authorisation from the countries and people concerned without compensatory payment.

GEAC (Genetic Engineering Approval Committee)

It is a statutory body constituted under the Environment (Protection) Act, 1986.

Nodal Ministry

Ministry of Environment, Forests & Climate Change.

Functions

It regulates the use, manufacture, storage, import and export of hazardous microorganisms or genetically engineered organisms and cells in India.

Conclusion

- This chapter has provided you with basic information about biotechnology and its significance and applications. Biotechnology has given several useful products to human beings by using microbes, plants, animals and their metabolic machinery. Techniques of tissue culture and somatic hybridisation offer vast potential for modifying new varieties of plants which are resistant to diseases and other vagaries. Whereas, gene therapy is used to treat diseases, especially hereditary diseases. In this way, biotechnology is significantly helping humans, however, at the same time, some ethical questions associated also need to be taken care of.

Glossary:

- **Biotechnology:** It deals with large-scale production and marketing of products and processes using live organisms, cells or enzymes.
- **Genetic engineering:** These techniques are used to alter the chemistry of genetic material (DNA and RNA).
- **Bioprocess engineering:** This technique is used for the maintenance of sterile (microbial contamination-free) ambience in chemical engineering processes.
- **Molecular scissors:** The cutting of DNA at specific locations using special enzymes called 'molecular scissors'– restriction enzymes.
- **Totipotency:** It is the ability of a single cell to divide and produce all of the differentiated cells in an organism.
- **Transformation**: It is a procedure through which a piece of DNA is introduced in a host bacterium.
- **Palindrome in DNA:** The palindrome in DNA is a sequence of base pairs that reads the same on the two strands when the orientation of the reading is kept the same.
- **Genetically Modified Organisms (GMO):** Plants, bacteria, fungi and animals whose genes have been altered by manipulation are called Genetically Modified Organisms (GMO).
- **Gene Therapy:** It is the insertion of genes into an individual's cells and tissues to treat diseases, especially hereditary diseases.
- **Enzyme-Linked Immuno-sorbent Assay (ELISA):** ELISA is a laboratory technique that detects certain antibodies, antigens and other substances in your blood, pee or other bodily fluid.
- **Transgenic animals:** Animals that have had their DNA manipulated to possess and express an extra (foreign) gene are known as transgenic animals.

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