TO THE POINT

CHRONICLE
Nurturing Talent Since 1990

GENERAL SCIENCE & ENVIRONMENT

- Chapter-wise Presentation of Topics based on Syllabus of General Studies with Comprehensive Coverage of General Knowledge.
- A Compilation of Old and New NCERT Books (Class 6 to 12) - NCERT Plus & Study Material of IGNOU & NIOS, and many other Standard Books from which Questions are often asked in Exams.

FOR ALL COMPETITIVE EXAMS

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For All Competitive Exams

***Edited by* - N.N. Ojha**

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1 CHAPTER

Units & Measurement

Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, internationally accepted reference standard called unit. The result of a measurement of a physical quantity is expressed by a number or (numerical measure) accompanied by a unit. The units for the fundamental or base quantities are called fundamental or base units. The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called derived units. A complete set of these units, both the base units and derived units, is known as the system of units.

Physical Quantities

Physical quantities are quantities that can be measured. In physical quantities include velocity, acceleration, force, area, volume, pressure, and so on.

Types of Physical Quantities

Physical quantities are classified into two types:

1. **Fundamental Physical Quantities:** Fundamental physical quantities are those that do not depend on or are independent of other quantities.
   - There are seven of them: **length, mass, time, thermodynamic temperature, electric current, luminous intensity, and substance amount.**
2. **Derived Physical Quantities:** Physical quantities that are derived from fundamental physical quantities are referred to as derived physical quantities.
   - For example, velocity is a derived physical quantity because it is derived from the fundamental quantities' length and time.

Units

A physical quantity is measured by comparing it to a standard quantity. This standard quantity is referred to as the quantity's unit.

- To measure the length of a desk, it is compared to the standard quantity known as **'Metre'**.
- For example, the length of a race, which is a physical quantity, can be expressed in metre (for sprinters) or Kilometers (for long distance runners).
- Without standardized units, it would be extremely difficult for scientists to express and compare measured values in a meaningful way.

Types of Units

Units are classified into two types:

1. **Fundamental Units:** Fundamental units are those that cannot be deduced from any other unit and cannot be resolved into any other basic or fundamental unit.
   - Fundamental units are also the units of fundamental physical quantities. The table below depicts the seven fundamental units of the **S.I. System**.
2. **Derived Units:** A derived unit is any unit that can be created by combining one or more fundamental units. **Area, Speed, Density, Volume, Momentum, Acceleration, Force,** and so on are some examples of the Derived Units.
   - Till now, the scientists of different countries adopted different systems of units for measurement and widely accepted among them were three such systems, i.e. the **CGS**, the **FPS** (or British) system and the **MKS** system.
   - In **CGS** system they were Centimetre, Gram and Second respectively.
   - In **FPS** system they were Foot, Pound and Second respectively.
   - In **MKS** system they were Metre, Kilogram and Second respectively.

- Here, in all these systems, the first unit is for length, second for weight and third for time.
- Now, the system of units which is internationally accepted for measurement is the **International System of Units** (French) shortly known as **SI**.
- The present SI, with standard scheme of symbols, units and abbreviations, was developed by **General Conference on Weights and Measures in 1960** for international usage in scientific, technical, industrial and commercial work.

Supplementary Units of SI System

1. **Radian (rad):** The radian is the plane angle formed by two radii of a circle intersecting on the circumference to form an arc of length equal to the radius.
2. **Steradian (sr):** The steradian is a solid angle with its vertex at the centre of a sphere that cuts off an area of the sphere's surface equal to that of a square with sides the length of the sphere's radius.

2
CHAPTER

Motion

Most motions are complex. Some objects may move in a straight line, others may take a circular path. Some may rotate and a few others may vibrate. There may be situations involving a combination of these. In this chapter, we shall first learn to describe the motion of objects along a straight line and circular path. We shall also learn to express such motions through simple equations and laws.

Motion and Dimension

Motion is change in position of an object with time in respect to its surroundings. When a body does not change its position with respect to time, then it is said to be at rest; while motion is the change of position of an object with respect to time.

- To study the motion of the object, one has to study the change in position (x,y,z coordinates) of the object with respect to the surroundings.
- These positions change even due to the change in one, two or all the three coordinates of the position of the objects with respect to time.
- No force is required to keep an object in uniform motion.
- When an object has uniform motion along a straight line in a given direction, the magnitude of displacement is equal to actual distance covered.

Thus, motion can be classified into three types:

1. **Motion in One Dimension:** It is defined as a motion in which a particle moves along a straight line.

   In other words, motion of an object is said to be one dimensional, if only one of the three coordinates specifying the position of the object changes with respect to time.

   For instance an ant moving in a straight line, running athlete, etc. It is also called **Rectilinear or Translatory motion.**
2. **Motion in Two Dimensions:** A motion wherein a particle rotates about a fixed axis.

   In this, the motion is represented by any two of the three coordinates. Example: a body moving in a plane. It is also called Rotational motion.
3. **Motion in Three Dimensions:** Motion of a body is said to be three dimensional, if all the three coordinates of the position of the body change with respect to time.
   - In other words, it is a motion in which a particle moves to and fro or back and forth about a fixed point. It is also called Vibratory or Oscillatory motion.
   - **Examples:** Motion of a flying bird, motion of a kite in the sky, motion of a molecule, etc.

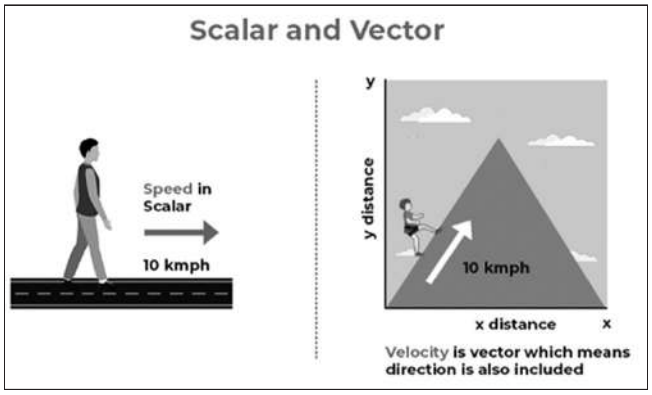
Particle or Point Mass

- The smallest part of matter with zero dimensions which can be described by its mass and position is defined as a particle.
- If the size of a body is negligible in comparison to its range of motion then that body is known as a particle.
- A body (Group of particles) to be known as a particle depends upon types of motion. For example in a planetary motion around the sun the different planets can be presumed to be the particles.
- In above consideration when we treat body as particle, all parts of the body undergo same displacement and have same velocity and acceleration.

Scalars and Vectors

Scalars: These are quantities completely specified by a single number and a proper unit and therefore have magnitudes only.

- Scalars can be added, subtracted, multiplied and divided just as ordinary numbers. Scalar product is Commutative. Mass, Speed, Distance, Temperature, Length, Time, Density, Energy, Electric potential etc. are scalar quantities.
- **Vectors:** Quantities possessing both magnitude and directions are known as vectors.
- Some of the examples of the vectors quantities are displacement, velocity, acceleration, momentum, force, etc.



3

CHAPTER

Work, Energy and Power

The terms 'work', 'energy' and 'power' are frequently used in everyday language. We shall find that there is at best a loose correlation between the physical definitions and the physiological pictures these terms generate in our minds. The aim of this chapter is to develop an understanding of these three physical quantities.

Primitive man used muscular energy to do work. Later, animal energy was harnessed to help people do various kinds of tasks. With the invention of various kinds of machines, the ability to do work increased greatly.

- Progress of our civilization now critically depends on the availability of usable energy. Energy and work are, therefore, closely linked.
- The rate of doing work improved with newer modes, i.e. as we shifted from
- Humans → Animals → Machines to provide necessary force. The rate of doing work is known as power.

Work

The scientific definition of work differs in some ways from its everyday meaning of hard work or carrying heavy load.

- The scientific definition of work has its relationship to energy—whenever work is done, energy is transferred.
- For work to be done a force must be exerted and there must be motion or displacement in the direction of the force, therefore Work is considered done when a force produces some kind of motion.
- For example, when a man climbs a mountain, work is done because while climbing a mountain he is moving against the force of gravity.

Factors Affecting Work

- The **magnitude of the force** forms the formula of work done. It is evident that the higher the magnitude of force, the higher the work gets done and vice-versa.
- The **magnitude of the displacement** form the formula of work done.
- It is evident that the higher the magnitude of the displacement, the higher the work gets done and vice-versa.
- The **direction between the force and the displacement,** If the angle between the force and the displacement is θ, then the value of cosθ is obtained to get the magnitude of work done. So, work done depends on the value of cosθ.
- The work done by a force is defined to be the product of the component of the force in the direction of the displacement and the magnitude of this displacement.

$$\mathbf{W = F\cos\theta} = \vec{F}\vec{d}$$

- Work (W) = FS Cos θ (angle between the displacement and force)
- Where W is the work done, F is the force, d is the displacement, θ is the angle between force and displacement and F cosθ is the component of force in the direction of displacement.
    - It is a scalar quantity as it is a dot product of Force and Displacement (Dot product is always a scalar quantity)
    - It has only magnitude not direction.
    - The SI unit of work is Joule (J) or Newton-metre (N.m)
    - Its dimension is $[ML^2T^{-2}]$ where (M= mass, L= length, T = time) and SI base unit is $kg.m^2/s^2$.

Alternative Units of Work and Energy in Joule

erg	10^{-7}J
electron volt (eV)	1.6×10^{-19}J
calorie (cal)	4.186J
kilowatt hour (kWh)	3.6×10^{6}J

No work is done if

- The **displacement** is **zero**. A weightlifter holding a 150 kg mass steadily on his shoulder for 30s does no work on the load during this time.
- The **force** is **zero**. A block moving on a smooth horizontal table is not acted upon by a Horizontal force (since there is no friction), but may undergo a large displacement.
- The force and displacement are mutually **perpendicular**.
    - For example, a man tries to move a wall but the wall does not move, hence the work done by the man is zero as there is no displacement produced.
    - But he does lose energy because in his attempt to push the wall he stretches his muscles and thus feels tired.

4 CHAPTER

Gravitation

From our early childhood days we have become aware that the tendency of all material objects to be attracted towards the earth. Anything thrown up falls down towards the earth, going uphill is lot more tiring than going downhill, raindrops from the clouds above fall towards the earth and there are many other such phenomena. In this chapter we are going to learn about Gravitation and its nature in a brief manner.

The force of attraction between any two bodies in the universe is called **gravitation**. In other words, gravitation is a natural phenomenon by which all physical bodies attract each other. Gravitation is also known as gravity and denoted by **g**.

- All the objects in the universe attract each other with a certain amount of force, but in most of the cases, the force is too weak to be observed due to the very large distance of separation.
- Besides, gravity's range is infinite, but the effect becomes weaker as objects move away.

History of Gravitational Theory

Ptolemy proposed the **Geocentric model** which failed in understanding planetary motions. It led to the development of the heliocentric model by **Nicholas Copernicus** whose idea is based on the rotation of a test mass around the source mass in circular orbits.

- Although the model correctly predicts the position of planets and their motions but has failed in explaining many aspects like the occurrence of seasons which led the construction of a model based on **Kepler's laws of planetary motion.**
- This force of attraction was first observed by **Sir Isaac Newton** and was presented as Newton's law of gravitation in the year 1680.
- The works of John Kepler, Isaac Newton and Albert Einstein contributed a lot in the development of gravitational theory.
- However, gravitation can generally exist in two main instances.
  - Gravitation may be the **attraction of objects by the earth**. **Example:** If a object (ball) is thrown upwards, it reaches a certain height and falls downwards because of the gravity of the earth.
  - Gravitation may be the **attraction of objects in outer space**. **Example:** Force of attraction between the other planets and the sun.

Kepler's Laws of Planetary Motion

- **Kepler** derived these laws from the observations of **Tycho Brahe** on planetary motion.
- **Kepler's First Law (The Law of Ellipses):** Each planet's orbit about the Sun is an ellipse.
  - The Sun's center is always located at one focus of the orbital ellipse.
  - The Sun is at one focus.
  - The planet follows the ellipse in its orbit, meaning that the planet to Sun distance is constantly changing as the planet goes around its orbit.
- **Kepler's Second Law (The Law of Equal Areas):** The imaginary line joining a planet and the Sun sweeps equal areas of space during equal time intervals as the planet orbits.
- Basically, that planets do not move with constant speed along their orbits.
- Rather, their speed varies so that the line joining the centers of the Sun and the planet sweeps out equal parts of an area in equal times.
  - The point of nearest approach of the planet to the Sun is termed perihelion.
  - The point of greatest separation is aphelion, hence by Kepler's Second Law, a planet is moving fastest when it is at perihelion and slowest at aphelion.
- **Kepler's Third Law (The Law of Harmonies):** The squares of the orbital periods of the planets are directly proportional to the cubes of the semi-major axes of their orbits.
  - Kepler's Third Law implies that the period for a planet to orbit the Sun increases rapidly with the radius of its orbit.
  - Thus, we find that Mercury, the innermost planet, takes only 88 days to orbit the Sun. The earth takes 365 days, while Saturn requires 10,759 days to do the same.

5 CHAPTER

Mechanical Properties of Solids and Fluids

Solids and liquids have much lower compressibility as compared to gases. Shear stress can change the shape of a solid keeping its volume fixed. The key property of fluids is that they offer very little resistance to shear stress; their shape changes by application of very small shear stress. The shearing stress of fluids is about million times smaller than that of solids.

Mechanics of Solids

A rigid body generally means a hard solid object having a definite shape and size. But in reality, bodies can be stretched, compressed and bent. Even the appreciably rigid steel bar can be deformed when a sufficiently large external force is applied on it. This means that solid bodies are not perfectly rigid.

- Solid is one of the four fundamental states of matter including liquid, gas and plasma.
- Solid is generally rigid in normal conditions and resists its change. However, it has elastic property in case of a force occurred on it.
- Due to stronger intermolecular force of attraction, solid has definite shape and size.
- All solids have rigid structures that tend to resist any external forces applied to them.
- Solids also are known to have a fixed, definite shape (unlike liquids and gases, which assume the shape of the container they are placed in).
- Furthermore, solids are also known to have a fixed, definite volume (unlike gaseous substances which expand to occupy the entire volume of the container they are placed in).
- Forces acting between the atoms due to electrostatic interaction between the charges of the atoms are called **interatomic forces**.
- A force which produces a change in configuration of the object on applying it is called a deforming force.
- In solid, the atoms and molecules are free to vibrate about their mean positions.
- If this vibration increases substantially, molecules shake apart and start vibrating in random directions.
- At this stage, the shape of the material is no longer fixed and converts into liquid state.
- The intermolecular force in liquid is respectively weaker; hence, it has no definite shape but has fix volume.
- In gases, the intermolecular force is minimum, so they don't have definite shape, size and volume. Solids do not have the ability to flow as liquids and gases do.
- Another dissimilarity between solids and gases is that gases can be compressed when some external pressure is applied to them, but solids are virtually incompressible.
- In the plasma state, matter exists in **ionised state**. Plasma state is common in stars.
- The atoms of a solid can be bound together in either a regular or an irregular manner. The manner in which the atoms of the solid are arranged in three-dimensional space determines the type of the solid.

Categories of Solids

(i) Crystalline Solid- Having regular pattern of constituent particles in three dimensional spaces, they have a definite external geometrical shape and a sharp melting point.

They are anisotropic i.e. their physical properties have different value in different directions. Examples- rice, sugar and diamond.

(ii) Amorphous or Glassy Solids- They have irregular arrangements of particles; hence, they don't have a definite external geometrical shape and sharp melting point.

They are isotropic i.e. their physical properties have same value in all directions. Examples- Glass, Cement, Rubber and Plastic, etc.

Major Classes of Solids Include

- **Minerals:** Minerals are natural solids formed by geological processes.
- A mineral has a uniform structure. Examples include diamond, salts, and mica.
- **Metals:** Solid metals include elements (e.g., silver) and alloys (e.g., steel). Metals are typically hard, ductile, malleable, and excellent conductors of heat and electricity.

6 CHAPTER

Thermodynamics

Thermodynamics is a branch of physics which deals with the energy and work of a system. It deals only with the large scale response of a system which we can observe and measure in experiments. Small scale gas interactions are described by the kinetic theory of gases. The methods complement each other; some principles are more easily understood in terms of thermodynamics and some principles are more easily explained by kinetic theory.

Let's split the term "Thermodynamics" into its two components, "Thermo" and "Dynamics." The term "Thermo" refers to heat, whereas the term "Dynamics" refers to a mechanical motion that requires "work." The field of physics that studies the relationship between heat and other types of energy is called thermodynamics.

Thermodynamics

Thermodynamics is the branch of physics concerned with heat and temperature and their relation to energy and work.

- Heat is a form of energy called thermal energy. Heat is referred to energy that is transferred from one body to another as a result of difference in temperature.
- The transfer of energy always takes place from the region of the higher temperature to the region of the lower temperature. Heat is the energy in flow due to the difference in temperature.

Branches of Thermodynamics

- The study of Thermodynamics is classified into several branches listed below:
- **Classical Thermodynamics:** The behavior of matter is examined using a macroscopic perspective in classical thermodynamics.
    - In order to determine the characteristics and predict the characteristics of the matter conducting the process, individuals take into account units like temperature and pressure.
- **Statistical Thermodynamics:** The development of atomic and molecular theories in the late 19th and early 20th centuries gave rise to statistical mechanics, also known as statistical thermodynamics, which added an interpretation of the microscopic interactions between individual particles or quantum-mechanical states to classical thermodynamics.
    - This field explains classical thermodynamics as a natural consequence of statistics, classical mechanics, and quantum theory at the microscopic level.
- **Chemical Thermodynamics:** Chemical thermodynamics is the study of how energy interacts with chemical processes or state changes in accordance with the laws of thermodynamics.
    - Determining the spontaneity of a certain transition is the main goal of chemical thermodynamics.
- **Equilibrium Thermodynamics:** Equilibrium thermodynamics is the study of matter and energy transfers in systems or substances that can be moved from one state of thermodynamic equilibrium to another by agents in their environment.
    - The phrase "thermodynamic equilibrium" refers to a condition of equilibrium in which all macroscopic flows are zero.
- **Non-equilibrium Thermodynamics:** Systems that are not in thermodynamic equilibrium are the focus of the field of thermodynamics known as non-equilibrium thermodynamics.
    - The majority of systems in nature are not in thermodynamic equilibrium because they are not in stationary states and are subject to fluxes of matter and energy to and from other systems on a continual and irregular basis.

Thermodynamic Systems

- A collection of an extremely large number of atoms or molecules confined within certain boundaries such that it has certain values of pressure (P), volume (V) and temperature (T) is called a thermodynamic system.
- Anything outside the thermodynamic system to which energy or matter is exchanged is called its surroundings. Taking into consideration the interaction between a system and its surroundings, a system may be divided into three classes-

1. **Open System:** A system is said to be an open system if it can exchange energy and matter with its surroundings. See figure 1(A).
2. **Closed System:** A system is said to be a closed system if it can exchange only energy (not matter) with its surroundings. See figure 1(B).

7 CHAPTER Oscillation

In your childhood you must have enjoyed rocking in a cradle or swinging on a swing. Both these motions are repetitive in nature. Here, the object moves to and fro about a mean position. Such a motion is termed as oscillatory motion. In this chapter we will study about oscillation.

Oscillation is a motion that repeats itself in a regular cycle or interval such as a wave or swinging pendulum. In other words, oscillation is the process of returning a system to its equilibrium position, the stable position of the system where the net force acting on it is zero.

- Periodic motion can be defined as repetition in motion of an object at a regular interval of time i.e. motion of planets around the Sun, motion of hands of a clock, etc.
- Dropping a stone into a still lake causes ripples to spread out to the edges; plucking a sitar string making vibrations in the wire of sitar, etc.
- The oscillation of a physical system is caused by elasticity and inertia. The total energy of an oscillating particle is equal to the sum of its kinetic energy and potential energy if conservative force acts on it.

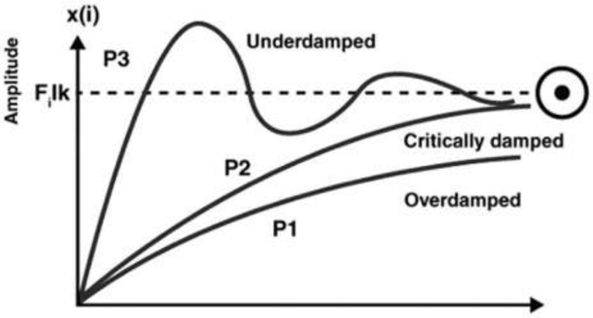
Variables of Oscillation

- **Amplitude** is the maximum displacement from the equilibrium point.
  - If a pendulum swings one centimeter from the equilibrium point before beginning its return journey, the amplitude of oscillation is one centimeter.
- **Period** is the time it takes for a complete round trip by the object, returning to its initial position.
  - If a pendulum starts on the right and takes one second to travel all the way to the left and another second to return to the right, its period is two seconds. Period is usually measured in seconds.
- **Frequency** is the number of cycles per unit of time.
  - Frequency equals one divided by the period. Frequency is measured in Hertz, or cycles per second.

Types of Oscillation

Oscillation can be classified into the following types which are as follows-

- **Free Oscillation:** When the body, in an oscillating movement, vibrates with a frequency of its own, the oscillation is known as free oscillation.
  - It has a constant amplitude and period to set the oscillation without any external force. Examples of free oscillation include the vibrations caused by a tuning fork.
- **Damped Oscillation:** The type of oscillation that is decreased with time is known as damped oscillation.
  - The damping is caused due to external factors which include friction or air resistance which further reduces the amplitude of the oscillation with time and these results in the loss of energy in the system.
  - Examples of damped oscillation include decaying oscillations of a pendulum.
- **Forced Oscillation:** When an external period force influences something to oscillate it is known as forced oscillation.
  - In this case, the amplitude experiences damping but due to external energy supplied to it, it remains constant. Examples of forced oscillation include feet moved by a child in order to move the swing.
- **Resonance:** When the frequency of external force (driver) is equal to the natural frequency of the oscillator (driven), then this state of driven is known as the state of resonance. In the state of resonance there occurs maximum transfer of energy from driven to the driver. Hence the amplitude of motion becomes maximum.



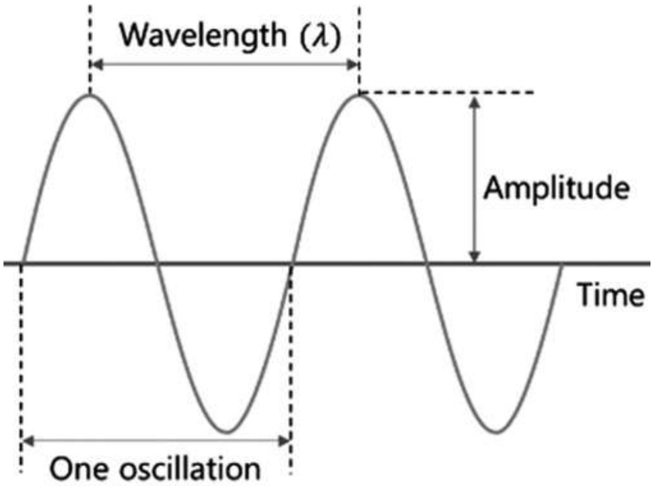
- **Coupled Oscillation:** A system of two or more oscillations linked together in such a way that there is a mutual exchange of energy between them is called a coupled system. The oscillations of such a system are called coupled oscillations.

CHAPTER 8
Wave

The disturbances produced in air are much less obvious and only our ears or a microphone can detect them. These patterns, which move without the actual physical transfer or flow of matter as a whole, are called waves. In this chapter, we will study such waves.

Wave is oscillation or disturbance that travels through a medium, accompanied by transfer of energy. In other word, wave is a rhythmic disturbance that transfers energy through matter or space without transporting matter from place to place.

- The wave motion is transferred continuously from one particle to its neighboring particle.



- Consider a slinky wave as an example of a wave. When the slinky is stretched from end to end and is held at rest, it assumes a natural position known as the equilibrium or rest position.
  - To introduce a wave into the slinky, the first particle is displaced or moved from its equilibrium or rest position.
  - The particle might be moved upwards or downwards, forwards or backwards; but once moved, it is returned to its original equilibrium or rest position.
  - The act of moving the first coil of the slinky in a given direction and then returning it to its equilibrium position creates a disturbance in the slinky.
  - A pulse is a single disturbance moving through a medium from one location to another location
  - The repeating and periodic disturbance that moves through a medium from one location to another is referred to as a wave.

When a slinky is stretched, the individual coils assume an equilibrium or rest position.

When the first coil of the slinky is repeatedly vibrated back and forth, a disturbance is created which travels through the slinky from one end to the other.

- A **medium** is a substance or material that carries the wave.
  - A wave medium is the substance that carries a wave (or disturbance) from one location to another.
  - The wave medium is not the wave and it doesn't make the wave; it merely carries or transports the wave from its source to other locations.
  - In the case of our slinky wave, the medium through that the wave travels is the slinky coils.

Types of Waves

- Waves occur in various forms. There are three types of Waves
  1. Mechanical Waves
  2. Electromagnetic Waves
  3. Matter Waves

Mechanical Waves

- The mechanical waves are seen as a propagation of a specific disturbance that travels in a material medium.
  - This type of wave is a result of the oscillation of matter. In this case, the transfer of energy happens through a medium.
  - The oscillating material performs motion at a stationary point. There is little translational motion involved in this type of propagation.
  - The distance covered by the propagation of a wave is determined by the transmission medium.
  - This wave is the outcome of the continuous periodic movement of the particles.

9 CHAPTER

Sound

Sound plays an important role in our lives. It helps us to communicate with one another. How is sound produced? How does it travel from one place to another? Why are some sounds louder than others? We shall discuss such questions in this chapter.

Sound is a kind of wave that propagates as a typically audible mechanical wave of pressure and displacement through a medium but not the vacuum. The two conditions that are required for the generation of a sound wave are **a vibratory disturbance** and an **elastic medium**, the most familiar of which is air.

- When a body vibrates in air, it forces the molecules of air to vibrate with it and creates the sound wave. It is **a longitudinal wave**.
- The properties of this wave depend upon the elasticity of air and are also called **elastic waves**. Sound waves can also propagate through **liquids** and **solids**.
- A wave is the propagation of a disturbance. The nature of the disturbance may be mechanical, electrical, thermal or even non-physical.
- The wave velocity is the speed with which the disturbance is propagated.
- It is a disturbance which can exist only in a medium; the neighbouring particles of the medium must somehow react upon one another for the disturbance to be propagated.
- For waves in solids, the stretch modules are used, for waves in liquids and gases, the bulk modules are used.
- **Compression** is a region of increased pressure and rarefaction is region of decreased pressure. The resulting succession of compression and rarefaction makes up the sound waves.
- Sound can be generated at a wide range of frequency; however, sound waves **between 20 Hz and 20,000 Hz** can be heard by normal human ears and are known as **audio waves**.
- The Sound Wave with frequency is **below 20 Hz** is called **infrasound** and those above **20,000 Hz** are known as **ultrasound**.

Speed of Sound

- The speed of the sound depends on the **density** and the **elasticity of the medium** through which it travels. In general, **sound travels faster in liquids than in gases and quicker in solids than in liquids.**
- The speed of sound v, in a medium can be defined as v = f λ, where λ is the wavelength and f is the frequency.
- The SI unit of velocity (v) is ms^{-1}, frequency (f) is Hz and wavelength (λ) is m (metre).
- At the peak of mountains, the speed of sound is less than that at sea level. This is not due to the lower pressures but because of the lower temperatures at the peak of mountains.
- Velocity of sound in a gaseous medium

$$\upsilon = \sqrt{\frac{K}{\rho}}$$

where K is the bulk modules of elasticity of a gas, and ρ is the density of the gas.

- When we increase pressure on a gas, it gets compressed but its density increases in the same proportion as the pressure i.e. P/ρ remains constant. It means that, pressure has no effect on the velocity of sound in a gas.
- The velocity of sound in air increases by about 0.061 metres/sec for each degree Centigrade rise in temperature.
- If the pressure and the value of Y is the same for two gases, the velocities of sound in the two gases are inversely proportional to the square roots of their densities.
- **The amplitude of sound** depends on its loudness as louder the sound bigger the amplitude.

Factors Affecting the Speed of Sound

- Density and temperature of the medium in which the sound wave travels affect the speed of sound.
  - **Density of the Medium:** When the medium is dense, the molecules in the medium are closely packed, which means that the sound travels faster. Therefore, the speed of sound increases as the density of the medium increases.
  - **Temperature of the Medium:** The speed of sound is directly proportional to the temperature. Therefore, as the temperature increases, the speed of sound increases.

Effect of Humidity on Velocity of Sound in Air

- As humidity in air increases (keeping conditions of temperature and pressure constant), its density increases and hence velocity of sound in air increases.

10 CHAPTER

Light

In this chapter, we shall study the nature, property and structure of light, intensity of illumination, phenomena of reflection and refraction. These basic concepts will help us in the study of some of the optical phenomena in nature. We shall try to understand in this chapter the reflection of light by spherical mirrors and refraction of light and their application in real life situations.

Nature has endowed the human eye (retina) with the sensitivity to detect electromagnetic waves within a small range of the electromagnetic spectrum.

- Electromagnetic radiation belonging to this region of the spectrum (wavelength of about 400 nm to 750 nm) is called light. It is mainly through light and the sense of vision that we know and interpret the world around us.
- Light is a kind of electromagnetic radiation or wave that is visible to the human eye.
- Electromagnetic radiation includes visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously.
- Light is transverse wave. Light can move without medium, so can spread in vacuum. It travels with constant speed in the vacuum.
- The spreading direction of light is perpendicular to vibrating direction.
- Light can experience reflection, refraction, interference, diffraction and polarization.
- Bodies that distribute light is called light source, while that cannot spread it are dark bodies.
- The study of light is known as Optics.

Nature of Light

Light shows two types of nature i.e. **particle nature** and **wave nature**. Light can be treated as either particle or wave but not both simultaneously.

(i) Wave Nature of Light

- According to quantum mechanical wave-particle duality theory, light exhibits both a particle and a wave character depending on the position.
- If the light is viewed as a wave, phenomena such as **diffraction, polarization, and interference** can be explained. By believing that light is made up of tiny particles called photons, phenomena such as the photoelectric effect can be explained.
- **According to Einstein,** light is made up of photons, a type of particle, and these photons travel in waves.
- **De-Broglie** introduced an important theory in **1924** as a result of the possibility that radiation could be considered of a dual nature.
- According to de-Broglie, if radiation exhibits wave behavior in some studies and particle behavior in others, then particles such as electrons should also occasionally exhibit wave behavior.
- The **key difference** between wave and particle nature of light is that the **wave nature of light states that light can behave as an electromagnetic wave, whereas the particle nature of light states that light consists of particles called photons.**
- **Wave-particle duality** is a concept in quantum mechanics. It states that all the particles and quantum entities have not only wave behaviour but also particle behaviour. The classical "wave" and "particle" concepts cannot completely describe the behaviour of quantum-scale objects; thus, the wave-particle duality theory is very important for this.
- According to its wave nature or the theory of electromagnetic radiation, each wave consists of two types of field, i.e; **Electric field** and the **Magnetic field**.
- It further says that light is composed of perpendicular magnetic and electric fields. Each wave has its associated wavelength, frequency and energy.
- The particle theory of light says that light is composed of particles which are termed as **photons**. Each photon has some energy associated with it which depends on the frequency of light.
    - We have stated that light is a wave, suggesting that every ray of light should have an associated wavelength and travel **in a straight line**.
- The **wavelength** is the distance between any two successive points on a wave that are in phase (e.g., two successive crests or two successive troughs).
- Light waves can have different wavelengths, which determine the colour of visible light that is observed.
    - This means that every time you view a beautiful red rose on a sunny day, your eyes perceive a reflection of red light from the rose, which has a wavelength of about 650nm.

11
CHAPTER

Magnetism

Magnetism is the force exerted by magnets when they attract or repel each other. It is caused by the motion of electric charges. The movement of electrons around the nucleus generates an electric current and causes each electron to act like a microscopic magnet.

Magnet

A magnet is a material which can attract iron objects. A natural magnet is an ore of iron (Fe_3O_4) called **magnetite** or **lodestone**. All magnets have north and south poles. Opposite poles are attracted to each other, while the same poles repel each other.

- When you rub a piece of iron along a magnet, the north-seeking poles of the atoms in the iron line up in the same direction. The force generated by the aligned atoms creates a magnetic field. The piece of iron has become a **magnet**. A magnet which is prepared artificially is called an **artificial magnet**. For Example: A bar magnet, a horseshoe magnet etc.
- The word magnetism is derived from iron ore magnetite (Fe_3O_4). Magnetism is the properties and interactions of magnets.

Historic Directions

- The ancient Greeks and Chinese knew about naturally magnetic stones called "lodestones." These chunks of iron-rich minerals may have been magnetized by lightning.
- The Chinese discovered that they could make a needle magnetic by stroking it against a lodestone, and that the needle would point north-south.

Properties of Magnet

- A magnet attracts ferromagnetic materials like **iron, nickel, and cobalt**.
- If a magnet is suspended from rigid support such that it can rotate freely, the magnet always points towards the north-south direction.
- **Poles**: These are the regions in magnet where the power of attracting iron is found to be maximum. Magnets have two ends or poles, called north and south poles.
- The poles are also called as the **magnetic dipole**. A single pole cannot exist. Two poles of a magnet inside a body are joined by **Magnetic Axis**.
- Magnet produces a magnetic field around it.
- A freely suspended magnet comes to rest in the North-South direction, i.e., in the direction of earth's magnetic field.
- The magnetic force (attraction or repulsion) between two objects is inversely proportional to the distance between them. The force is stronger when the objects are close.

Applications of Magnet

- Several **speakers** use a static magnet and a coil that currently holds to convert power (signal) into mechanical (noise-causing motion).
- The coil wound round the reel connected to the speaker cone holds the signal as a versatile current that interacts with the static magnet field.
- In addition to **invasive surgery**, hospitals use **resonance imaging** to diagnose the patient's limbs.
- **Nuclear resonance** could be a methodology employed by chemists to provide products.
- Magnets are widely used in daily life, science, and technology like permanent magnets are used in hard drives, television, cars, motors.

Electromagnet

- A current-carrying coil containing a soft iron core is called an electromagnet.
- Electromagnets are strong magnets, consisting of wires closely wrapped around an iron core. When a current is made to flow through the wires, it behaves like a magnet. As soon as the current is switched off, the magnetic behavior goes away.
- An electromagnet is utilised in the electric bell, telegraph receiver, telephone diaphragm, transformer, dynamo etc.
- Permanent magnets are made of steel and temporary magnet or electromagnets are made of soft iron because steel cannot be magnetised easily but when it is magnetised one time, cannot be demagnetised easily. The soft iron can be magnetised or demagnetised easily.

Magnetism

Magnetism is a concept introduced in physics to help you understand one of the fundamental interactions in nature, the interaction between moving charges.

12
CHAPTER

Electricity

Electricity has an important place in modern society. 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? In this chapter, we shall attempt to answer such questions. We shall also discuss the heating effect of electric current and its applications.

Electric Charge

Electric Charge is nothing but the amount of energy or electrons that pass from one body to another by different modes like conduction, induction or other specific methods.

- This is a basic electric charge definition. There are two types of electric charges. They are **positive charges** and **negative charges**.

- Charges are present in almost every type of body. All those bodies having no charges are the neutrally charged ones. We denote electric charge the with symbol 'q' and its standard unit is **Coulomb**.
- Mathematically, we can say that a charge is the number of electrons multiplied by the charge on 1 electron. Symbolically, it is q = ne
- where q is a charge, n is a number of electrons and e is a charge on 1 electron (1.6×10^{-19}C). The two very basic natures of electric charges are
  - Like charges repel each other.
  - Unlike charges attract each other.
- This means that while **protons repel protons**, they attract electrons. The nature of charges is responsible for the forces acting on them and coordinating the direction of the flow of them.
- The charge on electron and proton is the same in magnitude which is 1.6×10^{-19} C. The difference is only the sign that we use to denote them, +ve and -ve.

Properties of Electric Charges

- **Additivity of Electric Charges**: Electric charges when they are considered as point charges are scalar in nature. With that, it is important to note that charges can be point charges, but they are still positive and negative charges.
- The additive property of electric charges says that if there are n number of charges present inside, the total charge present will be the algebraic sum of the individual charges.

$$Q = q_1 + q_2 + q_3 + \ldots.. q_n$$

- **Conservation of Charges**: The Conservation of charges says that the charges are neither created not destroyed. They can be transferred from one body to another, but they cannot be created or destroyed. In an Isolated system, the charges are always conserved.
- **Quantization of Charge**: According to the quantization of electric charge, Electric charges are defined as the Integral multiple of the charge present on them, hence, in any system, The charges will be, ***q = ne***
  - Where,
  - n = Integer numbers
  - e = value of the charge (1.6×10^{-19} C)

Some other Properties of Electric Charge

- Charge is a scalar quantity.
- Charge is transferable; they transfer from one body to another.
- Like charges repel each other and unlike charges attract each other.
- Charge is always associated with mass.
- Conservation of Electric Charges

Conservation of Electric Charges

- Law of conservation of charge says that the net charge of an isolated system will always remain constant. This means that any system that is not exchanging mass or energy with its surroundings will never have a different total charge at any two times.
- **For example**, if two objects in an isolated system have a net charge of zero, and one object exchanges one million electrons to the other, the object with the excess electrons will be negatively charged and the object with the reduced number of electrons will have a positive charge of the same magnitude. The total charge of the system has not and will never change.

Electric Current

Electric current refers to the **flow of electricity** in an electronic circuit, and to the amount of electricity flowing through a circuit.

- If the two requirements of an electric circuit are met, then charge will flow through the external circuit. It is said that a current is a flow of charge.

13 CHAPTER

Atomic Physics

Atomic Physics is the foundation for a wide range of basic science and practical technology. The structure and properties of atoms are the basis of Chemistry, and hence of Biology. Atomic Physics underlies the study of Astrophysics and Solid State Physics. It has led to important applications in communications, lasers, etc.

An atom is the smallest particle of an element that can exist independently and retain all its chemical properties. The origins of atomic physics were entwined with the development of quantum mechanics itself ever since the first model of the hydrogen atom by Bohr.

Atom and Nucleus

Dalton's atomic theory, which suggested that the atom was indivisible and indestructible. But the discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of this aspect of Dalton's atomic theory.

Thomson proposed that

(i) An atom consists of a positively charged sphere and the electrons are embedded in it.

(ii) The **negative and positive charges are equal in magnitude**. So, the atom as a whole is electrically neutral.

- Rutherford's alpha-particle scattering experiment led to the discovery of the **atomic nucleus**.

Ernst Rutherford (1871-1937)

- British physicist who did pioneering work on radioactive radiation. He discovered **alpha-rays** and **beta-rays**.
- Along with Federick Soddy, he created the modem theory of radioactivity.
  - He studied the **'emanation' of thorium** and discovered a new noble gas, an **isotope of radon, now known as thoron.**
- By scattering alpha-rays from the metal foils, he discovered the atomic nucleus and proposed the planatery model of the atom. He also estimated the approximate size of the **nucleus**.

Neil's Bohr's Model of the Atom

- His model was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.

Nucleus

- In every atom, the positive charge and mass are densely concentrated at the centre of the atom forming its nucleus. The overall dimensions of a nucleus are much smaller than those of an atom.
- Experiments on scattering of **α-particles** demonstrated that the radius of a nucleus was smaller than the radius of an atom by a factor of about 10^4. This means the volume of a nucleus is about 10^{-12} times the volume of the atom.
- In other words, an atom is almost empty. If an atom is enlarged to the size of a classroom, the nucleus would be of the size of pinhead. Nevertheless, the nucleus contains most (more than 99.9 per cent) of the mass of an atom.
- Measurement of atomic masses is carried out with **a mass spectrometer.**
- The measurement of atomic masses reveals the existence of different types of atoms of the same element, which exhibit the same chemical properties, but differ in mass. Such atomic species of the same element differing in mass are called **isotopes**.
- In Greek, isotope means the same place, i.e. they occur in the same place in the periodic table of elements. It was found that practically every element consists of a mixture of several isotopes.
- The lightest element, **hydrogen has three isotopes**. The nucleus of the lightest atom of hydrogen, which has a relative abundance of 99.98 per cent, is called the **proton**.
  - The other two isotopes of hydrogen are called **deuterium** and **tritium**. Do not occur naturally and are produced artificially in laboratories.
- The positive charge in the nucleus is that of the **protons**. A proton carries one unit of fundamental charge and is **stable**.
  - It was earlier thought that the nucleus may contain electrons, but this was ruled out later using arguments based on quantum theory. All the electrons of an atom are outside the nucleus.
- We know that the number of these electrons outside the nucleus of the atom is Z, the atomic number.

UNIT - II

CHEMISTRY

- Nature and Scope of Chemistry
- Atoms
- Matter
- Periodic Properties of Elements
- Chemical Bonding
- Radioactivity
- Chemical Reaction
- Catalysis
- Metals, Metallurgy and Non-Metal
- Electrochemistry
- Soil Chemistry
- Food Chemistry
- Environmental Chemistry
- Scientific Laws, Instruments & Inventions
- Glossary

CHAPTER 1

Nature and Scope of Chemistry

Chemistry has influenced our life so much that we do not even realise that we come across chemicals at every moment; that we ourselves are beautiful chemical creations and all our activities are controlled by chemicals. In this chapter, we shall study the nature and scope of Chemistry as a subject.

Chemistry is the study of matter : what it consists of, what its properties are, and how it changes. Being able to describe the ingredients in a cake and how they change when the cake is baked is called chemistry.

- Matter is anything that has **mass** and takes up **space**-that is, anything that is **physically real.**

Scope of Chemistry

Chemistry is one branch of science. Science is the process by which we learn about the natural universe by observing, testing, and then generating models that explain our observations. Because the physical universe is so vast, there are many different branches of science.

- Thus, chemistry is the **study of matter**, biology is the study of **living things**, and geology is the study of **rocks and the earth.**
- Mathematics is the language of science, and we will use it to communicate some of the ideas of chemistry.
- According to **Roald Hoffmann**, "***Chemistry is the science of molecules and their transformations***." Sometimes, Chemistry is known as the central science because it links other natural sciences like physics, geology and biology.

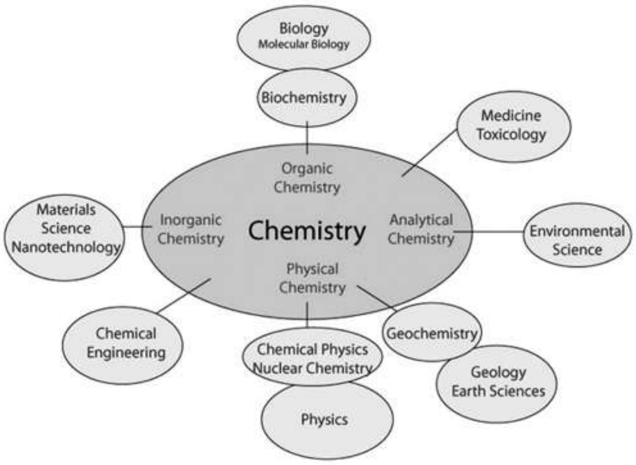


Figure: The Relationships between Some of the Major Branches of Science. Chemistry lies more or less in the middle, which emphasizes its importance to many branches of science.

Main Branches of Chemistry

Traditionally, chemistry is broken into five main branches. There are also more specialized fields, such as **food chemistry, environmental chemistry** and **nuclear chemistry,** but this section focuses on chemistry's five major sub-disciplines.

1. **Analytical Chemistry:** It involves the analysis of chemicals, and includes qualitative methods like looking at color changes, as well as quantitative methods like examining the exact wavelength (s) of light that a chemical absorbed to result in that color change.
   - These methods enable scientists to characterize many different properties of chemicals, and can benefit society in a number of ways.
   - For example, analytical chemistry helps food companies **make tastier frozen dinners by detecting how chemicals in food change** when they are frozen over time.
   - Analytical chemistry is also used to **monitor the health of the environment** by measuring chemicals in water or soil, for example.
2. **Bio-chemistry**: It uses chemistry techniques to understand how biological systems work at a chemical level.
   - Thanks to biochemistry, researchers have been able to **map out the human genome**, understand what different proteins do in the body and develop cures for many diseases.
3. **Inorganic Chemistry:** Inorganic chemistry studies the chemical compounds in inorganic, or non-living things such as minerals and metals.
   - Traditionally, inorganic chemistry considers compounds that do *not* contain carbon (which are covered by organic chemistry), but this definition is not completely accurate.
   - Some compounds studied in inorganic chemistry, like **"organometallic compounds,"** contain metals, which are metals that are attached to carbon.
   - The main element that's studied in organic chemistry. As such, compounds such as these are considered part of both fields.

2
CHAPTER

Atoms

By the nineteenth century, enough evidence had accumulated in favour of atomic hypothesis of matter. In this chapter we are going to study Atomic Molecular Theories and some major discoveries in Chemistry in a brief manner.

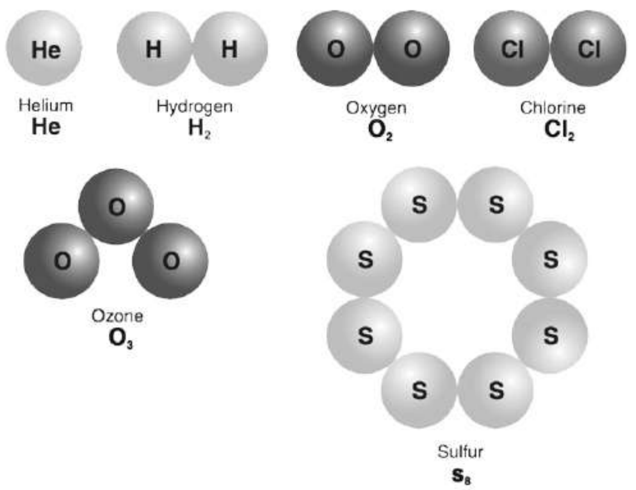
All the matter is made up of atoms. The atom is the one of the smallest part of the element that retains the chemical characteristics of the element itself. Atoms don't exist independently, instead, they form ions and molecules which further combine in large numbers to form matter that we see, feel and touch.

- Atoms are much too small to be seen; hence experiments to find out their structure and behavior have to be conducted with large numbers of them.
- From the results of these experiments we may attempt to construct a hypothetical model of an atom that behaves like the true atom.

Size of an Atom

- An atom is exceedingly small, much smaller than our imagination allows us to imagine.
- When more than millions of atoms are packed together, a layer of an atom the thickness of a thin sheet of paper is created.
- Because it's difficult to detect the positions of electrons surrounding the nucleus, measuring the size of an isolated atom is impossible.
- However, assuming that the distance between neighbouring atoms is equal to half the radius of an atom, the size of an atom can be approximated. The radius of an atom is usually measured in nanometers (10^{-9} m).

- An atom is composed of sub-atomic particles and these cannot be made or destroyed.
- All atoms of the same element are identical and different elements have different types of atoms. Chemical reactions occur when atoms are rearranged.
- Some elements are **monatomic**, meaning they are made of a single (*mon-*) atom (*-atomic*) in their molecular form. Helium (He) is an example of a monatomic element.
- Other elements contain two or more atoms in their molecular form. Hydrogen (H_2), oxygen (O_2), and chlorine (Cl_2) molecules, for example, each contains two atoms.
- Another form of oxygen, ozone (O_3), has three atoms, and sulfur (S_8) has eight atoms. All elemental molecules are made of atoms of a single element.



Structure of an Atom

Atoms are composed of protons, neutrons and electrons. Neutrons and protons have approximately the same mass and in contrast to this the mass of an electron is negligible.

- A proton carries a positive charge, a neutron has no charge and an electron is negatively charged.
  - **Proton** (p^+), which is positively (+ve) charged;
  - **Electron** (e^-), which is negatively (–ve) charged; and
  - **Neutron** (n^0), which has no charge, it is neutral (0).
- An atom contains equal numbers of protons and electrons and therefore overall an atom has no charge.
- The nucleus of an atom contains protons and neutrons only, and therefore is positively charged. The electrons occupy the region of space around the nucleus.
- Therefore, most of the mass is concentrated within the nucleus.
- Electrons (having negative charge) at the orbit in an atom are bound to the atom by the electromagnetic force, while the protons (having positive charge) and neutrons (with no charge) in the nucleus are bound to each other by the nuclear force.

3 CHAPTER Matter

In this chapter, we will learn more about solid, liquid and gaseous physical states of matter, particularly liquid and gaseous states. To begin with, it is necessary to understand the nature of intermolecular forces, molecular interactions and effect of thermal energy on the motion of particles because a balance between these determines the state of a substance.

Everything around us is composed of matter. The matter is defined as anything that has mass and occupies space (i.e., has a volume). The matter possesses mass, offers resistance and can be felt through one or more of our senses.

- Till very recently, it was assumed that matter can neither be created nor destroyed. Scientists have established that there are two fundamental entities in the universe: Matter and Energy.
- They have also come to the conclusion that the total quantity of matter and of energy in the universe is constant.
- After the discovery of radioactivity, and work done by scientists like Einstein, it was realized that matter and energy are inter-convertible.
- It is this convertibility of matter into energy that is responsible for construction of atom bombs and nuclear reactors.

Characteristics of Particles of Matter

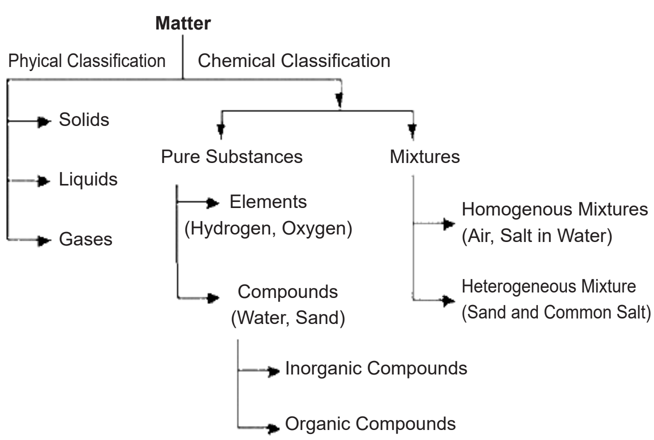
The important characteristics of particles of matter are the following:

- **The particles of matter are very, very small:** The very, very small size of particles of matter can be shown by performing the following experiment by using potassium permanganate and water.
  - Take 2-3 crystals of potassium permanganate and dissolve them in 100 ml of water in a beaker.
  - We will get a deep purple colored solution of potassium permanganate in water.
  - So we conclude that there must be millions of tiny particles in just one crystal of potassium permanganate, which keep on dividing themselves into smaller and smaller particles.
- **Particles in matter are in a state of continuous motion**: The particles present in matter are not stationary, but have a tendency to acquire motion.
- In fact they are in a state of continuous motion. The rate of movement of the particles is directly proportional to the thermal energy of the particles.
- **Particles in matter attract one another**: The particles in matter attract one another. This attraction is inversely proportional to the distance between the particles. However, the magnitude of these inter-particle forces differs from one substance to another.
- **Particles in matter have spaces between them**: Empty spaces called voids, separate the particles from one another. The distance between them ranges from 10^{-8} cm to 10^{-5} cm. Due to these voids matter is able to disperse into one another bringing about diffusion.

States of Matter

Matter exists in three physical states such as **solid, liquid** and **gas.** Every material substance is characterized by properties such as shape, texture, colour, mass, melting point, boiling point and so on.

- Matter can be classified as **solid**, **liquid** and **gas** on the basis of inter-particle forces and the arrangement of particles.
- These three forms of matter are interconvertible by increasing or decreasing pressure and temperature. For example, ice can be converted from solid to a liquid by increasing the temperature.



Solid

- Something is usually described as a solid if it can hold its own shape and is hard to compress (squash). The **molecules** in a solid are **closely packed together** – they have a high density.

4
CHAPTER

Periodic Properties of Elements

In this chapter, we will study the historical development of the Periodic Table as it stands today and the Modern Periodic Law. We will also learn how the periodic classification follows as a logical consequence of the electronic configuration of atoms. Finally, we shall examine some of the periodic trends in the physical and chemical properties of the elements.

Periodic Table is a graphical representation of certain data in a systematic way i.e. elements are vertically and horizontally arranged that show some gradation and periodic connection between them.

- After the discovery of some elements, periodic table was developed, amid the need arise, to organise them.
- At present **118 elements** are known as against only 31 till 1800.

Mendeleev's Periodic Table

Mendeleev in **1869** stated that ***"properties of elements are a periodic function of their atomic weights"*** i.e. if elements are arranged in the order of their atomic weights, similar elements are repeated at regular periods or intervals.

- Mendeleev arranged the elements in the order of their ascending atomic weights (mass) in the form of a table called **Mendeleev's periodic table** i.e. the first real periodic table. The table includes:
  - The nine vertical columns are called **Groups** numbered **from I to VII and 0**.
  - Group I to VII are subdivided into subgroups **A & B,** ***group*** *VIII* is the group of **transition elements** and *group* '0' is the group of noble gases.
  - The seven horizontal rows are called ***Periods*** numbered from 1 to 7.

Merits of Mendeleev's Periodic Table

A. Study of Elements - First time all known elements were classified in groups according to their **similar properties**. So study of the properties becomes easier of elements.

B. Prediction of New Elements - It gave encouragement to the discovery of new elements as some gaps were left in it. **Sc (Scandium), Ga (Gallium), Ge (Germanium), Tc (Technetium)** were the elements for whom position and properties were defined by Mendeleev even before their discoveries and he left the blank spaces for them. e.g.

For Example

- Blank space at atomic weight 72 in silicon group was called **Eka Silicon** (means properties like silicon) and element discovered later was named Germanium. Similarly, other elements discovered after Mendeleev periodic table were.
  - **Eka Aluminium-** Gallium (Ga); Eka Boron - Scandium (Sc)
  - **Eka Silicon –** Germanium (Ge); Eka Manganese - Technetium (Tc)

C. Correction of doubtful atomic weights - Correction was done in atomic weight of some elements.

Atomic Weight = Valency × Equivalent weight

- Initially, it was found that equivalent weight of Be is 4.5 and it is trivalent (V=3), so the weight of Be was 13.5 and there is no space in Mendeleev's table for this element.
- So, after correction, it was found that Be is actually divalent (V= 2).
- So, the weight of Be became 2 × 4.5 = 9 and there was a space between 'Li' and 'B' for this element in Mendeleev's table.
  - Corrections were done in atomic weight of elements are – U, Be, In, Au, Pt.

Demerits of Mendeleev's Periodic Table

A. Position of Hydrogen - Hydrogen resembles both, the alkali metals (IA) and the halogens (VIIA) in properties so Mendeleev could not decide where to place it.

B. Position of Isotopes - As atomic weight of isotopes differs, they should have placed in different position in Mendeleev's periodic table. But there were no such places for isotopes in Mendeleev's table.

C. Anomalous Pairs of Elements - There were some pair of elements which did not follow the increasing order of atomic wts.eg. Ar and Co were placed before K and Ni respectively in the periodic table, but having higher atomic weights.

D. Like elements were placed in different groups. There were some elements like Platinum (Pt) and Gold (Au) which have similar properties but were placed in different groups in Mendeleev's table.

5 CHAPTER

Chemical Bonding

Why do atoms combine? Why are only certain combinations possible? Why do some atoms combine while certain others do not? Why do molecules possess definite shapes? In this chapter we will find answer to such questions.

Chemical bonding is an important part of Inorganic Chemistry though some part of chemical bonding is also studied under physical chemistry. Under normal conditions, only Noble gases remains independent while most of the elements are found in compound or in mixture form.

- **Chemical bonds** are defined as the forces that hold the atoms of different elements together.
  - In other words, **the strong force of binding or combining between two or many atoms is referred to as a Chemical Bond** that forms a stable compound with properties of its own.
  - Chemical bonding, any of the interactions that account for the association of atoms into molecules, ions, crystals, and other stable species that make up the familiar substances of the everyday world.
- **Molecules form bonds** through **sharing electrons.** Atoms or molecules can share one, two, or three pairs of electrons, forming single, double, and triple bonds, respectively.

Octet Rule

Kössel and Lewis Theory

- **Kössel and Lewis** in **1916** developed an important theory of chemical combination between atoms known as electronic theory of chemical bonding.
- The outermost or valence electrons (extra electrons) of an atom are involved in chemical bonds. **Molecules of elements have tendency to attain octet configuration by formation of compounds, and that tendency is called the octet rule.**
- According to this, atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to have an octet in their valence shells.

Valency

- Valency is the number of atoms of a particular element that is combined with one atom of another element to form a molecule.
- Valency is also known as molecular weight. Valency is a measure of the **combining power of an atom**. The valency of an element is determined by the number of electrons in its outermost shell. The valency of an element can be increased either by gaining or losing electrons.
- Introduced in 1868, the term is used for the expression of both the possibility of combination of an element in general and the numerical value of the power of combination.
- Thus valence meaning is the number of electrons as most of the bonds are formed by the exchange of the valence electrons.
- When an atom donates one, two or three electrons from its valence or outermost shell to another able atom, it is known as **electrovalency**.

Importance of Valency

- The higher the valency, the stronger the bond. This is why elements with a high valency are often used in chemical reactions - they form strong bonds with other atoms.
- By understanding valency, we can better predict how chemicals will react with each other.

Applications of Valency

1. **Medicine:** Valency is used to determine the efficacy of a drug. Valency predicts **how much drug will be needed in order to treat a patient.**
   - Valency also determines how easily a drug can penetrate biological membranes such as the placenta (for pregnant women), blood-brain barrier.
2. **In Industrial Chemistry:** It is used to predict the properties of compounds and their suitability for particular applications.
3. **Genetics:** It results **from the binding of two alleles at a single loci,** where each allele may have a different valence depending on its own gene product and that of another allele present at the same locus.
4. **Properties of the Compound-** Valency helps in predicting the physical and chemical properties of the compound.

6 CHAPTER

Radioactivity

We shall discuss various properties of nuclei such as their size, mass and stability, and also associated nuclear phenomena such as radioactivity, fission and fusion in this chapter.

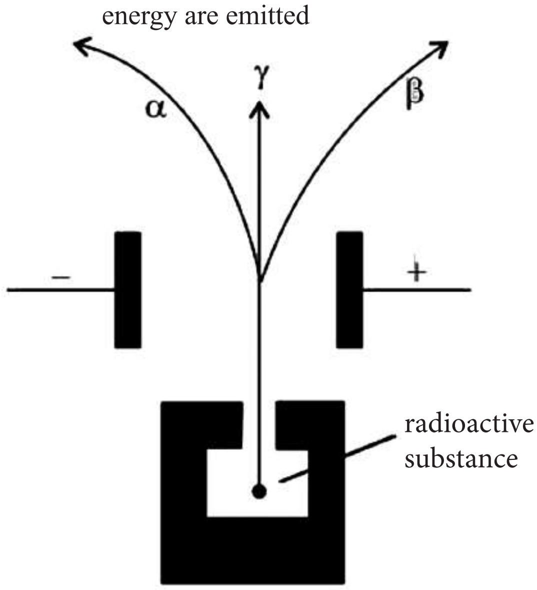
As its name implies, *radioactivity* is the act of **emitting radiation spontaneously.** This is done by an atomic nucleus that, for some reason, is unstable; it give up some energy in order to shift to a more stable configuration.

- Atoms become unstable due to **large neutron to proton ratio** and such unstable nucleus emits some radiations and then converts itself into some other stable nucleus, and the phenomenon is called Radioactivity.
- Like uranium, all other elements/compounds that emit highly penetrating radiations are called radioactive elements.
- The chance of encountering instability increases as the size of the nucleus increases because the mass of the nucleus becomes a lot when concentrated. That's the reason why atoms of **Plutonium, Uranium are extremely unstable and undergo the phenomenon of radioactivity.**
- Following Henri Becquerel's work, **in 1898 Pierre and Marie Curie** isolated polonium and radium, unknown radioactive elements present in uranium ore.

Discovery of Radioactivity

Henry Becquerel discovered radioactivity by accident in 1896. A **Uranium** compound was placed in a drawer containing photographic plates, wrapped in a black paper.

- He thought that the uranium salts, after being excited by light, emitted these X-rays. Imagine his surprise when, in Paris in **March 1896**, he discovered that **photographic film** had been exposed without exposure to sunlight.
- He concluded that uranium emitted invisible radiation, different from X-rays, spontaneously and inexhaustibly. The phenomenon he discovered was named **radioactivity** (from the **Latin radius**, meaning **ray**).
- When the plates were examined later, it was found that they were exposed. This exposure gave rise to the concept of **Radioactive decay**.
- In **1899, Ernest Rutherford**, a British physicist, analysed the Becquerel rays emitted by radioactive elements. He established the existence of two distinct components: α-particles and β-rays.
- The existence of third radiation – **gamma rays** – was established by **P. Villard.**
- Radioactivity can be seen in such forms –
  - **Alpha Decay** : Emission consists of Helium nucleus
  - **Beta Decay** : Emission consists of Electrons
  - **Gamma Decay** : Photons having high energy are emitted



Emission of α, β and γ Raditions

- Too many neutrons in a nucleus lead it to emit a **negative *beta*** particle, which changes one of the neutrons into a proton.
- Too many protons in a nucleus lead it to emit a **positron** (positively charged electron), changing a proton into a neutron.
- Too much energy leads a nucleus to **emit a *gamma*** ray, which discards great energy without changing any of the particles in the nucleus.
- Too much mass leads a nucleus to emit an *alpha* particle, discarding four heavy particles (two protons and two neutrons).

α-particles

Alpha particles are **helium nuclei ($^4He_2$)** and consist of two protons and two neutrons. Detailed studies of these particles revealed the following properties:

7 CHAPTER

Chemical Reactions

Chemical reactions are all around us. From the metabolism of food in our body to how we get the light from the sun is the result of chemical reactions. Before beginning with chemical reactions, it is important to know about physical and chemical changes. In this chapter we are going to discuss these concepts.

Chemical Reaction is a process that leads to the transformation of one set of chemical substances to another. The new substances produced in a chemical reaction have chemical properties different from those of the reactants. Generally, four basic types of chemical reactions occur:

Type of Chemical Reaction

i. **Displacement or Replacement Reaction:** This reaction takes place when a single uncombined element replaces another in a compound.
   - **E.g.** when magnesium replaces hydrogen in water to make magnesium hydroxide and hydrogen gas, $Mg+2H_2O \longrightarrow Mg(OH)_2+H_2$

ii. **Double Displacement Reactions:** This type of reactions occurs when the anions and cations of two compounds switch places and form two entirely different compounds.
   - **E.g.** When lead nitrate with potassium iodide to form lead iodide and potassium nitrate: $Pb(NO_3)_2+2Kl \longrightarrow PbI_2+2KNO_3$

iii. **Synthesis Reaction:** In this reaction, two or more simple substances combine to form a more complex substance or compound. **E.g.** $\mathbf{6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2}$

iv. **Decomposition Reaction:** Unlike synthesis reaction, this reaction takes place when a more complex substance breaks down into its more simple parts.

   E.g. $2H_2O ==> 2H_2+O_2$

Chemical Kinetics

Chemical Change: This is the phenomena in which new substances are formed, though cannot be reversed into the previous compound or substances.

- These chemical changes take place at a particular rate and this rate tells us how fast a reaction occurs.

Average reaction rate = Total change in concentration/ Time taken for the change

- The branch of chemistry which deals with the rate of chemical reactions or chemical change is called as **Chemical Kinetics**.

Major factors that affect the rate of a chemical reaction:

a. **Temperature:** Most of the chemical reactions take place at higher temperature.
   - Temperature increases the kinetic energy of the molecules increases, which increases the number of collisions between the molecules.

b. **Light:** Some reactions only take place in the presence of light.
   - **E.g.** photosynthesis in green plants or reaction between H2 and Cl2 to form HCl.

c. **Electricity:** Some reactions occur with the help of electric current. **E.g.**
   - $2H_2O \xrightarrow{Electricity} 2H_2 + O_2$
   - $PbBr_2 \xrightarrow{Electricity} Pb + Br_2$

d. **Pressure:** Some reactions require very high pressure to take place.
   - **E.g.**, in the manufacture of ammonia (NH_3) from nitrogen and hydrogen (Haber's process), a pressure of over 200 atmosphere is required in the presence of the catalyst iron and a temperature of 450°C to 500°C.

e. **Surface Area:** In case of reactions involving solid reactants and heterogeneous reactions, surface area of the reactant play an important role.
   - More number of molecules at the surface will be exposed to the reaction conditions, the rate of the reaction increases accordingly.

f. **Catalysts:** It is a substance that increases the rate of chemical reaction without undergoing any change itself.
   - The addition of catalyst generally increases the rate of the reaction at a given temperature.

Evidence of a Chemical Reaction/Change: Following events indicate that a chemical reactions has taken place-

a. Change of Colour. e.g. Black copper oxide on reaction with hydrogen converts to red coloured copper.

   $CuO + H_2 \rightarrow Cu + H_2O$

b. Formation of Gas

c. Change in Temperature or Energy

d. Formation of Precipitate

8 CHAPTER

Catalysis

The science of catalysis is of great significance in our daily life. Catalyst is a substance which enhances the rate of reaction. In this chapter we will study importance of catalysis, acids and bases.

There exists a wide variation in the rates of chemical reactions. Some are fast and some are slow. **Catalysis** is defined as increasing the rate of a chemical reaction by introducing a **catalyst**.

Catalyst

A catalyst, in turn, is a substance that is not consumed by the chemical reaction, but acts to lower its activation energy. In other words, a catalyst is both a reactant and product of a chemical reaction. Typically, only a very small quantity of catalyst is required in order to catalyze a reaction.

- The **SI unit** for catalysis is the **katal**.
- This is a derived unit which is **moles per second**.
- When enzymes catalyze a reaction, the preferred unit is the enzyme unit.
- The effectiveness of a catalyst may be expressed using the **Turnover Number (TON)** or **Turnover Frequency (TOF)**, which is TON per unit time.
- Catalysis is a vital process in the chemical industry. It is estimated that 90% of commercially-produced chemicals are synthesized via catalytic process.
- Sometimes the term "catalysis" is used to refer to a reaction in which a substance is consumed (e.g., base-catalyzed ester hydrolysis).
- According to the IUPAC, this is an incorrect usage of the term. In this situation, the substance added to the reaction should be called an activator rather than a catalyst.
  - **E.g. Hydrogen peroxide** normally decomposes slowly into oxygen and water, but in the presence of **platinum (pt)**, the decomposition becomes violent or explosive.
  - Likewise the rate of decomposition of potassium chloride speeds up in the presence of **manganese dioxide**.

$$2H_2O_2 \xrightarrow{Pt} 2H_2O + O_2$$

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

  - Here, **platinum and manganese dioxide are called Catalysts.**

- Thus, **Catalyst** is a substance which increases or decreases the rate of a chemical reaction, without being consumed in the process.
- Furthermore, some substances considerably **enhance the activity of a catalyst**, and are known as ***promoters***. Substances which inhibit catalytic activity are called ***poisons***.

Types of Catalysts

- The two main categories of catalysts are **heterogeneous** catalysts and **homogeneous** catalysts. Enzymes or biocatalysts may be viewed as a separate group or as belonging to one of the two main groups.

(i) Heterogeneous Catalysis: Heterogeneous catalysts are those which exist in a different phase from the reaction being catalyzed. For example, solid catalysts catalyze a reaction in a mixture of liquids or gases are heterogeneous catalysts.

- Surface area is critical to the functioning of this type of catalyst. E.g. formation of ammonia from nitrogen and hydrogen under the catalytic influence of Iron Oxide.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe_2O_3(S)} 2NH_3(g)$$

(ii) Homogeneous Catalysis: In homogeneous catalysis, the catalyst is in the same phase as the reactant (s).

- The number of collisions between reactants and catalyst is at a maximum because the catalyst is uniformly dispersed throughout the reaction mixture.
- Many homogeneous catalysts in industry are transition metal compounds. As an added barrier to their widespread commercial use, many homogeneous catalysts can be used only at relatively low temperatures, and even then they tend to decompose slowly in solution.
- Despite these problems, a number of commercially viable processes have been developed in recent years. **High-density polyethylene** and **polypropylene** are produced by homogeneous catalysis.

9 CHAPTER

Metals, Metallurgy and Non-Metals

You have seen that elements can be classified as metals or non-metals on the basis of their properties. What properties did you think of while categorizing elements as metals or non-metals? How are these properties related to the uses of these elements? Let us look at some of these properties in detail in this chapter.

On the basis of **physical** and **chemical** properties, elements have been broadly classified into **metals** and **non-metals**. **Metals** have generally low ionization energies, low electron affinities and low electronegative values that are responsible for their high electrical and thermal conductivities, high metal ability, ductility and hardness.

- Metals are the elements which form positive ions by losing electrons. Thus, metals are known as **Electropositive Elements**.
- Out of approx. **118 elements** known at present, about **88** of them are **metals**. Sometimes, metals find in nature as **free**, but most of the time in the **combined** state.
- Only those metals, which have little or no affinity from Oxygen, occur in the Free State. Active metals are found in the form of the combined state.
- The **earth's crust is the biggest source of metal**. The minerals from which **metals can be easily extracted** are referred to as **ores**.
- The impurities associated with minerals are collectively known as **gangue** or **matrix**. Hence, all ores are minerals, but all minerals are not ores.

Metals

Physical Properties of Metals

- **Hardness:** Most of the metals are hard, except alkali **metals**, such as **sodium, potassium, lithium,** etc. are very soft metals. These can be cut by using a knife.
- **Strength:** Most of the metals are strong and have high tensile strength. Because of this, big structures are made using metals, such as copper (Cu) and iron (Fe). (Except Sodium (Na) and potassium (K) which are soft metals).
- **State:** Metals are solid at room temperature **except for mercury (Hg).**
- **Sound:** Metals produce ringing sound, so, metals are called **Sonorous. Sound of metals** is also known as Metallic sound. This is the cause that metal wires are used in making musical instruments.
- **Conduction:** Metals are a good conductor of heat and electricity. This is the cause that electric wires are made of metals like copper and aluminium.
- **Malleability:** Metals are malleable. This means metals can be beaten into a thin sheet. Because of this property, iron is used in making big ships.
- **Ductility:** Metals are **ductile**. This means metals can be drawn into **thin wire**. Because of this property, a wire is made of metals.
- **Melting and Boiling Point:** Metals have generally high melting and boiling points. (Except **sodium and potassium metals** which have low melting and boiling point.)
- **Density:** Most of the metals have a high density.
- **Colour:** Most of the metals are grey in colour. But gold and copper are exceptions.

Chemical Properties of Metals

1. **Reaction with Oxygen**: Most of the metals form respective metal oxides when reacting with oxygen.

   Metal + Oxygen → Metal Oxide

   Examples:

   Reaction of Potassium with Oxygen: Potassium metal forms potassium oxide when reacts with oxygen.

4K	+	O_2	→	2K2O
Ptassium		**Oxygen**		**Potassium oxide**

Reaction of Sodium with Oxygen: Sodium metal forms sodium oxie when reacts with oxygen

4Na	+	O_2	→	$2Na_2O$
Sodium		**Oxygen**		**Sodium oxide**

2. **Reaction of Metals with Water:** Metals form respective hydroxide and hydrogen gas when reacting with water.

   Metal + Water → Metal hydroxide + Hydrogen

- Most of the metals do not react with water. However, alkali metals react vigorously with water.
- **Reaction of Sodium Metal with Water:** Sodium metal forms sodium hydroxide and liberates hydrogen gas along with lot of heat when reacting with water.

Na	+	H_2O	→	NaOH	+	H2
Sodium		**Water**		**Sodium oxide**		**Hydrogen**

10 CHAPTER

Electrochemistry

The reactions carried out electrochemically can be energy efficient and less polluting. Therefore, study of electrochemistry is important for creating new technologies that are eco-friendly. In this chapter, we will cover only some of its important elementary aspects.

Electrochemistry is that branch of chemistry which deals with the study of **production of electricity from** energy released during **spontaneous chemical reactions** and the use of electrical energy to bring about non-spontaneous chemical transformations.

- Electrochemistry is concerned with the relation between electrical energy and chemical change.
- Electricity is conducted by metals **without any chemical changes occurring** in the metal. The conduction in metals is due to the **flow of electrons** and hence the **type of conduction** is called electronic conduction.

Conductors

Substances which allow electric current to flow through them are called conductors. Examples - Metals, Aqueous solution of acids, bases and salts, fused salts and impure water etc.

Conductors are of two types:

(i) Metallic conductors

(ii) Electrolytic conductors or electrolytes.

1. **Metallic Conductors:** The conductors which conduct electric current by movement of electrons **without undergoing any chemical change** are known as metallic conductors. Metals **(Cu, Ag, Fe, Al etc.)**, non-metals (graphite) and various alloys and minerals are examples.
2. **Electrolytic Conductors:** Those substances whose water **solution conducts the electric current** and which are decomposed by the passage of current are called electrolytes.
   - In this case, conduction takes place by movement of ions. Electrolytes also conduct electricity in fused state and undergo decomposition by passing the electric current.
   - Substances whose aqueous solution does not conduct electric current are called non-electrolytes.
   - They do not conduct electricity in the fused state also. Solutions of cane **sugar, glycerin, glucose, urea** etc. are the examples of non-electrolytes.
   - **Strong Electrolyte:** Electrolytes which are **completely ionized in aqueous solution** or in their molten state, are called strong electrolytes. Example: **all salts, strong acid and strong base**
   - **Weak Electrolyte:** Electrolytes which are not completely ionized in aqueous solution or in their molten state, are called weak electrolytes. Examples: All carbonic acids (except sulphonic acid), CH_3COOH, HCN, NH_3, amine, etc.

Ohm's Law

- The current (I) carried by a conductor (or electrolytic solution) is directly **proportional** to the potential difference (V) between the two ends of conductor.

  $V \propto I \Rightarrow V = RI$

Resistance (R)

- The constant of proportionality in Ohm's law is called **resistance** offered by conductor. Its SI unit is Ω (ohm) or (volt/ampere).

$$R = \frac{V}{T}$$

- **Resistance** of a conductor is directly proportional to its length (l) and inversely proportional to its area of cross-section (A)

$$R \propto \frac{l}{a} \Rightarrow R = P\frac{l}{A}$$

- where, ρ = specific resistance or resistivity.

Specific Resistance (Resistivity) (ρ)

- Resistance offered by a conductor of unit length and unit cross-sectional area is called **specific resistance**.

$$\rho = R\frac{A}{l} = \frac{R \times 1}{1} = R$$

Conductance (G)

- It is the property of conductor (metallic as well as electrolytic) which facilitates the flow of electricity through it. It is equal to reciprocal of resistance. Its SI unit is Ohm^{-1} (Ω^{-1}) or mho.

$$G = \frac{1}{R}$$

11 CHAPTER

Soil Chemistry

Soils are heterogeneous mixtures of air, water, inorganic and organic solids, and microorganisms. Soil chemistry deals with the chemical composition, chemical properties, and chemical reactions of soils.

Soil

Soil is the loose surface material that covers most land. It consists of **inorganic particles and organic matter**. Soil provides the structural support to plants used in agriculture and is also their source of water and nutrients.

- Soils vary greatly in their chemical and physical properties.
- Processes such as leaching, weathering and microbial activity combine to make a whole range of different soil types.
- Each type has particular strengths and weaknesses for agricultural production.
- Soils are heterogeneous mixtures of air, water, inorganic and organic solids, and microorganisms (both plant and animal in nature). No two soils are exactly alike.
- The organic matter is often firmly combined with mineral particles forming aggregates.
- Soil reactions and processes occur over a wide range of spatial and temporal scales.

Physical Characteristics of Soil

- The physical characteristics of soils include all the aspects that you can see and touch such as:
  - texture
  - colour
  - depth
  - structure
  - porosity (the space between the particles)
  - stone content.

Soil Chemistry

Soil chemistry is a branch of soil science that deals with the chemical composition, chemical reactions and chemical properties in soils.

- Abiotic phases of the soil include solids (organic matter and inorganic minerals), liquids (soil water), and gases (soil air), while the biotic phase consists of living organisms.
  - Soil, therefore, is a **dynamic living system** in which ions and molecules constantly may move from one phase to the other, while interacting with each other.
- Soil chemical properties are based on the concentrations, and/or proportions of dissolved species in soil water and/or on the ion exchange complex.
- Soil chemical properties such as **cation exchange capacity (CEC)**, pH, redox potential (Eh or pe), and electrical conductivity (EC) are important as they **influence nutrient availability, plant growth, fate of pollutants, biological activity,** etc.
  - For example, CEC is a measure of the amount of **negative charge capable of adsorbing cations on mineral** or organic surfaces, usually expressed in centimoles of charge [cmol(+)] per kg of soil.
  - Soil pH is a measurement of the concentration of H^+ in the soil solution, while the Eh (or pe) is related to concentrations of oxidized/reduced species of **redox-sensitive elements** such as iron (Fe^{3+}/Fe^{2+}).
  - **Electrical conductivity (EC)** is another important soil property that provides an indication of the abundance of soluble salts in a soil.
- Most of the important chemical properties of soils are controlled by reactions that occur between the soil solution and surfaces of colloidal (particles <0.002 mm diameter) soil mineral particles and soil organic matter.

Soil Solution

- Soil water, including dissolved solutes, is referred to as the soil solution and is the lifeblood of soil.
- All chemical reactions, mineral precipitation/dissolution reactions, ion exchange reactions, redox reactions, and nutrient up take by plants occur in, or are mediated by the soil solution.
- Without soil water, very few chemical or biological reactions would occur in soil; in fact, there would be no life on this planet.
- The soil solution is very complex and contains a large variety of cations and anions (as both as free ions and complex ions) as well as dissolved organic molecules, usually in low concentrations.

12
CHAPTER

Food Chemistry

Chemistry is a branch of science that involves studying chemicals that make up a product. Food chemistry involves studying the chemicals that are inside food, how they contribute to our nutrition, and how different foods can be combined or changed to make new foods.

Food is essential to sustain life. Its main function is to supply energy required by the body, and for tissue building, body growth and in the regeneration of cells.

- There are three major components in food, namely, carbohydrates, fats (oils) and proteins.
- Food chemistry is the study of chemical processes and interactions of all biological and non-biological components of foods.
- The biological substances include such items as meat, poultry, lettuce, and milk as examples.
- It covers the basic composition, structure and properties of foods and the chemistry changes occurring during processing and utilization.

Brief History of Food Chemistry

- The history of food chemistry dates back to the late 1700s, when many famous chemists were involved in discovering chemicals important in foods.
- In 1785, for example, **Carl Wilhelm Scheele** isolated malic acid from apples.
- In 1813, **Sir Humphry Davy** published the first book on agricultural and food chemistry, titled **Elements of Agricultural Chemistry**, in a Course of Lectures for the Board of Agriculture, in the United Kingdom.
- In 1874, the **Society of Public Analysts** was formed, with the aim of applying analytical methods to benefit the public. Its early experiments were based on bread, milk, and wine.
- It was also out of concern for the quality of the food supply, mainly food adulteration and contamination issues stemming first from intentional contamination and proceeding later to chemical food additives by the 1950s.

Components of Food

Water

- A major component of food is water, which can range in content from 50 percent in meat products to 95 percent in lettuce, cabbage, and tomato products.
- It also provides a place for bacterial growth and food spoilage if it is not properly processed.
- One way of measuring this in food is by water activity, which is very important in the shelf life of many foods during processing.
- One of the keys to food preservation is to reduce the amount of water or alter the water's characteristics to enhance shelf-life. Such methods include dehydration, freezing, and refrigeration.

Water Content Range for Selected Foods

Percentage	Food Item
100%	Water
90–99%	Fat-free milk, cantaloupe, strawberries, watermelon, lettuce, cabbage, celery, spinach, pickles, squash (cooked)
80–89%	Fruit juice, yogurt, apples, grapes, oranges, carrots, broccoli (cooked), pears, pineapple
70–79%	Bananas, avocados, cottage cheese, ricotta cheese, potato (baked), corn (cooked), shrimp
60–69%	Pasta, legumes, salmon, ice cream, chicken breast
50–59%	Ground beef, hot dogs, feta cheese, tenderloin steak (cooked)
40–49%	Pizza
30–39%	Cheddar cheese, bagels, bread
20–29%	Pepperoni sausage, cake, biscuits
10–19%	Butter, margarine, raisins
1–9%	Walnuts, peanuts (dry roasted), chocolate chip cookies, crackers, cereals, pretzels, taco shells, peanut butter
0%	Oils, sugars

Carbohydrates

- Carbohydrates form the largest group of substances in food consumed by humans. A common carbohydrate is starch.
- The simplest version of a carbohydrate is a **monosaccharide**, made up of molecules in which carbon, hydrogen, and oxygen atoms are in the ratio 1:2:1.

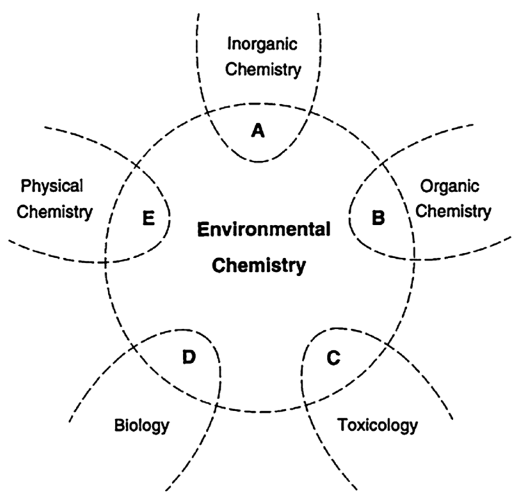
13
CHAPTER

Environmental Chemistry

In this chapter the focus will be on environmental chemistry which involves the study of the effects that chemicals have on the air, water and soil and how they impact the environment and human health.

Life evolved on the earth from millions and millions of year. Now the environment is quite different and polluted from earlier period. The environment has been harmed through the activities such as burning of wood, smelting of ores, tanning of leather, primitive methods of sewage disposal and so on.

- **Environmental chemistry** had an early beginning with **Antoine Lavoisier**, a French scientist born in Paris in **1743**.
- Lavoisier combined classical experiments on the composition of air and its use by animals to investigate the chemical nature of the atmosphere.
- Environmental chemistry is the study of sources, reactions, transport, and fate of chemical entities in the air, water, and soil environments, as well as their effects on human health and the natural environment.
- It contains aspects of related branches of chemistry, such as **Organic chemistry, Analytical chemistry, Physical chemistry, and Inorganic chemistry**, as well as more diverse areas, such as biology, Toxicology, Biochemistry, Public health, and Epidemiology.



- The primitive Earth's atmosphere contained simple gases that, on equilibration, followed by subsequent complex reaction sequences, have led to the formation of proteins, carbohydrates, fats, and other substances that are the basic molecules needed for life to develop.

Topics of Environmental Chemistry

Aspect of the Environment	Area within or relevant to Environmental Chemistry
Evolution	Chemical evolution
Chemical processes in sectors of the abiotic natural environment	Oceanic, Atmospheric, Soil and Limnological chemistry and Global chemical systems
Chemical influences in natural ecosystems	Chemical ecology, pheromones, allelochemist
Behaviour of hazardous chemicals in the environment	Mathematical modeling of environmental distribution, degradation processes, waste disposal
Effects of toxic chemicals on individuals, populations and ecosysstems	Environmental toxicology, Ecotoxicology, Quantitative Structure-Activity Relationships (QSARs), environmental analysis
Effects of chemicals on human populations	Environmental Health, Safety, Occupational, health, Epidemiolgy

- The environmental chemistry of a chemical can be seen as an interrelated set of characteristics –

CHARACTERISTICS OF THE MOLECULE
(eg. Surface area, Molecular weight, Functional groups and Chemical bonds etc.)
↓
PHYSICAL CHEMICAL PROPERTIES OF THE COMPOUND
(eg. Aqueous solubility, Vapour pressure, Melting point and Octanol/water partition coefficient etc.)
↓
TRANSFORMATION & DISTRIBUTION IN THE ENVIRONMENT
(eg. Persistence and Bioaccumulation etc.)
↓
BIOLOGICAL EFFECTS
(eg. Lethal toxicity, Reduction in growth, Reduction in reproduction etc.)

Components of Environment

Different organisms live in different types of surroundings such as air, water and soil. Different kinds of living organisms share these surroundings. The surroundings are the "environment" of an organism.

UNIT - III

BIOLOGY

- Introduction to Biology
- Cell Biology
- Genetics
- Evolution
- Diversity in the Living World
- Plant Kingdom
- Morphology of Flowering Plants
- Anatomy of Flowering Plants
- Plant Physiology
- Reproduction in Plants
- Animal Kingdom
- Skeletal System
- Animal Tissue
- Digestive System
- Sensory Organs
- Nervous System
- Endocrine System
- Immune System
- Circulatory System
- Respiratory System
- Excretory System
- Reproductive System
- Health and Nutrition
- Disease and Diagnosis
- Biotechnology
- Microbiology

1
CHAPTER

Introduction to Biology

Biology is the study of life in its entirety. The word 'biology' is derived from the Greek word 'bios' meaning life and 'logos' meaning study. Biology can also be described as the study of living organisms, divided into many specialized fields that cover their morphology, physiology, anatomy, behaviour, origin, and distribution.

Biology is the science of life and living organisms. It is a stream of natural science that uses scientific principles to study the living world. Today, the knowledge of biology is used in the study of **agriculture, medicine, sericulture, pisciculture, selective breeding of animals, etc.**

- Biology, as a branch of human knowledge started with observations made by the ancient Greek Philosopher **Aristotle** (384-322 BC). Thus, he is known as the "**Father of Biology"**.
- **Andreas Vesalius (1514-1564)**, often referred to as the founder of **modern human anatomy**, was the first to challenge the teachings of Aristotle.
- The term 'Biology' was, however, first used by the French naturalist **Jean Lamarck and Gottfried Reinhold Treviranus in 1800**.

Classification of Biology

Classification of biology refers to the process of grouping organisms according to certain similarities. **Carl Linnaeus** proposed the two kingdoms of classification; He called organisms in the animal kingdom as **Animalia** and in the plant kingdom as **Plantae.** Thus biology is broadly classified into:

(a) Botany (b) Zoology

- **Botany:** It is the branch of Biology, which deals with the study of plant life including their structure, properties and biochemical processes. It also includes plant classification, study of plant diseases, their genetics and breeding.
- Botany also helps us to understand basic ecology of plants that is relationship between plant and its environment.
- The principles and findings of botany have provided the base for such applied sciences **as agriculture, horticulture, and forestry.**
  - **Theophrastus** is known as the **Father of Botany**.
  - So far, scientists have discovered more than 3, 40,000 species of plants.
- **Zoology:** It is the branch of Biology, which deals with the study of animal kingdom including the structure, **Embryology, Evolution, Classification, Habitats,** and Distribution of all animals, both living and extinct.
- It is an interdisciplinary field, drawing on knowledge from Genetics, Biochemistry, Ecology and Physiology. Zoologists observe animals in their natural habitat and also classify them. Classification is based on their similarities and differences.
  - **Aristotle is known as the Father of Zoology.**
  - Out of all the known species (approximately 1.5 million) till now more then 95% are boneless and remaining **5% are animals with bone**. Animals could be **unicellular** like amoeba, paramecium, etc. or **multi-cellular** like Birds, Fishes, Snake, Rabbit, Human beings, etc.
  - In addition, animals exist in a great variety of forms, shapes and sizes. **For example**: The Blue Whale is the largest living animal of the world as it's over 30.5 meters long and 150 tons heavy whereas the smallest animal is not more than 0.001 mm in length on the scale of microscope.

Nature and Scope of Biology

- Biology creates an awareness of vast array of forms of life which normally goes unseen. Biology offers a large scope and provides a large field for study. Some of the most familiar aspects where biology helps us in various ways are:-
- **Helps us to Understand Ourselves Better:** It unfolds different queries of life along with its cultural, social, philosophical and economical aspect.
- **Biology and Inter-relationship of Living Beings:** Study of biology helps us in understanding the wonderful phenomenon and laws of nature which finally tell us to predict the behaviour of different living beings under changed conditions.
- **Biology and Resources:** Biology helps us to know how to tap and conserve the resources available to us e.g. fishes, birds, forests etc.
- **Study of Nature is a Rewarding Experience:** Many plants like Narcissus, Dahlia, Gloriosa, Roses, Marigold, Aster, etc. are used for ornamental purposes.

2 CHAPTER

Cell Biology

Cells are considered as the basic building blocks of all the organisms. All our tissues and organs are made up of billions of different types of cells such as blood cells, muscle cells, skin cells or nerve cells etc. Studying the basic structure of the cell and its different components has played a magnificent role in understanding plant and human anatomy.

Cell is the basic structural and functional unit of living organisms. All living organisms on the Earth are composed of cells and they are often called the **"building blocks of life"**. Each cell has a specific function but works in tandem with other types of cells to perform the enormous number of tasks needed to sustain life. Most body cells have similar basic structure.

- **Size:** Cell size depends shape and size of living organism. Such as Mycoplasma is smallest cell (size 0.34um) while bacteria could be 3 to 5 um. The Largest cell is egg of on ostrich and narve cell are some of the longest cells.
- **Shape:** Shape of a cell varies according to the role or function, cells have to perform as part of tissue or organ system. They may be **spherical, oval, rectangular, polygonal, spindle-shaped, rod-shaped or star shaped.**
- **Anton Von Leeuwenhoek** first saw and described a live cell. **Robert Brown** later discovered the nucleus.

Cell Theory

In 1838 **M.J. Schleiden** and **Theodore Schwann** formulated the "cell theory." Later in 1855 , **Rudolf Virchow** explained that cells are divided and new cells are formed from pre-existing cells and thus with few modifications he gave cell theory final shape.

- Cell theory is a widely accepted hypothesis of **how life operates** on the Earth. Understanding how cells form, grow, and die enables us to comprehend how all living beings function.
- With this knowledge, we may better understand how life first emerges, why organisms adopt particular forms, how cancer spreads, how to treat various diseases, and more.
- Cell theory has **three basic principles** as:
    - All living organisms are composed of cells and product of cells.
    - A cell is the basic structural and functional unit of living organisms.
    - All cells arise from pre-existing cells.
- This theory is one of the foundation stones of modern biology. However, viruses, fungi, etc. are exceptions to the rule that the cell is the basic unit of life.

Characteristics of Cell

- Cells help in building the structure of an organism.
- Inside each cell is a dense membrane bound structure called **nucleus**. This nucleus contains the chromosomes which in turn contain the **genetic material, RNA and DNA**. Cells that have membrane bound nuclei are called **eukaryotic** whereas cells that lack a membrane bound nucleus are **prokaryotic**
- In both prokaryotic and eukaryotic cells, a semi-fluid matrix called **cytoplasm** occupies the volume of the cell. The cytoplasm is the main arena of cellular activities in both the plant and animal cells.
- Besides the nucleus, the eukaryotic cells have other membrane bound distinct structures called organelles like the **Endoplasmic reticulum (ER), Golgi complex, Lysosomes, Mitochondria, Microbodies and Vacuoles**. The prokaryotic cells lack such membrane bound organelles.
- **Ribosomes** are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – **chloroplasts (in plants) and mitochondria and on rough ER.**
- Animal cells contain another non-membrane bound organelle called **centrosome** which helps in cell division.
- **Lysosomes** is a type of cell organelle which helps in cellular digestion.

Cell Structure

The cell structure includes individual parts with explicit capabilities fundamental for complete life's cycles. These parts incorporate the **Cell Membrane, Cell Wall, Protoplasm, Cytoplasm, Nucleus Core, and Cell Organelles.**

Cell Membrane

- The cell membrane, also called the plasma membrane, is found in all cells and separates the interior of the cell from the outside environment. The cell membrane consists of a **lipid bilayer** that is **semipermeable**. The cell membrane regulates the transport of materials entering and exiting the cell.

3 CHAPTER

Genetics

Genetics can be stated as the exploration of the working and major codes of variation and heredity. The groundwork on which heredity stands is known as inheritance. It is defined as the procedure by which characteristics are handed down from one generation to the other. In this chapter, we will study the important concepts related to genetics.

Genetics is the scientific study of genes and heredity; of **how certain qualities or traits are passed** from parents to offspring as a result of changes in DNA sequence. Gene is the basic physical and functional unit of heredity. These are made up of DNA. Some genes act as instruction of proteins for mation some gene do not code for protein.

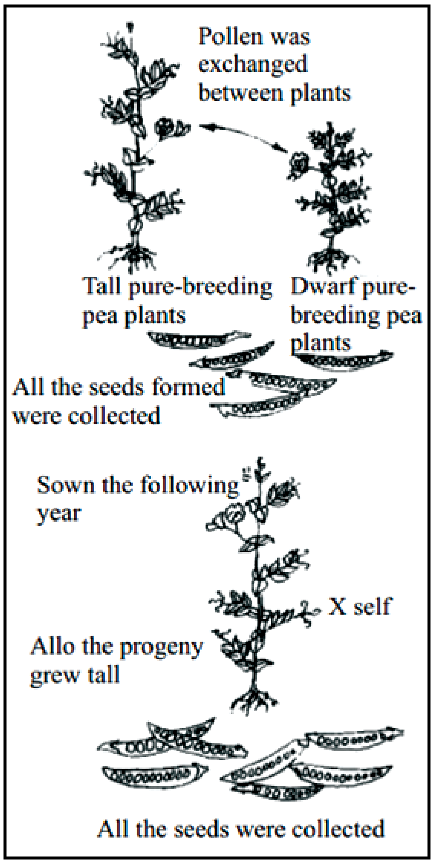
- In humans genes very in size from a few hundred DNA bases to more than 2 million basis. DNA is shaped like a corkscrew-twisted ladder, called a **double helix**.
- The two ladder rails are called backbones, and the rungs are pairs of four building blocks **(adenine, thymine, guanine, and cytosine)** called bases. The sequences of these bases provide the instructions for building molecules, most of which are proteins. Researchers estimate that humans have about **20,000 genes**.
- All of an organism's genetic material, including its genes and other elements that control the activity of those genes, is its genome.
- An organism's entire genome is found in nearly all of its cells. In human, plant, and animal cells, the genome is housed in a structure called the nucleus.
- The human genome is mostly the same in all people with just small variations.
- **Gregor Mendel** in 1866 in a journal "**Proceedings of Brunn Society for Natural History**" highlighted the theory of genetics. However, the term genetics was first coined by **Bateson in 1906.**
- **William Bateson**, who applied Mendel law on animals, is regarded as **Father of Animal Genetics**.
- **Gregor Johann Mendel is the Father of Genetics.**
- The process of transmission of characters from parents to offspring (progeny) is called **heredity**. The characters so transmitted are called **hereditary characters**.
- Due to these hereditary characters we resemble our parents and this consistency is maintained generation after generation.
- Besides the similarities, some differences are expressed by members of a species and also by the offspring of the some parents these differences are known as variation.

Thus, Genetics = Heredity + Variation.

Mendel's Experiments and Heredity

Gregor Johann Mendel was a German-speaking Moravian scientist and Augustinian friar who gained posthumous fame as the **Founder of the Modern Science of Genetics**.

- Though farmers had known for centuries that crossbreeding of animals and plants could favor certain desirable traits.
- Mendel's experiments established many of the rules of heredity, now referred to as the **laws of Mendelian inheritance.**



Prelude to Mendel's Experiments and Heredity: Genetics is the study of heredity.

- Johann Gregor Mendel set the framework for genetics long before chromosomes or genes had been identified, at a time when meiosis was not well understood.
- Mendel selected a simple biological system and conducted methodical, quantitative analyses using large sample sizes. Because of Mendel's work, the fundamental principles of heredity were revealed.

4

CHAPTER

Evolution

To understand the changes in flora and fauna that have occurred over millions of years on earth, we must have an understanding of the context of origin of life, i.e., evolution of earth, of stars and indeed of the universe itself. In this chapter, we will study the origin of life and evolution of life forms or biodiversity on planet earth in the context of evolution of earth and against the background of evolution of universe itself.

The origin of life is considered a unique event in the history of universe. The universe is vast. Relatively speaking the earth itself is almost only a speck. The universe is very old – almost **20 billion years old**. Huge clusters of galaxies comprise the universe. Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck.

- **The Big Bang theory** attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms.
- The universe expanded and hence, the temperature came down. Hydrogen and Helium formed sometimes later. The gases condensed under gravitation and formed the galaxies of the present day universe.
- In the solar system of the **Milky Way Galaxy**, earth was supposed to have been formed about **4.5 billion years** back. There was **no atmosphere on early earth**. Water vapor, methane, carbon dioxide and ammonia released from molten mass covered the surface.
- The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H2 escaped. Oxygen combined with ammonia and methane to form water, CO2 and others.
- The ozone layer was formed. As it cooled, the water vapor fell as rain, to fill all the depressions and form oceans. Life appeared 500 million years after the formation of earth, i.e., almost four billion years back

Theories of Origin of Life

The Earth formed roughly **4.5 billion years ago** and life probably began between **3.5 to 3.9 billion years** ago. There have been different theories of origin of life given at different points of time:

- **Theory of Special Creation:** Based upon religious mythologies of evolution given by **Father Saurez**, this theory states that all living organisms were created by God and first man called Adam was created by God.
- **Theory of Spontaneous Creation:** Propounded by **Aristotle and Epicurus**, this theory said that living things originated spontaneously from inanimate objects.
    - (a) In 1652, **Von Helmont** further added that "Mice could be produced from wheat grains when put in dark room with moist cloth."
    - (b) He further said that insects arose from dew and fly maggots evolved from meat. It is also called **abiogenesis or biopoiesis**.
- **Theory of Biogenesis:** Living things come from other living things through sexual or asexual reproduction. This theory was given by **Francisco Redi** and **Louis Pasteur**. They both demonstrated that life cannot be spontaneously created as given by Theory of Spontaneous creation
- **Cosmozoic Origin Theory:** According to this theory, life has reached on Earth from other heavenly bodies such as **meteorites, other planets or stars** in the form of **spores** which grew and evolved into different organisms. This theory too clearly lacks the scientific evidence.
- **Biological Origin Theory:** According to this theory, origin of life on earth is the result of a slow and gradual process of chemical evolution that probably occurred about 3.8 billion years ago. Propounded by **A.I. Oparin** and **J.B.S Haldane**, this theory is described in following **three stages**:
    - **(a)** **Chemogeny:** When temperature of earth crust became less than 10,000°C, the simple molecules like NH_3, CH_4, H_2O etc. combined to form saturated and unsaturated hydrocarbons that further combined to form **bio-molecules** such as Glucose, Amino acids, DNA, RNA, Starch, Cellulose, Carbohydrates etc.
    - **(b)** **Biogeny:** This theory refers to formation of life or self reproducing biological units. In this, bio-molecules aggregate in various combinations to form large colloidal particles called **coacervates** and these coacervates binding by limiting membrane helped in evolving bacteria and amoeba.

5 CHAPTER

Diversity in the Living World

If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. Each different kind of plant, animal or organism that you see, represents a species. The number of species that are known and described ranges between 1.7-1.8 million. This refers to biodiversity or the number and types of organisms present on earth.

There are millions of plants and animals in the world; we know the plants and animals in our own area by their local names. These local names would vary from place to place, even within a country. Probably you would recognize the confusion that would be created if we did not find ways and means to talk to each other, to refer to organisms we are talking about. Hence, there is a need to standardize the naming of living organisms such that a particular organism is known by the same name all over the world.

- This process is called **nomenclature**. Obviously, nomenclature or naming is only possible when the organism is described correctly and we know to what organism the name is attached to. This is **identification.**
- Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components – the **Generic name and the specific epithet**.
- This system of providing a name with two components is called **Binomial Nomenclature**.
- **For Example** The scientific name of mango is written as **Mangifera Indica**. In this name Mangifera represents the **genus** while indica, is a particular **species**, or a specific epithet.
- This naming system given by **Carolus Linnaeus** is being practiced by biologists all over the world.
- This naming system using a two word format was found convenient. Name of the author appears after the specific epithet. I.e., at the end ofthe biological name and is written in an abbreviated form, e.g. **Mangifera Indica Linn**. It indicates that this species was first described by Linnaeus.

Taxonomy

Since it is nearly impossible to study all the living organisms, it is necessary to devise some means to make this possible. This process is **classification.**

- Classification is the process by which anything is **grouped into convenient categories based on some easily observable characters**. For example, we easily recognize groups such as plants or animals or dogs, cats or insects.
- The moment we use any of these terms, we associate certain characters with the organism in that group. The scientific term for these categories is **taxa**.
- Hence Taxonomy is the science of naming, describing and classifying organisms and includes all plants, animals and microorganisms of the world.
- Using morphological, behavioural, genetic and biochemical observations, taxonomists identify, describe and arrange species into classifications, including those that are new to science.
- Organisms classification when takes place in the form of a taxonomic system is often referred to as Linnean Classification.

Importance of Taxonomy

- Global biodiversity is being lost at an unprecedented rate as a result of human activities, and decisions must be taken now to combat this trend.
- Taxonomy provides basic understanding about the **components of biodiversity** which is necessary for effective decision-making about conservation and sustainable use.
- It also helps in deciding where to establish the protected areas based on what needs to be protected.
- It helps to differentiate invasive alien species (IAS) from native species, followed by finding methods to protect from the threats emanating from these species.
- It makes possible to execute the international efforts such as Convention on Biodiversity (CBD) , protection of endangered species etc.

Taxonomic Categories

- Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category.

6 CHAPTER

Plant Kingdom

Plant kingdom is one of the five kingdoms of broad classification done by Whittaker (1969) of all living organisms. It includes everything about all the plants we see around us. In this chapter, we will deal in detail with further classification within Kingdom Plantae popularly known as the 'plant kingdom'.

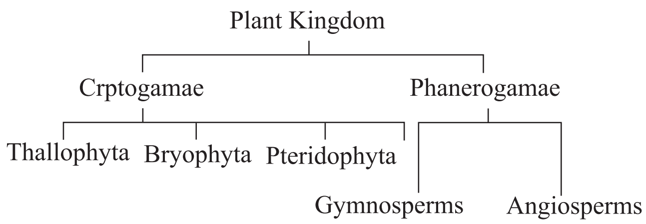
All plants that exist on the Earth come under the category of Plant Kingdom. Kingdom Plantae is a group that includes **autotrophic, multicellular, photosynthetic eukaryotes**. There are more than 3,000,000 species of plants.

- These are mainly **immobile, embryo forming organisms** which exist as only producers in the entire ecosystem because they can fix solar energy into chemical energy with the help of photosynthesis.
- We have studied in previous chapters that plant cell have rigid cell wall which is made up of cellulose.
- Plants play a key role in the history of life on planet earth. Plants are the main responsible sources for the addition of oxygen gas to the atmosphere.
- They are the only source of food for both animals and humans. They are the primary habitat for millions of other organisms.
- We must stress here that our understanding of the plant kingdom has changed over time.
- Fungi, and members of the Monera and Protista having cell walls have now been excluded from Plantae though earlier classifications placed them in the same kingdom.
- So, **the cyanobacteria that are also referred to as blue green algae are not 'algae' any more.**

Classification of Plants

Kingdom Plantae is classified into different groups and sub-groups based on different categories and hence the level of classification is grounded on the following three criteria:

1. **Plant Body:** Whether the body has well-differentiated body that is differentiated root, stems and leaves.
2. **Vascular System:** Whether the plant has a vascular system or not. The vascular system is comprised of two main types of tissue: the xylem and the phloem.
    - The xylem distributes water and dissolved minerals upward through the plant, from the roots to the leaves. The phloem carries food downward from the leaves to the roots.
3. **Seed Development:** Whether the plant allows flowers and seeds or not; if it does, then whether the seeds are naked or enclosed in a fruit.
    - Considering all these features, the plant kingdom has been divided into two sub-kingdoms called **Cryptogamae** and **Phanerogamae**.
    - While Cryptogamae further gets divided into Thallophyta, Bryophyta and Pteridophyta, Phanerogamae gets divided into **Gymnosperms** and Angiosperms.



Cryptogamae

Cryptogams consist of seedless and non-vascular plants whose body is not well differentiated into root, stem and leaves.

- These do not have flowers and fruits as well and thus are less evolved. They can reproduce by spores.
- Cryptogams can be divided into **Thallophyta, Bryophyta and Pteridophyta.**

Thallophyta

The plants present in this group are simple and their body is not differentiated into roots, stems and leaves. Hence this plant body is called thallus. **'Thallos' in Greek means undifferentiated and 'phyton' means plant**.

- The plant body lacks a vascular system here and hence the transportation of materials occurs by diffusion. Common examples under division Thallophyta include **algae, fungi, and lichens.**

The Algae

- They are a very large and diverse group of eukaryotic organisms, ranging from **unicellular genera** like Chlorella to multicellular like the giant kelp. **The study of algae is called Phycology.**

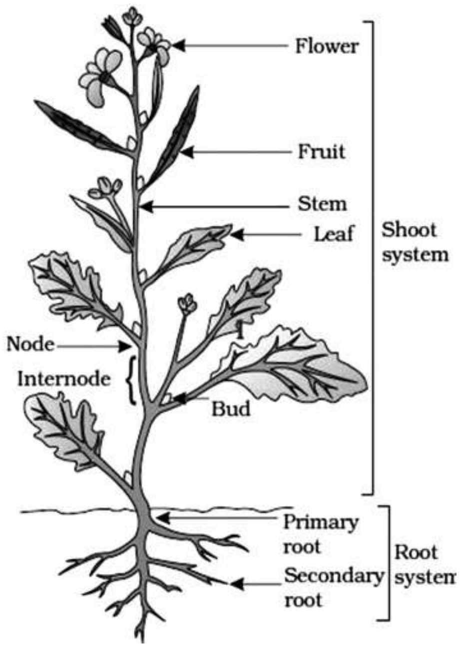
7
CHAPTER

Morphology of Flowering Plants

The wide range in the structure of higher plants will never fail to fascinate us. Even though the angiosperms show such a large diversity in external structure or morphology, they are all characterized by presence of roots, stems, leaves, flowers and fruits. In this chapter we will deal with the morphology of flowering plants.

Plant morphology or **phytomorphology** is the study of the physical form and external structure of plants, whereas **plant anatomy** is the study of the internal plant structure, mostly at the cellular/microscopic level.

- When we look into morphology of flowering plants, a plant system has two systems; **shoot system and root system**. Root system grows towards earth to get water, food and hold the plant. Whereas shoot system grows above the ground and includes leaves, buds, flowers and fruit of the plant.
- For any successful attempt at understanding any higher plants we need to know about the possible variations in different parts, found as adaptations of the plants to their environment, e.g., adaptions to various habitats, for protection, climbing, storage, etc.



Basic Structure of a Plant

The Root

Root lies on the descending portion of the plant anatomy. They are present below the ground. In addition to the normal work of plant fixation, absorption of water and minerals, root performs some special functions for which they get variously modified.

General Characteristic of Roots

- Roots have **geotropism property** i.e. grow in the direction of gravity while shoots have phototropism property (direction growth in response to light).
- Roots do not have chlorophyll pigments, and hence they are non-green and cannot perform photosynthesis.
- Roots do not have nodes and internodes. The lateral branches of the roots are endogenous in origin i.e. they arise from the inner tissue called **pericycle of the primary root**.
- **Depth:** The distribution, size, depth and strength of roots depend on plant form, the spatial and temporal availability of water and nutrients as well as the physical properties of the soil.
- The deepest roots are generally found in deserts and temperate coniferous forests while the shallowest are available in tundra, boreal forest and temperate grasslands. Some roots can grow as deep as the tree is high.

Structure of Roots

Roots include the following regions from the apex upwards:

- **Root Cap:** It is a cap like structure that covers the apex of the root. The main function of the root cap is to protect the root apex and to penetrate the soil. It consists of dead cells. Sometimes, the root caps are said to sense sunlight and gravity as they **go in the direction of gravity and away from light.**
- **Meristematic Zone or Zone of Cell Division:** This is the growing tip of the root. It exists under and behind the root cap. The cells of this region are actively dividing and continuously increase in number.
- **Region of Elongation:** It is a region that lies just above the meristematic zone. The cells of this zone increase in size. This zone helps in the growth in length of the plant root.
- **Region of Cell Differentiation (Cell maturation):** This zone lies above the zone of elongation and in this zone the cells differentiate into different types. They form the tissues like the epidermis, cortex and vascular bundles.

8 CHAPTER Anatomy of Flowering Plants

This chapter introduces you to the internal structure and functional organization of higher plants. The study of internal structure of plants is known as anatomy. Plants have cells as the basic unit, cells are organized into tissues and in turn the tissues are organized into organs. Different organs in a plant show differences in their internal structures. Internal structures also show adaptations to diverse environments.

Anatomy is the branch of biology that deals with the identification and description of the internal structures of living things. Plant anatomy is the study of the **tissue and cell structure of plant organs**. The term anatomy, as applied to plants, generally deals with structures that are observed under a high-powered light microscope or electron microscope.

The Tissue System

Tissues vary depending on their location in the plant body. Their structure and function would also be dependent on location. On the basis of their structure and location, there are three types of tissue systems.

- These are the epidermal tissue system, the ground or fundamental tissue system and the vascular or conducting tissue system.

Epidermal Tissue System: The epidermal tissue system forms the outer-most covering of the whole plant body and comprises **epidermal cells, stomata and the epidermal appendages** – the trichomes and hairs.

- The epidermis is the outermost layer of the primary plant body and is usually **single layered**. Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole.
- The outside of the epidermis is often covered with a waxy thick layer called the **cuticle** which prevents the loss of water. Cuticle is absent in roots.
- **Stomata** are structures present in the epidermis of leaves. Stomata regulate the process of transpiration and gaseous exchange.
- The cells of epidermis bear a number of hairs. The root hairs are unicellular elongations of the epidermal cells and help absorb water and minerals from the soil.

The Ground Tissue System

- All tissues except epidermis and vascular bundles constitute the ground tissue. It consists of simple tissues such as parenchyma, collenchyma and sclerenchyma.
- Parenchymatous cells are usually present in cortex, pericycle, pith and medullary rays, in the primary stems and roots.
- In leaves, the ground tissue consists of thin-walled chloroplast containing cells and is called mesophyll.

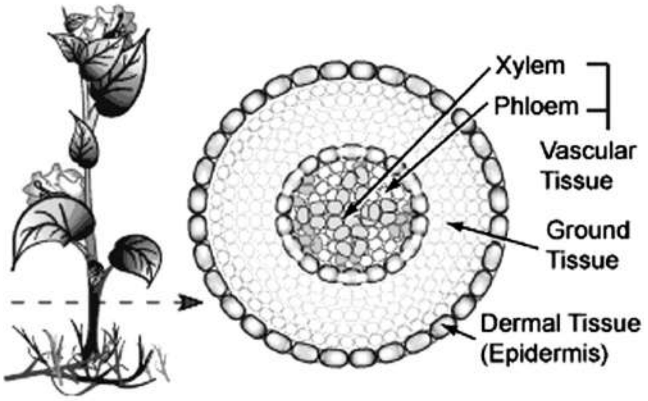
The Vascular Tissue System

- The vascular system consists of complex tissues, the phloem and the xylem. The Xylem and Phloem together constitutes vascular bundles.
- The xylem distributes water and dissolved minerals upward through the plant, from the roots to the leaves. The phloem carries food downward from the leaves to the roots.

Types of Vascular Bundles

Vascular bundles are divided into following types on the basis of location of xylem and phloem.

- **Radial vascular bundle:** Here xylem and phloem tissues occur at alternate radial locations in different groups.
- **Conjoint vascular bundle:** In conjoint type of vascular bundles, the xylem and phloem are jointly situated along the same radius of vascular bundles. It is found in stems and leaves.



Tissue System

Anatomy of Dicotyledonous and Monocotyledonous Plants

Flowering plants are actually classified into two categories based on their embryo called dicotyledonous and monocotyledonous plants.

9
CHAPTER

Plant Physiology

Description of physiological processes in flowering plants is given in this chapter. The processes of photosynthesis, respiration and ultimately plant growth and development are described in molecular terms but in the context of cellular activities and even at organism level.

Physiology is the science of life. It is the branch of biology that aims to understand the mechanisms of living things, from the basis of cell function at the ionic and molecular level to the integrated behaviour of the whole body and the influence of the external environment.

- Plant physiology is the study of processes such as photosynthesis, plant nutrition, respiration, function of plant hormones, tropism, pollination, photoperiodism, photomorphogenesis, circadian rhythms, environmental stress, seed germination, transpiration and plant water relations.
- Plant physiology focuses on the chemistry and physics of how plants function. Plants capture light energy and produce sugars through **photosynthesis** and break down these sugars through aerobic cellular **respiration**.
- Plants rely on soils for mineral nutrients and water, and biogeochemical cycles replenish soils with these nutrients. Once water and minerals are absorbed, they must be transported through the **xylem**.
- **Phloem** is another plant vascular tissue that conduction food and minerals made in the leaves during photosynthesis to all parts of plants.

Mode of Nutrition in Plants

Plants are the only organisms that can prepare food for themselves by using water, carbon dioxide and minerals. The raw materials are present in their surroundings. 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.

- The living organism which are capable to make-their own food called Autotraphic suchas plant and which are depend plants and other animal for food, called Heterotrophic organism such as human.
- 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).

Autotrophic Nutrition

- The process by which an autotrophic organism utilizes inorganic substances from the environment and produces organic compounds that are further used to produce energy and perform various cellular processes is called autotrophic nutrition.

Type of Autotrophic Nutrition

- **Photosynthesis:** It is a process used by plants to convert light energy of the Sun into chemical energy that can be later released to fuel the organisms' activities.
    - In other words, photosynthesis is the synthesis of food by all green plants with the help of carbon dioxide and water in the presence of sunlight.
    - In this procedure, chlorophyll present in green plants builds up sugar molecules from CO_2 and water, converting solar energy into chemical energy.
- **Chemosynthesis:** It is a process in which food is made by bacteria or other living organism using chemical as a source of energy, typically in the absence of sunlight. e.g. Nitrifying bacteria.

Differences between Photosynthesis and Chemosynthesis

Chemosynthesis	Photosynthesis
It occurs only in colourless anaerobic bacteria	This process occurs in all green plants including green bacteria.
During this process CO_2 is reduced to carbohydrates without light and chlorophyll.	CO_2 and H_2O are converted into carbohydrates in the presence of light and chlorophyll.
Chemical energy released during oxidation of inorganic substances is used up to synthesise carbohydrates.	Light energy is converted into chemical energy and stored in the form of carbohydrates.
In this process no. pigment molecule is involved and oxygen is not evolved.	Several pigments are involved and oxygen is evolved as a by-product.
No photophosphorylation takes place.	Photophosphorytion takes place i.e. ATP is produced.

10 CHAPTER

Reproduction in Plants

Reproduction is one of the most important characteristics of all living beings. It is necessary for the continuation of the species on earth and also to replace the dead members of the species. The process by which living organisms produce their offsprings for the continuity of the species is called reproduction.

This chapter deals the process of reproduction in plants. The modes of reproduction vary according to individual species and available conditions. It may be simply by division of the parent cell as in unicellular organisms, by fragmentation of the parent body, by formation of buds and spores, or it may be very elaborate involving development of male and female reproductive organs (stamens and pistils). Irrespective of the mode of reproduction, all organisms pass on their hereditary material to their offsprings during the process of reproduction.

Modes of Reproduction

There are two modes of reproduction in plants:

(a) Asexual

(b) Sexual

Asexual Reproduction

The mode of reproduction in which there is no fusion of male and female gametes and which produces individuals that are genetically identical to their parents is called asexual reproduction.

Asexual reproduction in plants is of further two types: Natural and Artificial

Natural Methods: It includes self-propagation without any artificial interference. It includes

- Vegetative Propagation
- Budding
- Fragmentation
- Spore Formation

Artificial Methods: There are artificial methods also through which reproduction in plants is performed such as:

- Cutting
- Layering
- Grafting
- Tissue Culture

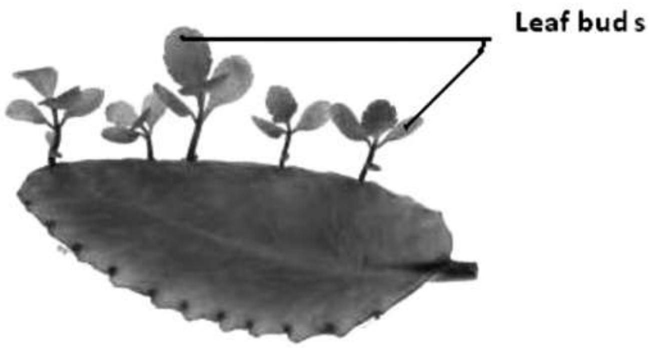
Natural Methods

Some basic features as well as examples of different methods of asexual reproduction are given below:

Vegetative Propagation: It involves formation of new plantlets from vegetative (somatic) cell, buds or organs of the plant.

Here, a vegetative part of the plant (**root, stem, leaf and bud**) gets detached from the parent body and grows into an independent plant and thus is named as vegetative reproduction.

- It occurs both naturally as well as artificially. It accour leaf,
  - **Leaf: Bryophyllum (sprout leaf plant)** has buds in the margins of leaves. If a leaf of this plant falls on a moist soil, each bud can give rise to a new plant.
  - **Roots**: The roots of some plants can also give rise to new plants. **Sweet potato and Dahlia** are examples.
  - **Seeds**: 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. It is also propagated artificially by cutting etc.
  - **Stem**: Stem cutting of Rose is a method used in propagation of rose plant.
- Plants produced by vegetative propagation take less time to grow and bear flowers and fruits earlier than those produced from seeds.
- The new plants are exact copies of the parent plant, as they are produced from a single parent.



Bryophyllum (Sprout Leaf Plant)

11
CHAPTER

Animal Kingdom

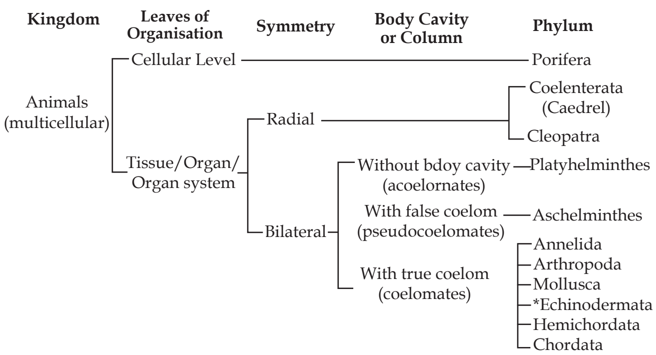
When you look around, you will observe different animals with different structures and forms. As over a million species of animals have been described till now, the need for classification becomes all the more important. The classification also helps in assigning a systematic position to newly described species.

Animal Kingdom is characterized by **multicellular**, eukaryotic organisms. The cells lack cell walls. They ingest and digest food (holozoic), hence they are **heterotrophic**. Higher forms show elaborate sensory and neuromotor systems. Majority of them are motile.

- Reproduction is mostly sexual and embryological development is present in them.
- About more than 1.2 million species of animals are described till now. The classification helps to assign a systematic position to newly described species.

Basis of Classification

Inspite of differences in structure and form of different animals, there are fundamental features common to various individuals in relation to the arrangement of cells, body symmetry, nature of coelom, patterns of digestive, circulatory or reproductive systems. These features are used as the basis of animal classification.



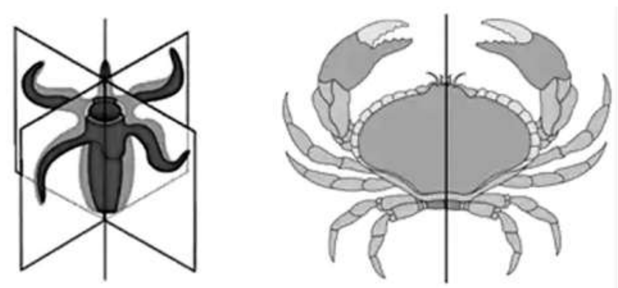
Broad classification of Kingdom Animalia based on common fundamental features

A. Levels of Organisation

- Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organization of cells.
  a) **Cellular Level –** In these animals, the cells of the body form loose aggregates e.g. **Sponges**.
  b) **Tissue Level -** In these animals, cells of the animal carrying out the same function are arranged in tissues e.g.:- **Coelenterates**.
  c) **Organ System Level -** In these animals, tissue are grouped together to form organs, each specialized for a particular function e.g.:- members of Platyhelminthes and other higher phyla.

B. Body Symmetry

- The arrangement of body parts around a central point or line determines **symmetry**.
- Some animals are **asymmetrical** which cannot be divided into two equal halves along any plane passing through the center E.g. Sponges.
- Some exhibit **radial symmetry** where the animal can be divided into two equal halves along any plane passing through the central axis e.g.:- Coelenterates, Ctenophores and Echinoderms.
- Still other animals exhibit **bilateral symmetry** where the body can be divided into identical left and right halves along only one plane e.g. Annelids, Arthropods, Chordates etc.



A **Radial symmetry** B **Bilateral symmetry**

C. Body Wall

- The body wall of the animal may be arranged in two or three embryonic layers.
- Accordingly the animals are called
- **Diploblastic:** Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals, e.g., **coelenterates**. An undifferentiated layer, mesoglea, is present in between the ectoderm and the endoderm, and

12 CHAPTER

Skeletal System

The skeletal system serves as a framework for the body. This framework consists of many individual bones and cartilages. There also are bands of ligaments and tendons in intimate relationship with the parts of the skeleton. In this chapter, we will study bones and muscles of human body.

In the preceding chapters you came across a large variety of organisms, both unicellular and multicellular, of the animal kingdom. In unicellular organisms, all functions like digestion, respiration and reproduction are performed by a single cell.

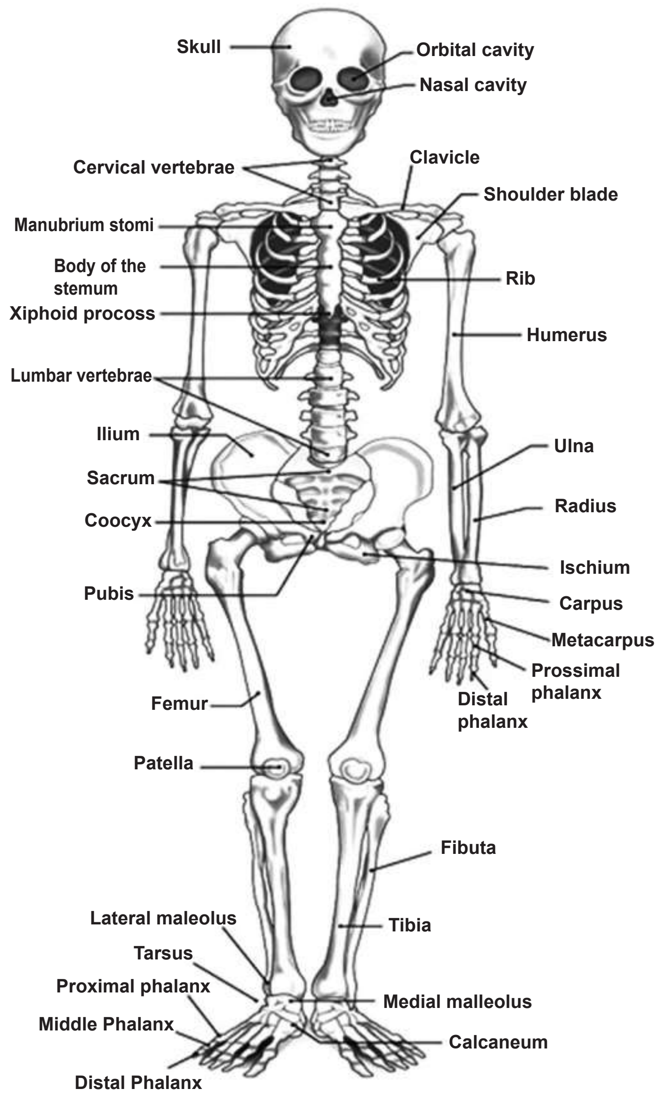
- In the complex body of multicellular animals the same basic functions are carried out by different groups of cells in a well-organized manner.
- The body of a simple organism like Hydra is made of different types of cells and the number of cells in each type can be in thousands. The human body is composed of billions of cells to perform various functions.
- These tissues are organized in specific proportion and pattern to form an organ like stomach, lung, heart and kidney. When two or more organs perform a common function by their physical and/or chemical interaction, they together form organ system, e.g., digestive system, respiratory system, etc.
- Cells, tissues, organs and organ systems split up the work in a way that exhibits division of labour and contribute to the survival of the body as a whole.
- Thus the human body has different structural levels of organization, starting with atoms molecules and compounds and increasing in size and complexity to cells, tissues, organs and the systems that make up the complete organism.
- There are **six levels of structural organization in human** and they are:
  - Chemical level → Cellular level → Tissue level → Organ Level → Organ System Level → Organismic Level

Skeletal System

Humans are vertebrates, animals having a vertebral column or backbone. They rely on a sturdy internal frame that is centered on a prominent spine. The human skeletal system consists of bones, cartilage, ligaments and tendons and accounts for about 20 percent of the body weight. This system provides 'the shape' to the body.

- This system is **useful in locomotion** as well as holding the weight. The skeleton serves as a framework for the attachment of muscles and as a protection for delicate organs.
- The bones can be long, short, flat or irregular in shape. Hands and legs have long bones. Carpals (wrist bones) and Tarsals (ankle bones) are shorter.
- There are 206 bones in the human skeleton.
- The human skeleton, like that of other vertebrates, consists of **two principal subdivisions**—the axial skeleton and appendicular skeleton.

The Human Skeleton



14 CHAPTER

Digestive System

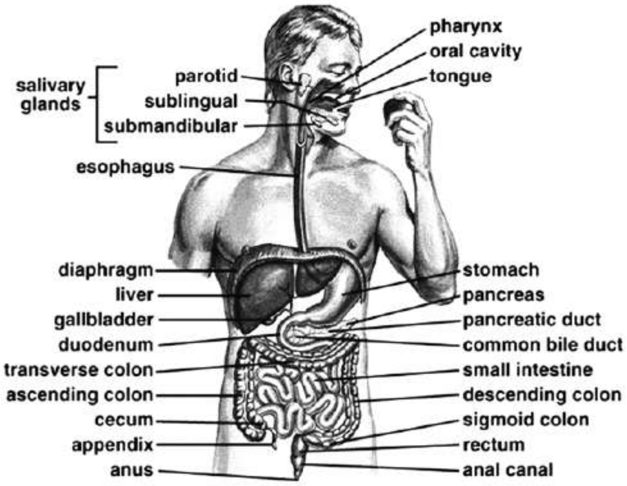
Food consists of complex organic molecules which have to be broken down into simpler forms before they can be absorbed into the body. Such breaking down of the food and subsequent absorption of food constituents occur inside the digestive tract. The digestive tract together with the associated glands constitutes the digestive system.

In the digestive system, a group of organs works altogether to convert food into energy and in other basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the alimentary canal or the gastrointestinal tract (GI tract) that is made up of the **oral cavity, pharynx, esophagus, stomach, small intestines, and large intestines.**

- Besides, there are several other important organs that help our body to digest food but do not have food pass through them. **Accessory organs of the digestive system include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.**
- The digestive system consists of a tube extending from the mouth to the anus. In this system food and fluids are taken in, moved through the body, and broken down into small molecules that are absorbed into the circulatory system. This breakdown, known as digestion, is both a mechanical and a chemical process.
- Food enters through the mouth, where chewing and saliva start to break it up and make it easier to swallow.
- The food mechanically breaks down due to contractions of the stomach's muscular wall. The chemical digestion continues when acid and enzymes are secreted into the stomach cavity.
- The liquefied food gradually passes into the small intestine. In the duodenum, enzymes from the pancreas are added that complete the chemical breakdown of the food.
- The digestion of fat is helped by bile that is made in the liver and stored in the gall bladder. The small intestine absorbs the nutrients released during these digestive activities.
- The liquid remainder of the food enters the large intestine, or colon where most of the fluid is absorbed and the relatively dry residues are expelled.

Alimentary Canal

- The food passes through a continuous canal called **alimentary canal**. The canal can be divided into various compartments: (1) the buccal cavity, (2) foodpipe or oesophagus, (3) stomach, (4) small intestine, (5) large intestine ending in the rectum and (6) the anus. The activities of the gastro-intestinal tract **(alimentary canal)** are under neural and hormonal control for proper coordination of different parts.
- The sight, smell and/or the presence of food in the oral cavity can stimulate the secretion of saliva.
- Gastric and intestinal secretions are also, similarly, stimulated by neural signals. The muscular activities of different parts of the alimentary canal can also be moderated by neural mechanisms.



Digestive System

Parts of Alimentary Canal

The Buccal Cavity or Oral Cavity contains **Teeth, Tongue and Saliva.**

- The process of taking food into the body is called **ingestion**. Ingestion happens through mouth. The mouth leads to the buccal cavity or oral cavity.
- The oral cavity has a number of teeth and a muscular tongue. Each tooth is embedded in a socket of jaw bone.

A. Teeth

- The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. Teeth forming cells are odontoblasts. Outermost layer of teeth is enamal which is hardest part of the body. It is made up of calcium carbonate and calcium phosphate.

15 CHAPTER

Sensory Organs

The sensory system receives and processes information that produces an individual's awareness of their environment. Numerous sensory perceptions then influence voluntary and involuntary motor activity to facilitate interaction with the world. In this chapter, we will study the sensory organs of human body.

Human beings have various specialized organs which are called as sensory organs and are composed of sensory neurons which help us to react and respond to our environment. These are eyes to see, sound to hear, nose to smell, tongue to taste and skin for touch.

- Specialized cells and tissues within these organs receive raw stimuli and translate them into signals the nervous system can use. Nerves relay the signals to the brain, which interprets them as sight (vision), sound (hearing), smell (olfaction), taste (gustation), and touch (tactile perception).

Eyes

Eyes are organs that allow us to see. Many parts of our eye work together to bring objects into focus and send visual information to your brain. It is situated in deep bony cavities called the orbits on the front side of the head. The adult human eye ball is nearly a spherical structure.

- Each eye consists of eyeball and accessory structures comprising the eyelids, eyelashes, lacrimal glands and the eyebrows which form the external portion of the eye. Also the other parts of eyes are cornea, iris, pupil, sclera, retina etc.

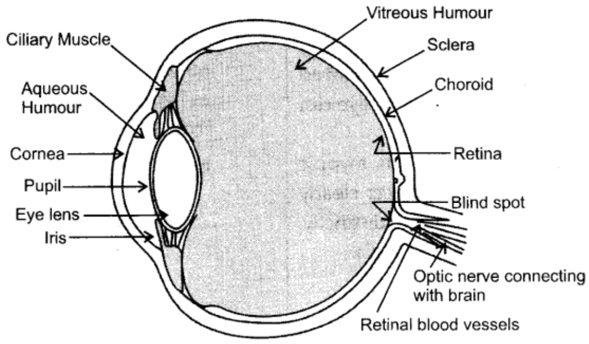
Chambers of Eyes

Eyes have 2 chambers:

(i) Anterior chamber,

(ii) Posterior chamber

- **Anterior:** The space between the cornea and the lens is called the aqueous chamber and contains a thin watery fluid called **aqueous humor.**



Structure of Human Eye

- **Posterior:** The space between the lens and the retina is called the vitreous chamber and is filled with a transparent gel called **vitreous humor.**
- Both chambers maintain the shape of eye ball and provide medium for light rays.

Parts of Eyes

- **Eyelids:** They are protective in nature as they shade the eyes during sleep. They protect the eyes from excessive light and external particles, and their blinking spread lubricating secretions over the eyeballs.
- **Eyelashes:** Each eyelid bears outwardly curved row of short thick hair. These prevent falling of larger particles in the eye.
- **Lacrimal Glands**: The lacrimal gland (tear gland) is an exocrine gland located above the eyeball, in the anterior part of the upper outer aspect of each orbit. Their secretion, called tears, is spread evenly by blinking of eyelids thus serving as lubricant and also washes away dust particles. Tears also have antiseptic property as they contain a bacterial enzyme, Lysozyme.
- **Eyebrows:** They are protective to internal eye as their coarse lateral hair project the eye from rain drop or perspiration trickling into them.
- **Conjunctiva:** It is a thin membrane covering the entire front part of the eye. It is continuous with the inner lining of the eyelids. Over the cornea, it is reduced to a single layer of transparent epithelium.
- **Eyeball**: The eyeball is approximately spherical in shape with a diameter of about 2.3 cm and is divided is divided into three layers – outer fibrous **Sclera**, middle vascular **choroid** and inner nervous coat **retina**.
- **Sclera:** Outermost layer made up of fibrous connective tissue. The sclera bulges in front as a non-vascular, transparent, fibrous coat, covering the coloured part of the eye. This part is called the **cornea**. Most of the refraction for the light rays entering the eye occurs at the outer surface of the cornea.
- **Choroid:** It is middle pigmented layer made of connective tissue. It absorbs rays to prevent reflection of light inside.

CHAPTER 16

Nervous System

Nervous system is your body's command centre. It's made up of your brain, spinal cord and nerves. Your nervous system works by sending messages, or electrical signals, between your brain and all the other parts of your body. In this chapter, we will study nervous system of human body.

The nervous system transmits information very rapidly by nerve impulses conducted from one body area to another. The nervous system serves as the chief coordinating agency. Conditions both within and outside the body are constantly changing; the purpose of the nervous system is to respond to these internal and external changes (known as stimuli) and so cause the body to adapt to new conditions.

- It is through the nerve impulse sent to the various organs by the nervous system that a person's internal harmony and the balance between the person and the environment are maintained.

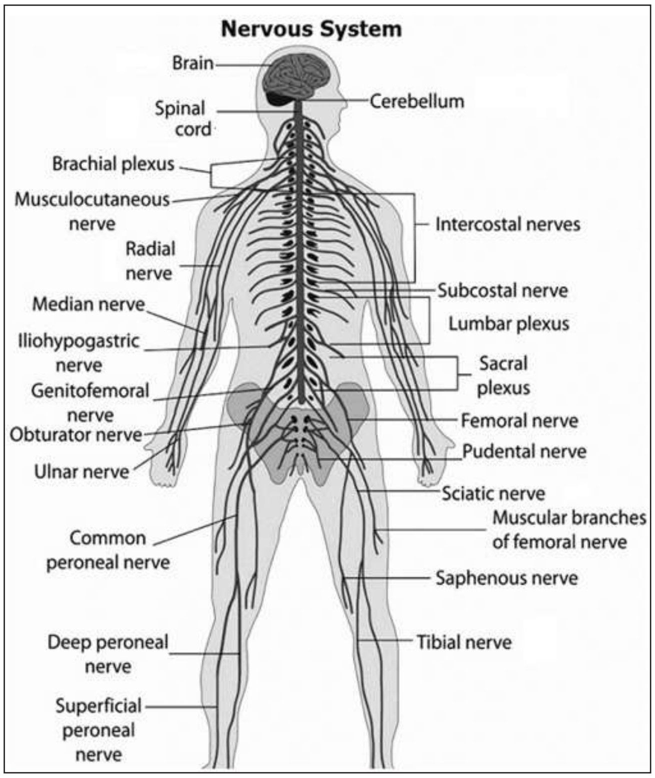
Difference between Nervous and Hormonal Control

Nervous Control	Hormonal Control
Information travels rapidly	Information travels slowly
It travels as electrical signals	They travel as chemical messengers
These signals travel through nerve fibres	These messengers travel through blood stream
Information goes to specific receptors like muscles and glands	Information is carried to different organs
Its effect is very short-lived	It has long lasting effect
Has no effect on growth	Affect growth
Does not influence chemical changes and cannot regulate metabolism	Bring about specific chemical changes and regulate metabolism

Basic Cells of the Nervous System

The two types of cells found in the nervous system are called **neurons** or nerve cells and **neuroglia**, which are specialized connective tissue cells. Neurons conduct impulses, whereas neuroglia supports neurons.

- The Nervous System is the supreme controlling and communicating system of animals.



Overview of Nervous System

- It controls and coordinates all essential functions of animal or human body.
- The system uses its millions of sensory receptors to monitor changes that occurs both inside and outside of the body. These sensory receptors are called **Stimuli**.
- The gathered information by nervous system is called **Sensory Input**.
- The system then process and interprets the sensory input and makes decisions about what should be done at each moment. This process is called **Integration**.
- The Nervous System then sends information to muscles, glands, and other organs so that they can respond correctly, e.g. walking, anger, etc.

Neurons

- Neuron is the basic unit of all vertebrates nervous tissues.

17 CHAPTER

Endocrine System

The endocrine system is a complex network of glands and organs. It customs hormones to control and coordinate human body's metabolism, energy level, reproduction, growth and development, and response to injury, stress, and mood. In this chapter, we will study the human endocrine system.

All the activities of the body are regulated by the coordinated efforts of the nervous system and the endocrine system. The endocrine system is a complex network of glands and organs. It uses hormones to **control and coordinate our body's metabolism**, energy level, reproduction, growth and development, and response to injury, stress, and mood.

- The hypothalamus provides the link between the brain and the endocrine system.
- The endocrine system performs the function by special compounds called hormones. The hormones may also influence the activation of nerves.
- The endocrine system includes the hypothalamus, pineal gland, pituitary gland, thyroid gland, parathyroid glands, thymus, adrenal glands, and pancreas. It also includes the testes in males and the ovaries and placenta (during pregnancy) in females.

Hormones

The term 'Hormone' means to stimulate. Hormones are information molecules secreted by the endocrine glands in response to the environment.

- Hormone is a chemical produced by endocrine glands and released into the blood and transported to a distantly located target organ.
- Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.
- Hormone was first discovered by **W.M. Bayliss** and **E.H. Starling** (1903).
- These are carried to all parts of the body by the blood but their effect is produced in one or more specific parts only called **target organ.**

Chemistry of Hormones

- Hormones fall chemically in two categories:

1. **Proteins**: Most hormones are proteins or related compounds composed of amino acids. All hormones except those of the adrenal cortex and the sex glands are made up proteins.
2. **Steroids:** These are hormones derived from lipids and produced by the adrenal cortex and the sex glands.

- All hormones are extremely potent, that is, they are effective in very small amounts.

Types of Glands

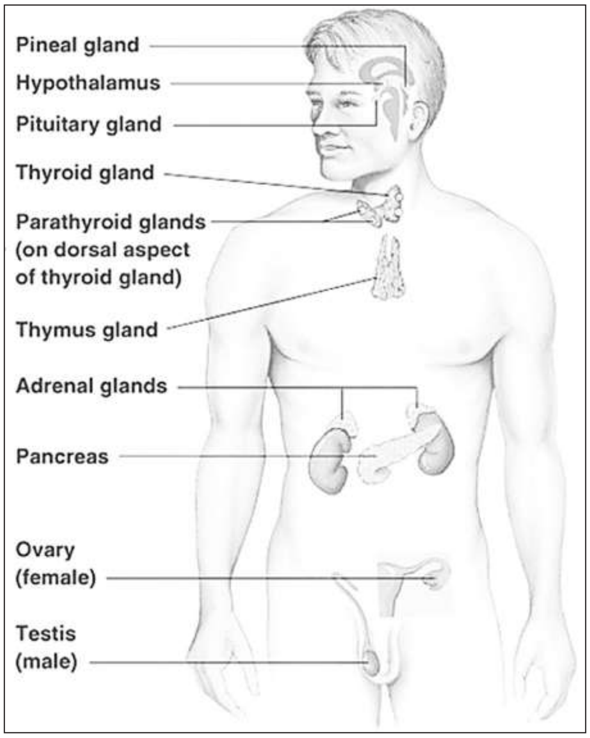
- There are two major categories of glands in the body - exocrine and endocrine.

Exocrine Glands

- Exocrine glands have ducts that carry their secretory product to a surface. These glands include the sweat, sebaceous, and mammary glands and, the glands that secrete digestive enzymes.

Endocrine Glands

- The endocrine glands do not have ducts to carry their product to a surface. They are called ductless glands.
- The secretory products of endocrine glands are called hormones and are secreted directly into the blood and then carried throughout the body where they influence only those cells that have receptor sites for that hormone.



Endocrine System

18 CHAPTER

Immune System

The immune system is a complex network of organs, cells and proteins that defend the body against infection, while protecting the body's own cells. In this chapter, we will study the human immune system.

We all get infections, but some of us fall sick more frequently than others. This is related to the immune system. Proper functioning of immune system protects us from the infections. On the other hand its malfunctioning provides opportunity to infectious agents for causing diseases. Besides protection from infection, immune system also performs a number of other functions.

- The immune system is a complex network of organs, cells and proteins that defends the body against infection, whilst protecting the body's own cells. The immune system keeps a record of every germ (microbe) it has ever defeated so it can recognize and destroy the microbe quickly if it enters the body again.
- Let us understand different mechanisms behind the working of our immune system.

Immunity

- Immunity is broadly defined as "the capacity of the body to recognize materials as foreign to itself and to neutralize, eliminate or metabolize them with or without injury to its own tissues".
- Immunobiology is the study of organization and functioning of immune system. Immune system provides 'immunity' (protection against diseases).
- **Edward Jenner (1749-1823)** is considered to be the **father of modern immunobiology.**
    - He demonstrated that inoculation of cowpox crusts afforded protection to humans against smallpox. He observed that **milkmaids** who recovered from cowpox never contracted the disease smallpox. Hence the name vaccination from the Latin word **"Vacca"** for cow came into beng.
    - The milkmaids and the vaccinated individuals were protected from smallpox virus. Such protection gave them what is called `immunity' to smallpox, although Jenner neither knew the actual causative agent of this disease nor the actual mechanism of protection.
- **Concept of self and non-self:** The basis of the above mentioned protection was the ability of the immune system of the milkmaid and vaccinated individuals to distinguish between 'self (their own tissues) and 'non-self' components of the outsiders i.e. the smallpox virus) in this context.
    - An individual induces a physiological response (immune response) to substances that are different from self-components. For example, an immune response is induced against pathogens (bacteria, virus, fungi and parasites) attacking the body of the host.

Defence Mechanisms in the Body

There are four defence mechanisms in our body:

1. Immunity to defend the body from infections.
2. Metabolic defence to metabolize and detoxify foreign chemicals.
3. Stoppage of bleeding (Haeostasis) to prevent to blood loss.
4. Resistance to stress mainly through release of hormone.
    - Immunological defence is the most important defence mechanism. It provides protection against various infective agents e.g. virus, bacteria, fungi and parasites and also against the development of a tumour.
    - Thus immunological defence serves three main functions :
        - Defence against microorganisms.
        - Recognition and destruction of mutant cells (Surveillance).
        - Removal of damaged or non-functional cells to maintain normal state (Homeostasis).

Tissues and Organs Involved in the Immune System

- **Lymphoid organs are divided into two groups :**
    - **Central lymphoid organs** or primary lymphoid tissue. Example : Thymus and bone marrow.
    - **Peripheral lymphoid organs** or secondary lymphoid tissue.
    - Examples spleen, Peyer's patches, tonsils, lymph nodes and mucosa-associated lymphoid tissue (MALT).

Cells of Immune System

- **Lymphocytes (Lymphoid cells):** All these are initially derived from the hemopoietic (blood cell producing) stem cells of bone narrow.

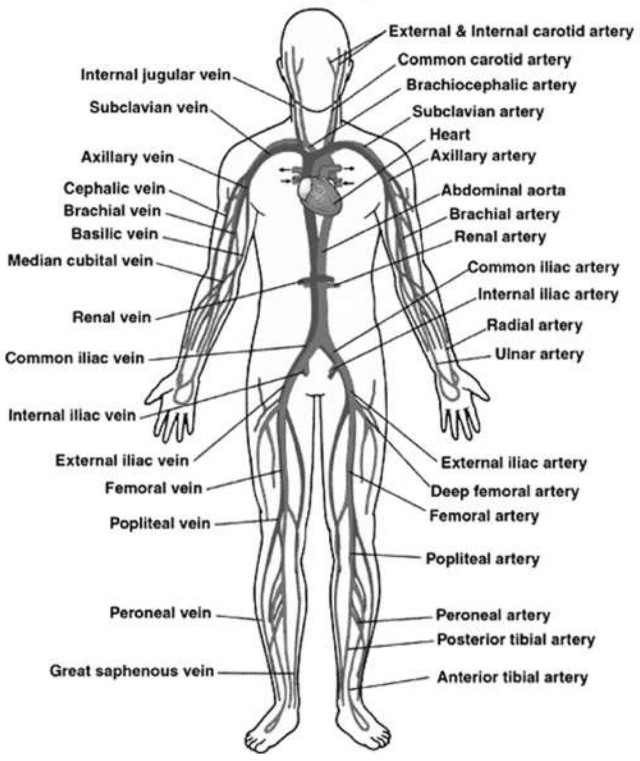
19 CHAPTER

Circulatory System

Our cardiovascular system, which is made up of heart and blood vessels, is a important part of human body. When our cardiovascular system is working right, the cells in human body get a continuous supply of oxygen and nutrients from blood. Blood vessels also remove carbon dioxide and other waste. Thus this chapter deals with the overall processes involved in our circulatory system.

The cardiovascular system or the circulatory system is the transport system of the body by which food, oxygen, water and all other essentials are carried to the tissue cells and their waste products are carried away. It consists of three parts:

- **The blood**, which is the fluid in which materials are carried to and from the tissue.
- **The heart**, which is the driving force which propels the blood.
- **The blood vessels**, the routes by which the blood travels to and through the tissues and back to the heart.
- This system is responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body.
- In simpler and unicellular animals like Amoeba, Paramecium, etc. the cell is in direct contact with the exterior so there is no need of transport mechanism.



- In higher and **multi cellular organisms cells** no longer remain in direct contact with the exterior. So there is a need to transport various substances like digested food materials to provide energy to perform physical activities of the body and for growth of the body.
- In **Sponges** and **Coelenterates (Hydra)**, there are no special circulatory systems. The water current that enters the body cavity brings nutrients that are digested and absorbed by the cells and the exchange of gases within them also takes place through the **water current**.
- In **Annelids (earthworm)**, a **closed type of circulatory system** is present which consists of various blood vessels and capillaries which help in transportation of blood throughout the body.
- In **Insect (cockroach)**, an **open type of circulatory system** is present, where there are no blood vessels to contain the blood and it flows freely through the cavities of the body.
- The blood continuously circulates in blood vessels and capillaries in a **unidirectional circuit** under the control of a central **pumping organ**, the heart.
- Thus the blood, heart, blood vessels and capillaries and lymph and lymph vessels constitute our **circulatory system**.

Heart

The heart is a muscular pump that drives the blood through the blood vessels. Slightly bigger than a fist, this organ is located between the lungs in the center and a bit to the left on the midline of the body.

- About two third of our heart is to the left and one third to the right of the midline of our body.

Structure of Heart

A. Shape and Size

- Heart is a hollow, muscular, cone-shaped organ and is about the size of a fist and weighs approximately 300 grams. It is enclosed in a membranous sac called **pericardium.** Pericardial fluid flows between the membrane and heart, protecting the later from shock, injury, and friction and keeps the heart moist.

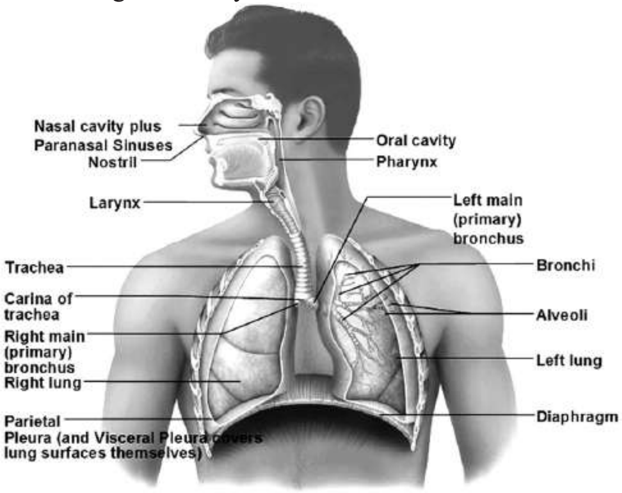
20 CHAPTER

Respiratory System

The process of exchange of O_2 from the atmosphere with CO_2 produced by the cells is called breathing, commonly known as respiration. Place your hands on your chest; you can feel the chest moving up and down. You know that it is due to breathing. How do we breathe? The respiratory organs and the mechanism of breathing are described in this chapter.

Respiration is the fundamental process of energy release. It refers to all the processes by which cells take in oxygen, convert energy into biologically available forms such as **ATP (Adenosine Triphosphate)** and give off carbon dioxide (CO_2).

- **Metabolic reactions** in human body use oxygen (O_2) to produce energy from nutrients in form of ATP. At the same time, these reactions release carbon dioxide (CO_2) which must be eliminated quickly to prevent acidity due to CO_2.
- The respiratory and cardiovascular systems cooperate to supply O_2 and eliminate CO_2.
- The respiratory system provides for gas exchange i.e. intake of O_2 and elimination of CO_2. The cardiovascular system transports these gases through blood between the lungs and body cells.



Respiratory System

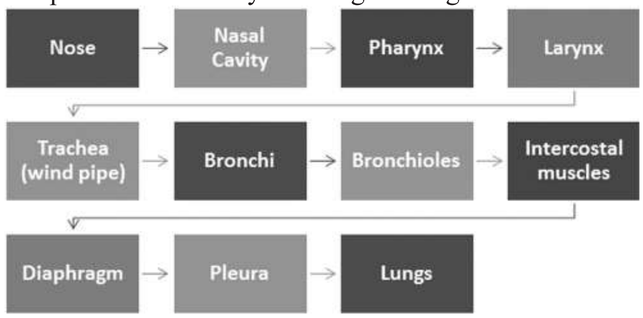
- The respiratory system also participates in **regulating blood pH, contains receptors for the sense of smell, filters inspired air, produces sounds, and rids the body of some water and heat in exhaled air.**
- **Thus Respiration involves the following steps:**
  - (i) Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.
  - (ii) Diffusion of gases (O_2 and CO_2) across alveolar membrane.
  - (iii) Transport of gases by the blood.
  - (iv) Diffusion of O_2 and CO_2 between blood and tissues.
  - (v) Utilisation of O_2 by the cells for catabolic reactions and resultant release of CO_2.

Parts of Respiratory System

There are three major parts of the respiratory system: the airway, the lungs, and the muscles of respiration.

1. The Airway

- Movement of Inhaled Air passes through various body parts before finally reaching to Lungs.



Nose

- It is only externally visible organ of respiratory system. Nose can be divided into 2 parts:
- **External Nose:** The external nose consists of a framework of bones and hyaline cartilage covered with muscle and skin and lined by a mucous membrane.
  - The frontal bone, nasal bones and maxillae form the bony framework of the external nose. On the undersurface of the external nose are two openings called the external nares or nostrils.
  - Interior to external nostrils is a portion called nasal vestibule which has coarse hairs that filter out dust particles.
- **Internal Nose:** Internal nose is larger cavity and is present inferior to nasal bone and superior to mouth.
  - Anteriorly, it merges with external nose and posteriorly joins with pharynx through 2 openings called **internal nares**.
  - Space within internal nose is called **nasal cavity**.

21
CHAPTER

Excretory System

Look at any construction site around you. You will find some garbage or waste material. This too happens with the human body. To throw such waste material out of human body, we have excretory system. Every cell of our body keeps on doing something or the other. Therefore, some garbage is always found there. These elements are harmful and should not be collected in body. It should be thrown out of the human body. In this chapter, we will learn about removal of nitrogenous wastes and maintenance of water and salt balance in the body.

All animals possess some mechanism of getting rid of the waste substances produced in their body during metabolic activities. These waste substances include CO_2, water, urea, uric acid and ammonia. Such substances can be harmful if retained in the body.

- Besides metabolic wastes, excess salt (eg. NaCl taken in food), H2O and even excess of some vitamins needs to be eliminated.
- Certain medicines (antibiotics) too are removed from the blood in the urine. Removal of all harmful.
- Excretory system is primarily associated with removal of nitrogenous wastes.
- Urea is the main nitrogenous waste in our body. It is formed by the breakdown of surplus amino acids and nucleic acids in the liver. Blood transports urea to the kidneys for filtration and removal in the form of urine.
- Some of these waste products may become toxic if they accumulate beyond a certain concentration.
- An important requisite for the continuation of life therefore is the removal of metabolic waste products such as ammonia, urea, uric acid, bile pigments, excess salts and water.

Excretory Products and their Elimination

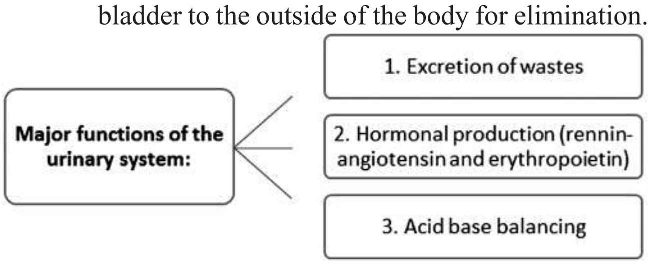
Animals accumulate **ammonia, urea, uric acid, carbon dioxide, water and ions like Na+, K+, Cl-, phosphate, sulphate**, either by metabolic activities or by other means like excess ingestion. These substances have to be removed totally or partially.

- **Ammonia, urea** and **uric acid** are the major forms of **nitrogenous wastes** excreted by the animals. The way in which waste chemicals are removed from the body of the animal depends on the availability of water.
- **Ammonia is the most toxic** form and requires large amount of water for its elimination, whereas **uric acid, being the least toxic**, can be removed with a minimum loss of water.
- Aquatic animals like fishes, excrete cell waste in **gaseous form (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** which is excreted through urine.
- 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**.
- The process of excreting ammonia in many bony fishes, aquatic amphibians and aquatic insects are **ammonotelic** in nature.
- Ammonia, as it is readily soluble, is generally excreted by **diffusion** across body surfaces or through gill surfaces (in fish) as ammonium ions. Kidneys do not play any significant role in its removal.

Human Excretory System: Anatomy

The excretory system is also called the urinary system of the body because one of its functions is to remove waste products from the blood and eliminate them from the body.

- The urinary system consists of:
  - **Two Kidneys:** this organ extracts wastes from the blood, balance body fluids and form urine.
  - **Two Ureters:** this tube conducts urine from the kidneys to the urinary bladder.
  - **The Urinary Bladder:** this reservoir receives and stores the urine brought to it by the two ureters.
  - **The Urethra:** this tube conducts urine from the bladder to the outside of the body for elimination.



22 CHAPTER

Reproductive System

The ability to reproduce is one of the essential characteristics of living beings. It involves the transmission of genetic material from the parental generation to the next generation, thereby ensuring that characteristics not only of the species but also of the parental organisms are perpetuated. In this chapter, types of reproduction, reproductive system in humans, etc. are discussed.

Reproduction is the biological process of producing the same kind of individuals. Most organisms reproduce by mating that increases the organism's genetic variability. The females and males have separate reproductive organs called gonads. These gonads forms gametes that fuse together to produce a single cell called a zygote.

- Few animals such as snails, earthworms, slugs, and more are hermaphrodites and possess male and female reproductive organs in the same organism.
- Most of the animals are diploid organisms, which means their haploid reproductive (gamete) cells and body (somatic) cells are diploid are produced via meiosis. Also, in some cases, reproduction in animals and humans occurs similarly to each other.

Types of Animal Reproduction

- The two types of animal reproduction include,
  - Asexual Reproduction
  - Sexual Reproduction

Asexual Reproduction

Asexual reproduction is a mode of reproduction in which a new offspring is produced by a **single parent**.

- The new individuals produced are genetically and physically identical to each other, i.e., they are the clones of their parents. Asexual reproduction is observed **in both multicellular and unicellular organisms**.

Types of Asexual Reproduction

Asexual Reproduction is of the following types:

- **Binary Fission:** It is seen in **amoeba and euglena**. The parent cell undergoes mitosis and increases in size. The nucleus also divides. Two identical daughter cells are obtained, each containing a nucleus. Prokaryotes like **bacteria** majorly reproduce by binary fission
- **Budding:** In this, the offspring grows out of the body of the parent. It remains attached to the parent until it matures. After maturation, it detaches itself from the parent and lives as an individual organism. This form of reproduction is most common in **Hydras.**
- **Fragmentation:** In some organisms like **Planarians**, when the body of an organism breaks into several pieces each piece grows into an individual offspring.
- This is known as fragmentation. It can occur through accidental damage by predators or otherwise, or as a natural form of reproduction. In a few animals such as sea stars, a broken arm grows into a complete organism.
- **Regeneration:** It is a modified form of fragmentation and occurs mostly in **Echinoderms.** When a part of an organism, like an arm, detaches from the parent body, it grows into a completely new individual. This is known as regeneration.
- **Parthenogenesis:** This is a form of asexual reproduction where the egg develops without fertilization. This process occurs in bees, wasps, ants, aphids, rotifers, etc. Ants, wasps, and bees produce haploid males. Parthenogenesis has been observed in a few vertebrates such as hammerhead sharks, Komodo dragons, and blacktop sharks when the females were isolated from the males.

Sexual Reproduction

Male and females have different reproductive organs in animals. The animal's reproductive parts produce gametes that fuse and form a zygote.

- The zygote then develops into a new similar species. The reproduction type through the fusion of male and female gametes is called sexual reproduction.
- Male gametes, produced by testes, are called sperms. Whereas, the female gametes, produced by the ovary, are called ova (or eggs). In the reproduction process, the first step is the fusion of a sperm and an egg (ovum).
- The fusion of the sperm and egg is known as fertilization.
- During fertilization, the sperm's nuclei and the egg fuse together and form a single nucleus that results in the formation of a fertilized egg, which is also called a zygote.

23 CHAPTER

Health and Nutrition

Food is the basic necessity of life. We all know that regular supply of food is essential for human beings in order to keep fit and to carry on all the life processes. We eat a large variety of food according to our taste, availability and bodily requirements. In this chapter, we will learn about nutritional requirement of the body and the problems of health related to specific nutrient deficiencies.

Food can be defined as anything solid or liquid which when swallowed, digested and assimilated in the body provides it with essential substances called nutrients and keeps it well. It is the basic necessity of life. Food supplies energy enables growth and repair of tissues and organs. It also protects the body from disease and regulates body functions. Thus food is any substance which performs the following functions in the body:

(i) Yields energy for life processes,

(ii) Builds up new cells during growth,

(iii) Repairs worn out (damaged) tissues,

(iv) Aids in production of useful body compounds.

Classification of Food

Food can be classified into three categories based on their functions –

(i) Energy providing foods: These are rich in carbohydrates and fats and provide energy on biological oxidation in the body.

- Example: cereals, sugar, fats, oils, jaggery, coconut, and groundnuts.

(i) Body building foods: These are rich in proteins and help in the formation of new tissues.

- Example: legumes, milk, egg, meat, fish, pulses, nuts and oilseeds.

(i) Protective/regulatory foods: These are rich in minerals, vitamins, roughage and water. They help in regulation of internal metabolism in the body.

- Example: green leafy vegetables, fruits, amla, guava, citrus, oranges and water melon.

Nutrition

Nutrition is the sum of the processes by which an organism takes in, metabolizes and utilizes food substance for its various biochemical activities.

- Nutrients are the organic or inorganic substances which help in our survival and in maintaining proper health. Nutrient supplies energy to the body, builds and repairs body tissues and regulates the body metabolism.

Types of Nutrition

Broadly, there are two types of nutrition among living organisms, namely:

A. Autotrophic Nutrition

- In the autotrophic mode, organisms use simple inorganic matters like water and carbon dioxide in the presence of light and chlorophyll to synthesize food on their own.
- In other words, the process of photosynthesis is used to convert light energy into food such as glucose.
- Such organisms are called autotrophs. **Plants, algae, and bacteria (cyanobacteria)** are some examples where **autotrophic nutrition** is observed.
- During photosynthesis, carbon dioxide and water get converted into carbohydrates.
- These carbohydrates are stored in the form of starch in plants. Plants later derive the energy required from the stored starch. The process of photosynthesis can be explained in three stages:
  1. **Absorption:** The chlorophyll present in leaves traps the light coming from the sun.
  2. **Conversion:** The absorbed light energy gets converted into chemical energy. And water absorbed will split into hydrogen and oxygen molecules.
  3. **Reduction:** At last, carbon dioxide gets reduced i.e. hydrogen molecules combine with carbon, to form carbohydrates (sugar molecules).

B. Heterotrophic Nutrition

- Every organism is not capable of preparing food on its own. Such organisms depend on others for their nutrition.
- The organisms which cannot produce food on their own and depend on other sources/organisms are called heterotrophs. This mode of nutrition is known as heterotrophic nutrition.
- **Fungi and all the animals including humans are heterotrophs.** Heterotrophs can be of many varieties depending upon their environment and adaptations.

24 CHAPTER

Disease and Diagnosis

Any malfunctioning process which interferes with the normal functioning of the body is called a disease. In other words, disease may be defined as a disorder in the physical, physiological, psychological or social state of a person caused due to nutritional deficiency, physiological disorder, genetic disorder, pathogen or any other reason. In this chapter, we will study different diseases and their diagonosis.

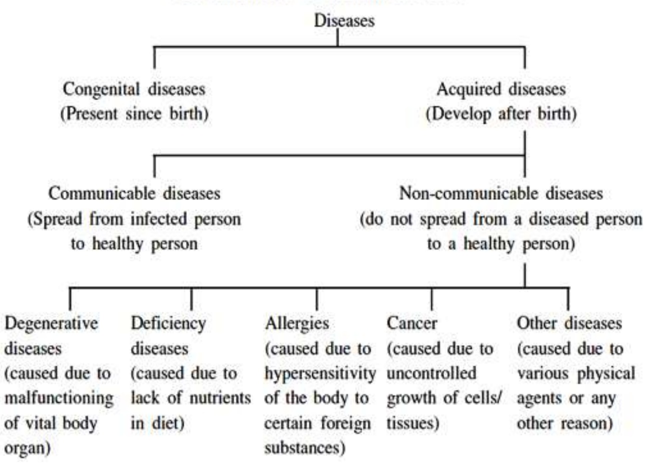
Each disease process has an origin, or etiology, but some diseases may present with different or confusing symptoms, making them difficult to diagnose or determine. The physical symptoms of disease may be accompanied by emotional symptoms, and some diseases that affect the chemical balances of the nervous system may manifest in physical symptoms.

- Categories of diseases include autoimmune, bacterial, blood, cancer, digestive, heart, nerve (or neurodegenerative), sexually transmitted or thyroid.

Types of Diseases

- The diseases may be classified into two broad categories –

Classification of human diseases



A. Congenital Disease: The disease which is present from birth (e.g. hole in the heart in infants). They are caused by some genetic abnormality or metabolic disorder or malfunctioning of an organ.

- The most common severe congenital disorders are **heart defects, neural tube defects and Down syndrome**. Although congenital disorders may be the result of one or more genetic, infectious, nutritional or environmental factors, it is often difficult to identify the exact causes. Some congenital disorders can be prevented.

B. Acquired Disease: The disease which may occur after birth during one's lifetime.

Acquired diseases may generally be classified into:

(i) Infectious Diseases

- The diseases which can be **transmitted from a diseased person** to a healthy person. E.g. **measles.**
- Diseases that spread from one person to another are called communicable diseases.
- They are usually caused by microorganisms called **pathogens** (fungi, rickettsia, bacteria, viruses, protozoans, and worms).
- When an infected person discharges bodily fluids, pathogens may exit the host and infect a new person (sneezing, coughing etc.). Examples include Cholera, chickenpox, malaria etc.

(ii) Degenerative Diseases

- They are mainly caused by the **malfunctioning of vital organs** in the body due to the deterioration of cells over time.
- Diseases such as **osteoporosis** show characteristics of degenerative diseases in the form of increased bone weakness. This increases the risk of bone fractures.
- When degeneration happens to the cells of the central nervous system, such as neurons, the condition is termed as a **neurodegenerative disorder**.
- Alzheimer's is a prominent example of this disorder. Degenerative diseases are usually caused by ageing and body wear.
- Others are caused by lifestyle choices and some are hereditary.

(iii) Deficiency Diseases

- They occur due to the deficiencies of hormones, minerals, nutrients, and vitamins. For example, diabetes occurs due to an inability to produce or utilize insulin, goitre is mainly caused by iodine deficiency, and kwashiorkor is caused by a lack of proteins in the diet.

25

CHAPTER

Biotechnology

Biotechnology deals with techniques of using live organisms or enzymes from organisms to produce products and processes useful to humans. It is the integration of natural science and organisms, cells, parts thereof, and molecular analogues for products and services.

Biotechnology is defined as the industrial application of living organisms and their biological processes such as biochemistry, microbiology, and genetic engineering, to make the best use of the microorganisms for the benefit of mankind. Biotechnology is a set of biological techniques developed through basic research and now applied to research and product development. Biotechnology refers to the **use of recombinant DNA**, cell fusion and new **bioprocessing techniques**.

- The term biotechnology was first used by **Károly Ereky in 1919**, to refer to the production of products from raw materials with the aid of living organisms.
- The core principle of biotechnology involves harnessing biological systems and organisms, such as **bacteria, yeast, and plants**, to perform specific tasks or produce valuable substances.
- The European Federation of Biotechnology (EFB) has given a definition of biotechnology that encompasses both traditional view and modern molecular biotechnology.
- Biotechnology is responsible for manufacturing any pharmaceutical drug product for the industries and biologicals using genetically modified plants, animals, microbes, and fungi.

The uses of biotechnology is enormous, and its mechanism are utilized in the following fields:

- Diagnostics
- Bioremediation
- Genetically Modified Plants For Agriculture
- Therapeutics
- Processed Food
- Waste Treatment
- Energy Production

Branches of Biotechnology

- **Red Biotechnology:** It involves medical processes such as getting organisms to produce new drugs, or using stem cells to regenerate damaged human tissues and perhaps re-grow entire organs.

  Example: The development of organisms capable of producing antibiotics.
  - Genetic engineering for genetic manipulation.
- **White Biotechnology:** It involves industrial processes such as the production of new chemicals or the development of new fuels for vehicles.
- **Green Biotechnology:** It applies to agriculture and involves such processes as the development of pest-resistant crops or the accelerated evolution of disease-resistant animals.
- **Blue Biotechnology:** It encompasses processes in marine and aquatic environments, such as controlling the proliferation of noxious water-borne organisms.
- **Yellow Biotechnology:** It refers to biotechnology with insects — analogous to the green (plants) and red (animals) biotechnology.
  - Active ingredients or genes in insects are characterized and used for research or application in agriculture and medicine.
- **Grey Biotechnology:** Its purpose is the conservation and restoration of contaminated natural ecosystems through bioremediation processes.
- **Violet Biotechnology:** It deals with the law, ethical and philosophical issues around biotechnology.
- **Dark Biotechnology**: It is associated with bioterrorism or biological weapons and biowarfare using microorganisms, and toxins to cause diseases and death in humans, domestic animals, and crops.

Principles of Biotechnology

Among many, the two core techniques that enabled birth of modern biotechnology are:

(i) Genetic Engineering: Techniques to alter the chemistry of genetic material (DNA and RNA), to introduce these into host organisms and thus change the phenotype of the host organism.

(ii) Bioprocess Engineering: Maintenance of sterile (microbial contamination-free) ambience in chemical engineering processes to enable growth of only the desired microbe/eukaryotic cell in large quantities for the manufacture of biotechnological products like antibiotics, vaccines, enzymes, etc.

Let us in detail understand the conceptual development of the principles of genetic engineering:

26
CHAPTER

Microbiology

Microbiology refers to the study of micro-organisms, or microbes, a diverse group of generally minute simple life-forms that include bacteria, archaea, algae, fungi, protozoa, and viruses. The field is concerned with the structure, function, and classification of such organisms and with ways of both exploiting and controlling their activities.

Microbiology is the study of living organisms that are too small to be seen by naked eyes and require a special instrument called microscope to observe them clearly.

- Microbiology is about diversity and evolution, about how different kinds of microorganisms arose and why.
- Microorganisms differ from the cells of macro-organisms. The cells of macro-organisms such as plants and animals are unable to live alone in nature and exist only as parts of multicellular structures, such as the organ systems of animals or the leaves of leafy plants.

The science of microbiology revolves around the following two themes:

(1) Understanding Basic Life Processes

- As a basic biological science, microbiology uses and develops tools for probing the fundamental processes of life.
- Scientists have been able to gain a sophisticated understanding of the chemical and physical basis of life from studies of microorganisms because microbial cells share many characteristics with cells of multicellular organisms; indeed, all cells have much in common.

(2) Applying Our Understanding of Microbiology for the Benefit of Humankind

- As an applied biological science, microbiology deals with many important practical problems in **medicine**, **agriculture**, and **industry** for example:
- Most animal and plant diseases are caused by microorganisms.
- Microorganisms play major roles as agents of soil fertility and in supporting domestic animal production.

Uses of Microorganisms in Our Daily Life

- We use microorganisms in our daily lives as following:
- **Dairy Products:** Bacteria helps in the fermentation that helps make different forms of dairy products like curd, butter, cheese and buttermilk.
- **Streptococcus** is the type of bacteria that is used in the commercial production of dairy products.
- **Bread Baking:** A species of Streptococcus is added to the dough before you start making bread to bring about the fermentation.
- **Organic Acids:** Fungi is used in the preparation of many organic acids.
- Rhizopus and Penicillium are two fungi used in the fermentation of fruits and sugar-containing syrups.
- The acids derived and manufactured exploiting fungi are acetic acid, citric acid, lactic acid, and gluconic acid.
- **Fertility of Soil:** Microorganisms play an essential role in maintaining the fertility of the earth.
- They are helpful in the composting process that in turn forms manure.
- When microorganisms are present in the soil, they help the ground aerate better and enrich the soil with nitrates and other essential nutrients, which allow the crops to have an abundant harvest.

Historical Roots of Microbiology

Although the existence of creatures too small to be seen with the naked eye had long been suspected, their discovery was linked to the invention of the microscope.

- **Robert Hooke (1635–1703)**, an English mathematician and natural historian, was also an excellent microscopist.
  - In his famous book **Micrographia (1665)**, the first book devoted to microscopic observations, Hooke illustrated, among many other things, the fruiting structures of molds.
  - This was the first known description of **microorganisms**.
- The first person to see bacteria was the Dutch draper and amateur microscope builder **Anton van Leeuwenhoek (1632–1723)**.
  - In **1684**, van Leeuwenhoek, who was aware of the work of Hooke, used extremely simple microscopes of his own construction to examine the microbial content of a variety of natural substances.
  - Van Leeuwenhoek's microscopes were crude by today's standards, but by careful manipulation and focusing he was able to see bacteria.
  - Microorganisms considerably smaller than molds.

UNIT - IV

ECOLOGY AND ENVIRONMENT

1

CHAPTER

Introduction to Environment

The environment means everything that surrounds us—our house, garden, town, shops, hills, rivers, ocean, the air, soil, sunlight, etc. and also the plants and animals around us. All living and non-living things that occur naturally on earth constitute the natural environment. In order to nurture our environment we need to understand its various components and their interrelationships.

Environment is the sum total of all the external forces, influences and conditions, which affect the life development and maturation of living organisms. Environmental studies deals with every issue that affects an organism.

- It is an applied science as it's seeks practical answers to making human civilization sustainable on the earth's finite resources. It is the science of physical phenomena in the environment.
- It embraces all those disciplines which are concerned with the **physical, chemical, and biological** surroundings in which organisms live.

Components of Environment

Non- living and living things constitute an ecosystem. Accordingly they are termed as abiotic and biotic components.

A. Abiotic Components: Abiotic components are the non-living physical and chemical factors in the environment of an ecosystem. It includes:

(i) Light
- Sunlight provides energy.
- Green plants utilize sunlight for photosynthesis for synthesizing food for themselves as well as all other living organisms.

(ii) Rainfall
- Water is essential for all living beings. Majority of biochemical reactions take place in an aqueous medium.
- Water helps to regulate body temperature. Further,
- Water bodies form the habitat for many aquatic plants and animals.

(iii) Temperature
- Temperature is a critical factor of the environment which greatly influences survival of organisms.
- Organisms can tolerate only a certain range of temperature and humidity.

(iv) Atmosphere
- The earth's atmosphere is made of **21% oxygen, 78% nitrogen and 0.038% carbon dioxide.**
- Rests are inert gases (0.93% Argon, Neon etc.)

(v) Substratum (Soil)
- Organisms may be terrestrial or aquatic.
- Land is covered by soil and a wide variety of microbes, protozoa, fungi and small animals (invertebrates) thrive in it.
- Roots of plants pierce through the soil to tap water and nutrients.

B. Biotic Components: Biotic components are the organisms which include plants, animals and micro-organisms in an ecosystem. Depending on the mode of nutrition, members of a biotic community are categorised into autotrophs, heterotrophs and saprotrophs.

(i) Autotrophs: Prepare food through photosynthesis for all living organisms.

In terrestrial ecosystems, the autotrophs are mainly the rooted plants while in aquatic ecosystem, Floating plants called phytoplankton and shallow water rooted plants called macrophytes are the examples of autotrophs

(ii) Heterotrophs: These are called consumers which feed on plants and animals.

Consumers include herbivores (that eat plant material) and carnivores (which eat other animals).

(iii) Saprotrophs: These also called decomposers feed on dead and decaying matter. They break down the complex organic compounds of dead plants and animals into simpler forms and return them back into the environment.

Decomposers form an important link between the living and non-living component of the ecosystem.

Some bacteria and fungi belong to this category.

Segments of Environment

The environment consists of four segments as follows:

1. **Atmosphere:** The atmosphere implies the protective **blanket of gases,** surrounding the earth:

2

CHAPTER

Ecology and Ecosystem

Earth is the only planet in the solar system that supports life. The portion of the earth which sustains life is called biosphere. Biosphere is very huge and cannot be studied as a single entity. It is divided into many distinct functional units called ecosystems. In this chapter we will study the structure and functions of ecosystem and how it is different from other aspects such as ecology.

The term 'ecosystem' was coined by **A.G. Tansley in 1935**. An ecosystem is a functional unit of nature encompassing complex interaction between its biotic (living) and abiotic (non-living) components. For example- a pond is a good example of ecosystem.

Ecology

The term ecology was first coined in **1869** by the German biologist **Ernst Haeckel**. Ecology may be defined as the scientific study of the relationship of living organisms with each other and with their environment.

- Thus while ecology is a broader concept and encompasses all living organisms and their environment, Ecosystem is a narrower concept and focuses specifically on particular area.

Levels of Ecological Organization

Ecology not only deals with the study of the relationship of individual organisms with their environment, but also with the study of organisms, populations, communities, ecosystems, biomes, and biosphere as a whole. These are six Levels of Organization, and all levels are listed according to their size in increasing order – from small to large.

Organism

- It is the lowest level of organization, which includes both unicellular and **multicellular organisms**. All the living species in this level exhibit all the characteristics required for the existence of life. It includes plant, animal, bacterium or fungi etc.

Population

- A population is a group of individuals of a **single species living together** within a particular geographic area. They interbreed and compete with each other for resources.

The Characteristics of Population

- ***Density of Population:*** The number of individuals per unit area at a given time is termed as population density.
- ***Natality (Birth Rate):*** The rate at which new individuals are born and added to a population under given environmental conditions is called Natality.
- ***Mortality (Death Rate):*** Loss of individuals from a population due to death under given environmental conditions is called mortality.
- ***Dispersal:*** The movement of individuals of a population out of a region on a permanent basis is termed emigration.
- While immigration refers to the movement of individuals into a new area.
- ***Age Distribution:*** Age distribution refers to the proportions of individuals of different age groups in a population.
- ***Sex Ratio:*** Sex ratio is an important aspect of population. It refers to the ratio between female and male individuals in a population.

Community

- It refers to several populations that interact and inhabit a common environment and are interdependent. The climate determines the type of environment, hence, the type of organisms in a community.

It is of two types based on size and degree of relative independence:

- **Major Communities:** Their size is large and relatively independent. They depend only on the sun's energy from outside. E.g.Tropical Evergreen Forests.
- **Minor Communities:** These are dependent on neighbouring communities and are often called societies. They are smaller in size such as "a mat of lichen on a cow dung pad".

Ecosystem

- It is a set of all living species and abiotic components existing and interacting in a given area. There is an interaction with both **living and non-living components of the environment.** For Example: Grassland ecosystem or wetland ecosystem. We will study different ecosystems in coming sections.

3 CHAPTER

Biodiversity and Conservation

Biodiversity is all the different kinds of life you'll find in one area—the variety of animals, plants, fungi, and even microorganisms like bacteria that make up our natural world. Each of these species and organisms work together in ecosystems, like an intricate web, to maintain balance and support life. In this chapter we will deal with different aspects of biodiversity and issues related to its conservation.

Biological Diversity is sum total of all the variety of living organisms on earth constitute biodiversity. In our biosphere immense diversity (or heterogeneity) exists not only at the species level but at all levels of biological organization ranging from macromolecules within cells to biomes.

Biodiversity

Biodiversity is the term popularized by the socio-biologist **Edward Wilson** to describe the combined diversity at all the levels of biological organization.

- Biological diversity is usually considered at three different levels:
  - Genetic diversity i.e. at genetic level;
  - Species diversity i.e. at the level of species; &
  - Ecosystem diversity i.e. at the level of ecosystem.

Genetic Diversity

- Each species, varying from bacteria to higher plants and animals, stores an immense amount of genetic information.
- Genetic diversity refers to the variety of genes contained within species of plants, animals and micro-organisms.
- For example, the number of genes is about 450-700 in mycoplasma, 4000 in bacteria, 13,000 in Fruit-fly; 32,000 – 50,000 in rice; and 35,000 to 45,000 in human beings (Homo sapiens).
- A species has more genetic variation, it can adapt better to the changed environmental conditions. Thus greater diversity is always good thing from the perspective of ecosystem.
- Lower diversity in a species leads to genetic uniformity of genetically similar crop plants.
- This homogeneity is desirable in producing uniform quality of grain.
- New genetic variation in individuals occurs by gene and chromosomal mutation, and in organisms with sexual reproduction may be spread across the population by recombination.

Species Diversity

- Species diversity refers to the **variety of species living within a geographical area.** For Example: the Western Ghats have greater amphibian species diversity than the Eastern Ghats.
- When taxonomically unrelated species are present in an area, the area represents greater species diversity as compared to an area represented by taxonomically related species.
- India is a country of vast diversity and it is among the 12 "mega-diversity" countries in the world.
- Species diversity can be measured in terms of following.
  - **Species richness**: refers to the number of various species in a defined area.
  - **Species abundance**: refers to the relative numbers among species.
  - **Taxonomic or phylogenetic diversity**: refers to the genetic relationships between different groups of species.

Ecosystem Diversity

- Ecosystem diversity deals with the study of different ecosystems in a certain location and their overall effects on humans and the environment as a whole. It refers to the presence of different types of ecosystems.
- The tropical south India with rich species diversity will have altogether different structure compared to the desert ecosystem which has far less number of plant and animal species.
- India has very diverse terrestrial and aquatic ecosystems ranging from ice-capped Himalayas to deserts, from arid scrub to grassland to wetlands and tropical rainforests, from coral reefs to the deep sea.
- A very large number of species found in these ecosystems are endemic or found in these areas only in India.
- The endemics are concentrated mainly in north-east, western-Ghats, North-West Himalaya, and Andaman and Nicobar Islands.
- Indian region is also notable for endemic fauna.

4 CHAPTER

Environment and Natural Resources

Resource is anything useful or can be made useful to humans to meet their needs. Thus natural resources are those which are directly supplied by our environment. When human population was small and they lived a controlled and moderate life, the resource use was limited. But increasing population and economic activity resulted in excessive material consumption which is putting heavy burden on natural resource base and causing severe damage to the environment. Thus it is important to know about all such resources and how we use or should use such gifts of nature.

The term "natural resource" means anything that we use from our environment to achieve our objective. For example, we require bricks, cement, iron, wood etc. to construct a building. All these items are called resources for construction of building. A resource can be defined as 'any natural or artificial substance, energy or organism, which is used by human being for its welfare. These resources can be two types:

(a) Natural resources, and

(b) Artificial resources.

Natural Resources

All that nature has provided such as soil, air, water, minerals, coal, sunshine (sunlight), animals and plants, etc., are known as **natural resources**.

- The resources, which have been developed by human beings during the growth of civilization, are called **artificial resources**.
- For example, biogas, thermal electricity, plastics. These man-made resources are generally derived from some other natural resources. For example, plastics from the natural resource, petroleum.

Classification of Natural Resources

- The air we breathe and the light we get from the sun are available in unlimited quantity. But what about coal, forest, and petroleum. The stock of these resources is limited and is depleting day by day.
- Natural resources are classified into exhaustible and inexhaustible resources:
  - **Inexhaustible Resources**: The resources which cannot be exhausted by human consumption are called inexhaustible resources.
  - These include energy sources like **solar radiation, wind power, water power** (flowing streams) and **tidal power,** and substances like sand, clay, air, water in oceans, etc.
  - **Exhaustible Resources**: On the other hand, there are some resources, which are available in limited quantities and are going to be exhausted as a result of continuous use.
  - These are called exhaustible resources. For example, the stock of coal in the earth is limited and one day there will be no more coal available for our use.
  - These are further divided into renewable and non-renewable resources.

Non-Renewable Resources

The resources, which cannot be replaced after the use, are known as non-renewable Resources. These include **minerals** (copper, iron etc.) **fossil fuels** (coal, oil etc.). Even wildlife species (rare plants and animals) belong to this category. These are a finite energy resource that means they are non-renewable resources and once consumed they are lost forever.

Let us look over some of the non-renewable energy resources:

Fossil Fuels

- Fossil fuels represent stored solar energy captured by plants in the past geological times.
- **Coal, petroleum and natural gas are called fossil fuels**, as they are the remains of prehistoric plants, animals and microscopic organisms that lived millions of year ago.
- These remain under the effect of intense heat and pressure underneath the earth's crust over long geological time and got transformed into fossil fuels.

Types of Fossil Fuels

- **Coal:** Coal is formed from plants and vegetation buried, 'in situ' or drifted in from outside to a place, which got covered by deposits of sediments.
  - Coal is a solid fossil fuel and a sedimentary rock composed primarily of carbon.
  - There are three basic grades of coal: **i) lignite (brown coal), ii) bituminous (soft coal) and iii) anthracite (hard coal).**

5 CHAPTER

Global Warming

There is much to celebrate and appreciate about the world we live in. It includes our environment. However, mostly due to our actions we are altering the very environment which sustains us. It would be very difficult for us to live in an unfriendly environment. This lesson exposes you to the various global environmental issues or concerns and possible strategies to cope with them.

Global warming is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere.

Global Warming

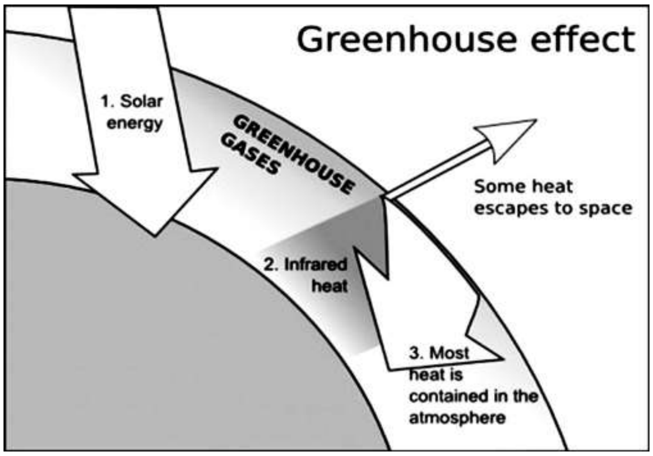
Since the pre-industrial period, human activities are estimated to have increased Earth's global average temperature by about 1 degree Celsius (1.8 degrees Fahrenheit).

- A number that is currently increasing by more than 0.2 degrees Celsius (0.36 degrees Fahrenheit) per decade.
- The current warming trend is unequivocally the result of human activity since the 1950s and is proceeding at an unprecedented rate over millennia.
- Global warming causes climate change, which poses a serious threat to life on Earth in the forms of widespread flooding and extreme weather. Scientists continue to study global warming and its impact on Earth.

Greenhouse Effect

- The temperature surrounding the earth has been rising during the recent past. This is due to the 'greenhouse effect'.
- A green house is a glass chamber in which plants are grown to provide them warmth by trapping sun light. Sunlight (a form of energy) passes through the glass a
- It gets absorbed inside releasing heat radiations. Unlike sunlight, heat radiation cannot escape through glass; the heat generated there from, cannot escape out of the glass chamber.
- Thus, even on a cold winter day, the inside of a greenhouse can become quite warm to support plant growth.
- The phenomenon of heat build-up inside a glass chamber from the absorption of solar radiation is called **greenhouse effect**.

Global Warming



- Atmospheric gases like carbon dioxide, methane, nitrous oxide, water vapour, and chlorofluorocarbons are capable of trapping the out-going infrared radiation from the earth.
- Infra-red radiations trapped by the earth's surface cannot pass through these gases and to increase thermal energy or heat in the atmosphere.
- Thus, the temperature of the global atmosphere is increased.
- If greenhouse gases are not checked, by the turn of the century the temperature may rise by 50°C.
- This will melt the polar ice caps and increase the sea level leading to **coastal flooding, loss of coastal areas** and **ecosystems** like swamps and marshes, etc.

Greenhouse Gases: The common greenhouse gases and their sources of pollution are listed below:

(1) **CO_2** - from fossil fuel burning.

(2) **NO_2** - from fertilizer plants, automobile exhaust use and animal waste.

(3) **CH_4** - from bacterial decomposition, biogas, flooded rice fields.

(4) **CFCs** - from freon, (a refrigerant), aerosol sprays.

(5) **HALONS (halocarbons)** - from fire extinguishers etc.

6 CHAPTER

Environmental Pollution and Land Degradation

Developmental activities such as construction, transportation and manufacturing not only deplete the natural resources but also produce large amount of wastes that lead to pollution of air, water, soil, and oceans. It also causes global warming and acid rains. Untreated or improperly treated waste is a major cause of pollution of rivers and environmental degradation, causing ill health and loss of crop productivity. In this chapter, we will study the basics of different types of pollution.

Human activities directly or indirectly affect the environment adversely. Pollution is an addition of undesirable material into the environment as a result of human activities.

Pollution

A **pollutant** is defined as a **physical, chemical** or **biological substance** unintentionally released into the environment which is directly or indirectly harmful to humans and other living organisms.

- Automobiles emit from their tail pipes oxides of nitrogen, sulphur dioxide, carbon dioxide, carbon monoxide and a complex mixture of unburned hydrocarbons and black soot which pollute the atmosphere.
- Domestic sewage and run off from agricultural fields, laden with pesticides and fertilizers, pollute water bodies.

Types of Environmental Pollution

Pollution may be of the following types:

- Air pollution
- Noise pollution
- Water pollution
- Soil pollution
- Radioactive pollution
- Thermal pollution
- Food pollution
- Oil pollution
- Industrial pollution

A. Air Pollution

- Air pollution is a result of industrial and certain domestic activity. An ever increasing use of fossil fuels in power plants, industries, transportation, mining, construction of buildings, stone quarries had led to air pollution.
- Air pollution may be defined as the presence of any solid, liquid or gaseous substance including noise and radioactive radiation in the atmosphere in such concentration that may be directly and indirectly injurious to humans or other living organisms, plants, property or interferes with the normal environmental processes

Air pollutants are of two types:

(1) Suspended particulate matter

(2) Gaseous pollutants like carbon dioxide (CO_2), NOx, etc.

Suspended Particulate Matter

- Particulate matter suspended in air is dust and soot released from the industrial chimneys. Their size ranges from **0.001 to 500 μm in diameter.**
- **Particles less than 10μm float and move freely** with the air current. Particles which are more than 10μm in diameter settle down. Particles less than 0.02 μm form persistent aerosols.
- Major source of SPM (suspended particulate matter) are vehicles, power plants, construction activities, oil refinery, railway yard, market place, industries, etc.
- **Fly Ash:** Fly ash is ejected mostly by thermal power plants as by-products of coal burning operations. Fly ash pollutes air and water and may cause heavy metal pollution in water bodies.
- Fly ash affects vegetation as a result of its direct deposition on leaf surfaces or indirectly through its deposition on soil.
- **Lead and other Metals Particles:** Tetraethyl lead (TEL) is used as an anti-knock agent in petrol for smooth and easy running of vehicles.
- The lead particle coming out from the exhaust pipes of vehicles is mixed with air. If inhaled it produces injurious effects on kidney and liver and interferes with development of red blood cells. Lead mixed with water and food can create cumulative poisoning.

Gaseous Pollutants

- Power plants, industries, and different types of vehicles use petrol and diesel as fuel and release gaseous pollutants such as carbon dioxide, oxides of nitrogen and sulphur dioxide along with particulate matter in the form of smoke.

7

CHAPTER

Forestry and Environment

Forest refers to an area covered with trees or a dense growth of trees and underbrush covering a large tract. The Latin word 'Foris' means the outer part of settlements. The importance of forests for our survival is of many folds - from air we breathe to the wood we use, forests provide habitats for wildlife and livelihoods for humans. Forests also offer watershed protection, prevent soil erosion and landslides and help in mitigating climate change. In this lesson you will learn about different aspects of forestry.

"A forest is a large area of land with a lot of vegetation but dominated by various types of trees. These trees are usually of different species and are of different age. Wild animals may or may not be present."

- Humans have altered the ecosystems according to their own needs without thinking about the effects. The expansion of agriculture, urbanization and industrialization needed the land which was obtained by large scale clearing of forests.

Forests

Forests are large areas supporting rich growth of trees. Depending on the climate and type of trees they are generally grouped into:

Tropical Rain Forests

- It includes trees with **broad-leaves, deciduous or evergreen.** Such forest occur in warm climatic zones of the world with high rainfall. Trees are covered with epiphytes and the soil is rich in humus. Large numbers of animals inhabit such forests e.g. vines, creepers, lianas and orchids.

Temperate Deciduous Forests

- Most of the trees in such forests drop their leaves in winter and **new leaves grow in springs.** There are found in temperate warm and temperate cold climates e.g. oak, beach, heath, hickory, bassword, chestnuts, cypress.

Boreal or North Coniferous Forests

- Trees with **needle-like leaves** with persistent foliage and cone bearing reproductive organs. Found in cold or temperate cold climates e.g. Pine, Citrus (Deodar), Fir, etc.

Social Forestry

Social forestry is the forestry **by the people** and for the people, whose main purpose is to fulfil the needs of forestry which are **- manure, food, fruit, fibre and productive capacity.**

- Social forestry's main objective is to reconstruct the ecosystem and conserve the environment.
- In India, biomass constituted 85% of the rural energy and with a per capita consumption of 1.0 ton/year, about 50% of it was collected from forests.
- In 1976, the National Commission on Agriculture in India introduced the concept of Social Forestry to encourage those who were dependent on fuelwood, fodder and other forest products
- Social forestry programmes included a wide range of activities such as growing trees on farm bunds and roadsides.
- Developing woodlots on common properties and collection, processing and management of forest products by involving local communities.
- The major focus was on the extension of forestry programme to non-forest lands with the active involvement of local communities.
- In 1985, the **National Wastelands Development Board** was established by the Government of India to promote the production of fodder, fuel and minor timber on wastelands, by involving local communities and voluntary agencies.
- The **National Commission on Agriculture (NCA)** defined the scope of social forestry as follows:

A. Farm or Agro Forestry

- Raising rows of trees on bundhs or boundaries of the fields and individual trees in private agricultural lands
- As over 70% of the agricultural lands in India are dependent on rainfall, the crop yields are comparatively low.
- Promotion of tree based farming system has good potential to improve the **Land Equivalent Ratio (LER)** as well as crop yields
- The system of combining horticultural crops with fodder, fuel, NWFP and agricultural crops can ensure the supply of essential commodities.

8 CHAPTER

Environmental Crisis and Hazards

Disasters are not random and do not occur by accident. They are the convergence of hazards and vulnerable conditions. Disasters not only reveal underlying social, economic, political and environmental problems, but unfortunately contribute to worsening them. Such events pose serious challenges to development, as they erode hard-earned gains in terms of political, social and educational progress, as well as infrastructure and technological development.

Disaster is a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. Environment provides significant services to human activities that help in regulating hazards. Ecological conditions not only modify the frequency and magnitude of hazard events, but also affect natural barriers that can moderate the impacts of a disaster and protect communities.

- **Example:** Wetland ecosystems function as natural sponges that trap and slowly release surface water, rain, snowmelt, groundwater and floodwaters, while mangroves, dunes and reefs create physical barriers between communities and coastal hazards.
- There is a strong causal relationship between poverty, a degraded environment and higher disaster risk. People who live in marginal or environmentally degraded areas struggle on a daily basis to survive.
- Limited livelihood alternatives, competition over scarce resources, weak governance structures and lack of access to healthcare and other services can compromise a community's ability to respond to and recover from a hazard event.
- Environmental degradation, settlement patterns, livelihood choices and behaviour can all contribute to increase disaster risk, which in turn adversely affects human development and contributes to further environmental degradation.

Major Environmental Hazards

Cold Waves

- A cold wave is a weather phenomenon that is characterized by cooling of the air. A cold wave is a rapid fall in temperature within a **24 hour period**. This minimum temperature is dependent on the geographical region and time of year.
- Cold waves affect much larger areas than **blizzard storms, ice storms,** and other meteorological hazards.

Characteristics of Cold Waves

- A cold wave develops when cold air masses over large areas are brought in. It occurs mainly during winter months when cold air masses are transported from the polar region.
- In those northern areas cold air develops to a large reservoir due to low or even missing solar radiation during short autumn and winter days. Particular weather conditions can transport these air masses to the interior of continents.
- Cold air masses are only slowly moving, therefore, a cold wave will normally last for several days.
- The cold air masses transport only little moisture. Precipitation occurs as snow or sleet due to temperatures falling below freezing point.
- Cold waves can also be accompanied by strong winds. Such a phenomenon is called winter storm.

Effects of Cold Waves

- **Death of Livestock and Wildlife:** A cold wave can cause death and injury to livestock and wildlife. If a cold wave is accompanied by heavy and persistent snow, grazing animals may be unable to reach needed food and die of **hypothermia or starvation.**
- **Diseases and Mortality:** Cold spells are associated with increased mortality rates in populations around the world. When exposed to cold waves, humans require greater caloric intake for themselves and animals. It leads to rise in diseases like **cold, flu, and pneumonia**.
- **Freezing of Water Pipelines:** Extreme winter cold often causes poorly insulated water pipelines and main lines to freeze. Even some poorly protected indoor plumbing ruptures as water expands within them, causing much damage to property and costly insurance claims.
- **Failure of Electrical Power:** Demand for electrical power and fuels rises dramatically during such times, even though the generation of electrical power may fail due to the freezing of water necessary for the generation of hydroelectricity.

9 CHAPTER Environmental Legislation

Environmental law plays a crucial role in regulating the use of natural resources and in protecting the environment. The success of environmental legislations mainly depends on the way they are enforced. Legislation also serves as a valuable tool for educating masses about their responsibility in maintaining healthy environment.

The genesis of various legislations in the country lies in the environmental problems. There should be effective legislations to protect the environment or else the need for resources by the growing population will create havoc on the environment. The other important aspect is enforcement of these laws. To safeguard our environment from further degradation and pollution these must be enforce laws forcefully and effectively

- In the recent past, numerous environmental problems have become threatening for human welfare.
- An important aspect of environmental problems is that their impact is not confined to the source area but spills over far and wide area.
- Effective legislation is needed in order to prevent misuse and degradation of the environment.
- To curb the destructive practices of unscrupulous people, forest mafia groups, poachers, polluters and over exploitation of environmental resources, effective legislation is necessary.
- Pollution is an important factor and it does not observe **political territories or legislative jurisdictions.** Thus environmental problems are intrinsically global in nature.
- Therefore, to prevent such problems environmental legislation is not needed only at the national level but also at the international level.

National Legislation

After the **United Nations Conference on Human Environment,** held in **Stockholm in 1972,** Indian Constitution was amended to include protection of the environment as a constitutional mandate.

- Although India had an Elephant's Preservation Act of 1879 and a Forest Act of 1927, environment related **legislation came very late in 1972 with Wild Life Protection Act 1971. It was amended in 2022.**
- The forty second amendment added Clause (g) to **Article 51A** of the Indian constitution made it a fundamental duty to protect and improve the natural environment.

  "It shall to be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and have compassion for living creatures."
- There is a directive, given to the State as one of the **Directive Principles of State Policy** regarding the protection and improvement of the environment. **Article 48A** states, "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country".
- The department of Environment was established in India in 1980 to ensure a healthy environment for the country. This later became the Ministry of Environment and Forests in 1985. This Ministry has overall responsibility for administering and enforcing environmental legislations and policies.
- The constitutional provisions are backed by a number of legislations – **Acts and rules.** Most of our environmental legislations are Acts of the Parliament or the State Legislatures.
- These Acts generally delegate powers to regulating agencies, to make rules for the purpose of their implementation.
- The **Environment Protection Act of 1986 (EPA)** came into force soon after the Bhopal Gas Tragedy and is considered umbrella legislation as it fills many lacunae in the existing legislations. Thereafter, a large number of environmental legislations have been passed to deal with specific environmental problems.

National Initiatives for Pollution Control

Among all the components of the environment air and water are necessary to fulfil the basic survival needs of all organisms. So, to protect them from degradation, the following initiatives have been taken:

The Air (Prevention and Control of Pollution) Act of 1981

The main objective of this Act is to improve the quality of air and to prevent, control and abate air pollution in the country.

Glossary

A

- **Abiotic Resources** are the resources which are considered abiotic and therefore not renewable. Zinc ore and crude oil are examples of abiotic resources.
- **Acceptable Daily Intake** is the highest daily amount of a substance that may be consumed over a lifetime without adverse effects.
- **Acid Deposition** is a comprehensive term for the various ways **acidic compounds precipitate** from the atmosphere and deposit onto surfaces. It can include:
  - wet deposition by means of acid rain, fog, and snow; and
  - dry deposition of acidic particles (aerosols).
- **Acid Rain** is rain mixed mainly with **nitric** and **sulphuric acid** that arise from emissions released during the burning of fossil fuels.
- **Acute Exposure** is one or a series of short-term exposures generally lasting less than 24 hours.
- **Adaptability** refers to the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate.
  - Adaptation can be spontaneous or planned, and be carried out in response to or in anticipation of changes in conditions.
- **Aerobic Composting** is a method of composting organic waste using bacteria that need oxygen. This requires that the waste be exposed to air either by turning or by forcing air through pipes that pass through the material.
- **Aerosols** are particles of solid or liquid matter that can remain suspended in air from a few minutes to many months depending on the particle size and weight.
- **Air Monitoring** is the sampling for and measuring of pollutants present in the atmosphere.
- **Air Quality Standard (AQS)** is the prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health.
- **Alternative Fuel** are fuels such as methanol, ethanol, natural gas, and liquid petroleum gas that are cleaner and help to meet mobile and stationary emission standards. These fuels may be used in place of less clean fuels for powering motor vehicles.
- **Ambient Air** is the air occurring at a particular time and place outside of structures. Often used interchangeably with outdoor air.
- **Ambient Air Quality Standards (AAQS)** are health and welfare-based standards for outdoor air which identify the maximum acceptable average concentrations of air pollutants during a specified period of time.
- **Ammonia** is a pungent colorless gaseous compound of nitrogen and hydrogen that is very soluble in water and can easily be condensed into a liquid by cold and pressure. **Ammonia reacts with NOx** to form ammonium nitrate -- a major PM2.5 component in the Western United States.
- **Asbestos** is a mineral fiber that can **pollute air or water and cause cancer or asbestosis** when inhaled.
- **Aquaculture**, or pisciculture is the breeding or rearing of freshwater or marine fish in captivity, fish farming.

B

- **Binding Targets** refers to environmental standards that are to be met in the future.
- **Biodegradable Material** is any organic material that can be broken down by microorganisms into **simpler, more stable compounds.** Most organic waste such as **foods, paper, etc are biodegradable**.
- **Biomass** is the living materials (wood, vegetation, etc.) grown or produced expressly for use as fuel.
- **Biomass Burning** is the burning of organic matter for energy production, forest clearing and agricultural purposes. Carbon dioxide is a bi-product of biomass burning
- **Biomass fuel** is wood and forest residues, animal manure and waste, grains, crops and aquatic plants are some common biomass fuels.
- **Biome** is a climatic region characterised by its dominant vegetation.
- **Bio Reserves** are the areas with rich ecosystems and species diversity are reserved for conservation.
- **Biota** is the flora and fauna of an area.
- **Biotic** are the resources which are considered biotic and therefore renewable. The rainforests and tigers are examples of biotic resources.
- **Brackish Water** contains 500 to 3000ppm of sodium chloride.