Monthly test - 2

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(Physics)
Geography
Unit 1 The Universe and Solar System

Pathway:

- This lesson focuses on the universe and the members of the solar system. It also deals with the motions of the Earth and their resultant effects. It also talks about the four spheres of the Earth.

Teacher: Students, do you all know where you reside?
Students: Yes, teacher.
Teacher: (Points out a student) Iniya, do you know your address? Can you tell me your full address?
Iniya: Yes teacher. My address is Iniya, 24, Bharathiar street, Thirunagar, Madurai - 625 006.
Teacher: Good. Iniya, where is Thirunagar?
Iniya: Thirunagar is in Madurai.
Teacher: Children, tell me where Madurai is?
Students: It is in Tamil Nadu.
Teacher: Good. Where is Tamil Nadu?
Students: In India ...teacher.
Teacher: Now tell me where India is?
Students: India is in the continent of Asia, teacher.
Teacher: Excellent! Can anyone tell me where is the continent of Asia?
Students: Yes teacher. It is on the Earth.
Teacher: Ok children, tell me where the Earth is located.
Students: (Remain silent and after sometime they reply in chorus) No. We don't know.
Teacher: Now, let me explain. The Earth is the third planet in the Solar System. The solar system is in the galaxy. It is named as the Milky way Galaxy. There are millions of such galaxies in the Universe.
Iniya: Teacher, shall I say the address of our Earth?
Teacher: Address of our Earth? It's interesting Iniya. Tell us the address.
Iniya: Miss. Earth, No.3. Solar System, Milkyway Galaxy, Universe. (Everyone clapped and the teacher appreciates Iniya.)
Teacher: That was very good Iniya. Now let us know about the solar system, galaxy, the Universe and all other bodies in detail in this lesson.

- Numerous stars and celestial bodies came into existence by a massive explosion called Big Bang. These celestial bodies together are called The Universe. It is also referred to as the Cosmos. The stars that you see are so far away that they appear to be small, but they are really huge in size.

The study of the Universe is called Cosmology. The term Cosmos is derived from the

Greek word 'Kosmos'.

1. Universe

- The Universe is a vast expanse of space. Most astronomers believe that the Universe came into existence after the Big Bang explosion that took place about 15 billion years ago. The universe consists of billions of galaxies, stars, planets, comets, asteroids, meteoroids and natural satellites. These are collectively called as celestial bodies, which are located far away from each other. A Light year is the unit used to measure the distance between the celestial bodies.

A light-year is the distance traversed by light in a year at a velocity of 300,000 km per second. Sound travels at a speed of 330 m per second.

Galaxy

- It is a huge cluster of stars which are held together by gravitational force. Most of the galaxies are scattered in space, but some remain in groups. The Milky Way Galaxy was formed about 5 billion years after the Big Bang explosion. Our solar system is a part of the Milky Way galaxy. Andromeda galaxy is the nearest to the Earth apart from the 'Magellanic Clouds' galaxy

2. The Solar System

- The word 'solar' is derived from the Roman word 'sol', which means 'Sun God'. The solar system is believed to have formed about 4.5 billion years ago. The solar system is a gravitationally bound system which comprises of the Sun, the eight planets, dwarf planets, satellites, comets, asteroids and meteoroids.

The Sun

- The Sun is at the centre of the solar system. Each member of the solar system revolves around the Sun. The Sun is so huge that it accounts for 99.8 percent of the entire mass of the solar system. The Sun is made up of extremely hot gases like Hydrogen and Helium. The Sun is a star. It is self-luminous so it gives light on its own. The surface temperature of the Sun is about 6,000° C. It is the source of light and heat energy to the entire solar system. Sunlight takes about 8.3 minutes to reach the Earth.

1.3 million Earths fit inside the Sun. Imagine how big the Sun is.

GEO CONNECT: The ancient Tamils knew that the planets went around the Sun. For example, in Tamil literature Sirupanatruppadai, the line வாள் நிற விசும்பின் கோள் மீன் சூழ்ந்த இளங்கதிர் ஞாயிறு mentions that the Sun is surrounded by planets.

Planets

- The word planet means wanderer. There are eight planets in the solar system. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. All the planets rotate anti-clockwise (from west to east) on their own axes except Venus and Uranus. The elliptical path in which the planets move around the Sun is known as orbit. The eight planets revolve in their respective orbits because of the gravitational pull of the Sun. They do not move out of their paths or away from the solar system.

- The four planets nearer to the Sun are called Inner or Terrestrial Planets (Mercury, Venus, Earth and Mars). The inner planets are comparatively smaller in size and are composed of rocks. The surface of inner planets has mountains, volcanoes and craters. The last four planets are called as Outer Planets or Jovian Planets (Jupiter, Saturn, Uranus, and Neptune). They are also called Gaseous Giants. An asteroid belt is found between Mars and Jupiter.

Mnemonic to remember the order of planets: My Very Educated Mother Just Showed Us Neptune.

Mercury (The Nearest Planet)

- Mercury is the smallest and closest planet to the Sun. It is named after the Roman deity 'Mercury', the messenger to the Gods. It is an airless and waterless planet. It does not have an atmosphere and so experiences extremes of temperature. It has no natural satellites. Mercury can be viewed in the morning and evening with naked eye.

Venus (The Hottest Planet)

- Venus is the second planet from the Sun. It is called Earth's twin, as it is almost the same size as the Earth. It has the longest rotation Venus period (243 days) among the planets in the Solar system. It rotates in the opposite direction to all other planets except Uranus. It has no natural satellites like Mercury. It is named after the Roman goddess of love and beauty. It is often visible in the mornings and the evenings and so it is frequently called as the Morning Star and the Evening Star. After the Moon, it is the brightest natural object in the night sky.

Earth (The Living Planet)

- The Earth is the third planet from the Sun and the fifth largest planet in the solar system. It is called 'blue planet' or 'watery planet' because three-fourth of the Earth is covered by water. The Earth is the only planet in the solar system which is not named after any Greek or Roman deity. It is the only planet known to support life. The polar diameter of the Earth is 12, 714 km and the equatorial diameter is 12, 756 km. The Earth revolves around the Sun at a speed of about 30 km per second. Life is possible on Earth because of the presence of land, air and water. The only natural satellite of the Earth is the Moon.

The distance between the Sun and the Earth is about 150 million kilometre. A flight flying at a speed of 800 km per hour from the Earth would take 21 years to reach the Sun.

Mars (The Red Planet)

- Mars is the fourth planet from the Sun and the second smallest planet in the solar system, after Mercury. It is named after the Roman God of war. It appears red in colour due to the presence of iron oxide on its surface. So, it is often described as The Red Planet. It has a thin atmosphere. It also has polar ice caps like the Earth. Mars has two natural satellites namely Phobos and Deimos. Many orbiters and rovers have been launched to explore this planet.

On 24th September, 2014 Mangalyan (Mars Orbiter Mission - MOM), launched by the Indian Space Research Organization (ISRO), reached the orbit of Mars to analyze its atmosphere and topography. ISRO has now become the fourth space agency to reach Mars after the Soviet Space programme, NASA and the European Space Agency.

Jupiter (the Largest Planet)

- Jupiter is the f fth planet from the Sun and the largest planet in the solar system. It is named after the king of the Roman gods. It is the third brightest object in the night sky, after moon and Venus. It is the fastest spinning planet in the solar system. It is called a gas giant planet. Its atmosphere is made up of mostly Hydrogen and Helium like the Sun. It has the largest number of natural satellites. Io, Europa, Ganymede and Callisto are a few large satellites of Jupiter.

Saturn (The Ringed planet)

- Saturn is the sixth planet from the Sun and the second largest planet in the solar system, after Jupiter. It is named after the Roman god of agriculture. Saturn has many rings around it. These rings are huge and are mostly made up of ice, rocks and dust particles.

- Saturn has 62 natural satellites around it. Titan, Saturn’s largest moon, is the only satellite in the solar system that has clouds and dense atmosphere composed of nitrogen and methane. The specific gravity of Saturn is less than that of water.

Uranus (The Somersaulting planet)

- Uranus is the seventh planet from the Sun. It was the first to be discovered with a telescope by the astronomer William Herschel in 1781. It appears green due to the presence of ethane. It is named after the Greek god of the sky. It rotates on its axis from east to west like Venus. Its axis is tilted so much that, it appears to orbit the Sun on its sides like a rolling ball. Uranus has 27 natural satellites, of which Titania is the largest.

Neptune (The coldest Planet)

- Neptune is the eighth and the farthest planet from the Sun. There are strong winds in this planet. It is named after the Roman god of sea. Neptune has 14 natural satellites, the largest being Triton. Because of its distance from the Sun, Neptune is one of the coldest planets in the solar system. The striking blue and white features of Neptune help to distinguish it from Uranus.

The Dwarf Planets

- Dwarf planets are small celestial bodies found beyond the planet Neptune. They are extremely cold and dark. They are almost spherical in shape, but unlike planets they can share their orbit with other dwarf planets. The five dwarf planets of the solar system are Pluto, Ceres, Eris, Makemake and Haumea.

The Moon - Earth's Satellite

- Satellites are celestial objects, which revolve around the planets. The moon is the Earth's only satellite. It revolves around the Earth once in every 27 days and 8 hours. It takes about the same time for it to complete one rotation around its axis. It has no atmosphere. The surface of the moon is characterized by craters created by the impact of meteors. The distance between the moon and the Earth is about 3, 84,400 km. The size of the moon is one-quarter of the Earth. The Moon is the only celestial body where humans have landed.

Asteroids

- Asteroids are small solid objects that move ISRO launched India's first ever Moon mission, Chandrayaan - 1 in 2008. Around the Sun. They are found as a belt between Mars and Jupiter. They are too small to be called as planets. They are also known as Planetoids or Minor Planets.

Comets

- A comet is a celestial object made up of a head and a tail. The head of a comet consists of solid particles held together by ice and the tail is made of gases. Halley's Comet is the most famous comet which comes close to the Earth every 76 years. It last appeared in 1986 and will next appear in 2061.

Meteors and Meteorites

- A meteor is a stone like or metallic body. When entering into the Earth's atmosphere, most of them burn. As they often appear as streaks of light in the sky, they are also known as Shooting Stars. Meteors which strike the Earth's surface are called meteorites.

3. Motions of the Earth

- Have you noticed the Sun in the morning, afternoon or evening? Is it in the same place throughout the day? No. It is seen in the east in the morning, overhead in the afternoon and in the west in the evening. Have you ever thought of the reason behind it? This is because of the constant moving of the Earth around the Sun. It seems that the Sun is moving, but it is not so. This is similar to what you experience when you are travelling in a bus or train. When you look out of the window, the trees, lamp posts and other objects seem to be moving, but actually it is you who are moving. To understand the motions of the Earth better, you need to be familiar with the shape and inclination of the Earth.

Shape and Inclination of the Earth

- The Earth is spherical in shape. It rotates on its axis, which is an imaginary line that runs from the North Pole to the South Pole passing through the centre of the Earth. The Earth's axis is always tilted or inclined from the vertical by an angle of 23½°. It makes an angle of 66½° with the plane of the Earth's orbit.

- The velocity of the Earth's rotation varies from 1670 km per hour at the equator to 845 km per hour at 60° N and S latitudes and zero at the poles.

Rotation

- It is the spinning movement of the Earth on its axis. The Earth rotates from west to east (anticlockwise) and takes 23 hours 56 minutes and 4.09 seconds to complete one rotation. The time taken by the Earth to complete one rotation is called a day. The rotation of the Earth causes day and night. As the Earth is spherical in shape, only one half of it is illuminated by the Sun at a time. The other half remains dark. The illuminated portion of the Earth experiences day, whereas the darkened part of the Earth experiences night. The line which divides the surface of the Earth into a lighted half and a dark half is called the Terminator Line.

The Midnight Sun is a natural phenomenon that occurs in the summer months in places north of the Arctic Circle or south of the Antarctic Circle, when the Sun remains overhead 24 hours a day.

Revolution

- It is the movement of the Earth around the Sun on its elliptical path. The Earth takes 365 ¼ days for it to complete one revolution. It revolves around the Sun at a speed of 30 km per second. For the sake of convenience, we take it as 365 days and call it a year. The remaining quarter day is added once in every four years in the month of February. That is why February has 29 days once in four years. It is called a Leap Year. The inclination of the Earth on its axis and its revolution around the Sun cause different seasons.

- The Northern Hemisphere is inclined towards the Sun for six months from 21st March to 23rd September while the Southern Hemisphere is tilted away from the Sun.

- From Sep 23rd to March 21st the southern hemisphere is inclined towards the Sun and the northern hemisphere faces away from the Sun. The changing position of the Earth in its orbit during revolution gives the impression that the Sun is continuously moving north and south of the equator. The equator faces the Sun directly on 21 March and 23 September. These two days are called Equinoxes, during which the day and night are equal throughout the Earth.

Perihelion is the Earth's closest position to the Sun. Aphelion is the farthest position of the Earth from the Sun.

- On 21st June, the Tropic of Cancer faces the Sun. This is known as Summer Solstice. It is the longest day in the Northern Hemisphere and longest night (shortest day) in the Southern Hemisphere. On 22nd December, the Tropic of Capricorn faces the Sun. It is called as Winter Solstice. It is the longest day in the Southern Hemisphere and longest night (shortest day) in the Northern Hemisphere.

4. Spheres of the Earth

- The Earth is the most suitable planet to support life. It has three major components that we call as the realms of the Earth-lithosphere, hydrosphere and atmosphere. The three components along with suitable climate make life possible on Earth. All living things exist in a narrow zone called the biosphere. Now let us have a close look at each of the spheres.

Lithosphere

- The word lithosphere is derived from the Greek word Lithos, which means rocky. The Lithosphere is the land on which we live. It is the solid outer layer of the Earth consisting of rocks and soils.

Hydrosphere

- The word Hydro means water in Greek. The hydrosphere consists of water bodies such as oceans, seas, rivers, lakes, ice caps on mountains and water vapour in the atmosphere.

Atmosphere

- The word Atmo means air in Greek. Atmosphere is the envelope of air that surrounds the Earth. Different types of gases make up the atmosphere. The major gases are Nitrogen (78%) and Oxygen (21%). The other gases like Carbon dioxide, Hydrogen, Helium, Argon, and Ozone are present in meager amounts.

Biosphere

- The narrow belt of interaction among the lithosphere, the hydrosphere and the atmosphere, where life exists is known as Biosphere. Bio means life in Greek. It consists of distinct zones. Each zone has its own climate, plant and animal life. These zones are known as ecosystems.

The Gulf of Mannar Biosphere Reserve in the Indian Ocean covers an area of 10,500 sq.km in the ocean.

Wrap Up

- ❖ The Universe was formed 15 billion years after the Big Bang explosion
- ❖ Many galaxies are found in the Universe.
- ❖ Our solar system is a part of the Milky Way Galaxy.
- ❖ The Sun is so huge that it accounts for 99.8 percent of the entire mass of the solar system.
- ❖ All planets rotate anti-clockwise on their own axes except Venus and Uranus.
- ❖ Asteroids are found as a belt between Mars and Jupiter.
- ❖ The rotation of the Earth causes day and night.
- ❖ The revolution of the Earth causes seasons.
- ❖ Summer solstice is the longest day in the Northern Hemisphere.
- ❖ The presence of land, water and air along with suitable climate makes life possible on Earth.

9^{th} book
Unit – 9 – Universe

Introduction

- In the earlier days, before the invention of astronomical instruments, people thought that Earth is the centre of all the objects in the space. This was known as the geocentric model, held by Greek astronomer Ptolemy (2nd Century), Indian astronomer Aryabhatta (5th Century) and many astronomers around the world. Later Polish astronomer Nicolaus Copernicus proposed the heliocentric model (helios = Sun), with Sun at the centre of the solar system. Invention of the telescope in the Netherlands, in 1608, created a revolution in astronomy. In this lesson, we will study about the building blocks of the universe, Kepler's laws of motion, time period of satellites and International Space Station (ISS).

Building block of the Universe

- The basic constituent of the universe is luminous matter i.e., galaxies which are really the collection of billions of stars. The universe contains everything that exists including the Earth, planets, stars, space, and galaxies. This includes all matter, energy and even time. No one knows how big the universe is. It could be infinitely large. Scientists, however, measure the size of the universe by what they can see. This is called the 'observable universe'. The observable universe is around 93 billion light years (1 light year = the distance that light travels in one year, which is 9.4607 × 1012 km) across.

- One of the interesting things about the universe is that it is currently expanding. It is growing larger and larger all the time. Not only is it growing larger, but the edge of the universe is expanding at a faster and faster rate. However, most of the universe what we think of is empty space. All the atoms together only make up around four percent of the universe. The majority of the universe consists of something scientists call dark matter and dark energy.

Age of the Universe

- Scientists think that the universe began with the start of a massive explosion called the Big Bang. According to Big Bang theory, all the matter in the universe was concentrated in a single point of hot dense matter. About 13.7 billion years ago, an explosion occurred and all the matter were ejected in all directions in the form of galaxies. Nearly all of the matter in the universe that we understand is made of hydrogen and helium, the simplest elements, created in the Big Bang. The rest, including the oxygen, the carbon, calcium, and iron, and silicon are formed in the cores of stars. The gravity that holds these stars together generally keeps these elements deep inside their interiors. When these stars explode, these fundamental building blocks of planetary systems are liberated throughout the universe.

Galaxies

- Immediately after the Big Bang, clouds of gases began to compress under gravity to form the building blocks of galaxies. A galaxy is a massive collection of gas, dust, and billions of stars and their solar systems. Scientists believe that there are one hundred billion (1011) galaxies in the observable universe. Galaxies are also in different shapes. Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular. Galaxies occur alone or in pairs, but they are more often parts of groups, clusters, and super clusters. Galaxies in such groups often interact and even merge together.

- Our Sun and all the planets in the solar system are in the Milky Way galaxy. There are many galaxies besides our Milky Way. Andromeda galaxy is our closest neighboring galaxy. The Milky Way galaxy is spiral in shape.

- It is called Milky Way because it appears as a milky band of light in the sky. It is made up of approximately 100 billion stars and its diameter is 1,00,000 light years. Our solar system is 25,000 light years away from the centre of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the centre of the galaxy and it takes 250 million years to do that.

The distance of Andromeda, our nearest galaxy is approximately 2.5 million light-years. If we move at the speed of the Earth (30 km/s), it would take us 25 billion years to reach it!

- Stars are the fundamental building blocks of galaxies. Stars were formed when the galaxies were formed during the Big Bang. Stars produce heat, light, ultraviolet rays, x-rays, and other forms of radiation. They are largely composed of gas and plasma (a superheated state of matter). Stars are built by hydrogen gases. Hydrogen atoms fuse together to form helium atoms and in the process they produce large amount of heat. In a dark night we can see nearly 3,000 stars with the naked eye. We don't know how many stars exist. Our universe contains more than 100 billion galaxies, and each of those galaxies may have more than 100 billion stars. Though the stars appear to be alone, most of the stars exist as pairs. The brightness of a star depends on their intensity and the distance from the Earth. Stars also appeartobe in different colours depending on their temperature. Hot stars are white or blue, whereas cooler stars are orange or red in colour. They also occur in many sizes.

- A group of stars forms an imaginary outline or meaningful pattern on the space. They represent an animal, mythological person or creature, a god, or an object. This group of stars is called constellations. People in different cultures and countries adopted their own sets of constellation outlines. There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

- The Solar System Sun and the celestial bodies which revolve around it form the solar system. It consists of large number of bodies such as planets, comets, asteroids and meteors. The gravitational force of attraction between the Sun and these objects keep them revolving around it.

The Sun

- The Sun is a medium sized star, a very fiery spinning ball of hot gases. Three quarters of the Sun has hydrogen gas and one quarter has helium gas. It is over a million times as big as the Earth. Hydrogen atoms combine or fuse together to form helium under enormous pressure. This process, called nuclear fusion releases enormous amount of energy as light and heat. It is this energy which makes Sun shine and provide heat. Sun is situated at the centre of the solar system. The strong gravitational fields cause other solar matter, mainly planets, asteroids, comets, meteoroids and other debris, to orbit around it. Sun is believed to be more than 4.6 billion years old.

Formation of the Sun

- At the time of the Big Bang, hydrogen gas condensed to form huge clouds, which later concentrated and formed the numerous galaxies. Some of the hydrogen gas was left free and started floating around in our galaxy. With time, due to some changes, this free-floating hydrogen gas concentrated and paved way for the formation of the Sun and solar system. Gradually, the Sun and the solar system turned into a slowly spinning molecular cloud, composed of hydrogen and helium along with dust. The cloud started to undergo the process of compression, as a result of its own gravity. Its excessive and high-speed spinning ultimately resulted in its flattening into a giant disc.

Planets

- A planet revolves around the Sun along a definite curved path which is called an orbit. It is elliptical. The time taken by a planet to complete one revolution is called its period of revolution.

- Besides revolving around the Sun, a planet also rotates on its own axis like a top. The time taken by a planet to complete one rotation is called its period of rotation. The period of rotation of the Earth is 23 hours and 56 minutes and so the length of a day on Earth is taken as 24 hours. Table 9.1 tells about the length of a day on each planet.

- The planets are spaced unevenly. The first four planets are relatively close together and close to the Sun. They form the inner solar

Planets	Length of a day
Mercury	58.65 days
Venus	243 days
Earth	23.93 hours
Mars	24.62 hours
Jupiter	9.92 hours
Saturn	10.23 hours
Uranus	17 hours
Neptune	18 hours

- system. Farther from the Sun is the outer solar system, where the planets are much more spread out. Thus the distance between Saturn and Uranus is much greater (about 20 times) than the distance between the Earth and the Mars.

- The four planets grouped together in the inner solar system are Mercury, Venus, Earth and Mars. They are called inner planets. They have a surface of solid rock crust and so are called terrestrial or rocky planets. Their insides, surfaces and atmospheres are formed in a similar way and form similar pattern. Our planet, Earth can be taken as a model of the other three planets.

- The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system and slowly orbit the Sun are called outer planets. They are made of hydrogen, helium and other gases in huge amounts and have very dense atmosphere. They are known as gas giants and are called gaseous planets. The four outer planets Jupiter, Saturn, Uranus and Neptune have rings whereas the four inner planets do not have any rings. The rings are actually tiny pieces of rock covered with ice. Now let us learn about each planet in the solar system.

- Mercury: Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. Mercury can be easily observed thorough telescope than naked eye since it is very faint and small. It always appears in the eastern horizon or western horizon of the sky.

- Venus: Venus is a special planet from the Sun, almost the same size as the Earth. It is the hottest planet in our solar system. After our moon, it is the brightest heavenly body in our night sky. This planet spins in the opposite direction to all other planets. So, unlike Earth, the Sun rises in the west and sets in the east here. Venus can be seen clearly through naked eye. It always appears in the horizon of eastern or western sky

- The Earth: The Earth where we live is the only planet in the solar system which supports life. Due to its right distance from the Sun it has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone. All these have made continuation of life possible on the Earth. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

- Mars: The first planet outside the orbit of the Earth is Mars. It appears slightly reddish and therefore it is also called the red planet. It has two small natural satellites (Deimos and Phobos).

- Jupiter: Jupiter is called as Giant planet. It is the largest of all planets (about 11 times larger and 318 times heavier than Earth). It has 3 rings and 65 moons. Its moon Ganymede is the largest moon of our solar system.

- Saturn: Known for its bright shiny rings, Saturn appears yellowish in colour. It is the second biggest and a giant gas planet in the outer solar system. At least 60 moons are present - the largest being Titan. Titan is the only moon in the solar system with clouds. Having least density of all (30 times less than Earth), this planet is so light.

- Uranus: Uranus is a cold gas giant and it can be seen only with the help of large telescope. It has a greatly tilted axis of rotation. As a result, in its orbital motion it appears to roll on its side. Due to its peculiar tilt, it has the longest summers and winters each lasting 42 years.

- Neptune: It appears as Greenish star. It is the eighth planet from the Sun and is the windiest planet. Every 248 years, Pluto crosses its orbit. This situation continues for 20 years. It has 13 moons – Triton being the largest. Triton is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.

Other Bodies of the Solar System

- Besides the eight planets, there are some other bodies which revolve around the Sun. They are also members of the solar system.

Asteroids

- There is a large gap in between the orbits of Mars and Jupiter. This gap is occupied by a broad belt containing about half a million pieces of rocks that were left over when the planets were formed and now revolve around the Sun. These are called asteroids. The biggest asteroid is Ceres – 946 km across. Every 50 million years, the Earth is hit by an asteroid nearing 10 km across. Asteroids can only be seen through large telescope.

Comets

- Comets are lumps of dust and ice that revolve around the Sun in highly elliptical orbits. Their period of revolution is very long. When approaching the Sun, a comet vaporizes and forms a head and tail. Some of the biggest comets ever seen had tails 160 million (16 crores) km long. This is more than the distance between the Earth and the Sun. Many comets are known to appear periodically. One such comet is Halley's Comet, which appears after nearly every 76 years. It was last seen in 1986. It will next be seen in 2062.

Meteors and Meteorites

- Meteors are small piece of rocks scattered throughout the solar system. Traveling with high speed, these small pieces come closer to
- the Earth's atmosphere and are attracted by the gravitational force of Earth. Most of them are burnt up by the heat generated due to friction in the Earth's atmosphere. They are called meteors. Some of the bigger meteors may not be burnt completely and they fall on the surface of Earth. These are called meteorites.

Satellites

- A body moving in an orbit around a planet is called satellite. In order to distinguish them from the man made satellites (called as artificial satellites), they are called as natural satellites or moons. Satellite of the Earth is called Moon (other satellites are written as moon). We can see the Earth's satellite Moon, because it reflects the light of the Sun. Satellite moves around the planets due to gravity, and the centripetal force. Among the planets in the solar system all the planets have moons except Mercury and Venus.

The Sun travelling at a speed of 250 km per second (9 lakh km/h) takes about 225 million years to complete one revolution around the Milky Way. This period is called a cosmic year.

Orbital Velocity

- We saw that there are natural satellites moving around the planets. There will be gravitational force between the planet and satellites. Nowadays many artificial satellites are launched into the Earth's orbit. The first artificial satellite Sputnik was launched in 1956. India launched its first satellite Aryabhatta on April 19, 1975. Artificial satellites are made to revolve in an orbit at a height of few hundred kilometres. At this altitude, the friction due to air is negligible. The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit.

- The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called orbital velocity.

- The orbital velocity of the satellite depends on its altitude above Earth. Nearer the object to the Earth, the faster is the required orbital velocity. At an altitude of 200 kilometres, the required orbital velocity is little more than 27,400 kph. That orbital speed and distance permit the satellite to make one revolution in 24 hours. Since Earth also rotates once in 24 hours, a satellite stays in a fixed position relative to a point on Earth's surface. Because the satellite stays over the same spot all the time, this kind of orbit is called 'geostationary'. Orbital velocity can be calculated using the following formula.

$$v = \frac{\sqrt{GM}}{(R+h)} \text{ where,}$$

G = Gravitational constant (6.673 × 10–11 Nm2kg-2)
M = Mass of the Earth (5.972 × 1024 kg)
R = Radius of the Earth (6371 km)
h = Height of the satellite from the surface of the Earth.

Microgravity is the condition in which people or objects appear to be weightless. The effects of microgravity can be seen when astronauts and objects float in space. Micro- means very small, so microgravity refers to the condition where gravity 'seems' to be very small.

Time period of a Satellite

Time taken by a satellite to complete one revolution round the Earth is called time period.

Time period, T = $\frac{Distance\ covered}{Orbital\ Velcity}$

T = $\frac{2\pi r}{V}$

Substituting the value of v, we get

T=$\frac{2\pi r(R+h)}{\frac{\sqrt{GM}}{(R+h)}}$

> All stars appear to us as moving from east to west, where as there is one star which appears to us stationary in its position. It has been named as Pole star. The pole star appears to us as fixed in space at the same place in the sky in the north direction because it lies on the axis of rotation of the Earth which itself is fixed and does not change its position in space. It may be noted that the pole star is not visible from the southern hemisphere.

Kepler's Laws

- In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor, Tycho Brahe with three statements that described the motion of planets in a Sun-centered solar system. Kepler's efforts to explain the underlying reasons for such motions are no longer accepted; nonetheless, the actual laws themselves are still considered an accurate description of the motion of any planet and any satellite. Kepler's three laws of planetary motion can be described as below.

First Law – The Law of Ellipses

All planets revolve around the Sun in elliptical orbits with Sun at one of their foci.
Second Law – The Law of Equal Areas
The line connecting the planet and the Sun covers equal areas in equal intervals of time.
Third Law – The Law of Harmonies
The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the distance between sun and the planets.

International Space Station

- ISS is a large spacecraft which can house astronauts. It goes around in low Earth orbit at approximately 400 km distance. It is also a science laboratory. Its very first part was placed in orbit in 1998 and its core construction was completed by 2011. It is the largest man-made object in space which can also be seen from the Earth through the naked eye. The first human crew went to the ISS in 2000. Ever since that, it has never been unoccupied by humans. At any given instant, at least six humans will be present in the

ISS. According to the current plan, ISS will be operated until 2024, with a possible extension until 2028. After that, it could be deorbited, or recycled for future space stations.

Benefits of ISS

- According to NASA, the following are some of the ways in which the ISS is already benefitting us or will benefit us in the future.

Supporting water-purification efforts

- Using the technology developed for the ISS, areas having water scarcity can gain access to advanced water filtration and purification systems. The water recovery system (WRS) and the oxygen generation system (OGS) developed for the ISS have already saved a village in Iraq from being deserted due to lack of clean water.

Eye tracking technology

- The Eye Tracking Device, built for a microgravity experiment, has proved ideal to be used in many laser surgeries. Also, eye tracking technology is helping disabled people with limited movement and speech. For example, a kid who has severe disability in body movements can use his eye-movements alone and do routine tasks and lead an independent life.

Robotic arms and surgeries

- Robotic arms developed for research in the ISS are providing significant help to the surgeons in removing inoperable tumours (e.g., brain tumours) and taking biopsies with great accuracies. Its inventors say that the robot could take biopsies with remarkable precision and consistency.

- Apart from the above-mentioned applications, there are many other ways in which the researches that take place in the ISS are helpful. They are: development of improved vaccines, breast cancer detection and treatment, ultrasound machines for remote regions etc,.

ISS and International Cooperation

- As great as the ISS' scientific achievements are, no less in accomplishment is the international co-operation which resulted in the construction of the ISS. An international collaboration of five different space agencies of 16 countries provides, maintains and operates the ISS. They are: NASA (USA), Roskosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Cananda). Belgium, Brazil, Denmark, France, Germany, Italy, Holland, Norway, Spain, Sweden, Switzerland and the UK are also part of the consortium.

11th geography

Unit II - The Solar System and the Earth

Introduction

- Have you ever relaxed lying on the terrace of a building or in the front yard at a cloudless night? If yes, could you watch the night sky filled with glittering stars which appear to be growing in numbers? These glittering stars, which we see, are a part of the universe. Let us now discuss in detail about the Universe, stars, planets and other objects. The universe is a vast endless space which includes galaxies, stars, planets and other forms of matter and energy in it.

Theories of the Earth's origin

- There are many theories supporting the origin of the earth. One of the earlier and popular arguments of the earth's origin was by a German professor Immanuel Kant. Mathematician Laplace revised it in 1796. It was known as Nebular Hypothesis. It considered that planets were formed out of a cloud of material associated with a youthful sun, which was slowly rotating. Lyttleton propounded the accretion theory of the earth's formation. According to this theory, approximately 4.6 billion years ago, the solar system was a cloud of dust and gas known as a solar nebula. As the solar nebula began to spin, the gravity collapsed the materials on itself and it formed the sun in the centre of the solar system. When the sun formed, the remaining materials began to clump up. Small particles drew together, bound by the force of gravity, into larger particles. The solar wind swept away lighter elements, such as hydrogen and helium, from the closer regions. It left only heavy rocky materials to create planets like the Earth. But farther away, the solar winds had less impact on lighter elements, allowing them to coalesce into gas giants. In this way, planets, moons, asteroids, comets, etc., were created.

> Voyager 2 travelling at the speed of more than 62,764.416 km/h will still take more than 296,000 years to pass Sirius, the brightest star in our night sky.

- Earth's rocky core formed first when heavy elements collided and bound together. Dense materials sank to the center, while the lighter material created the crust. The planet's magnetic field probably formed around this time. Gravity captured some of the gases that made up the planet's early atmosphere.

Modern theories of the origin of the Universe

- The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called expanding universe hypothesis. In 1927, Abbe Georges Lemaitre, a Belgian astronomer was the first to propose, a theory on the origin of the universe. It was Edwin Hubble who provided the evidence that the universe is expanding. It was called, 'the Big Bang Theory'. According to it, the universe was formed during a period of inflation that began about 13.75 billion years ago.

- Like a rapidly expanding balloon, it swelled from a size smaller than an electron to nearly its current size within a fraction of a second. Matter from the universe was thrown out with great force in all directions and started expanding outwards. From this matter, many groups of stars were formed which we call 'galaxies'. A galaxy is a system of billions of stars, stellar remnants, interstellar gas, dust, and dark matter. The word galaxy is derived from the Greek word Galaxias, literally "milky", a reference to the Milky Way (Figure 2.1). The Milky Way is the galaxy that contains our Solar System.

Galaxies are in three major forms:

- Spiral Galaxies: It consists of a fat and rotating disk of stars, gases and dust. It has a central concentration of stars known as the 'bulge'. The Milky Way and the Andromeda are spiral galaxies.

- Elliptical Galaxies: It contains older stars with fewer gases. Messier89 galaxy is an elliptical galaxy.

- Irregular Galaxies: They are youthful galaxies with more dust and gases. This can make them very bright. Large Magellanic Cloud is an example of irregular galaxy.
- Initially, the universe was saturated only by energy. Some of this energy set into particles, which assembled into light atoms like hydrogen and helium. These atoms grouped first into galaxies, then stars and all the other elements. This is generally agreed-upon concept of our universe's origin as estimated by scientists.

- In fact, the stars, planets and galaxies that can be detected make up only 4 percent of the universe, according to astronomers. The other 96 percent of the substances in the universe cannot be seen or easily understandable.

- The new measurement technique called gravitational lensing confirmed the age of the universe and the strength of dark energy. Dark energy is responsible for the accelerating expansion of the universe. Scientists used gravitational lensing to measure the distances light travelled from a bright, active galaxy to the earth and some details of its expansion.

Three scientists, Saul Perlmutter, Brian Schmidt and Adam Riess won the Nobel Prize in Physics (2011) for their discovery that the universe is just expanding and picking up speed.

Star and Constellations

- A star is type of astronomical object which has its own light and heat. The nearest star to earth is the Sun. Sirius is brighter star than the sun. 'Proxima Centaur? is the closest star to the sun. Star is formed when enough dust and gas clump together because of the gravitational forces. Star changes its forms during its lifetime such as-red giant, white dwarf, neutron star and black hole.

- Constellation (Figure 2.2) is a group of stars that forms a particular shape in the sky. In 1929, the International Astronomical Union (1AU) adopted official constellation boundaries that defined 88 official constellations that exist today. Earlier Ptolemy, in his book Almagest, listed 48 constellations.

- Ursa Major (Figure 2.3) is a constellation that can be seen in the northern hemisphere and part of the southern hemisphere. Ursa Major means Great Bear in Latin.

The Solar system

- A solar system consists of a star (Figure 2.4) at the centre and the eight planets, moons, asteroids, comets and meteoroids that revolve it. The eight planets, namely the Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, revolve around the sun in fixed elliptical paths known as 'orbits'. Most stars host their own planets. So there are billions of other solar systems in the Milky Way galaxy alone.

- Solar systems can also have more than one star. These are called binary star systems if there are two stars or multi-star systems if there are three or more stars. Our solar system is located in an outer spiral arm of the vast Milky Way galaxy. Our solar system orbits the centre of the Milky Way Galaxy at about 828,000 km/h. Our solar system takes about 230 million years to complete one orbit around the galactic centre.

- The solar system is believed to have been formed about 4.6 billion years ago. The solar system also includes the Kuiper Belt that lies past Neptune's orbit. This is a sparsely occupied ring of icy bodies. This is almost all smaller than the dwarf planet Pluto. Beyond the fringes of the Kuiper belt (Figure 2.5) is the Oort cloud. This giant spherical shell surrounds our solar system. It has never been directly observed, by gravitational attraction, producing immense pressure and temperature at its core. There are three main layers in the Sun's interior: the core, the radioactive zone, and the convective zone (Figure 2.6). The core is at the centre. It is the hottest region, where the nuclear fusion reaction to give the sun power. Moving outward next come the radioactive (or radiation) zone. Its name is derived from the way energy is carried outward through this layer, carried by photons as thermal radiation. The third and final region of the solar interior is named the convective (or convection) zone. It is also named after the dominant mode of energy flow in this layer. The boundary between the Sun's interior and the solar atmosphere is called the photosphere. It is what we see as the visible 'surface' of the Sun.

- Did you know that the Sun has an atmosphere? Te lower region of the solar atmosphere is called the chromosphere. Its name is derived from the Greek word chroma (meaning colour), for it appears bright red when viewed during a solar eclipse. A thin transition region, where temperature rises sharply, separates the chromospheres from the vast corona above. The uppermost portion of the Sun's atmosphere is called the corona, and is surprisingly much hotter than the Sun's surface (photosphere) The upper corona gradually turns into the solar wind. Solar wind is a flow of plasma that moves outward through our solar system into interstellar space.

- Therefore, the Sun has six regions: the core, the radioactive zone, and the convective zone in the interior; the photosphere; the chromospheres; and the corona. The temperature of the sun's surface is about 5,500 to 6,000 degrees Celsius.

- At the core, the temperature is about 15 million degrees Celsius, which is sufficient to sustain thermonuclear fusion. This is a process in which atoms combine to form larger atoms and in this process, released, staggering amounts of energy. Specifically, in the Sun's core, hydrogen atoms fuse to make helium.

Size and Distance

- The sun has a radius of 695,508 kilometres. It is far more massive than earth and 3,32,946 Earths equal to the mass of the Sun. The Sun's volume would need 1.3 million Earths to fill it.

Venus is hotter than Mercury because Venus has an atmosphere which is thicker and made almost entirely of carbon dioxide

Orbit and Rotation

- The Milky Way has four main spiral arms: the Norma and Cygnus arm, Sagittarius, Scutum-Crux, and Perseus. The Sun is located in a minor arm, the Sagittarius arm. From there, the Sun orbits the centre of the Milky Way Galaxy, bringing the planets, asteroids, comets and other objects along with it. Our solar system is moving with an average velocity of 828,000 kilometres per hour. It takes about 230 million years to make one complete orbit around the Milky Way. The Sun's spin has an axial tilt of 7.25 degrees with respect to the plane of the planets' orbits. Since the Sun is not a solid body, different parts of the Sun rotate at different rates. At the equator, the Sun spins around once about every 25 days, but at its poles the Sun rotates once on its axis every 36 Earth days. Most of the materials are pulled toward the centre to form our Sun. The Sun alone accounts for 99.8% of the mass of the entire solar system.

- Like all stars, the Sun will someday run out of energy. When the Sun starts to die, it will swell so big that it will engulf Mercury y and Venus and maybe even Earth. Scientists predict that the Sun is a little less than halfway through its lifetime and will last another 6.5 billion years before it shrinks down to be a white dwarf.

The Planets

- The word planet in Greek means 'wanderer'. Planet is the celestial body which does not have light or heat of its own. A planet should possess the following qualities:

❖ It should orbit around the sun.

❖ It should not be a satellite of any planet

Due to its own mass and self-gravity, it should get a spherical shape and
Any other celestial body should not cross in its orbit.

- The planets are classified in order of their distance from the sun and based on their characteristics. They are:

- The inner planets or terrestrial planets or rocky planets. Mercury, Venus, Earth and Mars are called inner or terrestrial planets.

- The outer planets or gaseous planets or giant planets. Jupiter, Saturn, Uranus and Neptune are called outer or gaseous planets.

- Each planet spins on its own axis. Tis movement is called rotation. One rotation makes one 'planet day'. The planets moving around the sun is called revolution or a 'planet-year'.

Planets in the Solar System

Name of the Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Diameter (KM)	4,879	12,104	12,756	6,794	1,42,984	1,20,536	51,118	49,528
Density (kg/m3)	5,427	5,427	5,514	3,933	1,326	687	1,271	1,638
Rotation Period (hours)	1,407.6	-5,832.5	23.9	24.6	9.9	10.7	17.2	16.1
Length of Day (hours)	4,222.6	2,802	24	24.7	9.9	10.7	17.2	16.1
The Average distance from the sun(10^6 km)	57.9	108.2	149.6	227.9	778.6	1,433.5	2,872.5	4,495.1
Orbital Period (days)	88	224.7	365.3	687	4331	10,747	30,589	59,800
Number of Satellites	0	0	1	2	67	53	27	13

The Mercury

- Mercury is the nearest planet to the sun and it is the smallest planet in the solar system. It does not have any satellite. It rotates on its own axis in 58.65 earth days while it takes 88 Earth days to complete one revolution around the sun. Mercury is 0.4 astronomical units away from the Sun. The sunlight takes 3.2 minutes to travel from the Sun to Mercury. Mercury is the second hottest planet though it is nearest to the sun.

The Venus

- 'Venus' is the second nearest planet to the sun. It is also called as 'Earth's Sister' planet due to its similar size and mass as that of our Earth. It is the hottest planet in the solar system and experiences a mean surface temperature of 462°C. It is popularly known as "Morning star and Evening star" It is seen in the east sky before sunrise (dawn) in the morning and in the west sky after the sunset (twilight). It rotates clockwise i.e. east to west direction on its own axis. The rotation and orbit of the Venus are unusual in several ways. Venus is one of just two planets that rotate from east to west. Only Venus and Uranus have this 'backwards' rotation. It completes one rotation in 243 Earth days which is the longest day of any planet in our solar system. The Venus takes 224.7 Earth days to complete one revolution around the sun, and it has no natural satellites. Venus is 0.7 astronomical units away from the sun. The sunlight takes 6 minutes to travel from the sun to Venus.

The Earth

- Earth is the third nearest planet to the sun. It is the fifth largest planet in the solar system. The Earth's orbit lies between the orbits of Venus and Mars. It takes 23 hours 56 minutes and 4 seconds for the earth to complete one rotation on its own axis. The Earth takes 365.25 days (Table 2.1) to complete one revolution around the Sun. Earth's surface temperature varies from - 88° to 58°C and it is the densest planet in the solar system.

- The Earth is a unique planet because of its distance from the sun, its motions, atmosphere with oxygen, presence of water and moderate temperature. The earth is neither too close nor too far from the sun. It is the only known planet to support life. It is also known as the 'Blue Planet' because of the presence of water. Earth has only one natural satellite called the Moon. The sun light takes about 8.3 minutes to reach the earth.

The Mars

- Mars is the fourth nearest planet to the sun and it is the second smallest planet in the Solar system. It is also described as the "Red planet". It is reddish in colour due to the presence of iron oxide on its surface. The landmass of Mars and Earth are very similar. It takes 24 hours and 37 minutes to complete one rotation on its axis and its takes 687 days to complete one revolution around the Sun. The surface temperature of the Mars is ranging from -153° to 20°C. With the exception of the Earth, Mars probably is the most hospitable to life. This planet has seasons, polar ice caps, volcanoes, canyons and weather. Mars has two satellites namely Phobos and Deimos.

The Jupiter

- Jupiter is the largest planet in the solar system. It is made primarily of gases and is therefore known as 'Giant Gas planet'. It takes 9 hours 55 minutes to complete one rotation on its axis and it takes 11.86 years to complete one revolution. Jupiter has the shortest day in the solar system. Jupiter has a faint ring system around it. They are mostly comprised of dust particles. Jupiter has 67 confirmed satellites orbiting the planet. Ganymede, the satellite of Jupiter, is the largest natural satellite in the solar system (even bigger than the planet Mercury).

The Saturn

- Saturn is the sixth planet from the sun and the second largest planet in the solar system. Saturn is called as the Ringed Planet. It is because of large, beautiful and extensive ring systems that encircles the planet. These rings are mostly made from the chunks of ice and carbonaceous dust. Saturn is the only planet in our solar system whose average density is less than water.

- The Saturn has 30 rings and 53confrmed natural satellites. The Saturn takes 10 hours 34 minutes to complete one rotation on its axis and it takes 29.4 years to complete one revolution around the sun.

The Uranus

- Uranus is the seventh planet from the sun and it is not visible to the naked eye. Like Venus, Uranus also rotates on its axis from east to west. Uranus is inclined on its axis at an angle of 98 degrees. The planet is almost lying on its side as it goes around the sun. The sunlight, thus, is received mostly in the polar areas. Hydrogen, helium and methane are the major gases of its atmosphere. It is very cold due to its great distance from the sun. Uranus is named after the ancient Greek god of the sky. It has a dense atmosphere primarily consisting of methane, which lends it a bluish-green appearance. Uranus also has rings and twenty-seven satellites.

The Neptune

- Neptune is the eighth planet from the sun. It takes 16 hours to complete one rotation on its own axis and it takes nearly 165 years to revolve around the sun. It has 13 natural satellites and 5 rings. It is the coldest planet in the Solar System because it is the farthest planet from the Sun. Neptune was the first planet located through mathematical calculations. Neptune is our solar system's windiest planet.

Dwarf Planets

- Dwarf planets are tiny planets in our solar system. Any celestial body orbiting around the sun, weighing for the self-gravity and nearly be round in shape is called 'Dwarf Planet'. It should not be a satellite of any planet. They are five in number Ceres, Pluto, Heumea, Makemake and Eris. As Pluto has not cleared the neighbourhood around its orbit, it is officially demoted in 2006 from its ninth position as a planet.

North Pole of the Uranus experiences 21 years of night time in winter, 21 years of daytime in summer and 42 years of day and night in the spring and fall.

Satellites

- The word 'Satellite' means companion. The moon was the only known satellite in the Solar System until 1610. Today, there are 163 known satellites in the Solar System. The satellites move around a planet from West to East. They do not have own light, but reflect the light of the Sun. They have no atmosphere and water.

Moon: the Earth's Satellite

- The moon is located at a distance of 8, 84,401 km from the earth (Figure 2.7). The moon revolves around the earth. The moon takes 27 days and 7 hours and 43 minutes for both its rotation and revolution around the earth.

- Hence, the observers on the earth could see only one side of the moon. The moon is the fifth largest natural satellite in the solar system. The moon was likely to be formed after a Mars-sized body collided with Earth. There are many craters, high and steep mountains of different sizes which cast shadows on the Moon's surface. The light which is reflected by the Moon will reach the Earth in just one and a quarter seconds.

Apollo 11 was the first manned mission to land on the Moon sent by NASA. Two American Astronauts Neil Armstrong and Edwin Aldrin set foot on the moon's surface on the waterless Sea of Tranquillity on 20th July, 1969. They stayed there for 21 hours 38 minutes and 21 seconds on the moon. Michael Collins piloted Apollo 11.

- Since the moon is smaller than the earth, it has 1/6 of the gravitational pull of the earth. So, man weighs 6 times less on the moon than the earth.

Asteroids

- Asteroids are small rocky celestial bodies that revolve around the Sun, like other planets. They are also called 'Minor Planets'. Tere are lots of asteroids in the solar system. Larger asteroids are called Planetoids. These are found in between the planets Mars and Jupiter. Tis belt is known as 'Asteroid belt'. The diameter of the asteroids varies from 100 km to a size of a pebble. The asteroids may be the fragments of a planet exploded in the past or some parts of comets. The new asteroids are being discovered continuously.

Comets

- Comets are the most exciting heavenly bodies and have ever been the objects of man's curiosity as well as fear. The word Comet (Figure 2.8) is derived from the Greek word Aster Kometes meaning 'Long Haired Star'. They are made up of small ice particles and meteoric fragments. They revolve around the Sun. But their orbits are irregular. Sometimes they get very close (Perihelion) to the sun and in other times they go far away (Aphelion) from the sun.

The best known Comet, Halley s Comet, appears once in every 76 years. The Halley s Comet was seen last in 1986 and it will be seen again on 28th July 2061.

Titan – only moon with clouds and atmosphere

Titan is Saturn's largest moon and the second largest (after Ganymede of Jupiter) in the solar system. It is the only moon in the solar system with clouds and a dense, planet-like atmosphere.

Scientists believe that conditions on Titan are similar to Earth's early years (the main difference is that, because of is closer to the sun, Earth has always been warmer). According to NASA, "In many respects, Titan, is one of the most Earth-like worlds we have found to date".
Titan was discovered by Dutch astronomer Christiaan Huygens in 1655. The Huygens lander probe sent to the moon aborad NASA's Cassini spacecraft by the European Space Agency is named in his honour. Huygens was the first human-built object to land on Titan's surface. Diameter:5,150 kilometres, about half the size of Earth and almost as large as Mars. Surface temperature:-179 degrees Celsius, which makes water as hard as rocks and allows methane to be found in its liquid form. Surface pressure. Earth's pressure at sea level is 1 bar while Titan's is 1.6 bars. Orbital period: 15;945 days. Titan's mass is composed mainly of water in the form of ice and rocky material. Titan has no magnetic field.

Meteors

- There is a bright streak of light flashing seen often in the sky during night for a few seconds. They are called as 'shooting stars'. They are the removed pieces of rocks mainly from the Asteroid belt. Tey are called Meteoroids before they enter into our atmosphere. Tey enter into the atmosphere with great speed. But most of them are burnt when they enter into the atmosphere.

- After entering into our atmosphere they are called as Meteors. Some pieces do not burn fully and they fall on the earth and make craters. The large unburned pieces of rocks that fall on the earth are called Meteorites.

- Examples for Meteorite Fall: Meteor crater in Northern Arizona and Lake Lonar in Buldhana District of Maharastra in India were created by meteor impacts.

Shape and size of the Earth

- It once was believed that the Earth was flat and that ships could sail over the edge. This view persisted even in the middle ages and was an issue in recruitment of Columbus.

- Early Greek view was that the world was surrounded by the ocean (Ocean us), origin of all rivers. Anaximander (600 B.C) proposed that cylindrical earth was surrounded by celestial sphere. Pythagoras (582-507 B.C.) believed that the Earth was a sphere, which was considered the most harmonious geometric shape. Aristotle (384-322 B.C.) described observations that supported the theory that the Earth was a sphere. These included the fact that the shadow of the moon is circular in lunar eclipses and constellations were higher in the sky as one travelled south. Eratosthenes

- (275-195 BCE) estimated size of earth from observations that the elevation of the sun varied with position on the Earth's surface in Egypt. Observations of the following suggested that the Earth is a sphere.

Mountain peaks lit by the Sun after sunset.

- Ships disappear below the horizon as they sail across ocean.

The moon looks like a disc.
The Earth casts a circular shadow during lunar eclipses.

- The Earth is an oblate spheroid, bulged at the equator and fattened at the poles. It is called 'Geoid' (Figure 2.9) meaning the earth is earth-shaped. The bulge at the equator is caused by the centrifugal force of the Earth's rotation. The gravitational pull of the earth is the strongest at the fattened poles and it is weaker towards the equator.

- The Sun's gravitational pull differs in force at the poles. The North Pole points in the same direction to the North Star when it revolves about the Sun. If the Earth would not have been tilted on its axis, the days and nights would have been of same duration always.

Motions of the earth

The earth has two basic movements: 1) Rotation and 2) Revolution.

Galactic movement:
This is the movement of the earth with the sun and the rest of
the solar system in an orbit around the centre of the Milky Way Galaxy. This, however, has little effect upon the changing environment of the earth.

1. Rotation:

- The spinning of the earth around its axis is called the rotation of the earth. The axis is the imaginary line passing through the centre of the earth. The earth completes one rotation in 23 hours, 56 minutes and 4.09 seconds. It rotates in an eastward direction opposite to the apparent movement of the sun. The earth's axis is inclined at an angle of 66½0 to the orbital plane as it moves around the sun. We can say, the earths axis is tilted at an angle of 23½° (Figure 2.10) from a perpendicular to the elliptic plane. The velocity of earth's rotation varies depending on the distance of a given place from the equator. The rotational velocity at the poles is nearly zero. The greatest velocity of the rotation is found at the equator. The velocity of rotation at the equator is 1,670 km per hour.

Effects of earth's rotation: The rotation of the earth causes the following effects:

- The apparent rising and setting of the sun is actually caused by the earth's rotation which results in the alternate occurrence of day and night everywhere on the earth's surface.

- Rotation of the earth is also responsible for the difference in time between different places on the earth. A 24 hour period divided by 360 degrees gives a difference of 4 minutes for every degree of longitude that passes the sun. The hour (60 minutes) is thus 1/24 of a day.

- When you observe through a moving train, trees, houses and fields on the other side of the track appear to move in the direction opposite to that of the speeding train. The apparent movement of the sun and the other heavenly bodies in relation to the rotating earth is similar. As the earth rotates from west to east, the sun, moon, planets and stars appear to rise in the east and set in the west.

- Rotation causes the working of the Coriolis force which results in the deflection of the winds and the ocean currents from their normal path.

- Tide is caused by the rotation of the earth apart from the gravitational pull of the sun and the moon.

- Rotation causes a flattening of Earth at the two poles and bulging at the Equator. Hence, there is a difference in diameter at the poles and equator.

- Circle of Illumination: The line around the earth separating the light and dark is known as the circle of illumination (Figure 2.11).

- It passes through the poles and allows the entire earth to have an equal amount of time during the daylight and night time hours. This line can be seen from space, and the exact location of the line is dependent on the various seasons.

Revolution of the Earth

- The movement of the earth in its orbit around the sun in an anti-clockwise direction, that is, from west to east is called revolution of the earth. The earth revolves in an orbit at an average distance of 150 million km. The distance of the earth from sun varies time to time due to the elliptical shape of the orbit. About January 3rd the earth is closest to the sun and it is said to be at Perihelion ('peri' means close to and Helios means sun). At Perihelion, the distance is 147 million km.

- Around July 4th the earth is farthest from the sun and it is said to be at Aphelion (Ap means away and Helios means sun). At Aphelion the distance of the earth is 152 million km away from the sun.

- The period taken by the earth to complete one revolution around the sun is 365 days and 6 hours (5 hours, 48 minutes and 45 seconds) or 365¼ days. The speed of the revolution is 1,07,000 km per hour. The speed is 30 km per second. The bullet from a gun travels with a speed of 9 km per second.

Period of Revolution and Leap year

- The period of time the earth takes to make one revolution around the sun determines the length of one year. The earth takes 365 days and 6 hours to complete one revolution. Earth takes 365.25 days to complete one trip around the Sun .That extra quarter of a day presents a challenge to our calendar system, which has one year as 365 days. To keep our yearly calendars consistent with our orbit around the Sun once in, every four years we add one day.

- The extra day added to is called a leap day, and the year the extra day is added to is called a leap year. The extra day is added to the month of February which has 29 days in a leap year.

Effects of revolution of the earth

- The revolution of the earth around the sun results in the following

Cycle of seasons,bVariation in length of days and nights,

- Variation in distribution of solar energy over the earth and the temperature zones.

Seasons

- The seasons are caused due to the combined effect of the earth's revolution and the tilt of its axis in the same direction throughout the year. In general, spring, summer, autumn and winter are the four seasons (Figure 2.12). The latitude at which the sun appears directly overhead changes as the earth orbits the sun. The sun appears to follow a yearly pattern of northward and southward motion in the sky, known as the 'apparent movement of the sun'. It gives an impression that the sun is continuously swinging north and south of the equator. Actually it is the earth that is moving around the sun on its tilted axis. It varies when observed on a daily and monthly basis, at different times of the year. On 21 March and 23 September the sun rises precisely in the east and sets exactly in the west.

Equinoxes and solstices

- You already knew that the sunrays are vertical at noon. The vertical rays fall on a small area, giving more heat.

Equinoxes

- Equinoxes occur when the earth reaches the points in its orbits where the equatorial and the orbital planes intersect, causing the sun to appear directly overhead at the equator. During the equinoxes the periods of day light and darkness are equal all over the world. On 21 March the sun is directly overhead at the equator. Throughout the world, on this day all the places experience almost equal hours of day and night. This position of the sun is called spring equinox. Again on 23 September the sun is directly overhead on the equator and it is called autumn equinox.

Position of the earth on 21 March

- Neither pole is inclined towards the sun. The rays of the sun fall vertically on the equator. All the places have equal days and nights as both the poles receive the rays of the sun. It is spring in the northern hemisphere and autumn in the southern hemisphere. This day (21 March) is known as spring equinox.

Position of the earth on 23 September.

- Neither pole of the earth is inclined towards the sun. The rays of the sun fall vertically on the equator. All the places have equal days and nights. It is autumn in the northern hemisphere and spring in the southern hemisphere. Tis day (23 September) when sun's rays for fall vertically on the equator, is known as autumnal equinox (Figure 2.13).

Position of the earth on 21 June

- The North Pole is inclined or tilted towards the sun. It, therefore, experiences complete light for 24 hours. The South Pole is tilted away from the sun so it is in complete darkness for 24 hours. The rays of the sun fall vertically at the tropic of cancer (23½^{o} N). In the Northern hemisphere, the days are longer than the nights (Table 2.2). It is summer in the northern hemisphere and winter in the southern hemisphere. The day 21 June is known as summer solstice.

Position of the earth on 22 December

Latitude	Summer Solstice	Winter Solstice	Equinoxes

0°	12hrs	12hrs	12hrs
10°	12hrs 35 min	11hrs 25 min	12hrs
20°	13hrs 12 min	10hrs 48 min	12hrs
30°	13hrs 56min	10hrs 4 min	12hrs
40°	14hrs52min	9hrs 8 min	12hrs
50°	16hrs18min	7hrs 8 min	12hrs
60°	18hrs27min	5hrs 42 min	12hrs
70°	24hrs (for 2 months)	0hrs00 min	12hrs
80°	24hrs (for 4 months)	0hrs00 min	12hrs
90°	24hrs (for 6 months)	0hrs00 min	12hrs

- The South Pole is inclined towards the sun and the North Pole is away from it. The rays of the sun fall vertically at the tropic of Capricorn (23½º S). The greater part of the southern hemisphere gets the direct rays of the sun so the days are long and the nights are short here. In the northern hemisphere the nights are longer than the days at this time. The southern hemisphere has summer. The northern hemisphere has winter. This day (22 December), when the sun's rays fall vertically on the Tropic of Capricorn, is known as winter solstice.

Eclipses

- Let us understand the effect of the revolution of the earth on the length of the days and the nights. The duration of the daylight varies with latitude and seasons.

- An eclipse is a complete or partial obscuration of light from a celestial body and it passes through the shadow of another celestial body. The eclipses are of two types. They are:

Solar Eclipse

- It occurs on New Moon days, when the moon is between the Sun and the Earth. Thus it obscures a part of the Sun viewed from the Earth, but only from a small area of the world. It lasts only for a few minutes. A partial solar eclipse (Figure 2.14) happens when the moon partially covers the disc of the sun. An annular solar eclipse occurs when the moon passes centrally across the solar disc. During a total solar eclipse, the moon's shadow is short enough to cover the whole sun. The outer regions still glow and look bright as a ring. Such a phenomenon is called Diamond Ring

Geo connects History

Secret to Great Pyramid's Near Perfect Alignment Possibly Found!

The Great Pyramid of Giza, 4,500 years ago, is an ancient feat of engineering. Now an archaeologist has figured out how the Egyptians may have aligned the pyramid almost perfectly along the cardinal points, north-south-east-west. Egyptians may have used the autumn
equinox. Methods used by the ancient Egyptians to align the pyramids along the

cardinal points are accurate. On the day of the fall equinox, a surveyor placed a rod into the ground and tracked its shadow throughout the day. The result was a line running almost perfectly east-west. Te Egyptians could have determined the day of the fall equinox by counting forward 91 days after the summer solstice.

Rotation	Revolution
Spinning of the earth from west to east on its axis	Movement of the earth around the sun in its elliptical orbit.
It takes 24 hours to complete a rotation (or a day)	It takes 365 ¼ days to complete on revolution (Or a year)
It is known as the daily or diurnal movement.	It is known as the annual movement of the earth.
Rotation causes days and nights to alternate, tides, deflection of winds and ocean currents and also gives the earth its shape.	Revolution results in the varying lengths of day and night,, changes in the altitude of the midday sun and change of seasons.

Lunar Eclipse

- It occurs on a Full Moon position when the earth is between the sun and the moon. The earth's shadow obscures the moon as viewed from the earth. A partial lunar eclipse can be observed when only a part of the moon's surface is obscured by earth's umbra (Figure 2.15). A penumbral lunar eclipse happens when the moon travels through the faint penumbral portion of the earth's shadow. A total lunar eclipse occurs when the earth umbra obscures the entire the moon's surface. Lunar eclipse can be seen from anywhere on the night side of the Earth. It lasts for a few hours due to the smaller size of the moon.

- The changing angles between the earth, the sun and the moon determine the phases of the moon. Phases of the moon (Figure 2.16) start from the 'New Moon' every month. Then, only a part of the Moon is seen bright called 'Crescent', which develops into the 'first quarter'. With the increasing brightness it turns into three quarters known as 'Gibbous' and then it becomes a 'Full Moon'. These stages are the waxing moon. After the full moon, the moon starts waning or receding through the stages of Gibbous, last quarter, crescent, and finally becomes invisible as dark New Moon.

The varying lengths of daylight in different latitudes

- It is evident from the table that the duration of daylight is 12 hours throughout the year at the equator only. As one moves away from the equator, the seasonal variations in the duration of daylight increase. The seasonal variations in the duration of daylight are maximum at the polar region.

Effects of the spherical shape of the earth

Variation in the amount of solar radiation received:

- If the earth were a flat surface, oriented at right angle to the sun, all the places on the earth would have received the same amount of radiation. But the earth is spherical/ geoid. Hence the sunrays do not heat the higher latitudes of the earth as much as the tropics. On any given day only the places located at particular latitude receive vertical rays from the sun. As we move north or south of this location, the sun's rays strike at decreasing angles. The yearly fluctuations in the angle of the sun's rays and the length of the days change with the continual change of the earth's position in its orbit around the sun at an inclination of 66½ to the orbital plane.

Difference in the angle of the sun's rays striking diferent parts of the earth.

- Away from the equator, the sun's rays strike the earth's surface at particular angle. The slanting rays are spread over a large area and do not heat with the same intensity as the direct rays. As we go pole wards, the rays spread over the regions beyond the Arctic and the Antarctic circles in an extremely slanting manner. This is how we get the various temperature zones.

- Lower the degree of latitude; higher the temperature. Not only that, the rays striking at a low angle must travel through a greater thickness of the atmosphere than the rays striking at a higher angle. The rays striking at a lower angle are subject to greater depletion by refection and absorption by the atmosphere.

Temperature zones

- The spherical shape of the earth along with its movement around the sun causes differences in the angles at which the sun's rays fall on the earth's surface. This causes a difference in the distribution of heat on the earth's surface.

- As a result, the world has been divided into three distinct heat zones or temperature zones. They are the Torrid zone, Temperate zone and Frigid zone. You will learn more about it under the unit atmosphere.

Time Zones of the World

- People during the medieval period were using sundials and water clocks to observe the Sun's meridian passing at noon. In 17th century, the people started using pendulum clock which did not show accurate time while travelling in the sea. Later chronometer was invented in 1764. Chronometer measures time accurately and the mariners widely used this during the 19th century. But in many towns and cities clocks were set based on sunset and sunrise. The use of local solar time hindered the development of railways and telecommunications. A time zone is a region on the earth where uniform standard time should be maintained for transport, commercial and social purposes. For example, if different time zones were followed, the trains coming from different regions, sharing single track may meet with accidents.

- The world time zone (Figure 2.17) was formed, relating longitude and the rotation of the earth. The Prime Meridian is the centre of time zone extending from 7½°W and 7½ ° E longitudes. The 24 hours time zone system had been developed so that all the time zones should be referred with respect to Greenwich Mean Time. Earth was divided into 24 time zones, each one zone for one hour of the day. It is because earth rotates 15° of longitude in one hour (360° divided by 24 hours). The time when solar noon occurs at the Prime Meridian is fixed as noon for all places between 7½° E and 7½° W.

Daylight Saving Time

In the mid latitude countries of Europe, North America, Australia and South America, the day time are longer in summer than the night. In spite of employing daylight duration, the clocks are adjusted 1 hour forward in spring and 1 hour backward in autumn. This time is generally known as 'the Daylight Saving Time' (DST).

Time Zones

- On its axis, the earth rotates 360 degrees every 24 hours. You can look at it as it takes one day to complete a full circle. Divided up into an hourly rate, the earth rotates 15 degrees every hour (360/24). This number plays an important role in determining time zones. You have already learned about the latitudes and longitudes and their importance in the lower classes.

- An important factor in determining time zones is the lines of latitude and longitude, imaginary lines known as latitudes and longitudes dividing the earth. Latitude lines are drawn east - west and they measure the location in northern and southern hemisphere. The line starts at the equator and measure distance from 0 degrees to 90 degrees north and also 0 degrees to 90 degrees south. They also become shorter farther away from the equator. On the other hand, longitude lines are drawn north - south and they measure eastern and western hemisphere. They start at the Prime Meridian (or 0 degree) and measure from 0 degrees to 180 degrees east and 180 degrees west. Unlike lines of latitude, these lines are fairly equal in length. The origin of this spherical coordinate system is at 0 degree latitude and 0 degree longitude. This spot can be found in the Atlantic Ocean just south west of Africa. Also, the two lines connect at 180 degrees or at the International Date Line (Figure 2.18). This too helps to determining different time zones of the world.

- Together all of the above information can be used to calculate the difference of time between two locations.

- First, we need to know what longitudes the two places are located.Next, you would need to find the differences in longitude (in degrees) between the two places. If both places are located on the same side of the Prime Meridian, then the numbers are just simply subtracted to find the difference. If they are on the opposite side of the Prime Meridian then the two numbers should be added together to find the difference.

- Third, we need to divide the difference (measured in degrees) by 15 since there are 15 degrees in every hour. This will give us the difference in time between the two locations. So if you know what time it is in one location, and the longitude of another location, then just simple addition or subtraction problem will give us the time in a different time zone. Let's look at another way we may have to calculate the difference between times of two locations.

- Another calculation you may have to make is over the International Date Line. This line is strategically placed in the Pacific Ocean so that no two neighbouring cities are one day apart in time. It can be difficult to calculate though the International Date Line when trying to determine the amount of time difference between locations on either side. This calculation is very similar to the situation with the Prime Meridian. We must start by finding the difference in longitude (or degrees) of the two places. We do this by adding the two numbers. Then, divide by the 15 degrees that occurs in one hour and this will give you the time difference between two locations through the International Date Line. And again, just add or subtract that difference from the time that we already know to come up with the new time in the new time zone.

Example of Time Calculations

- To review, to find the difference between the two longitudes and divide by 15, this gives you the difference in hours between the two locations. Second, add or subtract the number of hours from the time of day that was already known, we will need to add the numbers if we are going east, and subtract if we are going west. Here are some examples of how we may need to calculate the difference of time zones.

- If you are in London at 12:00, and want to know what time it is in Japan, you would need to first figure out that London is 0 degrees (right on the prime meridian), and Japan is 135 degrees East. So the difference is 135 degrees (135-0), divided by 15 which equals 9. It means there is a 9-hour difference between London and Japan. Since Japan is further east than London is, you would add 9 hours to 12:00. The answer is at 12:00 noon London time, it is 9:00pm in Japan.

- Now we suppose imagine that we are going through the International Date Line. Pretend you are in Japan, which is 135 degrees east and you wanted to know what time it is in Hawaii, which is 150 West. Well, there is 45 (180-135) degrees difference between Japan and the IDL. Also there is 30 (180-150) degrees difference between the IDL and Hawaii. Therefore the difference in time is (45 + 30/15 = 5) 5 hours. Now the tricky part is that Japan and Hawaii are on different days. It is one day ahead on the left side of the IDL compared to the right side. If it is 3:00pm in Japan on Thursday that means it is 3:00 + 5 hours = 8:00pm in Hawaii. However notice that when crossing the IDL we subtract a day going east. So, in Hawaii it is 8:00pm on Wednesday.

- Now note that Latitudinal lines are imaginary horizontal lines over the Earth's globe. 0° longitudinal line is Equator. Earth completes one rotation on its axis in 24 hours and in the process turns a complete circle of 360°. This means Earth rotates 360°/24 = 15° in one hour. Every gain or loss of 1° longitude stands for 4 minutes.

360° = 24 hours = 1440 min
Difference of time for 15° longitude = one hour.
Difference of time for 1° longitude = 4 minutes.

Longitude Calculations Procedures

First locate the two places involved
find the longitude difference
Convert the longitude difference to time and,
Adjust the time according to the direction of movement, (west or east).

Example 1

Ponni starts her journey at longitude 0° at 12 noon and she's moving towards eastward of longitude 10°. Calculate the time that Ponni will arrive at her destination.

Solution

Initial time = 12 noon
Destination = 10°E
Conversion of degree to time 1 hour =15°
and 4 minutes =1°
Hence 10° = (4 x 10) minutes
= 40 minutes
Destination time = Initial time + calculated time
= 12 noon + 40minutes
= 12:40pm

Example 2

If the time at village A (long 75° W) is 5:00 pm on Friday. Calculate the time and day at village B (long 120°E)

Solution

360° = 24hrs
15° = 1 hour
1° = 4 minutes
Village A = 75°W
Village B = 120°E
We will add (west and east)

(75 + 120)° = 195°
195 divided by 15°= 13hrs
Destination time = initial + calculated time
= 5:00 + 13hrs
= 18:00
18:00 = 6:00

Answer = 6:00am on Saturday

Example 3

Calculate the local time in New York (USA) longitude 75°W, when it is 10am in Nigeria of longitude 15°E

Solution

Initial time = 10:00am
New York = 75°W
Nigeria = 15° E We will add (west and east)
(75 + 15)° = 90°
90° divided by 15° = 6 hrs
Destination time = initial + calculated time
= 10:00am + 6hrs
= 14:00pm
14:00pm = 4:00pm

Answer = 4:00pm

Acids, Bases and salts

9th book
Unit – 14 – Acids, Bases and salts

Introduction

- We know that the physical world around us is made of large number of chemicals. Soil, air, water, all the life forms and the materials that they use are all consist of chemicals. Out of such chemicals, acids, bases and salts are mostly used in everyday life. Let it be a fruit juice or a detergent or a medicine, they play a key role in our day-to-day activities. Our body metabolism is carried out by means of hydrochloric acid secreted in our stomach. An acid is a the compound which is capable of forming hydrogen ions (H+) in aqueous solution whereas a base is a compound that forms hydroxyl ions (OH–) in solution. When an acid and a base react with each other, a neutral product is formed which is called salt. In this lesson let us discuss about them in detail.

Acids

- Look at the pictures of some of the materials used in our daily life, given below:

- All these edible items taste similar i.e. sour. What causes them to taste sour? A certain type of chemical compounds present in them gives sour taste. These are called acids. The word 'acid' is derived from the Latin name "acidus"

- which means sour taste. Substances with sour taste are called acids.

Source	Acid Present
Apple	Malic acid
Lemon	Citric acid
Grape	Tartaric acid
Tomato	Oxalic acid
Vinegar	Acetic acid
Curd	Lactic acid
Orange	Ascorbic acid
Tea	Tannic acid
Stomach juice	Hydrochloric acid
Ant, Bee	Formic acid

- In 1884, a Swedish chemist Svante Arrhenius proposed a theory on acids and bases. According to Arrhenius theory, an acid is a substance which furnishes H+ ions or H3O+ ions in aqueous solution. They contain one or more replaceable hydrogen atoms. For example, when hydrogen chloride is dissolved in water, it gives H1 and Cl2 ions in water.

$HCl_{(aq)} \rightarrow H1_{(aq)} + Cl2_{(aq)}$

- What happens to an acid or a base in water? Do acids produce ions only in aqueous solution? Hydrogen ions in HCl are produced in the presence of water. The separation of H+ ion from HCl molecules cannot occur in the absence of water.

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

- Hydrogen ions cannot exist alone, but they exist in combined state with water molecules. Thus, hydrogen ions must always be H+ (or) Hydronium (H3O+).

$H^+ + H_2O \rightarrow H_3O^+$

All acids essentially contain one or more hydrogens. But all the hydrogen containing substances are not acids. For example, methane (CH4) and ammonia (NH3) also contain hydrogen. But they do not produce H+ ions in aqueous solution.

- The following table enlists various acids and the ions formed by them in water.

Acid	Molecular Formula	Ions formed		No. of replaceable hydrogen
Acetic Acid	$CH-_3COOH$	H+	$CH-_3COO^-$	1
Formic Acid	HCOOH	H+	$HCOO^-$	1
Nitric Acid	HNO_3	H+	NO_3^-	1
Sulphuric Acid	H_2SO_4	2H+	SO_4^{2-}	2
Phosphoric Acid	H_3PO_4	3H+	PO_4^{3-}	3

Classification of Acids

- Acids are classified in different ways as given below:

(a) Based on their sources:

- **Organic Acids**: Acids present in plants and animals (living things) are organic acids. Example: HCOOH, CH_3COOH

- **Inorganic Acids**: Acids prepared from rocks and minerals are inorganic acids or mineral acids. Example: HCl, HNO_3, $H2SO_4$

(b) Based on their Basicity

- **Monobasic Acid**: Acid that contain only one replaceable hydrogen atom per molecule is called monobasic acid. It gives one hydrogen ion per molecule of the acid in solution. Example: HCl, HNO_3

For acids, we use the term basicity that refers to the number of replaceable hydrogen atoms present in one molecule of an acid. For example, acetic acid (CH3COOH) has four hydrogen atoms but only one can be replaced. Hence it is monobasic.

- **Dibasic Acid:** An acid which gives two hydrogen ions per molecule of the acid in solution. Example: H_2SO_4, H_2CO_3

- **Tribasic Acid**: An acid which gives three hydrogen ions per molecule of the acid in solution. Example: H3PO4

(c) Based on Ionisation

- Acids get ionised in water (produce H+ ions) completely or partially. Based on the extent of ionisation acids are classified as below.

- **Strong Acids**: These are acids that ionise completely in water. Example: HCl

- **Weak Acids**: These are acids that ionise partially in water. Example: CH_3COOH.

Ionisation is the condition of being dissociated into ions by heat or radiation or chemical reactions or electrical discharge.

(d) Based on Concentration

- **Concentrated Acid:** It has relatively large amount of acid dissolved in a solvent.

- **Dilute Acid:** It has relatively smaller amount of acid dissolved in solvent.

Properties of Acids

a) They have sour taste.
b) Their aqueous solutions conduct electricity since they contain ions.
c) Acids turns blue litmus red.
d) Acids react with active metals to give hydrogen gas.

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2 \uparrow$
$Zn + 2HCl \rightarrow ZnCl_2 + H_2 \uparrow$

Few metals do not react with acid and liberate hydrogen gas. For example: Ag, Cu.

e) Acids react with metal carbonate and metal hydrogen carbonate to give carbon dioxide.

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2 \uparrow$
$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2 \uparrow$

f) Acids react with metallic oxides to give salt and water.
$CaO + H2SO4 \rightarrow CaSO4 + H2O$
g) Acids react with bases to give salt and water.
$HCl + NaOH \rightarrow NaCl + H2O$

Uses of Acids

- ❖ Sulphuric acid is called King of Chemicals because it is used in the preparation of many other compounds. It is used in car batteries also.
- ❖ Hydrochloric acid is used as a cleansing agent in toilets.
- ❖ Citric acid is used in the preparation of effervescent salts and as a food preservative.
- ❖ Nitric acid is used in the manufacture of fertilizers, dyes, paints and drugs.
- ❖ Oxalic acid is used to clean iron and manganese deposits from quartz crystals. It is also used as bleach for wood and removing black stains.
- ❖ Carbonic acid is used in aerated drinks.
- ❖ Tartaric acid is a constituent of baking powder.

Role of water in acid solution
Acids show their properties only when dissolved in water. In water, they ionise to form H+ ions which determine the properties of acids. They do not ionise in organic solvents. For example, when HCl is dissolved in water it produces H+ ions and Cl_ ions whereas in organic solvents like ethanol they do not ionise and remain as molecule.

Aquaregia

- **We** know that metals like gold and silver are not reactive with either HCl or HNO3. But the mixture of these two acids can dissolve gold. This mixture is called Aquaregia. It is a mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3:1. It is a yellow-orange fuming liquid. It is a highly corrosive liquid, able to attack gold and other substances.

Chemical formula : 3 HCL + HNO_3
Solubility in water : Miscible in water
Melting point : - 42°C (- 44°F, 231K)
Boiling point : 108°C (226°F, 381K)

- The **term**aquaregia is a Latin phrase meaning ‘King’s Water’. The name reflects the ability of aquaregia to dissolve the noble metals such as gold, platinum and palladium.

Uses of Aquaregia

- **It** is used chiefly to dissolve metals such as gold and platinum.

It is used for cleaning and refining gold.

Bases

- According to Arrhenius theory, bases are substances that ionise in water to form hydroxyl ions (OH–). There are some metal oxides which give salt and water on reaction with acids. These are also called bases. Bases that are soluble in water are called alkalis. A base reacts with an acid to give salt and water only.

Base + Acid → Salt + Water

For example, zinc oxide (ZnO) reacts with HCl to give the salt zinc chloride and water.

$ZnO_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl2_{(aq)} + H2O_{(l)}$

Similarly, sodium hydroxide ionises in water to give hydroxyl ions and thus get dissolved in water. So it is an alkali.

$NaOH_{(aq)} \rightarrow Na^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$

- Bases contain one or more replaceable oxide or hydroxyl ions in solution. Table 14.3 enlists various bases and ions formed by them in water.

All alkalis are bases but not all bases are alkalis. For example: NaOH and KOH are alkalis whereas Al(OH)3 and Zn(OH)2 are bases.

Base	Molecular Formula	Ions formed		No. of replaceable hydroxyl ion
Calcium oxide	CaO	Ca^{2+}	O^{2-}	1
Sodium oxide	Na_2O	$2Na^{+}$	O^{2-}	1
Potassium hydroxide	KOH	K^{+}	OH^{-}	1
Calcium hydroxide	$Ca(OH)_2$	$Ca2^{+}$	OH^{-}	2
Aluminium hydroxide	$Al(OH)_3$	Al^{3+}	OH^{-}	3

Classification of Bases

(a) Based on their Acidity

- Monoacidic Base: It is a base that ionises in water to give one hydroxide ion per molecule. Example: NaOH, KOH

- Diacidic **Base**: It is a base that ionises in water to give two hydroxide ions per molecule. Example: Ca(OH)2. Mg(OH)2

- Triacidic **Base:** It is a base that ionises in water to give three hydroxide ions per molecule. Example: Al(OH)3, Fe(OH)3

(b) Based on concentration

- Concentrated **Alkali**: It is an alkali having a relatively high percentage of alkali in its aqueous solution.

- Dilute **Alkali**: It is an alkali having a relatively low percentage of alkali in its aqueous solution.

(c) Based on Ionisation

- Strong **Bases**: These are bases which ionise completely in aqueous solution.

Example: NaOH, KOH

- Weak **Bases**: These are bases that ionise partially in aqueous solution.

Example: NH4OH, Ca(OH)2

The term acidity is used for base, which means the number of replaceable hydroxyl groups present in one molecule of a base.

Properties of Bases

a) They have bitter taste.

b) Their aqueous solutions have soapy touch.

c) They turn red litmus blue.

d) Their aqueous solutions conduct electricity.

e) Bases react with metals to form salt with the liberation of hydrogen gas.

$$Zn + 2\ NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$$

- f) Bases react with non-metallic oxides to produce salt and water. Since this is similar to the reaction between a baseand an acid, we can conclude that non-metallic oxides are acidic in nature.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

g) Bases react with acids to form salt and water.

$$KOH + HCl \rightarrow KCl + H2O$$

The above reaction between a base and an acid is known as Neutralisation reaction.
h) On heating with ammonium salts, bases give ammonia gas.

$$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_3\uparrow$$

Few metals do not react with sodium hydroxide. Example: Cu, Ag, Cr

- In the above activity you can observe that the bulb will start glowing only in the case of acids. But, you will observe that glucose and alcohol solution do not conduct electricity. Glowing of the bulb indicates that there is a flow of electric current through the solution. The electric current is carried through the solution by ions. Repeat the same activity using alkalis such as sodium hydroxide and calcium hydroxide.

Uses of Bases

(i) Sodium hydroxide is used in the manufacture of soap.
(ii) Calcium hydroxide is used in white washing of building.
(iii) Magnesium hydroxide is used as a medicine for stomach disorder.
(iv) Ammonium hydroxide is used to remove grease stains from cloths.

Tests for Acids and Bases

a) Test with a litmus paper:

- An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

b) Test with an indicator Phenolphthalein:

- In acid medium, phenolphthalein is colourless. In basic medium, phenolphthalein is pink in colour.

c) Test with an indicator Methyl orange:

- In acid medium, methyl orange is pink in colour. In basic medium, methyl orange is yellow in colour.

Indicator	Colour in acid	Colour in acid
Litmus	Blue to Red	Red to Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Pink	Yellow

Strenght of Acidic or Basic solutions

pH Scale

- A scale for measuring hydrogen ion concentration in a solution is called pH scale. The 'p' in pH stands for 'potenz' in German meaning power. pH scale is a set of numbers from 0 to 14 which is used to indicate whether a solution is acidic, basic or neutral.

- Acids have pH less than 7
- Bases have pH greater than 7
- A neutral solution has pH equal to 7

Salts

- When you say salt, you may think of the common salt. Sea water contains many salts dissolved in it. Sodium chloride is separated from these salts. There are many other salts used in other fields. Salts are the products of the reaction between acids and bases. Salts produce positive ions and negative ions when dissolved in water.

Types of Salts

- Normal Salts: A normal salt is obtained by complete neutralization of an acid by a base.

NaOH + HCl → NaCl + H2O

- Acid Salts: It is derived from the partial replacement of hydrogen ions of an acid by a metal. When a calculated amount of a base is added to a polybasic acid, acid salt is obtained.

$$NaOH + H2SO_4 \rightarrow NaHSO_4 + H_2O$$

- **Basic Salts**: Basic salts are formed by the partial replacement of hydroxide ions of a diacidic or triacidic base with an acid radical.

Pb(OH)2 + HCl → Pb(OH)Cl + H2O

- Double **Salts**: Double salts are formed by the combination of the saturated solution of two simple salts in equimolar ratio followed by crystallization. For example, potash alum is a mixture of potassium sulphate and aluminium sulphate. $KAl(SO_4)_2 \cdot$12H2O

Properties of Salts

- Salts are mostly solids which melt as well as boil at high temperature.
- Most of the salts are soluble in water. For example, chloride salts of potassium and sodium are soluble in water. But, silver chloride is insoluble in water
- They are odourless, mostly white, cubic crystals or crystalline powder with salty taste.
- Salt is hygroscopic in nature.

Water of Crystallisation

- Many salts are found as crystals with water molecules. These water molecules are known as water of crystallisation. Salts that contain water of crystallisation are called hydrated salts. The number of molecules of water hydrated to a salt is indicated after a dot in its chemical formula. For example, copper sulphate crystal have five molecules of water for each molecule of copper sulphate. It is written as CuSO4.5H2O and named as copper sulphate pentahydrate. This water of crystallisation makes the copper sulphate blue. When it is heated, it loses its water molecules and becomes white.

- Salts that do not contain water of crystallisation are called anhydrous salt. They are generally found as powders. Fill in the blanks in the following table based on the concept of water of crystallisation.

Identification of Salts
(i) Physical examination of the salt.

- The physical examination of the unknown salt involves the study of colour, smell and density. This test is not much reliable.

(ii) Dry heating Test.

- This test is performed by heating a small amount of salt in a dry test tube. After all the water get evaporated, the dissolved salts are sedimented in the container.

(iii) Flame Test.

- Certain salts on reacting with concentrated hydrochloric acid (HCl) form their chlorides. The paste of the mixture with con. HCl is introduced into the flame with the help of platinum wire.

Colour of the flame	Inference
Brick red	Ca^{2+}
Golden Yellow	Na^{2+}
Pink Violet	K^{+}
Green Fleshes	Zn^{2+}

(iv) WhenHCl is added with a carbonate salt, it gives off CO2 gas with brisk effervescence.

Uses of Salts

- Common Salt (Sodium Chloride - NaCl)

It is used in our daily food and used as a preservative.

Washing Soda (Sodium Carbonate-Na_2CO_3)

i. It is used in softening hard water.
ii. It is used in glass, soap and paper industries.

Baking Soda (Sodium bicarbonate -$NaHCO_3$)

i. It is used in making of baking powder which is a mixture of baking soda and tartaric acid.
ii. It is used in soda-acid fire extinguishers.
iii. Baking powder is used to make cakes and bread, soft and spongy.
iv. It neutralizes excess acid in the stomach and provides relief.

Bleaching powder (Calcium Oxychloride - $CaOCl_2$)

i. It is used as disinfectant.
ii. It is used in textile industry for bleaching cotton and linen.

Plaster of Paris (Calcium Sulphate Hemihydrate - $CaSO_4 \cdot \frac{1}{2} H_2O$)

i. It is used for plastering bones.
ii. It is used for making casts for statues.

Unit – 9 SOLUTIONS

INTRODUCTION

- You have learnt about mixtures in your lower classes. Most of the substances that we encounter in our daily life are mixtures of two or more substances. The substances present in a mixture may exist in one or more physical state. For example, when we burn wood, the smoke released is a mixture of solid carbon and gases like CO2, CO, etc.

- In some cases of mixtures, their components can be separated easily whereas in some other cases they cannot be. Consider the two mixtures, one which contains salt and water, and the another which contains sand and water. Water is the one of the components in both the mixtures. In the first case salt disolves in water. In the second case the sand does not disolve in water. Sand in water can be separated by filtration but salt cannot be separated as it dissolves in water to form a homogeneous

mixture. This kind of homogenous mixtures are termed as "**solutions**".

SOLUTIONS IN DAY-TO-DAY LIFE

- One of the naturally existing solutions is sea water. We cannot imagine life on earth without sea water. It is a mixture of many dissolved salts. The another one is air. It is a mixture of gases like nitrogen, oxygen, carbon dioxide and other gases.

- All the life forms on the earth are associated with solutions. Plants take solutions of nutrients for their growth from the soil. Most of the liquids found in human body including blood, lymph and urine are solutions. Day to day human activities like washing, cooking, cleaning and few other activities involve the formation of solutions with water. Similarly, the drinks what we take, like fruit juice, aerated drinks, tea, coffee etc. are also solutions. Therefore, the ability of water to form solutions is responsible for sustenance of life. On the other hand, the same characteristic forms the basic cause of the addition of pollutants to water. However, the ability of water to form solutions influences the survival of man on the earth. In this lesson, let us learn the science of solutions.

COMPONENTS OF SOLUTIONS

- We know that, a **solution is a homogeneous mixture of two or more substances**. In a solution, the component which is present in lesser amount (by weight), is called **solute** and the component, which is present in a larger amount (by weight) is called **solvent**. The solute gets distributed uniformly throughout the solvent and thus forming the mixture homogeneous. So, the solvent acts as a dissolving medium in a solution. The process of uniform distribution of solute into solvent is called **dissolution**. Figure 9.2 shows the schematic representation of solution.

- A solution must at least be consisting of two components (a solute and a solvent). Such solutions which are made of one solute and one solvent (two components) are called **binary solutions**. e.g. On adding copper sulphate crystals to water, it dissolves in water forming a solution of copper sulphate as shown in Figure 9.3. It contains two components i.e. one solute- copper sulphate and one solvent-water. So it is a binary solution. Similarly, a solution may contain more than two components. For example if salt and sugar are added to water, both dissolve in water forming a solution. Here two solutes are dissolved in one solvent. Such kind of solutions which contain three components are called **ternary solutions**.

Types of Solutions

Based on the physical state of the solute and the solvent

- We know that substances normally exist in three physical states (phases) i.e., solid, liquid and gas. In binary solutions, both the solvent and solute may exist in any of these physical states. But the solvent constitutes the major part of the solution. Its physical state is the primary factor which determine the characteristics of the solution. Therefore, there are different types of binary solutions as listed.

Solute	Solvent	Example
Solid solution		
Solid	Solid	Copper dissolved in gold (Alloys)
Liquid	Solid	Mercury with sodium (amalgam)
Liquid solution		
Solid	Liquid	Sodium chloride dissolved in water
Liquid	Liquid	Ethyl alcohol dissolved in water
Gas	Liquid	carbon-di-oxide dissolved in water (Soda water)
Gaseous solution		
Liquid	Gas	Water vapour in air (cloud)
Gas	Gas	Mixture of Helium-Oxygen gases,

Based on the type of solvent

- Most of the substances are soluble in water. That is why, water is called as 'Universal solvent". However some substances do not dissolve in water. Therefore, other solvents such as ethers, benzene, alcohols etc., are used to prepare a solution. On the basis of type of solvent, solutions are classified into two types. They are aqueous solutions and non-aqueous solutions.

a) Aqueous solution:

- The solution in which water acts as a solvent is called aqueous solution. In general, ionic compounds are soluble in water and form aqueous solutions more readily than covalent compounds. E.g. Common salt in water, Sugar in water, Copper sulphate in water etc.

b) Non – Aqueous solution:

- The solution in which any liquid, other than water, acts as a solvent is called non-aqueous solution. Solvent other than water is referred to as non-aqueous solvent. Generally, alcohols, benzene, ethers, carbon disulphide, acetone, etc., are used as non-aqueous solvents. Examples for non-aqueous solutions: Sulphur dissolved in carbon disulphide, Iodine dissolved in carbon tetrachloride.

Based on the amount of solute

- The amount of the solute that can be dissolved in the given amount of solvent is limited under any given conditions. Based on the amount of solute, in the given amount of solvent, solutions are classified into the following types:

(i) Saturated solution
(ii) Unsaturated solution
(iii) Super saturated solution

(i) Saturated solution: A solution in which no more solute can be dissolved in a definite amount of the solvent at a given temperature is called saturated solution. e.g. 36 g of sodium chloride in 100 g of water at 25°C forms saturated solution.Further addition of sodium chloride, leave it undissolved.

(ii) Unsaturated solution: Unsaturated solution is one that contains less solute than that of the saturated solution at a given temperature. e.g. 10 g or 20 g or 30 g of Sodium chloride in 100 g of water at 25°C forms an unsaturated solution.

(iii) Super saturated solution: Supersaturated solution is one that contains more solute than the saturated solution at a given temperature. e.g. 40 g of sodium chloride in 100 g of water at 25°C forms super saturated solution. This state can be achieved by altering any other conditions liken temperature, pressure. Super saturated solutions are unstable, and the solute is reappearing as crystals when the solution is disturbed.

Concentrated and dilute solutions

- It is another kind of classification of unsaturated solutions. It expresses the relative concentration of two solutions with respect to their solutes present in the given amount of the solvent. For example, you are given two cups of tea. When you taste them, you feel that one is sweeter than the other. What do you infer from it? The tea which sweet more contains higher amount of sugar than the other. How can you express your observation? You can say that the tea is stronger. But a chemist would say that it is 'concentrated'.

- When we compare two having same solute and solvent in a solutions, the one which contains higher amount of solute per the given amount of solvent is said to be '**concentratedsolution' and the another is said to be 'dilute solution'. They are schematically represented by Figure 9.5.**

- Differentiating solutions as dilute and concentrated is a qualitative representation. It does not imply the quantity of the solute. This difference is observed by means of some physical characteristics such as colour, density, etc.

Solubility

- Usually, there is a limit to the amount of solute that can be dissolved in a given amount of solvent at a given temperature. When this limit is reached, we have a saturated solution and any excess solute that is added, simply resides at the bottom of the solution. The extent of dissolution of a solute in a solvent can be better explained by its solubility. Solubility is measure of how much of a solute can be dissolved in a specified amount of a solvent.

Solubility=$\frac{\textit{mass of the solve}}{\textit{mass of the solvent}} \times 100$

Solubility's of some common substances in water at 25°C

Name of the solute	**Formula of the solute**	**Solubility g/100 g water**
Calcium carbonate	$CaCO_3$(s)	0.0013
Sodium chloride	NaCl (s)	36
Ammonia	NH_3(g)	48
Sodium hydroxide	NaOH(s)	80
Glucose	$C_6H_{12}O_6$(s)	91
Sodium bromide	NaBr(s)	95
Sodium iodide	NaI(s)	184

Factors affecting solubility

- There are three main factors which govern the solubility of a solute. They are:

(i) Nature of the solute and solvent
(ii) Temperature
(iii) Pressure

(i) Nature of the solute and solvent

- The nature of the solute and solvent plays an important role in solubility. Although water dissolves an enormous variety of substances, both ionic and covalent, it does not dissolve everything. The phrase that scientists often use when predicting solubility is "like dissolves like." This expression means that dissolving occurs when similarities exist between the solvent and the solute. For example: Common salt is a polar compound and dissolves readily in polar solvent like water.

- Non-polar compounds are soluble in non-polar solvents. For example, Fat dissolved in ether. But non-polar compounds, do not dissolve in polar solvents; polar compounds do not dissolve in non-polar solvents.

(ii) Effect of Temperature

Solubility of Solids in Liquid:

- Generally, solubility of a solid solute in a liquid solvent increases with increase in temperature. For example, a greater amount of sugar will dissolve in warm water than in cold water.
- In endothermic process, solubility increases with increase in temperature.
- In exothermic process, solubility decreases with increase in temperature.

Solubility of Gases in liquid

- Do you know why is it bubbling when water is boiled? Solubility of gases in liquid decrease with increase in temperature. Generally, water contains dissolved oxygen. When water is boiled, the solubility of oxygen in water decreases, so oxygen escapes in the form of bubbles.

- Aquatic animals live more in cold regions because, more amount of dissolved oxygen is present in the water of cold regions. This shows that the solubility of oxygen in water is more at low temperatures.

(iii) Effect of Pressure

- Effectof pressure is observed only in the case of solubility of a gas in a liquid. When the pressure is increased, the solubility of a gas in liquid increases.

- The common examples for solubility of gases in liquids are carbonated beverages, i.e. soft drinks, household cleaners containingaqueous solution of ammonia, formalin-aqueous solution of formaldehyde, etc.

Concentration of a Solution

- So far, we discussed what is a solution? what does it consist of and its types. Most of the chemical reactions take place in solutions form. So it is essential to quantify the solute in solvent to study the reactions. To quantify the solute in a solution, we can use the term "**concentration**".

Concentration of a solution may be defined as the amount of solute present in a given amount of solution or solvent.

- Quantitatively, concentration of a solution may be expressed in different methods. But here, we shall discuss percentage by mass (% mass) and percentage by volume (% volume).

Mass percentage

- Mass percentage of a solution is defined as the percentage by mass of the solute present in the solution. It is mostly used when solute is solid and solvent is liquid.

Mass percentage $= \frac{\text{mass of the solute}}{\text{mass of the solution}} \times 100$

Mass percentage $= \frac{\text{mass of the solute}}{\text{mass of the solution} + \text{mass of the solvent}} \times 100$

For example: 5% sugar solution (by mass) means 5 g of sugar in 95 g of water. Hence it is made 100g of solution.

- Usually, mass percentage is expressed as w/w (weight / weight); mass percentage is independent of temperature.

Volume percentage

- Volume percentage is defined as the percentage by volume of solute (in ml) present in the given volume of the solution.

Volume percentage $= \frac{\text{volume of the solute}}{\text{volume of the solution}} \times 100$

Volume percentage $= \frac{\text{volume of the solute}}{\text{volume of the solution} + \text{volume of the solvent}} \times 100$

- For example, 10% by volume of the solution of ethanol in water, means 10 ml of ethanol in 100 ml of solution (or 90 ml of water)

- Usually volume percentage is expressed as v/v (volume / volume). It is used when both the solute and solvent are liquids. Volume percentage decreases with increases in temperature, because of expansion of liquid.

- You can notice that in the commercial products that we come across in our daily life such as a solution of syrups, mouth wash, antiseptic solution, household disinfectants etc., the concentration of the ingredients is expressed as v/v. Similarly, in ointments, antacid, soaps, etc., the concentration of solutions are expressed as w/w.

Hydrated salts and Water of Crystallization

- When ionic substances are dissolved in water to make their saturated aqueous solution, their ions attract water molecules which then attached chemically in certain ratio. This process is called hydration. These ionic substances crystallize out from their saturated aqueous solution with a definite number of molecules of water. The number of water molecules found in the crystalline substance is called **water of crystallization**. Such salts are called hydrated salts.

- On heating these hydrated crystalline salts, they lose their water of crystallization and become amorphous or lose their colour (if they are coloured). Table 9.3 shows some common hydrated salts:

Common Name	IUPAC Name	Molecular Formula
Blue Vitriol	Copper (II) sulphate pentahydrate	$CuSO_4.5H_2O$
Epsom Salt	Magnesium sulphate heptahydrate	$MgSO_4.7H_2O$
Gypsum	Calcium sulphate dihydrate	$CaSO_4.2H_2O$
Green Vitriol	Iron (II) sulphate heptahydrate	$FeSO_4.7H_2O$
White Vitriol	Zinc sulphate heptahydrate	$ZnSO_4.7H_2O$

Copper sulphatepentahydrateCuSO4.5H2O (Blue vitriol)

- The number of water molecules in blue vitriol is five. So its water of crystallization is 5. When blue coloured copper sulphate crystals are gently heated, it loses its five watermolecules and becomes colourless anhydrous copper sulphate.

$$CuSO_4 \cdot 5H_2O \underset{Cooling}{\overset{Heating}{\rightleftharpoons}} CuSO_4 + 5H_2O$$

(Copper sulphate pentahydrate) (Anhydrous copper sulphate)

- If you add few drops of water or allow it to cool, the colourless anhydrous salt again turns back into blue coloured hydrated salt.

Magnesium sulphateheptahydrateMgSO4.7H2O (Epsom salt)

- Its water of crystallization is 7. When magnesium sulphateheptahydrate crystals are gently heated, it loses seven water molecules, and becomes anhydrous magnesium sulphate.

$$MgSO_4 \cdot 7H_2O \underset{Cooling}{\overset{Heating}{\rightleftharpoons}} MgSO_4 + 7H_2O$$

(Magnesium sulphate heptahydrate) (Anhydrous Magnesium sulphate)

- If you add few drops of water or allow it to cool, the colourless anhydrous salt again turns back into hydrated salt.

Hygroscopy

- Certain substances, when exposed to the atmospheric air at ordinary temperature, absorb moisture without changing their physical state. Such substances are called **hygroscopic substances** and this property is called hygroscopy.

Hygroscopic substances are used as drying agents.

Example:

1. Conc.Sulphuric acid (H_2SO_4).
2. Phosphorus Pentoxide (P_2O_5).
3. Quick lime (CaO).
4. Silica gel (SiO_2).
5. Anhydrous calcium chloride ($CaCl_2$).

Deliquescence

- Certain substances which are so hygroscopic, when exposed to the atmosphericair at ordinary temperatures, absorb enough water and get completely dissolved. Such substances are called **deliquescent substances** and this property is called **deliquescence**.

- Deliquescent substances lose their crystalline shape and ultimately dissolve in the absorbed water forming a saturated solution.

Deliquescence is maximum when:

1)The temperature is low
2)The atmosphere is humid

Examples: Calcium chloride ($CaCl_2$), Caustic soda (NaOH), Caustic potash (KOH) and Ferric chloride ($FeCl_3$).

Problems Based on Solubility and Percentage by Mass and Volume

I. Problems based on solubility

- 1) 1.5 g of solute is dissolved in 15 g of water to form a saturated solution at 298K. Find out the solubility of the solute at the temperature.

Hygroscopic substances	Deliquescence substances
When exposed to the atmosphere at ordinary temperature, they absorb moisture and do not dissolve.	When exposed to the atmospheric air at ordinary temperature, they absorb moisture and dissolve.
Hygroscopic substances do not change its physical state on exposure to air.	Deliquescent substances change its physical state on exposure to air.
Hygroscopic substances may be amorphous solids or liquids.	Deliquescent substances are crystalline solids.

Mass of the solute = 1.5 g
Mass of the solvent = 15 g

Solubility of the solute = $\frac{mass\ of\ the\ solute}{mass\ of\ the\ solvent}\times 100$

Solubility of the solute $=\frac{1.5}{15}\times 100$

= 10 g

- 2) Find the mass of potassium chloride would be needed to form a saturated solution in 60 g of water at 303 K? Given that solubility of the KCl is 37/100 g at this temperature.

Mass of potassium chloride in 100 g of water in saturated solution = 37 g

Mass of potassium chloride in $=\frac{37}{100}\times 60$ =22.2g
60 g of water in saturated solution

- 3) What is the mass of sodium chloride that would be needed to form a saturated solution in 50 g of water at 30°C. Solubility of sodium chloride is 36 g at 30°C?

At 30°C, 36 g of sodium chloride is dissolved in 100 g of water.

∴Mass of sodium chloride that would be need for 100 g of water = 36 g

∴ Mass of sodium chloride= $\frac{37\times60}{100}$ =18g
dissolved in 50 g of water

- 4) The Solubility of sodium nitrate at 50°C and 30°C is 114 g and 96 g respectively. Find the amount of salt that will be thrown out when a saturated solution of sodium nitrate containing 50 g of water is cooled from 50°C to 30°C?

Amount of sodium nitrate dissolved in 100 g of water at 50°C is 114 g

∴ Amount of sodium nitratedissolving in 50 g of water at 50°C is

$= \frac{114\times50}{100}$ =57g

Similarly amount of sodium nitratedissolving in 50g of water at 30°C is

$= \frac{96\times50}{100}$ =48g

Amount of sodium nitrate thrown when 50g of water is cooled from 50°C to 30°C is

57-48 = 9 g

II. Problem based on mass percentage

- 1) A solution was prepared by dissolving 25 g of sugar in 100 g of water. Calculate the mass percentage of solute.

Mass of the solute = 25 g
Mass of the solvent = 100 g

Mass Percentage= $\frac{mass\ of\ the\ solute}{mass\ of\ the\ solvent}$**×100**

Mass Percentage= $\frac{mass\ of\ the\ solute}{mass\ of\ the\ solute + mass\ of\ the\ solvent} \times 100$

$= \frac{25}{25+100} \times 100$

$= \frac{25}{125} \times 100 = 20g$

- 2) 16 grams of NaOH is dissolved in 100 grams of water at 25°C to form a saturated solution. Find the mass percentage of solute and solvent.

Mass of the solute (NaOH) = 16 g
Mass of the solvent H2O = 100 g

(i) Mass percentage of the solute

Mass percentage of solute $= \frac{mass\ of\ the\ solute}{mass\ of\ the\ solute + mass\ of\ the\ solvent} \times 100$

$= \frac{16 \times 100}{16+100}$

$= \frac{1600}{116}$

Mass percentage of the solute = 13.79 %

(ii) Mass percentage of solvent = 100 – (Mass percentage of the solute)

= 100 – 13.79
= 86.21%

- 3) Find the amount of urea which is to be dissolved in water to get 500 g of 10% w/w aqueous solution?

Mass Percentage(w/w) = $\frac{mass\ of\ the\ solute}{mass\ of\ the\ solvent} \times 100$

10 $= \frac{mass\ of\ the\ urea}{500} \times 100$

Mass of urea = 50g

(iii) **Problem based on Volume – volume percentage.**

- 1) A solution is made from 35 ml of Methanol and 65 ml of water. Calculate the volume percentage.

Volume of the ethanol = 35 ml
Volume of the water = 65 ml

Volume Percentage $= \frac{\text{volume of the solute}}{\text{volume of the solution}} \times 100$

Volume Percentage $= \frac{\text{volume of the solute}}{\text{volume of the solution} + \text{volume of the solvent}} \times 100$

Volume percentage = $\frac{35}{35+65} \times 100$

Volume percentage = $\frac{35}{100} \times 100$

= 35%

- 2) Calculate the volume of ethanol in 200 ml solution of 20% v/v aqueous solution of ethanol.

Volume of aqueous solution = 200 ml
Volume percentage = 20%

VolumePercentage $= \frac{\text{volume of the solute}}{\text{volume of the solution}} \times 100$

$20 = \frac{\text{volume of the ethanol}}{200} \times 100$

Volume of ethanol $= \frac{20 \times 200}{100}$ **= 40 ml**

10th book

Unit 10 - TYPES OF CHEMICAL REACTIONS

INTRODUCTION

- As you know from your earlier studies, a chemical reaction involves breaking of old chemical bonds and formation of new chemical bonds. This change may happen spontaneously or it may be facilitated by external forces or energy. Chemistry is all about chemical reactions. In your day to day life, you could observe many chemical reactions. A clear understanding of these reactions is essential in order to manipulate them for the sake of human life and environment. So, chemistry mainly focuses on chemical reactions. Let us try to find the answer for the following questions:

    - You need energy to play, walk, run or to perform various physical activities. Where do you get the energy from?
    - How do plants grow and get their food?
    - How does a car move using fuel?
    - Why does iron rust on its exposure to water or air?

- You get energy from the digestion of the food you eat. Plants grow by absorbing nutrients from the Earth and get their food by photosynthesis. The combustion of a fuel makes the car to move. Oxidation of iron causes rusting. So, all these processes are chemical changes i.e. the materials, which undergo changes are converted into some other new materials. For example, by burning petrol, the hydrocarbons present in it are converted into carbon dioxide and water. In this chapter, let us discuss the nature and types of chemical reactions.

What happens during a chemical reaction?

- In a chemical reaction, the atoms of the reacting molecules or elements are rearranged to form new molecules.
- Old chemical bonds between atoms are broken and new chemical bonds are formed.
- Bond breaking absorbs energy whereas bond formation releases energy

How are chemical reactions represented?

- When methane reacts with oxygen, it forms carbon dioxide and water. How can you represent this reaction? It can be written as a word equation as shown below:

$$\text{Methane} + \text{Oxygen} \rightarrow \text{Carbon dioxide} + \text{Water}$$

- But, this equation does not give the chemical composition of the reactants and products. So, to learn the characteristics of a chemical reaction, it is represented by a chemical equation. In the chemical equation, the chemicals of the reaction are represented by their chemical formulas. The compounds or elements, which undergo reactions (reactants) are shown to the left of an arrow and the compounds formed (products) are shown to the right of the arrow. The arrow indicates the direction of the reaction. Thus, the aforesaid reaction can be written as follows:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

- But, this is also an incomplete chemical equation. Because, the law of conservation of matter states that matter cannot be created or destroyed. You cannot create new atoms by a chemical reaction. In contrast, they are rearranged in different ways by a chemical reaction to form a new compound. So, in a chemical equation, the number of atoms of the reactants and that of the products must be equal. The number of hydrogen and oxygen atoms in the reactants and the products are notequal in the given equation. On balancing the number of atoms, the following equation can be obtained:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- Further, the chemical equation provides information on the physical state of the substances and the conditions under which the reaction takes place.

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

TYPES OF CHEMICAL REACTIONS
Classification based on the nature of rearrangements of atoms

- So far you studied about a chemical reaction and how it can be described as a chemical equation. A large number of chemical reactions are taking place around us every day.Are they taking place in a similar way? No. Each reaction involves different kinds of atoms and hence the way they react also differs. Thus, based on the manner by which the atoms of the reactants are rearranged, chemical reactions are classified as follows.

Combination reactions

- A combination reaction is a reaction in which two or more reactants combine to form a compound. It is otherwise called 'synthesis reaction' or 'composition reaction'. When a reactant 'A' combines with 'B', it forms the product 'AB'. The generalised scheme of a combination reaction is given below:

Example:

- Hydrogen gas combines with chlorine gas to form hydrogen chloride gas.

$$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$$

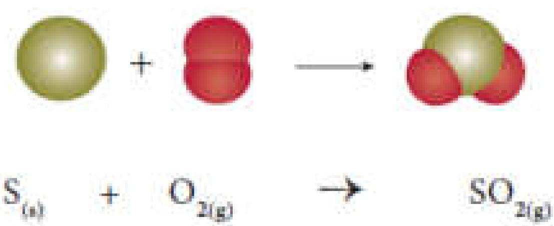
- Depending on the chemical nature of the reactants, there are threeclassesof combination reactions:

Element + Element → Compound

- In this type of combination reaction, two elements react with one other to form a compound. The reaction may take place between a metal and a non-metal or two non-metals.

Example 1:

- When solid sulphur reacts with oxygen, it produces sulphur dioxide. Here both the reactants are non-metals.



Example 2:

- Sodium, a silvery-white metal, combines with chlorine, a pale yellow green gas, to form sodium chloride, an edible compound. Here one of the reactants is a metal (sodium) and the other (chlorine) is a non-metal.

$$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$$

Test Yourself:

- Identify the possible combination reactions between the metals and non-metals given in the following table and write their balanced chemical equations:

Metals	Non-metals
Na, K, Cs, Ca, Mg	F, Cl, Br, I

Compound + Element → Compound

- In this case, a compound reacts with an element to form a new compound. For instance, phosphorous trichloride reacts with chlorine gas and forms phosphorous pentachloride.

$$PCl_{3(l)} + Cl_{2(g)} \rightarrow PCl_{5(s)}$$

Compound + Compound → Compound

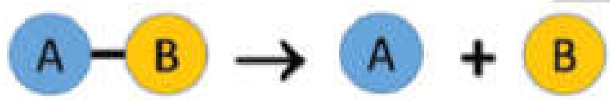
- It is a reaction between two compounds to form a new compound. In the following reaction, silicon dioxide reacts with calcium oxide to form calcium silicate.

$$SiO_{2(s)} + CaO_{(s)} \rightarrow CaSiO_{3(s)}$$

- Most of the combination reactions are exothermic in nature. Because, they involve the formation of new bonds, which releases a huge amount of energy in the form of heat.

Decomposition reactions

- In a decomposition reaction, a single compound splits into two or more simpler substances under suitable conditions. It is the opposite of the combination reaction. The generalised schemeof a decomposition reaction is given below:



- Breaking of bonds is the major phenomenon in a decomposition reaction and hence it requires energy to break the bonds, depending on the nature of the energy used in the decomposition reaction.

There are three main classes of decomposition reactions. They are

- Thermal Decomposition Reactions
- Electrolytic Decomposition Reactions
- Photo Decomposition Reactions

A solution of slaked lime is used for white washing walls. Calcium hydroxide reacts slowly with the carbon dioxide in air to form a thin layer of calcium carbonate on the walls. Calcium carbonate is formed aft er two to three days of white washing and gives a shiny finish to the walls. It is interesting to note that the chemical formula for marble is also$CaCO_3$

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

Thermal Decomposition Reactions

- In this type of reaction, the reactant is decomposed by applying heat. For example, on heating mercury (II) oxide is decomposed into mercury metal and oxygen gas. As the molecule is dissociated by the absorption of heat, it is otherwise called 'Thermolysis'.It is a class of compound to element/element decomposition. i.e. a compound (HgO) is decomposed into two elements (Hg and Oxygen).

$$2HgO_{(s)} \xrightarrow{\text{Heat}} 2Hg_{(l)} + O_{2(g)}$$

- Similarly, when calcium carbonate is heated, it breaks down in to calcium oxide and carbon dioxide. It is a type of compound to compound/compound decomposition.

$$CaCO_{3(s)} \xrightarrow{\text{Heat}} CaO_{(s)} + CO_{2(g)}$$

- In thermal decomposition reaction, heat is supplied to break the bonds. Such reactions, in which heat is absorbed, are called 'Endothermic reactions'.

Electrolytic Decomposition Reactions

- In some of the decomposition reactions, electrical energy is used to bring about the reaction. For example, decomposition of sodium chloride occurs on passing electric current through its aqueous solution. Sodium chloride decomposes in to metallic sodium and chlorine gas. This process is termed as 'Electrolysis'.

$$2NaCl_{(aq)} \xrightarrow{\text{Electricity}} 2Na_{(s)} + Cl_{2(g)}$$

- Here, a compound (NaCl) is converted into elements (Na and chlorine). So it is a type of compound to element/element decomposition.

Photo Decomposition Reactions

- Light is an another form of energy, which facilitates some of the decomposition reactions. For example, when silver bromide is exposed to light, it breaks down into silver metal and bromine gas. As the decomposition is caused by light, this kind of reaction is also called 'Photolysis'.

$$2AgBr_{(s)} \xrightarrow{\text{Ligh}} 2Ag_{(s)} + Br_{2(g)}$$

- The yellow coloured silver bromide turns into grey coloured silver metal. It is also a compound to element/element decomposition.

Single Displacement Reactions

- It is a reaction between an element and a compound. When they react, one of the elements of the compound-reactant is replaced by the element-reactant to form a new compound and an element. The general schematic representation of a single displacement reaction is given as:

- 'A' displaces element 'B' from the compound 'BC' and hence a single displacement reaction occurs. If zinc metal is placed in hydrochloric acid, hydrogen gas is evolved. Here, hydrogen is displaced by zinc metal and zinc chloride is formed.

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

$$Fe_{(s)} + CuSO_{4(aq)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$$

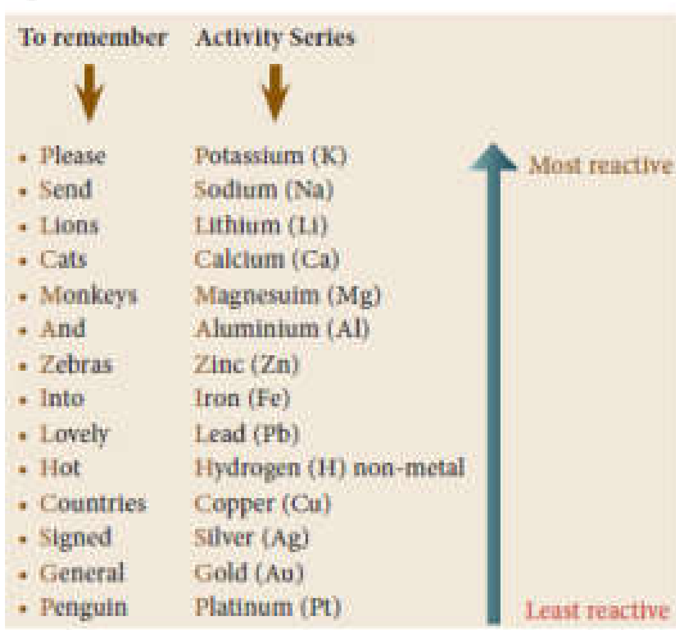
- If an iron nail is placed in an aqueous solution of copper (II) sulphate as shown in Fig. 10.2, the iron displaces copper from its aqueous solution and the so formed copper deposits over the iron nail.

- It is easy to propose so many reactions of this kind with different combinations ofreactants. Will they all occur in practice? No. This is most easily demonstrated with halogens. Let us consider the following two reactions:

$$2NaCl_{(aq)} + F_{2(g)} \rightarrow 2NaF_{(aq)} + Cl_{2(g)}$$
$$2NaF_{(aq)} + Cl_{2(g)} \rightarrow 2NaCl_{(aq)} + F_{2(g)}$$

- The first reaction involves the displacement of chlorine from NaCl, by fluorine. In the second reaction, chlorine displaces fluorine from NaF. Out of these two, the second reaction will not occur. Because, fluorine is more active than chlorine and occupies the upper position in the periodic table. So, in displacement reactions, the activity of the elements and their relative position in the periodic table are the key factors to determine the feasibility of the reactions. More active elements readily displace less active elements from their aqueous solution.

The activity series of some elements is given below:

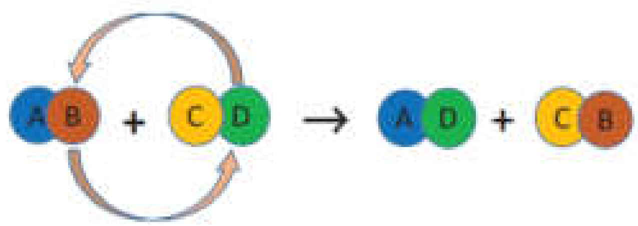


By referring the activity series, try to answer the following questions:

- Which of the metals displaces hydrogen gas from hydrochloric acid? Silver or Zinc. Give the chemical equation of the reaction and Justify your answer

Double Displacement Reactions

- When two compounds react, if their ions are interchanged, then the reaction is called double displacement reaction. The ion of one compound is replaced by the ion of the another compound. Ions of identical charges are only interchanged, i.e., a cation can be replaced by other cations. This reaction is also called 'Metathesis Reaction'. The schematic representation of a double displacement reaction is given below:



- For a double displacement reaction to take place, one of the products must be a precipitate or water. By this way, there are major classes of double displacement reactions. They are:

  1. Precipitation Reactions
  2. Neutralization Reactions

Precipitation Reactions

- When aqueous solutions of two compounds are mixed, if they react to form an insoluble compound and a soluble compound, then it is called precipitation reaction. Because the insoluble compound, formed as one of the products, is a precipitate and hence the reaction is so called.

Differences between combination and decomposition reactions

COMBINATION REACTIONS	DECOMPOSITION REACTIONS
One or more reactants combine to form a single product	A single reactant is decomposed to form one or more products
Energy is released	Energy is absorbed
Elements or compounds may be the reactants	Single compound is the reactant

- When the clear aqueous solutions of potassium iodide and lead (II) nitrate are mixed, a double displacement reaction takes place between them.

$$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)}\downarrow + 2KNO_{3(aq)}$$

Potassium and lead displace or replace one other and form a yellow precipitate of lead.

Neutralization Reactions

- In your lower classes, you have learned the reaction between an acid and a base. It isanother type of displacement reaction in which the acid reacts with the base to form a salt and water. It is called 'neutralization reaction' as both acid and base neutralize each other.

Acid + Base → Salt + Water

- Reaction of sodium hydroxide with hydrochloric acid is a typical neutralization reaction. Here, sodium replaces hydrogen from hydrochloric acid forming sodium chloride, a neutral soluble salt.

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

- Similarly, when ammonium hydroxide reacts with nitric acid, it forms ammonium nitrate and water.

$$HNO_{3(aq)} + NH_4OH_{(aq)} \rightarrow NH_4NO_{3(aq)} + H_2O_{(l)}$$

Combustion Reactions

- A combustion reaction is one in which the reactant rapidly combines with oxygen to form one or more oxides and energy (heat). So in combustion reactions, one of the reactants must be oxygen. Combustion reactions are majorly used as heat energy sources in many of our day to day activities. For instance, we use LPG gas for domestic cooking purposes. We get heat and flame from LPG gas by its combustion reaction of its constituent gases. LPG is a mixture of hydrocarbon gases like propane, butane, propylene, etc. All these hydrocarbons burn with oxygen to form carbon dioxide and water.

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)} + Heat$$

- Since heat is evolved, it is an exothermic reaction. As oxygen is added, it is also an oxidation. So, combustion may be called as an exothermic oxidation. If a flame is formed (as shown in Fig. 10.4), then it is called burning.

1. Digestion of Food
2. Rusting of iron

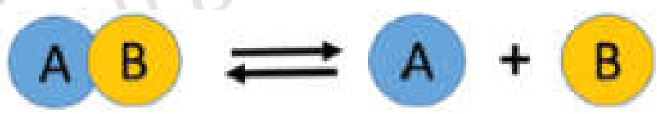
- Many thousands of reactions fall under these five categories and further you will learn in detail about these reactions in your higher classes.

Classification based on the direction of the reaction

- You know that innumerable changes occur every day around us. Are all they permanent? For example, liquid water freezes into ice, but then ice melts into liquid water. In other words, freezing is reversed. So, it is not a permanent change. Moreover, it is a physical change. Physical changes can be reversed easily. Can chemical changes be reversed? Can the products be converted into reactants? Let us consider the burning of a wood. The carbon compounds present in the wood are burnt into carbon dioxide gas and water. Can we get back the wood immediately from carbon dioxide and water? We cannot. So, it is a permanent change. In most of the cases, we cannot. But, some chemical reactions can be reversed. Our mobile phone gets energy from its lithium ion battery by chemical reactions. It is called discharging. On recharging the mobile, these chemical reactions are reversed. Thus, chemical reactions may be reversed under suitable conditions. Hence, they aregrouped into two categories such as reversible and irreversible reactions.

Reversible Reactions

- A reversible reaction is a reaction that can be reversed, i.e., the products can be converted back to the reactants. A reversible reaction is represented by a double arrow with their heads in the direction opposite to each other. Thus, a reversible reaction can be represented by the following equation:



Explanation:

- Here, the compound 'AB' undergoes decomposition to form the products 'A' and 'B'. It is the forward reaction. As soon as the products are formed, they combine together to form 'AB'. It is the backward reaction. So, the reaction takes place in both the directions. Do you think then that no products are formed in the aforesaid reaction? If you think so, you are wrong. Because, even though the reaction takes place in both the directions, at the initial stage the rates (speed) of these reactions are not equal. Consider the following decomposition reaction of phosphorous pentachloride into phosphorous trichloride and chlorine.

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

- The forward reaction is the decomposition of PCl_5 and the backward reaction is the combination of PCl_3 and Cl_2. Initially, the forward reaction proceeds faster than the backward reaction. After sometimes, the speed of both the reactions become equal. So, PCl_5 cannot be completely converted into the products as the reaction is reversed. It is a reversible reaction. The actual measurements of the given reaction show that the reaction is at equilibrium, but the amount of PCl_5 is more than that of PCl_3 and Cl_2.

- Thus, more amount of products can be obtained in a reversible reaction by the periodical removal of one of the products or the periodical addition of the reactants.

$$2H2O_{2(aq)} \rightleftarrows 2H_2O_{(l)} + O_{2(g)}$$

Irreversible Reactions

- The reaction that cannot be reversed is called irreversible reaction. The irreversible reactions are unidirectional, i.e., they take place only in the forward direction. Consider the combustion of coal into carbon dioxide and water.

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + Heat$$

- In this reaction, solid coal burns with oxygen and gets converted into carbon dioxide gas and water. As the product is a gas, as soon as it is formed it escapes out of the reaction container. It is extremely hard to decompose a gas into a solid. Thus, the backward reaction is not possible in this case. So, it is an irreversible reaction. Table 10.2 provides themain differences between a reversible and an irreversible reaction:

Differences between reversible and irreversible reactions

REVERSIBLE REACTION	IRREVERSIBLE REACTION
It can be reversed under suitable conditions.	It cannot be reversed.
Both forward and backward reactions take place simultaneously.	It is unidirectional. It proceeds only in forward direction.
It attains equilibrium	Equilibrium is not attained.
The reactants cannot be converted completely into products.	The reactants can be completely converted into products.
It is relatively slow.	It is fast.

RATE OF A CHEMICAL REACTION

- So far we discussed various types of chemical reactions and the nature of the reactants and products. Let us consider the following reactions:

1. Rusting of iron
2. Digestion of food
3. Burning of petrol
4. Weathering of rock

- How fast is each reaction? Rank them from the slowest to fastest. How will you determine, which is the fastest and which is the slowest? One of the ways to find out how fast a reaction is as follows: Measure the amount of reactants or products before and after a specific period of time. For example, let us assume that 100 gof a substance 'A' undergoes a reaction and after an hour 50 g of 'A' is left.

$$A \rightarrow \text{Product}$$

- In another instance, 100 g of substance 'C' undergoes a reaction and after an hour, 20 g of 'C' is left.

$$C \rightarrow \text{Product}$$

- Can you say which is the faster reaction? In the first reaction, 50 g of the reactant (A) is converted into products whereas in the second reaction 80 g of the reactant is converted into products in one hour. So, the second reaction is faster. This measurement is called 'the reaction rate'.

- "Rate of a reaction is the change in the amount or concentration of any one of the reactants or products per unit time".

Consider the following reaction

$$A \rightarrow B$$

The rate of this reaction is given by

$$\text{Rate} = -\frac{d[A]}{dt} = +\frac{d[B]}{dt}$$

Where,

[A] – Concentration of A
[B] – Concentration of B

- The negative sign indicates the decrease in the concentration of A with time.

- The postive sign indicates the increase in the concentration of B with time.

Note: '[ ]' represents the concentration, 'd' represents the infinitesimal change in the concentration.

Why is reaction rate important?

- Faster the reaction, more will be the amount of the product in a specified time. So, the rate of a reaction is important for a chemist for designing a process to get a good yield of a product. Rate of reaction is also important for a food processor who hopes to slow down the reactions that cause food to spoil.

Factors influencing the rate of a reaction

- Can the rate of a reaction be changed? The rate of a reaction can be changed. Forexample, iron gets rusted faster in an acid than in water. Important factors that affect rate of a reaction are

  1. Nature of the reactants
  2. Concentration of the reactants
  3. Temperature
  4. Catalyst
  5. Pressure
  6. Surface area of the reactants

Nature of the reactants

- The reaction of sodium with hydrochloric acid is faster than that with acetic acid. Do you know why? Hydrochloric acid is a stronger acid than acetic acid and thus more reactive. So, the nature of the reactants influence the reaction rate.

$$2Na_{(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_{2\,(g)} \text{ (fast)}$$

$$2Na_{(s)} + 2CH_3COOH_{(aq)} \rightarrow 2CH_3COONa_{(aq)} + H_{2(g)}\text{(slow)}$$

Concentration of the reactants

- Changing the amount of the reactants also increases the reaction rate. The amount of the substance present in a certain volume of the solution is called 'concentration'. More the concentration, more particles per volume exist in it and hence faster the reaction. Granulated zinc reacts faster with 2M hydrochloric acid than 1M hydrochloric acid.

Temperature

- Most of the reactions go faster at higher temperature. Because adding heat to the reactants provides energy to break more bonds and thus speed up the reaction. Calcium carbonate reacts slowly with hydrochloric acid at room temperature. When the reaction mixture is heated the reaction rate increases.

Food kept at room temperature spoils faster than that kept in the refrigerator. In the refrigerator, the temperature is lower than the room temperature and hence the reaction rate is less.

Pressure

- If the reactants are gases, increasing their pressure increases the reaction rate. This is because, on increasing the pressure the reacting particles come closer and collide frequently.

Catalyst

- A catalyst is a substance which increases the reaction rate without being consumed in the reaction. In certain reactions, adding a substance as catalyst speeds up the reaction. For example, on heating potassium chlorate, it decomposes into potassium chloride and oxygen gas, but at a slower rate. If manganese dioxide is added, it increases the reaction rate.

Surface area of the reactants

- When solid reactants are involve in a reaction, their powdered form reacts more readily. For example, powdered calcium carbonate reacts more readily with hydrochloric acid than marble chips. Because, powdering of the reactants increases the surface area and more energy is available on collision of the reactant particles. Thus, the reaction rate is increased.

STATE OF EQUILIBRIUM

- In a reversible reaction, both forward and backward reactions take place simultaneously. When the rate of the forward reaction becomes equal to the rate of backward reaction, then no more product is formed. This stage of the reaction is called 'equilibrium state'. After this stage, no net change in the reaction can occur and hence in the amount of the reactants and products. Since this equilibrium is attained in a chemical reaction, it is called 'Chemical Equilibrium'. Chemical Equilibrium: It is state of a reversible chemical reaction in which no change in the amount of the reactants and products takes place. At equilibrium,

Rate of forward reaction = Rate of backward reaction

Explanation:

- Initially the rate of the forward reaction is greater than the rate of the backward reaction. However, during the course of reaction, the concentration of the reactants decreases and the concentration of the products increases. Since the rate of a reaction is directly proportional to the concentration, the rate of the forward reaction decreases with time, whereas the rate of the backward reaction increases.

- At a certain stage, both the rates become equal. From this point onwards, there will be no change in the concentrations of both the reactants and the products with time. This state is called as equilibrium state.

- Let us consider the decomposition of calcium carbonate into lime and carbon dioxide. It is a reversible reaction. The speed of each reaction can be determined by how quickly the reactant disappears. If the reaction is carried out in a closed vessel, it reaches a chemical equilibrium. At this stage,

$$CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

- The rate of decomposition of $CaCO_3$= The rate of combination of CaO and CO_2.

- Not only chemical changes, physical changes also may attain equilibrium. When water kept in a closed vessel evaporates, it forms water vapour. No water vapour escapes out of the container as the process takes place in a closed vessel. So, it builds up the vapour pressure in the container. At one time, the water vapour condenses back into liquid water and when the rate of this condensation becomes equal to that of vapourisation, the process attains equilibrium.

- At this stage, the volume of the liquid and gaseous phases remain constant. Since it is a physical change, the equilibrium attained is called 'Physical Equilibrium'. Physical equilibrium is a state of a physical change at which the volume of all the phases remain unchanged.

$$H2O_{(l)} \underset{\text{Condensation}}{\overset{\text{Evaporation}}{\rightleftarrows}} H_2O\ C_{(g)}$$

Characteristics of equilibrium .

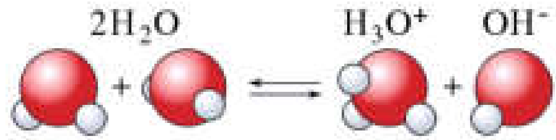
- ❖ In a chemical equilibrium, the rates of the forward and backward reactions are equal.
- ❖ The observable properties such as pressure, concentration, colour, density, viscosity etc., of the system remain unchanged with time.
- ❖ The chemical equilibrium is a dynamic equilibrium, because both the forward and backward reactions continue to occur even though it appears static externally.
- ❖ In physical equilibrium, the volume of all the phases remain constant.

Aerated soft drinks contain dissolved carbon dioxide in a pop bottle (Soda). When the bottle is sealed, the dissolved carbon dioxide (in the form of carbonic acid) and gaseous CO2 are in equilibrium with each other. When you open the bottle, the gaseous CO2 can escape. So, the dissolved CO2 begins to undissolve back to the gas phase trying to replace the gas that was lost, when you opened the bottle. That's why if you leave it open long enough, it will goes 'flat'. All the CO2 will be gone, blown away in the

IONIC PRODUCT OF WATER

- Although pure water is often considered as a non-conductor of electricity, precise measurements show that it conducts electricity to a little extent. This conductivity of water has resulted from the self-ionisation of water. Self-ionisation or auto ionisation is a reaction in which two like molecules react to give ions. In the process of ionisation of water, a proton from one water molecule is transferred to another water molecule leaving behind an OH^- ion. The proton gets dissolved in water forming the hydronium ion as shown in the following equation:

$$H2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$



- The hydronium ion formed is a strong acid and the hydroxyl ion is a strong base. So as fast as they are formed, they react again to produce water. Thus, it is a reversible reaction and attains equilibrium very quickly. So, the extent of ionisation is very little and the concentration of the ions produced is also very less. The product of the concentration of the hydronium ion and the hydroxyl ion is called 'ionic product of water'. It is denoted as 'Kw'. It is mathematically expressed as follows:

$$K_w = [H_3O^+]\,[OH^-]$$

$[H3O^+]$ may be simply written as $[H^+]$. Thus the ionic product of water may also be expressed as

$$K_w = [H^+]\,[OH^-]$$

Its unit is $mol^2\ dm^{-6}$. At 25° C, its value is 1.00×10^{-14}.

pHSCALE

- All the aqueous solutions may contain hydrogen and hydroxyl ions due to self-ionisation of water. In addition to this ionisation, substances dissolved in water also may produce hydrogen ions or hydroxyl ions. The concentration of these ions decides whether the solution is acidic or basic. pH scale is a scale for measuring the hydrogen ion concentration in a solution. The 'p' in pH stands for 'Potenz' in German meaning 'power'. pH notation was devised by the Danish biochemist Sorensen in 1909. pH scale is a set of numbers from 0 to 14 which is used to indicate whether a solution is acidic, basic or neutral.

  - Acids have pH less than 7
  - Bases have pH greater than 7
  - A neutral solution has pH equal to 7

The pH is the negative logarithm of the hydrogen ion concentration

$$pH = -\log_{10}[H^+]$$

Common Acids	**p^H**	**Common bases**	**p^H**
HCL(4%)	0	Blood plasma	7.4
Stomach acid	1	Egg white	8
Lemon juice	2	Sea water	9
Vinegar	3	Baking soda	10
Oranges	3.5	Antacids	10
Soda, Graps	4	Ammonia water	11
Sour milk	4.5	Lime water	12
Fresh Milk	5	Drain cleaner	13
Human saliva	6-8	Caustic soda 4% (NaOH)	14
Pure water	7	Milk of magnesia	10
Tomato juice	4.2	Coffee	5.6

How can we measure the pH of a given solution using pH Paper

- The pH of a solution can be determined by using a universal indicator. It contains a mixture of dyes. It comes in the form of a solution or a pH paper.

- A more common method of measuring pH in a school laboratory is by using the pH paper. A pH paper contains a mixture of indicators. It shows a specific colour at a given pH. A colour guide is provided with the bottle of the indicator or the strips of paper impregnated with it, which are called pH paper strips. The test solution is tested with a drop of the universal indicator, or a drop of the test solution is put on the pH paper. The colour of the solution on the pH paper is compared with the colour chart and the pH value is read from it. The pH values thus obtained are only approximate values.

ROLE OF pH IN EVERYDAY LIFE
Are plants and animals pH sensitive?

- Our body works within the pH range of 7.0 to 7.8. Living organisms can survive only in a narrow range of pH change. Different body fluids have different pH values. For example, pH of blood is ranging from 7.35 to 7.45. Any increase or decrease in this value leads to diseases. The ideal pH for blood is 7.4.

pH in our digestive system

- It is very interesting to note that our stomach produces hydrochloric acid. It helps in the digestion of food without harming the stomach. During indigestion the stomach produces too much acid and this causes pain and irritation. pH of the stomach fluid is approximately 2.0.

pH changes as the cause of tooth decay

- pH of the saliva normally ranges between 6.5 to 7.5. White enamel coating of our teeth is calcium phosphate, the hardest substance in our body. When the pH of the mouth saliva falls below 5.5, the enamel gets weathered. Toothpastes, which are generally basic are used for cleaning the teeth that can neutralise the excess acid and prevent tooth decay.

pH of soil

- In agriculture, the pH of the soil is very important. Citrus fruits require slightly alkaline soil, while rice requires acidic soil and sugarcane requires neutral soil.

pH of rain water

- The pH of rain water is approximately 7, which means that it is neutral and also represents its high purity. If the atmospheric air is polluted with oxide gases of sulphur and nitrogen, they get dissolved in the rain water and make its pH less than 7. Thus, if the pH of rain water is less than 7, then it is called acid rain. When acid rain flows into the rivers it lowers the pH of the river water also.

pH CALCULATION

The pH is the negative logarithm of the hydrogen ion concentration

$$pH = -\log_{10} [H^+]$$

Example:

Calculate the pH of 0.01 M HNO_3?

Solution:

$[H^+] = 0.01$
$pH = -\log_{10} [H^+]$
$pH = -\log_{10} [0.01]$
$pH = -\log_{10} [1 \times 10^{-2}]$
$pH = -(\log_{10}1 - 2 \log_{10}10)$
$pH = 0 + 2 \times \log_{10}10$
$pH = 0 + 2 \times 1 = 2$
$pH = 2$

pOH:

- The pOH of an aqueous solution is realted to the pH.
  The pOH is the negative logarithm of the hydroxyl ion concentration

$$pOH = -\log_{10}[OH^-]$$

Example:

- The hydroxyl ion concentration of a solution is 1×10^{-9}M. What is the pOH of the solution?

Solution

$pOH = -\log_{10} [OH^-]$
$pOH = -\log_{10} [1 \times 10^{-9}]$
$pOH = -(\log_{10} 1.0 + \log10\ 10^{-9})$
$pOH = -(0-9 \log_{10}10)$
$pOH = -(0 - 9)$
$pOH = 9$

Relationship between pH and pOH

- The pH and pOH of a water solution at 25oC are related by the following equation.

$pH + pOH = 14$

- If either the pH or the pOH of a solution is known, the other value can be calculated.

Example: A solution has a pOH of 11.76. What is the pH of this solution?

$$pH = 14 - pOH$$
$$pH = 14 - 11.76 = 2.24$$

PROBLEMS

Example 1:

Calculate the pH of 0.001 molar solution of HCl.

- **Solution:**

HCl is a strong acid and is completely dissociated in its solutions according to the process:

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

From this process it is clear that one mole of HCl would give one mole of H^+ ions. Therefore, the concentration of H+ ions would be equal to that of HCl, i.e., 0.001 molar or 1.0×10^{-3}mol litre^{-1}.

Thus, $[H^+] = 1 \times 10–3$ mol litre^{-1}

pH = $–\log10[H^+] = –\log1010^{-3}= –(–3 \times \log_{10}) = –(3 \times 1) = 3$

Thus, pH = 3

Example 2:

What would be the pH of an aqueous solution of sulphuric acid which is 5×10^{-5}mol litre^{-1} in concentration.

- **Solution:**

Sulphuric acid dissociates in water as:

$$H2SO_{4(aq)} \rightarrow 2\ H^+_{(aq)} + SO^{2-}{}_{4(aq)}$$

Each mole of sulphuric acid gives two mole of H^+ ions in the solution. One litre of H_2SO_4 solution contains 5×10^{-5} moles of H_2SO_4 which would give 2 × 5 × 10–5 = 10 × 10–5 or 1.0×10^{-4} moles of H^+ ion in one litre of the solution.

Therefore,

$[H+] = 1.0 \times 10^{-4}$mol litre^{-1}

pH = $–\log_{10}[H^+] = –\log_{10}10^{-4} = –(–4 \times \log_{10}10) = –(–4 \times 1) = 4$

Example 3:

Calculate the pH of 1 × 10–4 molar solution of NaOH.

- **Solution:**

NaOH is a strong base and dissociates in its solution as:

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

One mole of NaOH would give one mole of OH– ions. Therefore,

$$[OH^-] = 1 \times 10^{-4} \text{mol litre}^{-1}$$

$$pOH = -\log_{10}[OH^-] = -\log_{10} \times [10^{-4}]$$

$$= -(-4 \times \log_{10}10) = -(-4) = 4$$

Since, pH + pOH = 14

$$pH = 14 - pOH = 14 - 4 = 10$$

Example 4:

Calculate the pH of a solution in which the concentration of the hydrogen ions is 1.0 × 10^{-8} mol litre^{-1}.

- **Solution:**

Here, although the solution is extremely dilute, the concentration given is not of an acid or a base but that of H^+ ions. Hence, the pH can be calculated from the relation:

$pH = -\log10[H^+]$
given $[H^+] = 1.0 \times 10^{-8}$ mol litre^{-1}
$pH = -\log_{10}10^{-8} = -(-8 \times \log_{10}10)$
$= -(-8 \times 1) = 8$

Example 5:

If the pH of a solution is 4.5, what is its pOH?

Solution:

pH + pOH = 14
pOH = 14 – 4.5 = 9.5
pOH = 9.5

Genetics

10th book
Unit – 18 -Heredity

Gregor Johann Mendel - Father of Genetics

- Mendel (1822-1884) was an Austrian monk who discovered the basic principles of heredity through his experiments. His experiments are the foundation for modern genetics. He was born in 1822 to a family of farmers in Silesian of Czechoslovakia. After finishing his high school at the age of 18, he entered the Augustinian Monastery at Brunn as a priest. From there he went to the University of Vienna for training in physics, mathematics and natural science. Mendel returned to the monastery in 1854 and continued to work as a priest and teach in high school. In his leisure time he started his famous experiments on the garden pea plant. He conducted his experiments in the monastery for about nine years from 1856 to 1865. He had worked on nearly 10000 pea plants of 34 different varieties. Mendel noted that they diff er from one another in many ways.

Mono hybrid Cross – Inheritance of One Gene

- crosses involving inheritance of only one pair of contrasting characters are called monohybrid crosses. For example it is a cross between two forms of a single trait like cross between tall and dwarf plant

Mendel 's Explanation of Monohybrid Cross:

- Parental generation: Pure breeding tall plant and a purebreeding dwarf plant **F1 generation:** Plant raise from the seeds of pure breeding parental cross in F1 generation were tall and monohybrids.

- **F2 generation:**

  Selfing of th F1 monohybrids resulted in talland dwarf plants respectively in the ratio of 3:1.The actual number of talland dwarf plants obtained by Mendel was 787 tall and 277 dwarf External expression of a particular trait is known as phenotype. So the phenotypic ratio is 3:1.

    - In the F2 generation 3 different types were obtained:
    - Tall Homozygous – TT(Pure) – 1
    - Tall Heterozygous – Tt -2
    - Dwarf Homozygous – tt– 1
    - So the genotypic ratio 1:2:1.A genotype is the genetic expression of an organism.

Mendal 's Interpretation on Monohybrid cross

- Based on these observations it was confirmed by Mendel that 'factors' are passed on from one generation to another, now refered to as genes. Tallness and Dwarfnessare determined by a pair for contrasting factors , tall plant possess a pair of factors (represented by T- taking the first letter of the dominant character) and a plant is dwarf because it possess factors for dwarfness (represented as t- recessive character). These factors occur in pairs and may be alike as in pure breeding tall plants (TT) and dwarf plants (tt). This is referred to as homozygous. If they are unlike (Tt) they are referred to as heterozygous.

- Two factors making up a pair of contrasting characters are called allelesor allelomorphs. One member of each pair is contributed by one parent

- When two factors for alternative expression of a trait are brought together by fertilization only one expresses itself, (tallness) masking the expression of the other (dwarfness). The character which expresses itself is called dominant condition and that which is masked is called recessive condition.

- The factors are always pure and when gametes are formed, the unit factors segregate so that each gamete gets one of the two alternative factors. It means that factors for tallness(T) and dwarfness(t) are separate entities and in a gamete either T or t is present. When F1 hybrids are self crossed the two entities separate and then unite independently, forming tall and dwarf plants.

Dihybrid Cross- Inheritance Two Genes and Law of Independent Assortment:

- Dihybrid cross involves the inheritance of two pairs of contrasting characteristics (or contrasting traits) at the same time. The two pairs of contrasting characteristics chosen by Mendel were shape and colour of seeds: round-yellow seeds and wrinkled-green seeds.

- Mendel crossed pea plants having round-yellow seeds with pea plants having wrinkled-green seeds. Mendel made the following observations:

- Mendel first crossed pure breeding pea plants having round-yellow seeds with pure breeding pea plants having wrinkled-green seeds and found that only round-yellow seeds were produced in the first generation (F1). No wrinkled-green seeds were obtained in the F1 generation. From this it was concluded that round shape and yellow colour of the seeds were dominant traits over the wrinkled shape and green color of the seeds.

- When the hybrids of F1 generation pea plants having round-yellow seeds were cross-bred by self pollination, then four types of seeds having different combinations of shape and color were obtained in second generation or F2 generation. They were round yellow, round-green, wrinkled yellow and wrinkled-green seeds.

- The ratio of each phenotype (or appearance) of seeds in the F2 generation is 9:3:3:1. This is known as the Dihybrid ratio.

- From the above results it can be concluded that the factors for each character or trait remain independent and maintain their identity in the gametes. The factors are independent to each other and pass to the offsprings (through gametes).

Results of a Dihybrid Cross:

Mendel got the following results from his dihybrid cross

- **Four Types of Plants:**
  A dihybrid cross produced four types of F2 offsprings in the ratio of 9 with two dominant traits, 3 with one dominant trait and one recessive trait, 3 with another dominant trait and another recessive trait and 1 with two recessive traits.

- **New Combination:**
  Two new combinations of traits with round green and wrinkled yellow had appeared in the dihybrid cross (F2 generation).

Mendel's Laws

- Based on his experiments of monohybrid and dihybrid cross, Mendel proposed three important laws which are now called as Mendel's Laws of Heredity.

Law of Dominance:

- "When two homozygous individuals with one or more sets of contrasting characters are crossed, the characters that appear in the F1 hybrid are dominant and those that do not appear in F1 are recessive characters".

Law of Segregation or Law of purity of gametes:

- "When a pair of contrasting factors or genes or allelomorphs are brought together in a heterozygote or hybrid, the two members of the allelic pair remain together without mixing and when gametes are formed, the two separate out, so that only one enters each gamete."

Law of independent assortment:

- "In case of inheritance of two or more pairs of characters simultaneously, the factors or genes of one pair assort out independently of the other pair."

Down's syndrome

- This condition was first identified by a doctor named Langdon Down in1866.

- It is a genetic condition in which there is an extra copy of chromosome 21 (Trisomy 21). It is associated with mental retardation, delayed development, behavioural problems, weak muscle tone, vision and hearing disability are some of the conditions seen in these children.

Gene or point mutation

- Gene mutation is the changes occurring in nucleotide sequence of a gene. It involves substitution, deletion, insertion or inversion of a single or more than one nitrogenous base. Gene alteration results in abnormal protein formation in an organism.

Sickle cell anaemia is caused by the mutation of a single gene. Alteration in the gene brings a change in the structure of the protein part of haemoglobin molecule. Due to the change in the protein molecule, the red blood cell (RBC) that carries the haemoglobin is sickle shaped.

10th book
Unit – 19 -Origin & Evolution of Life

Theories on Origin of Life:

- Many theories have been postulated to explain the origin of life. The views on the origin of life has been putforth as

Special creation:

- This idea embodies that life on Earth is a divine creation and also attributes to supernatural event at a particular time in the past.It also emphasizes that life has not changed ever since its origin.

Spontaneous generation (Abiogenesis):

- According to this theory life originated spontaneously from lifeless matter. It was believed that fishes originated from mud, frogs from moist soil and insects from decaying matter.

Biogenesis:

- It was speculated by Louis Pasteur (1862) that life originates from pre-existing life. He showed that pre-sterilised flasks kept closed airtight, with killed yeast, did not give rise to any life form, while in another flask kept open to air living organisms arose from killed yeast.

Extraterresterial or Cosmic origin:

- Some scientists still believe that life came from outer space. This states that units of life called spores (Panspermia) were transferred to different planets including earth. This is still an idea of some astronomers.

Chemical Evolution of Life:

- This idea was developed by Oparin (1922) and Haldane (1929). They proposed that with the conditions prevailing on earth, life arose by a series of sequential chemical reactions. The first form of life could have come from pre-existing non-living inorganic molecules which gave rise to formation of diverse organic molecules which are transformed into colloid system to produce life. The modern concept on chemical evolution regarding origin of life was accepted.

Evidences from Morphology and Anatomy

- The comparative study of morphology and anatomy of animals, reveal that they possess common set of characteristics.

Homologous organs:

- The homologous organs are those which have inherited from common ancestors with similar developmental pattern in embryos. The fore limbs of mammals are homologous structures. A human hand, a front leg of a cat, flipper of a whale and a bat's wing look dissimilar and adapted for different functions. Their mode of development and basic structure of bone are similar.

Analogous organs:

- The analogous organs look similar and perform similar functions but they have different originand developmental pattern. The function of the wings of a bat, the wings of a bird and wings of an insect are similar, but their basic structures are different.

Vestigial organs:

- The degenerated and non-functional organsof animals are called vestigial organs. The same organs are found to be well-developed and functional, in some of the related forms. Some of the vestigial organs in man are vermiform appendix, nictitating membrane, caudal vertebra, coccyx etc.

Atavism:

- The reappearance of ancestral characters in some individuals is called atavism. e.g. Presence of rudimentary tail in new born babies, presence of thick hair on the human body.

Evidences from Embryology

- The study of comparative embryology of different animals, supports the concept of evolution. The embryos from fish to mammals are similar in their early stages of development. The differentiation of their special characters appear in the later stages of development.

- **Biogenetic law** or **Recapitulation theory** was given by Ernst Haeckel. According to this theory, Ontogeny recapitulates Phylogeny. The stages of development of the individualanimal repeats the evolutionary history of the entire race of the animal.

Evidences from Palaeontology:

- Palaeontology deals with the study of fossils. Leonardo da Vinci is called the Father of Palaeontology. The study of fossils helps us to understand the line of evolution of many invertebrates and vertebrates. Fossil records show that the evolution has taken a gradual process from simple to complex organisms. The origin of modern birds is supported by the evidences from palaeontology.

Archaeopteryx:

- Archaeopteryx is the oldest known fossil bird. It was an early bird-like form found in the Jurassic period.It is considered to be a connecting link between reptiles and birds. It had wings with feathers, like a bird. It had long tail, clawed digits and conical teeth, like a reptile.

Theories of Evolution

- Life had evolved along with evolution of earth towards the end of 18th century. Evolution is the gradual change occurring in living organisms over a period of time. Formation of new species due to changes in specific characters over several generations as response to natural selection, is called evolution. The natural changes occuring is explained through the theories of evolution as proposed by Lamarck and Darwin.

Lamarckism:

- Jean Baptiste Lamarck (1744-1829) was a French naturalist, well known for his theory of evolution. Lamarck's theory of evolution was published in 'Philosophic Zoologique' in the year 1809. It is popularly known as 'Theory of inheritance of Acquired Characters" or "Use and Disuse theory" or Lamarckism.

Principles of Lamarckism

I. Internal vital force

- Living organisms or their component parts tend to increase in size continuously. This increase in size is due to the inherent ability of the organisms

II. Environment and new needs

- A change in the environment brings about changes in the need of the organisms. In response to the changing environment, the organisms develop certain adaptive characters. The adaptations of the organisms may be in the form of development of new parts of the body.

III. Use and disuse theory

- Lamarck's use and disuse theory states that if an organ is used constantly, the organ develops well and gets strengthened. When an organ is not used for a long time, it gradually degenerates.

- The ancestors of giraffe were provided with short neck and short forelimbs. Due to shortage of grass, they were forced to feed onleaves from trees. The continuous stretching of their neck and forelimbs resulted in the development of long neck and long forelimbs which is an example for constant use of an organ. The degenerated wing of Kiwi is an example for organ of disuse.

IV. Theory of Inheritance of acquired characters

- When there is a change in the environment, the animals respond to the change. They develop adaptive structures. The characters developed by the animals during their life time, in response to the environmental changes are called acquired characters. According to Lamarck, the acquired characters are transmitted to the offspring by the process of inheritance.

Unit - 20 - Breeding & Biotechnology

Mutation Breeding

- Mutation is defined as the sudden heritable change in the nucleotide sequence of DNA in an organism. It is a process by which genetic variations are created which in turn brings about changes in the organism. The organism which undergoes mutation is called a mutant.

- The factors which induce mutations are known as mutagens or mutagenic agents. Mutagens are of two types namely physical mutagens and chemical mutagens.

Physical mutagens

- Radiations like X-rays, α, β and γ-rays, UV rays, temperature etc. which induce mutations are called physical mutagens

Chemical mutagens

- Chemical substances that induce mutations are called chemical mutagens. e.g. Mustard gas and nitrous acid. The utilisation of induced mutation in crop improvement is called mutation breeding.

Hybridization

- Hybridization may be defined as the process of crossing two or more types of plants for bringing their desired characters together into one progeny called hybrid. Hybrid is superior in one or more characters to both parents. Hybridization is the common method of creating genetic variation to get improved varieties.

Hybridization Experiment: Triticale (The first man – made cereal)

- Triticale is the first man- made cereal hybrid. It is obtained by crossing wheat (Triticum durum, 2n = 28) and rye (Secale cereal, 2n = 14). The F1 hybrid is sterile (2n = 21). Then the chromosome number is doubled using colchicine and it becomes a hexaploid Triticale (2n = 42).

- The cycle of crop raising and selection continues till the plants with the desired characters are finally obtained. The development of new varieties is a long-drawn process. Two main aspects of hybridization are to combine the characters of two plants in one plant and to utilize hybrid vigour.

Genetic Engineering

- Genetic engineering is the manipulation and transfer of genes from one organism to another organisms to create a new DNA called as recombinant DNA(rDNA). The term recombinant is used because DNA from two diff erent sources can be joined together. Hence, genetic engineering is also called as recombinant DNA technology.

Techniques of Genetic Engineering – Basic Requirements

Important discoveries that led to the stepping stone of rDNA technology were

- Presence of plasmid in bacteria that can undergo replication independently along with chromosomal DNA.

- Restriction enzymes cuts or break DNA at specifi c sites and are also called as molecular scissors.

- DNA ligases are the enzymes which help in ligating (joining) the broken DNA fragments.

Gene Cloning

- What reminds to your mind when you hear the word clone? Of course, 'DOLLY' the cloned sheep. The carbon copy of an individual is oft en called a clone. However, more appropriately, a clone means to make a genetically exact copy of an organism.

- In gene cloning, a gene or a piece of DNA fragment is inserted into a bacterial cell where DNA will be multiplied (copied) as the cell divides. A brief outline of the basic steps involved in gene cloning are:

    - Isolation of desired DNA fragment by using restriction enzymes

    - Insertion of the DNA fragment into a suitable vector (Plasmid) to make rDNA Transfer of rDNA into bacterial host cell (Transformation)
    - Selection and multiplication of recombinant host cell to get a clone

    - Expression of cloned gene in host cell.

Using this strategy several enzymes, hormones and vaccines can be produced

Biotechnology in Medicine

- Using genetic engineering techniques medicinally important valuable proteins or polypeptides that form the potential pharmaceutical products for treatment of various diseases have been developed on a commercial scale.

Pharmaceutical Products developed by rDNA technique

- Insulin used in the treatment of diabetes.
- Human growth hormone used for treating children with growth deficiencies
- Blood clotting factors are developed to treat haemophilia.
- Tissue plasminogen activator is used to dissolve blood clots and prevent heart attack.
- Development of vaccines against various diseases like Hepatitis B and rabies.

Gene Therapy

- Gene therapy refers to the replacement of defective gene by the direct transfer of functional genes into human to treat genetic disease or disorder. The genetic makeup of the patient' cell is altered using recombinant DNA technology. It was first successfully implemented in 1990.

Somatic gene therapy is the replacement of defective gene in Somatic cells.

- **Germ line gene therapy** replacement of defective gene in germ cell (Egg and Sperm)targeted only somatic (non –reproductive) cells. Correction of genetic defects in Somatic cells may be beneficial to the patient but the Corrected gene may not be carried to the next generation.

Stem Cells

- Our body is composed of over 200 specialised cell types, that can carry out specific functions. eg. neurons or nerve cell that can transmit signals, or heart cells which contract to pump blood or pancreatic cells to secrete insulin. These specialised cells are called as differentiated cell.In contrast to differentiated cells.
- In Contrast to differentiated cells, stem cells are undifferentiated or unspecialised mass of cells. The stem cells are the cells of variable potency. Potency refers to the number of possible fates that a cell can acquire. The two important properties of stem cells that differentiate them from other cells are:
  - Its ability to divide and give rise to more stem cells by self-renewal
  - Its ability to give rise to specialised cells with specific functions by the process of differentiation.

Types of stem cells

- **Embryonic stem cells** can be extracted and cultured from the early embryos. These cells are derived from the inner cell mass of blastocyst. These cells can be developed into any cell in the body.

- **Adult stem cell** or somatic stem cell are found in the neonatal (new born) and adults. They have the ability to divide and give rise to specific cell types. Sources of adult stem cells are amniotic fluid, umbilical cord and bone marrow.

Stem-cell therapy

- Sometimes cells, tissues and organs in the body may be permanently damaged or lost due to genetic condition or disease or injury. In such situations stem cells are used for the treatment of diseases which is called stem-cell therapy. In treating neurodegenerative disorders like Parkinson's disease and Alzheimer's disease neuronal stem cells can be used to replace the damaged or lost neurons.

DNA Finger Printing Technology

- The human genome has 3 billion base pairs. Did you know that the DNA pattern of two individuals cannot be same except for identical twins. Each person's DNA sequence is unique due to the small difference in the base pairs. Therefore, if we want to compare the genetic difference among the two individuals, DNA fingerprinting is the easier and quicker method. This technique was developed by Alec Jeffrey.

- The technique analyses each individual's unique DNA sequences and provides distinctive characteristics of individual which helps in identification. Variable number of tandem repeat sequences (VNTRs) serve as molecular markers for identification.

- In human beings, 99 % of the DNA base sequences are the same and this is called as bulk genomic DNA. The remaining 1 % DNA sequence differs from one individual to another. This 1 % DNA sequence is present as small stretch of repeated sequences which is known as satellite DNA. The number of copies of the repeat sequence also called as VNTRs differs from one individual to another, and results in variation in the size of the DNA segment.

VNTRs illustration of three persons

- As shown in the illustration, the sequence AGCT is repeated six times in fi rst person, fi ve times in second person and seven times in thirdperson. Because of this, DNA segment of third person will be larger in size followed by DNA segment of first person and then the second person. Thus, it is clear that satellite DNA bring about variation within the population. Variation in DNA banding pattern reveals differences among the individuals.

Applications of DNA Fingerprinting

- DNA fingerprinting technique is widely used in forensic applications like crime investigation such as identifying the culprit. It is also used for paternity testing in case of disputes.
- It also helps in the study of genetic diversity of population, evolution and speciation.

Genetically Modified Organisms (GMOs)

- One of the most tremendous development of genetic engineering is the production of genetically modified (GM) plants and animals. Genetic modification refers to the alteration or manipulation of genes in the organisms using rDNA techniques in order to produce the desired characteristics. The DNA fragment inserted is called transgene. Plants or animals expressing a modified endogenous gene or a foregin gene are also known as transgenic organisms.

- The transgenic plants are much stable, with improved nutritional quality, resistant to diseases and tolerant to various environment conditions. Similarly transgenic animalsare used to produce proteins of medicinal importance at low cost and improve livestock quality.

Genetically Modified Plants

Objective	Gene inserted	Achievement
Improved nutritional quality in Rice	Beta carotene gene (In humans, Beta carotene is required for the synthesis of Vitamin A)	Golden Rice (Genetically modified rice can produce beta carotene, that can prevent Vitamin A deficiency)
Increased crop production	Bt gene from bacteria Bacillus thuringiensis. (Bt gene produces a protein that is toxic to insects)	Insect resistant plants (These plants can produce the toxin protein that kills the insects which attack them)

Genetically Modified Animals

Objective	Gene inserted	Achievement
Improved wool quality and	Genes for synthesis of amino	Transgenic sheep

production	acid, cysteine	(gene expressed)
Increased growth in fishes	Salmon or Rainbow trout or Tilapia growth hormone gene	Transgenic fish (gene expressed)

Principles of Inheritance and Variation

- Genetics is a branch of biology that dealswith the study of heredity and variations. It describes how characteristics and features pass on from the parents to their offsprings in each successive generation. The unit of heredity is known as the gene. Gene is the inherited factor that determines the biological character of an organism. A variation is the degree by which the progeny differs from their parents.

Multiple alleles

- The genetic segregations in Mendelian inheritance reveal that all genes have two alternative forms – dominant and recessive alleles e.g. tall versus dwarf (T and t). The former is the normal allele or wild allele and the latter the mutant allele. A gene can mutate several times producing several alternative forms. When three or more alleles of a gene that control a particular trait occupy the same locus on the homologous chromosome of an organism, they are called multiple alleles and their inheritance is called multiple allelism.

ABO blood types
Multiple allele inheritance of ABO blood groups

- Blood differs chemically from person to person. When two different incompatible blood types are mixed, agglutination (clumping together) of erythrocytes (RBC) occurs. The basis of these chemical differences is due to the presence of antigens (surface antigens) on the membrane of RBC and epithelial cells. Karl Landsteiner discovered two kinds of antigens called antigen 'A' and antigen 'B' on the surface of RBC's of human blood. Based on the presence or absence of these antigens three kinds of blood groups, type 'A', type 'B', and type 'O' (universal donor)were recognized. The fourth and the rarest blood group 'AB' (universal recipient) was discovered in 1902 by two of Landsteiner's students Von De Castelle and Sturli.

- Bernstein in 1925 discovered that the inheritance of different blood groups in human beings is determined by a number of multiple allelic series. The three autosomal alleles located on chromosome 9 are concerned with the determination of blood group in any person. The gene controlling blood type has been labeled as 'L' (after the name of the discoverer, Landsteiner) or I (from isoagglutination). The I gene exists in three allelic forms, IA, IB and IO. IA specifies A antigen. IB allele determines B antigen and IO allele specifies no antigen. Individuals who possess these antigens in their fluids such as the saliva are called secretors.

- Each allele (IA and IB) produces a transferase enzyme. IA allele produces N-acetyl galactose transferase and can add N-acetyl galactosamine (NAG) and IB allele encodes for the enzyme galactose transferase that adds galactose to the precursor (i.e. H substances) In the case of IO/IO allele no terminal transferase enzyme is produced and therefore called "null" allele and hence cannotadd NAG or galactose to the precursor.

- From the phenotypic combinations it isevident that the alleles IA and IB are dominantto IO, but co-dominant to each other (IA=IB).Their dominance hierarchy can be givenas (IA=IB> IO). A child receives one of threealleles from each parent, giving rise to sixpossible genotypes and four possible bloodtypes (phenotypes). The genotypes are IAIA, IAIO, IBIB, IB IO, IAIB and IO IO.

Genetic basis of the human ABO blood groups

Genotype	ABO bloodgroupphenotype	Antigenspresent onred bloodcell	Antibodiespresent in blood plasma
IAIA	Type A	A	Anti -B
IAIo	Type A	A	Anti -B
IBIB	Type B	B	Anti -A
IBIo	Type B	B	Anti -A
IAIB	Type AB	A and B	Neither Anti -A nor Anti-B
IoIo	Type O	Neither A nor B	Anti –A and anti - B

Genetic control of Rh factor
Fisher and Race hypothesis:

- Rh factor involves three different pairs of alleles located on three different closely linked loci on the chromosome pair. This system is more commonly in use today, and uses the 'Cde' nomenclature.

Wiener Hypothesis

- Wiener proposed the existence of eight alleles (R1, R2, R0, Rz, r, r1, r11, ry) at a single Rh locus. All genotypes carrying a dominant 'R allele' (R1, R2 ,R0 ,Rz) will produce Rh+positivephenotype and double recessive genotypes (rr, rr1, rr11, rry) will give rise to Rh-negative phenotype.

Incompatibility of Rh – Factor – Erythroblastosis foetalis

- Rh incompatability has great significance in child birth. If a woman is Rh negative andthe man is Rh positive, the foetus may be Rh positive having inherited the factor fromits father. The Rh negative mother becomes sensitized by carrying Rh positive foetus within her body. Due to damage of blood vessels, during child birth, the mother's immune system recognizes the Rh antigens and gets sensitized. The sensitized mother produces Rh antibodies. The antibodies are IgG type which are small and can cross placenta and enter the foetal circulation. By the time the mother gets sensitized and produce anti 'D' antibodies, the child is delivered.

- Usually no effects are associated with exposure of the mother to Rh positive antigen during the first child birth, subsequent Rh positive children carried by the same mother, may be exposed to antibodies produced by the mother against Rh antigen, which are carried across the placenta into the foetal blood circulation. This causes haemolysis offoetal RBCs resulting in haemolytic jaundice and anaemia. This condition is known as Erythoblastosisfoetalis or Haemolyticdisease of the new born (HDN).

Inheritance of Y- linked genes

- Genes in the non-homologous region of the Y-chromosome are inherited directly from male to male. In humans, the Y-linked or holandric genes for hypertrichosis (excessive development of hairs on pinna of the ear) are transmitted directly from father to son, because males inherit the Y chromosome from the father. Female inherits only X chromosome from the father and are not affected.

Genetic Disorders:

- A genetic disorder is a disease or syndrome that is caused by an abnormalityin an individual DNA. Abnormalities can range from a small mutation in a single gene to the addition or subtraction of an entire chromosome or even a set ofchromosomes. Genetic disorders are of two types namely, Mendelian disorders and chromosomal disorders.

Mendelian disorders

- Alteration or mutation in a single gene causes Mendelian disorders. These disorders are transmitted to the offsprings on the same line as the Mendelian pattern of inheritance. Some examples for Mendelian disorders are Thalassemia, albinism, phenylketonuria, sickle cell anaemia, Huntington's chorea, etc., These disorders may be dominant or recessive and autosomal or sex linked.

Thalassemia

- Thalassemia is an autosomal recessive disorder. It is caused by gene mutation resultingin excessive destruction of RBC's due to the formation of abnormal haemoglobin molecules.

- Normally haemoglobin is composed of four polypeptide chains, two alpha and two betaglobin chains. Thalassemia patients have defects in either the alpha or beta globin chain causing the production of abnormal haemoglobin molecules resulting in anaemia.

- Thalassemia is classified into alpha and beta based on which chain of haemoglobin molecule is affected. It is controlled by two closely linked genes HBA1 and HBA2 on chromosome 16. Mutation or deletion of one or more of the four alpha gene alleles causes Alpha Thalassemia. In Beta Thalassemia, production of beta globin chain is affected. It is controlled by a single gene (HBB) on chromosome 11. It is the most common type of Thalassemia and is also known as Cooley's anaemia. In this disorder the alphachain production is increased and damages the membranes of RBC.

UNIT – 5 - Molecular Genetics

- Mendel's theory dispelled the mystery of why traits seemed to appear anddisappear magically from one generation to the next. Mendel's work reveals the patterns of heredity and reflect the transmission of evolved information from parents to offspring. This information is located on the chromosomes. One of the most advanced realizations of human knowledge was that our unique characteristics are encoded within molecules of DNA. The discovery that DNA is the genetic material left several questions unanswered.

- How is the information in DNA used? Scientists now know that DNA directs the construction of proteins. Proteins determine the shapes of cells and the rate of chemical reactions, such as those that occur during metabolism and photosynthesis. The hereditary nature of every living organism is defined by its genome, which consists of a long sequence of nucleic acids that provide the information needed to construct the organism. The genome contains the complete set of hereditary information for any organism. The genome may be divided into a number of different nucleic acid molecules. Each of the nucleic acid molecule may contain large number of genes. Each gene is a sequence within the nucleic acid that represents a single protein. In this chapter we will discuss the structure of DNA, its replication, the process of making RNA from DNA (transcription), the genetic code that determines the sequence of amino acid in protein synthesis (translation), regulation of gene expression and the essentials of human genome sequencing.

Gene as the functional unit of inheritance

- A gene is a basic physical and functional unit of heredity. The concept of the gene was first explained by Gregor Mendel in 1860's. He never used the term 'gene'. Hecalled it 'factor'. In 1909, the Danish biologist Wilhelm Johannsen, coined the term 'gene', that was referred to discrete determiners of inherited characteristics.

- According to the classical concept of gene introduced by Sutton in 1902, genes have been defined as discrete particles that follow Mendelian rules of inheritance, occupy a definite locus in the chromosome and are responsible for the expression of specific phenotypic character. They show the following properties:

  - Number of genes in each organism is more than the number of chromosomes; hence several genes are located on the same chromosome.

  - The genes are arranged in a single linear order like beads on a string.

  - Each gene occupies a specific position called locus.

  - Genes may exist in several alternate forms called alleles.

- Genes may undergo sudden change in positions and composition called mutations.
- Genes are capable of self-duplication producing their own copies.

One gene-one enzyme hypothesis:

The experiments of George Beadle and Edward Tatum in the early 1940's on Neurospora crassa (the red bread mould) led them to propose one geneone enzyme hypothesis, which states that one gene controls the production of one enzyme.

One gene-one polypeptide hypothesis:

It was observed that an enzyme may be composed of more than one polypeptide chain and a gene can code for only one polypeptide chain. Thus one gene-one polypeptide hypothesis states that one gene controls the production of only one polypeptide chain of an enzyme molecule.

In search of the genetic material

- As early as 1848, Wilhelm Hofmeister, a German botanist, had observed that cell nuclei organize themselves into small, rod like bodies during mitosis called chromosomes. In 1869, Friedrich Miescher, a Swiss physician, isolated a substance from the cell nuclei and called it as nuclein. It was renamed as nucleic acid by Altman (1889), and is now known as DNA. By 1920, it became clear that chromosomes are made up of proteins and DNA. Many experimentswere carried out to study the actual carriers of genetic information. Griffith's experiment proved that DNA is the genetic material which has been dealt in class XI. Bacterial transformation experiments provided the first proof that DNA is the genetic material.
- However, he could not understand the cause of bacterial transformation, and the biochemical nature of genetic material was not defined from his experiments.
- Later, Oswald Avery, Colin Macleod and Maclyn McCarty in 1944 repeated Griffith's experiments in an 'in vitro' system in order to identify the nature of the transforming substance responsible for converting a nonvirulent strain into virulent strain. They observed that the DNA, RNA and proteins isolated from the heat-killed S-strain when added to R-strain changed their surface character from rough to smooth and also made them pathogenic But when the extract was treated with DNase (an enzyme which destroys DNA) the transforming ability was lost. RNase (an enzyme which destroys RNA) and proteases(an enzyme which destroys protein) did not affect the transformation. Digestion with DNase inhibited transformation suggesting that the DNA caused the transformation. These experiments suggested that DNA and not proteins is the genetic material. The phenomenon, by which DNA isolated from one type

of cell (R – strain), when introduced into another type (S-strain), is able to retain some of the properties of the R - strain is referred to as transformation.

DNA is the genetic material

- Many biologists despite the earlier experiments of Griffith, Avery and others, still believed that protein, not DNA, was the hereditary material in a cell. As eukaryotic chromosomes consist of roughly equal amounts of protein and DNA, it was said that only a protein had sufficient chemical diversity and complexity to encode the information required for genetic material. In 1952, however, the results of the Hershey-Chase experiment finally provided convincing evidence that DNA is the genetic material.

Properties of genetic material (DNA versus RNA)

- The experiment by Hershey and Chase clearly indicates that it is DNA that acts as a genetic material. However, in some viruses like Tobacco mosaic virus (TMV), bacteriophage θB, RNA acts as the genetic material. A molecule that can act as a genetic material should have the following properties:

Self Replication:

- It should be able to replicate. According to the rule of base pairing and complementarity, both nucleic acids (DNA and RNA) have the ability to direct duplications. Proteins fail to fulfil this criteria.

Stability:

- It should be stable structurally and chemically. The genetic material should be stable enough not to change with different stages of life cycle, age or with change in physiology of the organism. Stability as one of property of genetic material was clearly evident in Griffith's transforming principle. Heat which killed the bacteria did not destroy some of the properties of genetic material. In DNA the two strands being complementary, if separated (denatured) by heating can come together (renaturation) when appropriate condition is provided. Further 2' OH group present at every nucleotide in RNA is a reactive group that makes RNA liable and easily degradable. RNA is also known to be catalytic and reactive. Hence, DNA is chemically more stable and chemically less reactive when compared to RNA. Presence of thymine instead of uracil in DNA confers additional stability to DNA.

Information storage:

- It should be able to express itself in the form of 'Mendelian characters'. RNA can directly code for protein synthesis and can easily express the characters. DNA, howeverdepends on RNA for synthesis of proteins. Both DNA and RNA can act as a genetic material, but

DNA being more stable stores the genetic information and RNA transfers the genetic information.

Variation through mutation:

- It should be able to mutate. Both DNA and RNA are able to mutate.RNA being unstable, mutates at a faster rate. Thus viruses having RNA genome with shorter life span can mutate and evolve faster.

- The above discussion indicates that both RNA and DNA can function as a genetic material. DNA is more stable, and is preferred for storage of genetic information.

- Chromosomes are carriers of genes which are responsible for various characters from generation to generation. Du Praw (1965) proposed a single stranded model (unineme), as a long coiled molecule which is associated with histone proteins in eukaryotes. Plants and animals have more DNA than bacteria and must fold this DNA to fit into the cell nucleus. In prokaryotes such as *E. coli* though they do not have defined nucleus, the DNA is not scattered throughout the cell. DNA (being negatively charged) is held with some proteins (that have positive charges) in a region called the nucleoid. The DNA as a nucleoid is organized into large loops held by protein. DNA of prokaryotes is almost circular and lacks chromatin organization, hence termed genophore.

Transcription

- The process of copying genetic information from one strand of DNA into RNA is termed transcription. This process takes place in presence of DNA dependent RNA polymerase.

- In some retroviruses that contain RNA as the genetic material (e.g, HIV), the flow of information is reversed. RNA synthesizes DNA by reverse transcription, then transcribed into mRNA by transcription and then into proteins by translation.

- For a cell to operate, its genes must be expressed. This means that the gene products, whether proteins or RNA molecules must be made. The RNA that carries genetic information encoding a protein from genes into the cell is known as messenger RNA (mRNA). For a gene to be transcribed, the DNA which is a double helix must be pulled apart temporarily, and RNA is synthesized by RNA polymerase. This enzyme binds to DNA at the start of a gene and opens the double helix. Finally, RNA molecule is synthesized. The nucleotide sequence in the RNA is complementary to the DNA template strand from which it is synthesized.

- Both the strands of DNA are not copied during transcription for two reasons. If both the strands act as a template, they would code for RNA with different sequences. This in turn would code for proteins with different amino acid sequences. This would result in one segment of DNA coding for two different proteins, hence complicate the genetic information transfer machinery. If two RNA molecules were produced simultaneously, double stranded RNA complementary to each other would be formed. This would prevent RNA from being translated into proteins.

Transcription unit and gene

- A transcriptional unit in DNA is defined by three regions, a promoter, the structural gene and a terminator. The promoter is located towards the 5' end. It is a DNA sequence that provides binding site for RNA polymerase. The presence of promoter in a transcription unit, defines the template and coding strands. The terminator region located towards the 3' end of the coding strand contains a DNA sequence that causes the RNA polymerase to stop transcribing. In eukaryotes the promoter has AT rich regions called TATA box (Goldberg-Hogness box) and in prokaryotes this region is called Pribnow box. Besides promoter,eukaryotes also require an enhancer.

- The two strands of the DNA in the structural gene of a transcription unit have oppositepolarity. DNA dependent RNA polymerase catalyses the polymerization in only one direction, the strand that has the polarity 3' 5' acts as a template, and is called the template strand. The other strand which has the polarity 5' 3' has a sequence same as RNA (except thymine instead of uracil) and is displaced during transcription. This strand is called coding strand.

- The structural gene may be monocistronic (eukaryotes) or polycistronic (prokaryotes). In eukaryotes, each mRNA carries only a single gene and encodes information for only a singleprotein and is called monocistronic mRNA. In prokaryotes, clusters of related genes, known asoperon, often found next to each other on the chromosome are transcribed together to give a single mRNA and hence are polycistronic. Before starting transcription, RNA polymerase binds to the promoter, a recognition sequence in front of the gene. Bacterial (prokaryotic) RNA polymerase consists of two major components, the core enzyme and the sigma subunit. The core enzyme (β1, β, and α) is responsible for RNA synthesis whereas a sigma subunit isresponsible for recognition of the promoter. Promoter sequences vary in different organisms.

- RNA polymerase opens up the DNA to form the transcription bubble. The core enzyme moves ahead, manufacturing RNA leaving the sigma subunit behind at the promoter region. The end of a gene is marked by a terminator sequence that forms a hair pin structure in the RNA. The sub-class of terminators require a recognition protein, known as rho (ρ), to function.

Genetic Code

- DNA is the genetic material that carries genetic information in a cell and from generation to generation. At this stage, an attempt will be made to determine in what manner the genetic information exists in DNA molecule? Are they written in coded language on a DNA molecule? If they occur in the language of codes what is the nature of genetic code? The translation of proteins follows the triplet rule; a sequence of three mRNA base (a codon) designates one of the 20 different kinds of amino acids used in protein synthesis.

- Genetic code is the sequence relationship between nucleotide in genes (or mRNA) and the amino acids in the proteins they encode. There are 64 possible triplets, and 61 of them are used to represent amino acids. The remaining three triplet codons are termination signals for polypeptide chains. Since there are only 20 amino acids involved in protein synthesis, most of them are encoded by more than one triplet. Two things make this multiple (degenerate) coding possible. First, there is more than one tRNA for most amino acids. Each tRNA has a different anticodon. Second, this pairing is highly specific for the first two portions on the codon, permitting Watson and Crick base pairs (A – U and G - C) to be formed. But at the third position there is a great deal of flexibility as to which base pairs are acceptable. Most part of the genetic code is universal, being the same in prokaryotes and eukaryotes.

- The order of base pairs along DNA molecule controls the kind and order of amino acids found in the proteins of an organism. This specific order of base pairs is called genetic code, the blue print establishing the kinds of proteins to be synthesized which makes an organism unique.

- Marshall Nirenberg, Severo Ochoa (enzyme polynucleotide phosphorylase called Ochoa'senzyme), Hargobind Khorana, Francis Crick and many others have contributed significantlyto decipher the genetic code. The order in which bases are arranged in mRNA decides the order in which amino acids are arranged in proteins.

The salient features of genetic code are as follows:

- The genetic codon is a triplet code and 61 codons code for amino acids and 3 codons do not code for any amino acid and function as stop codon (Termination).

- The genetic code is universal. It means that all known living systems use nucleic acids and the same three base codons (triplet codon) direct the synthesis of protein from amino acids. For example, the mRNA (UUU) codon codes for phenylalanine in all cells of all organisms. Some exceptions are reported in prokaryotic, mitochondrial and chloroplast genomes. However similarities are more common than differences.

- A non-overlapping codon means that the same letter is not used for two different codons. For instance, the nucleotide sequence GUU GUC represents only two codons.

- It is comma less, which means that the message would be read directly from one end to the other i.e., no punctuation are needed between two codes.

- A degenerate code means that more than one triplet codon could code for a specific amino acid. For example, codons GUU, GUC, GUA and GUG code for valine.

- Non-ambiguous code means that one codon will code for one amino acid.

- The code is always read in a fixed direction i.e. from 5'→3' direction called polarity.

- AUG has dual functions. It acts as a initiator codon and also codes for the amino acid methionine.

- UAA, UAG (tyrosine) and UGA (tryptophan) codons are designated as termination (stop) codons and also are known as "non-sense" codons.

Mutation and genetic code

- Comparative studies of mutations (sudden change in a gene) and corresponding alteration in amino acid sequence of specific protein have confirmed the validity of the genetic code. The relationship between genes and DNA are best understood by mutation studies. The simplest type of mutation at the molecular level is a change in nucleotide that substitutes one base for another. Such changes are known as base substitutions which may occur spontaneously or due to the action of mutagens. A well studied example is sickle cell anaemia in humans which results from a point mutation of an allele of β-haemoglobin gene (βHb). A haemoglobin molecule consists of four polypeptide chains of two types, two α chains and two β-chains. Each chain has a heme group on its surface. The heme groups are involved in the binding of oxygen. The human blood disease, sickle cell anaemia is due to abnormal haemoglobin. This abnormality in haemoglobin is due to a single base substitution at the sixth codon of the beta globin gene from GAG to GTG in β -chain of haemoglobin. It results in a change of amino acid glutamic acid to valine at the 6th position of the β -chain. This is the classical example of point mutation that results in thechange of amino acid residue glutamic acid to valine. The mutant haemoglobinundergoes polymerisation under oxygen tension causing the change in the shape of the RBC from biconcave to a sickle shaped structure.

Regulation of gene expression

- We have previously established how DNA is organized into genes, how genes store genetic information, and how this information is expressed. We now consider the most fundamental issues in molecular genetics. How is genetic expression regulated? Evidence in support of the idea that genes can be turned on and off is very convincing. Regulation of gene expression has been extensively studied in prokaryotes, especially in E. coli. Gene expression can be controlled or regulated at transcriptional or post transcriptional or translational level. Here, we are going to discuss regulation of gene expression at transcriptional level. Usually, small extracellular or intracellular metabolites trigger initiation or inhibition of gene expression. The clusters of gene with related functions are called operons. They usually transcribe single mRNA molecules. In E.coli, nearly 260 genes are grouped into 75 different operons.

Structure of the operon:

- Each operon is a unit of gene expression and regulation and consistsof one or more structural genes and an adjacent operator gene that controls transcriptional activity of the structural gene.

- The structural gene codes for proteins, rRNA and tRNA required by the cell.

- Promoters are the signal sequences in DNA that initiate RNA synthesis. RNA polymerase binds to the promoter prior to the initiation of transcription.

- The operators are present between the promoters and structural genes. Therepressor protein binds to the operator region of the operon.

The Lac (Lactose) operon:

- The metabolism of lactose in E.coli requires three enzymes – permease, β-galactosidase (β-gal) and transacetylase. The enzyme permease is needed for entry of lactose into the cell, β-galactosidase brings about hydrolysis of lactose to glucose and galactose, while transacetylase transfers acetyl group from acetyl Co A to β-galactosidase.

- The lac operon consists of one regulator gene ('i' gene refers to inhibitor) promoter sites (p), and operator site (o). Besides these, it has three structural genes namely lac z,y and lac a. The lac 'z' gene codes for β-galactosidase, lac 'y' gene codes for permease and 'a' gene codes for transacetylase. Jacob and Monod proposed the classical model of Lac operon to explain gene expression andregulation in E.coli. In lac operon, a polycistronic structural gene is regulated by a common promoter and regulatory gene. When the cell is using its normal energy source as glucose, the 'i' gene transcribes a repressor mRNA and after its translation, a repressor protein is produced.

- It binds to the operator region of the operon and prevents translation, as a result, β-galactosidase is not produced. In the absence of preferred carbon source such as glucose, if lactose is available as an energy source for the bacteria then lactose enters the cell as a result of permease enzyme. Lactose acts as an inducer and interacts with the repressor to inactivate it.

- The repressor protein binds to the operator of the operon and prevents RNA polymerasefrom transcribing the operon. In the presence of inducer, such as lactose or allolactose, the repressor is inactivated by interaction with the inducer. This allows RNA polymerase to bind to the promotor site and transcribe the operon to produce lac mRNA which enables formation of all the required enzymes needed for lactose metabolism. This regulation of lac operon by the repressor is an example of negative control of transcription initiation. Lacoperon is also under the control of positive regulation as well.

Human GenomeProject (HGP)

- The international human genome project was launched in the year 1990. It was a mega project and took 13 years to complete. The human genome is about 25 times larger than the genome of any organism sequenced to date and is the first vertebrate genome to be completed. Human genome is said to have approximately 3×109 bp. HGP was closely associated with the rapid development of a new area in biology called bioinformatics.

Goals and methodologies of Human Genome Project

The main goals of Human Genome Project are as follows

- Identify all the genes (approximately 30000) in human DNA.
- Determine the sequence of the three billion chemical base pairs that makeup the human DNA.
- To store this information in databases.
- Improve tools for data analysis.
- Transfer related technologies to other sectors, such as industries.
- Address the ethical, legal and social issues (ELSI) that may arise from the project.

- The methodologies of the Human Genome Project involved two major approaches. One approach was focused on identifying all the genes that are expressed as RNA (ETSS – Expressed Sequence Tags). The other approach was sequence annotation. Here, sequencing the whole set of genome was taken, that contains all the coding and non-coding sequences and later assigning different regions in the sequences with functions. For sequencing, the total DNA froma cell is isolated and converted into random fragments of relatively smaller sizes and cloned in suitable hosts using specialized vectors. This cloning results in amplification of pieces of DNA fragments so that it could subsequently be sequenced with ease. Bacteria and yeast are two commonly used hosts and these vectors are called as BAC (Bacterial Artificial Chromosomes) and YAC (Yeast Artificial Chromosomes). The fragments are sequenced using automated DNA sequencers (developed by Frederick Sanger). The sequences are then arranged based on few overlapping regions, using specialized computer based programs. These sequences were subsequently annotated and are assigned to each chromosome. The genetic and physical maps on the genome are assigned using information on polymorphism of restriction endonuclease recognition sites and some repetitive DNA sequences, called microsatellites. The latest method of sequencing even longer fragments is by a method called Shotgun sequencing using super computers, which has replaced the traditional sequencing methods.

Salient features of Human Genome Project:

- Although human genome contains 3 billion nucleotide bases, the DNA sequences that encode proteins make up only about 5% of the genome.

- An average gene consists of 3000 bases, the largest known human gene being dystrophin with 2.4 million bases.

- The function of 50% of the genome is derived from transposable elements such as LINE and ALU sequence.

- Genes are distributed over 24 chromosomes. Chromosome 19 has the highest gene density. Chromosome 13 and Y chromosome have lowest gene densities

- The chromosomal organization of humangenes shows diversity.

- There may be 35000-40000 genes in thegenome and almost 99.9 nucleotide basesare exactly the same in all people.

- Functions for over 50 percent of thediscovered genes are unknown.

- Less than 2 percent of the genome codesfor proteins.

- Repeated sequences make up very largeportion of the human genome. Repetitivesequences have no direct coding functionsbut they shed light on chromosomestructure, dynamics and evolution(genetic diversity).

- Chromosome 1 has 2968 genes whereaschromosome 'Y' has 231 genes.

- Scientists have identified about 1.4million locations where single baseDNA differences (SNPs – Singlenucleotidepolymorphism – pronounce as'snips') occur in humans. Identification of'SNIPS' is helpful in finding chromosomallocations for disease associated sequencesand tracing human history

Applications and future challenges

- The mapping of human chromosomes is possible to examine a person's DNA and to identify genetic abnormalities. This is extremely useful in diagnosing diseases and to provide genetic counselling to those planning to have children. This kind of information would also create possibilities for new gene therapies. Besides providing clues to understand human biology, learning about non-human organisms, DNA sequences can lead to an understanding of their natural capabilities that can be applied towards solving challenges in healthcare, agriculture, energy production and environmental remediation. A new era of molecular medicine,characterized by looking into the most fundamental causes of disease than treating the symptoms will be an important advantage.

  - Once genetic sequence becomes easierto determine, some people may attemptto use this information for profit or forpolitical power.

  - Insurance companies may refuse to insurepeople at 'genetic risk' and this would savethe companies the expense of future medical bills incurred by 'less than perfect' people.

- Another fear is that attempts are beingmade to "breed out" certain genes ofpeople from the human population inorder to create a 'perfect race'.

Pharmacogenomics is the study of how genes affect a person's response to drugs. This relatively new field combines pharmacology (the science of drugs) and genomics (the study of genes and their functions) to develop effective, safe medications and doses that will be tailored to a person's genetic makeup.

DNA fingerprinting technique

- The DNA fingerprinting technique was first developed by Alec Jeffreys in 1985 (Recipient of the Royal Society's Copley Medal in 2014). Each of us have the same chemical structure of DNA. But there are millions of differences in the DNA sequence of base pairs. This makes the uniqueness among us so that each of us except identical twins is different from each other genetically. The DNA of a person and finger prints are unique. There are 23 pairs of human chromosomes with 1.5 million pairs of genes. It is a well known fact that genes are segments of DNA which differ in the sequence of their nucleotides. Not all segments of DNA code for proteins, some DNA segments have a regulatory function, while others are intervening sequences (introns) and still others are repeated DNA sequences. In DNA fingerprinting, short repetitive nucleotide sequences are specific for a person. These nucleotide sequences are called as variable number tandem repeats (VNTR).The VNTRs of two persons generally show variations and are useful as genetic markers.

- DNA finger printing involves identifying differences in some specific regions in DNA sequence called repetitive DNA, because in these sequences, a small stretch of DNA is repeated many times. These repetitive DNA are separated from bulk genomic DNA as different peaks during density gradient centrifugation. The bulk DNA forms a major peak and the other small peaks are referred to as satellite DNA. Depending on base composition (A : T rich or G : C rich), length of segment and number of repetitive units, the satellite DNA is classified into many sub categories such as micro-satellites, mini-satellites, etc., These sequences do not code for any proteins, but they form a large portion of human genome. These sequences show high degree of polymorphism and form the basis of DNA fingerprinting (Fig. 5.15). DNA isolated from blood, hair, skin cells, or other genetic evidences left at the scene of a crime can be compared through VNTR patterns, with the DNA of a criminal suspect to determine guilt or innocence. VNTR patterns are also useful in establishing the identity of a homicide victim, either from DNA found as evidence or from the body itself.

The Steps in DNA Fingerprinting technique

Extraction of DNA

- The process of DNA fingerprinting starts with obtaining a sample of DNA from blood, semen, vaginal fluids, hair roots, teeth, bones, etc.,

Polymerase chain reaction (PCR)

- In many situations, there is only a small amount of DNA available for DNA fingerprinting. If needed many copies of the DNA can be produced by PCR (DNA amplification).

Fragmenting DNA

- DNA is treated with restriction enzymes which cut the DNA into smaller fragments at specific sites.

Separation of DNA by electrophoresis

- During electrophoresis in an agarose gel, the DNA fragments are separated into bands of different sizes. The bands of separated DNA are sieved out of the gel using a nylon membrane (treated with chemicals that allow for it to break the hydrogen bonds of DNA so there are single strands).

Denaturing DNA

The DNA on gels is denatured by using alkaline chemicals or by heating.

Blotting

- The DNA band pattern in the gel istransferred to a thin nylon membraneplaced over the 'size fractionated DNAstrand' by Southern blotting.

Using probes to identify specific DNA

- A radioactive probe (DNA labeled witha radioactive substance) is added to theDNA bands. The probe attaches by basepairing to those restriction fragments thatare complementary to its sequence. Theprobes can also be prepared by using either'fluorescent substance' or 'radioactiveisotopes'.

Hybridization with probe

- After the probe hybridizes and the excessprobe washed off, a photographic filmis placed on the membrane containing'DNA hybrids'.

Exposure on film to make a genetic/DNA Fingerprint

- The radioactive label exposes the filmto form an image (image of bands)corresponding to specific DNA bands. The thick and thin dark bands form a pattern of bars which constitutes a genetic fingerprint.

Application of DNAfinger printing

- **Forensic analysis** - It can be used in theidentification of a person involved incriminal activities, for settling paternityor maternity disputes, and in determiningrelationships for immigration purposes.

- **Pedigree analysis** – inheritance patternof genes through generations and fordetecting inherited diseases.

- **Conservation of wild life** – protection ofendangered species. By maintaining DNArecords for identification of tissues of thedead endangered organisms.

- **Anthropological studies**–It is useful indetermining the origin and migration of human populations and genetic diversities.

UNIT – 6- Evolution:

Origin of life – Evolution of life forms

- Theory of special creation states that life was created by a supernatural power, respectfully referred to as “God”. According to Hinduism, Lord Brahma created the Earth. Christianity, Islam and most religions believe that God created the universe, the plants and the animals.

- According to the theory of spontaneous generation or Abiogenesis, living organisms originated from non-living materials and occurred through stepwise chemical and molecular evolution over millions of years. Thomas Huxley coined the term abiogenesis.

- Big bang theory explains the origin of universe as a singular huge explosion in physical terms. The primitive earth had no proper atmosphere, but consisted of ammonia, methane, hydrogen and water vapour. The climate of the earth was extremely high. UV rays from the sun split up water molecules into hydrogen and oxygen. Gradually the temperature cooled and the water vapour condensed to form rain. Rain water filled all the depressions to form water bodies. Ammonia and methane in the atmosphere combined with oxygen to form carbon-dioxide and other gases.

> Coacervates (large colloidal particles that precipitate out in aqueous medium) are the first pre-cells which gradually transformed into living cells.

- According to the theory of biogenesis life arose from pre-existing life. The term biogenesis also refers to the biochemical process of production of living organisms This term was coined by Henry Bastian.

- According to the theory of chemical evolution primitive organisms in the primordial environment of the earth evolved spontaneously from inorganic substances andphysical forces such, as lightning, UV radiations, volcanic activities, etc.,., Oparin (1924) suggested that the organic compounds could have undergone a series of reactions leading to more complex molecules. He proposed that the molecules formed colloidal aggregates or ‘coacervates’ in an aqueous environment. The coacervates were able to absorb and assimilate organic compounds from the environment. Haldane (1929) proposed that the primordial sea served as a vast chemical laboratory powered by solar energy. The atmosphere was oxygen free and the combination of CO2, NH3 and UV radiations gave rise to organic compounds. The sea became a ‘hot’ dilute soup containing large populations of organic monomers and polymers. They envisaged that groups of monomers and polymers acquired lipid membranes and further developed into the first living cell. Haldane coined the term prebiotic soup and this became the powerful symbol of the Oparin-Haldane view on the origin of life (1924-1929).

- Oparin and Haldane independently suggested that if the primitive atmosphere was reducing and if there was appropriate supply of energy such as lightning or UV light then a wide range of organic compounds can be synthesized.

Evidences for biological evolution
Paleontological evidences

- Paleontology is the study of prehistoric life through fossils. Fossils are described as the true witnesses of evolution or documents of various geological strata of evolution. Fossilization is the process by which plant and animal remains are preserved in sedimentary rocks. They fall under three main categories.

Actual remains :

- The original hard parts such as bones, teeth or shells are preserved as such in the earth's atmosphere. This is the most common method of fossilization. When marine animals die, their hard parts such as bones, shells, etc., are covered with sediments and are protected from further deterioration. They get preserved as such as they are preserved in vast ocean; the salinity in them prevents decay. The sediments become hardened to form definite layers or strata. For example, Woolly Mammoth that lived 22 thousand years ago were preserved in the frozen coast of Siberia as such. Several human beings and animals living in the ancient city of Pompeii were preserved intact by volcanic ash which gushed out from Mount Vesuvius.

Petrifaction

- When animals die the original portion of their body may be replaced molecule for molecule by minerals and the original substance being lost through disintegration. This method of fossilization is called petrifaction. The principle minerals involved in this type fossilization are iron pyrites, silica, calcium carbonate and bicarbonates of calcium and magnesium.

Natural moulds and casts

- Even after disintegration, the body of an animal might leave indelible impression on the soft mud which later becomes hardened into stones. Such impressions are called moulds. The cavities of the moulds may get filled up by hard minerals and get fossilized, which are called casts. Hardened faecal matter termed as coprolites occur as tiny pellets. Analysis of the coprolites enables us to understand the nature of diet the pre-historic animals thrived on.

Embryological evidences

- Embryology deals with the study of the development of individual from the egg to the adult stage. A detailed study of the embryonic development of different forms makes us to think that there is a close resemblance during development.

- The development of heart in all vertebrates follows the same pattern of development as a pair of tubular structures that later develop into two chambered heart in fishes, three chambered in amphibians and in most reptiles and four chambered in crocodiles, birds and mammals; indicating a common ancestry for all the vertebrates,

- Hence scientists in the 19th century concluded that higher animals during their embryonic development pass through stages of lower animals (ancestors). Ernst Von Haeckel, propounded the "biogenetic law ortheory of recapitulation" which states that the life history of an individual (ontogeny) briefly repeats or recapitulates the evolutionary history of the race (phylogeny). In other words "Ontogeny recapitulates Phylogeny". The embryonic stages of a higher animal resemble the adult stage of its ancestors. Appearance of pharyngeal gill slits, yolk sac and the appearance of tail in human embryos are some of the examples. The biogenetic law is not universal and it is now thought that animals do not recapitulate the adult stage of any ancestors. The human embryo recapitulates the embryonic history and not the adult history of the organisms.

- The comparative study of the embryo of different animals shows structural similarities among themselves. The embryos of fish, salamander, tortoise, chick and human start life as a single cell, the zygote, and undergo cleavage to produce the blastula, change to gastrula and are triploblastic. This indicates that all the above said animals have evolved from a common ancestor.

Molecular evidences

- Molecular evolution is the process of change in the sequence composition of molecules such as DNA, RNA and proteins across generations. It uses principles of evolutionary biology and population genetics to explain patterns in the changes of molecules.

- One of the most useful advancement in the development of molecular biology is proteins and other molecules that control life processes are conserved among species. A slight change that occurs over time in these conserved molecules (DNA, RNA and protein) are often called molecular clocks. Molecules that have been used to study evolution are cytochrome c (respiratory pathway) and rRNA (protein synthesis).

Theories of biological evolution

Lamarck's theory

- Jean Baptiste de Lamarck, was the first to postulate the theory of evolution in his famous book 'Philosophie Zoologique' in the year 1809. The two principles of Lamarckian theory are:

- **The theory of use and disuse**– Organsthat are used often will increase in size and those that are not used will degenerate. Neck in giraffe is an example of use and absence of limbs in snakes is an example for disuse theory.

- **The theory of inheritance of acquired characters** - Characters that are developed during the life time of an organism are called acquired characters and these are then inherited.

The main objection to Lamarckism

- Lamarck's "Theory of Acquired characters" was disproved by August Weismann who conducted experiments on mice for twenty generations by cutting their tails and breeding them. All mice born were with tail. Weismann proved that change in the somatoplasm will not be transferred to the next generation but changes in the germplasm will be inherited.

Neo-Lamarckism

- The followers of Lamarck (Neo-Lamarckists) like Cope, Osborn, Packard and Spencer tried to explain Lamarck's theory on a more scientific basis. They considered that adaptations are universal. Organisms acquire new structures due to their adaptations to the changed environmental conditions. They argued that external conditions stimulate the somatic cells to produce certain 'secretions' which reach the sex cells through the blood and bring about variations in the offspring.

Darwin's theory of Natural Selection

- Charles Darwin explained the theory of evolution in his book 'The Origin of Species by Natural Selection'. During his journey around the Earth, he made extensive observations of plants and animals. He noted a huge variety and remarkable similarities among organisms and their adaptive features to cope up to their environment. He proved that fittest organisms can survive and leave more progenies than the unfit ones through natural selection.

Darwin's theory was based on several facts, observations and influences. They are:

Over production (or) prodigality of production

- All living organisms increase their population in larger number. For example, Salmon fish produces about 28 million eggs during breeding season and if all of them hatch, the seas would be filled with salmon in few generations. Elephant, the slowest breeder that can produce six young ones in its life time can produce 6 million descendants at the end of 750 years in the absence of any check.

Struggle for existence

- Organisms struggle for food, space and mate. As these become a limiting factor, competition exists among the members of the population. Darwin denoted struggle for existence in three ways –

- Intra specific struggle between the same species for food, space and mate.

- Inter specific struggle with different species for food and space.
- Struggle with the environment to cope with the climatic variations, flood, earthquakes, drought, etc.,

Universal occurrence of variations

- No two individuals are alike. There are variations even in identical twins. Even the children born of the same parents differ in colour, height, behavior, etc., The useful variationsfound in an organism help them to overcome struggle and such variations are passed on to the next generation.

Origin of species by Natural Selection

- According to Darwin, nature is the most powerful selective force. He compared origin of species by natural selection to a small isolated group. Darwin believed that the struggle for existence resulted in the survival of the fittest. Such organisms become better adapted to the changed environment.

Objections to Darwinism

Some objections raised against Darwinism were –

- Darwin failed to explain the mechanism of variation.
- Darwinism explains the survival of the fittest but not the arrival of the fittest.
- He focused on small fluctuating variations that are mostly non-heritable.
- He did not distinguish between somatic and germinal variations.
- He could not explain the occurrence of vestigial organs, over specialization of some organs like large tusks in extinct mammoths, oversized antlers in the extinct Irish deer, etc.,

Neo Darwinism

- Neo Darwinism is the interpretation of Darwinian evolution through Natural Selection as it has been modified since it was proposed. New facts and discoveries about evolution have led to modifications of Darwinism and is supported by Wallace, Heinrich, Haeckel, Weismann and Mendel. This theory emphasizes the change in the frequency of genes in population arises due to mutation, variation, isolation and Natural selection.

Mutation theory

- Hugo de Vries put forth the Mutation theory. Mutations are sudden random changes that occur in an organism that is not heritable. De Vries carried out his experiments in the Evening Primrose plant (Oenothera lamarckiana) and observed variations in them due to mutation.

- According to de Vries, sudden and large variations were responsible for the origin of new species whereas Lamarck and Darwin believed in gradual accumulation of all variations as the causative factors in the origin of new species.

Salient features of Mutation Theory

- Mutations or discontinuous variation are transmitted to other generations.
- In naturally breeding populations, mutations occur from time to time.
- There are no intermediate forms, as they are fully fledged.
- They are strictly subjected to natural selection.

Modern synthetic theory

- Sewell Wright, Fisher, Mayer, Huxley, Dobzhansky, Simpson and Haeckel explained Natural Selection in the light of Post-Darwinian discoveries. According to this theory gene mutations, chromosomal mutations, genetic recombinations, natural selection and reproductive isolation are the five basic factors involved in the process of organic evolution.

- **Gene mutation** refers to the changes in the structure of the gene. It is also called gene/ point mutation. It alters the phenotype of an organism and produces variations in their offspring.

- **Chromosomal mutation** refers to the changes in the structure of chromosomes due to deletion, addition, duplication, inversion or translocation. This too alters the phenotype of an organism and produces variations in their offspring.

- **Genetic recombination** is due to crossing over of genes during meiosis. This brings about genetic variations in the individuals of the same species and leads to heritable variations.

- **Natural selection** does not produce any genetic variations but once such variations occur it favours some genetic changes while rejecting others (driving force of evolution).

- **Reproductive isolation** helps in preventing interbreeding between related organisms.

Evolution by anthropogenic sources
Natural Selection (Industrial melanism)

- Natural selection can be explained clearly through industrial melanism. Industrial melanism is a classical case of Natural selection exhibited by the peppered moth, Bistonbetularia. These were available in two colours, white and black. Before industrialization peppered moth both white and black coloured were common in England. Pre-industrialization witnessed white coloured background of the wall of the buildings hence the white coloured moths escaped from their predators. Post industrialization, the tree trunks became dark due to smoke and soot let out from the industries. The black moths camouflaged on the dark bark of the trees and the white moths were easily identified by their predators. Hence the dark coloured moth population was selected and their number increased when compared to the white moths. Nature offered positive selection pressure to the black coloured moths. The above proof shows that in a population, organisms that can adapt will survive and produce more progenies resulting in increase in population through natural selection.

- Artificial selection is a byproduct of human exploitation of forests, oceans and fisheries or the use of pesticides, herbicides or drugs. For hundreds of years humans have selected various types of dogs, all of which are variants of the single species of dog. If human beings can produce new varieties in short period, then "nature" with its vast resources and long duration can easily produce new species by selection.

Adaptive Radiation

- The evolutionary process which produces new species diverged from a single ancestral form becomes adapted to newly invaded habitats is called adaptive radiation. Adaptive radiations are best exemplified in closely related groups that have evolved in relatively short time. Darwin's finches and Australian marsupials are best examples for adaptive radiation. When more than one adaptive radiation occurs in an isolated geographical area, having the same structural and functional similarity it is due to convergent evolution.

Darwin's finches

- Their common ancestor arrived on the Galapagos about 2 million years ago. During that time, Darwin's finches have evolved into 14 recognized species differing in body size, beak shape and feeding behavior. Changes in the size and form of the beak have enabled different species to utilize different food resources such as insects, seeds, nectar from cactus flowers and blood from iguanas, all driven by Natural selection. represents some of the finches observed by Darwin. Genetic variation in the ALX1 gene in the DNA of Darwin finches is associated with variation in the beak shape. Mild mutation in the ALX1 gene leads to phenotypic change in the shape of the beak of the Darwin finches.

- Marsupials in Australia and placental mammals in North America are two subclasses of mammals they have adapted in similar way to a particular food resource, locomotory skill or climate. They were separated from the common ancestor more than 100 million year ago and each lineage continued to evolve independently. Despite temporal and geographical separation, marsupials in Australia and placental mammals in North America have produced varieties of species living in similar habitats with similar ways of life. Their overall resemblance in shape, locomotory mode, feeding and foraging are superimposed upon different modes of reproduction. This feature reflects their distinctive evolutionary relationships.

- Over 200 species of marsupials live in Australia along with many fewer species of placental mammals. The marsupials have undergone adaptive radiation to occupy the diverse habitats in Australia, just as the placental mammals have radiated across North America.

Mechanism of evolution

- Microevolution (evolution on a small scale) refers to the changes in allele frequencies within a population. Allele frequencies in a population may change due to four fundamental forces of evolution such as natural selection, genetic drift, mutation and gene flow.

Natural selection

- It occurs when one allele (or combination of alleles of differences) makes an organism more or less fit to survive and reproduce in a given environment. If an allele reduces fitness, its frequencies tend to drop from one generation to the next.

- The evolutionary path of a given gene i.e., how its allele's change in frequency in the population across generation, may result from several evolutionary mechanisms acting at once. For example, one gene’s allele frequencies might be modified by both gene flow and genetic drift, for another gene, mutation may produce a new allele, that is favoured by natural selection.

Selection

- There are mainly three types of natural selection

Stabilising Selection (centipetal selection):

- This type of selection operates in a stable environment. The organisms with average phenotypes survive whereas the extreme individuals from both the ends are eliminated. There is no speciation but the phenotypic stability is maintained within the population over generation. For example, measurements of sparrows that survived the storm clustered around the mean, and the sparrows that failed to survive the storm clustered around the extremes of the variation showing stabilizing selection.

Directional Selection:

- The environment which undergoes gradual change is subjected to directional selection. This type of selection removes the individuals from one end towards the other end of phenotypic distribution. For example, size differences between male and female sparrows. Both male and female look alike externally but differ in body weight. Females show directional selection in relation to body weight.

Disruptive Selection (centrifugal selection):

- When homogenous environment changes into heterogenous environment this type of selection is operational. The organisms of both the extreme phenotypes are selected whereas individuals with average phenotype are eliminated. This results in splitting of the population into sub population/species. This is a rare form of selection but leads to formation of two or more different species. It is also called adaptive radiation. E.g. Darwin's finches-beak size in relation to seed size inhabiting Galapagos islands.

- Group selection and sexual selection are other types of selection. The two major group selections are Altrusim and Kin selection.

Gene flow

- Movement of genes through gametes or movement of individuals in (immigration) and out (emigration) of a population is referred to as gene flow. Organisms and gametes that enter the population may have new alleles or may bring in existing alleles but in different proportions than those already in the population. Gene flow can be a strong agent of evolution.

Genetic drift / Sewall Wright Effect

- Genetic drift is a mechanism of evolution in which allele frequencies of a population change over generation due to chance (sampling error). Genetic drift occurs in all population sizes, but its effects are strong in a small population . It may result in a loss of some alleles (including beneficial ones) and fixation of other alleles. Genetic drift can have major effects, when the population is reduced in size by natural disaster due to bottle neck effect or when a small group of population splits from the main population to form a new colony due to founder's effect.

Origin and Evolution of Man

- Mammals evolved in the early Jurassic period, about 210 million years ago. Hominid evolution occurred in Asia and Africa. Hominids proved that human beings are superior to other animals and efficient in making tools and culture. The earliest fossils of the prehistoric man like Ramapithecus and Sivapithecus lived some 14 mya and were derived from ape like Dryopithecus. Dryopithecus and Ramapithecus were hairy and walked like gorillas and chimpanzees. Australopithecus lived in East African grasslands about 5 mya and was called the Australian ape man. He was about 1.5 meters tall with bipedal locomotion, omnivorous, semi erect, and lived in caves. Low forehead, brow ridges over the eyes, protruding face, lack of chin, low brain capacity of about 350 – 450 cc, human like dentition, lumbar curve in the vertebral column were his distinguishing features. Homo habilis lived about 2 mya. Their brain capacity was between 650 – 800cc, and was probably vegetarian. They had bipedal locomotion and used tools made of chipped stones.

- Homo erectus the first human like being was around 1.7 mya and was much closer to human in looks, skull was flatter and thicker than the modern man and had a large brain capacity of around 900 cc. Homo erectus probably ate meat.

- Homo ergaster and Homo erectus were the first to leave Africa. Neanderthal human was found in Neander Valley, Germany with a brain size of 1400 cc and lived between 34,000 - 1,00,000 years ago. They differ from the modern human in having semierect posture, flat cranium, sloping forehead, thin large orbits, heavy brow ridges, protruding jaws and no chin. They used animal hides to protect their bodies, knew the use of fire and buried their dead. They did not practice agriculture and animal domestication. Cro-Magnon was one of the most talked forms of modern human found from the rocks of Cro-Magnon, France and is considered as the ancestor of modern Europeans. They were not only adapted to various environmental conditions, but were also known for their cave paintings, figures on floors and walls.

- Homo sapiens or modern human arose in Africa some 25,000 years ago and moved to other continents and developed into distinct races. They had a brain capacity of 1300 – 1600 cc. They started cultivating crops and domesticating animals.

Isolating Mechanism

- Isolation is the separation of the members of a single population into sub populations so that genetic integrity of the subpopulation can be maintained. Closely related species living in the same area do not breed together; they are prevented by isolating barriers. An isolating barrier is any evolved character of the two species that stops them from interbreeding. Several kinds of isolating barriers are distinguished. The most important distinction is Prezygotic and post zygotic isolation. Prezygotic mechanisms include those which prevent two species from coming into contact. This includes ecological, seasonal, ethological and morphological. Post zygotic mechanisms are those which act after fertilization that include hybrid sterility, hybrid inviability and hybrid breakdown.

- **Ecological isolation or habitat isolation** – the members of the same population may be separated from one another by a differences in their habitat. For example Rana areolata occupies burrows dug by mammals and tortoises during the day and breeds in grassy shallow ponds whereas Rana grylio breeds in deep waters. Due to the difference in their habitat the two species are able to maintain their respective species identities.

- **Seasonal isolation** – In this type ofisolation, difference in the breedingseasons prevents interbreeding. E.g.Toad, Bufo americanus breeds muchearly in the spring; whereas Bufofowleri breeds very late in the season.They are able to maintain their speciesidentity because of the differences in thebreeding seasons

- **Sexual or ethological isolation/Behavioural isolation** – Preventsmating due to the difference in theirsexual behavior. The species are notseparated from one another either intime or in space. The mating calls oftwo closely related species of frogs,Hyla versicolor (grey tree frog) andHylafemoralis (pine wood tree frog) aredifferent which prevents interbreeding.

- **Morphological isolation or mechanical isolation** – This type of isolation isdue to the differences in their externalgenitalia that is seen in two differentspecies. The size difference between thetoad species Bufo quercicus and Bufovalliceps, prevents their interbreeding.

- **Physiological isolation –**Thoughmating may occur, the gametes areprevented from fertilization due tomechanical or physiological factors.E.g. The sperms of Drosophila virilissurvive only for about a day whenintroduced into the sperm receptacle ofDrosophila American a while the spermsof Drosophila American a live for a longertime.

- **Cytological isolation** – Fertilizationdoes not take place due to thedifferences in the chromosome numbersbetween the two species, the bull frogRana catesbiana and gopher frog Ranaareolata

- **Hybrid inviability** – In this type, thesperm enters the egg, fertilization occursand the embryo develops into the adultbut it dies before reaching maturity.In certain fishes, frogs, beetles, even iffertilization takes place between twospecies, due to genetic incompatibilitythey do not leave any surviving offspring.

- **Hybrid sterility** – In this type,hybrids are formed due to inter specificcrosses but they are sterile due to thefailure of the chromosomes to segregatenormally during meiosis, example Mule(inter specific cross between a horse anda donkey).

- **Hybrid breakdown** – F1 Hybrids areviable and fertile, but F2 hybrids may beinviable or sterile.

Speciation

- The process by which one species evolves into one or more different species is called speciation. A.E. Emerson defines species as a 'genetically distinctive, reproductively isolated natural population'. Speciation is a fundamental process in evolution. Evolution of a new species in a single lineage is called an agenesis / phyletic speciation. If one species diverges to become two or more species it is cladogenesisor divergent evolution.

Sympatric speciation/Reproductive isolation

- It is a mode of speciation through which new species form from a single ancestral species while both species continue to inhabit the same geographical region. Two or more species are involved. New species formed due to genetic modification in the ancestor that is naturally selected can no longer breed with the parent population. Sexual isolation is strongest. Phenotypic plasticity has emerged as potentially important first step in speciation initiated within an isolated population.

> Phenotypic plasicity is the ability of single genotype to produce more than one phenotype. When this plasticity is expressed seasonally in planktons, it is referred to as cyclomorphosis.

Allopatric speciation/ Geographical speciation

- It is a mode of speciation that occurs when biological populations of similar species become isolated from each other that prevents gene flow. One species becomes two species due to geographical barriers hence new species is evolved e.g. Darwin's finches. The barriers are land separation, migration or mountain formation. When barriers occur between species, change in ecological conditions and environment leads to adaptations that produce differences. If there are no adaptations, they will not survive. Sexual isolation is weakest.

- A well studied example is the adaptation of Apple maggots that feed on apples in North America. When the apple trees were imported to North America, Apple maggot flies (Rhagoletispomonella) a parasitic insect that normally laid its eggs in the fruit of wild hawthorns until one subset of population began to lay its eggs in the fruit of domesticated apple trees (Malus domestica) that grew in the same area. This small group of apple maggot flies selected a different host species from the rest of the population and its offsprings became accustomed to domesticated apples.

Extinction of Animals
Extinction

- Extinction was common if not inevitable because species could not always adapt to large or rapid environmental changes. Theimpact of extinction can conveniently be considered at three levels.

- **Species extinction** eliminates an entire species, by an environmental event (flood etc.,) or by biological event (disease or non availability of food resource half or more).

- **Mass extinction** eliminates half or more species in a region or ecosystem, as might occur following a volcanic eruption. Five major mass extinction that occurred since the Cambrian period. This mass extinction is often referred to as K-T extinction

- **Global extinction** eliminates most of the species on a large scale or larger taxonomic groups in the continent or the Earth. Snow ball Earth and extinction following elevation in CO2 levels are example. Extinction events opens up new habitats and so can facilitate the radiation of organisms that survived the mass extinction.

UNIT- 10 - Application of Bio Technology

- Geneticengineering involves the manipulation of DNA and naturally occurring processes such as protein synthesis for a wide range of applications including the production of therapeutically important proteins. This also involves extracting a gene from one organism and transferring it to the DNA of another organism, of the same or another species. The DNA produced in this way is referred to as recombinant DNA (rDNA) and this technique asrecombinant DNA technology. All these are part of the broad field biotechnology which can be definedas the applications of scientific and engineering principles to the processing of material by biologicalagents to provide goods and services.

- Biotechnology is an umbrella term that covers various techniques for using the properties of living things to make products or provide services. The term biotechnology was first used before 20th century for such traditional activities as making idli, dosa, dairy products, bread or wine, but none of these would be considered biotechnology in the modern sense.

Gene Therapy

If a person is born with a hereditary disease, can a corrective therapy be given for such disease? Yes, this can be done by a process known as gene therapy. This process involves the transfer of a normal gene into a person's cells that carries one or more mutant alleles. Expression of normal gene in the person results in a functional gene product whose action produces a normal phenotype. Delivery of the normal gene is accomplished by using a vector. The main thrust of gene therapy has been directed at correcting single gene mutations as in cystic fibrosis and haemophilia. At present most genetic diseases have no effective treatment and so gene therapy could offer hope for many people. There are two strategies involved in gene therapy namely; Gene augmentationtherapy which involves insertion of DNA into the genome to replace the missing gene product and Gene inhibition therapy which involves insertion of the anti sense gene which inhibits the expression of the dominant gene The two approaches to achieve gene therapy are somatic cell and germ line gene therapy.

Diffentiation between somatic cell gene therapy and germ line gene therapy

Somatic Cell Gene Therapy	Germ Line Gene Therapy
Therapeutic genes transferred into the somatic cells.	Therapeutic genes transferred into the germ cells.
Introduction of genes into bone marrow cells,	Genes introduced into eggs and sperms.

blood cells, skin cells etc.,	
Will not be inherited in later generations.	Heritable and passed on to later generations.

The first clinical gene therapy was given in 1990 by French Anderson to a four year oldgirl with adenosine deaminase (ADA) deficiency. ADA deficiency or SCID (Severe combined immunodeficiency) is an autosomal recessive metabolic disorder. It is caused by the deletion or dysfunction of the gene coding for ADA enzyme. In these patients the nonfunctioning T-Lymphocytes cannot elicit immune responses against invading pathogens.The right approach for SCID treatment would be to give the patient a functioning ADA which breaks down toxic biological products.

In some children ADA deficiency could be cured by bone marrow transplantation, where defective immune cells could be replaced with healthy immune cells from a donor. In some patients it can be treated by enzyme replacement therapy, in which functional ADA is injected into the patient.

During gene therapy the lymphocytes from the blood of the patient are removed and grown in a nutrient culture medium. A healthy and functional human gene, ADA cDNA encoding this enzyme is introduced into the lymphocytes using a retrovirus. The genetically engineered lymphocytes are

subsequently returned to the patient. Since these cells are not immortal, the patient requires periodic infusion of such genetically engineered lymphocytes. The disease could be cured permanently if the gene for ADA isolated from bone marrow cells are introduced into the cells of the early embryonic stages.

- Somatic cell therapy involves the insertion ofa fully functional and expressible gene into atarget somatic cell to correct a genetic diseasepermanently whereas Germline gene therapyinvolves the introduction of DNA into germ cellswhich is passed on to the successive generations.

- Gene therapy involves isolation of a specificgene and making its copies and inserting theminto target cells to make the desired proteins.It is absolutely essential for gene therapists toensure that the gene is harmless to the patientand it is appropriately expressed and that thebody's immune system does not react to theforeign proteins produced by the new genes.

Stem Cell Therapy

- Stem cells are undifferentiated cells found in most of the multi cellular animals. These cells maintain their undifferentiated state even after undergoing numerous mitotic divisions.

- Stem cell research has the potential to revolutionize the future of medicine with the ability to regenerate damaged and diseased organs. Stem cells are capable of self renewal and exhibit 'cellular potency'. Stem cells can differentiate into all types of cells that are derived from any of the three germ layers ectoderm, endoderm and mesoderm.

- In mammals there are two main types of stem cells – embryonic stem cells (ES cells) and adult stem cells. ES cells are pluripotent and can produce the three primary germ layers ectoderm, mesoderm and endoderm. Embryonic stem cells are multipotent stem cells that can differentiate into a number of types of cells (Fig. 10.5). ES cells are isolated from the epiblast tissue of the inner cell mass of a blastocyst. When stimulated ES can develop into more than 200 cells types of the adult body. ES cells are immortal i.e., they can proliferate in a sterile culture medium and maintain their undifferentiated state.

- Adult stem cells are found in various tissues of children as well as adults. An adult stem cell or somatic stem cell can divide and create another cell similar to it. Most of the adult stem cells are multipotent and can act as a repair system of the body, replenishing adult tissues.The red bone marrow is a rich source of adult stem cells.

- The most important and potential application of human stem cells is the generation of cells and tissues that could be used for cell based therapies. Human stem cells could be used to test new drugs.

Totipotency (Toti-total) is the ability of a single cell to divide and produce all of the differentiated cells in an organism.

Pluripotency (Pluri-several) refers to a stem cell that has the potential to differentiate into any of the three germ layers-ectoderm, endoderm and mesoderm.

Multipotency (multi-Many) refers to the stem cells that can differentiate into various types of cells that are related. For example blood stem cells can differentiate into lymphocytes, monocytes , neutrophils etc.,

Oligopotency (Oligo-Few) refers to stem cells that can differentiate into few cell types. For example lymphoid or myeloid stem cells can differentiate into B and T cells but not RBC.

Unipotency (Uni- Single) refers to the ability of the stem cells to differentiate into only one cell type.

Stem Cell Banks

- Stem cell banking is the extraction, processing and storage of stem cells, so that they may be used for treatment in the future, when required. Amniotic cell bank is a facility that stores stem cells derived from amniotic fluid for future use. Stem cells are stored in banks specifically for use by the individual from whom such cells have been collected and the banking costs are paid. Cord Blood Banking is the extraction of stem cells from the umbilical cord during childbirth. While the umbilical cord and cord blood are the most popular sources of stem cells, the placenta, amniotic sac and amniotic fluid are also rich sources in terms of both quantity and quality.

Molecular Diagnostics

- Early diagnosis of infectious diseases or inherent genetic defects is essential for appropriate treatment. Early detection of the disease is not possible using conventional diagnostic methods like microscopic examinations, serum analysis and urine analysis.These laboratory techniques are indirect and not always specific. Scientists are continuously searching for specific, sensitive and simple diagnostic techniques for diagnosis of diseases. Recombinant DNA technology, Polymerase Chain Reactions (PCR) and Enzyme Linked Immunosorbent Assay (ELISA) are some of the techniques that are reliable and help in early diagnosis. Presence of pathogens like virus, bacteria, etc., is detected only when the pathogen produces symptoms in the patient. By the time the symptoms appear concentration of pathogen becomes very high in the body. However very low concentration of a bacteria or a virus, even when the symptoms of the disease does not appear, can be detected by amplification of their nucleic acid.

ELISA [Enzyme Linked Immunosorbent Assay]

- ELISA is a biochemical procedure discovered by Eva Engvall and Peter Perlmanin (1971) to detect the presence of specific antibodies or antigens in a sample of serum, urine, etc., It is a very important diagnostic tool to determine if a person is HIV positive or negative. ELISA is a tool for determining serum antibody concentrations (such as the antibodies produced in a person infected by pathogens such as HIV) and also for detecting the presence of specific antigens and hormones such as human chorionic gonadotropins.

- During diagnosis the sample suspected to contain the antigen is immobilized on the surface of an ELISA plate. The antibody specific to this antigen is added and allowed to react with the immobilized antigen. The anti-antibody is linked to an appropriate enzyme like peroxidase. The unreacted anti-antbody is washed away and the substrate of the enzyme (hydrogen peroxidase) is added with certain reagents such as 4-chloronaphthol. The activity of the enzyme yields a coloured product indicating the presence of the antigen. The intensity of the colour is directly proportional to the amount of the antigen. ELISA is highly sensitive and can detect antigens in the range of a nanogram.

- There are four kinds of ELISA namely, Direct ELISA, Indirect ELISA, sandwich ELISA and competitive ELISA. It is a highly sensitive and specific method used for diagnosis. ELISA possesses the added advantages of not requiring radioisotopes or a radiation counting apparatus.

PCR (Polymerase Chain Reaction)

- The polymerase chain reaction (PCR) is an invitro amplification technique used for synthesising multiple identical copies (billions) of DNA of interest. The technique was developed by Kary Mullis (Nobel laureate, 1993) in the year 1983.

- Denaturation, renaturation or primer annealing and synthesis or primer extension, are the three steps involved in PCR. The double stranded DNA of interest is denatured to separate into two individual strands by high temperature . This is called denaturation. Each strand is allowed to hybridize with a primer (renaturation or primer annealing). The primer template is used to synthesize DNA by using Taq – DNA polymerase.

- During denaturation the reaction mixture is heated to 950 C for a short time to denature the target DNA into single strands that will act as a template for DNA synthesis. Annealing is done by rapid cooling of the mixture, allowing the primers to bind to the sequences on each of the two strands flanking the target DNA. During primer extension or synthesis the temperature of the mixture is increased to 750C for a sufficient period of time to allow Taq DNA polymerase to extend each primer by copying the single stranded template. At the end of incubation both single template strands will be made partially double stranded. The new strand of each double stranded DNA extends to a variable distance downstream. These steps are repeated again and again to generate multiple forms of the desired DNA. This process is also called DNA amplification.

- The PCR technique can also be used for amplifications of RNA in which case it is referred to as reverse transcription PCR (RT-PCR). In this process the RNA molecules (mRNA) must be converted to complementary DNA by the enzyme reverse transcriptase. The cDNA then serves as the template for PCR.

PCR In Clinical Diagnosis

- The specificity and sensitivity of PCR is useful for the diagnosis of inherited disorders (genetic diseases), viral diseases, bacterial diseases, etc., The diagnosis and treatment of a particular disease often requires identifying a particular pathogen. Traditional methods of identification involve culturing these organisms from clinical specimens and performing metabolic and other tests to identify them. The concept behind PCR based diagnosis of infectious diseases is simple – if the pathogen is present in a clinical specimen its DNA will be present.

Polymerase chain reaction

- Its DNA has unique sequences that can be detected by PCR, often using the clinical specimen (for example, blood, stool, spinal fluid, or sputum) in the PCR mixture. PCR is also employed in the prenatal diagnosis of inherited diseases by using chorionic villi samples or cells from amniocentesis. Diseases like sickle cell anemia, β-thalassemia and phenylketonuria can be detected by PCR in these samples. cDNA from PCR is a valuable tool for diagnosis and monitoring retroviral infections – e.g., Tuberculosis by Mycobacterium tuberculosis.

- Several virally induced cancers, like cervical cancer caused by Papilloma virus can be detected by PCR. Sex of human beings and live stocks, embryos fertilized invitro can be determined by PCR by using primers and DNA probes specific for sex chromosomes. PCR technique is also used to detect sex-linked disorders in fertilized embryos.

Applications of PCR

- The differences in the genomes of two different organisms can be studied by PCR. PCR is very important in the study of evolutions, more specifically phylogenetics.

- As a technique which can amplify even minute quantities of DNA from any source, like hair, mummified tissues, bones or any fossilized materials.

- PCR technique can also be used in the field of forensic medicine . A single molecule of DNA from blood stains, hair, semen of an individual is adequate for amplification by PCR. The amplified DNA is used to develop DNA fingerprint which is used as an important tool in forensic science.Thus, PCR is very useful for identification of criminals. PCR is also used in amplification of specific DNA segment to be used in gene therapy.

Transgenic Animals

- In early days selective breeding methods were carried out to improve the genetic characteristics of live stock and other domestic animals. With the advent of modern biotechnology it is possible to carry out manipulations at the genetic level to get the desired traits in animals. Transgenesis is the process of introduction of extra (foreign/exogenous) DNA into the genome of the animals to create and maintain stable heritable characters. The foreign DNA that is introduced is called the transgene and the animals that are produced by DNA manipulations are called transgenic animals or the genetically engineered or genetically modified organisms.

The various steps involved in the production of transgenic organisms are

- Identification and separation of desired gene.

- Selection of a vector (generally a virus) or direct transmission.

- Combining the desired gene with the vector.
- Introduction of transferred vector into cells, tissues, embryo or mature individual.
- Demonstration of integration and expression of foreign gene in transgenic tissue or animals. Transgenic animals such as mice, rat, rabbit, pig, cow, goat, sheep and fish have been produced.

Uses Of Transgenesis

- Transgenesis is a powerful tool to study gene expression and developmental processes in higher organisms.
- Transgenesis helps in the improvement of genetic characters in animals.Transgenic animals serve as good models for understanding human diseases which help in the investigation of new treatments for diseases.Transgenic models exist for many human diseases such as cancer, Alzheimer's, cystic fibrosis, rheumatoid arthritis and sickle cell anemia.
- Transgenic animals are used to produce proteins which are important for medical and pharmaceutical applications.
- Transgenic mice are used for testing the safety of vaccines.
- Transgenic animals are used for testing toxicity in animals that carry genes which make them sensitive to toxic substances than non-transgenic animals exposed to toxic substances and their effects are studied.
- Transgenesis is important for improving the quality and quantity of milk, meat, eggs and wool production in addition to testing drug resistance.

Biological products and their uses

- A biological product is a substance derived from a living organism and used for the prevention or treatment of disease. These products include antitoxins, bacterial and viral vaccines, blood products and hormone extracts. These products may be produced through biotechnology in a living system, such as a microorganism, plant cell or animal cell, and are often more difficult to characterize than small molecule drugs. Through recombinant DNA technology it is possible to produce these biological products on demand. There are many types of biological products approved for use -they are, therapeutic proteins, monoclonal antibodies and vaccines. Health care and pharmaceutical industries have been revolutionised by biotechnological proteins. Hormones and antibodies are produced commercially, primarily for the medical industry. Recombinant hormones like Insulin, Human growth hormone, Recombinant vaccines and recombinant proteins like human alpha lactalbumin are available today.

- Animals are used as bioreactors to produce desirable proteins. Antibodies are substances that react against the disease causing antigens and these can be produced using transgenic animals as bioreactors. Monoclonal antibodies, which are used to treat cancer, heart disease and transplant rejection are produced by this technology. Natural protein adhesives are non toxic, biodegradable and rarely trigger an immune response, hence could be used to reattach tendons and tissues, fill cavities in teeth, and repair broken bones.

Animal Cloning

- Cloning is the process of producing genetically identical individuals of an organism either naturally or artificially. In nature many organisms produce clones through asexual reproduction.

- Cloning in biotechnology refers to the process of creating copies of organisms or copies of cells or DNA fragments (molecular cloning).

- Dolly was the first mammal (Sheep) clone developed by Ian Wilmut and Campbell in 1997. Dolly, the transgenic clone was developed by the nuclear transfer technique and the phenomenon of totipotency. Totipotency refers to the potential of a cell to develop different cells, tissues, organs and finally an organism.

- The mammary gland udder cells (somatic cells) from a donor sheep (ewe) were isolated and subjected to starvation for 5 days. The udder cells could not undergo normal growth cycle, entered a dormant stage and became totipotent. An ovum (egg cell) was taken from another sheep (ewe) and its nucleus was removed to form an enucleated ovum. The dormant mammary gland cell/udder cell and the enucleated ovum were fused. The outer membrane of the mammary cell was ruptured allowing the ovum to envelope the nucleus. The fused cell was implanted into another ewe which served as a surrogate mother. Five months later dolly was born. Dolly was the first animal to be cloned from a differentiated somatic cell taken from an adult animal without the process of fertilization

Advantages and Disadvantages Of Cloning Animals:

- Offers benefits for clinical trials and medical research. It can help in the production of proteins and drugs in the field of medicine.

- Aids stem cell research.

- Animal cloning could help to save endangered species.

- Animal and human activists see it as a threat to biodiversity saying that this alters evolution which will have an impact on populations and the ecosystem.
- The process is tedious and very expensive.
- It can cause animals to suffer.
- Reports show that animal surrogates were manifesting adverse outcomes and cloned animals were affected with disease and have high mortality rate.
- It might compromise human health through consumption of cloned animal meat.
- Cloned animals age faster than normal animals and are less healthy than the parent organism as discovered in Dolly.
- Cloning can lead to occurrence of genetic disorders in animals.
- More than 90% of cloning attempts fail to produce a viable offspring.

Ian Wilmut and Campbell removed 277 cells from the udder of an adult sheep and fused those cells with 277 unfertilised egg cells from which the nuclear material was removed. After culturing the resulting embryos for 6 days , they implanted 29 embryos into the surrogate mother's womb and only one Dolly was produced.

A gene 'knock out' is a genetically engineered organism that carries one or more genes in its chromosomes that have been made inoperative.

Ethical Issues

- Biotechnology has given to the society cheap drugs, better friuts and vegetables, pest resistant crops, indigenious cure to diseases and lot of controversy. This is mainly because the major part of the modern biotechnology deals with genetic manipulations. People fear that these genetic manipulations may lead to unknown consequences. The major apprehension of recombinant DNA technology is that unique microorganisms either inadvertently or deliberately for the purpose of war may be developed that could cause epidemics or environmentalcatastrophies. Although many are concerned about the possible risk of genetic engineering, the risks are in fact slight and the potential benefits are substantial.

Regulations in Biotechnology

- Regulations apply to the production, sale and use of biotech products and genetically modified organisms. GMOs are carefully tested and documented before the products are available. GMOs should be labelled and used according to instructions. These regulations are designed to protect the people, living organisms and the environment. The Biotechnology Regulatory Authority of India (BRAI) is a proposed regulatory body in India for uses of biotechnology products including GMOs. The Genetic Engineering Approval Committee (GEAC), a body under the Ministry of Environment, forests and climate change (India) is responsible for approval of genetically engineered products in India. If the bill is passed the responsibility will be taken over by the Environmental Appraisal Panel, a subdivision of the BRAI. The bill also proposes setting up an inter ministerial governing body to oversee the performance of BRAI and a National Biotechnology Advisory Council of stakeholders to provide feedback on the use of, import and manufacture of biotechnology products and organisms in the society. The regulatory body is an autonomous and statutory agency to regulate the research, transport, import and manufacture of biotechnology products and organisms.

- GEAC is assisted by the State Biotechnology Co-ordination Committee (SBCC) and District Level committee (DLC). The most important committees are The Institutional Biosafety Committee (IBSC), responsible for the local implementation of guidelines; Review Committee on Genetic Manipulation (RCGM) is responsible for issuing permits and the GEAC is responsible for monitoring the large scale and commercial use of transgenic materials.

- The biotechnology industry is governed by different enactments depending on their relevance / applicability on a case to case basis. "Recombinant DNA safety guidelines, 1990" were released by the Department of Biotechnology (DBT) which cover areas of research involving genetically engineered organisms and these guidelines were further revised in 1994.

- RCGM under the DBT comprises representatives of DBT, Indian Council for Medical Research, Indian Council for Agricultural research and Council for Scientific and Industrial Research.

Possible threats of Genetically Modified Organisms

- Genetically Modified Organisms (GMOs) also called Genetically Engineered organisms (GEOs) are created to play a role in agriculture, forestry, aquaculture, bioremediation and environmental management in developed and developing countries. However, deliberate or inadvertent release of GMOs into the environment could have negative ecological effects under certain circumstances.

The possible risks of GMOs

- Creating new or more vigorous pests and pathogens. Worsening the effects of existing pests through hybridization with related transgenic organisms.

- Harming non-target species such as soil organisms, non-pest insects, birds and other animals.

- Disrupting biotic communities including agro ecosystems.
- Irreparable loss or changes in species diversity or genetic diversity within species.

- Creating risks for human health.

- The release of GMOs into the environment could also have far reaching consequences. This is because the living GMOs proliferate, persist,disperse and sometimes may transfer their DNA into other organisms. GEOs could also displace the existing organism and create new species which may cause severe environmental damage. Due to these risks the regulatory authorities are very careful in permitting the field trials of GMOs into the environment.

Biosafety Guidelines

- Due to the growing concerns arising from Genetically Modified Organisms (GMOs) throughout the globe the WHO has built an informal working group on biosafety in 1991. This group prepared the 'voluntary code for the release of organisms into the environment'. ICGEB (International Centre for Genetic Engineering and Biotechnology) has played a significant role in issues related to biosafety and the environmentally sustainable use of biotechnology. The main 'topic of concern' related to the release of GMO's are risks for human health, environment, and agriculture which is found on the website of ICGEB.

- In India, DBT has evolved 'rDNA safety guidelines' to exercise powers conferred through the Environmental Protection Act 1986 for the manufacture, use, import, export and storage of hazardous micro organisms and genetically engineered organisms, cells etc., These guidelines are implemented and monitored by the Institutional Biosafety Committees (IBSCs), the Review Committee on Genetic Manipulation (RCGM) and the Genetic Engineering Approval Committee (GEAC) of the Ministry of Environment and Forest.

Intellectual Property Rights (IPR) and Protection (IPP)

- The physical objects like household goods or land or properties of a person and the ownership and rights on these properties is protected by certain laws operating in the country. This type of physical property is tangible; but the transformed microorganisms, plants, animals and technologies for the production of commercial products are exclusively the property of the intellectuals. The discoverer or inventor has complete rights on his property or invention. The rights of intellectuals are protected by laws framed by a country. The intellectual property is an intangible asset. Legal rights or patents provide an inventor only a temporary monopoly on the use of an invention, in return for disclosing the knowledge to the others who may use the knowledge to develop further inventions and innovations.

- The laws are formulated from time to time at national and international levels. Development of new crop varieties is also an intellectual property right. It is protected by 'plant breeders rights' (PBRs). PBRs recognize the fact that farmers and rural communities have contributed to the creation, conservation, exchange and knowledge of genetic and species utilization of genetic diversity. IPR and IPP are granted by the Government to plant breeders for producing a specific plant variety that is new and never existed before.

- IPR is protected by different ways like patents, copyrights and trade marks.

Patents

- The science of biotechnology involves the production of enormous number of commercial products of economic importance. The inventions include biotechnology products and processes. The products include living entities like micro organisms, animals, plants, cell lines, cell organelles, plasmids and genes and naturally occurring products like primary and secondary metabolites produced by living systems e.g. alcohol, antibiotics.

- The biotechnological processes involve isolation, purification, cultivation, bioconversion of novel, innovative, simple and cost effective processes, and creation of biotechnological products.

- A patent is a Government issued document that allows the person for an exclusive right to manufacture, use or sell aninvention for a defined period (usually 20 years). It is a legal document safeguarding the rights and privileges of an inventor / invention. The purpose of patenting in biotechnology ensures fair financial returns for those who have invested finances, ideas, time and hard work for an invention.

The following criteria must be satisfied for patenting:

- The invention must be novel and useful;
- The product must be inventive and reproducible;
- The patent application should provide the full description of the invention and the invention must be patentable.

The first living organism that was patented was a genetically engineered species of bacteria - Pseudomonas putida in 1980 which was genetically engineered by Ananda Mohan Chakrabarty in 1971.

Classical Genetics

- Genetics is the study of how living things receive common traits from previous generations. No field of science has changed the world more, in the past 50 years than genetics. The scientific and technological advances in genetics have transformed agriculture, medicine and forensic science etc.

- Genetics – The Science of heredity (Inheritance) - "Genetics" is the branch of biological science which deals with the mechanism of transmission of characters from parents to off springs. Th e term Genetics was introduced by W. Bateson in 1906.

The four major subdisciplines of genetics are

- **Transmission Genetics / Classical Genetics** – Deals with the transmission of genes from parents to off springs. The foundation of classical genetics came from the study of hereditary behaviour of seven genes by Gregor Mendel.

- **Molecular Genetics** – Deals with the structure and function of a gene at molecular level.

- **Population Genetics** – Deals with heredity in groups of individuals for traits which is determined by a few genes.

- **Quantitative Genetics** – Deals with heredity of traits in groups of individuals where the traits are governed by many genes simultaneously.

> What is the reason for similarities, diff erences of appearance and skipping of generations? Genes – Functional Units of inheritance: The basic unit of heredity (biological information) which transmits biochemical, anatomical and behavioural traits from parents to off springs.

Heredity and variation

- Genetics is often described as a science which deals with heredity and variation.

- **Heredity:** Heredity is the transmission of characters from parents to offsprings.

- **Variation:** The organisms belonging to the same natural population or species that shows a difference in the characteristics is called variation. Variation is of two types (i) Discontinuous variation and (ii) Continuous variation

1. **Discontinuous Variation:**

   Within a population there are some characteristics which show a limited form of variation. Example: Style length in Primula, plant height of garden pea. In discontinuous variation, the characteristics are controlled by one or two major genes which may have two or more allelic forms. These variations are genetically determined by inheritance factors. Individuals produced by this variation show differences without any intermediate form between them and there is no overlapping between the two phenotypes. The phenotypic expression is unaffected by environmental conditions. This is also called as qualitative inheritance.

2. **Continuous Variation**:

   This variation may be due to the combining effects of environmental and genetic factors. In a population most of the characteristics exhibit a complete gradation, from one extreme to the other without any break. Inheritance of phenotype is determined by the combined effects of many genes, (polygenes) and environmental factors. This is also known as quantitative inheritance. Example: Human height and skin color.

Importance of variations

- Variations make some individuals betterfitted in the struggle for existence.
- They help the individuals to adapt themselves to the changing environment.
- It provides the genetic material for natural selection
- Variations allow breeders to improve better yield, quicker growth, increased resistance and lesser input.
- They constitute the raw materials for evolution.

Mendelism

- The contribution of Mendel to Genetics is called Mendelism. It includes all concepts brought out by Mendel through his original research on plant hybridization. Mendelian genetic concepts are basic to modern genetics. Therefore, Mendel is called as Father of Genetics.

Father of Genetics – Gregor Johann Mendel (1822 – 1884)

- The first Geneticist, Gregor Johann Mendel unraveled the mystery of heredity. He was born on 22nd July 1822 in Heinzendorf Silesia (now Hyncice, Czechoslovakia), Austria. After school education, later he studied botany, physics and mathematics at the University of Vienna.He then entered a monastery of St.Thomas at Brunn in Austria and continued his interest in plant hybridization.In 1849 Mendel got a temporary position in a school as a teacher and he performed a series of elegant experiments with pea plants in his garden. In 1856, he started his historic studies on pea plants. 1856 to 1863 was the period of Mendel's hybridization experiments on pea plants. Mendel discovered the principles of heredity by studying the inheritance of seven pairs of contrasting traits of pea plant in his garden. Mendel crossed and catalogued 24,034plants through many generations. His paper entitled "Experiments on Plant Hybrids" was presented and published in The Proceedings of the Brunn Society of Natural History in 1866. Mendel was the first systematic researcher in the field of genetics.

Mendel was successful because:

- He applied mathematics and statisticalmethods to biology and laws of probabilityto his breeding experiments.
- He followed scientific methods and keptaccurate and detailed records that includequantitative data of the outcome of hiscrosses.
- His experiments were carefully plannedand he used large samples.
- The pairs of contrasting characters whichwere controlled by factor (genes)werepresent on separate chromosomes.
- The parents selected by Mendel were purebreed lines and the purity was tested by selfcrossing the progeny for many generations.

Mendel's Experimental System – The Garden pea.
He chose pea plant because,

- It is an annual plant and has clearcontrasting characters that are controlledby a single gene separately.
- Self-fertilization occurred under normalconditions in garden pea plants. Mendelused both self-fertilization and cross-fertilization.
- The flowers are large hence emasculationand pollination are very easy forhybridization.

Mendel's experiments on pea plant

- Mendel's theory of inheritance, known as the Particulate theory, establishes the existence of minute particles or hereditary units or factors, which are now called as genes. He performed artificial pollination or cross pollination experiments with several true-breeding lines of pea plants. A true breeding lines (Pure-breeding strains) means it has undergone continuous self pollination having stable trait inheritance from parent to offspring. Matings within pure breeding lines produce offsprings having specific parental traits that are constant in inheritance and expression for many generations. Pure line breed refers to homozygosity only. Fusion of male and female gametes produced by the same individual i.e pollen and egg are derived from the same plant is known as self-fertilization. Self pollination takes place in Mendel's peas. The experimenter can remove the anthers (Emasculation) before fertilization and transfer the pollen from another variety of pea to the stigma of flowers where the anthers are removed. This results in cross-fertilization, which leads to the creation of hybrid varieties with different traits. Mendel's work on the study of the pattern of inheritance and the principles or laws formulated, now constitute the Mendelian Genetics.

Can you identify Mendel's gene for regulating white colour in peas? Let us

find the molecular answer to understand the gene function. Now the genetic mystery of Mendel's white flowers is solved.

It is quite fascinating to trace the Mendel's genes. In 2010, the gene responsible for regulating flower colour in peas were identified by an international team of researchers. It was called Pea Gene A which encodes a protein that functions as a transcription factor which is responsible for the production of anthocyanin pigment. So the flowers are purple. Pea plants with white flowers do not have anthocyanin, even though they have the gene that encodes the enzyme involved in anthocyanin synthesis.

Researchers delivered normal copies of gene A into the cells of the petals of white flowers by the gene gun method. When Gene A entered in a small percentage of cells of white flowers it is expressed in those particular cells, accumulated anthocyanin pigments and became purple.

In white flowers the gene A sequence showed a single-nucleotide change that makes the transcription factor inactive. So the mutant form of gene A do not accumulate anthocyanin and hence they are white.

- Mendel worked at the rules of inheritance and arrived at the correct mechanism before any knowledge of cellular mechanism, DNA, genes, chromosomes became available. Mendel insights and meticulous work into the mechanism of inheritance played an important role which led to the development of improved crop varieties and a revolution in crop hybridization.

- Mendel died in 1884. In 1900 the work of Mendel's experiments were rediscovered by three biologists, Hugo de Vries of Holland, Carl Correns of Germany and Erich von Tschermak of Austria.

Terminology related to Mendelism

- Mendel noticed two different expressions of a trait – Example: Tall and dwarf. Traits are expressed in different ways due to the fact that a gene can exist in alternate forms (versions) for the same trait is called alleles.

- If an individual has two identical alleles of a gene, it is called as homozygous(TT). An individual with two different alleles is called heterozygous(Tt). Mendels non-true breeding plants are heterozygous, called as hybrids

- When the gene has two alleles the dominant allele is symbolized with capital letter and the recessive with small letter. When both alleles are recessive the individual is called homozygous recessive (tt) dwarf pea plants. An individual with two dominant alleles is called homozygous dominant (TT) tall pea plants. One dominant allele and one recessive allele (Tt) denotes non-true breeding tall pea plants heterozygous tall.

Mendelian inheritance – Mendel's Laws of Heredity

- Mendel proposed two rules based on his observations on monohybrid cross, today these rules are called laws of inheritance The first law is The Law of Dominance and the second law is The Law of Segregation. These scientific laws play an important role in the history of evolution.

The Law of Dominance:

- The characters are controlled by discrete units called factors which occur in pairs. In a dissimilar pair of factors one member of the pair is dominant and the other is recessive. This law gives an explanation to the monohybrid cross (a) the expression of only one of the parental characters in F1 generation and (b) the expression of both in the F2 generation. It also explains the proportion of 3:1 obtained at the F2.

The Law of Segregation (Law of Purity of gametes):

- Alleles do not show any blending, both characters are seen as such in the F2 generation although one of the characters is not seen in the F1 generation. During the formation of gametes, the factors or alleles of a pair separate and segregate from each other such that each gamete receives only one of the two factors. A homozygous parent produces similar gametes and a heterozygous parent produces two kinds of gametes each having one allele with equal proportion. Gametes are never hybrid.

Monohybrid cross

- Monohybrid inheritance is the inheritance of a single character i.e. plant height. It involves the inheritance of two alleles of a single gene. When the F1 generation was selfed Mendel noticed that 787 of 1064 F2 plants were tall, while 277 of 1064 were dwarf. The dwarf trait disappeared in the F1 generation only to reappear in the F2 generation. The term genotype is the genetic constitution of an individual. The term phenotype refers to the observable characteristic of an organism. In a genetic cross the genotypes and phenotypes of offspring, resulting from combining gametes during fertilization can be easily understood with the help of a diagram called Punnett's Square named after a British Geneticist Reginald C.Punnett. It is a graphical representation to calculate the probability of all possible genotypes of offsprings in a genetic cross. The Law of

Dominance and the Law of Segregation give suitable explanation to Mendel's monohybrid cross.

Reciprocal cross

- In one experiment, the tall pea plants were pollinated with the pollens from a true-breeding dwarf plants, the result was all tall plants. When the parental types were reversed, the pollen from a tall plant was used to pollinate a dwarf pea plant which gave only tall plants. The result was the same - All tall plants. Tall x Dwarf and Tall x Dwarf matings are done in both ways which are called reciprocal crosses.The results of the reciprocal crosses are the same. So it was concluded that the trait is not sex dependent. The results of Mendel's monohybrid crosses were not sex dependent.

- The gene for plant height has two alleles: Tall (T)x Dwarf (t). The phenotypic and genotypicanalysis of the crosses has been shown byChecker board method or by Forkline method.

Mendel's analytical and empirical approach

- Mendel chose two contrasting traits for each character. So it seemed logical that two distinct factors exist. In F1 the recessive trait and its factors do not disappear and they are hidden or masked only to reappear in ¼ of the F2 generation. He concluded that tall and dwarf alleles of F1 heterozygote segregate randomly into gametes. Mendel got 3:1 ratio in F2 between the dominant and recessive trait. He was the first scientist to use this type of quantitative analysis in a biological experiment. Mendel's data is concerned with the proportions of offspring.

- Mendel's analytical approach is truly an outstanding scientific achievement. His meticulous work and precisely executed breeding experiments proposed that discrete particulate units of heredity are present and they are transmitted from one generation to the other. Now they are called as genes. Mendel's experiments were well planned to determine the relationships which govern hereditary traits. This rationale is called an empirical approach. Laws that were arrived from an empirical approach is known as empirical laws.

Test cross

- Test cross is crossing an individual of unknowngenotype with a homozygous recessive.

- In Mendel's monohybrid cross all the plants are tall in F1 generation. In F2 tall and dwarf plants were in the ratio of 3:1.Mendel self pollinated dwarf F2 plants and got dwarf plants in F3 and F4 generations. So he concluded that the genotype of dwarf was homozygous (tt). The genotypes of tall plants TT or Tt from F1and F2 cannot be predicted. But how we can tell if a tall plant is homozygous or heterozygous? To determine the genotype of a tall plant Mendel crossed the plants from F2 with the homozygous recessive dwarf plant. This he called a test cross. The progenies of the test cross can be easily analysed to predict the genotype of the plant or the test organism. Thus in a typical test cross an organism (pea plants) showing dominant phenotype (whose genotype is to be determined) is crossed with the recessive parent instead of self crossing. Test cross is used to identify whether an individual is homozygous or heterozygous for dominant character.

Back Cross

- Back Cross is a cross of F1hybrid with any one of the parental genotypes . The back cross is f two type; they are dominant back cross and recessive back cross.
- It involves the cross between the F1 offspringwith either of the two parents.
- When the F1offsprings are crossed withthe dominant parents all the F2 developdominant character and no recessiveindividuals are obtained in the progeny.
- If the F1 hybrid is crossed with the recessive parent individuals of both the phenotypes appear in equal proportion and this cross is specified as test cross.
- The recessive back cross helps to identify the heterozygosity of the hybrid.

Dihybrid cross

- It is a genetic cross which involves individuals differing in two characters. Dihybrid inheritance is the inheritance of two separate genes each with two alleles.
- **Law of Independent Assortment** – When two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent to the other pair of characters. Genes that are located in different chromosomes assort independently during meiosis. Many possible combinations of factors can occur in the gametes.
- Independent assortment leads to genetic diversity. If an individual produces genetically dissimilar gametes it is the consequence of independent assortment. Through independent assortment, the maternal and paternal members of all pairs were distributed to gametes, so all possible chromosomal combinations were produced leading to genetic variation. In sexually reproducing plants / organisms, due to independent assortment, genetic variation takes place which is important in the process of evolution. The Law of Segregation is concerned with alleles of one gene but the Law of Independent Assortment deals with the relationship between genes.
- The crossing of two plants differing in two pairs of contrasting traits is called dihybrid cross. In dihybrid cross, two characters (colour and shape) are considered at a time. Mendel considered the seed shape (round and wrinkled) and cotyledon colour (yellow & green) as the two characters. In seed shape round (R) is dominant over wrinkled (r) ; in cotyledon colour yellow (Y)is dominant over green (y). Hence the purebreeding round

yellow parent is represented bythe genotype RRYY and the pure breeding greenwrinkled parent is represented by the genotyperryy. During gamete formation the paired genesof a character assort out independently of theother pair. During the F1 x F1 fertilization eachzygote with an equal probability receives oneof the four combinations from each parent.The resultant gametes thus will be geneticallydifferent and they are of the following four types:

Yellow round (YR)	9/16
Yellow wrinkled (Yr)	3/16
Green round (yR)	3/16
Green wrinkled (yr)	1/16

- These four types of gametes of F1 dihybridsunite randomly in the process of fertilization and produce sixteen types of individuals in F2 in the ratio of 9:3:3:1 as shown in the figure. Mendel's 9:3:3:1 dihybrid ratio is an ideal ratio based on the probability including segregation, independent assortment and randomfertilization. In sexually reproducing organism / plants from the garden peas to human beings, Mendel's findings laid the foundation for understanding inheritance and revolutionized the field of biology. The dihybrid cross and its result led Mendel to propose a second set of generalisations that we called Mendel's Law of independent assortment.

How does the wrinkled gene make Mendel's peas wrinkled? Find out the molecular explanation.

The protein called starch branching enzyme (SBEI) is encoded by the wild-type allele of the gene (RR) which is dominant. When the seed matures, this enzyme SBEI catalyzes the formation of highly branched starch molecules. Normal gene (R) has become interrupted by the insertion of extra piece of DNA (0.8 kb) into the gene, resulting in r allele. In the homozygous mutant form of the gene (rr) which is recessive, the activity of the enzyme SBEI is lost resulting in wrinkled peas. The wrinkled seed accumulates more sucrose and high water content. Hence the osmotic pressure inside the seed rises. As a result, the seed absorbs more water and when it matures it loses water as it dries. So it becomes wrinkled at maturation. When the seed has atleast one copy of normal dominant gene heterozygous, the dominant allele helps to synthesize starch, amylopectin an insoluble carbohydrate, with the osmotic balance which minimises the loss of water resulting in smooth structured round seed.

Trihybrid cross

- The trihybrid cross demonstrates that Mendel's laws are applicable to the inheritance of multiple traits. Mendel Laws of segregation and independent assortment are also applicable to three pairs of contrasting characteristic traits called trihybrid cross.

- A cross between homozygous parents that differ in three gene pairs (i.e. producing trihybrids) is called trihybrid cross. A self fertilizing trihybrid plant forms 8 different gametes and 64 different zygotes. In this a combination of three single pair crosses operating together.

Extensions of Mendelian Genetics

- Apart from monohybrid, dihybrid and trihybrid crosses, there are exceptions to Mendelian principles, i.e. the occurrence of different phenotypic ratios. The more complex patterns of inheritance are the extensions of Mendelian Genetics. There are examples where phenotype of the organism is the result of the interactions among genes.

- **Gene interaction** – A single phenotype is controlled by more than one set of genes, each of which has two or more alleles. This phenomenon is called Gene Interaction. Many characteristics of the organism including structural and chemical which constitute the phenotype are the result of interaction between two or more genes.

- Mendelian experiments prove that a single gene controls one character. But in the post Mendelian findings, various exception have been noticed, in which different types of interactions are possible between the genes. This gene interaction concept was introduced and explained by W. Bateson. This concept is otherwise known as Factor hypothesis or Bateson's factor hypothesis. According to Bateson's factor hypothesis, the gene interactions can be classified as

    - Intragenic gene interactions or Intra allelic or allelic interactions
    - Intergenic gene interactions or inter allelic or non-allelic interactions.

Intragenic gene interactions

- Interactions take place between the alleles of the same gene i.e., alleles at the same locus is called intragenic or intralocus gene interaction. It includes the following:

    - Incomplete dominance
    - Codominance
    - Multiple alleles
    - Pleiotropic genes are common examples for intragenic interaction.

Incomplete dominance – No blending of genes

- The German Botanist Carl Correns's (1905) Experiment - In 4 O' clock plant, Mirabilis jalapa when the pure breeding homozygous red (R1R1) parent is crossed with homozygous white (R2R2), the phenotype of the F1 hybrid is heterozygous pink (R1R2). The F1 heterozygous phenotype differs from both the parental homozygous phenotype. This cross did not exhibit the character of the dominant parent but an intermediate colour pink. When one allele is not completely dominant to another allele it shows incomplete dominance. Such allelic interaction is known as incomplete dominance. F1 generation produces intermediate phenotype pink coloured flower. When pink coloured plants of F1 generationwere interbred in F2 both phenotypic and genotypic ratios were found to be identical as 1 : 2 : 1(1 red : 2 pink : 1 white). Genotypic ratio is 1 R1R1 : 2 R1R2 : 1 R2R2.From this we conclude that the alleles themselves remain discrete and unaltered proving the Mendel's Law of Segregation. The phenotypic and genotypic ratios are the same. There is no blending of genes. In the F2 generation R1 and R2 genes segregate and recombine to produce red, pink and white in the ratio of 1 : 2 : 1. R1 allele codes for an enzyme responsible for the formation of red pigment. R2 allele codes for defective enzyme. R1 and R2 genotypes produce only enough red pigments to make the flower pink. Two R1R1 are needed for producing red flowers. Two R2R2 genes are needed for white flowers. If blending had taken place, the original pure traits would not have appeared and all F2 plants would have pink flowers. It is very clear that Mendel's particulate inheritance takes place in this cross which is confirmed by the reappearanceof original phenotype in F2.

How will you explain incomplete dominance at the molecular level?

Gene expression is explained in a quantitative way. Wild-type allele which is a functional allele when present in two copies (R1 R1) produces an functional enzyme which synthesizes red pigments. The mutant allele which is a defective allele in two copies (R2 R2) produces an enzyme which cannot synthesize necessary red pigments. The white flower is due to the mutation causing complete loss of function. The F1 intermediate phenotype heterozygote (R1R2) has one copy of the allele R1. R1 produces 50% of the functional protein resulting in half of the pigment of red flowered plant and so it is pink. The intermediate phenotype pink heterogyzote with 50% of functional protein is not enough to create the red phenotype homozygous, which makes 100% of the functional protein.

Codominance (1 : 2 : 1)

- This pattern occurs due to simultaneous (joint) expression of both alleles in the heterozygote - The phenomenon in which two alleles are both expressed in the heterozygous individual is known as codominance. Example: Red and white flowers of Camellia, inheritance of sickle cell haemoglobin, ABO blood group system in humanbeings. In humanbeings, IA and IB alleles of I gene are codominant which follows Mendels law of segregation. The codominance was demonstrated in plants with the help of electrophoresis or chromatography for protein or flavonoid substance. Example: Gossypium hirsutum and Gossypium sturtianum, their F1 hybrid (amphiploid) was tested for seed proteins by electrophoresis. Both the parents havedifferent banding patterns for their seed proteins. In hybrids, additive banding pattern was noticed. Their hybrid shows the presence of both the types of proteins similar to their parents.

- The heterozygote genotype gives rise to a phenotype distinctly different from either of the homozygous genotypes. The F1 heterozygotes produce a F2 progeny in a phenotypic and genotypic ratios of 1 : 2 : 1.

Lethal genes

- An allele which has the potential to cause the death of an organism is called a "Lethal Allele". In 1907, E. Baur reported a lethal gene in snapdragon (Antirrhinum sp.). It is an example for recessive lethality. In snapdragon there are three kinds of plants.

- Green plants with chlorophyll. (CC)

- Yellowish green plants with carotenoids arereferred to as pale green, golden or aureaplants (Cc)

- White plants without any chlorophyll. (cc)

- The genotype of the homozygous greenplants is CC. The genotype of the homozygous white plant is cc.

- The aurea plants have the genotype Cc because they are heterozygous of green and white plants. When two such aurea plants are crossed the F1 progeny has identical phenotypic and genotypic ratio of 1 : 2 : 1 (viz. 1 Green (CC) : 2 Aurea (Cc) : 1 White (cc))

- Since the white plants lack chlorophyll pigment, they will not survive. So the F2 ratio is modified into 1 : 2. In this case the homozygous recessive genotype (cc) is lethal.

- The term "lethal" is applied to those changes in the genome of an organism which produces effects severe enough to cause death. Lethality is a condition in which the death of certain genotype occurs prematurely. The fully dominant or fully recessive lethal allele kills the carrier individual only in its homozygous condition. So the F2 genotypic ratio will be 2 : 1 or 1 : 2 respectively.

Pleiotropy – A single gene affects multiple traits

- In Pleiotropy, the single gene affects multiple traits and alter the phenotype of the organism. The Pleiotropic gene influences a number of characters simultaneously and such genes are called pleiotropic gene. Mendel noticed pleiotropy while performing breeding experiment with peas (Pisum sativum). Peas with purple flowers, brown seeds and dark spot on the axils of the leaves were crossed with a variety of peas having white flowers, light coloured seeds and no spot on the axils of the leaves, the three traits for flower colour, seed colour and a leaf axil spot all were inherited together as a single unit. This is due to the pattern of inheritance where the three traits were controlled by a single gene with dominant and recessive alleles. Example: sickle cell anemia.

Intergenic gene interactions

- Interlocus interactions take place between the alleles at different loci i.e between alleles of different genes.It includes the following:

- **Dominant Epistasis** – It is a gene interaction in which two alleles of a gene at one locus interfere and suppress or mask the phenotypic expression of a different pair of alleles of another gene at another locus. The gene that suppresses or masks the phenotypic expression of a gene at another locus is known as epistatic. The gene whose expression is interfered by non-allelic genes andprevents from exhibiting its character is known as hypostatic. When both the genes are present together, the phenotype is determined by the epistatic gene and not by the hypostatic gene.

- In the summer squash the fruit colour locus has a dominant allele 'W' for white colour and a recessive allele 'w' for coloured fruit. 'W' allele is dominant that masks the expression of any colour. In another locus hypostatic allele 'G' is for yellow fruit and its recessive allele 'g' for green fruit. In the first locus the white is dominant to colour where as in the second locus yellow is dominant to green. When the white fruit with genotype WWgg is crossed with yellow fruit with genotype wwGG, the F1 plants have white fruit and are heterozygous (WwGg). When F1 heterozygous plants are crossed they give rise to F2 with the phenotypic ratio of 12 white : 3 yellow : 1 green.

Intra –genic or allelic interaction

Gene interaction	Example	F2Phenotypic ratio
Incomplete Dominance	Flower colour in Mirabilis jalapa. Flower colour in snapdragon(Antirrhinum spp.)	1 : 2 : 1 1 : 2 : 1
Codominance	ABO Blood group system	1 : 2 : 1

	in humans	

Inter-genic or non-allelic interaction

Epistatic interaction	Example	F2 Ratio Phenotypic ratio
Dominant epistasis	Fruit colour in summer squash	12 : 3 : 1
Recessive epistasis	Flower colour of Antirrhinumspp.	9 : 3 : 4
Duplicate genes with cumulative effect	Fruit shape in summer squash	9 : 6 : 1
Complementary genes	Flower colour in sweet peas	9 : 7
Supplementary genes	Grain colour in Maize	9 : 3 : 4
Inhibitor genes	Leaf colour in rice plants	13 : 3
Duplicate genes	Seed capsule shape (fruit shape) in shepherd's purse Bursa bursa-pastoris	15 : 1

Polygenic Inheritance in Wheat (Kernel colour)

- Polygenic inheritance - Several genes combine to affect a single trait.
- A group of genes that together determine (contribute) a characteristic of an organism is called polygenic inheritance. It gives explanations to the inheritance of continuous traits which are compatible with Mendel's Law.

- The first experiment on polygenic inheritance was demonstrated by Swedish Geneticist H. Nilsson - Ehle (1909) in wheat kernels. Kernel colour is controlled by two genes each with two alleles, one with red kernel colour was dominant to white. He crossed the two pure breeding wheat varieties dark red and a white. Dark red genotypes R1R1R2R2 and white genotypes are r1r1r2r2. In the F1 generation medium red were obtained with the genotype R1r1R2r2. F1 wheat plant produces four types of gametes R1R2, R1r2, r1R2, r1r2. The intensity of the red colour is determined by the number of R genes in the F2 generation.

- **Four R genes:** A dark red kernel colour is obtained.Three R genes: Medium - dark red kernel colour is obtained.Two R genes: Medium-red kernel colour is obtained.One R gene: Light red kernel colour is obtained.

- **Absence of R gene**:Results in White kernel colour.The R gene in an additive manner produces the red kernel colour. The number of each phenotype is plotted against the intensity of red kernel colour which produces a bell shaped curve. This represents the distribution of phenotype. Other example: Height and skin colour in humans are controlled by three pairs of genes.

Extra Chromosomal Inheritance or Extra Nuclear Inheritance (Cytoplasmic Inheritance)

- DNA is the universal genetic material. Genes located in nuclear chromosomes follow Mendelian inheritance. But certain traits are governed either by the chloroplast or mitochondrial genes. This phenomenon is known as extra nuclear inheritance. It is a kind of Non-Mendelian inheritance. Since it involves cytoplasmic organelles such as chloroplast and mitochondrion that act as inheritance vectors, it is also called Cytoplasmic inheritance. It is based on independent, self-replicating extra chromosomal unit called plasmogene located in the cytoplasmic organelles, chloroplast and mitochondrion.

Chloroplast Inheritance

- It is found in 4 O' Clock plant (Mirabilis jalapa). In this, there are two types of variegated leaves namely dark green leaved plants and pale green leaved plants. When the pollen of dark green leaved plant (male) is transferred to the stigma of pale green leaved plant (female) and pollen of pale green leaved plant is transferred to the stigma of dark green leaved plant, the F1 generation of both the crosses must be identical as per Mendelian inheritance. But in the reciprocal cross the F1 plant differs from each other. In each cross, the F1 plant reveals the character of the plant which is used as female plant.

- This inheritance is not through nuclear gene. It is due to the chloroplast gene found in the ovum of the female plant which contributes the cytoplasm during fertilization since the male gamete contribute only the nucleus but not cytoplasm.

Mitochondrial Inheritance

- Male sterility found in pearl maize (Sorgum vulgare) is the best example for mitochondrial cytoplasmic inheritance. So it is called cytoplasmic male sterility. In this, male sterility is inherited maternally. The gene for cytoplasmic male sterility is found in the mitochondrial DNA.

- In this plant there are two types, one with normal cytoplasm (N) which is male fertile and the other one with aberrant cytoplasm (S) which is male sterile. These types also exhibit reciprocal differences as found in Mirabilis jalapa.

- Recently it has been discovered that cytoplasmic genetic male sterility is common in many plant species. This sterility is maintained by the influence of both nuclear and cytoplasmic genes. There are commonly two types of cytoplasm N (normal) and S (sterile). The genes for these are found in mitochondrion. There are also restores of fertility (Rf) genes. Even though these genes are nuclear genes, they are distinct from genetic male sterility genes of other plants. Because the Rf genes do not have any expression of their own, unless the sterile cytoplasm is present. Rf genes are required to restore fertility in S cytoplasm which is responsible for sterility.

- So the combination of N cytoplasm with rfrf and S cytoplasm with RfRf produces plants with fertile pollens, while S cytoplasm with rfrf produces only male sterile plants.

Atavism

- Atavism is a modification of a biological structure whereby an ancestral trait reappears after having been lost through evolutionary changes in the previous generations. Evolutionary traits that have disappeared phenotypically do not necessarily disappear from an organism’s DNA. The gene sequence often remains, but is inactive. Such an unused gene may remain in the genome for many generations. As long as the gene remains intact, a fault in the genetic control suppressing the gene can lead to the reappearance of that character again. Reemergence of sexual reproduction in the flowering plant Hieracium pilosella is the best example for Atavism in plants.

UNIT – 3
Chromosomal Basis of Inheritance

Chromosomal Theory of Inheritance

- G. J. Mendel (1865) studied the inheritance of well-defined characters of pea plant but for several reasons it was unrecognized till 1900. Three scientists (de Vries, Correns and Tschermak) independently rediscovered Mendel's results on the inheritance of characters. Various cytologists also observed cell division due to advancements in microscopy. This led to the discovery of structures inside nucleus. In eukaryotic cells, worm-shaped structures formed during cell division are called chromosomes (colored bodies, visualized by staining). An organism which possesses two complete basic sets of chromosomes are known as diploid. A chromosome consists of long, continuous coiled piece of DNA in which genes are arranged in linear order. Each gene has a definite position (locus) on a chromosome. These genes are hereditary units. Chromosomal theory of inheritance states that Mendelian factors (genes) have specific locus (position) on chromosomes and they carry information from one generation to the next generation.

Historical development of chromosome theory

- The important cytological findings related to the chromosome theory of inheritance are given below.

  - **Wilhelm Roux (1883)** postulated that the chromosomes of a cell are responsible for transferring heredity.
  - **Montgomery (1901)** was first to suggest occurrence of distinct pairs of chromosomes and he also concluded that maternal chromosomes pair with paternal chromosomes only during meiosis.
  - **T.Boveri (1902)** supported theidea that the chromosomes containgenetic determiners, and he waslargely responsible for developing thechromosomal theory of inheritance.
  - **W.S. Sutton (1902)**, a young Americanstudent independently recognized aparallelism (similarity) between thebehaviour of chromosomes and Mendelian factors during gamete formation.
  - **Sutton and Boveri (1903)** independentlyproposed the chromosome theory of inheritance. Sutton united the knowledge of chromosomal segregation with Mendelian principles and called it chromosomal theory of inheritance.

Salient features of the Chromosomal theory of inheritance

- Somatic cells of organisms are derived from the zygote by repeated cell division (mitosis). These consist of two identical sets of chromosomes. One set is received from female parent (maternal) and the other from male parent (paternal). These two chromosomes constitute the homologous pair.

- Chromosomes retain their structural uniqueness and individuality throughout the life cycle of an organism.

- Each chromosome carries specific determiners or Mendelian factors which are now termed as genes.

- The behaviour of chromosomes during the gamete formation (meiosis) provides evidence to the fact that genes or factors are located on chromosomes.

Support for chromosomal theory of heredity

- This theory was widely discussed and controversies by scientists around the world. However, this debate has been finally cleared by the works of Thomas Hunt Morgan (1910) on the fruit fly Drosophila melanogaster (2n=8). This fruit fly completed their life cycle within two weeks. The alleles for red or white eye colour are present on the X chromosome but there is no counterpart for this gene on the Y chromosome. Thus, females have two alleles for this gene, whereas males have only one. The genetic results were completely based on meiotic behaviour of the X and Y chromosomes. Similarly, the genes for yellow body colour and miniature wings are also carried on the X chromosome. This study strongly supports the idea that genes are located on chromosomes. The linked genes connected together on sex chromosome is called sex linkage.

Comparison between gene and chromosome behaviour

- Around twentieth century cytologists established that, generally the total number of chromosomes is constant in all cells of a species. A diploid eukaryotic cell has two haploid sets of chromosomes, one set from each parent. All somatic cells of an organism carry the same genetic complement. The behaviour of chromosomes during meiosis not only explains Mendel's principles but leads to new and different approaches to study about heredity.

Mendelian factors	Chromosomes behaviour
Alleles of a factor occur in pair	Chromosomes occur in pairs
Similar or dissimilar alleles of a factor separate during the gamete formation	The homologous chromosomes separate during meiosis
Mendelian factors can assort independently	The paired chromosomes can separate independently during meiosis but the linked genes in the same chromosome normally do not assort independently

The important aspects to be remembered about the chromosome behaviour during cell division (meiosis) are as follows.

- The alleles of a genotype are found in the same locus of a homologous chromosome (A/a).

- In the S phase of meiotic interphase each chromosome replicates forming two copies of each allele (AA/aa), one on each chromatid.

- The homologous chromosomes segregate in anaphase I, thereby separating two different alleles (AA) and (aa).

- In anaphase II of meiosis, separation of sister chromatids of homologous chromosomes takes place. Therefore, each daughter cell (gamete) carries only a single allele (gene) of a character (A), (A), (a) and (a).

Fossil Genes: Some of thejunk DNA is made up of pseudogenes, the sequences presence in that was once working genes. They lost their ability to make proteins. They tell the story of evolution through fossilized parts.

Linkage

- The genes which determine the character of an individual are carried by the chromosomes. The genes for different characters may be present either in the same chromosome or in different chromosomes. When the genes are present in different chromosomes, they assort independently according to Mendel's Law of Independent Assortment. Biologists came across certain genetic characteristics that did not assort out independently in other organisms after Mendel's work. One such case was reported in Sweet pea (Lathyrus odoratus) by Willium Bateson and Reginald C. Punnet in 1906. They crossed one homozygous strain of sweet peas having purple flowers and long pollen grains with another homozygous strain having red flowers and round pollen grains. All the F1 progenies had purple flower and long pollen grains indicating purple flower long pollen (PL/PL) was dominant over red flower round pollen (pl/pl). When they crossed the F1 with double recessive parent (test cross) in results, F2 progenies did not exhibit in 1:1:1:1 ratio as expected with independent assortment. A greater number of F2 plants had purple flowers and long pollen or red flowers and round pollen. So they concluded that genes for purple colour and long pollen grain and the genes for red colour and round pollen grain were found close together in the same homologous pair of chromosomes. These genes do not allow themselves to be separated. So they do not assort independently. This type of tendency of genes to stay together during separation of chromosomes is called Linkage.

- Genes located close together on the same chromosome and inherited together are called linked genes. But the two genes that are sufficiently far apart on the same chromosome are called unlinked genes or syntenic genes. Such condition is known as synteny. It is to be differentiated by the value of recombination frequency. If the recombination frequency value is more than 50 % the two genes show unlinked. when the recombination frequency value is less than 50 %, they show linked. Closely located genes show strong linkage, while genes widely located show weak linkages.

Coupling and Repulsion theory

- The two dominant alleles or recessive alleles occur in the same homologous chromosomes, tend to inherit together into same gamete are called coupling or cis configuration. If dominant or recessive alleles are present on two different, but homologous chromosomes they inherit apart into different gamete are called repulsion or trans configuration.

Kinds of Linkage

- T.H. Morgan found two types of linkage. They are complete linkage and incomplete linkage depending upon the absence or presence of new combination of linked genes.

Complete Linkage

- If the chances of separation of two linked genes are not possible those genes always remain together as a result, only parental combinations are observed. The linked genes are located very close together on the same chromosome such genes do not exhibit crossing over. This phenomenon is called complete linkage. It is rare but has been reported in male Drosophila (Figure 3.7). C.B Bridges (1919) discovered that crossing over is completely absent in some species of male Drosophila.

Incomplete Linkage

- If two linked genes are sufficiently apart, the chances of their separation are possible. As a result, parental and non-parental combinations are observed. The linked genes exhibit some crossing over. This phenomenon is called incomplete linkage. This was observed in maize. (Figure 3.8) It was reported by Hutchinson.

Genetic Mapping

- Genes are present in a linear order along the chromosome. They are present in a specific location called locus (plural: loci). The diagrammatic representation of position of genes and related distances between the adjacent genes is called genetic mapping. It is directly proportional to the frequency of recombination between them. It is also called as linkage map. The concept of gene mapping was first developed by Morgan's student Alfred H Sturtevant in 1913. It provides clues about where the genes lies on that chromosome.

Map distance

- The unit of distance in a genetic map is called a map unit (m.u). One map unit is equivalent to one percent of crossing over (Figure 4.). One map unit is also called a centimorgan (cM) in honour of T.H. Morgan. 100 centimorgan is equal to one Morgan

(M). For example: A distance between A and B genes is estimated to be 3.5 map units. It is equal to 3.5 centimorgans or 3.5 % or 0.035 recombination frequency between the genes.

- Genetic maps can be constructed from a series of test crosses for pairs of genes called two point crosses. But this is not efficient because double cross over is missed.

Three point test cross

- A more efficient mapping technique is to construct based on the results of three-point test cross. It refers to analyzing the inheritance patterns of three alleles by test crossing a triple recessive heterozygote with a triple recessive homozygote. It enables to determine the distance between the three alleles and the order in which they are located on the chromosome. Double cross overs can be detected which will provide more accurate map distances.

- Three-point test cross can be best understood by considering following an example.

Uses of genetic mapping

- It is used to determine gene order, identify the locus of a gene and calculate the distances between genes.

- They are useful in predicting results of dihybrid and trihybrid crosses.

- It allows the geneticists to understand the overall genetic complexity of particular organism.

Multiple alleles

- A given phenotypic trait of an individual depends on a single pair of genes, each of which occupies a specific position called the locus on homologous chromosome. When any of the three or more allelic forms of a gene occupy the same locus in a given pair of homologous chromosomes, they are said to be called multiple alleles.

Characteristics of multiple alleles

- Multiple alleles of a series always occupythe same locus in the homologouschromosome. Therefore, no crossing overoccurs within the alleles of a series.

- Multiple alleles are always responsible forthe same character.

- The wild type alleles of a series exhibitdominant character whereas mutanttype will influence dominance or anintermediate phenotypic effect.

- When any two of the mutant multiplealleles are crossed the phenotype is alwaysmutant type and not the wild type.

Self-sterility in Nicotiana

- In plants, multiple alleles have been reported in association with self-sterility or self-incompatibility. Self-sterility means that thepollen from a plant is unable to germinate on its own stigma and will not be able to bring about fertilization in the ovules of the same plant. East (1925) observed multiple alleles in Nicotiana which are responsible for self-incompatibility or self-sterility. The gene for self-incompatibility can be designated as S, which has allelic series S1, S2, S3, S4 and S5.

- The cross-fertilizing tobacco plants were not always homozygous as S1S1 or S2S2, but all plants were heterozygous as S1S2, S3S4, S5S6. When crosses were made between different S1S2 plants, the pollen tube did not develop normally. But effective pollen tube development was observed when crossing was made with other than S1S2 for example S3S4.

Sex determination in plants

- About 94% of all flowering plants have only one type of individual, which produces flowers with male organs (the stamens) and female organs (the carpels). Such plants are termed as sexually monomorphic. Some 6% of flowering plants which have two separate sexes are called dimorphic. Male plants produce flowers with stamens and female plants produce flowers with carpels only. Researchers are interested to study the mechanism of sex determination in plants.C.E. Allen (1917) discovered sex determination in plants. Sex determination is a complex process determined by genes, the environment and hormones.

- Sex determination in Silene latifolia (Melandrium album) is of controlled by three distinct regions in a sex chromosome.

  1. Y chromosome determines maleness
  2. X specifies femaleness
  3. X and Y show different segments (I II III IV and V)

Sex determination in papaya

- Recently researchers in Hawaii discovered sex chromosomes in Papaya (Carica papaya, 2n=36). Papaya has 17 pairs of autosomes and one pair of sex chromosomes. Male papaya plants have XY and female plants have XX. Unlike human sex chromosomes, papaya sex chromosomes look like autosomes and it is evolved from autosome. The sex chromosomes are functionally distinct because the Y chromosome carries the genes for male organ development and X bears the female organ developmental genes.

- In papaya sex determination is controlled by three alleles. They are m, M1 and M2 of a single gene.

Genotype	Dominant/ recessive	Modification	Sex
mm	Homozygous recessive	Restrict maleness	Female
M1m	Heterozygous	Induces maleness	Male
M2m	Heterozygous	Induces both the sex	Bisexual (rare)
M1M1 or M2M2 or M1M2	Homozygous/ Heterozygous dominant	Inviable plants	Sterile

Sex Determination in Sphaerocarpos

- Sex determination was first described in the bryophyte Sphaerocarposdonnellii which has heteromorphic chromosomes. The gametophyte is haploid and heteromorphic. The male gametophyte as well as the female gametophyte is an haploid organism with 8 chromosome (n=8). The diploid sporophyte is always heterogametic. Seven autosomes are similar in both male and female gametophyte. But the eighth chromosome of female is X which is larger than the seven autosomes. The eighth chromosome of male is Y which is comparatively smaller than autosomes. The sporophyte containing XY combination produces two types of meiospores, that is some with X and others with Y chromosomes. The meiospores with X chromosomes produce female gametophyte and those with Y chromosome produces male gametophyte.

Sex determination in maize

- Zea mays (maize) is an example for monoecious, which means male and female flowers are present on the same plant. There are two types of inflorescence. The terminal inflorescence which bears staminate florets develops from shoot apical meristem called tassel. The lateral inflorescence which develop pistillate florets from axillary bud is called ear or cob. Unisexuality in maize occurs through the selective abortion of stamens in ear florets and pistils in tassel florets. A substitution of two single gene pairs 'ba' for barren plant and 'ts' for tassel seed makes the difference between monoecious and dioecious (rare) maize plants. The allele for barren plant (ba) when homozygous makes the stalk staminate by eliminating silk and ears. The allele for tassel seed (ts) transforms tassel into a pistillate structure that produce no pollen. The table-3.7 is the resultant sex expression based on the combination of these alleles. Most of these mutations are shown to be defects in gibberellin biosynthesis. Gibberellins play an important role in the suppression of stamens in florets on the ears.

Mutation

- Genetic variation among individuals provides the raw material for the ultimate source of evolutionary changes. Mutation and recombination are the two major processes responsible for genetic variation. A sudden change in the genetic material of an organisms is called mutation. The term mutation was introduced by Hugo de Vries (1901) while he has studying on the plant, evening primrose (Oenothera lamarkiana) and proposed 'Mutation theory'. There are two broad types of changes in genetic material. They are point mutation and chromosomal mutations.

- **Mutational events that take place within individual genes are called gene mutations or point mutation, whereas the changes occur in structure and number of chromosomes is called chromosomal mutation. Agents which are responsible for mutation are called mutagens,**that increase the rate of mutation. Mutations can occur either spontaneously or induced. The production of mutants through exposure of mutagens is called mutagenesis, and the organism is said to be mutagenized.

Types of mutation

Let us see the two general classes of gene mutation:

- Mutations affecting single base or basepair of DNA are called point mutation

- Mutations altering the number of copiesof a small repeated nucleotide sequence within a gene

Point mutation

- It refers to alterations of single base pairs of DNA or of a small number of adjacent base pairs

Types of point mutations

- Point mutation in DNA are categorised into two main types. They are base pair substitutions and base pair insertions or deletions. Base substitutions are mutations in which there is a change in the DNA such that one base pair is replaced by another. It can be divided into two subtypes: transitions and transversions. Addition or deletion mutations are actually additions or deletions of nucleotide pairs and also called base pair addition or deletions. Collectively, they are termed indel mutations (for insertion-deletion).

- Substitution mutations or indel mutations affect translation. Based on these different types of mutations are given below.

- The mutation that changes one codon for an amino acid into another codon for that same amino acid are called Synonymous or silent mutations. The mutation where the codon for one amino acid is changed into a codon for another amino acid is called Missense or non-synonymous mutations. The mutations where codon for one amino acid is changed into a termination or stop codon is called Nonsense mutation. Mutations that result in the addition or deletion of a single base pair of DNA that changes the reading frame for the translation process as a result of which there is complete loss of normal protein structure and function are called Frameshift mutations.

Mutagenic agents

- The factors which cause genetic mutation are called mutagenic agents or mutagens. Mutagens are of two types, physical mutagen and chemical mutagen. Muller (1927) was the first to find out physical mutagen in Drosophila.

Physical mutagens:

- Scientists are using temperature and radiations such as X rays, gamma rays, alfa rays, beta rays, neutron, cosmic rays, radioactive isotopes, ultraviolet rays as physical mutagen to produce mutation in various plants and animals.

Temperature:

- Increase in temperature increases the rate of mutation. While rise in temperature, breaks the hydrogen bonds between two DNA nucleotides which affects the process of replication and transcription.

Radiation:

- The electromagnetic spectrum contains shorter and longer wave length rays than the visible spectrum. These are classified into ionizing and non-ionizing radiation. Ionizing radiation are short wave length and carry enough higher energy to ionize electrons from atom. X rays, gamma rays, alfa rays, beta rays and cosmic rays which breaks the chromosomes (chromosomal mutation) and chromatids in irradiated cells. Non-ionizing radiation, UV rays have longer wavelengths and carry lower energy, so they have lower penetrating power than the ionizing radiations. It is used to treat unicellular microorganisms, spores, pollen grains which possess nuclei located near surface membrane.

Sharbati Sonora

- Sharbati Sonora is a mutant variety of wheat, which is developed from Mexican variety (Sonora 64) by irradiating of gamma rays. It is the work of Dr. M.S.Swaminathan who is known as 'Father of Indian green revolution' and his team.

Castor Aruna

- Castor Aruna is mutant variety of castor which is developed by treatment of seeds with thermal neutrons in order to induce very early maturity (120 days instead of 270 days as original variety).

Chemical mutagens:

- Chemicals which induce mutation are called chemical mutagens. Some chemical mutagens are mustard gas, nitrous acid, ethyl and methyl methane sulphonate (EMS and MMS), ethyl urethane, magnous salt, formaldehyde, eosin and enthrosine. Example: Nitrous oxide alters the nitrogen bases of DNA and disturb the replication and transcription that leads to the formation of incomplete and defective polypeptide during translation.

Comutagens

- The compounds which are not having own mutagenic properties but can enhance the effects of known mutagens are called comutagens.
  Example: Ascorbic acid increase the damage caused by hydrogen peroxide.
  Caffeine increase the toxicity of methotrexate

Chromosomal mutations

- The genome can also be modified on a larger scale by altering the chromosome structure or by changing the number of chromosomes in a cell. These large-scale variations are termed as chromosomal mutations or chromosomal aberrations. Gene mutations are changes that take place within a gene, whereas chromosomal mutations are changes to a chromosome region consisting of many genes. It can be detected by microscopic examination, genetic analysis, or both. In contrast, gene mutations are never detectable microscopically. Chromosomal mutations are divided into two groups: changes in chromosome number and changes in chromosome structure.

Changes in chromosome number

- Each cell of living organisms possesses fixed number of chromosomes. It varies in different species. Even though some species of plants and animals are having identical number of chromosomes, they will not be similar in character. Hence the number of chromosomes will not differentiate the character of species from one another but the nature of hereditary material (gene) in chromosome that determines the character of species.

- Sometimes the chromosome number of somatic cells are changed due to addition or elimination of individual chromosome or basic set of chromosomes. This condition in known as numerical chromosomal aberration or ploidy. There are two types of ploidy.

I. Ploidy involving individual chromosomes within a diploid set (Aneuploidy)
II. (Ploidy involving entire sets of chromosomes (Euploidy)

Aneuploidy

- It is a condition in which diploid number is altered either by addition or deletion of one or more chromosomes. Organisms showing aneuploidy are known as aneuploids or heteroploids. They are of two types, Hyperploidy and Hypoploidy.

Hyperploidy

- Addition of one or more chromosomes to diploid sets are called hyperploidy. Diploid set of chromosomes represented as Disomy. Hyperploidy can be divided into three types. They are as follows,

Trisomy

- Addition of single chromosome to diploid setis called Simple trisomy(2n+1). Trisomics werefirst reported by Blackeslee (1910) in Daturastramonium (Jimson weed). But later it wasreported in Nicotiana, Pisum and Oenothera.Sometimes addition of two individualchromosome from different chromosomalpairs to normal diploid sets are called Doubletrisomy (2n+1+1).

Tetrasomy

- Addition of a pair or two individual pairs ofchromosomes to diploid set is called tetrasomy(2n+2) and Double tetrasomy (2n+2+2)respectively. All possible tetrasomics areavailable in Wheat.

Pentasomy

- Addition of three individual chromosome from different chromosomal pairs to normal diploid set are called pentasomy (2n+3).

2.Hypoploidy

- Loss of one or more chromosome from the diploid set in the cell is called hypoploidy. It can be divided into two types. They are

Monosomy

- Loss of a single chromosome from the diploid set are called monosomy(2n-1). However loss of two individual or three individual chromosomes are called double monosomy (2n-1-1) and triple monosomy (2n-1-1-1) respectively. Double monosomics are observed in maize.

Nullisomy

- Loss of a pair of homologous chromosomes or two pairs of homologous chromosomes from the diploid set are called Nullisomy (2n-2) and double Nullisomy (2n-2-2) respectively. Selfing of monosomic plants produce nullisomics. They are usually lethal.

Euploidy

- Euploidy is a condition where the organisms possess one or more basic sets of chromosomes. Euploidy is classified as monoploidy, diploidy and polyploidy. The condition where an organism or somatic cell has two sets of chromosomes are called diploid (2n). Half the number of somatic chromosomes is referred as gametic chromosome number called haploid(n). It should be noted that haploidy (n) is different from a monoploidy (x). For example, the common wheat plant is a polyploidy (hexaploidy) 2n=6x=72 chromosomes. Its haploid number (n) is 36, but its monoploidy (x) is 12. Therefore, the haploid and diploid condition came regularly one after another and the same number of chromosomes is maintained from generation to generation, but monoploidy condition occurs when an organism is under polyploidy condition. In a true diploid both the monoploid and haploid chromosome number are same. Thus a monoploid can be a haploid but all haploids cannot be a monoploid.

Polyploidy

- Polyploidy is the condition where an organism possesses more than two basic sets of chromosomes. When there are three, four, five or six basic sets of chromosomes, they are called triploidy (3x) tetraploidy (4x), pentaploidy (5x) and hexaploidy (6x) respectively. Generally, polyploidy is very common in plants but rarer in animals. An increase in the number of chromosome sets has been an important factor in the origin of new plant species. But higher ploidy level leads to death. Polyploidy is of two types. They are autopolyploidy and allopolyploidy

Autopolyploidy

- The organism which possesses more than twohaploid sets of chromosomes derived fromwithin the same species is called autopolyploid.They are divided into two types. Autotriploidsandautotetraploids.

- Autotriploids have three set of its own genomes. They can be produced artificially by crossing between autotetraploid and diploid species. They are highly sterile due to defective gamete formation. Example: The cultivated banana are usually triploids and are seedless having larger fruits than diploids. Triploid sugar beets have higher sugar content than diploids and are resistant to moulds. Common doob grass (Cyanodondactylon) is a natural autotriploid. Seedless watermelon, apple, sugar beet, tomato, banana are man madeautotriploids.

- Autotetraploids have four copies of its own genome. They may be induced by doubling the chromosomes of a diploid species. Example: rye, grapes, alfalfa, groundnut, potato and coffee.

2. Allopolyploidy

- An organism which possesses two or more basic sets of chromosomes derived from two different species is called allopolyploidy. It can be developed by interspecific crosses and fertility is restored by chromosome doubling with colchicine treatment. Allopolyploids are formed between closely related species only.

Significance of Ploidy

- Many polyploids are more vigorous andmore adaptable than diploids.
- Many ornamental plants are autotetraploidsand have larger flower and longer floweringduration than diploids.
- Autopolyploids usually have increase in freshweight due to more water content.
- Aneuploids are useful to determine thephenotypic effects of loss or gain of differentchromosomes.
- Many angiosperms are allopolyploids andthey play a role in an evolution of plants.

Structural changes in chromosome (Structural chromosomal aberration):

- Structural variations caused by addition or deletion of a part of chromosome leading to rearrangement of genes is called structural chromosomal aberration. It occurs due to ionizing radiation or chemical compounds. On the basis of breaks and reunion in chromosomes, there are four types of aberrations. They are classified under two groups.

Changes in the number of the gene loci

- Deletion or Deficiency
- Duplication or Repeat

Changes in the arrangement of gene loci

- Inversion

- Translocation

Deletion or Deficiency

- Loss of a portion of chromosome is calleddeletion. On the basis of location of breakageon chromosome, it is divided into terminaldeletion and intercalary deletion. It occursdue to chemicals, drugs and radiations. It isobserved in Drosophila and Maize.

There are two types of deletion:

Terminal deletion: Single break in any oneend of the chromosome.

- **Intercalary deletion or interstitial deletion**:It is caused by two breaks and reunion ofterminal parts leaving the middle.

- Both deletions are observable during meiotic pachytene stage and polytene chromosome. The unpaired loop formed in the normal chromosomal part at the time of chromosomal pairing. Such loops are called as deficiency loops and it can be seen in meiotic prophase. Larger deletions may lead to lethal effect.

Duplication or Repeat

- The process of arrangement of the same orderof genes repeated more than once in the same chromosome is known as duplication. Due to duplication some genes are present in more than two copies. It was first reported in Drosophila by Bridges (1919) and other examples are Maize and Pea. It is three types.

Tandem duplication

- The duplicated segment is located immediatelyafter the normal segment of the chromosome inthe same order.

Reverse tandem duplication

- The duplicated segment is located immediatelyafter the normal segment but the gene sequenceorder will be reversed.

Displaced duplication

- The duplicated segment is located in the samechromosome, but away from the normalsegment.

Duplications play a major role in evolution.

Inversion

- A rearrangement of order of genes in achromosome by reversed by an angle 1800. Thisinvolve two chromosomal breaks and reunion.During this process there is neither gain nor loss but the gene sequences is rearranged. Inversionwas first reported in Drosophila by Sturtevant(1926). There are two types of inversion,paracentric and pericentric (Figure 3.26).

I. **Paracentric inversion:** An inversion whichtakes place apart from the centromere

II. **Pericentric inversion:** An inversion that includes the centromere.
Inversions lead to evolution of a new species.

Translocation

- The transfer of a segment of chromosome to a non-homologous chromosome is called translocation. Translocation should not be confused with crossing over, in which an exchange of genetic material between homologous chromosome takes place. Translocation occurs as a result of interchange of chromosome segments in non-homologous chromosomes. There are three types
  - Simple translocation
  - Shift translocation
  - Reciprocal translocation

Simple translocation

- A single break is made in only one chromosome. The broken segment gets attached to one end of a non-homologous chromosome. It occurs very rarly in nature.

Shift translocation

- Broken segment of one chromosome gets inserted interstitially in a non-homologous chromosome.

Reciprocal translocations

- It involves mutual exchange of chromosomal segments between two non-homologous chromosomes. It is also called illegitimate crossing over. It is further divided into two types.

- **Homozygous translocation**: Both the chromosomes of two pairs are involved in translocation. Two homologous of each translocated chromosomes are identical.

- **Heterozygous translocation**: Only one of the chromosome from each pair of two homologous are involved in translocation, while the remaining chromosome is normal. Translocations play a major role in the formation of species.

DNA Metabolism in Plants

- As the repository of genetic information, DNA occupies a unique and central place among biological macromolecules. The structure of DNA is a marvelous device for the storage of genetic information. The term "DNA Metabolism" can be used to describe process by which copies of DNA molecules are made (replication) along with repair and recombination.

- **DNA Replication:** In the double helix the two parental strands of DNA separate and each parental strand synthesizes a new complementary strand. DNA replication is semiconservative, i.e each new DNA molecule conserves one original strand.

DNA Repair: How is genomic stability maintained in all living organisms? How do organisms on earth survive? What is essential for their survival?

- DNA is unique because it is the only macromolecule where the repair system exists, which recognises and removes mutations. DNA is subjected to various types of damaging reactions such as spontaneous or environmental agents or natural endogenous threats. Such damages are corrected by repair enzymes and proteins, immediately after the damage has taken place. DNA repair system plays a major role in maintaining the genomic / genetic integrity of the organism. DNA repair systems protect the integrity of genomes from genotoxic stresses.

Plants are sessile. How do they protect themselves from the exposure of sunlight throughout the day?

Plants have effective DNA repair mechanism to prevent UV damage from sunlight. They produce an enzyme called photolyase, which can repair the thymine dimers and restore the structure of DNA.

- **Recombination:** In cells the genetic information within and among DNA molecule are re-arranged by a process called genetic recombination. Recombination is the result of crossing over between the pairs of homologous chromosomes during meiosis. In earlier classes you have learnt chromosomal recombination. In molecular level it involves breakage and reunion of polynucleotides.

Eukaryotic DNA replication

- Replication starts at a specific site on a DNA sequence known as the Origin of replication. There are more than one origin of replication in eukaryotes. Saccharomyces cerevisiae (yeast) has approximately 400 origins of replication. DNA replication in eukaryotes starts with the assembly of a prereplication complex (preRC) consisting of 14 different proteins. Part of a preRC is a group of 6 proteins called the origin recognition complex (ORC) which acts as initiator in eukaryotic DNA replication. The origin of replication in yeast is called as ARS sites (Autonomously Replicating Sequences). In yeast, ORC was identified as a protein complex which binds directly to ARS elements.

- Replication fork is the site (point of unwinding) of separation of parental DNA strands where new daughter strands are formed. Multiple replication forks are found in eukaryotes. The enzyme helicases are involved in unwinding of DNA by breaking hydrogen bonds holding the two strands of DNA and replication protein A (RPA) prevents the separated polynucleotide strand from getting reattached.

- Topoisomerase is an enzyme which breaks DNAs covalent bonds and removes positive supercoiling ahead of replication fork. It eliminates the torsional stress caused by unwinding of DNA double helix.

- DNA replication is initiated by an enzyme DNA polymerase α / primase which synthesizes short stretch of RNA primers on both leading strand (continuous DNA strand) and lagging strands (discontinuous DNA strand). Primers are needed because DNA polymerase requires a free 3′ OH to initiate synthesis. DNA polymerase covalently connects the nucleotides at the growing end of the new DNA strand.

- DNA Pol α (alpha), DNA Pol δ (delta) and DNA Pol ε (Epsilon) are the 3 enzymes involved in nuclear DNA replication.

  DNA Pol α – Synthesizes short primers of RNA
  DNA Pol δ – Main Replicating enzyme of cell nucleus
  DNA Pol ε – Extend the DNA Strands in replication fork

DNA Polymerase β does not play any role in the replication of normal DNA. Function -Removing incorrect bases from damagedDNA. It is involved in Base excision repair

Experimental evidence of DNA replication: Taylors Experiment

- J.Herbert Taylor, Philip Woods and WalterHughes demonstrated the semiconservativereplication of DNA in the root cells of Viciafaba. They labelled DNA with 3H Thymidine,a radioactive precursor of DNA and performedautoradiography. They grew root tips in amedium in the presence of radioactive labeled thymidine, so that the radioactivity wasincorporated into the DNA of these cells. Theoutline of this labelled chromosomes appears inthe form of scattered black dots of silver grainson a photographic film.

- In the chromosome of first generation theradioactivity was found to be distributed toboth the chromatids because in the originalstrand of DNA double helix was labeled with radioactivity and the new strand wasunlabelled.

- In the chromosome of the second generation only one of the two chromatids in eachchromosome was radioactive (labelled).

  The results proved the semiconservative method of DNA replication

Translation

- The genetic information in the DNA code is copied onto mRNA bound in ribosomes for making polypeptides. The mRNA nucleotide sequence is decoded into amino acid sequence of the protein which is catalyzed by the ribosome. This process is called translation.

Process of translation

The following are major steps in translation process

Initiation

- The translation begins with the AUG codon(start codon) of mRNA. Translation occurson the surface of the macromolecular arenacalled the ribosome. It is a non-membranousorganelle. During the process of translationthe two subunits of ribosomes unite (combine)together and hold mRNA between them. Theprotein synthesis begins with the reading ofcodons of mRNA. The tRNA brings amino acidto the ribosome, a molecular machine whichunites amino acids into a chain according to theinformation given by mRNA. rRNA plays thestructural and catalytic role during translation.

- A ribosome has one binding site for mRNA and two for tRNA. The two binding sites of tRNA are

  1. P-Site – The peptidyl – tRNA binding siteis one of the tRNA binding site. At this sitetRNA is held and linked to the growing endof the polypeptide chain.

  2. A-Site – The Aminoacyl – tRNA binding site. This is another tRNA binding site which holds the incoming amino acids called aminoacyl tRNA. The anticodons oftRNA pair with the codons of the mRNA inthese sites.

Elongation of polypeptide chain

- The P and A sites are nearby, so that two tRNAform base pairs with adjacent codon. Thepolypeptide chain is formed by the pairingof codons and anticodons according to thenucleotide sequence of the mRNA.

Translators of the genetic code - tRNA

- The tRNA translates the genetic code from the nucleic acid sequence to the amino acid sequence i.e from gene – Polypeptide. When an amino acid is attached to tRNA it is called aminoacylated or charged. This is an energy requiring process whichuses the ATP for its energy requirement. Protein synthesis takes place as the next aminoacyl tRNA binds to the A-Site.

- The translation begins with the AUG codon (start codon) of mRNA. The tRNA which carries first amino acid methionine attach itself to P-site of ribosome. The ribosome adds new amino acids to the growing polypeptides. The second tRNA molecules has anticodons which carries amino acid alanine pairs with the mRNA codon in the A-site of the ribosome. The aminoacids methionine and alanine are close enough so that a peptide bond is formed between them.

- The bond between the first tRNA and methionine now breaks. The first tRNA leaves the ribosome and the P-site is vacant. The ribosome now moves one codon along the mRNA strand. The second t-RNA molecule now occupies the P-site. The third t-RNA comes and fills the A site (serine).Now a peptide bond is formed betweenalanine and serine. The mRNA then movesthrough the ribosome by three bases. Thisexpels deacylated / uncharged tRNA fromP-site and moves peptidyl tRNA into theP-site and empties the A-site.This movementof tRNA from A-site to P-site is said to betranslocation. The translocation requires thehydrolysis of GTP.

- The ribosome (ribozyme - peptidyl transferase) catalyses the formation of peptide bond by adding amino acid to the growing polypeptide chain.

- The ribosome moves from codon to codon along the mRNA in the 5′ to 3′ direction. Amino acids are added one by one translated into polypeptide as dictated by the mRNA. Translation is an energy intensive process. A cluster of ribosomes are linked together by a molecule of mRNA and forming the site of protein synthesis is called as polysomes or polyribosomes.

Termination of polypeptide synthesis

- Eukaryotes have cytosolic proteins called release factors which recognize the termination codon, UAA, UAG, or UGA when it is in the A site. When the ribosome reaches a stop codon the protein synthesis comes to an end. So ribosomes are the protein making factories of a cell. When the polypeptide is completed the ribosome releases the polypeptide and detaches from the mRNA molecule. Now the ribosome splits into small and large subunits after the release of mRNA.

Alternative Splicing in plants

- It is very useful in regulating gene expression to overcome the environmental stress in plants.

- Alternative splicing is an important mechanism / process by which multiple mRNA's and multiple proteins products can be generated from a single gene. The different proteins generated are called isoforms. There are various modes of alternative splicing. When multiple introns are present in a gene, they are removed separately or as a unit. In certain cases one or more exons which is present between the introns are also removed.

Significance of alternative splicing

- The proteins transcribed from alternatively spliced mRNA containing different aminoacid sequence lead to the generation of protein diversity and biological functions.

- Multiple protein isoforms are formed.

- It creates multiple mRNA transcriptsfrom a single gene. A process of producingrelated proteins from a single gene therebythe number of gene products are increased.

- It plays an important role in plant functions such as stress response and trait selection.The plant adapts or regulates itself to thechanging environment.

Jumping Genes

- This is the nick name of transposable genetic elements. Transposons are the DNA sequences which can move from one position to another position in a genome. This was first reported in 1948 by American Geneticist Barbara McClintock as "mobile controlling element" in Maize. One of the most significant scientists of 20th century was Barbara McClintock because she gave a shift in gene organization. McClintock was awarded Nobel prize in 1983 for her work on transposons. Barbara McClintock when studying aleurone of single maize kernels, noted the unstable inheritance of the mosaic pattern of blue, brown and red spots due to the differential production of vacuolar anthocyanins.

- In maize plant genome has AC / Ds transposon (AC = Activator, Ds = Dissociation). The activity of AC element is very distinct in maize plant. The transposition in somatic cells results in the changes in gene expression such as variegated pigmentation in maize kernels. Maize genome has transposable elements which regulated the different colour pattern of kernels.

- McClintock's findings concluded that Ds and AC genes were mobile controlling elements. We now call it as transposable elements, a term coined by maize geneticist, Alexander Brink. McClintock gave the first direct experimental evidence that genomes are not static but are highly plastic entities

Significance of transposons

- They contribute to many visible mutations and mutation rate in an Organism.

- In evolution, they contribute to genetic diversity.

- In genetic research transposons are valuable tools which are used as mutagens, as cloning tags, vehicles for inserting foreign DNA into model organism.

- **Plant genome** – The word genome is defined as the full complement of DNA (including all the genes and the intergenic regions) present in an organism It specifies the entire biological information of an organism. There are three distinct genomes in eukaryotic cells and they are

    - The nuclear genome
    - The mitochondrial genome and

- The chloroplast genome present only in plants.

- It is a model plant for the study of genetic and molecular aspects of plant development.
- It belongs to mustard family and it is the first flowering plant, where its entire genome is sequenced.

- The two regions of the nucleolar organiser ribosomal DNA which codes for the ribosomal RNA are present at the extremity of chromosomes 2 and 4

- It is Diploid plant having small genome with 2n = 10 chromosomes. Several generations can be produced in one year. So it facilitates rapid genetic analysis. The genome has low repetitive DNA, over 60% of the nuclear DNA have protein coding functions.

- The plant is small, self fertilizes, annual long-day plant with short-life cycle (only 6 weeks), large numbers of seeds are produced and they are easy to be grown in laboratory. It is easy to induce mutations. It has many genomic resources and the transformation can be done easily.

- In 1982, Arabidopsis has successfully completed its life cycle in Microgravity i.e. space. This shows that Human Space Missions with plant companions may be possible.

UNIT – 4 -Principles and processes of Biotechnology

Advancements in Modern Biotechnology

- The modern biotechnology embraces all the genetic manipulations, protoplasmic fusion techniques and the improvements made in the old biotechnological processes. Some of the major advancements in modern biotechnology are described below.

Genetic Engineering

- Genetic engineering or recombinant DNA technology or gene cloning is a collective term that includes different experimental protocols resulting in the modification and transfer of DNA from one organism to another.

- The definition for conventional recombination was already given in Unit II. Conventional recombination involves exchange or recombination of genes between homologous chromosomes during meiosis. Recombination carried out artificially using modern technology is called recombinant DNA technology (r-DNA technology). It is also known as gene manipulation technique. This technique involves the transfer of DNA coding for a specific gene from one organism into another organism using specific agents like vectors or using instrumentslike electroporation, gene gun, liposome mediated, chemical mediated transfers and microinjection.

Steps involved in Recombinant DNA Technology
The steps involved in recombinant DNA technology are:

- Isolation of a DNA fragment containing a gene of interest that needs to be cloned. This is called an insert.

- Generation of recombinant DNA (rDNA) molecule by insertion of the DNA fragment into a carrier molecule called a vector that can self-replicate within the host cell.

- Selection of the transformed host cells that is carrying the rDNA and allowing them to multiply thereby multiplying the rDNA molecule.

Tools for Genetic Engineering

- Now we know from the foregoing discussion that in order to generate recombinant DNA molecule, certain basic tools are necessary for the process. The basic tools are enzymes, vectors and host organisms. The most important enzymes required for genetic engineering are the restriction enzymes, DNA ligase and alkaline phosphatase.

Restriction Enzymes

- The two enzymes responsible for restricting the growth of bacteriophage in Escherichia coli were isolated in the year 1963. One was the enzyme which added methyl groups to DNA, while the other cut DNA. The later was called restriction endonuclease. A restriction enzyme or restriction endonuclease is an enzyme thatcleaves DNA into fragments at or near specific recognition sites within the molecule known as restrictionsites. Based on their mode of action restriction enzymes are classified into Exonucleases and Endonucleases.

- Exonucleases are enzymes which remove nucleotides one at a time from the end of a DNA molecule. e.g. Bal 31, Exonuclease III.

- Endonucleases are enzymes which break the internal phosphodiester bonds within a DNA molecule. e.g. Hind II, EcoRI, Pvul, BamHI, TaqI.

Vectors

- Another major component of a gene cloning experiment is a vector such as a plasmid. A Vector is a small DNA molecule capable of self-replication and is used as a carrier and transporter of DNA fragment which is inserted into it for cloning experiments. Vector is also called cloning vehicle or cloning DNA. Vectors are of two types:

    - Cloning Vector,
    - **Expression Vector.**

- Cloning vector is used for the cloning of DNA insert inside the suitable host cell. Expression vector is used to express the DNA insert for producing specific protein inside the host.

Properties of Vectors

- Vectors are able to replicate autonomously to produce multiple copies of them along with their DNA insert in the host cell.

- It should be small in size and of low molecular weight, less than 10 Kb (kilo base pair) in size so that entry/transfer into host cell is easy.

- Vector must contain an origin of replication so that it can independetly replicate within the host.

- It should contain a suitable marker such as antibiotic resistance, to permit its detection in transformed host cell.

- Vector should have unique target sites for integration with DNA insert and should have the ability to integrate with DNA insert it carries into the genome of the host cell. Most of the commonly used cloning vectors have more than one restriction site. These are

Multiple Cloning Site (MCS) or polylinker. Presence of MCS facilitates the use of restriction enzyme of choice.

- The following are the features that are required to facilitate cloning into a vector.

- **Origin of replication (ori):** This is a sequence from where replication starts and piece of DNA when linked to this sequence can be made to replicate within the host cells.

- **Selectable marker:** In addition to ori the vector requires a selectable marker, which helps in identifying and eliminating non transformants and selectively permitting the growth of the transformants.

- **Cloning sites:** In order to link the alien DNA, the vector needs to have very few, preferably single, recognition sites for the commonly used restriction enzymes.

Types of vector

Few types of vectors are discussed in detail below:

Plasmid

- Plasmids are extra chromosomal, self replicating ds circular DNA molecules, found in the bacterial cells in addition to the bacterial chromosome. Plasmids contain Genetic information for their own replication.

pBR 322 Plasmid

- pBR 322 plasmid is a reconstructed plasmid and most widely used as cloning vector; it contains 4361 base pairs. In pBR, p denotes plasmid, Band R respectively the names of scientist Boliver and Rodriguez who developed this plasmid. The number 322 is the number of plasmid developed from their laboratory. It contains ampR and tetR two different antibiotic resistance genes and recognition sites for several restriction enzymes. (Hind III, EcoRI, BamH I, Sal I, Pvu II, Pst I, Cla I), ori and antibiotic resistance genes. Rop codes for the proteins involved in the replication of the plasmid.

Ti Plasmid

- Ti plasmid is found in Agrobacterium tumefaciens, a bacteria responsible for inducing tumours in several dicot plants. The plasmid carries transfer (tra) gene which help to transfer T- DNA from one bacterium to other bacterial or plant cell. It has Onco gene for oncogenecity,ori gene for origin for replication and inc gene for incompatibility. T-DNA of Ti-Plasmid is stably integrated with plant DNA. Agrobacterium plasmids have been used for introduction of genes of desirable traits into plants.

Transposon as Vector

- Transposons (Transposable elements or mobile elements) are DNA sequence able to insert itself at a new location in the genome without having any sequence relationship with the target locus and hence transposons are called walking genes or jumping genes. They are used as genetic tools for analysis of gene and protein functions, that produce new phenotype on host cell. The use of transposons is well studied in Arabidopsis thaliana and bacteria such as Escherichia coli.

> **Walking Genes** - Gene walking involves the complete sequencing of large more than 1 kb stretches of DNA.

Expression vectors

- Vectors which are suitable for expressing foreign proteins are called expression vectors. This vector consists of signals necessary for transcription and translation of proteins in the host. This helps the host to produce foreign protein in large amounts. Example: pUC 19.

Competent Host (For Transformation with Recombinant DNA)

- The propagation of the recombinant DNA molecules must occur inside a living system or host. Many types of host cells are available for gene cloning which includes E.coli, yeast, animal or plant cells. The type of host cell depends upon the cloning experiment. E.coli is the most widely used organism as its genetic make-up has been extensively studied, it is easy to handle and grow, can accept a range of vectors and has also been studied for safety. One more important feature of E.coli to be preferred as a host cell is that under optimal growing conditions the cells divide every 20 minutes.

- Since the DNA is a hydrophilic molecule,it cannot pass through cell membranes, In order to force bacteria to take up the plasmid, the bacterial cells must first be made competent to take up DNA. This is done by treating them with a specific concentration of a divalent cation such as calcium. Recombinant DNA can then be forced into such cells by incubating the cells with recombinant DNA on ice, followed by placing them briefly at 420C (heatshock) and then putting them back on ice. This enables bacteria to take up the Recombinant DNA.

- For the expression of eukaryotic proteins, eukaryotic cells are preferred because to produce a functionally active protein it should fold properly and post translational modifications should also occur, which is not possible by prokaryotic cell (E.coli).

Methods of Gene Transfer

- The next step after a recombinant DNA molecule has been generated is to introduce it into a suitable host cell. There are many methods to introduce recombinant vectors and these are dependent on several factors such as the vector type and host cell.

- For achieving genetic transformation in plants, the basic pre-requisite is the construction of a vector which carries the gene of interestflanked by the necessary controlling sequences, i.e., the promoter and terminator, and deliver the genes into the host plant. There are two kinds of gene transfer methods in plants. It includes:

    - Direct or vectorless gene transfer
    - Indirect or vector – mediated gene transfer

Direct or Vectorless Gene Transfer

- In the direct gene transfer methods, the foreign gene of interest is delivered into the host plant without the help of a vector. The following are some of the common methods of direct gene transfer in plants.

- **Chemical mediated gene transfer:** Certain chemicals like polyethylene glycol (PEG) and dextran sulphate induce DNA uptake into plant protoplasts.

- **Microinjection:** The DNA is directly injected into the nucleus using fine tipped glass needle or micro pipette to transform plant cells. The protoplasts are immobilised on a solid support (agarose on a microscopic slide) or held with a holding pipette under suction.

- **Electroporation Methods of Gene Transfer:** A pulse of high voltage is applied to protoplasts, cells or tissues which makes transient pores in the plasma membrane through which uptake of foreign DNA occurs.

- **Liposome mediated method of Gene Transfer:** Liposomes the artificial phospholipid vesicles are useful in gene transfer. The gene or DNA is transferred from liposome into vacuole of plant cells. It is carried out by encapsulated DNA into the vacuole. This technique is advantageous because the liposome protects the introduced DNA from being damaged by the acidic pH and protease enzymes present in the vacuole. Liposome and tonoplast of vacuole fusion resulted in gene transfer. This process is called lipofection.

- **Biolistics:** The foreign DNA is coated onto the surface of minute gold or tungsten particles (1-3 µm) and bombarded onto the target tissue or cells using a particle gun (also called as gene gun/micro projectile gun/shotgun). Then the bombarded cells or tissues are cultured on selected medium to regenerate plants from the transformed cells.

Indirect or Vector-Mediated Gene Transfer

- Gene transfer is mediated with the help of a plasmid vector is known as indirect or vector mediated gene transfer. Among the various vectors used for plant transformation, the Ti-plasmid from Agrobacterium tumefaciens has been used extensively. This bacterium has a large size plasmid, known as Ti plasmid (Tumor inducing) and a portion of it referred as T-DNA (transfer DNA) is transferred to plant genome in the infected cells and cause plant tumors (crown gall). Since this bacterium has the natural ability to transfer T-DNA region of its plasmid into plant genome, upon infection of cells at the wound site, it is also known as the natural genetic engineer of plants.

- The foreign gene (e.g.Bt gene for insect resistance) and plant selection marker gene, usually an antibiotic gene like npt II which confers resistance to antibiotic kanamycin are cloned in the T DNA region of Ti-plasmid in place of unwanted DNA sequences.

Screening for Recombinants

- After the introduction of r-DNA into a suitable host cell, it is essential to identify those cells which have received the r-DNA molecule. This process is called screening. The vector or foreign DNA present in recombinant cells expresses the characters, while the non-recombinants do not express the characters or traits. For this some of the methods are used and one such method is Blue-White Selection method.

Insertional Inactivation - Blue- White Colony Selection Method

- It is a powerful method used for screening of recombinant plasmid. In this method, a reporter gene lacZ is inserted in the vector. The lacZ encodes the enzyme β-galactosidase and contains several recognition sites for restriction enzyme.

- β-galactosidase breaks a synthetic substrates called X-gal (5-bromo-4-chloro-indolyl-β-D-galacto-pyranoside) into an insoluble blue coloured product. If a foreign gene is inserted into lacZ, this gene will be inactivated. Therefore, no-blue colour will develop (white) because β-galactosidase is not synthesized due to inactivation of lacZ. Therefore, the host cell containing r-DNA form white coloured colonies on themedium contain X-gal, whereas the other cells containing non-recombinant DNA will develop the blue coloured colonies. On the basis of colony colour, the recombinants can be selected.

Antibiotic resistant markers

- An antibiotic resistance marker is a gene that produces a protein that provides cells with resistance to an antibiotic. Bacteria with transformed DNA can be identified by growing on a medium containing an antibiotic. Recombinants will grow on these medium as they contain genes encoding resistance to antibiotics such as ampicillin, chloro amphenicol, tetracycline or kanamycin, etc., while others may not be able to grow in these media, hence it is considered useful selectable marker.

Replica plating technique

- A technique in which the pattern of colonies growing on a culture plate is copied. A sterile filter plate is pressed against the culture plate and then lifted. Then the filter is pressed against a second sterile culture plate. This results in the new plate being infected with cell in the same relative positions as the colonies in the original plate. Usually, the medium used in the second plate will differ from that used in the first. It may include an antibiotic or without a growth factor. In this way, transformed cells can be selected.

Molecular Techniques - Isolation of Genetic Material and Gel Electrophoresis

- Electrophoresis is a separating technique used to separate different biomolecules with positive and negative charges.

Principle

- By applying electricity (DC) the molecules migrate according to the type of charges they have. The electrical charges on different molecules are variable.

+ ve charged Cations will move towards -ve Cathode
-ve charged Anions will move towards +ve Anode

Agarose GEL Electrophoresis

- It is used mainly for the purification of specific DNA fragments. Agarose is convenient for separating DNA fragments ranging in size from a few hundred to about 20000 base pairs. Polyacrylamide is preferred for the purification of smaller DNA fragments. The gel is complex network of polymeric molecules. DNA molecule is negatively charged molecule - under an electric field DNA molecule migrates through the gel. The electrophoresis is frequently performed with marker DNA fragments of known size which allow accurate size determination of an unknown DNA molecule by interpolation. The advantages of agarose gel electrophoresis are that the DNA bands can be readily detected at high sensitivity. The bands of DNA in the gel are stained with the dye Ethidium Bromide and DNA can be detected as visible fluorescence illuminated in UV light will give orange fluorescence, which can be photographed.

Nucleic Acid Hybridization - Blotting Techniques

- Blotting techniques are widely used analytical tools for the specific identification of desired DNA or RNA fragments from larger number of molecules. Blotting refers to the process of immobilization of sample nucleic acids or solid support (nitrocellulose or nylon membranes.) The blotted nucleic acids are then used as target in the hybridization experiments for their specific detection.

Types of Blotting Techniques

Southern Blotting: The transfer of DNA from agarose gels to nitrocellulose membrane.

Northern Blotting: The transfer of RNA to nitrocellulose membrane.

Western Blotting: Electrophoretic transfer of Proteins to nitrocellulose membrane.

Southern Blotting Techniques - DNA

- The transfer of denatured DNA from Agarose gel to Nitrocellulose Blotting or Filter Paper technique was introduced by Southern in 1975 and this technique is called Southern Blotting Technique.

Bioassay for Target Gene Effect

- Target gene is target DNA, foreign DNA, passenger DNA, exogenous DNA, gene of interest or insert DNA that is to be either cloned or specifically mutated. Gene targeting experiments have been targeting the nuclei and this leads to 'gene knock-out'. For this purpose, two types of targeting vectors are used. They are insertion vectors and replacement or transplacement vectors.

- Insertion vectors are entirely inserted into targeted locus as the vectors are linearized within the homology region. Initially, these vectors are circular but during insertion, become linear. It leads to duplication of sequences adjacent to selectable markers.

- The replacement vector has the homology region and it is co-linear with target. This vector is linearized prior to transfection outside the homology region and then consequently a crossing over occurs to replace the endogenous DNA with the incoming DNA.

Transfection: Introduction of foreign nucleic acids into cells by non-viral methods.

Genome Sequencing and Plant Genome Projects

- The whole complement of gene that determine all characteristic of an organism is called genome. The genome may be nuclear genome, mitochondrial genome or plastid genome. Genome of many plants contain both functional and non-expressive DNA proteins. Genome project refer to a project in which the whole genome of plant is analysed using sequence analysis and sequence homology with other plants. Such genome projects have so far been undertaken in Chlamydomonas(algae), Arabidopsis thaliana, rice and maize plants.

- Genome content of an organism is expressed in terms of number of base pairs or in terms of the content of DNA is expressed in c-value.

- **Genome sequencing:** The location of genes on the entire diploid chromosome of an organism.

Evolutionary pattern assessed using DNA.

- In recent years the evolutionary relationship between different plant taxa is assessed using DNA content as well as the similarities and differences in the DNA sequence (sequence homology). Based on such analysis the taxa and their relationship are indicated in cladogram. Such cladogram will show the genetic distance between two taxa. It is also showed antiquity or modernity of any taxon with respect to one another.

Genome editing and CRISPR - Cas9

- Genome editing or gene editing is a group of technologies that has the ability to change an organism's DNA. These technologies allow genetic material to be added, removed, or altered at particular locations in the genome. Several approaches to genome editing have been developed. A recent one is known as CRISPR-Cas9, which is short form of Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9. The CRISPR-Cas9 system has generated a lot of excitement in the scientific community because it is faster, cheaper, more accurate, and more efficient than other existing genome editing methods.

- Rice, was among the first plants to be used to demonstrate the feasibility of CRISPR-mediated targeted mutagenesis and gene replacement. The gene editing tool CRISPR can be used to make hybrid rice plants that can clone their seed. Imtiyaz Khand and Venkatesan Sundaresan and colleagues reported in a new study which clearly shows one can re-engineer rice to switch it from a sexual to an asexual mode.

RNA Interference (RNAi)

- All characters of organism are the result of expression of different genes which are regions of nuclear DNA. This expression involves transcription and translation. Transcription refers to the copying of genetic information from one strand of the DNA (called sense strand) by RNA. This RNA, as soon as it formed cannot be straight away sent to the cytoplasm to undertake the process of translation. It has to be edited and made suitable for translation which brings about protein synthesis. One of the main items removed from the RNA strand are the introns. All these changes before translation normally take place whereby certain regions of DNA are silence. However, there is an (RNAi) pathway. RNA interference is a biological process in which RNA molecules inhibit gene expression or translation. This is done by neutralisingtargetd mRNA molecules.

- A simplified model for the RNAi pathway is based on two steps, each involving ribonuclease enzyme. In the first step, the trigger RNA (either dsRNA or miRNA primary transcript) is processed into a short interfering RNA (siRNA) by the RNase II enzymes called Dicer and Drosha. In the second step, siRNAs are loaded into the effector complex RNA-induced silencing complex (RISC). The siRNA is unwound during RISC assembly and the single-stranded RNA hybridizes with mRNA target. This RNAi is seen in plant feeding nematodes.

Transgenic Plants / Genetically Modified Crops (Gm Crops)
Herbicide Tolerant – Glyphosate

- Weeds are a constant problem in crop fields. Weeds not only compete with crops for sunlight, water, nutrients and space but also a carrier for insects and diseases. If left uncontrolled, weeds can reduce crop yields significantly.

Transgenic plants contain a novel DNA introduced into its genome.

- Glyphosate herbicide produced by Monsanto, USA company under the trade name 'Round up' kills plants by blocking the 5-enopyruvate shikimate-3 phosphate synthase (EPSPS) enzyme, an enzyme involved in the biosynthesis of aromatic amino acids, vitamins and many secondary plant metabolites. There are several ways by which crops can be modified to be glyphosate-tolerant.

- One strategy is to incorporate a soil bacterium gene that produces a glyphosate tolerant form of EPSPS. Another way is to incorporate a different soil bacterium gene that produces a glyphosate degrading enzyme.

Advantages of Herbicide Tolerant Crops

- Weed control improves higher crop yields;
- Reduces spray of herbicide;
- Reduces competition between crop plant and weed;
- Use of low toxicity compounds which do not remain active in the soil; and
- The ability to conserve soil structure and microbes.

Herbicide Tolerant - Basta

- Trade name 'Basta' refers to a non-selective herbicide containing the chemical compound phosphinothricin. Basta herbicide tolerant gene PPT (L-phosphinothricin) was isolated from Medicago sativa plant. It inhibits the enzyme glutamine synthase which is involved in ammonia assimilation. The PPT gene was introduced into tobacco and transgenic tobacco produced was resistant to PPT. Similar enzyme was also isolated from Streptomyces hygroscopicus with bar gene encodes for PAT (Phosphinothricin acetyl transferase) and was introduced into crop plants like potato and sugar-beet and transgenic crops have been developed.

Insect resistance - Bt Crops:
Bt Cotton

- Bt cotton is a genetically modified organism (GMO) or genetically modified pest resistant plant cotton variety, which produces an insecticide activity to bollworm.

- Strains of the bacterium Bacillus thuringiensis produce over 200 different Bt toxins, each harmful to different insects. Most Bt toxins are insecticidal to the larvae of moths and butterflies, beetles, cotton bollworms and gatflies but are harmless to other forms of life.

- The genes are encoded for toxic crystals in the Cry group of endotoxin. When insects attack and eat the cotton plant the Cry toxins are dissolved in the insect's stomach.

- The epithelial membranes of the gut block certain vital nutrients thereby sufficient regulation of potassium ions are lost in the insects and results in the death of epithelial cells in the intestine membrane which leads to the death of the larvae.

Advantages

The advantages of Bt cotton are:

- Yield of cotton is increased due to effective control of bollworms.
- Reduction in insecticide use in the cultivation of Bt cotton
- Potential reduction in the cost of cultivation.

Disadvantages
Bt cotton has some limitations:

- Cost of Bt cotton seed is high.
- Effectiveness up to 120 days after that efficiency is reduced
- Ineffective against sucking pests like jassids, aphids and whitefly.
- Affects pollinating insects and thus yield

i. **Bt Brinjal**

- The Bt brinjal is another transgenic brinjal created by inserting a crystal protein gene (Cry1Ac) from the soil bacterium Bacillus thuringiensis into the genome of various brinjal cultivars. The insertion of the gene, along with other genetic elements such as promoters, terminators and an antibiotic resistance marker gene into the brinjal plant is accomplished using Agrobacterium-mediated genetic transformation. The Bt brinjal has been developed to give resistance against Lepidopteron insects, in particular the Brinjal Fruit and Shoot Borer (Leucinodesorbonalis).

ii. **Dhara Mustard Hybrid (DMH)**

- DMH -11 is transgenic mustard developed by a team of scientists Centre for Genetic Manipulation of Crop Plants at Delhi University under Government sponsored project. It is genetically modified variety of Herbicide Tolerant (HT) mustard. It was created by using "barnase/ barstar" technology for genetic modification by adding genes from soil bacterium that makes mustard, a self-pollinating plant. DMH -11 contains three genes viz. Bar gene, Barnase and Barstar sourced from soil bacterium. The bar gene had made plant resistant to herbicide named Basta.

Virus Resistance

- Many plants are affected by virus attack resulting in series loss in yield and even death. Biotechnological intervention is used to introduce viral resistant genes into the host plant so that they can resist the attack by virus. This is by introducing genes that produce resistant enzymes which can deactivate viral DNA.

FlavrSavr Tomato

- Agrobacterium mediated genetic engineering technique was followed to produce Flavr-Savr tomato, i.e., retaining the natural colour and flavor of tomato.
- Through genetic engineering, the ripening process of the tomato is slowed down and thus prevent it from softening and to increase the shelf life. The tomato was made more resistant to rotting by Agrobacterium mediated gene transfer mechanism of introducing an antisense gene which interferes with the production of the enzyme polygalacturonase, which help in delaying the ripening process of tomato during long storage and transportation.

Golden rice - Biofortification

- Golden rice is a variety of Oryza sativa (rice) produced through genetic engineering of biosynthesized beta-carotene, a precursor of Vitamin-A in the edible parts of rice developed by Ingo Potrykus and his group. The aim is to produce a fortified food to be grown and consumed in areas with a shortage of dietary Vitamin-A, which kills so many children under five year age. Golden rice differs from its parental strain by the addition of three beta-carotene biosynthesis genes namely 'psy' (phytoene synthase) from daffodil plant Narcissus pseudonarcissus and 'crt-1' gene from the soil bacterium Erwinia auredorora and 'lyc' (lycopene cyclase) gene from wild-type rice endosperm.
- The endosperm of normal rice, does not contain beta-carotene. Golden-rice has been genetically altered so that the endosperm now accumulates Beta-carotene. This has been

done using Recombinant DNA technology. Golden rice can control childhood blindness - Xerophthalmia.

GM Food - Benefits

- High yield without pest
- 70% reduction of pesticide usage
- Reduce soil pollution problem
- Conserve microbial population in soil

Risks - believed to

- Affect liver, kidney function and cancer
- Hormonal imbalance and physical disorder
- Anaphylactic shock (sudden hypersensitive reaction) and allergies.
- Adverse effect in immune system because of bacterial protein.
- Loss of viability of seeds show in terminator seed technology of GM crops.

Polyhydroxybutyrate (PHB)

- Synthetic polymers are non-degradable and pollute the soil and when burnt add dioxin in the environment which cause cancer. So, efforts were taken to provide an alternative eco-friendly biopolymers. Polyhydroxyalkanoates (PHAs) and polyhydroxybutyrate (PHB) are group of degradable biopolymers which have several medical applications such as drug delivery, scaffold and heart valves. PHAs are biological macromolecules and thermoplastics which are biodegradable and biocompatible.

- Several microorganisms have been utilized to produce different types of PHAs including Gram-positive like Bacillus megaterium, Bacillussubtilis and Corynebacterium glutamicum, Gram-negative bacteria like group of Pseudomonas sp. and Alcaligenes eutrophus.

Polylactic acid (PLA)

- Polylactic acid or polylactide (PLA) is a biodegradable and bioactive thermoplastic. It is an aliphatic polyester derived from renewable resources, such as corn starch, cassava root, chips or starch or sugarcane. For the production of PLA, two main monomers are used: lactic acid, and the cyclic diester, lactide. The most common route is the ring-opening polymerization of lactide with metal catalysts like tin octoate in solution. The metal-catalyzed reaction results in equal amount of d and polylactic acid.

Green Fluorescent Protein (GFP)

- The green fluorescent protein (GFP) is a protein containing 238 amino acid residues of 26.9 kDa that exhibits bright green fluorescence when exposed to blue to ultraviolet range (395 nm). GFP refers to the protein first isolated from the jellyfish Aequorea victoria. GFP is an excellent tool in biology due to its ability to form internal chromophore without requiring any accessory cofactors, gene products, enzymes or substrates other than molecular oxygen. In cell and molecular biology, the GFP gene is frequently used as a reporter of expression. It has been used in modified forms to make biosensors.

Biopharming

- Biopharming also known as molecular pharming is the production and use of transgenic plants genetically engineered toproduce pharmaceutical substances for use of human beings. This is also called "molecular farming or pharming". These plants are different from medicinal plants which are naturally available. The use of plant systems as bioreactors is gaining more significance in modern biotechnology. Many pharmaceutical substances can be produced using transgenic plants. Example: Golden rice

Bioremediation

- It is defined as the use of microorganisms or plants to clean up environmental pollution. It is an approach used to treat wastes including wastewater, industrial waste and solid waste. Bioremediation process is applied to the removal of oil, petrochemical residues, pesticides or heavy metals from soil or ground water. In many cases, bioremediation is less expensive and more sustainable than other physical and chemical methods of remediation.Bioremediation process is a cheaper and eco-friendly approach and can deal with lower concentrations of contaminants more effectively. The strategies for bioremediation in soil and water can be as follows:
    - Use of indigenous microbial population as indicator species for bioremediation process.
    - Bioremediation with the addition of adapted or designed microbial inoculants.
    - Use of plants for bioremediation - green technology.

Some examples of bioremediation technologies are:

- **Phytoremediation** - use of plants to bring about remediation of environmental pollutants.
- **Mycoremediation** - use of fungi to bring about remediation of environmental pollutants.
- **Bioventing** is the process that increases the oxygen or air flow to accelerate the degradation of environmental pollutants.
- **Bioleaching** is the use of microorganisms in solution to recover metal pollutants from contaminated sites.

- **Bioaugmentation** is the addition of selected microbes to speed up degradation process.
- **Composting** is the process by which the solid waste is composted by the use of microbes into manure which acts as a nutrient for plant growth.
- **Rhizofiltration** is the uptake of metals or degradation of organic compounds by rhizosphere microorganisms.
- **Rhizostimulation** is the stimulation of plant growth by the rhizosphere by providing better growth condition or reduction in toxic materials.

Limitations

- Only biodegradable contaminants can be transformed using bioremediation processes.
- Bioremediation processes must be specifically made in accordance to the conditions at the contaminated site.
- Small-scale tests on a pilot scale must be performed before carrying out the procedure at the contaminated site.
- The use of genetic engineering technology to create genetically modified microorganism or a consortium of microbes for bioremediation process has great potential.

Biofuel: Algal Biofuel

- Algal fuel, also known as algal biofuel, or algal oil is an alternative to liquid fossil fuels, the petroleum products. This use algae as a source of energy-rich oils. Also, algal fuels are an alternative to commonly known biofuel sources obtained from corn and sugarcane. The energy crisis and the world food crisis have initiated interest in algal culture (farming algae) for making biodiesel and other biofuels using land unsuitable for agriculture. Botryococcusbraunii is normally used to produce algal biofuel.

Biological hydrogen production by algae

- The biological hydrogen production with algae is a method of photo biological water splitting. In normal photosynthesis the alga, Chlamydomonas reinhardtii releases oxygen. When it is deprived of sulfur, it switches to the production of hydrogen during photosynthesis and the electrons are transported to ferredoxins. [Fe]-hydrogenase enzymes combine them into the production of hydrogen gas.

Bioprospecting

- Bioprospecting is the process of discovery and commercialization of new products obtained from biological resources. Bioprospecting may involve biopiracy, in which indigenous knowledge of nature, originating with indigenous people, is used by others for profit, without authorization or compensation to the indigenous people themselves.

Biopiracy

- Biopiracy can be defined as the manipulation of intellectual property rights laws by corporations to gain exclusive control over national genetic resources, without giving adequate recognition or remuneration to the original possessors of those resources. Examples of biopiracy include recent patents granted by the U.S. Patent and Trademarks Office to American companies on turmeric, 'neem' and, most notably, 'basmati' rice. All three products are indigenous to the Indo-Pak subcontinent.

Biopiracy of Neem

- The people of India used neem and its oil in many ways to controlling fungal and bacterial skin infections. Indian's have shared the knowledge of the properties of the neem with the entire world. Pirating this knowledge, the United States Department of Agriculture (USDA) and an American MNC (Multi Nation Corporation) W.R.Grace in the early 90's sought a patent from the European Patent Office (EPO) on the "method for controlling of diseases on plants by the aid of extracted hydrophobic neem oil". The patenting of the fungicidal and antibacterial properties of Neem was an example of biopiracy but the traditional knowledge of the Indians was protected in the end.

Biopiracy of Turmeric

- The United States Patent and Trademark Office, in the year 1995 granted patent to the method of use of turmeric as an antiseptic agent. Turmeric has been used by the Indians as a home remedy for the quick healing of the wounds and also for purpose of healing rashes. The journal article published by the Indian Medical Association, in the year 1953 wherein this remedy was mentioned. Therefore, in this way it was proved that the use of turmeric as an antiseptic is not new to the world and is not a new invention, but formed a part of the traditional knowledge of the Indians. The objection in this case US patent and trademark office was upheld and traditional knowledge of the Indians was protected. It is another example of Biopiracy.

Biopiracy of Basmati

- On September 2, 1997, the U.S. Patent and Trademarks Office granted Patent on "basmati rice lines and grains" to the Texas-based company RiceTec. This broad patent gives the company several rights, including exclusive use of the term 'basmati', as well proprietary rights on the seeds and grains from any crosses. The patent also covers the process of breeding RiceTec's novel rice lines and the method to determine the cooking properties and starch content of the rice grains.

- India had periled the United States to take the matter to the WTO as an infringement of the TRIPS agreement, which could have resulted in major embarrassment for the US.

Hence voluntarily and due to few decisions take by the US patent office, Rice Tec had no choice but to lose most of the claims and most importantly the right to call the rice "Basmati". In the year 2002, the final decision was taken. Rice Tec dropped down 15 claims, resulting in clearing the path of Indian Basmati rice exports to the foreign countries. The Patent Office ordered the patent name to be changed to 'Rice lines 867'.

Applications of Biotechnology

- Biotechnology is one of the most important applied interdisciplinary sciences of the 21st century. It is the trusted area that enables us to find the beneficial way of life.
- Biotechnology has wide applications in various sectors like agriculture, medicine, environment and commercial industries.
- This science has an invaluable outcome like transgenic varieties of plants e.g. transgenic cotton (Bt-cotton), rice, tomato, tobacco, cauliflower, potato and banana.
- The development of transgenics as pesticide resistant, stress resistant and disease resistant varieties of agricultural crops is the immense outcome of biotechnology.
- The synthesis of human insulin and blood protein in E.coli and utilized forinsulin deficiency disorder in human is a breakthrough in biotech industries in medicine.
- The synthesis of vaccines, enzymes, antibiotics, dairy products and beverages are the products of biotech industries.
- Biochip based biological computer is one of the successes of biotechnology.
- Genetic engineering involves genetic manipulation, tissue culture involves aseptic cultivation of totipotent plant cell into plant clones under controlled atmospheric conditions.
- Single cell protein from Spirulina is utilized in food industries.
- Production of secondary metabolites, biofertilizers, biopesticides and enzymes.
- Biomass energy, biofuel, Bioremediation, phytoremediation for environmental biotechnology.

UNIT – 5- Plant Tissue Culture

- Growing plant protoplasts, cells, tissues or organs away from their natural or normal environment, under artificial condition, is known as Tissue Culture. It is also known as in vitro (In vitro is a Latin word, it means that - in glass or in test-tube) growth of plant protoplasts, cells, tissues and organs. A single explant can be multiplied into several thousand plants in short time period and space under controlled conditions. Tissue culture techniques are oft en used for commercial production of plants as well as for plant research. Plant tissue culture serves as an indispensable tool for regeneration of transgenic plants. Apart from this some of the main applications of Plant tissue culture are clonal propagation of elite varieties, conservation of endangered plants, production of virus-free plants, germplasm preservation, industrial production of secondary metabolites. etc., In this chapter let us discuss the history, techniques, types , applications of plant tissue culture and get aware on ethical issues. Gottlieb Haberlandt (1902) the German Botanist proposed the concept Totipotency and he was also the first person to culture plant cells in artificial conditions using the mesophyll cells of Lamium purpureum in culture medium and obtained cell proliferation. He is regarded as the father of tissue culture.

Basic concepts of Tissue Culture

- Basic concepts of plant tissue culture are totipotency, differentiation, dedifferentiation and redifferentiation.

Totipotency

- The property of live plant cells that they have the genetic potential when cultured in nutrient medium to give rise to a complete individual plant.

Differentiation

- The process of biochemical and structural changes by which cells become specialized in form and function.

Redifferentiation

- The further differentiation of already differentiated cell into another type of cell. For example, when the component cells of callus have the ability to form a whole plant in a nutrient medium, the phenomenon is called redifferentiation.

Dedifferentiation

- The phenomenon of the reversion of mature cells to the meristematic state leading to the formation of callus is called dedifferentiation. These two phenomena of redifferentiation and dedifferentiation are the inherent capacities of living plant cells or tissue. This is described as totipotency.

Plant Tissue Culture (PTC):

- Plant tissue culture is used to describe the in vitro and aseptic growth of any plant part on a tissue culture medium. This technology is based on three fundamental principles:
- The plant part or explant must be selectedand isolated from the rest of plant body.
- The explant must be maintained in controlled physically (environmental) and chemicallydefined (nutrient medium) conditions.

Explant: The tissue taken from a selected plant transferred to a culture medium often to establish a new plant.

Laboratory Facilities for PTC

For PTC, the laboratory must have the following facilities:

- Washing facility for glassware and ovens fordrying glassware.
- Medium preparation room with autoclave,electronic balance and pH meter.
- Transfer area sterile room with laminarair-flow bench and a positive pressureventilation unit called High EfficiencyParticulate Air (HEPA) filter to maintainaseptic condition.
- **Culture facility:** Growing the explantinoculated into culture tubes at 22-28° Cwith illumination of light 2400 lux, with aphotoperiod of 8-16 hours and a relativehumidity of about 60%.

Technique Involved in PTC
Sterilization:

- Sterilization is the technique employed to getrid of microbes such as bacteria and fungi in theculture medium, vessels and explants.
- **Maintenance of Aseptic Environment:**During in vitro tissue culture maintenance ofaseptic environmental condition should befollowed, i.e., sterilization of glassware, forceps,scalpels, and all accessories in wet steamsterilization by autoclaving at 15 psi (121°C)for 15 to 30 minutes or dipping in 70% ethanolfollowed by flaming and cooling.
- **Sterilization of culture room:** Floor andwalls are washed first with detergent and thenwith 2% sodium hypochlorite or 95% ethanol.The cabinet of laminar airflow is sterilized byclearing the work surface with 95% ethanol andthen exposure of UV radiation for 15 minutes.

- **Sterilization of Nutrient Media:** Culturemedia are dispensed in glass containers, plugged with non-absorbent cotton or sealed with plastic closures and then sterilized using autoclave at15 psi (121°C) for 15 to 30 minutes. The plantextracts, vitamins, amino acids and hormonesare sterilized by passing through Millipore filterwith 0.2 mm pore diameter and then addedto sterilized culture medium inside LaminarAirflow Chamber under sterile condition.

- **Sterilization of Explants:** The plantmaterials to be used for tissue culture should besurface sterilized by first exposing the materialin running tap water and then treating it insurface sterilization agents like 0.1% mercuricchloride, 70% ethanol under aseptic conditioninside the Laminar Air Flow Chamber.

Media Preparation

- The success of tissue culture lies in thecomposition of the growth medium, plantgrowth regulators and culture conditionssuch as temperature, pH, light and humidity.No single medium is capable of maintainingoptimum growth of all plant tissues. Suitablenutrient medium as per the principle of tissueculture is prepared and used.

- MS nutrient medium (Murashige and Skoog 1962) is commonly used. It has carbon sources, with suitable vitamins and hormones. The media formulations available for plant tissue culture other than MS are B5 medium (Gamborg.et.al 1968), White medium (white 1943), Nitsch's medium (Nitsch & Nitsch 1969). A medium may be solid or semisolid or liquid. For solidification, a gelling agent such as agar is added.

Agar: A complex mucilaginous polysaccharide obtained from marine algae (sea weeds) used as solidifying agent in media preparation

Culture condition
Ph

- The pH of medium is normally adjusted between 5.6 to 6.0 for the best result.

Temperature

- The cultures should be incubated normally at constant temperature of 25°C ± 2°C for optimal growth.

Humidity and Light Intensity

- The cultures require 50-60% relative humidity and 16 hours of photoperiod by the illumination of cool white fluorescent tubes of approximately 1000 lux.

Aeration

- Aeration to the culture can be provided by shaking the flasks or tubes of liquid culture on automatic shaker or aeration of the medium by passing with filter-sterilized air.

Induction of Callus

- Explant of 1-2 cm sterile segment selected from leaf, stem, tuber or root is inoculated (transferring the explants to sterile glass tube containing nutrient medium) in the MS nutrient medium supplemented with auxins and incubated at 25°C ± 2°C in an alternate light and dark period of 12 hours to induce cell division and soon the upper surface of explant develops into callus. Callus is a mass of unorganized growth of plant cells or tissues in in vitro culture medium

Embryogenesis

- The callus cells undergoes differentiation and produces somatic embryos, known as Embryoids. The embryoids are sub-cultured to produce plantlets.

Hardening

- The plantlets developed in vitro require ahardening period and so are transferred togreenhouse or hardening chamber and then tonormal environmental conditions.

- Hardening is the gradual exposure of in vitrodeveloped plantlets in humid chambers indiffused light for acclimatization so as to enablethem to grow under normal field conditions.

Types of Plant tissue cultures

Based on the explants some other plant tissue culture types are

- Organ culture
- Meristem culture
- Protoplast culture
- Cell culture.

Organ culture

- The culture of embryos, anthers, ovaries, roots, shoots or other organs of plants on culture media.

Meristem Culture:

- The culture of any plant meristematic tissue onculture media.

Protoplast Culture:

- Protoplasts are cells without a cell wall, butbounded by a cell membrane or plasmamembrane. Using protoplasts, it is possible toregenerate whole plants from single cells andalso develop somatic hybrids. The steps involved in protoplast culture.

Isolation of protoplast:

- Small bits of planttissue like leaf tissue are used for isolation ofprotoplast. The leaf tissue is immersed in 0.5%Macrozyme and 2% Onozuka cellulase enzymesdissolved in 13% sorbitol or mannitol at pH 5.4.It is then incubated over-night at 25°C. After agentle teasing of cells, protoplasts are obtained,and these are then transferred to 20% sucrosesolution to retain their viability. They are thencentrifuged to get pure protoplasts as differentfrom debris of cell walls.

Fusion of protoplast:

- It is done through theuse of a suitable fusogen. This is normally PEG(Polyethylene Glycol). The isolated protoplastare incubated in 25 to 30% concentration ofPEG with Ca++ ions and the protoplast showsagglutination (the formation of clumps of cells)and fusion.

Culture of protoplast:

- MS liquid medium is used with some modification in droplet, platingor micro-drop array techniques. Protoplastviability is tested with fluorescein diacetatebefore the culture. The cultures are incubated incontinuous light 1000-2000 lux at 25°C. The cellwall formation occurs within 24-48 hours andthe first division of new cells occurs between2-7 days of culture.

Selection of somatic hybrid cells:

- Thefusion product of protoplasts without nucleus ofdifferent cells is called a cybrid. Following thisnuclear fusion happen. This process is calledsomatic hybridization.

Cell Suspension Culture

- The growing of cells including the cultureof single cells or small aggregates of cellsin vitroin liquid medium is known as cellsuspension culture. The cell suspension isprepared by transferring a portion of callus tothe liquid medium and agitated using rotary shaker instrument. The cells are separated from the callus tissue and used for cell suspension culture.

Production of Secondary Metabolites

- Cell suspension culture can be useful for the production of secondary metabolites like alkaloids, flavonoids, terpenoids, phenolic compounds and recombinant proteins. Secondary metabolites are chemical compounds that are not required by the plant for normal growth and development but are produced in the plant as 'byproducts' of cell metabolism. For Example: Biosynthesis and isolation of indole alkaloids from Catharanthus roseusplant cell culture.

- The process of production of secondary metabolites can be scaled up and automated using bio-reactors for commercial production. Many strategies such as biotransformation, elicitation and immobilization have been used to make cell suspension cultures more efficient in the production of secondary metabolites. Few examples of industrially important plant secondary metabolites are listed below in the table

Secondary metabolites	Plant source	Uses
Digoxin	Digitalis purpuria	Cardiac tonic
Codeine	Papaver sominiferum	Analgesic
Capsaicin	Capsicum annum	Rheumatic pain treatment
Vincristine	Catharanthus roseus	Anti-carcinogenic
Quinine	Cinchona officinalis	Antimalarial

Somatic Embryogenesis

- Somatic embryogenesis is the formation of embryos from the callus tissue directly and these embryos are called Embryoids or from the in vitro cells directly form pre-embryonic cells which differentiate into embryoids.

Applications

- Somatic embryogenesis provides potentialplantlets which after hardening period can establish into plants.
- Somatic embryoids can be be used for theproduction of synthetic seeds.
- Somatic embryogenesis is now reportedin many plants such as Allium sativum, Hordeum vulgare,Oryza sativa, Zea mays and this possible in any plant.

Synthetic seeds are produced by encapsulation of embryoids in agarose gel or calcium alginate.

Applications of Plant Tissue Culture

Plant tissue culture techniques have several applications such as:

- Improved hybrids production throughsomatic hybridization.
- Somatic embryoids can be encapsulatedinto synthetic seeds (synseeds). Theseencapsulated seeds or synthetic seeds helpin conservation of plant biodiversity.
- Production of disease resistant plantsthrough meristem and shoot tip culture.
- Production of stress resistant plants likeherbicide tolerant, heat tolerant plants.
- Micropropagation technique to obtainlarge numbers of plantlets of both crop andtree species useful in forestry within a shortspan of time and all through the year.
- Production of secondary metabolites fromcell culture utilized in pharmaceutical,cosmetic and food industries.

Somaclonal variations: Somatic variations found in plants regenerated in vitro (i.e. variations found in leaf, stem, root, tuber or propagule)

Gametoclonal variations: Gametophytic variations found in plants regenerated in vitro gametic origin (i.e. variations found in gametes and gametophytes)

Artificial Seed

- Artificial seeds or synthetic seeds (synseeds) are produced by using embryoids (somatic embryos) obtained through in vitro culture. They may even be derived from single cells from any part of the plant that later divide to form cell mass containing dense cytoplasm, large nuclceus, starch grains, proteins, and oils etc., To prepare the artificial seeds different inert materials are used for coating the somatic embryoids like agrose and sodium alginate

Advantages of Artificial seeds

Artificial seeds have many advantages over the true seeds

- Millions of artificial seeds can be producedat any time at low cost.
- They provide an easy method to producegenetically engineered plants with desirable traits.
- It is easy to test the genotype of plants.
- They can potentially stored for long timeunder cryopreservation method.

- Artificial seeds produce identical plants
- The period of dormancy of artificial seeds isgreatly reduced, hence growth is faster witha shortened life cycle.

Virus-free plants

- The field grown plants like perennial crops, usually are infected by variety of pathogens like fungi, bacteria, mycoplasma, viruses which cause considerable economic losses. Chemical methods can be used to control fungal and bacterial pathogens, but not viruses generally.
- Shoot meristem tip culture is the method to produce virus-free plants, because the shoot meristem tip is always free from viruses.

Germplasm Conservation

- Germplasm conservation refers to the conservation of living genetic resources like pollen, seeds or tissue of plant material maintained for the purpose of selective plant breeding, preservation in live condition and used for many research works.
- Germplasm conservation resources is a part of collection of seeds and pollen that are stored in seed or pollen banks, so as to maintain their viability and fertility for any later use such as hybridization and crop improvement. Germplasm conservation may also involve a gene bank, DNA bank of elite breeding lines of plant resources for the maintenance of biological diversity and also for food security.

Cryopreservation (–195.C)

- Cryopreservation, also known asCryo-conservation, is a process by which protoplasts, cells, tissues, organelles, organs, extracellular matrix, enzymes or any other biological materials are subjected to preservation by cooling to very low temperature of –196°C using liquid nitrogen. At this extreme low temperature any enzymatic or chemical activity of the biological material will be totally stopped and this leads to preservation of material in dormant status. Later these materials can be activated by bringing to room temperature slowly for any experimental work.
- Protective agents like dimethyl sulphoxide, glycerol or sucrose are added before cryopreservation process. These protective agents are called cryoprotectants, since they protect the cells, or tissues from the stress of freezing temperature.

Intellectual Property Right (IPR)

- Intellectual property right (IPR) is a category of property that includes intangible creation of the human intellect, and primarily consists of copyrights, patents, and trademarks. It also includes other types of rights, such as trade secrets, publicity rights, moral rights, and rights against unfair competition.

- In biotechnology, the transformedmicroorganisms and plants and technologies for the production of commercial productsare exclusively the property of the discoverer.
- The discoverer has the full rights on hisproperty. It should not be neglected by theothers without legal permission.
- The right of discoverer must be protectedand it does by certain laws framed by acountry.
- The IPR is protected by different wayslike patents, copyrights, trade secrets and trademarks, designs and geographical indications.

Patents

- It is a special right to the discoverer/inventorthat has been granted by the governmentthrough legislation for trading new articles.

- A patent is a personal property whichcan be licensed or sold by the person ororganisation just like any other property.

- Patent terms give the inventor the rights toexclude others from making, using or sellinghis invention.

- It is difficult to keep secret certain inventionsand therefore, guidance should be obtainedfrom a qualified patent attorney.

- A patent consists of three parts: the grant,specifications and claims.

- The grant is filled at the patent office whichis not published. It is a signed document,actually the agreement that grants patentright to the inventor.

- The specification and claims are publishedas a single document which is made publicfrom the patent office. The specification partis narrative in which the subject matter ofinvention is described as how the inventionwas carried out.

- The claim specifically defines the scope ofthe invention to be protected by the patentwhich the others may not practice.

Biosafety and Bioethics

- Advances in biotechnology and their applications are mostly associated with controverisies. This is because the major part of the modern biotechnology deals with genetic manipulations. ELSI which represents ethical, legal and social implications of biotechnology broadly covers the relationship between biotechnology and society with particular reference to ethical and legal aspects.

Biosafety

- Biosafety is the prevention of large-scale loss of biological integrity, focusing both on ecology and human health. These prevention mechanisms include conduction of regular reviews of the biosafety in laboratory settings, as well as strict guidelines to follow. Biosafety is used to protect from harmful incidents. Many laboratories handling biohazards employ an ongoing risk management assessment and enforcement process for biosafety. Failures to follow such protocols can lead to increased risk of exposure to biohazards or pathogens. Human error and poor techniques contribute to unnecessary exposure to hazards and compromise the best safeguards set into place for protection.

Potential risks and consideration for safety aspects

- Pathogenicity of living organisms andviruses - natural and genetically modified-to infect humans, animals and plants tocause diseases.

- Toxicity of allergy associated with microbialproduction.

- Increasing number of antibiotic resistantpathogenic microorganisms.

- Problems associated with the disposal ofspent microbial biomass and purification ofeffluent from biotechnological process.

- Safety aspects associated with contamination, infection or mutation of process strains.

- Safety aspects associated with the industrialuse of microorganisms containing in vitrorecombinants.

Biosafety guidelines are being implemented by:

- The Institutional Bio-safety Committees(IBSCs) monitor the research activity atinstitutional level.

- The Review Committee on GeneticManipulation (RCGM) functioning inthe Department of Biotechnology (DBT)monitors the risky research activities in thelaboratories.

- The Genetic Engineering ApprovalCommittee (GEAC) of Ministry ofEnvironment and Forest has the powerto permit the use of Genetically ModifiedOrganism (GMO) at commercial level andopen field trials of transgenic materialsincluding agricultural crops, industrialproducts and health care products.

Bioethics - Ethical, Legal and Social Implications (ELSI)

- Bioethics refers to the study of ethical issues emerging from advances in biology and medicine. It is also a moral discernment as it relates to medical policy and practice. Bioethicists are concerned with the ethical questions that arise in the relationships amonglife sciences, biotechnology and medicine. It includes the study of values relating to primary care and other branches of medicine.The scope of bioethics is directly related to biotechnology, including cloning, gene therapy, life extension, human genetic engineering, astroethics life in space, and manipulation of basic biology through altered DNA, RNA and proteins. These developments in biotechnology will affect future evolution, and may require new principles, such as biotic ethics, that values life and its basic biological characters and structures.

- The Ethical, Legal, and Social Implications (ELSI) program was founded in 1990 as an integral part of the Human Genome Project. The mission of the ELSI program was to identify and address issues raised by genomic research that would affect individuals, families, and society. A percentage of the Human Genome Project budget at the National Institutes of Health and the U.S. Department of Energy was devoted to ELSI research.

Ethical issues in Genomic Research

- Privacy and fairness in the use of geneticinformation, including the potential forgenetic discrimination in employment andinsurance.

- The integration of new genetic technologies,such as genetic testing, into the practice ofclinical medicine.

- Ethical issues surrounding the design andconduct of genetic research with people,including the process of informed consent.

Genetic Engineering Appraisal Committee (GEAC)

- GEAC is an apex body under Ministry of Environment, Forests and Climate change for regulating manufacturing, use, import, export and storage of hazardous microbes or genetically modified organisms (GMOs) and cells in the country. It was established as an apex body to accord approval of activities involving large scale use of hazardous microorganismsand recombinants in research and industrial production. The GEAC is also responsible for approval of proposals relating to release of genetically engineered organisms and products into the environment including experimental field trials (Biosafety Research Level trial-I and II known as BRL-I and BRL-II).

Future of Biotechnology

- Biotechnology has become a comprehensive scientific venture from the point of academic and commercial angles, within a short time with the sequencing of human genome and genome of some important organisms. The future developments in biotechnology will be exciting. Thus the development in biotechnology will lead to a new scientific revolution that would change the lives and future of people. Like industrial and computer revolution, biotechnological revolution will also promise major changes in many aspects of modern life.

Monsoon, Rainfall, Weather, Climate

8TH Term I

Unit - 2 - Weather And Climate

Introduction

- Climate is one of the basic elements in the natural environment. It affects landforms, soil types, fauna and flora. It influences man to a large extent.

- Weather and climate influence man's activities like what we eat, wear, the house in which we live and work, farming, sailing, fishing, modern transport and even our play time etc. Hence one should have knowledge about the weather and climate. So, in this chapter we are going to learn about weather and climate, its elements and how they influence our lifestyle

Weather

- Weather is the day today conditions(state) of the atmosphere at any place as regards sunshine, temperature, cloud cover, Wind fog condition, air pressure, humidity, precipitation and such other elements. It refers to short periods like a day, a week, a month or a little longer and as such the weather changes from time to time in a day and one period to the other in an year.

Earth's atmosphere is a layer of gases surrounding the planet earth and retained by the earth's gravity. It contains about 78% nitrogen, 21% oxygen, 0.97% argon, 0.03% carbon dioxide and 0.04% trace amounts of other gases and water vapour

Climate

- **Climate is generally defined as the average conditions (state) of the weather of a place or a region. The average atmospheric conditions are determined by measuring the weather elements for a long period of time which is usually for 35 years. The elements of weather and climate are the same. The climate does not change often like weather.**

The word Climate is derived from the ancient Greek word "Klimo" which means "Inclination".

Controlling factors of weather and climate

- Angle of the sun's rays, the length of daytime, altitude, distribution of land and water bodies, location and direction of mountain ranges, air pressure, winds and ocean currents are the major factors which affect the weather and climate of a region.

- The earth is spherical in shape. So, the sun's rays fall unevenly on the earth's surface. The Polar regions receive slanting sun's rays. Hence there is little or no sunlight, thus there is an extreme cold winters. Vertical sun's ray's fall directly on regions around the equator,hence the climate is very hot and almost no winters. The difference in temperature makes the air and water move in currents. Warm air rises and creates more space for air beneath, while cool air settles down.

Scientific study of weather is called Meteorology and the scientific study of climate is called climatology

Elements of weather and climate

- Temperature, rainfall, pressure, humidity and wind are the major elements of weather and climate.

Temperature

- Temperature is one of the key elements of weather and climate. The earth and its atmosphere get heated from the sun through insolation. The degree of heat present in the air is termed as temperature. Apart from sun's rays, the heat in air also depends the atmospheric mass to a small extent.

Distribution of weather elements are shown by means of Isolines on maps. Isolines are those which join the places of equal values. Isolines are given different names based on the weather element they represent.

Isotherm	Equal Temperature
Isocryme	Equal Lowest mean temperature for a specified period
Isohel	Equal Sunshine
Isollobar	Equal Pressure tendency showing similar changes over a given time
Isobar	Equal atmospheric pressure
Isohyet	Equal amount of rainfall.

- Temperature varies with time due to changes in the level of radiation which reach the earth surface. This is due to motions of the earth (The rotation and revolution) and inclination of the earth's axis.

- The temperature influences the level of humidity, the process of evaporation, condensation and precipitation.

- Heat energy from solar radiation is received by the earth through three mechanisms. They are radiation, conduction and convection. The Earth's atmosphere is heated more by terriestrial radiation than insolation.

Temperature varies both horizontally and vertically. Temperature decreases with increasing height is known as Lapse rate which is 6.5 degree celsius per 1000 meters in troposphere

Factors affecting the distribution of temperature

- Latitude, altitude, nature of land, ocean currents, prevaling winds, slope, shelter and distance from the sea, natural vegetation and soil are the major factors which affect the distribution of temperature.

Measuring Temperature

- The temperature of a unit volume of air at a given time is measured in scales like Celsius, Fahrenheit, and Kelvin. Meteorologist measures the temperature by the Thermometer, Stevenson screen and minimum and maximum Thermometer. The energy received by the earth through insolation is lost by outgoing radiation. Atmosphere is mainly heated by outgoing radiation from 2 to 4pm .So the maximum temperature is recorded between 2 and 4 pm regularly and minimum temperature is recorded around 4 am before sunrise.

Mean Temperature

- The average of maximum and minimum temperatures within 24 hours is called mean daily temperature [(87oF+73oF)/2=80oF]. Diurnal range of temperature is the difference between the maximum and minimum temperatures of a day. Annual range of temperature is the difference between the highest and lowest mean monthly temperatures of a year. The distribution of temperature is shown by means of Isotherms. Isotherms are imaginary lines which connect the same temperatures of different places.

Heat zones of the earth

- The fact that the earth is spherical in shape results in different parts of the earthgetting heated differently.Based on the heat received from the sun, Earth is divided into three heat zones. They are

Torrid Zone

- It is a region between the tropic of cancer and the tropic of Capricorn. This region receives the direct rays of the sun and gets the maximum heat from the sun.This zone known as the torrid or the tropical zone

Temperate zone

- This zone lies between the Tropic of cancer and the Arctic circle in the Northern Hemisphere and between the Tropic of Capricorn and the Antartic circle in the southern Hemisphere.This zone gets the slanting rays of the sun and the angle of the sun's rays goes on decreasing towards ds the poles.Thus this zone experiences moderate temperature.

Frigid Zone

- The frigid zone lies between the Arctic circle and the North Pole and between the Antartic circle and the South Pole.This region also known as Polar region.Since it receives the extremely low temperature throughout the year,these regions are covered with snow.

Highest Temperature ever recorded

- The highest temperature ever recorded on the earth is 56.7°C (134°F). It was recorded on 10th July 1913 at Greenland Ranch of Death Valley, California, USA.

Lowest Temperature ever recorded

- The lowest temperature ever recorded on the earth is −89.2 °C (−128.6 °F; 184.0 K). It was recorded on 21st July, 1983 at Soviet Vostok Station in Antarctica.

Rainfall

- Rain is a liquid water in the form of droplets that have condensed from atmospheric water vapour and then become heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It is the source of water for all purposes. There is a close relationship between the temperature and rainfall distribution. Generally rainfall is high in the equatorial region and decreases gradually towards poles. Rainfall is measured by Raingauge.

- The weight of air above a given area on the earth's surface is called atmospheric pressure or air pressure. The air pressure is measured by Barometer. The standard air pressure at sea level is 1013.25mb. At the earth's surface the pressure is 1.03kg.per sq cm. The variation in standard atmospheric pressure is found both horizontally and vertically. Based on the level of pressure, it is categorised into low pressure and high pressure. Low pressure area is an area in the atmosphere where the pressure is lower than its surrounding areas. In this situation, the wind from the surroundings blow towards the centre of low pressure. High pressure is an area of atmosphere where the barometric pressure is higher than its surrounding areas. In this case, the wind from the centre of high pressure blows towards the surrounding low pressure areas. Low pressure system is marked as "L" on weather map, where as the high pressure system is marked as "H". Low pressure systems are also called as a depression and cyclones. High pressure system is called anti cyclones. Low pressure leads to cloudiness, wind, and precipitation. High pressure leads to fair and calm weather. Isobar is used to show the distribution of air pressure.

Highest pressure ever recorded.

The highest ever air pressure at sea level was recorded at Agata, Russia on 31st December, 1968. The pressure was1083.8mb

Lowest pressure ever recorded

The lowest pressure of 870mb was recorded at Typhoon Tip, near Guam, Mariana Island in Pacific Ocean on 12th October, 1979.

- Humans are not sensitive to small variation in air pressure. But the small variations in pressure that do exist largely determine the wind and storm patterns of the earth. The distribution of atmospheric pressure is controlled by altitude, atmospheric temperature, air circulation, earth rotation, water vapour, atmospheric storms etc.

Measuring air pressure

- Meteorologist uses barometer/aneroid barometer to measure the air pressure. Barograms are used for recording continuous variation in atmospheric pressure.

Humidity

- Humidity refers to the degree of water vapour present in the atmosphere in gaseous form in particular time and place. It ranges from 0-5 percent by volume in atmosphere. Climatically it is an important constituent of the atmosphere and its quantity depends on the level of temperature. So, the level of humidity decreases towards poles from equator. Humidity is expressed in different ways.

- **Specific humidity** is a ratio of the water vapor content of the mixture to the total air content on a mass basis. It is expressed in grams of vapour per kilogram of air

- Absolute **Humidity** is the mass or weight of water vapour present per unit volume of air. It is expressed usually in grams per cubic meter of air.

- **Relative humidity** is a ratio between the actual amount of water vapour present in the air and the maximum amount of water vapour it can hold at a given temperature. It is expressed as a percentage.

- Generally, warm air holds more water vapour than the cold air. When relative humidity reaches 100%, the air gets saturated. In this condition the temperature is said to be at dew-point. Further cooling will condense the water vapour into the clouds and rain. Relative humidity affects human health and comfortness. Very high and very low humidity are injurious to health. It also affects the stability of different objects, buildings and electrical applications.

Measurement of Humidity

- Hygrometer is used to measure the humidity. (which comprises wet and dry bulb-plate side by side in the Stevenson screen)

With decreasing air pressure,the availability of oxygen to breath also decreases. At very high altitudes, atmospheric pressure and available oxygen get so low that people can become sick and even die. Mountain climbers use bottled oxygen when they ascend very high peaks. They also take time to get used to the altitude as the quick move from high pressure to low pressure can cause decompression sickness. Aircraft create artificial pressure in the cabin which makes the passengers remain comfortable while flying.

Wind

- The horizontal movement of air is called wind. Vertical movement of air is said as air current. The winds move from high pressure to low pressure. Unlike other elements a wind is made up of a series of gusts and eddies which can only be felt and not seen. Winds get their name from the direction from which they blow i.e, wind blows from south west is called southwest wind.

The wind systems are broadly categorized into three as follows.

- Planetary winds
- Seasonal winds
- Local winds

- Planetary Winds are the ones which blow almost in the same direction throughout the year. So, they are called as Permanent or planetary winds. Trade winds, Westerlies and polar easterlies are the types of prevailing winds.

- Seasonal winds are those which change their direction according to season in a year. They are called as monsoon winds. These winds blow from sea to land during summer and land to sea during winter. Local winds are the winds blow over a small area only during a particular time of a day or a short period of a year. Land and sea breezes are example of these winds.

- The Beaufort scale is a scale for measuring wind speed. It is based on observation rather than accurate measurement. It is the most widely used system to measure wind speed today. The scale was developed in 1805 by Francis Beaufort, an officer of the Royal Navy and first officially used by HMS Beagle.

Al-Balakhi, an Arab Geographer collected climatic data from the Arab travellers and prepared the First climatic Atlas of the world

Measuring wind direction and speed

- Meteorologist measures wind direction using wind vane or weather cock. Wind speed is measured by anemometer. Wind rose is a diagram used to depict the direction and periods (No. of days) of prevailing winds on map. Meteorograph or triple register is an instrument which records wind speed and direction, sunshine and precipitation. It also provides graphic representation.

Brazil has a large area where the average wind speed is low. Gabon, Congo and DR Congo in Africa, Sumatra, Indonesia and Malaysia are the least windy places on earth.

10th Full Book

Unit 2- Climate & Natural Vegetation of India

Equable climate is also called as the British climate, Which is neither too hot nor too cold

The factors affecting the climate

- Climate of India is affected by the factors of latitude, distance from the seas, monsoon wind, relief features and jet stream.

Latitude

- Latitudinally, India lies between 8°4'N and 37°6'N latitudes. The Tropic of cancer divides the country into two equal halves. The area located to the south of Tropic of cancer experiences high temperature and no severe cold season throughout the year whereas, the areas to the north of this parallel enjoys sub-tropical climate. Here, summer temperature may rise above 40°C and it is close to freezing point during winter.

Altitude

- When the altitude increases, The temperatures decreases. Temperature decreases at the rate of 6.50C for every 1000 metres of ascent. It is called normal lapse rate.

- Hence, places in the mountains are cooler than the places on the plains. That is why the places located at higher altitudes even in south India have cool climate. Ooty and several other hill stations of south India and of the Himalayan ranges like Mussourie, Shimla etc., are much cooler than the places located on the Great Plains.

Distance from the Sea

- Distance from the sea does not cause only temperature and pressure variations but also affects the amount of rainfall. A large area of India, especially the peninsular region, is not very far from the sea and this entire area has a clear maritime influence on climate. This part of the country does not have a very clearly marked winter and the temperature is equable almost throughout the year. Areas of central and north India experience much seasonal variation in temperature due to the absence of influence of seas. Here, summers are hot and winters are cold. The annual temperature at Kochi does not exceed 30°C as its location is on the coast while it is as high as 40°C at Delhi, since it is located in the interior part. Air near the coast has more moisture and greater potential to produce precipitation. Due to this fact, the amount of rainfall at Kolkata located near the coast is 119 cm and it decreases to just 24 cm at Bikaner which is located in the interior part.

Monsoon Wind

- The most dominant factor which affects the climate of India is the monsoon winds. These are seasonal reversal winds and India remains in the influence of these winds for a considerable part of a year. Though, the sun's rays are vertical over the central part of India during the mid-June, the summer season ends in India by the end of May. It is because theonset of southwest monsoon brings down the temperature of the entire India and causes moderate to heavy rainfall in many parts of the country. Similarly, the climate of southeast India is also influenced by northeast monsoon.

Relief

- Relief of India has a great bearing on major elements of climate such as temperature, atmospheric pressure, direction of winds and the amount of rainfall. The Himalayas acts as a barrier to the freezing cold wind blows from central Asia and keep the Indian subcontinent warm. As such the north India experiences tropical climate even during winter. During southwest monsoon, areas on the western slope of the Western Ghats receive heavy rainfall. On the contrary, vast areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil nadu lie in rain shadow or leeward side of the Western Ghats receive very little rainfall. During this season, Mangalore, located on the coast gets the rainfall of about 280 cm whereas the Bengaluru located on the leeward side receives only about 50 cm rainfall.

Jet Streams

- Jet streams are the fast moving winds blowing in a narrow zone in the upper atmosphere. According to the Jet stream theory, the onset of southwest monsoon is driven by the shift of the sub tropical westerly jet from the plains of India towards the Tibetan plateau. The easterly jet streams cause tropical depressions both during southwest monsoon and retreating monsoon.

Monsoon

- The word 'monsoon' has been derived from the Arabic word 'Mausim' which means 'season'. Originally, the word 'monsoon' was used by Arab navigators several centuries ago, to describe a system of seasonal reversal of winds along the shores of the Indian Ocean, especially over the Arabian Sea. It blows from the south-west to north-east during summer and from the north-east to south-west during winter.

- Monsoons are a complex meteorological phenomenon. Meteorologists have developed a number of concepts about the origin of monsoons. According to the Dynamic concept, Monsoon wind originates due to the seasonal migration of planetary winds and pressure belts following the position of the sun. During summer solstice, the sun's rays fall vertically over the Tropic of cancer. Therefore, all the pressure and wind belts of the globe shift northwards. At this time, Inter -Tropical Convergence Zone (ITCZ) also moves northward, and a major part of Indian landmass comes under the influence of southeast trade winds. While crossing equator this wind gets deflected and takes the direction of southwest and becomes south-west monsoon. During the winter season, the pressure and wind belts shift southward, thereby establishing the north-east monsoon (trade winds) over this region. Such systematic change in the direction of planetary winds is known as monsoon.

Atacama desert is the driest place on the earth.

Seasons

The meteorologists recognize the four distinct seasons in India. They are;

- Winter or cold weather season (January - February).
- Pre Monsoon or summer or hot weather season (March - May).
- Southwest monsoon or rainy season (June - September).
- Northeast monsoon season (October - December).

Winter or cold weather season

- During this period, the vertical rays of the sun falls over tropic of capricorn which is far away from India. Hence, India receives the slanting sun's rays which results in low temperature. The cold weather season is characterized by clear skies, fine weather, light northerly winds, low humidity and large day time variations of temperature. During this season a high pressure develops over north India and a north-westerly wind blows down the Indus and Ganges valleys. In south India, the general direction of wind is from east to west. The mean temperature increases from north to south, the decrease being sharp as one moves northwards in the north-western part of the country. The mean daily minimum temperatures range from 22°C in the extreme south, to 10°C in the northern plains and 6°C in Punjab. The rain during this season generally occurs over the Western Himalayas, Tamil nadu and Kerala. Western disturbances and associated trough in westerlies are main rain bearing system in northern part of the country. The jet stream plays a dominant role in bringing these disturbances to India. These disturbances cause rainfall in Punjab, Haryana and Himachal Pradesh, and snowfall in the hills of Jammu and Kashmir. This rainfall is very useful for the cultivation of winter wheat.

Pre Monsoon or summer or hot weather season

- During this season, the vertical rays of the sun falls over the peninsular India. Hence, there is a steady increase in temperature from south to north. It is practically hot and dry in the entire country in the initial part of this season. Weather over the land areas of the country is influenced by thunderstorms associated with rain and sometimes with hail mostly in the middle and later part. During this season, temperature starts increasing all over the country and by April, the interior parts of south India record mean daily temperatures of 30°C–35°C. Central Indian land mass becomes hot with day-time maximum temperature reaching about 40°C at many locations. Many stations in Gujarat, North Maharashtra, Rajasthan and North Madhya Pradesh exhibit high day-time and low night-time temperatures during this season.

- Because of the atmospheric pressure conditions, the winds blow from southwest to northeast direction in Arabian Sea and Bay of Bengal. They bring pre monsoon showers to the west coast during the month of May. There are few thunder showers called "Mango Showers" which helps in quick ripening of mangoes along the coast of Kerala and Karnataka. "Norwesters" or "Kalbaisakhis" are the local severe storms or violent thunderstorms associated with strong winds and rain lasting for short durations. It occurs over the eastern and north eastern parts over Bihar, West Bengal and Assam during April and May. They approach the stations from the northwesterly direction.

Southwest monsoon or Rainy Season

- The southwest monsoon is the most significant feature of the Indian climate. The onset of the southwest monsoon takes place normally over the southern tip of the country by the first week of June, advances along the Konkan coast in early June and covers the whole country by 15th July. The monsoon is influenced by global phenomenon like ElNino.

- Prior to the onset of the southwest monsoon, the temperature in north India reaches upto 46°C. The sudden approach of monsoon wind over south India with lightning and thunder is termed as the 'break' or 'burst of monsoon'. It lowers the temperature of India to a large extent. The monsoon wind strikes against the southern tip of Indian land mass and gets divided into two branches. One branch starts from Arabian sea and the other from Bay of Bengal. The Arabian sea branch of southwest monsoon gives heavy rainfall to the west coast of India as it is located in the windward side of the Western Ghats. The other part which advances towards north is obstructed by Himalayan Mountains and results in heavy rainfall in north. As Aravalli Mountain is located parallel to the wind direction, Rajasthan and western part do not get much rainfall from this branch. The wind from Bay of Bengal branch moves towards northeast India and Myanmar. This wind is trapped by a chain of mountains namely Garo, Khasi and Jaintia are mainly responsible for the heaviest rainfall caused at Mawsynram located in Meghalaya. Later on, this wind travel towards west which results in decrease in rainfall from east to west. Over all about 75% of Indian rainfall is received from this monsoon. Tamil nadu which is located in the leeward side receives only a meagre rainfall.

Post monsoon or Retreating or Northeast monsoon season

- The southwest monsoon begins to retreat from north India by the end of September due to the southward shifting pressure belts. The southwest monsoon wind returns from Indian landmass and blows towards Bay of Bengal. The coriolis force deflects this wind and makes itto blow from northeast. Hence, it is known as Northeast monsoon or Post-monsoon season. The season is associated with the establishment of the north-easterly wind system over the Indian subcontinent. Andhra Pradesh, Tamil nadu, Kerala and south interior Karnataka receive good amount of rainfall accounted for 35% of their annual total. Many parts of Tamil nadu and some parts of Andhra Pradesh and Karnataka receive rainfall during this season due to the storms forming in the Bay of Bengal. Large scale losses to life and property occur due to heavy rainfall, strong winds and storm surge in the coastal regions. The day time temperatures start falling sharply all over the country. The mean temperature over north-western parts of the country shows a decline from about 38°C in October to 28°C in November.

Mawsynram, the place which receives highest rainfall (1141 cm) in the world. It is located in Meghalaya.

Distribution of rainfall

- The average annual rainfall of India is 118 cm. However, spatial distribution of rainfall in the country is highly uneven. About 11% area receives over 200 cm of annual rainfall, 21% area receives 125 to 200 cm, 37% area receives 75 to 125 cm, 24% area gets 35 to 75 cm and 7% area gets less than 35 cm. The Western coast, Assam, South Meghalaya, Tripura, Nagaland and Arunachal Pradesh are the heavy rainfall areas which get more than 200 cm rainfall. The whole of Rajasthan, Punjab, Haryana, Western and Southwestern parts of Uttar Pradesh, Western Madhya Pradesh, the entire Deccan Trap or Plateau region east of Western Ghats except for a narrow strip along Tamil nadu coast receive a low rainfall of less than 100 cm. The rest of the areas receive a rainfall ranging between 100 and 200 cm.

12th book
Unit 7 - Sustainable Development

- United Nations and Sustainable Development Sustainability was fi rst featured in the principles adopted by the United Nations Conference on the Human Environment held at Stockholm on 16 June 1972. It was now realized that development needed to be sustainable – it should not only focus on economic and social matters, but also on matters related to the use of natural resources. The United Nations commissioned a group of 22 people from both developed and developing countries to identify long-term environmental strategies for the international community. This World Commission on Environment and Development (WCED), was headed by Gro Harlem Brundtland, then the Prime Minister of Norway. This commission cameto be known as the Brundtland Commission, which submitted its report, entitled Our common future, to the UN in 1987.

- The Brundtland Report focused on the needs and interests of humans. It was concerned with securing a global equity for future generations by redistributing resources towards poorer nations to encourage their economic growth in order to enable all human beings to achieve their basic needs. The report highlighted the three fundamental components of sustainable development, the environment, the economy, and society, which later became known as the triple bottom line.

- The 1992 and 2002 Earth Summits held at Rio de Janeiro and Johannesburg were the United Nations Conference on Environment and Development (UNCED), a direct result of the Brundtland Commission. An important achievement of the Rio summit was an agreement on the Climate Change Convention which led to the Kyoto Protocol which you have learned about earlier.

- The United Nations Conference on Sustainable Development (UNCSD), also known as Rio 2012, Rio+20 or Earth Summit 2012 was the third and recent International conference on sustainable development. It was hosted by Brazil in Rio de Janeiro from 13 to 22 June 2012.

Concept and Goals of Sustainable Development

- In 1980 the International Union for the Conservation of Nature introduced the term "sustainable development". Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

- A primary goal of sustainable development is to achieve a reasonable and equitably distributed level of economic wellbeing that can be continued for many human generations.

Sustainable Development Goals (SDGs)

- In 1992, the UN Conference on Environment and Development published the Earth Charter, which outlined the building of a just, sustainable, and peaceful global society in the 21st century. The action plan was known as 'Agenda 21' for sustainable development.

- In September 2015, the United Nations General Assembly formally adopted the "Universal, integrated and transformative"2030 Agenda for Sustainable Development, a set of 17 Sustainable Development Goals (SDGs). The goals are to be implemented and achieved in every country from the year 2016 to 2030.

- Countries adopted a set of goals to end poverty, protect the planet and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years.

- For the goals to be reached, everyone needs to do their part: governments, the private sector, civil society and people.

End poverty in all its forms everywhere

- One in five people in developing countries still live on less than $1.90 a day, many people risk slipping back into poverty. Economic growth must be inclusive to provide sustainable jobs and promote equality.

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

- Agriculture, forestry and fisheries can provide nutritious food for all and generate decent incomes, while supporting people-centred rural development and protecting the environment. A profound change of the global food and agriculture system is needed if we are to nourish today's 815 million hungry and the additional 2 billion people expected by 2050.

Ensure healthy lives and promote well-being for all at all ages

- Significant strides have been made in increasing life expectancy and reducing some of the common killers associated with child and maternal mortality. Major progress has been made on increasing access to clean water and sanitation, reducing malaria, tuberculosis, polio and the spread of HIV/AIDS.

Ensure inclusive and quality education for all and promote lifelong learning

- Major progress has been made towards increasing access to education at all levels and increasing enrolment rates in schools particularly for women and girls. For example, the world has achieved equality in primary education between girls and boys, but few countries have achieved that target at all levels of education.

Achieve gender equality and empower all women and girls

- Gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world.

Ensure access to water and sanitation for all

- Clean, accessible water for all is an essential part of the world we want to live in. There is sufficient fresh water on the planet to achieve this. But due to bad economics or poor infrastructure, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene. By 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water.

Ensure access to affordable, reliable, sustainable and modern energy for all

- Energy is central to nearly every major challenge and opportunity the world faces today. Sustainable energy is opportunity – it transforms lives, economies and the planet.

Promote inclusive and sustainable economic growth, employment and decent work for all

- Sustainable economic growth will require societies to create the conditions that allow people to have quality jobs that stimulate the economy while not harming the environment. Job opportunities and decent working conditions are also required for the whole working age population.

Build resilient infrastructure, promote sustainable industrialization and foster innovation

- Inclusive and sustainable industrial development is the primary source of income generation, allows for rapid and sustained increases in living standards for all people, and provides the technological solutions to environmentally sound industrialization.

Reduce inequality within and among countries

- To reduce inequality, policies should be universal in principle paying attention to the needs of disadvantaged and marginalized populations

Make cities inclusive, safe, resilient and sustainable

- Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing and declining infrastructure.

Ensure sustainable consumption and production patterns

- Sustainable consumption and production is about promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all. Its implementation helps to achieve overall development plans, reduce future economic, environmental and social costs, strengthen economic competitiveness and reduce poverty.

Take urgent action to combat climate change and its impacts

- Climate change is now affecting every country on every continent. It is disrupting national economies and affecting lives, costing people, communities and countries dearly today and may be even more tomorrow.

Conserve and sustainably use the oceans, seas and marine resources

- The world's oceans – their temperature, currents and life – drive global systems that make the earth habitable for humankind. Careful management of this essential global resource is a key feature of a sustainable future.

Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

- Forests cover 30 per cent of the Earth's surface and in addition to providing food security and shelter, forests are key to combating climate change, protecting biodiversity and the homes of the indigenous population. Thirteen million hectares of forests are being lost every year while the persistent degradation of dry lands has led to the desertification of 3.6 billion hectares.

Promote just, peaceful and inclusive societies

- This Goal is dedicated to the promotion of peaceful and inclusive societies for sustainable development, the provision of access to justice for all, and building effective, accountable institutions at all levels.

Revitalize the global partnership for sustainable development

- A successful sustainable development agenda requires partnerships between governments, the private sector and civil society. These inclusive partnerships built upon principles and values, a shared vision, and shared goals that place people and the planet at the centre, are needed at the global, regional, national and local level.

Paris Agreement

To address climate change, countries adopted the Paris Agreement at the COP21 in Paris on 12 December 2015. The Agreement entered into force shortly thereafter, on 4 November 2016. In the agreement, all countries agreed to work to limit global temperature rise to well below 2°C, and given the grave risks, to strive for 1.5°C.

Climate Change and Sustainability

- The Earth's climate has changed throughout history. In the last 650,000 years there have been several cycles of glacial and warm periods each lasting thousands or millions of years. Most of these climate changes are attributed to very small variations in earth's orbit that changes the amount of solar energy our planet receives. It is understood that at present the Earth's climate is getting warmer which is referred to as 'Global Warming'. Earth's temperature has gone up about one degree Fahrenheit in the last 100 years. This is a very small change but small changes in earth's temperature can have big effects. Some effects are already happening such as melting of glaciers, rise in the level of oceans, prolonged droughts, excessive rain and floods, etc.

Reasons for Climate change

- Burning fossil fuels emits gases into the atmosphere. Burning fossil fuel to provide energy, coupled with the effects of major transportation and deforestation causes a rapid increase in global temperatures. This can change the climate of a place.

- Effects **of climate change** – Scientists had predicted in the past that the result from global climate change are now occurring, loss of sea ice, accelerated sea level rise and longer, more intense heat waves.

- Temperatures **will continue to rise** - Experts agree that greenhouse gases which trap heat and prevent it from leaving the earth's atmosphere are mostly responsible for the temperature spike.

- Frost**-free season (and growing season) will lengthen -** it could actually have detrimental effects on the crops we grow. Warmer weather helps pests survive longer which can destroy crops. Rising temperatures are also expected to contribute to a shift in areas which are agriculturally most productive and the crops that grow there.

- Changes **in precipitation patterns -** The contrast between wet and dry areas will increase globally. In other words, the wet areas will get wetter and the dry areas will get drier.

- More **droughts and heat waves -** With rising temperatures and shifting rainfall patterns, heat waves and droughts are increasing in frequency and intensity.

- **Sea level rise -** Scientists have determined that global sea level has been steadily rising since 1900 at a rate of at least 0.1 to 0.25 centimeter per year. Sea level can rise by two different mechanisms with respect to climate change.

- Arctic **likely to become ice-free -** The Arctic Ocean is expected to become essentially ice free in summer before mid-century.

UNFCCC Process for Climate Change Adaptation, On17, May 2017: Policy makers, implementers, supporters and investors from all over the world met during the UNFCCC Bonn Climate Change Conference at the Technical Expert Meeting (TEM) on Adaptation to discuss 'Integrating climate change adaptation with the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction.

Response to Climate Change

- There are two main responses to climate change.

- Mitigation **-**which addresses the root causes of climate change, by reducing greenhouse gas emissions.

- **Adaptation -** seeks to lower the risks posed by the consequences of climatic changes. Both approaches will be necessary to deal with the global changes that have already been set in motion.

Mitigation measures:

- It is important that we learn how to reduce climate change, and put them into practice now, before it is too late.

- **Cleaner alternative energy sources:** One important way to fight climate change is to reduce our reliance on and usage of fossil fuels, and depend on alternative renewable and greener sources of energy such as wind energy, solar energy, water or hydropower, biomass, and geothermal energy.

- Energy **saving tips -** we can adopt energy saving tips by investing in more expensive energy-saving appliances like the compact fluorescent light (CFL) bulbs, Air-conditioners, refrigerators etc. Switching off our electrical appliances when not in use.

- **Green driving tips -** The best strategy to reduce toxic gas emissions is definitely to reduce the use of automobiles. Use public transport, carpooling, use of electricity powered cars or two wheelers can be an alternative.

- **Reduce - Reuse - Recycle practices** - Reducing, reusing and recycling helps us conserve resources and energy, and reduce pollution and greenhouse gas emissions produced thereby.

- **Re-forestation** - The cleanest and most efficient remover of carbon dioxide from our atmosphere actually is nothing but green plants and trees. The rate at which we are cutting down our trees and forests to make way for human developments has greatly reduced the earth's ability to remove carbon dioxide from the atmosphere.

- **Organic farming** - Soils are an important sink for atmospheric carbon dioxide. Nevertheless, deforestation making way for conventional agriculture is increasingly depleting this sink. Sustainable and organic agriculture helps to counteract climate change by restoring soil organic matter content as well as reduce soil erosion and improve soil physical structure. Organic farming uses natural fertilizers and helps maintain crop yields.

Watershed management and its importance

- Watershed is a geographical area drained by a stream or a system connecting stream in which water from all over an area flow under gravity to a common drainage channel. A watershed system delivers water through rills, gullies and streams to a larger body of water.

- Watershed management is proper utilization of land and water resource for optimum production with minimum hazards to natural resources. It relates to soil and water conservation proper land uses, promote afforestation and sustainable farming practices, conserve farmland and pastureland, maintaining soil fertility, proper management of local water for farming, drainage, construct small dams for flood protection, improving individuals standard of living and thereby promote ecological balance.

Key steps in watershed management

- Watershed plans should first identify the characteristics of the watershed and inventory the watershed's natural resources. The first steps in watershed management planning are to:

- ➢ Delineate and map the watershed's boundaries and the smaller drainage basins within the watershed.
- ➢ Map and prepare an Inventory of resources in the watershed
- ➢ Prepare an Inventory and map the natural and manmade drainage systems in the watershed.
- ➢ Prepare an Inventory and map land use and land cover
- ➢ Prepare a soil map of the watershed
- ➢ Identify areas of erosion, including stream banks and construction sites.

- Identify the quality of water resources in the watershed as a baseline; and

- Prepare a map and Inventory of pollution sources, both point sources (such as industrial discharge pipes) and nonpoint sources (such as municipal storm water systems, failing septic systems, illicit discharges).

Watershed Management in India:

- Watershed development project in the country has been sponsored and implemented by Government of India from early 1970s onwards. Various watershed development programs like Drought Prone Area Program (DPAP), Desert Development Program (DDP), River Valley Project (RVP), National Watershed Development Project for Rain-fed Areas (NWDPRA) and Integrated Wasteland Development Program (IWDP) were launched subsequently in various hydro-ecological regions. Entire watershed development programs primarily focused on soil conservation and rainwaterharvesting during 1980s and before.

Rain Water Harvesting (RWH)

- Millions of people throughout the world do not have access to clean water for domestic purposes. In many parts of the world conventional piped water is either absent, unreliable or too expensive. One of the biggest challenges of the 21st century is to overcome the growing water shortage. Rain Water Harvesting (RWH) has thus regained its importance as a valuable alternative or supplementary water resource, along with more conventional water supply technologies. Water shortages can be relieved if rain water harvesting is practiced more widely.

Need for Rain Water Harvesting

- To overcome the situation of inadequacy of water supply.

- The most economical way to increase the ground water table.

- To replenish the sub soil of the urban area covered with pavements.

- To recharge the underground water table at places where the availability of rain water is higher or to overcome the situation of water logging.

- Rain water harvesting also improves the quality of underground water through a process called dilution.

- To get water for irrigation of greenbelts, farms, gardens, etc.

Rain Water Harvesting Techniques

- There are two main techniques of rain water harvestings:

- Storage of rain water on surface for future use. Recharge to ground water.

- The storage of rain water on surface is a traditional technique and structures used were underground tanks, ponds, check dams, weirs, etc. Recharge of ground water is a new concept of rain water harvesting and the structures generally used are: Recharge pits filled with boulders, gravels, and coarse-sand, Wells, Trenches etc.

Environmental Impact Assessment

- Every country strives to progress ahead. One aspect of progress is economic development through manufacturing and trading. Every country builds industries which provide employment, serve the consumers needs and help to generate revenue. The dominant pattern of development that humankind hasfollowed in recent decades has brought about large scale changes in the earth systems. We are already feeling the impact of these changes upon our health, livelihoods and safety. On the other hand, the fruits of development are not equally distributed. Some countries and some communities have a high standard of living, while others are not able to meet their basic needs.

- Development projects in the past were undertaken without any consideration about their environmental consequences. As a result rivers and lakes have been polluted, air pollution has reached threatening levels and pilling of domestic and industrial wastes has resulted in land degradation. Industrialization and economic growth provided material comforts but at the same time deteriorated the quality of life.

The Objective of EIA

- To identify, predict and evaluate the economic, environmental and social impact of development activities

- To provide information on the environmental consequences for decision making and

- To promote environmentally sound and sustainable development through the identification of appropriate alternatives and mitigation measures.

Steps in the EIA Process

The eight steps of the EIA process:

- Screening**:** First Stage of EIA, which determines whether the proposed project, requires an EIA and if it does, then the level of assessment required.

- **Scoping:** This stage identifies the key impacts that should be investigated. This stage also defines the time limit of the study.

- Impact **analysis:** This stage of EIA identifies and predicts the likely environmental and social impact of the proposed project and evaluates the significance

- Mitigation**:** This step in EIA recommends the actions to reduce and avoid the potential adverse environmental consequences of development activities.

- **Reporting:** This stage presents the result of EIA in a form of a report to the decision-making body and other interested parties.

- **Review of EIA:** It examines the adequacy and effectiveness of the EIA report and provides the information necessary for decision –making.

- **Decision-making**: It decides whether the project is rejected, approved or needs further change.

- **Post monitoring:** This stage comes into play once the project is commissioned. It checks to ensure that the impacts of the project do not exceed the legal standards and implementation of the mitigation measures are in the manner as described in the EIA report.

Environmental Impact Assessment in India

- EIA was introduced in India in 1978, with respect to river valley projects. On 27 January 1994, the Union Ministry of Environment and Forests (MEF), Government of India, under the Environmental (Protection) Act 1986, made Environmental Clearance (EC) mandatory for expansion or modernisation or for setting up new projects listed in Schedule 1 of the notification. Since then there have been 12 amendments made in the EIA notification of 1994. Both central and state authorities share the responsibility of EIA's development and management. EIA is now mandatory for 30 categories of projects, and these projects get Environmental Clearance (EC) only after the EIA requirements are fulfilled.

- The MoEF recently notified new EIA legislation in September 2006. The notification makes it mandatory for all projects to get environment clearance from the central government under the following categories:

  - Industries
  - Mining
  - Thermal power plants
  - River valley projects
  - Infrastructure and CRZ (Coastal Regulation Zone)

➢ Nuclear power projects.

- However, the new legislation has entrusted the decision of clearing projects on the state government depending on the size/ capacity of the project. EIA appraises the environmental health and social implications of planned developmental projects. It thus links environment with development. The goal of EIA is to ensure environmentally safe and sustainable development.

Measures for Promotion of Sustainable Development

- As discussed earlier, the United Nations 17 Sustainable Development Goals and 169 targets are part of the 2030 Agenda for Sustainable Development adopted by 193 Member States at the UN General Assembly Summit in September 2015, and which came into effect on 1 January 2016. These goals are the result of international consultations that brought national governments and millions of citizens from across the globe together to negotiate and adopt the global path to sustainable development for the next 15 year.

- The SDGs and targets will stimulate action in the following critically important areas: poverty, hunger, education, health and well-being, education, gender equality, water and sanitation, energy, economic growth and decent work, infrastructure, industry and innovation, reducing inequalities, sustainable cities, consumption and production, climate action, ecosystems, peace and justice, and partnership. This agenda recognises that it is not enough to focus on economic growth alone but in creating more equal societies, and a safer and more prosperous planet.

Baripada: A hamlet that conserves forest, promotes growth

Baripada, a small hamlet straddling the Maharashtra-Gujarat border, is a collective tribal wisdom which has taken it to the next level. With a population of barely 1,000, the village has not only helped conserve their forest but also meet the United Nations' sustainable development goals, benefiting everyone in the process.

The villagers conserved the forest. And, forest helped in conservation of water. Water enabled agriculture and farming. Farming brought prosperity, which in turn helped improve literacy. And, literacy broadened horizons and led us to total transformation.

Having developed dairy and poultry over the years, the villagers have also evolved a system for marketing their products. This ensured a steady flow of revenue and kept poverty at bay. The villagers share their common land with landless families to ensure 'zero hunger' and 'reduction of inequality'.
Besides, the villagers are game for any experiments involving water, land, forest conservations, biodiversity registration, biogas, solar power, building basic infrastructure through public participation. "Decisions on prohibition, tree plantation were made at the village meeting and immediately implemented. But, to restrict entry of humans and animals in the 445 hectares of village forest was a major task".

Which countries are achieving the UN Sustainable Development Goals fastest?

- The ultimate aim of the Sustainable Development Goals is to end poverty, protect the planet and ensure prosperity for everyone. Each goal has specific targets that need to be met by 2030.

- So how close are countries to meeting them? To find out, non-profit organization Bertelsmann Stiftung and the UN Sustainable Development Solutions Network have created a prototype index that measures their performance.

- Sweden leads the list, followed by Denmark and Finland. Among the G7countries, only Germany and France can be found among the top ten performers. The United States ranks 42nd on the Index, while Russia and China rank 62nd and 71st respectively. Also in the top 20 were Canada (13th), the Czech Republic (15th) and Slovenia (17th). Asia-Pacific's top performers Japan, Singapore and Australia rounded off the list at 18th, 19th and 20th, respectively. The SDG Index underlines that despite achieving high percentages, all countries still have their work cut out to close the remaining gap.

- India ranks 116 out of 157 nations on a global index that assesses the performance of countries towards achieving the ambitious sustainable development goals (SDGs).

INDUS VALLY CIVILIZATION

6th Term I
Unit -1
What is history?

History is the study of past events in chronological order

- We understand the period and lifestyles of people of Old Stone Age from used stone tools, like what you understand about your grandpa and his time from his diary writing.

- What are the other sources that help us understand the lifestyles of Stone Age people?

- We came to know their hunting style through their paintings on the rocks and the walls of the caves

- Rock paintings? It sounds really surprising. Why did they draw these paintings?

Numismatics – The study of Coins
Epigraphy- The study of inscription

- Some would have stayed back, without joining the hunting team. So for their benefit, these pictures could have been drawn. They might have done it as a part of their passtime.

- The period between the use of first stone tools and the invention of writing systems is pre-history. Stone tools, excavated materials and rock paintings are the major sources of pre-history.

Indus Civilization

- Initially, people lived in groups. Then they formed communities out of these groups. Then evolved the societies which in due course become civilisations.

Mighty Emperor Ashoka
The most famous ruler of ancient India was Emperor Ashoka. It was during his period that Buddhism spread to different parts of Asia. Ashoka gave up war after seeing many people grieving death after the Kalinga war. He embraced Buddhism and then devoted his life to spread the message of peace and dharma. His service for the cause of public good was exemplary. He was the first ruler to give up war after victory. He was the first to build hospitals for animals. He was the first to lay roads. Dharma Chakra with 24 spokes in our national flag was taken from the Saranath Pillar of Ashoka.
Even though Emperor Ashoka was great, his greatness had been unknown until 20th

century.The material evidence provided by William Jones, James Prinsep and Alexander Cunningham revealed the greatness of Emperor Ashoka.
Based on these accounts, Charles Allen wrote a book titled The Search for the India's Lost Emperor, which provided a comprehensive account of Ashoka. Many researches made thereafter brought Ashoka's glorious rule to light. These inscriptions were observed on the rocks, SanchiStupa and Saranath Pillar and helped to understand the greatness of Ashoka to the world.

- Now one can understand the importance of historical research. But for the efforts of scholars, the greatness of Emperor Ashoka would not have come to light.

- That is the period between pre history and history

- The period for which records in writing are available but not yet deciphered is called proto history. Today, we are leading a safe life with all modern equipment. But our ancestors did not live in such a safe environment. There might have been chances of wild animals entering their caves. But, they realised that dogs could help them prevent the entry of such dangerous animals by its sniffing skill. Hence they started domesticating dogs for their protection and hunting activities.

- We also know how inscriptions, monuments, copper plates, accounts of foreigners or foreign travellers and folk tales play a vital role in constructing and reconstructing history.

'Dhamma' is the prakrit word for the sanskrit term 'dharma', which means religious duty.

6^{th} term I
Unit -2 Human Evolution

The story of human evolution can be scientifically studied with the help of archaeology and anthropology

- They pushed the button to 1950 CE. They saw mostly people walking, a few riding bicycles and buses appearing rarely on the roads. Slowly they moved back to 1850. There were no buses or cycles. Carts pulled by mules and bullocks were seen on the roads. Horse-drawn cart was a rare occurrence.

- Then turned the button to 8,000 years back. People were engaged in raising crops and livestock. She pushed the button to get a picture of life 18,000 years ago. She saw the humans living in caves. They were using tools made of stones and bones for hunting was frightened by the hunting scene and pushed the button forward to return to the present.

- Anthropologists have unearthed the footprints of humans in a country called Tanzania, which is in eastern Africa. They were found in rock beds submerged under the sand.

Archaeology is the study of pre historic humans remained materials used by pre historic humans. Excavated material remains are the main source for archaeological studies

Anthropology is the study of humans and evolutionary history.
The word anthropology is derived from two Greek words: anthropos meaning "man" or "human"; and logos, meaning "thought" or "reason." Anthropologists attempt, by investigating the whole range of human development and behavior, to achieve a total description of cultural and social phenomena.

- Radio carbon dating was used to ascertain the period. It was found out that the foot prints of humans they had discovered were about 3.5 millions years old. When there is sudden change in nature, the living beings adapt themselves to the changes and survive. Humans have thus evolved over millions of years adapting themselves to the changing times.

People and their Habitat
Australopithecus - East Africa
Homohabilis-South Africa
Homoerectus - Africa and Asia
Neanderthal - Eurasia (Europe and Asia)
Cro-Magnons - France
Peking -China
Homo sapiens - Africa
Heidelbergs- London

Cromagnons learned to live in caves.Lascaus caves in France is the evidence for cave living of Cromagnons. They habitude to bury the dead

- Human evolution means the process through which the humankind changes and develops towards an advanced stage of life.

- `Homo sapiens who migrated out of eastern Africa settled in different parts of the world. Their lifestyle also evolved and they made it suitable to the environs in which they lived. So humans in different places adopted different forms of lifestyle. Based on the weather, climate and nature of the living place, their physique and complexion also differed. This resulted in the formation of different races. Human procreation resulted in an increase in the population.

Hunting and Food Gathering

- Millions of years ago, our ancestors led a nomadic life. They lived in groups in a cave or a mountain range. Each group consisted of 30 to 40 people. They kept on moving in search of food. They hunted pig, deer, bison, rhino, elephant and bear for food. They also scavenged the animals killed by other wild animals like tiger. They learnt the art of fishing. They collected honey frombeehives, plucked fruits from the trees and dug out tubers from the ground. They also collected grains from the forest. Once the food resource got exhausted in one area, they moved to another place in search of food. They wore hides of animals and barks of trees and leaves for protecting their bodies during winter. So humans began hunting to satisfy their need for food.

- Hunting was the main occupation of humans in the past. It was difficult for humans to kill a big animal with a stick or a stone. So they decided to use sharpened weapons.

- The best stone for the making weapons was chikki – mukkikal (flint). It is known for its strength and durability. Humans spent many hours in search of a flint stone. They made sharp weapons and tools with the help of the stones and fitted them with wood to grip them. Humans created tools like axes with big stones.

- The axes were made to cut trees, remove barks, dig pits, hunt animals and remove the skin of animals.

- Humans discovered the use of fire.

Even today in the villages of Nilgiris district in Tamil Nadu, people have the habit of making fire without use of match box.

- At first, humans were afraid of fire and lightning. Probably fire caused by lightning had killed many wild animals. Humans tasted the flesh of the killed animals, which was soft and tasty. This made humans aware of the effect of fire. They used flint stone to make fire and used it to protect them from predators, for cooking food and for creating light during night. Thus fire became important for man in olden times.

- The next human invention was the wheel. This was the first scientific invention of humans using their brain and cognitive skills

Invention of the Wheel

- The invention of wheel by humans is considered to be the foremost invention. When humans saw the stones rolling down from the mountains, probably they would have got the idea of making the wheel.

Pot Making

- Humans learned to make pot with clay. The invention of wheel made pot making easier, and the pots made were burnt to make it stronger. They decorated pots with lot of colours. The colour dyes were made from the extracts of roots, leaves or barks. These natural dyes were used in rock paintings.

Hunting scene in which men and women are taking part

- In fact, it is the first art of humanity. Before the use of language, humans expressed their feelings through actions and also recorded it in rock paintings.

Ancient Rock Paintings

- In India, we can see many paintings in rocks and caves. The rock paintings give some information about the past. Approximately there are 750 caves, in which 500 caves have paintings. There are many more undiscovered caves. The rock paintings depict hunting pictures of the male and the female, dancing pictures and pictures of children playing.

- We are able to gain some knowledge about the past lifestyle through these paintings.

- These rock and cave paintings tell us many stories about our ancestors.

- There were many dangers involved in hunting. Due to large-scale hunting in the mountain areas and in the forests, many animals became extinct. Non availability of meat forced the humans to look for fruits and vegetables for food.

- The seed of fruits and the nuts they ate were thrown into the soil. During rains, the soil gave it life. Some days later, the saplings sprouted from the soil. By observation and logic, they learn that:

- a plant grows from a single seed and yields lots of fruits and vegetables.

- seeds that fall in the river beds sprout easily.
- plants grow faster in water fed areas.
- alluvial soil is more suitable for plant growth than any other.

- With the above knowledge they gained, they realised that with proper sowing and nurturing, they could increase the number of plants more than the ones that grew naturally. Thus agriculture and farming came into existence. They domesticated theanimals and used them in their farming.

- Breeding of animals now became an important part of their life. Oxen were used for ploughing. Oxen made the practice of agriculture easier. Life was becoming organised than it was, when they were hunting. It enabled them to settle down in a place. Now with settlement came the problem of utensils and vessels for cooking and storage. The potter's wheel and fire solved this problem.

- The invention of plough helped the farming practices. Farming started with the clearing of land and burning the left-over shrubs. They ploughed the land, sowed seeds in them and harvested the produce. Once the fertility of the soil decreased, they moved to a new place. Initially agriculture was done for immediate food requirement. Later when they found out ways to increase production, they started storing the produce. The food products stored were used during the lean harvest periods. By their experience, they understood that land close to the river side was suitable for farming. So they decided to stay there permanently.

- Humans thought of ways to better their skills at hunting. They found out that the dogs could sniff other animals and chase them away. So humans found them useful for hunting. Thus dogs became the first animal to be domesticated by humans. Following the dogs, they started domesticating hen, goat and cow.

- Humans stayed on the plains for a long time. During this period, they have not only learnt agriculture, but slowly developed skills of handicraft. Permanent settlement in a place increased the yield of crops. Now they had grains in excess of what they consumed. The surplus grains were exchanged with other groups for the other things they were in need of. This is called the barter system. Thus trade and commerce developed and towns and cities emerged.

6th term 1
Unit - 3 Indus Civilization

Why did people settle near rivers?

People preferred to settle near the rivers for the reasons given below.

- The soil is fertile.
- Fresh water is available for drinking, watering livestock and irrigation.
- Easy movement of people and goods is possible.

Discovery of a lost city – Harappa

- The ruins of Harappa were first described by the British East India Company soldier and explorer Charles Masson in his book. When he visited the North-West Frontier Province which is now in Pakistan, he came across some mysterious brick mounds. He wrote that he saw a "ruined brick castle with very high walls and towers built on a hill". This was the earliest historical record of the existence of Harappa.

- In 1856 when engineers laid a railway line connecting Lahore to Karachi, they discovered more burnt bricks. Without understanding their significance, they used the bricks for laying the rail road.

- In the 1920s archaeologists began to excavate the cities of Harappa and Mohenjo-Daro. They unearthed the remains of these long-forgotten cities. In 1924 the Director General of ASI, Sir John Marshall, found many common features between Harappa and Mohenjo-Daro. He concluded that they were part of a large civilization.

- Some slight differences are found in the earthenwares of Harappa and Mohenjo-Daro. This made the researchers conclude that Harappa was older than Mohenjo-Daro.

The Archaeological Survey of India (ASI) was started in 1861 with Alexander Cunningham as Surveyor. Its headquarters is located in New Delhi.

How do archaeologists explore a lost city?

- ✓ Archaeologists study the physical objects such as bricks, stones or bits of broken pottery (sherds) to ascertain the location of the city and time that it belong to.
- ✓ They search the ancient literary sources for references about the place.
- ✓ They look at aerial photographs of the excavation sites or cities to understand the topography.
- ✓ To see under the ground, they may use a magnetic scanner
- ✓ The presence and absence of archeological remains can be detected by RADAR and Remote Sensing Methods.

Sites in Indian borders

- Archaeologists found major Harappan sites within Indian borders

Time Span of Indus Civilisation

Geographical range: South Asia
Period: Bronze Age
Time: 3300 to1900 BCE (determined using the radiocarbon dating method)
Area: 13 lakh sq.km
Cities: 6 big cities
Villages: More than 200

Urban Civilisation

Harappan civilisation is said to be urban because of the following reasons

- Well-conceived town planning
- Astonishing masonry and architecture
- Priority for hygiene and public health
- Standardised weights and measures
- Solid agricultural and artisanal base.

Unique Features of Harappan Civilisation

- Town planning is a unique feature of the Indus Civilisation. The Harappan city had two planned areas.

Mehergarh – the Precursor to Indus Civilisation
Mehergarh is a Neolithic site. It is located near the Bolan Basin of Balochistan in Pakistan. It is one of the earliest sites known. It shows evidence of farming and herding done by man in very early times. Archaeological evidence suggests that Neolithic culture existed in Mehergarh as early as 7000 BCE

Streets and Houses

- The streets are observed to have a grid pattern. They were straight running from north to south and east to west and intersected each other at right angles

- The roads were wide with rounded corners

- Houses were built on both sides of the street. The houses were either one or two storeys

- Most of the houses had many rooms, a courtyard and a well. Each house had toilets and bathrooms

- The houses were built using baked bricks and mortar. Sun-dried bricks were also used. Most of the bricks were of uniform size. Roofs were flat
- There is no conclusive evidence of the presense of palaces or places of worship.

why burnt bricks are used in construction?
They are strong, hard, durable, resistant to fire and will not dissolve in water or rain.

Bronze Age
It is a historical period characterised by the use of articles made of bronze

Drainage System

- Many of these cities had covered drains. The drains were covered with slabs or bricks.
- Each drain had a gentle slope so that water could flow.
- Holes were provided at regular intervals to clear the drains.
- House drains passed below many lanes before finally emptying into the main drains.
- Every house had its own soak pit, which collected all the sediments and allowed only the water to flow into the street drain.

The Great Bath

- The great bath was a large, rectangular tank in a courtyard. It may be the earliest example of a water-proof structure
- The bath was lined with bricks, coated with plaster and made water-tight using layers of natural bitumen
- There were steps on the north and south leading into the tank. There were rooms on three sides
- Water was drawn from the well located in the courtyard and drained out after use.

The Great Granary

- The granary was a massive building with a solid brick foundation
- Granaries were used to store food grain
- The remains of wheat, barley, millets, sesame and pulses have been found there.

A granary with walls made of mud bricks, which are still in a good condition, has been discovered in Rakhigarhi, a village in Haryana, belonging to Mature Harappan Phase

The Assembly Hall

- The Assembly Hall was another huge public building at Mohenjo-Daro. It was a multi-pillared hall (20 pillars in 4 rows to support the roof).

Trade and Transport

- Harappans were great traders.
- Standardised weights and measures were used by them. They used sticks with marks to measure length
- They used carts with spokeless solid wheels
- There is evidence for extensive maritime trade with Mesopotamia. Indus Seals have been found as far as Mesopotamia (Sumer) which are modern-day Iraq, Kuwait and parts of Syria
- King Naram-Sin of Akkadian Empire (Sumerian) has written about buying jewellery from the land of Melukha (a region of the Indus Valley)
- Cylindrical seals similar to those found in Persian Gulf and Mesopotamia have also been found in the Indus area. This shows the trade links between these two areas.

A naval dockyard has been discovered in Lothal in Gujarat. It shows the maritime activities of the Indus people.

Dockyard at Lothal

Lothal is situated on the banks of a tributary of Sabarmati river in Gujarat.

Leader in Mohenjo-Daro

- A sculpture of a seated male has been unearthed in a building, with a head band on the forehead and a smaller ornament on the right upper arm.
- His hair is carefully combed, and beard finely trimmed.
- Two holes beneath the ears suggest that the head ornament might have been attached till the ear.
- The left shoulder is covered with a shawl-like garment decorated with designs of flowers and rings.
- This shawl pattern is used by people even today in those areas

Technology

- Indus people had developed a system of standardised weights and measures.

- Ivory scale found in Lothal in Gujarat is 1704mm (the smallest division ever recorded on a scale of other contemporary civilisations).

The word ‘civilisation’ comes from the ancient Latin word civis, which means ‘city’.

This little statue was found at Mohenjo-Daro. When Sir John Marshall saw the statuette known as the dancing girl, he said, “When I first saw them I found it difficult to believe that they were pre-historic modeling. Such as this was unknown in the ancient worlds up to the age of Greece. I thought that these figures had found their way into levels some 3000 years old to which they properly belonged”.

KVT Complex (Korkai-Vanji-Thondi) spread over Afghanistan and Pakistan has many places, names of those were mentioned in sangam literature.
Korkai, Vanji, Tondi, Matrai, Urai and Kudalgarh are the names of places in Pakistan.
Gurkay and Pumpuhar in Afghanistan are related to the cities and ports mentioned in the Sangam Age. The names of the rivers Kawri and Poruns in Afghanistan and the rivers KaweriWala and Phornai in Pakistan also occur in the Sangam literature.

Do you know The hidden treasures of the Indus civilisation

- Inscriptions (written in a script of those times) can provide us information about customs, practices and other aspects of any place or time. So far, the Indus script has not been deciphered. Therefore, we must look for other clues to know about the Indus people and their lifestyle

Apparel

- Cotton fabrics were in common use.
- Clay spindles unearthed suggest that yarn was spun.
- Wool was also used.

Love and peace

- Settlements were built on giant platforms and elevated grounds
- The Indus Civilisation seems to have been a peaceful one. Few weapons were found and there is no evidence of an army
- They displayed their status with garments and precious jewellery
- They had an advanced civic sense.

Ornaments

- Ornaments were popular among men and women
- They adorned themselves with necklaces, armlets, bangles, finger rings, ear studs and anklets.
- The ornaments were made of gold, silver, ivory, shell, copper, terracotta and precious stones.

Iron was unknown to people of Indus

Copper was the first metal discovered and used by humans

Indus people used the red quartz stone called Carnelian to design jewellery.

Who Governed them?

- Historians believe that there existed a central authority that controlled planning of towns and overseas trade, maintenance of drainage and peace in the city.

Occupation

- The main occupation of the Indus Civilisation people is not known.
- However, agriculture, handicrafts, pottery making, jewellery making, weaving, carpentry and trading were practiced
- There were merchants, traders and artisans.
- Rearing of cattle was another occupation.
- People of those times knew how to use the potter's wheel
- They reared domesticated animals.

Pottery

- Pottery was practiced using the potter's wheel. It was well fired. Potteries were red in colour with beautiful designs in black.
- The broken pieces of pottery have animal figures and geometric designs on it.

Religious Belief

- We don't have any evidence pointing to specific deities or their religious practices. There might have been worship of Mother Goddess (which symbolized fertility), which is concluded based upon the excavation of several female figurines.

Toy Culture

Toys like carts, cows with movable heads and limbs, clay balls, tiny doll, a small clay monkey, terracotta squirrels eating a nut, clay dogs and male dancer have been found.

They made various types of toys using terracotta, which show that they enjoyed playing

The earliest form of writing was developed by Sumerians

What happened to Harappans?

- By 1900 BCE, the Harappan culture had started declining. It is assumed that the civilisation met with

- repeated floods
- ecological changes
- invasions
- natural calamity
- climatic changes
- deforestation
- an epidemic

Archaeological site at Mohenjo-Daro has been declared as a World Heritage Site by UNESCO

Radiocarbon Dating Method: A Standard Tool for Archaeologists

Also known as C14 method, the radiocarbon method uses the radioactive isotope of carbon called carbon14 to determine the age of an object.

General Facts about Indus Civilisation

- It is among the oldest in the world.
- It is also the largest among four ancient civilisations
- The world's first planned cities are found in this civilisation
- The Indus also had advanced sanitation and drainage system
- There was a high sense of awareness on public health.

9th Book

Evolution of Humans and Society – Pre Historic Period

- Prehistoric people were the pioneers of creative knowledge. From the artefacts and the languages they developed, we are able to understand how intelligent they were.

Origin of the Earth and the Geological Ages

- The history of humans is closely related to the history of the earth. The earth contains geological, archaeological and biological records of historical times in its upper layers. They are important for reconstructing the history of the earth and various living organisms. The fossil bones of the human ancestors are embedded in the earth's layers.

- Palaeoanthropologists and archaeologists excavate the soil and rock layers on the earth and extract evidence about human ancestors. These layers and the fossils are scientifically dated to study the various stages in human evolution and prehistory. Through the gathered evidence, they attempt to understand the evolution of human history and developments in a chronological order.

- Archaeology is the study of human past through the analysis and interpretation of material remains.

- Palaeoanthropology is the study of the human ancestors and their evolution by the study of the fossil remains.

- The earth was formed approximately 4.54 billion years ago. Gradually, conditions emerged for the growth of organisms. Then plants and animals came into being, and thereby foundation was laid for the evolution of humans. The long span of time in the history of earth is divided into eras, periods and epochs by the geologists

1 billion = 100 crore
1 million = 10 lakh

- Australopithecines were the apes from which modern humans evolved. Now they are extinct, but they are considered to be the close relatives of humans.

Human Enquiries into the Past and Origin of the World

The Age of Speculation

- Humans are the only species on earth concerned with understanding as well as explaining the world and the universe. In the course of evolution, humans became conscious and knowledgeable. They turned curious and began to think and ask questions about nature, organisms and the world around them. At first, they considered nature as

God. They worshipped sun, moon and various natural forces about which they developed their own understanding, some of which is not scientific. The lack of scientific knowledge on the creation of the world is reflected in the ancient writings and religious literature.

BC (BCE) – Before Common Era
AD (CE) - Common Era

Scientific Foundations of Geology, Biology and Archaeology

- The beginning of history writing can be traced to the ancient Greeks. Herodotus (484–425 BC (BCE)) is considered the Father of History, because the history he wrote was humanistic and rationalistic.The rise of scientific enquiry into the origin of humans was possible because of

➢ The interest in collection of archaeological remains and the opening of museums after the Renaissance Movement;
➢ The development of ideas of stratigraphy and geology;
➢ Darwin's theory of biological evolution;
➢ The discovery of human and animal fossils, stone tools, and artefacts of early civilizations; and
➢ The ability to decipher early scripts

- **Stratigraphy** – The study of origin, nature and relationships of rock and soil layers that were formed due to natural and cultural activities.

- Oldest Museum – The museum of Ennigaldi- Nanna in Mesopotamia was established in 530 BC (BCE). The Princess Ennigaldi was the daughter of the neo-Babylonian king Nabonidus.The Capitoline Museum in Italy is perhaps the oldest surviving museum (1471 AD (CE)) at present. Ashmolean Museum at Oxford University is the oldest university museum in the world. It was established in 1677 AD (CE)

- Herbert Spencer's (1820–1903 AD (CE)) biological evolution, and Charles Darwin's (1809–1882 AD (CE)) theory on concepts of natural selection and survival of the fittest contributed to the scientific understanding of human origins. Charles Darwin published the books On the Origin of Species in 1859 and The Descent of Man in 1871.

Natural selection – The process by which organisms that are better adapted to their environment would survive and produce more offspring.

Survival of the fittest means "survival of the form that will leave the most copies of itself in successive generations."

Fossil – Prehistoric animal or plant that turns into stone over a period of time (millions of years) because of chemical and physical processes. Animal bones are preserved due to mineralization. Palaeontology is the study of fossils.

Stone Age – the period when stone was mainly used for making implements.

Bronze Age – the period when bronze metallurgy (extraction of metal from ores) developed.

Iron Age – the period when iron was smelted to produce implements.

- Since the 19th century, scholars have used advanced scientific techniques. They undertook systematic studies to contribute to the current state of knowledge on prehistory,human origins and the early civilisations. Now the theory of human evolution is widely accepted.

Prehistory: From Australopithecus through Homo erectus to Homo sapiens

- The chimpanzee, gorillas and orangutans, along with humans, are collectively called the Great Apes. Among them, the chimpanzee is genetically the closest to humans.

- The ancestors to humans were called Hominins, and their origins have been traced in Africa. They evolved from those origins and then began to move to other parts of the world in due course of time. The Hominins emerged around 7 to 5 million years ago. Skeletons of Australopithecus, one of the early species of this tribe, have been found in Africa.

- The Great Rift Valley in Africa has many sites that have evidence for the prehistoric period.

The DNA of a chimpanzee is 98% identical to that of a human being

- The Great Rift Valley is a valley-like formation that runs for about 6,400 km from the northern part of Syria to Central Mozambique in East Africa. This geographical feature is visible even from the space, and many prehistoric sites are found in eastern Africa.

- Human ancestors are divided into various species according to their physical features.

Hominid refers to all the species of the modern and extinct great apes, which also includes humans.

Hominins (a zoological tribe) refers to the close relatives of human ancestors and their sister species including Homo sapiens (the modern humans) and the extinct members of Homo neanderthalensis, Homo erectus, Homo habilis and various species of Australopithecines. Humans are the only living species of this 'tribe'. They stand erect, walk with two legs and have large brains. They can use tools and a few of them can communicate. It excludes the gorillas.

- Homo habilis (handy human) was the earliest known human ancestors to make tools in Africa about 2.6 million years ago. Around 2 million years ago, the species of Homo erectus/ergaster emerged. This species made hand axes between 2 and 1 million years ago. They began to spread into various parts of Asia and Africa in time.

- Anatomically, modern humans, called Homo sapiens (wise man), first appeared around 3,00,000 years ago in Africa. It is believed that these modern humans eventually migrated and dispersed into various parts of the world from around 60,000 years ago.

Prehistoric Cultures

- Prehistoric period does not have evidence of writing. While the fossil bones are classified as various species such as Homo habilis, Homo erectus and Neanderthalensis, based on the lithic tools, cultures are assigned names such as Earliest Lithic Assemblages, Oldowan Technology, Lower, Middle and Upper Paleolithic and Mesolithic cultures.

The chimpanzee and the pygmy chimpanzee (also known as bonbo) are our closest living relatives.

Earliest Lithic Assemblages of Human Ancestors

- The earliest tools made by human ancestors are found in Lomekwi in Kenya. They are dated to 3.3 million years. Oldowan tools occur in the Olduvai gorge in Africa. They are 2 to 2.6 million years old. The human ancestors (Australopithecines) used hammer stones and produced sharp-edged flakes. The tools were used for cutting, slicing and processing food.

Lower Paleolithic Culture

- The Lower Paleolithic Culture is marked by the human ancestors belonging to the species Homo habilis and Homo erectus. The human ancestors flaked large stone blocks and designed various tools including hand axes. These tools, which are found in Africa, Asia, and Europe, are dated the earliest to about 1.8 million years ago. They made various tools such as hand axes and cleavers to meet their subsistence needs. These tools are also known as bifaces. These tools have physical symmetry and convey the humans' cognitive (perception) skills. This culture is called the Lower Paleolithic Culture. The hand axe tools are also known as Acheulian. This tool-making tradition continued till 250,000 years to 60,000 years ago in India.

Acheulian – They were first hand axes recognized at a place called St. Acheul in France. Hence they are called Acheulian tools.

Bifaces are tools that have flaking on both sides (bi = two, face = side).

- Subsistence **necessities** of prehistoric humans were mainly food and water.

- The human ancestors perhaps did not possess complex language skills as we have now. They might have voiced a few sounds or words and possibly used sign language.

They were intelligent enough to select stones as raw material and used the hammer stones to carefully flake the rocks and design tools for their needs. They hunted animals, fed on the meat of the animals killed by predators and gathered plant foods such as roots, nuts and fruits. In India, the Acheulian tools have been found near Chennai and many other sites such as Isampur in Karnataka and Bhimbetka in Madhya Pradesh.

- Raw material is the naturally available stone block or pebbles selected by humans for making tools. Since these stones produced flakes with sharp edges, they were selected for making stone tools.

- **Core** is the main block of stone from which small chips are flaked by using a hammer stone.

- **Flake** is a small chip removed from a large stone block called the core.

Middle Paleolithic Culture

- After about 3,98,000 years BC (BCE), further changes took place in the lithic technology in Africa. The Homo erectus species existed during this period. Anatomically modern humans are said to have emerged around 3 lakh years ago.

Lithic Technology: 'Lith' means stone. The methods and techniques involved in the production of stone tools are called Lithic technology.

- The hand axes turned out to be much attractive in design and many smaller tools were also produced. The core was prepared and then tools were made. Points and scrapers were used. Short blades were also produced. The lithic tool-making tradition of the Levalloisian belonged to this period. The tools made during this time are found in Europe and Central and western Asia.

- **Levalloisian** tools are the implements made after preparing the core. It was named after the town of Levallois in France.

- The Middle Paleolithic Culture appeared between 3,85,000 and 1,98,000 years BC (BCE) ago in Europe and parts of western and South Asia. The tools that were made during this period were in use till about 28,000 BC (BCE).

- The people of this period were called Neanderthals. They buried the dead people systematically. Perhaps they were the first human ancestors to mourn death properly and bury the dead.

Upper Paleolithic Culture

The cultural phase that succeeded the Middle Paleolithic is called the Upper Paleolithic phase. This period was marked by innovation in tool technology. Long blades and burins were produced during this time. People used different varieties of silica- rich raw materials in this phase. Numerous paintings and art objects were made. The diversity of artefacts suggests the improvement in cognitive skills and the development of languages. Microliths appeared in this phase.

Burin is a stone-made chisel with a sharp cutting edge

- The modern humans, who first appeared as a result of human evolution in the sub-Saharan Africa 300,000 years ago, began to move to various parts of Asia around 60,000 years ago. They probably replaced the earlier populations. In Europe, humans known as Cro-Magnons lived in this period.

- Horns and ivory were used for making tools and art works. Bone needles, fishhooks, harpoons and spears were also employed creatively. The humans of this time wore clothes and cooked food. The dead were placed in the burials with folded hands placed over their chest. Pendants and richly carved tools were also seen in use. Evidences from paintings, clay model sculptures and carvings are available. Images of Goddess Venus made up of stones and bones in Europe and in some parts of Asia.

Ice Age – the period before 8,000 BC (BCE) when many parts of the world remained covered by ice sheets and snow

Mesolithic Culture

- Mesolithic period is known as the Middle Stone Age, as it is placed between the Paleolithic and Neolithic periods. People mainly used microlithic (small stone) tools during this period. These people were hunter- gatherers. With the global warming occurring after the Ice Age, they became highly mobile and occupied various eco-zones.

- People of Mesolithic period widely employed microlithic technology. They made tiny artefacts that were less than 5 cm in size. They produced points, scrapers and arrowheads. They also used geometric tools such as lunates, triangles and trapezes. These tools were hafted onto wooden or bone handles and used.

Microliths are stone artefacts of small size.

Neolithic Culture and the Beginning of Agriculture

- The period called Neolithic marks the beginning of agriculture and animal domestication. It is an important phase in history. Early evidence of the Neolithic period is found in the fertile crescent region of Egypt and Mesopotamia, the Indus region, the Gangetic valley and in China. By about 10,000 BC (BCE) to 5000 BC (BCE), agriculture had come to be practised in these regions.

Wheat, barley and peas were cultivated around 10,000 years ago. Fruit and nut trees were cultivated around 4,000 BC (BCE). They comprised olives, figs, dates, pomegranates and grapes.

- Fertile **Crescent Region** refers to the area covering Egypt, Israel-Palestine and Iraq, which is in the shape of crescent moon.

- Neolithic Age is called the 'new age', because of the new grinding and polishing techniques used for the tools. The Neolithic people also used the flaked stone tools. Until the Mesolithic period, people mainly hunted and gathered food for their subsistence. By hunting and gathering people obtained very limited food as a result of which only a small number of people could exist in a particular region.

- The introduction of domestication of animals and cultivating plants at home led to production and supply of large quantities of grains and animal food. The fertile soil deposited by the river on its banks helped the growth of agriculture. People preferred to live on river banks as it was better for adaptation. As a result of domestication and cultivating plants, there was an excess food production. The surplus food production was a main factor for the development of early civilisations. Permanent residences were built and large villages emerged as a result. Hence, the development of this period is called Neolithic Revolution.

Prehistoric Tamilagam

Lower Paleolithic Culture in Tamil Nadu

- One of the oldest Stone Age tools in the world made by human ancestors, calledhominins, had been produced in Tamil Nadu. These stone tools are found near the Chennai region at several sites, especially at Athirampakkam. The archaeological excavations at this site and cosmic-ray exposure dating of the artefacts suggest that people lived here about 1.5 to 2 million years ago. The Kosasthalaiyarriver is one of the major cradles of human ancestors in the world. The people who lived here belonged to the species of Homo erectus.

Archaeological excavation refers to digging undertaken to recover archaeological evidence such as stone tools, pottery, animal bones and pollens, in order to understand the past lifestyle of humans.

Cosmic-ray exposure dating – A method in which exposure to cosmogenic rays is done for dating the samples.

- In 1863, Sir Robert Bruce Foote, a geologist from England, first discovered Paleolithic tools at Pallavaram near Chennai. They are the earliest finds of such tools in India. Hence, the hand axe assemblages were considered the Madras Stone Tool Industry. The tools that he discovered are now housed in the Chennai Museum.

- The Paleolithic people hunted wild animals and gathered the naturally available fruits, roots, nuts and leaves. They did not have knowledge of iron and pottery making, which developed much later in history.

- Hand axes and cleavers are the important tool types of the Lower Paleolithic period. These tools fitted with a wooden and bone handle were used for cutting, piercing and digging. The people of this time also used hammer stones and spheroids. The quartzite pebbles and cobbles were chosen as raw materials. The tools are found in the soil deposits and also in the exposed river side. They occur at Pallavaram, Gudiyam cave, Athirampakkam, Vadamadurai, Erumaivettipalayam and Parikulam.

- The Lower Paleolithic tools are also found in the North Arcot and Dharmapuri districts. The people belonging to this period used basalt rocks for manufacturing artefacts. However, the southern part of Tamil Nadu and Sri Lanka do not have evidence of Lower Paleolithic Culture.

Basalt rocks are igneous rocks: Igneous rocks are those formed from the molten lava from the earth.

- The Lower Paleolithic Culture is datable to about 2 - 1.5 million years at Athirampakkam. This cultural phase continued in other parts of India up to 300,000 years ago.

Middle Paleolithic Culture in Tamil Nadu

- In the course of time, the Middle Paleolithic Culture emerged during 3,85,000 - 1,72,000 years ago. The tool types of this period underwent a change and smaller artefacts were used. Cores, flakes, scrapers, knives, borers, Levalloisian flakes, hand axes and cleavers are the artefact types of this period. Compared to the previous phase, these tool types became smaller in size.

- Evidence for the Middle Paleolithic Culture can be observed in some parts of Tamil Nadu. In the southern part of Tamil Nadu, at T. Pudupatti and Sivarakkottai, artefacts of the Middle Paleolithic tools have been collected. Also near Thanjavur and Ariyalur, similar artefacts have been found.

Mesolithic Culture in Tamil Nadu

- In many parts of the world, and in some parts of India, the Upper Paleolithic Culture succeeded the Middle Paleolithic Culture. There is no evidence for the Upper Paleolithic Culture in Tamil Nadu. But the people who used microliths or small-stone artefacts lived in many parts of TamilNadu. Athirampakkam and Gudiyam Cave yielded both Early and Middle Paleolithic artefacts. Since this cultural period occurs between Paleolithic and Neolithic Culture, it is known as Mesolithic Culture or Middle Stone Age.

- Evidence for the existence of Mesolithic hunter-gatherers is found at Chennai, North Arcot, Dharmapuri, Salem, Coimbatore, Ariyalur, Tiruchirappalli, Pudukkottai, Madurai, Sivagangai, Tirunelveli and Kanyakumari. The teri sites near Thoothukudi have evidence of microlithic artefacts. These sites have red sand dunes called teris.

- The people of this period used small artefacts made of chert and quartz. The tool types are scrapers, lunates and triangles. These people hunted wild animals and gathered fruits, nuts and roots for their subsistence.

Scrapers are tools used for scraping the surfaces. Scrapers are similar to the tools used in the kitchen for removing skin of vegetables.

Triangles are tools in the shape of triangles

Lunates are tools in the shape of a crescent.

Neolithic Culture in Tamil Nadu

- The culture that domesticated animals and cultivated crops is called Neolithic. It is known as the New Stone Age. The Neolithic people used polished stone axes called celts. Cattle rearing was their main occupation. They lived in small villages with houses made of thatched roof and walls plastered with

Timeline: The Course of Cultures in Ancient Tamilagam

Culture	Time Period	Cultural Traits
Paleolithic Period	Circa. 20,00,000 years to circa. 8,000 BC (BCE)	Hand axes, cleavers Hunting and gathering
Mesolithic Period	Circa. 8,000 years to circa. 1,300 BC (BCE)	Microlithic tools No knowledge of metal Hunting of animals and birds Gathering of plant food
Neolithic Period	Circa. 2,000 BC (BCE) to 1,000 BC (BCE)	Polished Stone Axes Microliths Domestication of animals Cultivation of crops Multiplicity of groups Co-existence of hunter-gatherers and pastoral groups
Iron Age	Circa. 1,300 BC (BCE) to 500 BC (BCE)	Megalithic burial custom Co-existence of hunter-gatherers and pastoral groups Development of chiefdom Knowledge of iron, black and red ware, black ware ceramics Craft specialisation,

		specialised groups: potters, blacksmiths
Early Historic and Sangam Age	300 BC (BCE) to 300 AD (CE)	Cultural traits of Iron age Monarchies of Chera, Chola and Pandya Development of hero worship Poetic traditions and literature Trade and exchange by sea

clay. Evidence of Neolithic village is found at Payyampalli in Vellore district and a few sites in the Dharmapuri region.

Neolithic people perhaps devised the first pottery. They made pottery, using a slow wheel called turn-table or made pottery out of hand. Before firing, the pottery was polished with pebbles. This process is known as burnishing.

- Payyampalli is a village in Vellore district of Tamil Nadu. The earliest evidence for the domestication of animals and cultivation of plants is found at this site, which was excavated by the Archaeological Survey of India. Evidence for pottery making and cultivation of horse gram and green gram has been found in this village.

Iron Age/Megalithic period

- The cultural period that succeeded the Neolithic is called the Iron Age. As the name suggests, people used iron technology. It preceded the Sangam Age. The Iron Age was a formative period and the foundation for the Sangam Age was laid in this time. During the Iron Age, many parts of Tamil Nadu were occupied by people. An exchange relationship developed among the people.

The people of this age had knowledge of metallurgy and pottery making. They used iron and bronze objects and gold ornaments.

Lemuria and the Tamils

Some researchers relate the origin of the Tamils to the submerged continent of Lemuria. This theory of Lemuria continent was proposed in the 19th century. In the wake of advancements in plate tectonics theory, differing views are put forth by scholars.

The available literary references point to the submergence of areas around Kanyakumari. Some parts of Sri Lanka and Tamil Nadu were connected by land about 5000 years BC (BCE). It is possible that some land might have submerged near Kanyakumari and around the coast of India, because of the rising sea levels. Underwater surveys are necessary in this area.

Archaeological research reveals that at least a section of people may have been living continuously in South India, including Tamil Nadu, from the Mesolithic and Neolithic times.

- They used shell ornaments and beads made of carnelian and quartz. The evidence for Iron Age is found at many sites including Adhichanallur in Thoothukudi district, Sanur near Madhuranthakam and Sithannavasal near Pudukkottai. Megalithic burial sites are found in the whole of Tamil Nadu.

Megalithic Burial Types

- The Iron Age is also known as megalithic, since people created burials with large stones for the dead people. Within these burials, the skeletons or a few bones of the dead persons were placed along with grave goods including iron objects, carnelian beads and bronze objects. Some of the burials do not have human bones and they have only the grave goods. They may be called memorial burials.

- **Grave goods** are the objects placed in the burials along with the physical remains (bones) of the dead. People may have believed that these would be useful in the after-life. Egyptian pyramids also have similar artefacts.

- Similar burials were also built in the early historic period or the Sangam Age. The Sangam literature mentions the various burial practices of the people. The megalithic burials are classified as dolmens, cists, menhirs, rock-cut caves, urn burials and sarcophagus. The burial types of Kodakkal (umbrella stone), Toppikkal (hatstone) and Paththikal (hoodstone) are found in Kerala.

- Dolmens, table-like stone structures, were erected as funerary monuments. Cists are stone enclosures buried under the earth. They were created by placing four stone slabs on the sides, one on top of each other. The cists and dolmens have openings called portholes. Urns are pottery jars and were used for burying the dead. Sarcophagi are burial receptacles made of terracotta. They sometimes had multiple legs. Menhirs are pillar-like stones erected as part of the burials or memorials.

- Portholes are holes found in the cists and dolmens on one side. They may have acted as the entrance to the burials. There is a view that they were meant for the movement of the soul or spirit.

- The menhirs may have been erected for the heroes in the Iron Age. The tradition of hero stones might have begun in the Iron Age or even before.

Agriculture and Pastoralism

- The people in the Iron Age practiced agriculture, domesticated cattle and sheep, and some of the groups were still hunting and gathering. Millets and rice were cultivated. Irrigation management developed in this period, since many of the megalithic sites are found nearby rivers and tanks. In the deltaic regions, irrigation as a technology had developed. Evidence of rice is seen in the megalithic sites like Adhichanallur in Thoothukudi district and Porunthal near Palani.

Iron Age Society and Polity

- The Iron Age society had farming communities, pastoralists and hunter-gatherers. Craft specialists, potters and blacksmiths were the professionals during this period. The society had several groups of peoples (tribes). The size of the burials and the variations found in the burial goods suggests the existence of numerous social groups and their diverse practices. Some of them seem to have had organised chiefdoms. Cattle lifting leading to wars and encroachment and expansion of territories had also started taking place in this period.

Pottery

- Pottery is an important evidence found in the archaeological sites. The Iron Age and Sangam age people used the black and red colours to make black ware and red ware pottery. Potteries were used for cooking, storage and dining purposes. The black and red ware pottery has a black inside and a red outside, with lustrous surfaces.

Iron Technology and Metal Tools

- The megalithic burials have abundant iron objects placed in the burials as grave goods. Weapons such as swords and daggers, axes, chisels, lamps and tripod stands are also found. Some of these objects were hafted to wooden or bone or horn handles and used. The iron tools were used for agriculture, hunting, gathering and in battles. Bronze bowls, vessels with stylish finials decorated with animals and birds, bronze mirrors and bells have also been found.

9th book
Unit – 2 Ancient Civilizations

Introduction

- Societies that adopted complex ways of life were more organised than the early hunter-gatherer and Neolithic farming societies. Urban societies had social stratification and well-planned cities. They practised crafts, engaged in trade and exchange, adopted science and technology and formed political organisation (early form of state). Hence the term 'civilisation' is used to distinguish them from the early forms of societies. However, they should not be considered superior to other forms of societies, since each culture or civilisation had its own unique features.

Ancient Civilisations

- Civilisation is seen as an advanced, organised way of life. It instilled a way of life that could be considered as an adaptation to particular environmental and cultural contexts. When it became necessary for large numbers of people to live in close proximity, they brought in planning, organisation and specialisation. Settlements were planned and laid out, a polity emerged, society became organised and food production and craft production were regulated. As civilisations began to take shape, huge buildings were built, the art of writing developed and science and technology contributed to the betterment of society.

- The Egyptian, the Mesopotamian, the Chinese and the Indus were the important early civilisations. While these civilisations flourished in certain regions, people in other parts of the world lived as hunters-gatherers and pastoralists. The hunters-gatherers and pastoralists maintained their relationships with these civilisations through interactions. Their history is also equally important. During the time of these civilisations, South India witnessed theemergence of Neolithic agro-pastoral communities and Microlithic form of life by hunter-gatherers.

The Egyptian Civilisation

As one of the oldest civilisations, the Egyptian civilisation is known for its monumental architecture, agriculture, arts, sciences and crafts at a very early age.

Geography

- Egypt lies in the north-eastern corner of the African continent. It is bounded by the Red Sea on the east and Mediterranean Sea in the north. Egypt is irrigated by the River Nile,which originates in Lake Victoria in the south and flows into the Mediterranean Sea in the north. Deserts are seen on both sides of the Nile River. The Egyptian civilisation depended solely upon the flow of Nile River, and hence Egypt was called the Gift of Nile by the Greek historian Herodotus. The Nile also served as a means of transport. The Nile valley is very rich and fertile as the river deposits fresh alluvium every year. This alluvium nurtured agriculture and helped to produce surplus of food grains, leading to the development of Egyptian civilisation. The dry regions on both the sides of the Niles, however remained deserts.

- Egypt became intimately connected with the Sangam Age Tamilagam by the sea route.

- **The Hyksos** were the rulers of the 15th dynasty of Egypt and they were probably from West Asia.

- **Persians** are the people from the region of Persia, the ancient Iran.

- **Greek** refers to the language and people of modern-day State of Greece in **Europe**.

- **Rome** refers to the ancient Roman Empire, which had as its capital the city of Rome in Italy.

Pharaohs, Society and Administration

- The Egyptian king was known as the Pharaoh. The people treated pharaoh as a divineform. Under the pharaoh, there was a hierarchy of officials including viziers, the governors of provinces, local mayors and tax collectors. The entire social system was supported by the work and production of artisans including stone cutters, masons, potters, carpenters, coppersmiths and goldsmiths, peasants and workers. Land belonged to the king and was assigned to the officials. Slavery was not common, but captives were used as slaves.

- Viziers were the high officials who administered territories under the direction of the Pharaohs.

- The Egyptians believed in life after death. Therefore, they preserved the dead body. The art of preserving the dead body is known as mummification. Pyramids and tombs were built to preserve the body of pharaohs.

- The famous Egyptian pharaoh Tutankhamen's (who ruled from 1332 to 1322 BC (BCE)) tomb with a rich variety of offerings is located near Luxor in Egypt. The mask of his mummy made of gold and decorated with precious stones is an important artefact of the Egyptian civilisation.

Agriculture and Trade

- The Egyptians cultivated wheat, barley, millets, vegetables, fruits, papyrus and cotton.

- Papyrus was used for making rope mats sandals and later for producing paper. They domesticated cattle, sheep, goat and pigs, and hunted wild animals. They had pets such as dogs, cats and monkeys. The Egyptians had trade relations with Lebanon, Crete, Phoenicia, Palestine and Syria. Gold, silver and ivory were imported, and they acquired the Lapis Lazuli, a precious stone of bluish colour, from Afghanistan.

Mummies of Egypt
The preserved dead body is called the mummy. The Egyptians had the tradition of preserving the dead bodies using Natron salt, a combination of sodium carbonate and sodium bicarbonate. The preservation process is called mummification. After 40 days, when the salt absorbed all the moisture, the body was filled with sawdust and wrapped with strips of linen cloth and covered with a fabric. The body was stored in a stone coffin called sarcophagus

Art and Architecture

- The Egyptians excelled in art and architecture. Their writing is also a form of art. Numerous sculptures, painting and carvings attest to the artistic skills of the Egyptians.

- The pyramids are massive monuments built as tombs of mourning to the Pharaohs. The great pyramids near Cairo are known as the Giza Pyramids.

- **The Great** Sphinx **of Giza** is a massive limestone image of a lion with a human head. It is dated to the time of Pharaoh Khafre. It is one of the largest sculptures of the world and measures seventy three metres in length and twenty metres in height.

Religion

- The Egyptians practiced polytheism. Amon, Re, Seth, Thoth, Horus and Anubis are some of the Gods of Egyptians. They worshipped many Gods, but the Sun God, Re, was the predominant one. Later on, the Sun God was called Amon.

Philosophy, Science and Literature

- The Egyptian civilisation excelled in science, literature, philosophy, astronomy, mathematics and the measurement system. Sundial, water clock and glass were developed by the Egyptians. They devised a solar calendar that consisted of twelve months of thirty days each, with five days added to the end of a year. This calendar was introduced as early as 4200 BC (BCE). Literary works included treatises on mathematics, astronomy, medicine, magic and religion. The Egyptians also distinguished themselves in painting, art, sculpture, pottery, music and weaving.

Writing System

- The Egyptians are well known for their writing system. Their form of writing is known as hieroglyphic. Hieroglyphic was used in the inscriptions on seals and other objects. The heretic, an another form of writing, was used for common purposes. This form of writing used a pictogram-based system. It was developed around 3000 BC (BCE) and many texts and books were written using this script. Now this inscription is on display in the British Museum, London.

Characteristics and Contributions of the Egyptian Civilisation

- **The Egyptians developed a solar calendar system.**
- **The pyramids and their designs show their mathematical and surveying skills.**
- **Hieroglyphic writing system attests to their skills in handling symbols.**
- **Preservation of human body in the form of Mummies.**
- **They applied innovation in the use of science and technology.**

The word 'paper' comes from 'Papyrus'. The Egyptians wrote on the leaves of a plant called papyrus, a kind of reed, which grew on the banks of Nile

The Mesopotamian Civilisations

- Mesopotamia refers to the region of Iraq and Kuwait in West Asia. Several kingdoms emerged around the city states of this region from the early third millennium BC (BCE). The Sumerian, Akkadian, Babylonian and Assyrian civilisations flourished in Mesopotamia.

Geography

- In the Greek language, meso means 'in between' and potamus means river. The Euphrates and Tigris flow here and drain into the Persian Gulf is since this area is in between two rivers it is known as Mesopotamia. The northern part of Mesopotamia is known as Assyria, and the southern part is called Babylonia.

The Sumerians

- The oldest civilisation in Mesopotamia belonged to the Sumerians. The Sumerians were the contemporaries of the people of Indus and the Egyptian civilisations. These civilisations hadtrade connections. The Sumerians settled in the Lower Tigris valley around 5,000 to 4,000 BC (BCE). They were believed to have originated from Central Asia. They founded many cities and Nippur was one of the important cities. They developed the cuneiform writing system. During the early phase of the Sumerian civilisation, Kings acted as the chief priests. Their political domination came to an end by 2,450 BC (BCE).

The Akkadians

- The Akkadians dominated Sumeria briefly from 2450 to 2250 BC (BCE). The Sargon of Akkad was a famous ruler. The Sargon and his descendants (ca.2334–2218 BC (BCE)) ruled Mesopotamia for more than hundred years. In the cuneiform records of Akkadians, mention is made about the Indus civilisation. The documents of the Sargon of Akkad (2334–2279 BC (BCE)) refer to the ships from Meluhha, Magan and Dilmun in the quay of Akkad.

The city of Akkad later became the city of Babylon, a commercial and cultural centre of West Asia.

The Babylonians

- The Semitic people called Amorites from the Arabian desert moved into Mesopotamia. They were known as the Babylonians as they established a kingdom and made Babylon its capital. By the time of the king Hammurabi, they extended their domination to the western part of Mesopotamia. The powerful states of Ur (2112 to 2004 BC (BCE)) and Babylon (1792 to 1712 BC (BCE)) controlled this region. The hero Gilgamesh referred to in the first ever epic on the earth may have been a king of Sumeria. Hammurabi, the sixth king of Babylon belonging to the first Amorite dynasty (1792–1750 BC (BCE)), attained fame as a great law-maker.

The Assyrians

- The Assyrian Empire was politically active in Mesopotamia around 1000 BC (BCE). The Assyrian kings were the priests of Ashur, the chief deity of Assyria. The Assyrian government was controlled by the emperor and provincial governors were appointed by the emperor to administer provinces. Assur was the capital city of Assyria. Ashurbanipal was a popular ruler of the late or neo-Assyrian empire (ca. 668 to 627 BC (BCE)). He maintained a famous library of cuneiform records. The Assyrians worshipped the deity of Lamassu for protection.

Society, State and Administration

- The Sumerian civilisation had many city states. A typical Sumerian city was surrounded by cultivable lands. The fortified Sumerian cities had the temples called Ziggurats at its centre. The temple was controlled by the priests. Priests, scribes and nobles were part of the government. The rulers and priests occupied the top of the social hierarchy. The ruler performed the role of the chief priest. The scribes, merchants and artisans were placed next in the hierarchy. The scribes maintained the account of the taxes and the priests collected the taxes. The temples acted as storehouses of the taxed commodities. Assemblies were created for the administration of the state. Cultivable lands were owned by the kings and the higher classes of people in the hierarchy. The peasants who remained to the temples in the earlier phase of Mesopotamian civilisation, became free from that association in the later period. Not all people were allowed to live in the cities.

The Assyrian Empire was the first military State in history. They emerged militarily powerful because they were the earliest to use iron technology effectively

Food and Agriculture

- Agriculture was the main occupation of the Mesopotamians. They had developed irrigation systems for ensuring the availability of water for agriculture and cultivated wheat, barley, onions, turnips, grapes, apples and dates. They domesticated cattle, sheep and goats. Fish was part of their diet.

Trade and Exchange

- Trade was an important economic activity of the Mesopotamian society. Traders assisted in the exchange of goods procured from the potters and artisans. They traded with Syria and Asia Minor in the West, and in Iran and the Indus Valley civilisation in the east. They travelled in ships across the seas for trade. Their temples acted as banks and lent credit on their own account. The Mesopotamian documents have references to loan and repayment, with or without interest. Perhaps this is the first written evidence of charging an interest on borrowed money.

Cities and Town Planning

- The Mesopotamian cities featured mud or baked brick walls with gates. Some people lived in reed huts outside the cities. The Ziggurats were at the city centre on a platform and appeared like steep pyramids, with staircases leading to the top. Around this temple were complexes of ceremonial courtyards, shrines, burial chambers for the priests and priestesses, ceremonial banquet halls, along with workshops, granaries, storehouses and administrative buildings.

Religion

- The Sumerian religion was polytheistic. They worshipped several Gods and Goddesses. The Sumerians prayed to Enlil, the God of sky and wind. The city of Nippur was centre of Enlil's worship. Ninlil was the Sumerian Goddess of grain. The Babylonians worshipped Marduk, and Ashur was the supreme God of the Assyrians. Ishtar was Goddess of love and fertility, Tiamat the God of the sea and chaos, and Sin, the moon God. The kings were seen as representatives of the Gods on earth. The Mesopotamians developed a rich collection of myths and legends. The most famous of these is the epic of Gilgamesh, which is written in the cuneiform text. It contains a legend of the flood and has similarities with the account of Noah's Ark mentioned in the Bible and other myths in the Hindu puranas.

The Hammurabi's Law Code

- The Hammurabi Code is an important legal document that specifies the laws related to various crimes. It has 282 provisions specifying cases related to family rights, trade, slavery, taxes and wages. It is carved on a stone, which portrays Hammurabi as receiving the code from the Sun God Shamash. It was a compilation of old laws based on retributive principles. 'An eye for an eye' and ' a tooth for a tooth' form of justice is used in the Hammurabi Code.

Cuneiform: The Sumerian Writing System

- Cuneiform is the Sumerian writing system. The shape of the letter is in the form of wedge and hence it is called cuneiform. Evolving around 3000 BC (BCE), it is one of the earliest scripts of the world. They used this script for commercial transactions and writing letters and stories. The clay tablets contain loads of information on the Sumerian civilisation.

Art

- The Mesopotamian art included sculptures in stone and clay. A few paintings and sculptures from the Mesopotamian times have survived today. Mesopotamian sculptures portray animals, such as goats, rams, bulls and lions. Some mythological figures like lions and bulls with human head have also been found in their art. Massive sculptures were created at the time of the Assyrian and the Babylonian empires.

Development of Script

Development of script is an important milestone in human history. Writing system began to emerge in Sumeria in the later part of fourth millennium BC (BCE). Hieroglyphic, the Egyptian system of writing, developed in early third millennium BC (BCE). The Harappans also had a system of writing around the same time, but it has not yet been deciphered. The Chinese civilisation too developed a writing system from a very early period.

Science

- The Mesopotamians excelled in mathematics, astronomy and medicine. They developed the concepts of multiplication, division and cubic equation. The numerical system based on 60 was conceived by them. They were the ones to formulate the 60-minute hour, the 24-hour day and the 360° circle. The Sumerian calendar had seven days in a week. Their numerical system had place values. They created the water clock and the lunar calendar based on the movement of the moon. They developed methods for measuring areas and solids. They also developed advanced weightand measurement systems.

- They introduced the twelve month calendar system based on lunar months. Their ideas influenced Greek astronomy. They had developed a medicinal system as well. A text called the Diagnostic Handbook, dated to the 11th century BC (BCE) Babylon, lists symptoms and prognoses. This indicates their scientific understanding of herbs and minerals.

Contributions of the Mesopotamian Civilisation

- The invention of the potter's wheel is credited to the Sumerians
- They developed the calendar system of 360 days and divided a circle into 360 units
- The cuneiform system of writing was their contribution

- The Hammurabi’s law code was another legacy of the Mesopotamians.

The Chinese Civilisation

- China has two major rivers. One is known as Huang He (Yellow River) and the other is called Yangtze River. The Yellow River is known as the Sorrow of China, since it changed its course and caused frequent floods.

- Evidence for the prehistoric Peking man (700,000 BP and 200,000 BP) and Yuanmou Man exists in China. Neolithic communities lived in China between 4,500 and 3,750 BC (BCE). The Henan province in the Yellow and Yangtze river valley contain evidence for Neolithic villages. China had many city states and gradually these states became part of an empire.

Polity and Emperors

- Shi Huangdi (Qin Shi Huang, which means the first emperor) founded the Qin (Chin) dynasty. The emperor had the title ‘son of heaven’. He is considered to be the first emperor of China. The period between 221 and 206 BC (BCE) is known as the imperial era in China. He conquered other principalities in 221 BC (BCE) and remained the emperor till 212 BC (BCE). He defeated the feudal lords and established a strong empire. He is credited with unifying China. Shi Huangdi destroyed the walled fortifications of different States and constructed the Great Wall of China to protect the empire from the invading nomadic people. He also built roads to integrate the empire.

The Han Empire (206–220 AD (CE))

- During this period, a written history of this empire was made available in China. The greatest of the Han emperors, Wu Ti (Han Wu the Great, 141 to 87 BC (BCE)), expanded the empire and built many public amenities, including irrigation tanks. He sent Zhang Qian as emissary to the West in 138 BC (BCE) and thereby paved the way for the opening of the Silk Road in 130 BC (BCE) to encourage trade activities.

- Because of the Silk Road and the resultant trade connections, China benefitted immensely during the rule of Emperor Zhang (75–88 AD (CE)). Chinese silk was much sought after by the Romans during the time of the Roman emperor Marcus Aurelius in 166 AD (CE). Some of the Chinese silk might have reached Rome through the ports of Tamilagam.

The Terracotta Army

The Terracotta Army refers to the large collection of terracotta warrior images found in China. They depict the armies of the king Qin Shi Huang, the first emperor of China. They were buried with the king in 210–209 BC (BCE). They are found at the northern foot of the Lishan Mountain, thirty five kilometres northeast of Xi'an, Shaanxi Province, as part of the mausoleum of the king.

Philosophy and Literature

- Chinese poets and philosophers such as Lao Tze, Confucius, Mencius, Mo Ti (Mot Zu) and Tao Chien (365-427 AD (CE)) contributed to the development of Chinese civilisation. Sun-Tzu, a military strategist, wrote the work called Art of War. The Spring and Autumn Annals is the official chronicle of the state at the time. The Yellow Emperor's Canon of Medicine is considered China's earliest written book on medicine. It was codified during the time of Han Dynasty.

- Lao Tze (c. 604– 521 BC (BCE)) was the master archive keeper of Chou state. He was the founder of Taoism. He argued that desire is the root cause of all evils Confucius (551–497 BC (BCE)) was famous among the Chinese philosophers. He was a political reformer. His name means Kung, the master. He insisted on cultivation of one's own personal life. He said, "If personal life is cultivated, family life is regulated; and once family life is regulated, national life is regulated."

- Mencius (372–289 BC (BCE)) was another well-known Chinese philosopher. He travelled throughout China and offered his counsel to the rulers.

Chinese Script

- Chinese developed a writing system from an early time. Initially it was a pictographic system and later it was converted into a symbol form.

Contribution of the Chinese Civilisation

- **Writing system was improved**
- **Invention of paper**
- **Opening of the Silk Road**
- **Invention of gun powder.**

Indus Civilisation

- The Indus civilisation, also known as the Harappan civilisation, covers an area of over 1.5 million square kilometres in India and Pakistan. Sutkagen-Dor in the west on the Pakistan– Iran border Shortugai (Afghanistan) in the north Alamgirpur (Uttar Pradesh in India) in the east and Daimabad (Maharashtra in India) in the south are the boundaries with in which the Harappan culture has been found. Its main concentration is in the regions of Gujarat, Pakistan, Rajasthan and Haryana.

Planned Towns

- Harappa (Punjab, Pakistan), Mohenjo-Daro (Sindh, Pakistan), Dholavira (Gujarat, India), Kalibangan (Rajasthan, India), Lothal (Gujarat, India), Banawali (Rajasthan, India.,) Rakhigarhi (Haryana, India) and Surkotada (Gujarat, India) are the major cities of the Indus civilisation. Fortification, well-planned streets and lanes and drainages can be observed in the Harappan towns. The Harappans used baked and unbaked bricks and stones for construction. A civic authority perhaps controlled the planning of the towns. A few of the houses had more than one floor. The tank called the Great Bath at Mohenjo-Daro was an important structure, well paved with several adjacent rooms. Some unearthed structures have been identified as the granary. We do not knowabout the nature of the state or political organisation of the Harappans. But they must have had a political organisation at the level of an early form of state. A male image from Mohenjo-Daro has been identified as 'priest king', but we do not know about the accuracy of this interpretation.

The Indus Valley civilisation is also known as the Harappancivilisation, since Harappa was the first site to be discovered. This civilisation is known as Harappancivilisation rather than Indus Valley civilisation, since it extended beyond the Indus river valley.

The structure identified as granary should be considered archaeologists' interpretation.
Agriculture and Animal Domestication

- The Harappans practiced agriculture. They cultivated wheat, barley and various types of millets. They adopted a double cropping system. Pastoralism was also known to them. They reared cattle, sheep and goats. They had knowledge of various animals including elephants but did not use horses. The Harappan cattle are called Zebu, and it is a large breed, often represented in their seals.

Pottery

- The Harappans used painted pottery. Their potteries have a deep red slip and black paintings. The pottery has shapes like dish-on-stands, storage jars, perforated jars, goblets, S-shaped jars, plates, dishes, bowls and pots. The painted motifs, generally noticed on the pottery, depict pipal tree leaves, fish-scale designs, intersecting circles, zigzag lines, horizontal bands, and geometrical motifs, and floral and faunal patterns.

Metal Tools and Weapons

- The Harappans used chert blades, copper objects and bone and ivory tools. They did not possess knowledge about iron. The tools and equipments such as points, chisels, needles, fishhooks, razors, weighing pans, mirror and antimony rods were made of bronze. The chisels made out of Rohrichert were used by the Harappans. Their weapons included arrows, spears, a chisel-bladed tool and axe. The bronze image of dancing girl from Mohenjo-Daro is suggestive of the use of lost-wax process.

Rohrichert refers to the chert raw material collected from Rohri in Pakistan. It was used by the Harappans for making blades.TheHarappans used both stone and bronze tools.

Textiles and Ornaments

The Harappans used metal and stone ornaments. They had knowledge of cotton and silk textiles. They made carnelian, copper and gold ornaments. Faience, stoneware and shell bangles were also used. Some of them had etched designs, and the Harappans exported them to the Mesopotamia.

Trade and Exchange

- The Harappans had close trade links with the Mesopotamians. Harappan seals have been found in the West Asian sites namely Oman, Bahrain, Iraq and Iran. The cuneiform inscriptions mention the trade contacts between Mesopotamia and the Harappans. The mention of 'Meluhha' in the cuneiform inscriptions is considered to refer to the Indus region.

Weights and Measures

- The Harappans developed a system of proper weights and measures. Since they engaged in commercial transactions, they needed standard measures. The cubical chert weights are found at the Harappan sites. The copper plates for weighing balances have also been found.The weights point to their knowledge of the binary system. The ratio of weighing is doubled as 1:2:4:8:16:32.

Seals, Sealings and Scripts

- The seals from various media such as steatite, copper, terracotta and ivory are found in the Harappan sites. They were probably used in the trade activities. The Harappan script is not yet deciphered. About5,000 texts have been documented from the Harappan sites. Some scholars are of the view that the script is in Dravidian language.

Arts and Amusement

- The terracotta figurines, paintings on the pottery and the bronze images from the Harappan sites suggest the artistic skills of the Harappans. 'Priest king' made of steatite and dancing girl made of bronze (both from Mohenjo-Daro) as well as stone sculptures from Harappa, Mohenjo-Daro and Dholavira are the important objects of art. Toy carts, rattles, wheels, tops, marbles and hop scotches made in terracotta suggest the amusement of the Harappan people.

Religion

- The Indus people had a close relationship with nature. They worshipped pipal trees. Some of the terracotta figures resemble the mother Goddess. Fire altars have been identified at Kalibangan. The Indus people buried the dead. Burials were done elaborately and evidence for cremation has also been found.

Original Inhabitants and their Culture

- The authors of the Harappan civilisation are not known, since the script has not been deciphered. One school of thought argues that they spoke the Dravidian language. The archaeological evidence shows movement of the Harappans to the east and south after the decline of the Indus civilisation. It is probable that some of the Harappan people moved into different parts of India. Only the decipherment of the script can give a definite answer.

- Indus civilisation had more than one group of people. Several groups including farmers, pastoralists and hunter-gatherers lived in the Indus region. The Indus region had villages and large towns. The population was mixed.

- The period of the civilisation has been divided into Early Harappan, starting around 3300 BC (BCE) and continuing to 2600 BC (BCE) and mature Harappan, are the last phase civilisation from 2600 to 1900 BC (BCE). The later Harappan existed upto 1700 BC (BCE).

Decline of Indus Culture

- The Indus civilisation and its urban features started declining from about 1900 BC (BCE). Changes in climate, decline of the trade with Mesopotamia and drying up or flooding of the river Indus, foreign invasion were some of the reasons attributed to the collapse of this civilisation and for the migration of people in the southern and eastern directions. It did not completely disappear. It continued as rural culture.

Indus Script

Cracking The Indus Script

Harappans knew the art of writing. The script is found on seals, in moulded terracotta and on pottery. It has not been deciphered till now. Because the Indus texts are very short, the average length of the inscription is less than five signs. It has no bilingual text (like a Rosetta stone written in Egyptian and Greek).

It was written generally from right to left.

- Based on computer analysis, the Russian scholar Yuri Knorozov suggested that the Indus inscriptions have a Dravidian-like word order.
- Scholar and researcher IravathamMahadevan, who has done extensive research on Indus civilisation, says, “We may hopefully find that the proto Dravidian roots of Harappa language and South Indian Dravidian languages are similar.”
- According to Mahadevan, a stone Celt discovered in Mayiladuthurai (Tamil Nadu) has same marking as that of the symbol of the Indus script.
- In May 2007, the TamilNadu Archaeology Department found pots with arrow head symbols at Melaperumpallam near Poompuhar, which resembled the seals in Mohenjo-Daro.

According to Parpola, the sign of the Indus script is likely to represent Dravidian mono-syllabic roots.

11th Book
Unit - 1
Early India from the Beginnings to the Indus civilization

Introduction

- India experienced an early development of cultures and civilisations. Since the Old Stone Age, several groups in India had migrated multiple times and made cultural adaptations to diverse eco-zones. Each group evolved its own culture responding to their living experiences in each place, which eventually led to pluralistic beliefs and systems. From a life of foraging through nomadic pastoralism, the settlers in Indus region reached a matured stage of living in the Bronze Age.

Sources

- Archaeological sources form the bedrock of information for us to understand this long span of time in Indian history. They include archaeological sites, geological sediments, animal bones and fossils, stone tools, bone tools, rock paintings and artefacts. There is no written evidence for this period. Although the Harappans used a script, it is yet to be deciphered.

- The faunal (animal) and floral (plant) sources are important for understanding the relationship of the Stone Age people with their environment. Floral evidence found in the form of charred seeds, pollens and phytoliths (plant stones) helps us to gain knowledge of farming practiced by Stone Age people.

- The human genes also constitute an important source for understanding prehistoric migrations. The mitochondrial DNA (mt-DNA) studies provide information on pre-historic migrations. Scientists are trying to extract ancient DNA from the bones of the pre-historic era to understand human dispersals.

- Language is another important source of history. Indo-Aryan, Dravidian, Austro-Asiatic and Tibeto-Burman language families have flourished in India.

These languages developed and evolved during the various phases of migrations in Indian history.

Pre-historic India

- The period before the development of script is called the pre-historic times. It is also referred to as the Stone Age. When we talk about the Stone Age, we includethe entire South Asia, the region covering India, Pakistan, Sri Lanka, Nepal and Bangladesh, as a whole.

- Human ancestors are likely to have first evolved in Africa and later migratedto different parts of the world. The earliest human ancestor species to migrate out of Africa was the Homo erectus. Till the end of the 20th century, the pre-history of India was considered to have begun within the time span of one million years (MYR) ago. But, recent investigations have produced evidence for the presence of human ancestors in India between two million and one million years ago.

- Generally, the period before the invention of script is broadly divided into Stone Age, Bronze Age and Iron Age. Hence, the names of materials that they used (for example, painted grey ware culture or Iron Age culture) or the geographical region (Indus) or the first site to be identified (for example, Acheulian or Harappan) are used to name the cultures.

  - The earliest age in history is called Old Stone Age or Palaeolithic. This period is divided into
  - Lower Palaeolithic culture
  - Middle Palaeolithic culture
  - Upper Palaeolithic culture

- The period after the Old Stone Age (Palaeolithic) is called the Mesolithic Age.The period that followed the Mesolithic is called the Neolithic Age. This is the agein which animal and plant domestication developed, leading to food production. The classification of these cultures is done on the basis of stratigraphic, chronological and lithic (stone tool) evidence.

Lower Palaeolithic Culture

- The earliest lithic artefacts come from different parts of the Indian subcontinent. During the Lower Palaeolithic cultural

Wild and Domestic
Wild plants and animals grow naturally and independently. When they are domesticated, their lifestyle and physical characteristics (such as self-propagation) change. Consequently, the seeds of domestic plants become smaller in size. In the case of domesticated animals, they lose their ferociousness

- phase, human ancestor species of Homo erectus is believed to have lived in India. The first Palaeolithic tools were identified at the site of Pallavaram near Chennai by Robert Bruce Foote in 1863. He found many prehistoric sites when he extensively surveyed different parts of South India. Since then, numerous Palaeolithic sites have been identified and excavated all over India.

Lithic Tools

- The study of pre-history mainly depends upon lithic tools. Pre-historic sites are identifiable based on the presence of stone tools. Human ancestors made large stone blocks and pebbles and chipped tools out of them, using another strong stone. Hand axes, cleavers, choppers and the like were designed in this way by flaking off the chips. The tools show well thought-out design and physical symmetry, and convey highquality cognitive (perception) skills and capabilities of pre-historic humans. They used the tools for hunting, butchering and skinning the animals, breaking the bones for bone marrow and to recover tubers and plant foods, and for processing food.

- The industries of Palaeolithic cultures are divided into the Early, Middle and LateAcheulian Industries. The early Acheulian tools include polyhedrons, spheroids, hand axes, cleavers and flake tools.

- The Acheulian tradition is absent in the Western Ghats, coastal areas and north-eastern India. Heavy rainfall isattributed to its absence. Uncongenial conditions and lack of raw materials might have prevented the occupation of these areas. Perhaps there was no necessityfor the pre-historic people to move into these areas. These sites are found more in Central India and in south-eastern part of India (near Chennai). These areas receive high rainfall and are therefore endowed with thick green cover and rich resources.

Acheulian and Sohanian

Based on research, two independent cultural traditions of hand axe (Acheulian) and pebble-flake (Sohanian) industries were confirmed in India. Acheulian industry mainly had hand axes and cleavers. The Sohan industry is considered to have used only chopper and chopping tools. The Sohan industry gets its name from the Sohan river valley of Pakistan. These two cultural traditions are not considered distinct any longer. Recent studies argue that there was no independent Sohan tradition as Acheulian tools are found in the Sohan industry as well.

Distribution

- Lower Palaeolithic tools are found in most parts of India, except in a few regions of the Ganges valley, southern Tamil Nadu and in the hilly areas of the Western Ghats. Athirampakkam, Pallavaram and Gudiyam near Chennai, Hunsgi valley and Isampurin Karnataka, and Bhimbetka in Madhya Pradesh are some important Palaeolithic sites where the Acheulian tools are found.

Chronology

- Recent research places the beginning of lower Palaeolithic around two million years ago. This culture continued upto 60,000 years ago.

Hominin and Animal Fossils

- Unlike Africa, evidence of hominin [immediate ancestor of Homo Sapiens]fossil is rare in India. There is a report of a fossil fragment discovered by Robert Bruce Foote from Athirampakkam. Its whereabouts are not known now. The only well-known hominin fossil of India was found at Hathnora near Hoshangabad in Madhya Pradesh. The cranium is named Narmada human. A partly preserved hominid skull cap was found in a basal conglomerate deposit in 1982. It is considered to represent the Archaic Homo sapiens. It is the only existing fossil find ofhuman ancestors in India.

- Animal fossils are useful to understand the palaeo-environmental context in whichpeople lived. In the Narmada valley, animal fossils of Elephasnamadicus (giant tusked pre-historic elephant), Stegodonganesa (a giant pre-historic elephant), Bosnamadicus (wild cattle) and Equusnamadicus (extinct great horse like animal) have been recovered. Teeth of Equus, evidence of water buffalo and nilgai as well as 17 animal hoof prints have been uncovered at Attirampakkam.

- They suggest an open, wet landscape near the Chennai region in the pre-historic period.

Equus refers to the genus of animals including horses, asses and zebras

Way of Life

- The people of Lower Palaeolithic culture hunted animals and gathered roots, nuts and fruits. They fed on the flesh and bones of animals killed by predators. They lived in open air, river valleys, caves and rock shelters, as seen from evidence in Bhimbetka in Madhya Pradesh and Gudiyam near Chennai. The pre-historic human ancestors, who belonged to the species of Homo erectus, did not have a complex language culture like us, the Homo sapiens. They may have expressed a few sounds or words and used a sign language. They were intelligent enough to select stones as raw material and used the hammer stones to carefully flake the rocks and design tools.

Middle Palaeolithic Culture

- After about 4,00,000 years BP (Before Present), changes took place in the lithictechnology and the species of human ancestors diverged. The species of Homoerectus existed in this period. Some of the Middle Palaeolithic tools are attributed to behavioural modernity. Anatomically modern humans are said to have emerged around 3,00,000 years ago. In India, the Middle Palaeolithic phase was first identified by H.D. Sankalia on the Pravara River at Nevasa. After this discovery, several sites of this period have been identified. Recently, the Middle Palaeolithic of Athirampakkam is dated to be around 3.85-

1.72 lakh years BP. Indian Middle Palaeolithics probably may be as old as the African Middle Palaeolithic culture.

Industries and Tool Types

- The tool types of the Middle Palaeolithic period are hand axes, cleavers, choppers, chopping tools, scrapers, borers and points, projectile points or shouldered points ,and knives on flakes. Flake industry was predominant in the Middle Palaeolithic period and tools such as scrapers, points and borers were made. Scrapers were used for wood and skin working.

Chronology

- The Middle Palaeolithic culture in India is dated between 3,85,000 and 40,000 BCE. While the African Middle Stone Age is associated with the Homo sapiens, it is associated with the Neanderthals in Europe. No hominin fossil bones of this species have been found in India.

Distribution

- The Middle Palaeolithic sites are found in Narmada, Godavari, Krishna, Yamuna and other river valleys.

Ways of Life and MainCharacteristics

- The Middle Palaeolithic people occupied open-air, cave and rock shelter sites. They were hunter-gatherers. The main features of the Indian Middle Palaeolithic period include the following:

- The tools became smaller.The decrease in the use of hand axes in relation to other tools.

- Use of core preparation techniques in stone tool production.

- Use of chert, jasper, chalcedony and quartz as raw materials.

Upper Palaeolithic Culture

- The cultural phase that followed the Middle Palaeolithic is called Upper Palaeolithic. This period is marked by innovation in tool technology and increased cognitive capability of humans. The modern humans, who first evolved in sub-Saharan Africa, sometime before 300,000 years ago, migrated to and occupied various parts of Asia around 60,000 years ago. They probably replaced the earlier populations. There is a possibility that these new groups were responsible for the Upper Palaeolithic culture of India.

An Upper Palaeolithic Shrine

An interesting find is of a possible shrine, indicated by a block of sandstone surrounded by a rubble circle, similar to the contemporary shrines. Found at Baghor in Uttar Pradesh, it is the earliest known evidence of a shrine in India.

Lithic Tools and Industries

- The lithic industry of the Upper Palaeolithic period is based on blade and bone tool technologies. Microliths (tiny stone tools) were introduced in the Upper Palaeolithic Period and these tools were made using different varieties of silica-rich raw materials. Bone tools and faunal remains have been found in Kurnool caves in Andhra Pradesh.

Chronology

- The Upper Palaeolithic culture is represented in India at several sites. A time bracket of c.40,000 years to 10,000 years BP is suggested for this period.

Distribution

- The people of this period used caves as well as the open air space for living.Meralbhavi in Karnataka, Kurnool caves and Godavarikhani in Telangana, BaghorI and Baghor III of Son Valley in Madhya Pradesh and Patne in Maharashtra are some of the Upper Palaeolithic sites of India.

Sri Lanka has evidence of microliths and hominin fossils. Incised ostrich eggshell, and shell and stone beads have been found at Jwalapuram in Andhra Pradesh, Patne in Maharashtra and Batadomba-Lena and FaHien Cave in Sri Lanka.

Ostrich Egg Shells
Evidence of ostrich has been found in some pre-historic sites of India. The egg shell of this bird had been used as beads and those from Patne have been dated to 25,000 BP. They are found in Bhimbetka and Patne

Ways of Life and Main Characteristics

- Evidence of art in the Upper Palaeolithic period appears in the form of paintings. Beads and ornaments of this period have also been found. The lithic blade industry advanced in this period. Some of the green colour paintings of Bhimbetka are dated to Upper Palaeolithic period based on style and archaeological evidence.

Mesolithic Culture

- Mesolithic sites are found in most parts of India. They occur in all eco-zones from thecoasts to the hills: sand dunes, rock shelters, deltaic regions, lake areas, forested territories, hilly and mountainous areas, rocky terrains and coastal environments.

- Mesolithic sites in India are found in Paisra (Bihar), Langhnaj (Gujarat), Baghor II, ChopaniMando, SaraiNaharRai, Mahadaha and Damdama (all in Uttar Pradesh), Sankanakallu and Kibbanahalli (Karnataka). Rock shelter sites are found in Lekhakia, BaghaiKhor, Adamgarh and Bhimbetka.

- Coastal sites are seen at Mumbai, teri sites of Thoothukudy in Tamil Nadu and Vishakapatnam, which have microlithic evidence.

Teri
A costal landscape caused by sand dunes. These soils may have originated in the Pleistocene epoch of the Quaternary period.

Climate

- After the Ice Age, with the advent of global warming, human groups became highly mobile and began to occupy various ecozones. The monsoon pattern had already emerged. Some regions witnessed higher rainfall. At Didwana in western Rajasthan, fresh water lakes were known to exist between 10,000 and 3500 BP. The animal bones from this period suggest a dry deciduous type of forest during the Mesolithic period.

Chronology

- The date of the Mesolithic culture varies in different parts of the world. This culture isassigned to pre-agricultural times in certain areas. In Levant (Eastern Mediterranean), they are dated between 20,000 and 9500 BCE. In India, Mesolithic cultures appeared around 10,000 BCE. In certain parts of India including Kerala and Tamil Nadu, it continued up to 1000 BCE, till the beginningof the Iron Age. In Sri Lanka, the microliths appeared about 28,500 years BP.

Economy

- Hunting wild animals and gathering plant food and fishing were people's main occupation during this age. Agriculture was not practised in the early stages. At the end of the Mesolithic period, humans domesticated animals and paved the way for the Neolithic way of life. The rock paintings of Central India depict hunting, trapping, fishing and plant food collection.

- The faunal evidence from this period shows that people belonging to this period hunted cattle, gaur, buffalo, barasingha, porcupines, sambar, chital, gazelle, hog deer, nilgai, jackal, turtle, fish, wild hare, lizard fox and monitor lizard. Bones of rhinoceros and elephant have also been found. They used spears, bow and arrow and traps. The paintings of Bhimbetka show that various animals were hunted and for this men and women went together.

- The people used fire and perhaps roasted food. Domestic animal bones of cattle, sheep, goats, pig and dog have been found at Kanewal, Loteshwar and Ratanpur, and from

Adamgarh and Bhimbetka in Madhya Pradesh sites. Camel bones have been found from Kanewal.

Camps and Houses

- The Mesolithic people were highly mobile. They moved in search of animalsand plant foods. They made temporary huts and also used caves and rock shelters. Circular huts with postholes and burnt clay lumps bearing reed impressions have been found. Many of caves and shelters feature paintings. Circular huts are seen in rock paintings. The temporary huts were built using perishable materials. Traces of oval and circular huts and possible wattle daub are found in ChopaniMando and Damdama in Uttar Pradesh and Bagor and Tilwara in Rajasthan.

Burials

- The Mesolithic people buried the dead, which suggests their beliefs and humanerelationships. Human skeletons have been found in Mahadaha, Damdama and SaraiNaharRai in Uttar Pradesh. At Mahadaha, a man and a woman were buried together. One burial had an ivory pendant as the grave good.

Art

- Art is an integral part of human existence. While evidence of art is found in Europe in large volume, they are found only at a few sites in India. A chert stone used as a core had geometric engravings from Chandravati in Rajasthan, bone objects from Bhimbetka and human tooth engraved with geometric design. Rock paintings are found in the rock shelters of Madhya Pradesh and Central India. They show people hunting, trapping animals and fishing and dancing. Bhimbetka near Bhopal, Raisen and Pachmarhi in Madhya Pradesh and South Mirzapur in Uttar Pradesh are some of the sites. Haematite, an iron-rich stone with traces of rubbing, has been found. These people might have decorated themselves with flowers and leaves.

Hunter and gatherers of the Historical Period

- The hunter and gatherers using microlithic tools continued to live in thelater period, even after the development of Neolithic, Iron Age and historicalperiods. Perhaps they became part of the marginalised communities, when thepeople who lived in the cities acquired more wealth. Some of the people wholive in the forests even today in some remote areas and also in the Andamanregion could be considered as those people who prefer to live by hunting andgathering. Many such groups lived in the 19th and 20th century, as recorded inthe Edgar Thurston's Castes and Tribes of Southern India. Describing them asprimitive is incorrect. They should be considered as people who preferred tolive by hunting and gathering. When the Indus Civilisation was in its peak, Tamil Nadu had microlithic hunter-gatherers. The Andhra–Karnataka region had the agro-pastoralists of the Neolithic period.

Characteristics of the Mesolithic Cultures

- The Mesolithic people lived in semipermanentand temporary settlements.
- They occupied caves and open grounds.
- They buried the dead.
- They had artistic skill.
- They were spread over wider geographical regions.
- Cultural continuity is noticed in many parts of India from this period.
- Theirmicrolithic tools enabled them to hunt smaller animals and birds.

Early Neolithic Cultures and the Beginning of Agriculture

- The Neolithic period marked the beginning of agriculture and animal domestication. It is an important phase in Indian history. Early evidence of Neolithic culture is found in the Fertile Crescent region of Egypt andMesopotamia, the Indus region, the Gangesvalley of India and also in China. Between 10,000 BCE to 5000 BCE, agriculture emerged in these regions, which led to several cultural developments.

- The introduction of domestication of animals and plants resulted in the productionand supply of a large quantity of grains and animal food. The fertile soil deposited by the rivers enhanced the growth of agriculture, generating a surplus of grains. Surplus food production played a major role in the rise of early civilisations. Large villages came to exist and pottery developed. Permanent residences were built. Hence, the cultural developments of this period are called Neolithic revolution.

- The Neolithic cultures of India are divided into various regional cultures and they flourished in different time periods. In the north-western part of India and Pakistan, it began at a very early date. In north-eastern India, Neolithic cultures appeared at a very late date, around the early historic time.

The Neolithic Culture of North-Western India

- The Neolithic culture of north-western India is the earliest to have evidence of plant and animal domestication in India. Mehrgarh, RanaGhundai, Sarai Kala and Jalilpur are some of the Neolithic sites. These sites are now situated in Pakistan.

- The site of Mehrgarh has produced evidence of early Neolithic times, dating to c. 7000 BCE. Wheat and barley were cultivated and sheep, goat and cattle were domesticated. This culture preceded the Indus Civilisation.

- The first cultural period (I) of the Neolithic age at Mehrgarh dates

Early Dentistry in the Neolithic Mehrgarh
The human ancestors had knowledge of medicinal herbs and were capable of taking care of health for survival from the pre-historic times. As their ways of life changed, new diseases appeared and they had to find remedies.

From the Neolithic period, people began to eat ground grain and cooked food, which caused dental and other health problems. The earliest evidence for drilling human tooth (of a living person) has been found at Mehrgarh. It is seen as a prelude to dentistry.

from c. 7000 to 5500 BCE. The people belonging to this age did not use pottery, but cultivated six-row barley, emmer and einkorn wheat, jujube, ilanthai and dates, and also domesticated sheep, goat and cattle. They were semi-nomadic, pastoralgroups. They built their houses with mud and buried the dead. They used ornamentsof sea shell, limestone, turquoise, lapis lazuli and sandstone.

- The period II at Mehrgarh dates from c. 5500 to 4800 BCE and the period III from 4800 to 3500 BCE. There is evidence for pottery during these periods. Terracotta figurines and glazed faience beads have been found. Evidence for ornaments on women has been uncovered. Longdistance trade was practiced, as revealed by Lapis Lazuli, which is available only in Badakshan. The town was abandoned after the rise of mature phase of the Indus Civilisation.

The Neolithic Culture of Kashmir

- Neolithic culture in Kashmir region was contemporary to the Harappan civilisation. Burzahom, an important site of this culture, provides evidence for the Megalithic and Early Historic Periods. In this place, people lived in pit houses (about four metres in depth) in order to escape the cold weather.

- The houses were oval in shape, wide at the bottom and narrow on the top. Postholesused for constructing a thatched structure were found around the pit houses. The Neolithic period of Kashmir had domestic sheep, goat and cultivated plants. The Neolithic people of Burzahom traded with the people of the Harappan Civilisation. They used handmade pottery. They used tools such as stone axes, chisels, adzes, pounders, mace-heads, points and picks. Awls were used for stitching skins into clothes to beat the weather. Scrapers were used for working the skins.

- Two phases of Neolithic culture have been identified. They are termed aceramicand ceramic phases. Aceramic phase did not have evidence of ceramics. Ceramic phase shows evidence for the existence of pottery. In the ceramic phase, people built mud houses. They used copper arrowheads. They also used black ware pottery, beads of agate and carnelian and painted pottery. A burial at this site produced wild dog bone and antler horn. An engraving of a hunting scene is depicted on a stone here with dog and sun.

- Seeds of wheat, barley, common pea and lentil have been recovered from theexcavations. people domesticated animals include cattle, sheep, goat, pig, dog and fowl. Bones of wild animals such as red deer, Kashmir stag, ibex, bear and wolf suggest that they hunted animals.

- There is evidence of menhirs and the use of redware pottery and metal objectsin the megalithic culture. The use of lentil suggests that contacts had been established with Central Asia. These people had interactions with Harappan Civilisation.

The Neolithic Culture of Ganges Valley and Central India

- In the Ganges Valley, and in Central India Neolithic sites are found at Lehuradeva, and ChopaniMunda. The site of Lehuradeva has produced early evidence of rice cultivation dated to c. 6500 BCE.

- These sites are characterised bycord-marked pottery. Koldiwa, Chirand, Senuwar and Mahagara are important Neolithic sites in this region. These sites also have evidence of pottery and plantand animal domestication.

- Evidence for the cultivation of hulled and six-rowed barley, several types of wheat, rice, pea, green gram, and gram/chicken pea, mustard, flax/linseed and jackfruit have been found at the sites of Central India.Sheep, goat and cattle bones have been found besides bones of wild animals.

- The Neolithic people used a type of pottery with cord impression on the surfaces. They used microliths, bone and antler tools and terracotta objects. These sites perhaps flourished till about the middle of the second millennium BCE.

The Neolithic Culture of Eastern India

- The Neolithic sites are found at many sites in Bihar and West Bengal. Birbhanpurand Chirand are some of the prominent Neolithic sites in this region along with Kuchai, Golbaisasan and Sankarjang. These cultures show similarities with the Neolithic complexes of east and Southeast Asia. Pointed butt celts, chisel andshouldered axes have been found in the region from the Neolithic era.

Neolithic Culture of South India

- The Neolithic cultures of South India have been found mainly in Andhra Pradesh and Karnataka and the north-western part of Tamil Nadu.
-
- These sites have ash mounds in the centre with settlements around them. More than 200 Neolithic sites have been identified as part of the Neolithic complex. These sites are found near the granite hills with water sources. These sites have been spotted in the river valleys of Godavari, Krishna, Pennaru, Tungabhadra and Kaveri. Sanganakallu, Tekkalakota, Brahmagiri, Maski, Piklihal, Watkal, Hemmige and Hallur in Karnataka,

Nagarjunakonda, Ramapuram and Veerapuram in Andhra Pradesh and Paiyyampalli in Tamil Nadu are the major Neolithic sites in South India.

- Some early Neolithic sites have ash mounds. Utnur and Palvoy in AndhraPradesh and Kodekal, Kupgal and Budihal in Karnataka feature ash mound sites. Soft ash and decomposed cow dung layers are also found at this site. The evidence of habitation in the form of houses and burials are found around the ash mounds.

Neolithic Culture of North-eastern India

- In north-eastern India, Neolithic culture appears at to a very late period. The Neolithic cultures of north-eastern India generally date from 2500-1500 BCE or even later. Shouldered axes and splayed celts have been found at the sites in Assam, Meghalaya, Nagaland and Arunachal Pradesh. DaojaliHading and Sarutaru are the Neolithic sites in the Assam region. This region bears evidence for shifting cultivation. Cultivation of yams and taro, building stone and wooden memorials for the dead, and the presence of Austro-Asiatic languages are the marked features of this region, which shows cultural similarities with South-east Asia.

The Indus Civilisation

- The Indus Civilisation represents the first phase of urbanisation in India. While the civilisation was in its peak, several cultures, namely, Mesolithic and Neolithic cultures that we discussed earlier in the chapter, prevailed in other parts of India.

Nomenclature, Phases and Chronology

- The civilisation that appeared in the northwestern part of India and Pakistan in third millennium BCE is collectively called the Indus Civilisation. Since Harappa was the first site to be identified in this civilisation, it is also known as HarappanCivilisation. This civilisation did not appear all of a sudden. The beginnings of the Neolithic villages in this region go back to about 7000 BCE at the Neolithic site of Mehrgarh. Harappan culture is divided into various phases:

Early Harappan 3000–2600 BCE
Mature Harappan 2600–1900 BCE
Late Harappan 1900–1700 BCE

- The urban phase was prevalent in the mature Harappan period and began to decline afterwards.

- The Indus valley site of Harappa was first visited by Charles Mason in1826, and Amri by Alexander Burnes in 1831. The site of Harappa was destroyed for laying the railway line from Lahore to Multan. The seal from this site reached Alexander Cunningham, the first surveyor of the Archaeological Survey of India (ASI). Alexander Cunningham visited the site in 1853, 1856 and 1875. But the importance of the site and the associated civilisation were not realized until Sir John Marshal took over as the Director General of ASI and initiated research at the site.

- Sir John Marshal played an important role in the development of archaeology inIndia. Later in the 1940s, Mortimer Wheeler excavated the Harappan sites. After the partition of the Indian subcontinent, many of the Harappan sites went to Pakistan and thus archaeologists were keen to trace the Harappan sites on the Indian side. Kalibangan, Lothal, RakhiGarhi and Dholavira are the Indian sites that have been since excavated. The explorations and excavations conducted after the 1950s have helped to understand the Harappan Civilisation and its nature.

Geographical Area and the Settlements

- The Indus Civilisation and the contemporary cultures covered nearly 1.5 million sq. km area in India and Pakistan. The settlements of Sutkagen-dor in the west on the Pakistan– Iran border; Shortugai (Afghanistan) in the north; Alamgirpur (Uttar Pradesh, India) in the east and Daimabad (Maharashtra, India) in the south are the boundaries of this civilisation. Its core area was in the regions of Pakistan, Gujarat, Rajasthan and Haryana.

The Early Beginnings

- The Indus region (Mehrgarh) is one of the areas of the world where agricultureand animal domestication began very early. We do not know if there is any continuity between the Neolithic cultures of the Indus region and the later urban civilisation. The early Harappan phase saw the development of villages and towns in the entire region. In the Mature Harappan phase, urban centres developed.

Planned Towns

- Harappa (Punjab, Pakistan), Mohenjo-Daro (Sindh, Pakistan), Dholavira, Lothal, and Surkotada (Gujarat, India), Kalibangan and Banawali (Rajasthan, India), and Rakhigarhi (Haryana, India) are the major cities in the Harappan period. Fortification, wellplanned streets and lanes and drainages are noticed in the Harappan towns. A civic authority perhaps controlled the planning of the towns. The Harappans used baked and unbaked bricks, and stones for construction. The towns had a grid pattern and drainages were systematically built. The houses were built of mud bricks while the drainages were built with burnt bricks. Houses had more than one floor.

- The site of Mohenjo-Daro had a planned town, built on a platform. It has two distinct areas. One is identified as a citadel and another as the lower town. The houses had bathrooms paved with burnt bricks and proper drains. Some houses had stairs indicating the existence of an upper floor. The houses had multiple rooms. Many of the houses had a central courtyard with rooms all around.

The citadel area had important residential structures that were either used by the public or select residents.

In Mohenjo-Daro, a building has been identified as a warehouse.

- The Great Bath is a tank situated within a courtyard. The corridors were present on all four sides and stairs are seen on the northern and southern sides. It was well paved with several adjacent rooms. Some structures are identified as granary. The bricks were laid watertight with gypsum mortar. It had drainage. It is associated with a ritual bath.

Subsistence and Economic Production

- Agriculture was an important source of subsistence for the Harappans. TheHarappans cultivated diverse crops such as wheat, barley, lentil, chickpea, sesame and various millets. Agricultural surplus was an important stimulus for a number of developments. They adopted a double cropping system.

- The Harappans used ploughs. They perhaps ploughed the land and then sowed the seeds. Ploughed fields have been found at Kalibangan. They used both canal and well irrigation.

Archaeobotanists study ancient agriculture, and human and environmental relationships.

Animal Domestication

- Pastoralism was also practised by the Harappans. They domesticated sheep, goat and fowl. They had knowledge of various other animals including buffalo, pig and elephant. But horse was not known to them. The Harappan cattle are called Zebu. It is a large breed, often represented in their seals. They also ate fish and birds. Evidence of boar, deer and gharial has been found at the Harappan sites.

Craft Production

- Craft production was an important part of the Harappan economy. Bead and ornament making, shell bangle making and metalworking were the major crafts.They made beads and ornaments out of carnelian, jasper, crystal, and steatite, metals like copper, bronze and gold and shell, faience and terracotta or burnt clay. The beads were made in innumerable designs and decorations. They were exported to Mesopotamia and the evidence for such exported artefacts have been found from the excavations in Mesopotamian sites.
- Certain Harappan sites specialized in the production of certain craft materials. The following table presents the major centres of craft production.

Material	Site or Source
Shell	Nageshwar and Balakot
Lapis lazuli	Shortughai

Carnelian	Lothal
Steatite	South Rajasthan
Copper	Rajasthan and Oman

Pottery

- The Harappans used diverse varieties of pottery for daily use. They use well-fired pottery. Their potteries have a deep red slip and black paintings. The pottery are shaped like dish-on-stands, storage jars, perforated jars, goblets, S-shaped jars, plates, dishes, bowls and pots. The painted motifs, generally noticed on the pottery, are pipal leaves, fish-scale design, intersecting circles, zigzag lines, horizontal bands and geometrical motifs with floral and faunal patterns. The Harappan pottery is wellbaked and fine in decorations.

Metal, Tools and Weapons

- The Harappan civilisation belongs to the Bronze Age civilisation and Harappansknew how to make copper bronze tools. Although they produced bronze implements, they needed various kinds of tools for agriculture and craft production. The Harappans used chert blades, copper objects, and bone and ivory tools. The tools of points, chisels, needles, fishhooks, razors, weighing pans, mirror and antimony rods were made of copper. The chert blades made out of Rohrichert was used by the Harappans. Their weapons include arrowheads, spearhead, celt and axe. They did not have the knowledge of iron.

Rohrichert
The chert, a fine grained sedimentary rock, was found in the region of Rohri in Pakistan. It was used by the Harappans for making stone blades and tools

Textiles and Ornaments

- The Harappans wore clothes and used metal and stone ornaments. They hadknowledge of cotton and silk. The image identified as a priest is depicted wearing a shawl-like cloth with flower decorations.

- The terracotta images of women are shown wearing different types of ornaments. The image of dancing girl found at Mohenjo- Daro is shown wearing bangles in large numbers up to the upper arm. They made carnelian, copper and gold ornaments. Some of them had etched designs and they exported them to the Mesopotamian world. Faience, stoneware and shell bangles were also used. The ornaments produced were either sold or exchanged as part of the trade activities.

Trade and Exchange

- One of the sources of Harappan economy was trade and exchange activities.Harappans had close trade contacts with the Mesopotamians and also with various cultures of India. The Harappan seals and materials have been found in the Sumerian sites in Oman, Bahrain, and Iraq and Iran. The cuneiform inscriptions mention the trade contacts between Mesopotamia and Harappans. The mention of "Meluhha" in the cuneiform inscriptions refers to the Indus region. A Harappan jar has been found in Oman. Harappan seals, weights, dice and beads are found in Mesopotamia. Carnelian, lapis lazuli, copper, gold and varieties of wood were exported to Mesopotamia. Harappans also interacted with various regions of India and acquired raw materials and processed them.

Weights and Measures

- Harappans had developed proper weights and measures. Since they were involvedin commercial transactions, they needed standard measures. Cubical chert weightshave been unearthed from Harappan sites.

- The weights exhibit a binary system. The ratio of weight is doubled as 1:2:4:8:16:32.The small weight measure of 16th ratio weighs 13.63 grams. They also used a measuring scale in which one inch was around 1.75 cm. Weights made of chert were cubical. They used binary numbering system (1, 2, 4, 8, 16, 32, etc.). They might have been used for weighing jewellery and metal.

Seals, Sealings and Scripts

- The seals from various media such as steatite, copper, terracotta and ivory arefrequently found in the Harappan sites. The Harappan script has not yet been convincingly deciphered. About 5,000 texts have been documented from the Harappan sites. The longest text has about twenty six signs. Some scholars are of the view that it is Dravidian. Seals might have been used as an identity marker on the materials that were transported. They might have indicated the ownership.

Arts and Amusement

- The terracotta figurines, the paintings on the pottery, and the bronze images from the Harappan sites suggest the artistic nature of the Harappans. "Priestking" of steatite, dancing girl of copper (both from Mohenjo- Daro), and stonesculptures from Harappa, Mohenjo-Daro and Dholavira are the important objects of art. Toy carts, rattles, wheels, tops, marbles and hop scotches exhibit the amusement of the Harappan people.

Faith and Belief System

- The Indus people worshipped nature. They worshipped the pipal tree. Some ofthe terracotta figures appear to be mother goddess. Fire altars have been identified at Kalibangan. They buried the dead. Burials were made elaborately and evidence of cremation is also reported. The Harappan burials have pottery, ornaments, jewellery, copper mirrors and beads. These suggest their belief in an afterlife.

Polity

- Uniformity in pottery, seals, weights and bricks reveals the existence of a polity.Labour mobilisation may also suggest the existence of a political system. Harappa and Mohenjo-Daro might have had a city-state like polity. The uniformity in the cultural materials and measurement units point to a central authority during the Harappan times.

Authorship and the Making of Indian Culture

- One school of thought argues that the authors of Harappan Civilisation were speakers of the Dravidian languages. The archaeological evidence shows movement of the Harappans to the east and the south after the decline of their civilisation. Some of the Harappan people could have moved into different parts of India. However, only the decipherment of the script would give us a definite answer.

Contemporary Cultures of the Indus Civilisation

- Several groups including pastoral people, farmers and hunter-gatherers lived in the Indus region. The Indus region had villages and large towns. The population of that time was mixed. Innumerable communities of hunters-gatherers, pastoral people and farmers, from Kanyakumari to Kashmir and Gujarat to Arunachal Pradesh could have existed during this period. Their history is also equally important, as cultural and ecological knowledge of all these groups contributed to Indian culture.

- While the Indus Civilisation was flourishing in the north-western part ofIndia, several cultures were developing in different parts of India. In the southern part of the subcontinent, Kerala and Sri Lanka were given to hunting Harappans who had knowledge of water crafts might have had connections and interactions with South India, but no clear archaeological evidence on this is available. The northern part of South India, i.e. the Karnataka and Andhra region, had Neolithic cultures, engaged in pastoralism and plough agriculture. Similarly, the Chalcolithic cultures were prevalent in Deccan and western India, while Neolithic cultures permeated northern India including Kashmir, Ganges valley and central and eastern India. Thus India was a cultural mosaic during the time of the Harappans.

Decline

- The Indus Valley Civilisation declined from about 1900 BCE. Changes inclimate, decline of the trade with the Mesopotamia, and the drying of the riverand water resources due to continuous drought are some of the reasons attributed by historians for the decline. Invasions, floods and shifting of the river course are also cited as reasons for the ruin of Indus civilisation. In course of time, the people shifted to the southern and eastern directions from the Indus region.

Indus Civilisation and Tamil Civilisation
The Indus Civilisation represents the first urbanisation of Indian history.

The origin and authorship of the Indus Civilisation are keenly debated historical questions. The Indus script has not yet been conclusively deciphered and hence the authorship is not certain. The graffiti found on the megalithic burial pots of South India and the place names presented are cited to establish the relationship between Indus and Tamil cultures.

The archaeological evidence points to several groups of people living in Tamil Nadu and South India continuously from the Mesolithic period. One cannot rule out the migration of a few groups from the Indus region. More research is necessary before arriving at any definite conclusion.

The towns of ancient Tamizhagam such as Arikamedu, Keezhadi and Uraiyur that flourished are part of the second urbanisation of India and these towns are quite different from the Indus cities.