General Science-1-Biochemistry and Cell Biology

Basic Features of Life

Biology is the science of living things or organisms. Scientific evidence suggests that life began on

Earth approximately 3.5 billion years ago by variously proposed mechanisms.

Basic Features

Life is considered a characteristic of organisms that exhibit all or most of the certain phenomena

such as Homeostasis, organization, growth, adaptation, response to stimuli and reproduction.

Homeostasis is the regulation of the internal environment to maintain a constant state. For

example: electrolyte concentration or sweating to reduce temperature.

Organization means that any living organism is made of one or more cells and cells serve as

basic unit of life.

Metabolism refers to life-sustaining chemical transformations within the cells of living

organisms. Metabolic reactions are of two types viz. anabolism and catabolism. Anabolism

refers to transformation of energy by converting chemicals and energy into cellular

components. Catabolism refers to decomposing organic matter. Living things require energy

to maintain internal organization (homeostasis) and to produce the other phenomena

associated with life.

Growth refers to increase in size in all of parts of an organism. To grow, the organisms need

to maintain a higher rate of metabolism than catabolism.

Adaptation is the ability to change over time in response to the environment. This ability is

fundamental to the process of evolution and is determined by the organism's heredity, diet,

and external factors.

Response to stimuli can take many forms, from the contraction of a unicellular organism to

external chemicals, to complex reactions involving all the senses of multicellular organisms.

A response is often expressed by motion; for example, the leaves of a plant turning toward

the sun (phototropism), and chemotaxis.

Reproduction is the ability to produce new individual organisms, either asexually from a single

parent organism, or sexually from two parent organisms.

Are Viruses Living Organisms?

Viruses are most often considered replicators rather than forms of life. They have been described as

"organisms at the edge of life, because

They possess genes

They evolve by natural selection

They replicate by creating multiple copies of themselves through self-assembly.

However, viruses do not metabolize and they require a host cell to make new products. Virus selfassembly

within host cells has implications for the study of the origin of life, as it may support the

hypothesis that life could have started as self-assembling organic molecules.

Living properties	Non-living properties
The presence of DNA or RNA (but never both)	The absence of cell.
Structural diversity	The lack of protoplasm.
Geneticity and parasitic properties	No any reproduction and growth outside the living cell.
Sensitivity and evolution	Stored in the form of crystal outside the living cell.
Capable of spreading the disease	The lack of metabolic activities like nutrition, digestion

Carbon Bonds – The Basic Feature of Life on Earth

Life on earth is carbon based because carbon makes up 18 percent of the weight of the human body.

Due to its unique electron configuration, carbon needs to share electrons. It can form four covalent

bonds with other carbon atoms or a variety of other elements.

Comparison of Carbon and Silicon

We note here that technically, life on Earth could be based on silicon also because this element has

the same bonding properties as carbon. However, there is much less silicon than there is carbon on

Earth. Further, Carbon wins the competition on many accounts as follows:

The bonding versatility of Carbon allows it take on many forms: long side chains that make

up fatty acids and cell membranes, ring structures that compose hormones and sugars, and

even simple gaseous molecules like methane (CH_4) or carbon dioxide (CO_2). Silicon has not

those capabilities.

While carbon is perfectly comfortable in a variety of different structures (rings, long chains,

multi-ring chains, and double-bonded carbon catenations), silicon's analogous structures are comparatively unstable and sometimes highly reactive. Additionally, such analogous silicon

compounds may never occur in nature; the largest silicon molecule ever observed had only

six silicon atoms. In contrast, some carbon-based molecules can have tens of thousands!

Molecules of Life

Four chemical elements that make up the majority of living biological matter are *Carbon, Hydrogen,*

Oxygen and Nitrogen. Organisms are made of both organic and inorganic substances.

Inorganic substances

Some of the most common inorganic substances needed for life are water, mineral salts, molecular

oxygen, molecular carbon dioxide etc. Out of them, water is the most abundant inorganic substance

in almost all animals and plants. Mineral salts are simple, inorganic substances made up of metallic

chemical elements, such as iron, sodium, potassium, calcium and magnesium, or of non-metallic

elements, such as chlorine and phosphorus. The mineral salts are found in two forms viz. solubilized

ions (such as sodium and potassium ions in cells) or non-solubilized form such as calcium in our

bones.

Organic Molecules

There are many types of organic molecules that are important for living organisms. Out of them,

four molecules viz. nucleic acids (DNA & RNA) , Proteins, Carbohydrates and Lipids are referred to as bioorganic *molecules* because they are essential to living organisms and contain carbon. These perform

the basic functions of life such as structural functions (compose, surround and maintain organs,

membranes, cell organelles, etc.), energy functions (chemical reactions in metabolism), control and

informative functions (genetic code control, inter and intracellular signalling etc.) and enzymatic

functions (facilitation of chemical reactions).

These molecules are much more complex and made of sequences of carbon chains bound to other

elements called *polymers* or *biopolymers* or *giant polymers*. They are also called *macromolecules*– the

molecules which have molecular weight greater than 1,000 Daltons.

These four kinds of Macromolecules are quite diverse in terms of structure, size, and function. Some

of the common features of all of them are as follows:

All are comprised of single units linked together to create a chain. Similar to a freight train

with many cars. All the monomers or single units contain carbon.

All monomers are linked together through a process known as *dehydration synthesis*, which

literally means "building by removing water."

All polymers are broken down by the same method calledh *ydrolysis*. Hydrolysis means

"breaking with water."

Carbohydrates, lipids, and even proteins can be metabolized for energy. ATP and related compounds

are used as temporary energy storage vehicles. The comparative value of the common energy sources

for cells is given below:

Carbohydrate → 4 kcal/g

Fat → 9 kcal/g

Protein → 4 kcal/g

Importance of Water for Life

Water is the basis of life. There are various properties of water that make it basis of life. These

include its molecular polarity, high specific heat, its boiling and melting points which allow it to

remain liquid in most environments on Earth, its acid-base neutrality, small molecular size and low

chemical reactivity.

Water as solvent

It serves as *fundamental solvent* for the chemical reactions in living organisms and is the main means

of substance transportation between cells and tissues. It is responsible for correct temperature for life

of an organism and is either regent or product of chemical reactions. All important macromolecules

are produced by dehydration synthesis and broken down by hydrolysis.

Water in Human Body

Water makes around 65% of human body mass. It makes 90% of our brain, 85% of

muscles and 25-40% of bones. Children have a greater proportion of water in their

body in comparison to elders.

Polarity of Water

In water, two hydrogen atoms are attached to one central atom of oxygen by covalent bond, making

an angular spatial structure. Since the hydrogen atoms lend electrons to the oxygen;*o xygen atom* *becomes more negative while the hydrogen atoms become more positive*. The spatial geometry of water

makes it thus a polar molecule with negative and positive poles. If a molecule is polari,t will be

attracted to other polar molecules. This can affect a wide range of chemical interactions, including

whether a substance will or will not dissolve in water, the shape of a protein, and the complex helical

structure of DNA.

Water and working of a microwave Oven

Water is the most common example of a polar molecule and that is also the reason that

when we put a potato in a paper plate in a microwave, potato gets hot but not the

paper plate. If we put the potato in a wet paper plate, it would get cooked along with

Potato.

The implication of water being a polar molecule is that it works as an excellent solvent for polar

substances because the electrical activity (attraction and repulsion) of its poles helps in the separation

and the mixing of these substances, giving them more movement and thus increasing the number of

molecular collisions and the speed of chemical reactions. On the other hand, water is not a good

solvent for non-polar substances.

Water Soluble and Fat Soluble Substances

Water-soluble substances are polar molecules, meaning that they have electrically charged areas. Fatsoluble

substances are non-polar molecules, meaning that they are electrically neutral.

Role of Water for Enzyme Activity

There can be no enzyme activity without water. The enzymes need water and correct pH to do their

job. The pH is result of release of hydrogen cations (H_) and hydroxyl anions (OH_) by the acids and
bases in water solutions.

Significance of heat capacity of water

The specific heat of water is 1 cal/gram °C. This implies that there is 1°C per gram change in its
temperature per every addition or subtraction of 1 cal of energy. This is a very high value (compare it
with ethanol that has 0.58 cal/g°C, and mercury that has 0.033 cal/g°C). This feature of water makes
it an excellent thermal protector against temperature variations. Even if there is a sudden external
temperature change, the internal biological conditions are kept stable in organisms containing
enough water.

Mineral Salts and Ions

Inorganic substances made of metallic elements such as iron, sodium, potassium, calcium and
magnesium, or of non-metallic elements, such as chlorine and phosphorus. The mineral salts are
found in two forms viz. solubilized ions (such as sodium and potassium ions in cells) or nonsolubilized
form such as calcium in our bones.

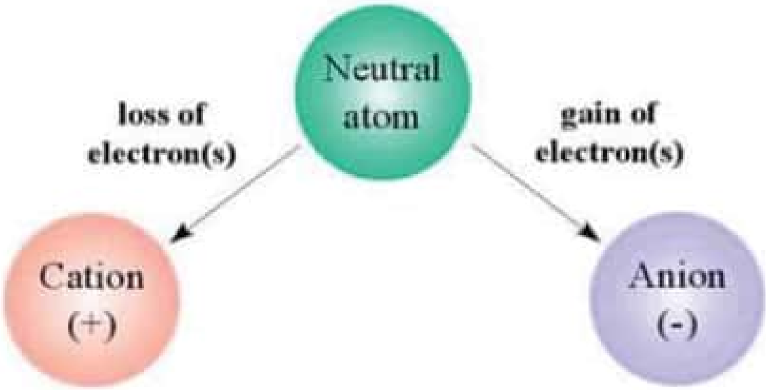
Cations and Anions

Ions are atoms or molecules that are electrically charged due to losing or gaining electrons {electrons
are negatively charged as we all know}.

The cations are ions with positive charge. A cation is formed when a neutral atom or
molecule loses electrons (gains positive charge). Important cations in our body are sodium
(Na+), potassium (K+), calcium (Ca++), iron (Fe++, Fe+++), magnesium (Mg++), zinc (Zn++) and
manganese (Mn++).

Anions are ions with negative electrical charge. An anion is formed when a neutral atom or
molecule gains electrons (gains negative charge). Important anions in our body are chloride

(Cl–), phosphate (PO4—), bicarbonate (HCO3–), nitrate NO3–) and sulphate (SO4–).



Role of mineral salts in osmotic regulation

In our body, *mineral salts along with glucose, proteins and urea*are key substances for osmotic
regulation. These molecules being inside or outside of the cell generate a larger or smaller osmotic
gradient between intracellular and extracellular space.

Role of mineral salts in nervous system

The mineral salts play important role in the creation of electric voltage at cellular level. This cellular
electric activity depends on the concentration of the cations and anions between inner and outer
surfaces of the cell membrane. This is very important function which allows the neurons work.

Role of mineral salts in enzyme activity

pH regulation is very important because some enzymes work only under certain pH range. The
mineral salts play important role pH regulation. Further, some minerals work as cofactors of
enzymes and without them, enzymes cannot work.

Importance of Sodium

Sodium is a necessary ion in both plants and animals. In plants, it's a micronutrient that aids in
metabolism. It also serves as substitute for Magnesium for several functions in plants such as opening
and closing of stomata. *Excessive sodium in soil would result in lower water potential, reducing uptake of
water from soil by plants.*

In animals, Sodium is necessary for maintenance of electrolyte balance; fluid balance; generation of the nerve impulses, heart activity, blood volume, blood pressure, osmotic equilibrium, pH and many metabolic activities. In humans, table salt is the most important source of Sodium. A human needs half gram sodium every day, which can be obtained from 1.2 to 1.5 grams of table salt. However, generally we take more than that required amount. In excessive amount, salt would promote hypertension.

Hypernatremia, Hyponatremia and Thirst

In human body, the brain part hypothalamus and pituitary glands control the balance of sodium and water concentration in extracellular fluids. If a person loses too much body water, the sodium concentration in blood will rise higher than normal. The hypothalamus would sense it and would result in thirst. This condition is also known as Hypernatremia. On the other hand, if we drink lots of water, it would reduce concentration of sodium in blood, which is called Hyponatremia. This would cause loss of water as urine. We note here that when a severally hydrated person is rescued from desert or ocean, he would have very high blood sodium concentration. This must be slowly and carefully treated because rapid correction of Hypernatremia can result in brain damage from cellular swelling.

Importance of Calcium

Calcium is present in almost all cells and plays important role in physiology and biochemistry in both plants and animals. In plants, Calcium and Potassium ions both work in tandem in the opening and closing of stomata. In some cases, Sodium can work in place of Potassium in case of deficiency of the later. Without Calcium, the mitotic spindle cannot form during cell division and thus needed for healthy plant growth. Further, Calcium ion is an essential component of cell walls and cell

membranes. It is needed to stabilize the permeability of cell membranes. This is very important
function in fruits where without Calcium; the cell walls would become weak and will not be able to
hold the fruit content. Calcium is also stored in plants and provides some mechanical strength.
In animals and humans, Calcium plays important role in muscular contraction, blood coagulation,
formation of bone tissue, teeth, motility of the sperm cells and transmission of the nerve impulses.
Bones serve as storage site for Calcium and when needed, Calcium is released from Bones into blood.
It remains in the blood as dissolved ion or bound to serum albumin. This function is controlled by
Parathyroid gland and its parathyroid hormone.

Importance of Iodine

Iodine is needed for proper functioning of the thyroid. Iodine deficiency creates hypothyroidism also
known as goitre.

Importance of Chloride

Like Sodium, chloride also actively participates in the osmotic regulation. Both sodium and chloride
play important role in acid-base balance of an organism.

Carbohydrates

Carbohydrates are compounds of Carbon, Hydrogen and Oxygen and are known as Hydrates of
Carbon. The common formula of all Carbohydrates is $C_m(H_2O)_n$, where m and n may be different
values. However, Deoxyribose Sugar of DNA is an exception and its molecular formula is $C_5H_{10}O_4$.
Sugars, starch and cellulose are some of the common examples of Carbohydrates.

Classification

Carbohydrates are classified in several ways. Monosaccharides (single unit sugars) are grouped by the
number of carbon molecules they contain: For example, triose has three pentose has five and hexose
has six. Carbohydrates are also classified by their overall length (monosaccharide, disaccharide or
polysaccharide) or function.

Monosaccharides are simple carbohydrates molecules that cannot be broken down into smaller
molecules of other carbohydrates. Glucose and fructose are examples of Monosaccharides.
Disaccharides are carbohydrates made up of two monosaccharides and which are missing one
molecule of water (dehydration). The chemical bond between two monosaccharides is known
as a *glycosidic bond*. Table sugar *Sucrose* is a disaccharide made of one molecule of glucose and one molecule of fructose. *Maltose* is also a disaccharide that *consists of two glucose molecules*.
Lactose or milk sugar is another disaccharide made of one molecule of galactose and one
molecule of glucose.
Oligosaccharides are carbohydrates made of maximum of 10 Monosaccharides.
Polysaccharides are polymers of monosaccharides made of more than 10 units. Common
examples of polysaccharides are cellulose, starch, glycogen, chitin etc. Polysaccharides do
structural and storage functions. *Storage polysaccharides* (glycogen and starch) store energy
while *structural polysaccharides* (cellulose and chitin) provide support for organisms without a
bony skeleton
Hexose Sugars and Pentose Sugar examples
Hexose sugars are carbohydrates made of six carbon atoms. Glucose, fructose and
galactose are all examples of hexose. Hexose sugars are energy sources for the
metabolism.
Deoxyribose and Ribose sugars are fundamental components of DNA and RNA respectively. Both of
these are pentose sugars.

Lipids

Lipids refer to a group of molecules comprising *fats, oils, phospholipids, waxes and steroids*. All lipids
are hydrophobic and don't dissolve in water. However, they dissolve in organic solvents. The

backbone of all lipid compounds is Glycerol or Glycerine. Glycerol is a sugar alcohol, made of a linear
chain of *three carbon atoms* and three hydroxyl groups. It is soluble in water.

Hydrophobic and Hydrophilic molecules

Hydrophobic molecules are molecules which don't dissolve in water (hydro = water, phobia = fear).
Hydrophilic molecules dissolve in water (philia = friendship). Water is a polar substance. The thumb
rule is that "equal dissolves equal", so, hydrophobic substances are non-polar molecules whereas
hydrophilic molecules are polar molecules. Fats and oils are hydrophobic molecules, meaning that
they are non-polar and insoluble in water. Lipids in general are molecules with a large non-polar
extension, making them soluble in non-polar solvents, such as benzene, ether and chloroform. There
exist some amphipathic lipids (example Phospholipids) which are soluble in water as well as organic
solvents.

Fats and Oils

The fats are triglycerides made of three molecules of fatty acids bound to one molecule of glycerol.
Thus, fats are also known as triesters of glycerol. Fats are not soluble in water but soluble in organic
solvents.

Phospholipids

Phospholipids are molecules made up of *one molecule of glycerol* bound to two *molecules of fatty acids*
and also one phosphate group. They are main components of the cell membranes. Phospholipids are
amphipathic molecules, meaning that they have a non-polar portion, due to the long fatty acid chains,
and a polar portion, due to the phosphate group. They dissolve in water as well as organic solvents.

Steroids

Steroids are another class of lipids, which have a unique chemical structure. They are built from four
carbon-laden fused ring structures. Bile salts, cholesterol, the sexual hormones estrogen,

progesterone and testosterone, corticosteroids and pro-vitamin D are examples of steroids. Their
functions are as follows:
Aldosterone : Maintains water and salt balance by the kidney, controls blood pressure
Bile acids : Produced by the liver, help in the digestion of dietary lipids
Cholesterol : Provides stability and flexibility to cell membranes
Cortisone : Carbohydrate metabolism
HDL (high density lipoproteins) and LDL (low density lipoproteins): Lipid-protein combinations
that transport lipids in the blood
Testosterone, estrogens, progesterone: Maintain sex characteristics. Allow reproduction to occur.

Saturated and Unsaturated Fats

In Saturated fats, the Carbon molecule is bound to as many hydrogen molecules as many it is
possible. Thus, all C-C bonds in saturated fats are single bonds only. There are no double or triple
bonds in saturated fats. *Generally, saturated fats are solid at room temperature.* Examples of saturated fat
are ghee, cream, cheese, butter etc.
In unsaturated fats, double and triple C-C bonds are found, and thus there is a possibility of adding
few more hydrogen atoms. Generally, unsaturated facts are liquid at room temperature. If there are
more than carbon-carbon double / triple bonds present, such fat is called Poly Unsaturated Fatty
Acid (PUFA). Examples of such PUFA include palmitoleic acid, oleic acid, myristoleic acid, linoleic
acid, and arachidonic acid.

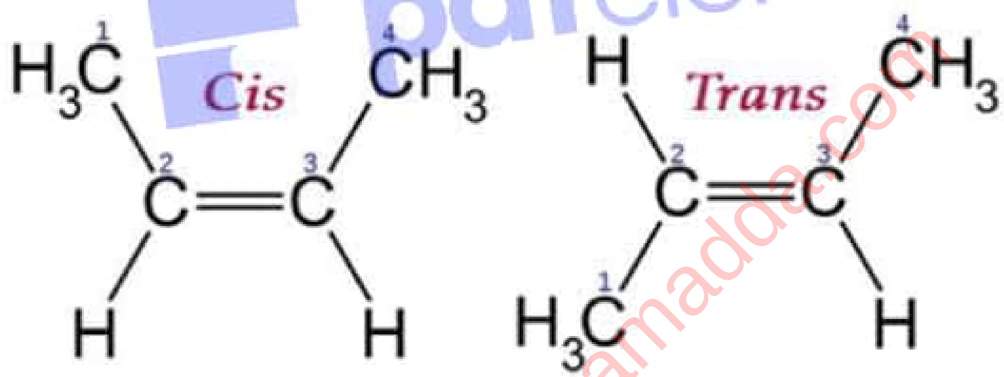
Hydrogenation: Converting Unsaturated Fat to Saturated Fat

The unsaturated fatty acids have double bonds, and therefore have fewer hydrogen atoms than
maximum possible. The process of hydrogenation can convert an unsaturated fat into saturated fat
by adding extra hydrogen atoms to it. Thus, hydrogenation converts liquid vegetable oils into solid or
semi-solid fats. *This reaction is the basis of Vegetable Oil industry and is achieved in the presence of some*

catalysts such as nickel, palladium or platinum metals. This method has prevented oxidation and thus
rancidity and has allowed for the development of foods with less animal and saturated fats. However, the consumption of hydrogenated fatty acids increases risk of heart disease, because the fats cause a
change in the structure of targeted unsaturated fatty acids. Kindly note that *majority but not all double*
/ triple bonds broken during hydrogenation of unsaturated fats. Hydrogenation may also result in
creation of unsaturated fats with peculiar hydrogen atoms arrangement called "Trans Fats".

Trans and Cis Fats

Cis and *trans* are terms that refer to the arrangement of the two hydrogen atoms bonded to the
carbon atoms involved in a double bond in *unsaturated fats*. There are no cis or trans types in
saturated fats because they have single bonds only.
In the cis arrangement, the hydrogen atoms are on the same side of the double bond. In the trans
arrangement, the hydrogens are on opposite sides of the double bond.



We note here that most naturally occurring fats are Cis fats. Only a handful of naturally occurring
fats are trans fats such as those found in milk and body fat of ruminants (such as cattle and sheep).
Further, trans fats are generated during hydrogenation processing of polyunsaturated fatty acids in
food production. They are outcome of the Partial Hydrogenation anndo t the complete
Hydrogenation, because complete Hydrogenation would end the double bonds.

The process of hydrogenation adds hydrogen atoms to unsaturated fats, eliminating double bonds and making them into partially or completely saturated fats. However, partial hydrogenation, if it is chemical rather than enzymatic, converts a part of cis-isomers into trans-unsaturated fats instead of hydrogenating them completely.

Impacts of Trans fats on health

The consumption of trans fats has been shown to slightly increase the levels of bad cholesterol (LDL) in the blood. However, as per recommendations of the US National Academy of Sciences (NAS), trans fats are not essential and provide no known benefit to human health", whether of animal or plant origin. While both saturated and trans fats increase bad cholesterol; the trans unsaturated fats also lower levels of good cholesterol. In this way, trans fats increase the risk of heart diseases.

Good Fats or Bad Fats

One thing is clear that no fats are "bad," as fats are excellent sources of energy and help to maintain the health of the body. However, Fat is only bad if it is too much. There are several fats that are considered essential (the omega-6 and omega-3 fatty acids)-in other words, they are substances that our bodies require for maintenance but that we cannot manufacture. These are considered to be "good" fats. Comparatively, the fats we don't need to ingest are often dubbed as "bad."

Thermal Properties of Fats and Lipids

Fats are poor heat conductors and they also form thick layers of fatty tissue (called adipose tissue) when accumulated in an organism. This is the reason that they serve as good thermal insulators. In cold climate fauna such as polar bears, seals and whales, adipose tissue helps the maintenance of internal body temperature.

Fats as source of Energy

In carbohydrates are the main energy sources for aerobic cell respiration. However, when carbohydrates are absent or deficient, the body can use lipid (and also proteins) to break them and get energy.

Cholesterol

Cholesterol refers to *a subclass of lipids known as steroids*. Cholesterol is also the molecule from which steroid hormones and bile acids are built.

Importance of Cholesterol

Cholesterol is a steroid of fat used to *maintain the strength, permeability and flexibility of cell membranes*.

It also serves as a precursor for the biosynthesis of sex hormones, bile acids, and vitamin D.

Sources of Cholesterol

Cholesterol is predominantly synthesized in our body in Liver and also provided in food. Food also supplements Cholesterol. All foods containing animal fat contain cholesterol to varying extents.

Major dietary sources of cholesterol include cheese, egg yolks, beef, pork, poultry, fish, and shrimp.

Cholesterol is not found in significant amounts in plant sources. However, ingested cholesterol is esterified. This esterified cholesterol is poorly absorbed. That is the reason that *cholesterol intake in food has little effect on total body cholesterol content or concentrations of cholesterol in the blood*. In our body, Liver secretes it in a non-esterified form (via bile) into the digestive tract. Typically about 50% of the excreted cholesterol is reabsorbed by the small intestine back into the bloodstream.

Transport of Cholesterol in Lipoproteins

Cholesterol is only slightly soluble in water; it can dissolve and travel in the water-based bloodstream at exceedingly small concentrations. Since cholesterol is insoluble in blood, it is transported in the circulatory system within lipoproteins.

There are several types of lipoproteins in blood, called, in order of increasing density, chylomicrons, very-low-density lipoprotein (VLDL), intermediate-density lipoprotein (IDL), low-density lipoprotein (LDL), and high-density lipoprotein (HDL). The more lipid and less protein a lipoprotein has, the less dense it is.

Control of Cholesterol: Statins

Statins are a group of drugs that work to lower cholesterol Levels, particularly the "bad cholesterol".
Low-density lipoprotein known as LDL. The drugs work in two ways. First, they block an enzyme
that is needed for cholesterol production. Second, they increase LDL membrane receptors in the
liver.

Proteins

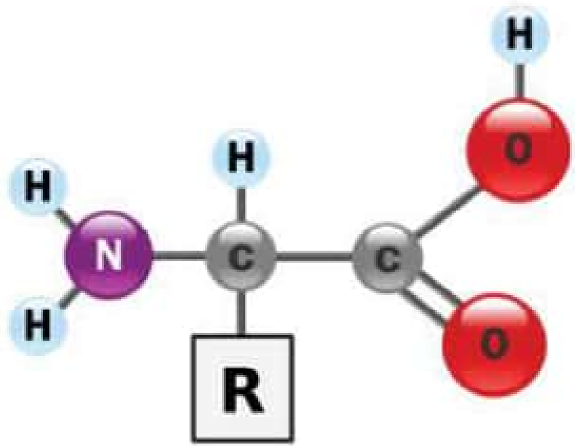
Proteins are made up of chains of amino acids bound by bonds called peptide bond. There are some
22 different *known* amino acids which can compose proteins. There may be many more unknown to
us.

Functional Versatility of Proteins

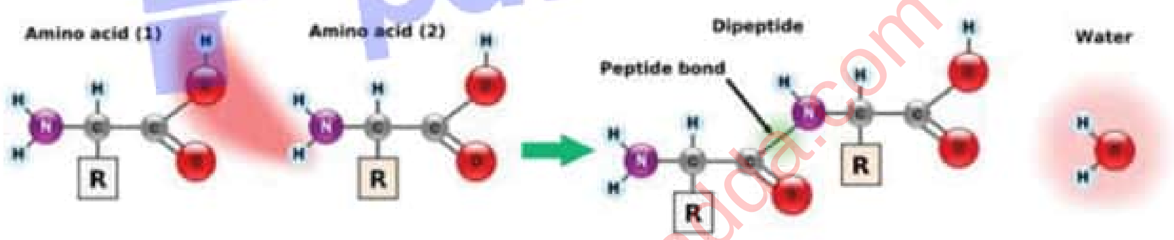
Numerous combinations of amino acids can form different polypeptide chains and thus a great
variety of proteins can be produced. Consequently, proteins can take different configurations and
thus play role in a lots of biological processes. Thus, there are several types of Proteins which do
specific functions as follows:
Defensive Proteins: Antibodies that respond to invasion
Enzymatic Protein: Increase the rate of reactions, build and breakdown molecules
Hormonal Proteins: Insulin and glucagon, which control blood sugar
Receptor Proteins: Cell surface molecules that cause cells to respond to signals
Storage Proteins: Store amino acids for use in metabolic processes
Structural Proteins: Major components of muscles. Skin, hair, horns etc.
Transportal Proteins: Haemoglobin carries oxygen from lungs to cells

Formation of Proteins

Amino acids are the basic units of proteins. There are 22 known amino acids and many more might
be there unknown to us. Each amino acid has at least one carboxyl group –COOH, one amine group
– NH_2 and an hydrogen atom –H. Further, there is a variable radical called -R. All of these are bound
to a central carbon atom as shown below:



The R may be a complex chain of carbon atoms, or simply a methyl group or even a hydrogen atom.
R is what distinguishes one amino acid from others. Two amino acids are bound by a peptide bond as
mentioned above. The peptide bond is such that carboxyl group of one amino acid is connected to
the nitrogen atom of the amine group of another amino acid. A molecule of water is released when
such bond is established as shown below:



As shown above, many amino acids can bind through these peptide bonds and create linear chains.
We note here that the same amount of amino acids can create different proteins because the
difference depends on the types of amino acids or on the sequence in which they form the protein.
A chain of more than 50 peptide molecules is called Polypeptide. Proteins have very complex
structural patterns of these polypeptides. They require up to four levels of structure in order to be
functional. The four levels of Protein Structure are as follows:

Primary: Polypeptide chain of up to 500 amino acids covalently bonded. The sequence is important and unique for each polypeptide.

Secondary: The formation of hydrogen bonds between nearby amino acids causes the polypeptide chain to twist and/or pleat.

Tertiary: Distant amino acids form bonds and associations in reaction to changes that occur in the secondary level.

Quaternary: Two separate polypeptide chains intermingle to form a molecule that has a larger, more complex structure than that found in the other protein levels.

This structural complexity makes the proteins so versatile that relatively slight environmental changes cause a shift in structural levels that may be sufficient to radically change the function of the protein.

Further, the secondary, tertiary and quaternary structures of a protein are *spatial structures*. If there is any change in that spatial structure, the protein will denature and cease to do the function which it was supposed to do. This denaturation may or may not be reversible. The factors that cause such denaturation include change in temperature, change in pH, change in concentration of solutes in surrounding environment etc. This is the reason that organisms need to maintain stable internal temperature and pH so that proteins including enzymes etc. can do their normal jobs.

Cooking and Denaturation of protein

When we cook food, proteins become denatured. This is the reason that the boiled eggs become hard and cooked meat become firm. In an unboiled egg, the egg white is transparent and liquid. When its boiled or cooked, egg white turns opaque and solid mass.

Essential and Non-essential amino acids

Some 12 of the 22 known amino acids can be synthesized in our body. These are non-essential.

Essential amino acids are those that the body is not able to synthesize and which need to be taken as diet. Examples of some of the essential amino acids are {don't cram→} phenylalanine, histidine, isoleucine, lysine, methionine, threonine, tryptophane and valine.

Examples of Common Proteins

Myosin protein when bound to actin produces a muscle contraction.

CD4 is a membrane protein in some lymphocytes, the cells that are infected by HIV.

Albumin is an energy storage protein and also an important osmoregulator of blood.

Keratin is a protein with a structural function and which is present in the epidermis and skin appendages (hair, nails) of vertebrates.

Immunoglobulins are antibodies, specific proteins that attack and inactivate foreign agents that enter the body.

Reverse transcriptase is the enzyme protein responsible for the transcription of RNA and the formation of DNA in the life cycle of retroviruses.

Haemoglobin is the protein that carries oxygen from the lungs to cells.

Insulin is a hormone secreted by the pancreas that participates in the metabolism of glucose.

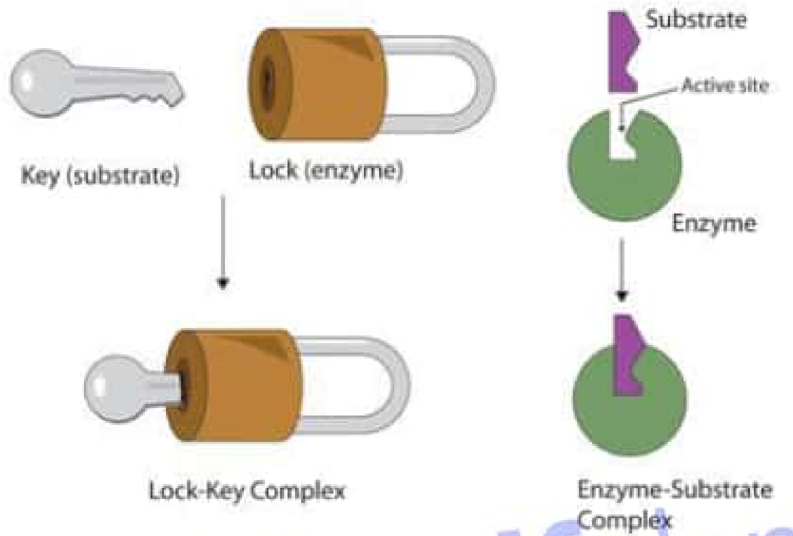
Enzymes

Enzymes are proteins that act as biological catalysts. They decrease the amount of energy needed (activation energy) to start a metabolic reaction. Without enzymes, organisms are not being able to harvest energy and nutrients from food. One common example is the*L actose intolerance*. Lactose intolerance is the inability to produce lactase, the enzyme that breaks down milk sugar (lactose).

Functions of Enzymes

Enzymatic reactions can build up or break down specific molecules. The specific molecule an enzyme works on is the substrate. In the function of the Enzyme, *Shape is very critical*. We note that enzymes are complex proteins with specific three dimensional spatial shapes. The "active site" of an enzyme is

the area where substrate binds and the reaction takes place. How an enzyme reacts with its substrate
is similar to how a lock and key work. There are minor bonds that form between the enzyme and
substrate until locking and unlocking is done.



Anything affecting the shape of the key would make the key unable to lock and unlock.

Naming of Enzymes

The naming of the enzymes is peculiar. Individual enzymes are named by adding the suffix "ase" to
the name of the substrate with which the enzyme reacts. For example enzyme amylase controls the
breakdown of amylose (starch), hydrolases control hydrolytic reactions; proteinases control protein
breakdown; synthetases control synthesis reactions. However, some enzymes retain their name from
older system when this 'ase' nomenclature was not adopted. Examples are trypsin and pepsin, both
digestive enzymes that breakdown protein.

Applications of Enzymes

Enzymes are used in the chemical industry and other industrial applications when extremely specific
catalysts are require. For example:
Amylases from fungi and plants are used in Food Processing Industry. For Instance,

production of sugars from starch, such as in making high-fructose corn syrup.
Proteases are used by the biscuit manufacturers to lower the protein level of flour.
Trypsin enzyme is used in the making of Baby Foods
Several enzymes are used in making wines and whiskeys. Enzymes from barley are released
during the mashing stage of beer production.
Cellulases, pectinases are used in packing juices; they help to clear the cellulose from juice.
Rennin, derived from the stomachs of young ruminant animals (like calves and lambs) are used in the
dairy industry to produce Cheese.
Papain obtained from Papaya is used as a softener in meat cooking.
Amylases, Xylanases, Cellulases and ligninases are used in Paper Industry.
A class of drugs called protease inhibitors are powerful HIV-fighting medications Protease
inhibitors prevent T-cells that have been infected with HIV from making new copies of the
virus.

Enzymes and pH

Since changes in temperature and pH can cause the structure of a protein to change, every enzyme
has criteria that must be met in order for it to perform its function. For example, the amylase that is
active in the mouth cannot function in the acidic environment of the stomach; pepsin, which breaks
down proteins in the stomach, cannot function in the mouth.

Spinach TNT and Enzymes

TNT is a dangerous explosive. Spinach contains a powerful enzyme called nitro-reductase that is able
to neutralize TNT by converting it to other compounds that are less dangerous. Through additional
reactions, these less-harmful compounds can be converted to carbon dioxide gas.

Enzyme cofactors

Few enzymes need other associated molecules to do their job properly. These molecules are called
enzyme cofactors. They can be organic ions like mineral salts, or organic molecules, or Vitamins.

Inactive enzymes which are not bound to their cofactors are called apoenzymes. Active enzymes
bound to their cofactors are called holoenzymes.

Use of Enzyme Inhibitors in Health Science

Substances that "simulate" substrates can bind to the activation center of enzymes, thus blocking the
true substrates from binding to these enzymes and paralyzing the enzymatic reaction. These "fake
substrates" are called enzyme inhibitors. Many Pharma drugs such as some antibiotics are enzyme inhibitors that block enzyme activity. We note here that Penicillin {first antibiotic discovered}
inhibits the enzymes necessary for the synthesis of peptidoglycans, a component of the bacterial cell
wall. Using this would block growth of the bacteria and this is what won Nobel Prize for Alexander
Fleming for discovery of penicillin. Similarly, some antiretroviral drugs called "protease inhibitors"
are used against HIV infection. Protease is an enzyme necessary for the construction of the human
immunodeficiency virus (HIV) after the synthesis of its proteins within the host cell. The protease
inhibitor binds to the activation center of the enzyme blocking the formation of the enzymesubstrate
complex and enzyme activity, thus stopping viral replication.

Nucleic Acids

DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are nucleic acids. Nucleic acids are
molecules comprised of monomers known as *nucleotides*. These molecules may be relatively small (as
in the case of certain kinds of RNA) or quite large (a single DNA strand may have millions of
monomer units) individual nucleotides and their derivatives are important in living organisms. ATP,
the molecule that transfers energy in cells is built from a nucleotide as are a number of other
molecules crucial to metabolism.

*DNA and RNA molecules are responsible for hereditary information that controls the protein synthesis in
living organisms.* They are called nucleic acids because they were first discovered within the nucleus of

the cell by a Swiss biochemist Friedrich Miescher.

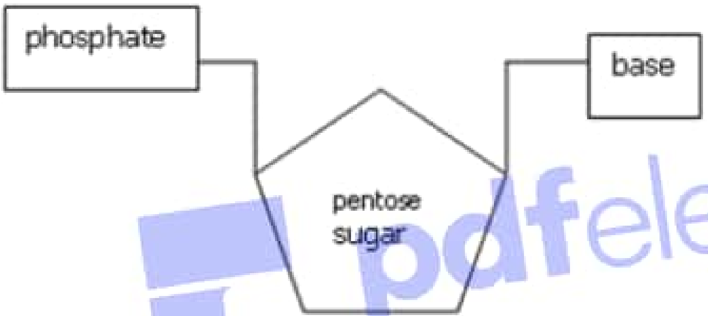
Location of DNA and RNA

In prokaryotic cells, DNA and RNA are found dispersed in the cytosol, the fluid space inside the cell.

In eukaryotic cells, *DNA and RNA are found within the cell nucleus and also in mitochondria and chloroplats*. Further, RNA is also the main component of nucleolus and ribosome in eukaryotic cells.

Composition of DNA and RNA

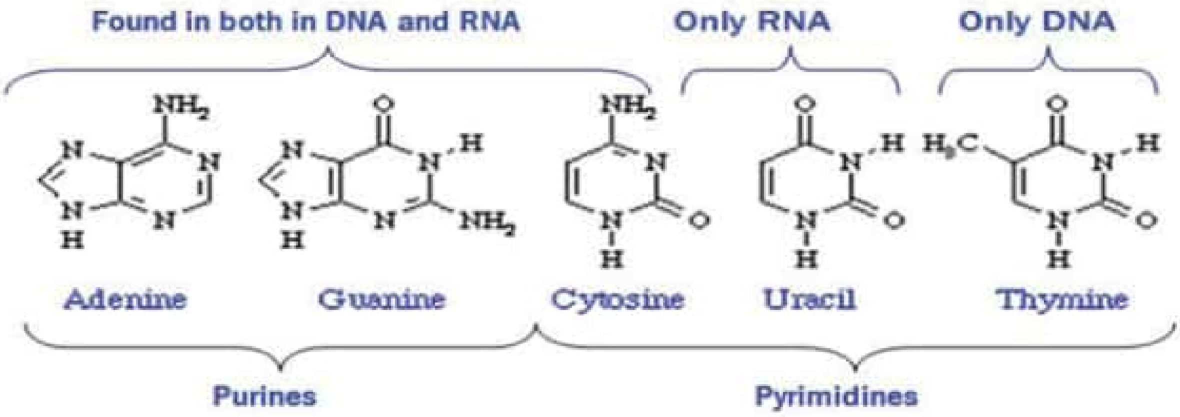
Both DNA and RNA are formed by sequences of nucleotides. A Nucleotide is made of one molecule of a pentose sugar (Deoxyribose in DNA and Ribose in RNA) bound to one molecule of phosphate and to one nitrogenous base.



While remaining things are same, the nitrogenous bases are of five types viz. Adenine (A), Guanine (G), Cytosine (C), Thymine (T) and Uracil (U).

Out of them, adenine and guanine are called Purines (because they have fused ringed structure), while cytosine, thymine and uracil are called Pyrimidines (because they have single ring structure).

Further, while both DNA and RNA consist of adenine, guanine and cytosine; *thymine is only found in DNA* and *uracil in RNA*. This is shown in below image:

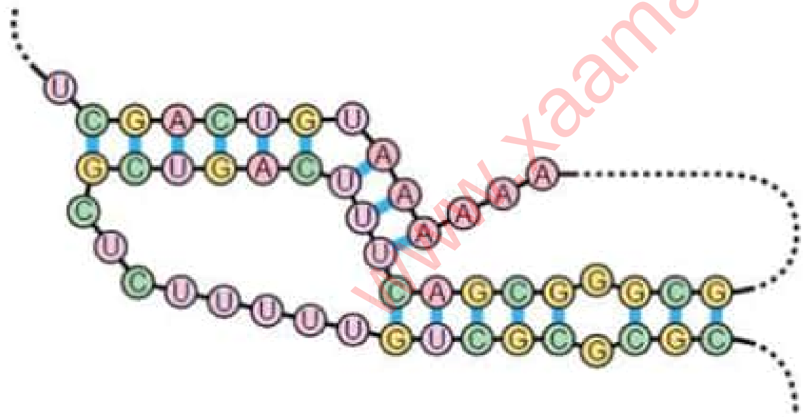


The nucleotides are joined together supported by the backbone of the sugar and phosphate. These nucleotide chains are long and may be either single stranded, or single stranded folded onto itself or double stranded. Whenever the strand folds onto itself or two strands come together for making a double stranded structure, the nucleotides are joined together with hydrogen bond between nitrogenous bases. This is called base pairing. The rule of base pairing is such that:

In DNA, Adenine links to thymine (A-T) while cytosine links to guanine (C-G).

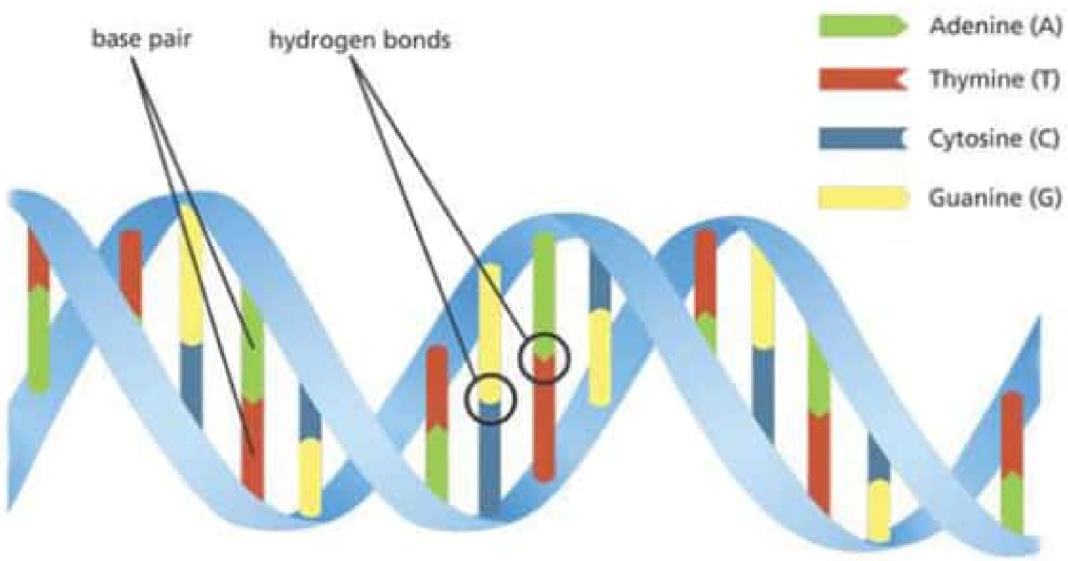
In RNA, Adenine links to uracil (A-U) and cytosine links to guanine (C-G).

The RNA is either single stranded or a single strand folded onto itself. Its structure would look something like this:



However, DNA is double helix in its structure. The double helix structure of DNA was discovered by

Watson, Crick and Wilkins.



Different Functions of DNA and RNA

DNA contains the genetic instructions used in the development and functioning of all known living
organisms. It is a medium of long-term storage and transmission of genetic information. On the
other hand, RNA plays an important role in the process of translating genetic information stored in
DNA into protein products. In other words, DNA is the boss who has all instructions. RNA is his
assistant who takes blueprint (via a process called *transcription*) to produce different proteins from
him and then plugs it into cellular machines calledr *ibosome*. Ribosomes are the sites of protein
synthesis.

How DNA and RNA Work?

As discussed above, DNA is the hereditary material that contains the genetic code for long term
storage. RNA takes that blueprint from DNA via transcription and plugs that blueprint in protein
factories called Ribosomes. The ribosomes produce required protein in a process called translation.
There are three types of RNAs viz. *ribosomal RNA (rRNA), messenger RNA (mRNA)*, and *transfer RNA*

(tRNA). All of them originate from DNA itself as copy of one the strands of DNA. The resultant RNA
has same sequence as the other strand of DNA, except that uracil will replace thymine. The
ribosomal RNA is the structural component of the protein making factories (Ribosomes). Messenger
RNA carries the genetic message from DNA to Ribosome. Transfer RNA is the smallest of three
types and it carries amino acids to Ribosomes during translation process. This entire process is called
Central Dogma in biology.

Vitamins and Minerals

Vitamin is an *organic non-protein* substance that is required by an organism for normal metabolic
function but *cannot be synthesized in sufficient quantity* by that organism. In other words, vitamins are
crucial molecules that must be acquired from outside sources. While most vitamins are present in
food, vitamin D for example, is produced as a precursor in our skin and converted to the active form
by sunlight.
Vitamins are classified by their biological and chemical activityn, *ot their structure*. Thus, each
"vitamin" refers to a number of *vitamer* compounds that all show the biological activity associated
with a particular vitamin. Such a set of chemicals is grouped under an alphabetized vitamin "generic
descriptor" title, such as "Vitamin A", which includes the compounds retinal, retinol, and four known
carotenoids.

Vitamin	Vitamers	Solubility	Diseases	Sources
Vitamin A	Retinol, retinal, and four carotenoids	Fat	Night-blindness, Hyperkeratosis, and Keratomalacia	Orange, ripe yellow fruits, leafy vegetables, carrots, pumpkin, squash, spinach, liver
Vitamin B1	Thiamine	Water	Beriberi, Wernicke-Korsakoff syndrome	Pork, oatmeal, brown rice, vegetables, potatoes, liver, eggs
Vitamin B2	Riboflavin	Water	Ariboflavinosis	Dairy products, bananas, popcorn, green beans, asparagus

Vitamin	Vitamers	Solubility	Diseases	Sources
Vitamin B3	Niacin, niacinamide	Water	Pellagra	Meat, fish, eggs, many vegetables, mushrooms, tree nuts
Vitamin B5	Pantothenic acid	Water	Paresthesia	Meat, broccoli, avocados
Vitamin B6	Pyridoxine, pyridoxamine, pyridoxal	Water	Anaemia peripheral neuropathy.	Meat, vegetables, tree nuts, bananas
Vitamin B7	Biotin	Water	Dermatitis, enteritis	Raw egg yolk, liver, peanuts, certain vegetables
Vitamin B9	Folic acid, folinic acid	Water	Megaloblast and Deficiency during pregnancy is associated with birth defects, such asneural tube defects	Leafy vegetables, pasta, bread, cereal, liver
Vitamin B12	Cyanocobalamin, hydroxycobalamin, methylcobalamin	Water	Megaloblastic anaemia	Meat and other animal products
Vitamin C	Ascorbic acid	Water	Scurvy	Many fruits and vegetables, liver
Vitamin D	Cholecalciferol	Fat	Rickets and Osteomalacia	Fish, eggs, liver, mushrooms

Vitamin E	Tocopherols, tocotrienols	Fat	Deficiency is very rare; mild hemolytic anemia in newborn infants.	Many fruits and vegetables, nuts and seeds
Vitamin K	phylloquinone, menaquinones	Fat	Bleeding diathesis	Leafy green vegetables such as spinach, egg yolks, liver

Important Facts on Vitamins

Vitamin A (Retinol)

Vitamin A is required in the production of rhodopsin, the visual pigment used in low light levels.
This is why eating foods rich in vitamin A is often said to allow an individual to see in the dark,
although the effect they have on one's vision is negligible.

Vitamin A is also essential for the correct functioning of epithelial cells. In vitamin A deficiency,
mucus-secreting cells are replaced by keratin producing cells, leading to xerosis.

Vitamin B (Thiamine)

Vitamine B (Thiamine) deficiency produces beriberi, Wernicke-Korsakoff syndrome, and optic
neuropathy.
Beriberi is a neurological and cardiovascular disease. The three major forms of the disorder are dry
beriberi, wet beriberi, and infantile beriberi.*D ry beriberi is characterized principally by muscular
dysfunctions, while Wet beriberi is associated with mental confusion, muscular atrophy, edema*. Infantile
beriberi occurs in infants breast-fed by thiamin-deficient mothers.

Vitamin C (Ascorbic Acid)

Ascorbic acid is found in plants and animals where it is produced from glucose. Humans are unable
to make ascorbic acid. This Vitamin is also an antioxidant and antioxidant properties of ascorbic acid
are only a small part of its effective vitamin activity.

Vitamin D (Calciferol)

Calciferol is not actually an essential dietary vitamin in the strict sense, as it can be synthesized in
adequate amounts by most mammals exposed to sunlight.

Vitamin E (Tocopherol)

Vitamin E is a series of organic compounds consisting of various methylated phenols. Because the vitamin activity was first identified in 1936 from a dietary fertility factor in rats, it was given the name "tocopherol" or *birth carrying vitamin*.

There are eight forms of Vitamin E. In general, food sources with the highest concentrations of vitamin E are vegetable oils, followed by nuts and seeds including whole grains. The highest sources of Tocoferol are Wheat germ oil (215.4 mg), Sunflower oil (55.8 mg), Almond oil (39.2 mg), Sunflower seed (35.17 mg) and Almond (26.2 mg).

Vitamin E deficiency causes neurological problems due to poor nerve conduction. It has been linked to Age-related macular degeneration (AMD), Alzheimer's disease. Vitamin E is widely used as an inexpensive antioxidant in cosmetics and foods. Vitamin E containing products are commonly used in the belief that vitamin E is good for the skin; many cosmetics include it. The function is mainly associated with Vitamin E being a powerful antioxidant. It also plays important role in skin health.

Vitamin K1 (Phylloquinone)

Phylloquinone is an electron acceptor during photosynthesis. Its best-known function in animals is as a cofactor in the formation of coagulation factors II (prothrombin), VII, IX, and X by the liver. It found in highest amounts in green leafy vegetables because it is directly involved in photosynthesis.

It may be thought of as the "plant form" of vitamin K.

Vitamin K2 (menaquinone)

It may be thought of as the "animal form" of vitamin K. Bacteria in the colon (large intestine) can also convert K1 into vitamin K2.

Vitamin B5 (Pantothenic acid)

Animals require pantothenic acid to synthesize coenzyme-A (CoA), as well as to synthesize and metabolize proteins, carbohydrates, and fats.

Vitamin B7 (Biotin)

Biotin is a coenzyme for carboxylase enzymes, involved in the synthesis of fatty acids, isoleucine, and valine, and in gluconeogenesis. It is also known as Vitamin H. Biotin deficiency is rare and mild, and can be addressed with supplementation.

It is caused by the consumption of raw egg whites (two or more daily for several months) due the avidin they contain, a protein which binds extremely strongly with biotin, making it unavailable.

The defecinecy causes hairloss and skin problems mainly.

Vitamin B6 (Pyridoxine)

Pyridoxine assists in the balancing of sodium and potassium as well as promoting red blood cell production. It is linked to cardiovascular health by decreasing the formation of homocysteine.

Pyridoxine may help balance hormonal changes in women and aid the immune system. Lack of pyridoxine may cause anemia, nerve damage, seizures, skin problems, and sores in the mouth.

Vitamin B3 (Niacin)

It is also known as nicotinic acid and vitamin PP. Niacin is used to increase levels of HDL in the blood and has been found to modestly decrease the risk of cardiovascular events in a number of controlled human trials.

Vitamin B9 (Folic acid)

Also known as Vitamin M and Folate, Vitamin B9 is essential to numerous bodily functions. The human body needs folate in DNA synthesis and repair. It is also important in cell division and growth during pregnancy. Children and adults both require folic acid to produce healthy red blood cells and prevent anaemia. Deficiency can result in many health problems, the most notable one being neural tube defects in developing embryos.

Pandemic deficiency diseases

Deficiency diseases of five vitamins are called Pandemic deficiency diseases. These include:

Niacin Deficiency (Pellagra)

Vitamin C Deficiency (Scurvy)
Thiamine Deficiency (Beriberi)
Vitamin D Deficiency (Rickets)
Vitamin A Deficiency (Night Blindness)

Cell Biology

A cell is a functional basic unit of life discovered *by Robert Hooke* in *Cork cells* and is the smallest unit of life that is classified as a living thing, and is often called the building block of life. In the beginning of the 18th century, *Antonie van Leeuwenhoek*, a Dutch tradesman and scientist built a microscope and drew the protozoa from rainwater and bacteria from his own mouth. He is known as the "Father of Microbiology".

In 1665 Robert Hooke discovered cells in cork, then in living plant tissue using an early microscope.

He was the first person to use the term "cell".

Largest and smallest cells

The organisms which have a single cell are unicellular and the organisms that have multiple cells are multicellular. There are 1 trillion cells is a human body. The size of a typical cell is 10 micrometer and largest cells in human body are nerve cells called neurons. The largest known cells are unfertilized ostrich egg cells which weigh 3.3 pounds. Pleuropneumonia-Like Organisms (PPLO) which are now known as Mycoplasma are the smallest cells.

Cell Theory

Cell Theory was proposed by Scheilden and Schwann and this theory stated that:

The body of all organisms is made up of cells
New cells arise from the pre existing cells
Cells are structural units of all organisms
Cells are units of all biological functions.

Before the discovery of the cell, people were unaware that living organisms were made of building blocks like cells.

Prokaryotic and Eukaryotic cells

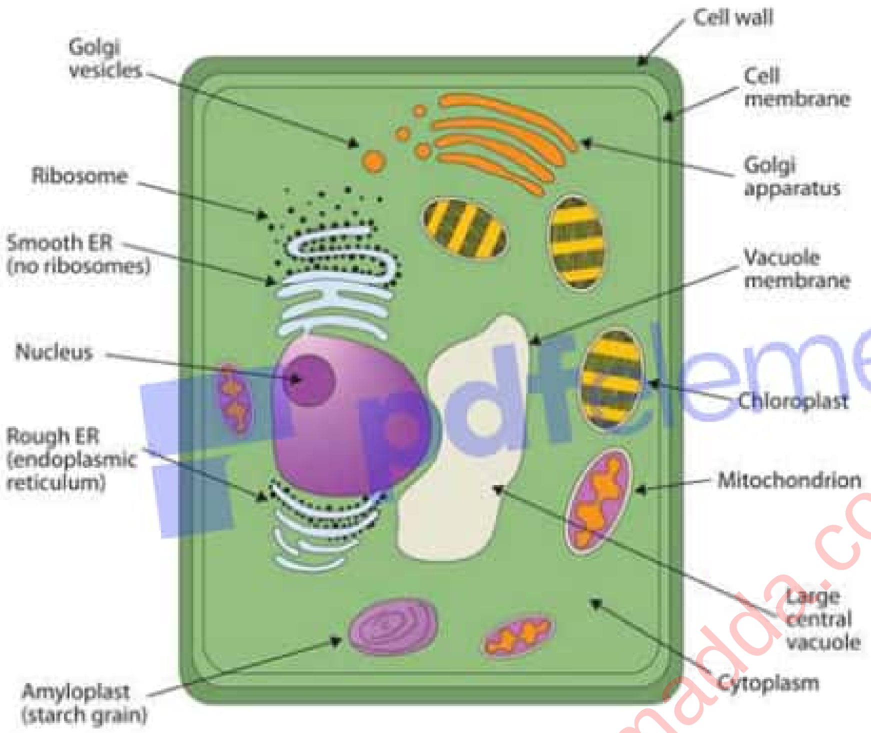
Prokaryotic cells are primitive cells in which there is no enclosed nucleus. Eukaryotic cells are those

with a nucleus enclosed by a membrane. Bacteria and blue green algae are examples of prokaryotic
cells. Algae, plants and animal cells are eukaryotic cells.

Cell Components

Cell Membrane / Plasma Membrane

The cell membrane or plasma membrane is the outer membrane of a cell. Cell membrane is found
around *all cells* and is selectively-permeable. Cell membrane encloses the cell itself, maintaining
specific conditions for cellular function within the cell.



It controls the movement of substances in and out of cells. Main function of cell membrane is to
protect the intracellular components from the extracellular environment. The cell membrane
facilitates the transport of materials needed for survival. The movement of substances across the
membrane can be active (with use of energy) or passive (diffusion without use of energy). Exocytosis
and endocytosis are the processes by which the materials are taken in or out of a cell. The cell

membrane plays an important role in the respiration and electron transport chains.

Cell wall

Cell walls are found in *plants, fungi and prokaryotic cells*. They work like a bulwark or a pressure vessel,
preventing over-expansion when water enters the cell. Cell walls are absent in animals and protozoa.
Major components of the cell wall in plants are Cellulose, hemicelluloses and pectin. In the
industrial uses, the cellulose is mainly obtained from wood pulp and cotton and used to
produce the textiles and paper.
Cell walls of Fungi are made of Chitin. Chitin is the same substance that makes the
exoskeleton of arthropods (insects etc.)
The cell walls of diatoms are composed of silicic acid.
The Bacterial cell walls are made of peptidoglycan which is also called murein.

Nucleus

Nucleus is the master of a cell. It controls the cell functions such as metabolism, reproduction and
development. It consists of Nuclear membrane, Nucleoplasm, Nucleolus and Chromatin. Kindly note
that *Mammalian red blood cells have no nucleus.*

Nuclear Membrane

The nuclear membrane is a double membrane and the space between the two membranes is called
pronuclear space. The outer membrane is continuous with the endoplasmic reticulum which
indicates its firm position in the cell. During the cell division the membrane disintegrates and
reappears once the division is almost complete.

Nucleoplasm

Nucleoplasm is a transparent and gel like matrix. It contains the nucleolus, chromatin threads and
Ribosomes.

Nucleolus

Nucleolus also disappears in the later phase of cell division and reappears once the process is almost
complete. It is made of RNA and protein and is the site of RNA synthesis.

Chromatin

Chromatin, dispersed in the nucleus, is a set of filamentous DNA molecules attached to nuclear
proteins called histones. Each DNA filament is a double helix of DNA and therefore a chromosome.

The Cytoplasm

Part of a cell that is enclosed within the cell membrane except the nucleus is cytoplasm. Cytoplasm
contains organelles, such as mitochondria, Golgi bodies, Endoplasmic reticulum, Plastids etc.
Cytoplasm is the site where most cellular activities occur, such as metabolism, glycolysis, cell
division, protein synthesis etc. It is divided into two parts, the inner, granular mass is called the
endoplasm and the outer, clear and glassy layer is called the cell cortex or the ectoplasm.T he cell
membrane is the outermost layer of the cytoplasm.

Major Cell Organelles

There are two kinds of organelles in the cytoplasm viz. living and non living. The living organelles
include the Plastids, Mitochondria, Endoplasmic reticulum, Golgi Bodies, Ribosome, lysosomes,
Micro bodies such as peroxisomes, Microtubules, Centrosomes, Cilia and Flagella. The nonliving
substances, called ergastic substances include the reserve products such as carbohydrates Fats, Oils
and nitrogenous substances, Secretary products such as pigments, enzymes and nectar and execratory
products such as tannins, resins, latex, alkaloids, essential oils, mineral crystals etc.

Plastids

Plastids are major organelles found in the cells of plants and algae. The term plastid was used by
Schimper for the first time. Major function of the plastids includes photosynthesis, storage of products like starch. They are of 3 types:
Leucoplasts: Colorless plastids,
Chloroplasts: Green plastids.
Chromoplasts: Colored plastids.
The plastids are of various shapes and have the ability interchange between the above forms & and

many shapes. For example due to continuous absence of the sunlight the green chloroplast may turn
to colourless leucoplasts. In tomato, when it ripes, the chloroplasts change into Chromoplasts and
this turns the color of tomato from green to red.
The leucoplasts don't have any color. So they have no role in photosynthesis. Their major function is
of storing. On the basis of the stored material they have been divided into 3 types viz. Amyloplats
(which store the carbohydrates), Elaioplasts (which store the fats) and Aleuroplats (which store
proteins).
Chloroplasts have a green pigment in them called Chlorophyll. They are responsible for
photosynthesis. The number, shape and size of the chloroplasts vary from plants to plants. In higher
plants they are biconvex in shape.
Each chloroplast is covered by a double membrane envelope. Thiesn velope is made up of
lipoproteins. The space between these two membranes is called periplastidial space. Inside these
membranes are located the membrane-bound compartment called thylakoid which is basically a sac.
This sac has stacks of disks referred to as "grana", (singular: granum). Each grana is connected to
other grana by intergrana or stroma thylakoid. The space enclosed by a thylakoid is called lumen. All
lumens are collectively called thylakoid space. Each chloroplast has 40-60 grana. The inner side of the
thylakoid membrane has some particles which are called quantasomes. Each quantasome has around
230-250 chlorophyll pigments.

Why Chlorophyll is green?

The chlorophyll *absorbs light most strongly in the* ***blue portion*** of the electromagnetic spectrum,
followed by the red portion. But it is a poor absorber of green and near-green portions of the
spectrum, hence the color of the tissues which contain chlorophyll is Green. The chlorophyll was

first isolated by Joseph Bienaimé Caventou and Pierre Joseph Pelletier in 1817.

What are Carotenoids and how they are related to Vitamin A?

There are two types of pigments Chlorophyll a and Chlorophyll b. Apart from these pigments, there
are Carotenoids occurring in the chloroplasts and Chromoplasts. These Carotenoids are responsible
for different colours. There are more than 600 known Carotenoids. Among them the most
important are carotenes and Xanthophylls. Carotenes are pure hydrocarbons, means they are
basically made up of Carbon and Hydrogen. The Xanthophylls have oxygen too.
The Carotenoids absorb blue light of the spectrum generally.

Absorption of blue light serves a major purpose and that is they save the chloroplasts from the photo
damage.
Most fruits have Carotenoids. The Beta carotene is one example which gets converted into
Vitamin A.
Beta carotene is the precursor of Vitamin A.
Vitamin A occurs in many forms. One form of Vitamin A is retinal, which is vitamin A
aldehyde. The four kinds of Carotenoids viz. beta-carotene, alpha-carotene, gamma-carotene,
and beta-cryptoxanthin can be converted in human beings in retinal.
This retinal form of Vitamin A is a Chromophore and is responsible for its color, it absorbs
certain wavelengths of visible light and transmits or reflects others.
Retinal binds to some proteins called Opsins in the Eye's retina. ThisV itamin A + Opsins
bond is the chemical basis of vision.
The Carotenoids also get converted to another type of Vitamin A called RetinolR. etinol is fatsoluble
vitamin important in vision and bone growth. All Retinol, retinal (aldehyde form), retinoic
acid (acid form) and retinyl esters (ester forms) are converted from the carotenes and thus important
for Human vision.

Mitochondria

Mitochondria (singular: mitochondrion) are the power houses of the cells. They were discovered by
Fleming; however the term was used by Benda & Meeves. Another name for mitochondria is
Chondriosomes. They are absent in Prokaryotic cells.
Since they are the "Power houses of the Cells" the number of mitochondria in cells idsi rectly
proportional to the metabolic activity of the cells. This means that the more active a cells is
metabolically, more is the number of mitochondria in that cell.*T his is the reason that number of*
mitochondria is maximum in muscular cells.
The shape of the mitochondria may be spherical, filamentous or even rod shaped. Like the
chloroplasts, they are also bound by double unit membranes. The space between these two
membranes is called perimitochondrial space. The liquid inside these membranes is called matrix.
The matrix contains the enzymes. Apart from the enzymes matrix contains ribosomes, double
stranded DNA and RNA.
Due to presence of double stranded DNA along with the RNA and Ribosome, the mitochondria are
called semiautonomous structures. Both chloroplasts and mitochondria are semiautonomous
structures.

Role of Mitochondria in Krebs cycle

Mitochondria are the sites of oxidation of food material. This oxidation is called aerobic respiration.

It is carried out by *Krebs cycle or TCA cycle*. The Krebs cycle is also known as *Citric Acid Cycle* and is
basically a series of enzyme-catalyzed chemical reactions. The raw material in the Krebs cycle is
carbohydrates, fats and proteins and the final products are Carbon Dioxide and Water and Energy.
The usable energy which is produced by the Krebs cycle is in the form of ATP which is Adenosine
triphosphate. The correct name of ATP is Adenosine-5′-triphosphate.

Endoplasmic Reticulum

The interconnected network of tubules, vesicles, and cisternae within cells is called "Endoplasmic reticulum". The term was coined by Keith R. Porter in 1945. The tubules are narrow long structures, vesicles are round structures and cisternae are long, flat unbranched structures which are parallel to each other. They are of two types, Rough endoplasmic reticulum (appears rough because it has ribosomes on it) which synthesize proteins and the smooth endoplasmic reticulum which synthesize lipids and steroids, metabolize carbohydrates and steroids, and regulate calcium concentration, drug detoxification, and attachment of receptors on cell membrane proteins.
Another function of the endoplasmic reticulum is that it provides the mechanical support to the cytoplasm and provides larger surface area for exchange of materials and transportation.
During the cell division, the endoplasmic reticulum organizes the nuclear envelope at the telophase stage of cell division.

Golgi Apparatus

These are named after Camillo Golgi who identified them in 1898. The size of the Golgi body changes as per the metabolic activity of the cells and they are bigger in young cells and metabolically active cells. Function of the Golgi apparatus is to process and package proteins, polysaccharides and lipids. During the cell division they provide a cell plate. At the end of the cell division (telophase) the Golgi vesicles fuse and make the new plasma membrane. The Lysosomes which digest excess or worn-out organelles, food particles, and engulfed viruses or bacteria etc. are formed by the Golgi body. Golgi Bodies, unlike the Chloroplasts and Mitochondria are bound by the single membranes.

Lysosomes

Lysosomes are very small sacs with irregular shapes. These are bags of Hydrolytic or digestive enzymes and so also called Suicide Bags. The major function is the autolysis of a cell by release of the

enzymes within the cells. It also helps in the intracellular digestion of dead, injured or defective cells.
Intracellular digestion of the material taken from the endocytosis.

Ribosome

Ribosomes were discovered by Palade in 1955. They are not enclosed by any unit membrane. They are made up of RNA and proteins.

Peroxisomes

These are also sac like structures bound with single membranes. They have enzymes and take part in the metabolism of fatty acids, respiration and many other metabolic processes.

Glyoxisomes

They are mainly found in plants particularly in plants the fat storage tissues of germinating seeds such as castor seed. The major function is in the conversion of the fatty acids in Carbohydrates.

Spherosomes

Spherosomes are present in the endosperm and cotyledons of seeds. They have the enzymes which are necessary in synthesis of oils and fats.

Centrioles

Centrioles are present in animal cells mostly and not in higher plants.T hey organize the spindle fibers in cell division.

Cilia and Flagella

Both Cilia and Flagella are present in the motile cells. Both help in cell mobility. Both are made up of fibrils. When they cut in a section, they show 9+2 arrangement which shows that they have 9 pairs of fibrils on the circumference and 2 pairs of fibrils at the centre.

Prokaryotic and Eukaryotic cells

There are two groups of cells. All cells are either prokaryotic or eukaryotic. Prokaryotic cells are primitive and don't possess a well defined nucleus. Eukaryotic cells have a nucleus.

Difference Prokaryotic Cells Eukaryotic cells

Difference	Prokaryotic Cells	Eukaryotic cells
Nucleus	Absent	Present
Chromosomes	No true chromosomes are found. Chromosomal material is called Plasmid	True chromosomes are present.
Cell Type	Generally unicellular, some blue green algae are multicellular.	Generally multicellular
Sexual Reproduction	Absent. Only Genetic recombination is found.	Present through meiosis.
Cell organelles	Mitochondria, Chloroplasts, Golgi Bodies, Lysosomes, Endoplasmic reticulum and Peroxisomes are absent	These are Present
Ribosomes	Smaller	Larger
Chlorophyll	Since there is no chloroplast, the chlorophyll scattered in the cytoplasm	Present in Chloroplast
Difference	Prokaryotic Cells	Eukaryotic cells
Cell size	1-10um (smaller)	10-100um (Large and larger)
Examples	Bacteria and Blue green algae	Animal and Plant cells

In prokaryotic cells DNA material remains scattered in the Cytoplasm only. Further, same compartment is used in the Prokaryotic cells for synthesis of RNA and protein while in the Eukaryotic cells the RNA is synthesized in the Nucleus while the protein in the cytoplasm. There is no sexual reproduction in Prokaryotic cells and only genetic recombination is present in the name of sexual reproduction while in eukaryotic cells, the true sexual reproduction is present.

Difference between Plant cells and Animal cells

The animal cells don't contain the cell wall and the outer boundary of the animal cells is cell membrane. In Plant cells the cell wall is present which is made up of mostly cellulose, is located outside the cell membrane and provides these cells with structural support and protection, and also acts as a filtering mechanism.

In bacteria the cell wall is made of peptidoglycan. There are no plastids in animal cells. There is no
photosynthesis in animal cells. Cytokinesis which is a process by which cytoplasm of a single
eukaryotic cell is divided to form two daughter cells, is by equatorial furrowing from periphery to the
centre in animal cells and by disk formation in plant cells.
In animal cells the ribosome are of 55S and 80S types while in the plant cells they are of 70s and 80S
types.

Cell Division

The cell division is of two types viz. Mitosis and Meiosis.

Mitosis

In mitosis the mother cell divides into two daughter cells which are genetically identical to each
other and to the parent cell. In mitosis:
The number of the Chromosomes in Parent and daughter cells remains constant
The parent and daughter cells are similar in all respects.
The parent and daughter cells are genetically identical
The purpose of Mitosis is growth by increasing number of cells.
In most plants and animals the regeneration of the lost parts and vegetative propagation in
some plant species takes place by Mitosis.

Meisis

In Meiosis, the number of chromosomes is divided into half in this process. Meiosis is required to
create the Gametes in animals and Spores in other organisms. Meiosis is reproduction in organisms with Eukaryotic cells.

Significance of Meiosis

The cell division in the reproductive cells takes place by Meiosis. In meiosis the number of the
chromosomes is reduced to half of that in the parent cells.*M eiosis maintains the number of
Chromosomes constant in all sexually reproducing organisms.*

Mitosis	Meiosis
(i) It occurs in somatic cells. (ii) The daughter cells contain same no. of chromosomes (diploid) as that of the parent cells. (iii) Two daughter cells are formed. (iv) Only one division occurs.	(i) It occurs in reproductive cells. (ii) The daughter cells have half the no. of chromosomes (haploid) as that of the parent cells. (iii) Four daughter cells are formed. (iv) Two divisions occur.

Programmed cell death

Apoptosis, or programmed cell death is a process by which cells deliberately destroy themselves. The process follows a sequence of events controlled by nuclear genes. In this process, the chromosomal DNA breaks into fragments, and this is followed by breakdown of the nucleus. The cell then shrinks and breaks up into vesicles that are phagocytosed by macrophages and neighbouring cells.

Significance of Apoptosis

Apoptosis plays an important role in maintaining the life and health of organisms. During human embryonic development apoptosis removes the webbing between the fingers and toes; it is also vital to the development and organization of both the immune and nervous systems.

How cells become Cancerous?

Cancer is caused by the unrestrained growth of cells. Cells that do not "follow the rules" of normal cell cycling may eventually become cancerous. This means that the cells reproduce more often than normal, creating tumors. Usually this happens over an extended period of time and begins with changes at the molecular level. Our body has trillions of cells and all cells replicate in normal fashion.

However, some agents may change the way genes carry the information regarding the cell division and thus cells become cancerous. Such genes are called Oncogenes and such agents are called Carcinogens.

In normal cells, there are have types of genes that are important in determining whether or not cancerous tissue can form. These genes control the production of proteins that affect the cell cycle.

Proto-oncogenes are DNA sequences that promote normal cell division. By mutation, these genes
may be converted into oncogenes, which promote the overproduction of cells. Another class of
genes, known as tumor-suppressor genes prevents excess reproduction of cells. Mutation in these
genes can also allow cells to become cancerous.

How Cyanide kills cells?

Cyanide acts by inhibiting the enzymes cells need for oxygen utilization. Without these enzymes, a cell cannot produce ATP and will die. Very small amounts of cyanide naturally occur in some foods
and plants. For example. cyanide is present in cigarettes and in the smoke produced by burning
plastics.

How carbon monoxide kills people using heating appliances using fossil Fuels?

Because of its molecular similarity to oxygen, haemoglobin can bind to carbon
monoxide instead of oxygen, and this subsequently disrupts haemoglobin's efficiency as
an oxygen carrier. Carbon monoxide in fact has a much greater affinity (about 300
times more!) for haemoglobin than oxygen. When carbon monoxide replaces oxygen,
this causes cell respiration to stop, leading to death. The particular danger of carbon
monoxide poisoning lies in the fact that a person exposed to high levels of this toxin
cannot be saved by being transporting to an environment free of the poison and rich
with oxygen. Since the haemoglobin remains blocked, artificial respiration with over
pressurized pure oxygen must first be performed to return the haemoglobin to its
original function and the body to normal cell respiration.

What is impact of Coffee on Cellular level?

Caffeine affects cells by stimulating lipid metabolism and slowing the use of glycogen as an energy
source. As a whole, the body responds to caffeine by extending endurance, allowing us to stay awake

for longer periods of time or perform extra activities. Adverse effects of excess caffeine intake
include stomach upset, headaches, irritability, and diarrhoea.

General Science-2: Plant Kingdom

Biological Classification

When we classify the organisms into hierarchical series of groups on the basis of their evolutionary
relationships, it is called *Systematics*. Classification is a subtopic of Systematics which deals with
ordering of organisms into groups and *taxonomy* is the study of principles and procedures of
classification. Nomenclature is the process of naming an organism so that this particular organism is
known by same name all over the world. Currently, the scientists follow binomial nomenclature in
which any organism is denotes by a name with two components viz. Genus and Species. For
example, Mango is named as *Mangifera indica*, whereby, *Mangifera* is its Genus and *indica* is its
species. While first letter of Genus is always capitalized, first letter of species is always in lower case.
For example:
Tomato → Solanum lycopersicum
Potato → Solanum tuberosum
Brinjal →Solanum melongena
In the above example, Tomato, Potato and Brinjal belong to same genus while they are different
species. We note here that for plants, scientific names are based on agreed principles and criteria,
which are provided in International code for Botanical Nomenclature (ICBN). Animal taxonomists
have evolved International Code of Zoological Nomenclature (ICZN).

Taxonomical Hierarchy

Species is the smallest taxonomical unit and refers to a group of individual organisms which interbred among themselves and produce fertile offspring when they interbred. The group of related species is called Genus. Related Genera {General is plural of Genus} are kept in a family, related families are kept in Order. Related Orders are kept in classes. Classes comprising animals like fishes, amphibians, reptiles, birds, mammals etc. constitute the next higher category calle*Pdh ylum*.

Generally animals are subdivided into phyla, while plants are subdivided int*Doi visions*. All animals/plants belonging to various phyla/divisions are assigned to the highest category called Kingdom. The below graphic shows position of humans in above taxonomic ranks:

Species	•*Homo sapiens*
Genus	•Homo
Family	•Hominidae
Order	•Primata
Class	•Mammalia
Phylum	•Chordata
Kingdom	•Animalia

Five Kingdom Classification

Initially, the scientists had put all the living organisms into two Kingdoms viz. Plantae and Animalia.

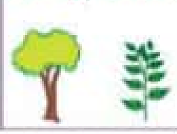
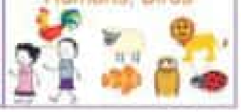
However, there were some problems such as – this classification did not distinguish between Eukaryotes / Prokaryotes, unicellular / multicellular, photosynthetic / non-photo synthetic organisms. Later, they divided the entire living world into five Kingdoms viz. *Monera, Protista, Fungi, Plantae* and *Animalia*. This five kingdom classification was based on several features such as cell structure, thallus organisation, mode of nutrition, reproduction and phylogenetic relationships.

All the prokaryotes were kept in Monera. This Kingdom comprises mainly Bacteria and blue green algae.

All unicellular eukaryotes were kept in Protista. This kingdom comprised of Algae and

Protozoa.

All fungi were kept in Kingdom Fungi while multicellular plants and animals were kept in Plantae and Animalia respectively.

	Monera	Protista	Fungi	Plantae	Animalia
Type	Unicellular Prokaryotes	Unicellular Eukaryotes	Multicellular Non green Eukaryotic	Multicellular, Eukaryotic	Multicellular Eukaryotic
examples	Bacteria, Blue-green Algae 	Amoeba, Paramecium, Euglena 	Yeast, Rhizopus, Mushrooms moulds 	Trees, Plants, Shrubs 	Fish, Insects, Animals like elephant, Humans, Birds 

In the above classification, Viruses have not been included because of their pseudo-living nature.

Viruses

Virus is a Latin word, literally meaning "poison". Tobacco Mosaic Virus was the first Virus discovered by Russian scientist *Dimitri lvanovsky* in 1892. A Virus is an extreme micro, parasitic noncellular *nucleoprotein particle* which can persist only if it is inside any living organism. This means that all viruses are parasites.

Salient Features

Viruses are very small acellular and infectious particles which can be seen only by an electron microscope. They can pass through bacteria-proof filters. They cannot be grown on artificial media in the laboratory. They are not cells and they behave as living organisms inside the host tissue only where they can multiply. They lack functional autonomy. They are not affected by antibiotics but can be made inactive by chemotherapy and thermotherapy. They react to stimuli such as light, radiations, chemicals, heat etc.

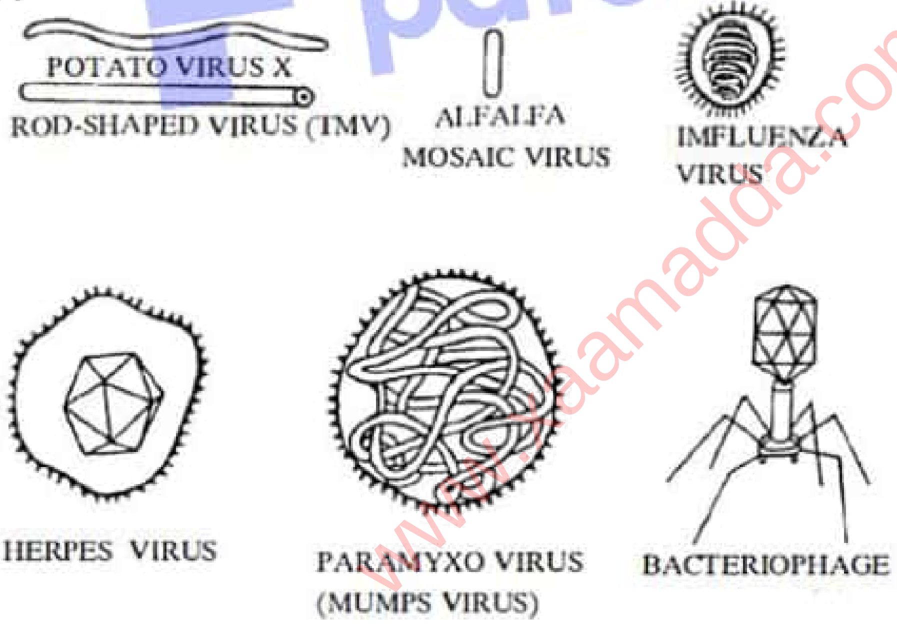
Viruses have been excluded from the biological classification because they are not living things in first instance. However, they do posses some properties of the both *living and non-living*.

Living properties	Non-living properties
The presence of DNA or RNA (but never both)	The absence of cell.
Structural diversity	The lack of protoplasm.
Geneticity and parasitic properties	No any reproduction and growth outside the living cell.
Sensitivity and evolution	Stored in the form of crystal outside the living cell.
Capable of spreading the disease	The lack of metabolic activities like nutrition, digestion

There are three types of Viruses viz. Plant Viruses, Animal Viruses and Bacteriophage (viruses that are parasites on bacteria).

Structure

The sizes of viruses normally range from 40 to 350 nm. The smallest virus is of Hepatitis B (42nm), while largest Virus is Pandoravirus. The shapes of Viruses are also variable ranging from spherical (polio virus), rod-shape (TMV), tadpole-like (bacteriophages), polyhedral (adenovirus) and of other types.



A virus is made of three components viz. a protein capsid, nucleic acid and a thick outer layer. *Viruses may contain either DNA or RNA but not both together. Generally, plant viruses are RNA viruses while animal*

viruses are DNA viruses. Further, Bacteriophage is always a DNA virus. Viruses produce diseases in
plants, animals and human beings.

Plant Viral Diseases

Common *plant viral diseases* are Tobacco mosaic, Cauliflower Mosaic Sandalwood spike, Sugarcane
mosaic, Bean mosaic, Aster yellow, Bunchy top of Banana, Leaf Curl of Papaya, Potato leaf roll,
Twisted leaf disease of Tomato etc.

Use of TMV in Research

The Tobacco Mosaic Virus has become a popular tool for scientific research. The main reason is that
it is available in large quantities and it does not infect animals. After growing a few infected tobacco
plants in a greenhouse and a few simple laboratory procedures, a scientist can easily produce several
grams of virus. As a result of this, TMV can be treated almost as an organic chemical, rather than an
infective agent. Tobacco mosaic virus (TMV) and Cauliflower mosaic virus (CaMV) are frequently
used in plant molecular biology. Of special interest is the CaMV 35S promoter, which is a very
strong promoter most frequently, used in plant transformations.

Animal and Human Diseases

Common animal viral diseases include African horse sickness, Foot and mouth disease of cattle,
Virus pneumonia of pigs, Rabies etc. Common human viral diseases include Influenza, Measles,
Herpes, Dengue, Smallpox, Mumps, Common cold, Hepatitis, AIDS. The recent viral pandemics /
epidemics include Ebola Virus Disease, Rift Valley fever, Bolivian hemorrhagic fever, Crimean
Congo Hemorrhagic Fever, SARS, and MERS etc.

Human Viral Diseases

Common animal viral diseases include African horse sickness, Foot and mouth disease of cattle,
Virus pneumonia of pigs, Rabies etc. Common human viral diseases include Influenza, Measles,
Herpes, Dengue, Smallpox, Mumps, Common cold, Hepatitis, AIDS. The recent viral pandemics /

epidemics include Ebola Virus Disease, Rift Valley fever, Bolivian hemorrhagic fever, Crimean
Congo Hemorrhagic Fever, SARS, and MERS etc.

Flu

Flu is caused by influenza virus, which is a highly mutant virus. Influenza generally spreads through
air via cough or sneezes. There are three species of Influenza Virus viz. Influenza-A, Influenza-B,
and Influenza-C. Out of them, Influenza A infects birds and mammals. It has very high rate of
mutation, and this is the reason that so many different strains of influenza virus are found. In a first,
they don't infect humans, but if they do so, they cause devastating pandemics. The common
Influenza outbreaks caused by Influenza-A strains include H1N1 (swine flu) in 2009; and H5N1 (Bird Flu) in 2004. H1N1 is the same strain which causes seasonal outbreaks of flu in humans on a regular
basis. Since doctors have found it very hard to predict who will develop complications, it has been
dubbed a "*Jekyll and Hyde*" virus.

Meaning of H and N in Flu

Various strains of Virus differ in certain proteins on the virus surface — hemagglutinin
(HA) and neuraminidase (NA) proteins. The scientists give them different names on
this bases.

Influenza B and C are less common and are less mutants in comparison to A.

Hepatitis / Jaundice

Hepatitis literally means inflammation of the liver. There are three major types of Hepatitis virus viz.
Hepatitis A virus, Hepatitis B virus (HBV) and Hepatitis C Virus (HCV).

A is acute (*acute means short term*), B is acute as well as chronic (*Chronic means long term*) while
C is almost chronic.

A spreads easily, B spreads relatively less easily and C spreads rarely.

A spreads via food, water etc. and can infect many people at once. For example, a food
handler in a restaurant can spread Hepatitis A to many people at once; B spreads by blood or
other body floods. C spreads only by blood.

A gets better on its own but can be serious in older people; B is common in India, Asia and
Africa. We note here that Amitabh Bachchan has recently revealed that he has lost 75% of is
liver to Hepatitis B. C is even more dangerous.
A and B can be prevented by vaccination, but not C. However, there are medicines available
to treat C.

AIDS

Human immunodeficiency virus (HIV) also known as human T-lymphotropic virus-III (HTLV-III),
lymphadenopathy-associated virus (LAV), and AIDS-associated retrovirus (ARV) is a retrovirus.
{Retrovirus means it replicates via reverse transcription} in host cell. It transmits via anal, vaginal or
oral sex, blood transfusion, contaminated hypodermic needles, exchange between mother and baby
during pregnancy, childbirth, breastfeeding or other exposure to one of the above bodily fluids.
Due to weakened immune system the person is attacked by infections caused by bacteria, viruses,
fungi and parasites that are normally controlled by the elements of the immune system that HIV
damages.

What is the difference between human immunodeficiency virus (HIV) and AIDS ?

The term AIDS applies to the most advanced stages of HIV infection. The Center for Disease
Control (CDC) definition of AIDS includes all HIV-infected people who have fewer than 200 CD4+ T cells per cubic millimetre of blood. (Healthy adults usually haveCD4 + T cell count of 1,000 or
more.) The definition also includes 26 clinical conditions (mostly opportunistic infections) that affect
people with advanced HIV disease.
Opportunistic infections are common in people with AIDS. HIV affects nearly every organ system.
People with AIDS may develop various cancers such as Kaposi's sarcoma, cervical cancer and cancers
of the immune system known as lymphomas. Besides the people infected with AIDS often have

systemic symptoms of infection like fevers, sweats (particularly at night), swollen glands, chills,
weakness, and weight loss.

Smallpox

Smallpox is one of the three diseases (other two Guinea worm and Polio) that have been eradicated
from India. Smallpox was eradicated globally in 1980s. *This Virus has been used in biological warfare
also*. British used smallpox as a biological warfare agent during seven years war in 18th century.

Chickenpox

Chickenpox or varicella is caused by Varicella Zoster Virus (VZV).

Poliomyelitis

Polio virus is an enterovirus which means that the route of entry of this virus is through the
gastrointestinal system. It's an *RNA virus*. Polio is usually spread via the fecal-oral route (i.e., the
virus is transmitted from the stool of an infected person to the mouth of another person from
contaminated hands or such objects as eating utensils). Some cases may be spread directly via an oral
to oral route.

Measles

Both measles and German measles (rubella) are caused by viruses; and are rashes on the skins.
German measles is accompanied by a blotchy red rash. The patient sometimes suffers a slight cold
prior to the appearance of the rash. German measles can be dangerous for pregnant women, who
have no immunity for the virus. It is called German measles because it was German physicians who
first described this disease. Mild upper respiratory affect, high temperature that can last for four days
and conjunctivitis are some symptoms of measles.

Rubella or German measles

Rubella (German measles) spreads when infected person coughs or sneezes. It causes a rash, a slight
fever, aching joints, headaches, runny nose and red eyes. The virus spread by sneezes or coughs can

lead to serious birth defects if contracted by pregnant woman. In 2015, the North and South America region have become the first region of the world to eradicate Rubella. There are no home-grown cases in five years.

Dengue

Dengue virus is transmitted by a bite of *female* mosquito of any of two species of mosquitoes of the genus Aedes.

The mosquito, which typically bites humans in the daylight hours, can be easily recognized because of its peculiar white spotted body and legs.

Outbreak of the disease **typically occurs in summer season**when the mosquito population reaches its peak.

Unlike malaria, which is a major health concern in rural areas, dengue is equally prevalent in the urban areas too. In fact, it is predominantly reported in urban and semi-urban areas.

A severe form of the infection is known as dengue hemorrhagic fever (DHF). DHF can be fatal.

Because of the severe joint pain, dengue is also known as **break-bone fever**.

DHF is characterized by a fever that lasts for 2 to 7 days, with general signs and symptoms consistent with dengue fever. In addition to these symptoms, *if a patient suspected with dengue experiences decrease in platelets or an increase in blood haematocrit, it becomes more certain that the patient is suffering from the infection. Platelets are cells in blood that help to stop bleeding, while haematocrit indicates thickness of blood.*

The smallest blood vessels become excessively permeable allowing fluid component to escape from blood vessels to organs of the body. This may lead to failure of circulatory system, which might also cause death.

Chikungunya

This disease is caused by Chikungunya virus transmitted by both Aedes aegypti and *Aedes albopictus.*

The mosquitoes usually transmit the disease by biting infected persons and then biting others. The infected person cannot spread the infection directly to other person.

Symptoms of Chikungunya fever are most often clinically indistinguishable from those observed in
dengue fever. However, unlike dengue, haemorrhagic manifestations are rare and shock is not
observed in Chikungunya virus infection. It is characterized by fever with severe joint pain
(arhralgia) and rash.

Rabies

Rabies or hydrophobia is found among dogs, cats, bats and other wild mammals. The transmission to
humans occurs through the saliva of contaminated animals, mainly through bites. The rabies virus is
neurotropic and attacks the central nervous system in a fast and lethal fashion. The prevention of the
disease is done through the prophylactic vaccination of animals and humans. The treatment is done
with an anti-rabies serum containing specific antibodies against the virus.

Yellow Fever

Yellow fever is a viral infection that occurs mainly in Central Africa and in the Amazon region of
South America. It is prevented through vaccination and is transmitted by many species of
mosquitoes of the *Aedes* genus, including *Aedes aegypti*. The infection causes clinical
manifestations that range from asymptomatic cases to lethal fulminant cases. Generally, the disease
begins a with fever, chills, discomfort, headache and nausea and evolves to jaundice (increase of
bilirubin in blood, after which the disease is named), mucosal and internal hemorrhages,
hemorrhagic vomiting and kidney failure.

Prevention is done by regular mass vaccination and the vaccination of travelers to endemic areas.

The fight against the vector mosquito is also an important prophylactic measure.

Acute Encephalitis Syndrome

Encephalitis refers to acute Inflammation of the brain. There are two main types of encephalitis viz.
viral encephalitis and Japanese encephalitis. While Viral encephalitis is caused by water-borne

enterovirus; Japanese encephalitis is caused by mosquito *Culex tritaeniorhynchus* and *Culex vishnui*.
Every monsoon sees an outbreak of acute encephalitis syndrome, or AES, diseases. Japanese
encephalitis and viral encephalitis diseases; and both of these make the Acute encephalitis syndrome,
or AES. This disease is called a poor man's disease and affects largely to paddy farmers.

Other Notes on Viral Diseases

Common Cold is caused by a rhinovirus
Hepatitis (inflammation of the liver, jaundice)
Rabies (transmitted by bites from infected bats, raccoons, dogs)
Polio (may cause paralysis)
Smallpox (eradicated from the world in 1977 through vaccination)
Yellow Fever is a viral hemorrhagic fever transmitted by infected mosquitoes.

Industrial and Scientific Applications of Viruses

Since Viruses contain the characteristics of both living and non-living organisms, they are utilized in
the field of *Biotechnology research.* Bacteriophage can be used in water preservation as it can destroy
the bacteria and keep water fresh. Here are some other applications of Viruses:
Molecular Biology, Cellular Biology, Molecular genetics, such as DNA replication,
transcription, RNA processing, translation, protein transport, and immunology.
Virotherapy uses viruses as vectors to treat various diseases, as they can specifically target
cells and DNA. It shows promising use in the treatment of cancer and in gene therapy.
The viruses represent largest reservoirs of unexplored genetic diversity on Earth. They can be
used as alternative to the antibiotics because of the high level of antibiotic resistance now
found in some pathogenic bacteria.
Viruses contain protein and this property can be used in production of various proteins such
as vaccine antigens and antibodies.

In nanotechnology, viruses can be regarded as organic nanoparticles. Because of their size, shape, and well-defined chemical structures, viruses have been used as templates for organizing materials on the nanoscale.

It's relatively easy to synthesize a new Virus. First synthetic virus was created in 2002, which is actually a DNA genome (in case of a DNA virus), or a cDNA copy of its genome (in case of RNA viruses). Ability to synthesize viruses has far-reaching consequences, since viruses can no longer be regarded as extinct; as long as the information of their genome sequence is known and permissive cells are available. Currently, the full-length genome sequences of 2408 different viruses (including smallpox) are publicly available at an online database.

Viruses can cause devastating epidemics in human societies. They can be weaponised for biological warfare.

Virus and Aquatic Ecosystem

A teaspoon of seawater contains about one million of Viruses, making them the most abundant biological entity in aquatic environments. They are useful in the regulation of saltwater and freshwater ecosystems. The Bacteriophage, which is harmless to plants and animals, play the most important role here. They infect and destroy the bacteria in aquatic microbial communities, comprising the most important mechanism of recycling carbon in the marine environment.

However, the organic molecules released from the bacterial cells by the viruses stimulate fresh bacterial and algal growth. Viruses are useful for the rapid destruction of harmful algal blooms that arises generally from the Blue Green algae and often kills other marine life. Viruses INCREASE the amount of Photosynthesis in Oceans and are responsible for reducing the amount of carbon dioxide in the atmosphere by approximately 3 gigatonnes of carbon per year.

Bacteria

General Information about Bacteria

The bacteria are unicellular microorganisms which were first observed and reported by*A nton Von*
Leeuwenhoeck in 1676. All bacteria are unicellular and prokaryotic. Their size and shape varies as per
the species. Majority of Bacteria are in the size range of 0.5 to 50 µ, the smallest bacterium is
"pasteurella" which is 0.7µ and largest bacteria Beggiota is 15-22 µ in size.

Different shapes of Bacteria

Bacteria are the monocellular microorganisms which are found in almost places in singleton form or
in group. The cellular wall of the bacteria is thick and it is made from chitin, Murine etc. They have
different shapes such as Coccus (spherical), Bacillus (rod shaped), Vibrio (comma shaped) and
Spirillum (cork screw shaped)

G+ and G- Bacteria

Gram staining is a method to identify some of the bacteria on the basis of some chemical properties
of their *cell wall.* Not all bacteria can be identified on the basis of gram method. If a bacterium can be
judged using this method, it would be called Gram variable otherwise Gram indeterminate. can be
classified by using this technique are called *Gram variable*. What is basically done is to color the cell
walls using a stain called Crystal violet. If a bacteria has lipids and peptidoglycan in its cell wall, it
would appear violet in microscope and will be called gram positive. Otherwise, they would be called
gram negative.
The cell wall of Gram positive bacteria is thicker and more peptidoglycan in comparison to gram
negative bacteria. Further, a chemical called Teichoic acid is present in + and absent in – bacteria.

Movement

The tail-like projection that protrudes from the cell body of certain prokaryotic and eukaryotic cells
is Flagella. It helps in locomotion. If bacteria have no Flagella, then it is called *atrichous*.

Nutrition in Bacteria

Bacteria are autotrophic, heterotrophic as well as saprophytic. The autotrophic bacteria are either
photo-autotrophic or chemo-autotrophic. Some bacteria grow on the dead and decaying material
and they are called Saprophytes. The bacteria that grow on plants and animals are called parasitic
bacteria. The bacteria which make mutually beneficial association are called symbioants.
Chemotropic bacteria use chemicals to produce energy. For example, Hydrogen bacteria use
Hydrogen and as source of energy. Similarly, Sulphur bacteria are capable of oxidation of the reduced
Sulphur compounds such as Hydrogen Sulphide (H_2S), Inorganic Sulphur etc.

Reproduction

In bacteria reproduction takes place by two methods viz. Asexual and Sexual. Asexual reproduction
happens via binary fission which is similar to mitosis. Sexual reproduction occurs via conjugation,
transduction and transformation.

Applications of Bacteria

Pasteurization

Pasteurization is one of the methods of preservation of products such as milk, alcoholic beverages
etc. at higher temperatures. Pasteurization is defined as the process of heating products to a
particular temperature and holding it at that temperature for a particular time till the pathogenic
(disease causing) micro-organisms are destroyed causing minimum change in composition, flavor
and nutritive value of products such as milk.
There are two methods of pasteurization (of milk) in general use. One is low temperature
holding (LTH) method in which milk is heated to 62.8°C (145F) for 30 minutes in
commercial pasteurizers (or) large closed vats which are heated by steam coils, hot water
jackets etc.

The other method (i.e.) high temperature short time (HTST) method in which the milk is
heated to 71.7°C (161F) for 15 seconds.
The heating is accomplished by electricity (or) hot water and requires a heat exchange system, which
preheats raw, cold milk and cools the hot pasteurized milk. Please note that Pasteurization conditions
are not sufficient to destroy thermo-resistant spores (reproductive part of microorganisms). Thus,
Pasteurization does not sterilize the products but kills only those organisms that grow most readily at
low temperatures. The surviving organisms must be kept from multiplying by constant refrigeration.

Nitrogen Fixation

The Nitrogen Fixation is the procedure by which atmospheric Nitrogen is converted into ammonia.
The Nitrogen fixation is one of the important components of the Nitrogen cycle.
Nitrogen fixation can be biotic or abiotic. The examples of abiotic processes are lightening, Industrial
processes such as Haber-Bosch Process, and combustion. The biotic nitrogen fixation was discovered
by *Martinus Beijerinck*.

How does it work?

Two molecules of ammonia are produced from one molecule of nitrogen gas, at the expense of 16
units of ATP and a supply of electrons and protons (hydrogen ions):
$N_2 + 8H^+ + 8e^- + 16\ ATP = 2NH_3 + H_2 + 16ADP + 16\ Pi$
Please note that *exclusively the prokaryotes do this reaction*. The enzyme used is called *nitrogenase*. The
nitrogenase enzyme has two kinds of proteins viz. Iron Protein, and Iron-Molybdenum protein. The
N_2 is is bound to the nitrogenase enzyme complex. The Fe protein is first reduced by electrons
donated by ferredoxin. Then the reduced Fe protein binds ATP and reduces the molybdenum-iron
protein, which donates electrons to N_2, producing HN=NH. There are two more cycles and each
requires electrons donated by ferredoxin) HN=NH is reduced to H_2N-NH_2, and this in turn is

reduced to $2NH_3$.

Thus in summary

16 ATP are used in BNF (Biological Nitrogen Fixation)

Two minerals viz. *Iron and Molybdenum* play important role in BNF.

End product is *ammonia + Hydrogen*

Enzyme used is Nitrogenase

Role of Bacteria

Both anaerobic bacteria as well as the aerobic bacteria do biological nitrogen fixation however, the process occurs *in absence of Oxygen* and *thus is anaerobic process*. Further, biological nitrogen fixation is done by both free living and symbiotic bacteria. The notable examples are given below:

Free living aerobic bacteria: Azotobacter

Free living anaerobic bacteria: Clostridium, purple sulphur bacteria

Symbiotic in legumes and pulses: Rhizobium (found in *root nodules*)

Symbiotic in sugarcane: *Glucoacetobacter diazotrophicus* (found in *stem knots*)

Symbiotic in other plants: Frankia, Azospirillum

Why BNF occurs only in anaerobic conditions?

The enzyme nitrogenase is susceptible to destruction by oxygen. Many bacteria cease production of the enzyme in the presence of oxygen that is why many nitrogen-fixing organisms exist only in anaerobic conditions. Some aerobic bacteria which carry out the Nitrogen Fixation use another protein called *Leghemoglobin* to bind the oxygen and bring its level down.

BNF in Legume Plants

Plants that contribute to nitrogen fixation include the legume family – Fabaceae – with plants such as pulses, groundnut, clover, soybeans, alfalfa, lupines, peanuts etc. They contain symbiotic bacteria called *Rhizobium* within nodules in their root systems. Further, it is not necessary that ONLY symbiotic bacteria are able to fix nitrogen by BNF. It is also NOT necessary that only leguminous plants do this. BNF is also found in sugarcane in which such bacteria live in stem nodules. Moreover, fixed nitrogen is released only when the plant dies. This helps to fertilize the soil.

Bacteria in Nitrification

Nitrification is the process in which the ammonia is converted into Nitrate. Nitrification is a two step process and based upon these two steps, the bacteria are divided into Nitrosifying and Nitrite-Oxidizing bacteria. Example of Nitrosifying bacteria is *Nitrosomonas,* which converts the Ammonia (NH_3) into Nitrite (NO_2^-). Example of Nitrite-Oxidizing bacteria is Nitrobacter which are able to oxidize the Nitrite and crate Nitrate (NO_3^-).

Bacteria in Industry and Everyday Life

Some other notable used of bacteria include in Dairy Industry, Food Industry, Soil Health, Bioremediation, Biotoilet

Dairy Industry

In Dairy Industry, *Lactobacillus* bacteria are used in fermentation of lactose sugar to form lactic acid (in curd). Lactobacillus in combination with yeasts and molds, have been used for thousands of years in the preparation of fermented foods such as cheese, pickles, soy sauce, sauerkraut, vinegar, wine, and yogurt.

Food Industry

The *Bacillus megatherium* bacterium is used in the Flavoring of Tea and Tobacco. *Acetobacter aceti* is used in preparation of vinegar from Alcohol.

Industrial Uses

Clostridium acetobutylicum is able to produce acetone from acetic acid as well as butanol from butyric acid. In Biogas plants, the bacterium called *Methanobecterium* is used for production of Methane.

Bacteria are useful in the Fibre ratting in which the fibres of Jute, hemp and Flax are prepared.

Clostridium butyricum is used in the process and these bacteria hydrolyze the middle lamella of these plant fibres. Microbial mining, which is the bacteria and other microorganisms are cultured in container and then used to bring these processes e.g., copper extraction, iron extraction; which involves bacteria called Ferro-oxidans.

Bacteria in soil formation and soil fertility

As soon as a fresh rock is exposed to a biological environment certain organisms, notably the bacteria take possession of it. There is an instance of increased production of organic matter and it results in formation of soil contents. There are many bacteria which decompose the rotten substances like dung, dead residues of animals etc. Some bacteria enhance the fertility of the soil by means of denitrification especially of plants *Rhizobium* bacteria are found in the roots of the plants which nitrified (transformed) atmospheric nitrogen into the nitrates. Such nitrates act like fertilizers and along with the growth of the plants fertility of the soil is also enhanced.

Other uses

Bacteria work as natural scavengers as they are able to decay huge amount of plant, animal and human waste.

Using biotechnology techniques, bacteria can also be bioengineered for the production of therapeutic proteins, such as insulin, growth factors or antibodies.

Some bacteria living in the gut of cattle, horses and other herbivores secrete cellulase, an enzyme that helps in the digestion of the cellulose contents of plant cell walls. Cellulose is the major source of energy for these animals. generally plant cells contain cellulose.the bacteria present in the stomach of cattle will help in the digestion of cellulose.

Escherichia coli that live in the human large intestine synthesize vitamin B and release it for human use. Similarly, Clostridium butyclicum is used for commercial preparation of riboflavin, and vitamin B.

Bacillus thuringiensis (also called BT), a Gram-positive, soil dwelling bacterium is used for Pest Control and producing Bt crops.

Bioremediation techniques such as Oil zapper use bacteria.

Many antibiotics are used from bacteria. Some of them are Bacitracin, Polymyxin B, Streptomycine, Erythromycine, neomycin-B, Chloramophenicol etc.

Antibiotics (medicines)	Bacteria
Streptomycin	Streptococcus groseis
Chloromycetin	S.Venzualae
Teramcyin	S.Rimosus
Nystatin	S.Noursei

Antibiotics (medicines)	Bacteria
Erythromycin	S.Erythreus
Tyrothrycin-A	Bacillus brevis
Polymyxin-B	Bacillus polymixa
Bacitracin	B.Subtilis, Bacillus Licheniformis

Pleasant smell of the earth after the first shower

Pleasant smell of the earth after the first shower (earthy odour) is caused by the
production of a series of streptomycete metabolites called geosmins.
These substances are sesquiterpenoid compounds and unsaturated compound of
carbon, oxygen and hydrogen. The geosmins first discovered has the chemical name
trans-1, 10-dimethyl-trans-9-decalol; however, other volatile products produced by
certain species of Streptomyces may also be responsible for the characteristic smell.

Oil Zapper

'Oilzapper' technology was developed by ONGC-Teri Biotech Ltd (OTBL), a joint venture between ONGC and TERI. This technology was first used by OTBL in Mehsana in Gujarat to eliminate an oil spill and manage the sludge created from the first oil well in the region. The water became clean and subsequently a home to a variety of birds.

Bacteria in the Bio-Digester Toilet

Bio-Digester Toilet is a decomposition mechanized toilet system by means of which the sludge(Human Waste), the fecal matter is decomposed to bits in the digester tank using a specific high graded bacteria further converting them into methane and water, discharged further to the desired surface. The Bio-digester toilet *is total maintenance-free system & does not require any sewage system*. The specific high graded bacteria involved in these bio-digester toilets carries on to further auto generation on their own because of their supreme quality. Bio-toilet technology is based on anaerobic biodegradation of organic waste by unique microbial consortium and works at a wide temperature range. *The bacterial consortium* degrades night soil at temp as low as -20 degree C and produces colourless, odourless and inflammable gas containing 50 – 70% methane.

This *bacterial consortium has been made through acclimatization, enrichment and bio-augmentation of coldactive bacteria collected from Antarctica and the other low temperature areas.*

Bacterial Diseases

Common Bacterial diseases include Diarrhoea, Dysentery, Typhoid, Whooping Cough, TB, Diphtheria, Cholera etc.

Diarrhoea

Diarrhea can be caused by all sorts of parasites including viruses, Bacteria and protozoa. Most common virus causing Diarrhoea in adults is **Norovirus.** Most common virus causing Diarrhoea in children below 5 years **is rotavirus.** A *rotavirus vaccine Rotavac has been recently launched in India.*

Most common bacteria causing Diarrhoea is *campylobacter*; others are *salmonellae, shigellae and some strains of Escherichia coli (E.coli).*

Dysentery

Dysentery is usually caused by a **bacterial or protozoan** infection or infestation of parasitic worms, but can also be caused by a chemical irritant or also **viral infection**. The most common cause of the disease in developed countries is infection with a bacillus of theS *higella* group (causing bacillary dysentery). Infection with the amoeba *Entamoeba histolytica* can cause amoebic dysentery

Typhoid

Typhoid is transmitted by the ingestion of food or water contaminated with the feces of an infected person, which contain the bacterium *Salmonella enterica enterica.* The bacteria perforate through the intestinal wall and are phagocytosed by macrophages. It is a G- short bacillus that is motile due to its peritrichous flagella.

Whooping Cough

Pertussis or Whooping cough is a highly contagious bacterial disease caused by Bordetella Pertussis.

Tuberculosis

Tuberculosis is caused by various strains of M*ycobacterium,* usually *Mycobacterium tuberculosis.* It usually attacks the lungs but can also affect other parts of the body. It is spread through the air when people who have active infection cough, sneeze, or spit. In most cases the disease is asymptomatic, latent infection, and about 10% latent infections eventually progresses to active disease. If untreated, it killed 50% of its victims.

MDR and XDR TB

TB that is resistant at least to isoniazid and rifampicin the two most powerful first-line anti-TB drugs is called the Multi-drug-resistant tuberculosis (MDR-TB). It develops because the when the

course of antibiotics is interrupted and the levels of drug in the body are insufficient to kill 100% of
bacteria. This means that even if the patient forgets to take medicine, there are chances of developing
MDR-TB. MDR-TB is treated with secondline of antituberculosis drugs such as a combination of
several medicines called **SHREZ** (Streptomycin+isonicotinyl Hydrazine+Rifampicin+Ethambutol+pyraZinamide)+MXF+cycloserine.

XDR-TB

When the rate of multidrug resistance in a particular area becomes very high, the control of
tuberculosis becomes very difficult. This gives rise to a more serious problem of extensively drugresistant
tuberculosis (XDR-TB). XDR-TB is caused by strains of the disease resistant to both first

and second-line antibiotics. This confirms the urgent need to strengthen TB control.

Extent of TB

One third of the world's population is thought to be infected with M. tuberculosis, and every second
a new infection occurs. About 80% of the population in many Asian and African countries test
positive in tuberculin tests. The highest number of deaths from TB is in Africa Region.

HIV and TB

HIV and TB form a lethal combination, each speeding the other's progress. TB is a leading cause of
death among people who are HIV-positive. In Africa, HIV is the single most important factor
contributing to the increase in the incidence of TB since 1990. Tuberculosis was declared a global
emergency by the WHO in 1993.

BCG

BCG (Bacillus Calmette-Guérin) was the first vaccine for TB that discovered in 1905 by Albert
Calmette and Camille Guérin. Once WHO declared TB a global emergency, BCG vaccine along with

DOTS was used in more than 192 countries as a preventive therapy. However, there was a
controversial side of BCG vaccination that it showed variable efficacy, that depended on geography.
It was concluded that BCG efficiency goes down as one gets closer to equator. There were several
explanations to this phenomenon. One such theory said that in areas where there are high levels of
background exposure to tuberculosis, every susceptible individual *is already exposed to TB prior to*
BCG, which is why the natural immunizing effect of background tuberculosis duplicates any benefit
of BCG. This means that BCG is less effective in the area where the Mycobacteria are less prevalent.
Another theory says that Variable efficacy is because of the Genetic variation in BCG strains.

DOTs

DOTS, is an acronym for Directly Observed Treatment, Short course. The DOTS strategy represents
the most important public health breakthrough of the decade, in terms of lives which will be saved. It
is based largely on research done in India in the field of TB over the past 35 years.

Leprosy

Leprosy or Hansen's disease is caused by the bacteria*M ycobacterium leprae* and *Mycobacterium*
lepromatosis. Leprosy has a high degree of stigma attached to it because of the fact that there was no
cure for the disease till the eighties and also due to disfigurement caused by the disease.
Some drugs such as rifampicin, clofazimine, and dapsone are used to treat Leprosy.

Diphtheria

Diphtheria is caused by *Corynebacterium diphtheriae*, an anaerobic Gram-positive bacterium. It is an
acute respiratory disease caused by bacteria, which leads to a thick coating in the nose, throat or
airway. Diphtheria takes its name from Greek word 'dipthera' referring to the leathery membrane or
coating that grows on the tonsils, throat and in the nose.

Diphtheria is a purely vaccine-preventable disease and effective vaccine is available.

Cholera

Cholera is an infection of the small intestine that is caused by the bacterium Vibrio cholerae. The
main symptoms are profuse watery diarrhea and vomiting.

Kingdom Fungi

Fungi are among the most primitive members of the plant kingdom. Study of the fungi is called
mycology. The fungi are non-chlorophylous, nucleated, non-vascular, thallophytic micro organism
and due to lack of chlorophyll they do not prepare their own food. The fungi are among the
thallophytes or plants with a thallus, which are simple plants, have no roots, stems, flowers and
seeds- structures we commonly associate with higher plants. The thallus of a fungus is usually made
of branching threads called *hyphae*.

Why Photosynthesis does not take place in Fungi?

Fungi lack chlorophyll and cannot prepare their own food and depend on other organism for
nourishment. On the basis of nourishment the fungi are of three types –
Saprophytes: The fungi which obtain their food or do nutrition from decayed moist leaves,
moist dead wood or by some other useless rotten residues or organic substances. The fungi
like *Rhizopus*, Penicillium etc are saprophytes.
Parasites: The fungi which obtain their food by taking or sharing the food of any other
organisms. The fungi like *Ustilago, Puccinia* etc that are harmful parasites.
Symbiotic: The fungi, which coexist with other plants and facilitate water and mineral salt and
plants prepare food for them. The microbe lichen is the best example of symobiotic fungus.

Benefits of Fungi

Soil Formation and Fertility

The fungi decompose moist residues of leaves, dead wood, animal along dung and other rotten
organic substances into another, which act like manures, and thus soil becomes more fertile.

Food

There are various fungi which are used as food. ***Agaricus*** and *Morchella* are used in the forms of
vegetables (mushrooms) fungi. *Aspergillus, penicillium* are used in cheese industry, yeast a (a type of
fungi) like *Saccharomyces cervisiae* is used in making double roti (bread dough). Wines, beers are also
prepared by the alcoholic fermentations of the yeasts.

Nitrogen fixation

The fungi like *Rodoturela* do the process of nitrogen fixation due to which the fertility of the soil is
enhanced.

Medicines

In the fungi there are various types of antibiotics which are utilized in making medicines like
chloromycetin, neomycin, streptomycin, teramycin etc.

Chemical Industry

Various types of acids and chemical substances are prepared. *Aspergillus gallomyces* and *Pencillium*
glaucum are used in the Gallic acid. Similarly Gluconic acid and Fumeric acid are prepared by the
fungi *Aspergillus niger* and *Rhizopus nigricans* respectively.

Enzymes and Vitamins

By the fungi and some yeast, various types of enzymes are prepared. The enzymes amylase is
prepared from *Aspergillus orizae*. Similarly, invertase is prepared by yeasts. Various vitamins like
vitamin B is prepared from *Streptomyces griseus.*

Mycoremediation

Bioremediation by means of Fungi is called*M ycoremediation*. Fungi have been shown to
biomineralize uranium oxides, suggesting they may have application in the bioremediation of
radioactively polluted sites. Some fungi are hyperaccumulators, capable of absorbing and
concentrating heavy metals in the mushroom fruit bodies.

Pest control

Beauveria bassiana, Metarhizium spp, Hirsutella spp, Paecilomyces (Isaria) spp, and Lecanicillium lecanii have been used in *Pest Control. One gene-one enzyme hypothesis* was formulated by scientists who used the bread mold Neurospora crassa to test their biochemical theories. Aspergillus nidulans and the yeasts, Saccaromyces cerevisiae and Schizosaccharomyces pombe, have a long history of use to investigate issues in eukaryotic cell biology and genetics, such as cell cycle regulation, chromatin structure, and gene regulation.

Common fungal diseases

Wart disease of potato, Late blight of potato, Green ear disease of bajra, Rust of wheat, Loose smut of wheat, Tikka disease of groundnut, Red rot of sugarcane, Brown leaf spot of rice, Ergot disease of rye, Powdery mildew of wheat etc.

Common animal and human fungal diseases include Athlete's foot scabies, Scabies , Ring worm, Meningitis, Asthma, Baldness, Aspergillosis etc.

Lichens

Lichens are symbiotic associations of fungi and algae. In this association, the fungi (called mycobiont) facilitate water, minerals, vitamins, etc to the algae and algae (called phycobiont) prepare carbohydrate by the process of photosynthesis and supply the food to the fungi. Study of lichens is called Lichenology. Lichens are most commonly found on the trees. Lichens are useful and by the help of these various economic activities can be observed. Lichens are capable to indicate air pollution, water pollution, heavy metals as well as radioactive particles. Lichens like Reindeer mosses, Iceland moss etc are utilized as food stuffs.

Kingdom Plantae

Algae

Algae (seaweeds) are usually aquatic, either marine or fresh water plants. A few algae also occur in terrestrial habitats such as moist soils, wet rocks, tree trunks, etc. These are unicellular or multicellular, autotrophic plants which don't have vascular tissues {tissues that provide mechanical strengh} and their body are called thallus.

Types of algae

Algae have been divided on the basis of nature of pigments present in them and the mode of storing
food. These pigments give them specific color.

Green Algae or Chlorophyceae

Green algae have chloroplast and chlorophyll in their cells. Examples are*C hlamydomonas, Volvox,*
*Spirogyra, Ulothrox, Oedogonium and Char*a are some example.

Brown algae or Phaeophyceae

Brown algae store food in the form of *laminarin* and *mannitol*. Many of brown algae are called *Kelps*.
Ectocarpus, Laminaria, Sargassum are common examples of brown algae.

Red Algae or Rhodophyceae

Red algae are red because of a pigment called Phycoerythrin. Most red algae are found in marine
habitats. They store food in Floridean starch. Common examples are Gracilaria, Porphyra etc.

Blue Green Algae or Cyanophyceae

Blue green algae are most primitive algae and are prokaryotic. Modern classification puts them in
Kingdom Monera along with bacteria.

Economic Importance of Algae

Benefits

Nitrogen fixation and Biofertilizers

There are many species of blue-green algae capable of fixing atmospheric nitrogen in the soil and are
used as biofertilizers. Common examples are Anabaena and Nostic. Anabaena, in association with
water fern Azolla contributes nitrogen and also enriches soils with organic matter.

Other Uses

Many green algae such as Chlorella, Ulva, Caulerpa, Enteromorpha, etc. are used as food.
Chlorella has about 50% protein and 20% of lipid and carbohydrates. Chlorella also yields an
antibiotic chlorellin.
Agar is obtained from the Red algae *Gracilaria* and Agar is used as a culture medium for
growing of microbes in labs. Agar is also used in Food and Pharmaceuticals.

Carragineen which is used in the Dairy industry is obtained from a red alga called *Chondrus crispus*. It is also used in cosmetics and Pharma.

Alginic acid, which is used as a stabilizer and thickening agent is obtained from Laminaria, the brown algae.

Dynamite is prepared with the cell walls of Diatoms.

Brown algae Laminaria is a good source of Iodine.

Macrocystis algae are source of Potash. It's a brown algae (phaeophyceae) and is largest algae among all.

Algal Hazards

Algal toxicity

Some algae are extremely poisonous to fishes. The blue-green alga Microcystis secretes hydroxylamine which kills aquatic life while Lyngbya and Chlorella may cause skin allergies in human beings.

Algal parasitism

The red alga Cephaleuros virescens causes Red Rust of Tea.

Algal blooms

Algae grow abundantly in water reservoirs where excess of nutrients are available to them. This algal growth floats on the water surface and look like foam or soap lather. It is called water bloom.

Examples: Microcystis, Anabaena, Oscillatoria, etc.

Color of Red Sea

Red Sea is the part of the Mediterranean sea where a Blue green algae Trichodesmium grows profusely is called Red Sea. It is due to the presence of red Phycoerythrin in the cells of Trichodesmium.

Bryophytes

The common word for Bryophytes is Moss, which are the first land plants in context with evolution of plants. The branch of science that deals with Bryophytes is called Bryology. Please note that Mosses don't have a vascular tissue such as Xylem and Phloem, which we find in plants of higher

orders. Due to this, they are also known as Atracheates which means no trachea. In IndiaS, *R*
Kashyap did a commendable job in the studies of Bryphytes and that is why is called Father of Indian
Bryology.

Amphibians of Plant Kingdom

Bryophytes are called the "amphibians" of the plant kingdom. They can live on land but for
reproduction and fertilization, need water essentially.
The Bryophytes were the first plants in which alternation of generation was seen for the first time in
the embryophytes as Gametophyte→Mitosis → gametes →Sporophyte → Spores → Meiosis
→Gametophytes.

Bryophytes: Important Points

One of the famous Bryophyte is **Peat Moss**. Its botanical name is *Sphagnum*. It grows in
swamps and damp areas. This is one of the most economically important Bryophyte. In
World War I, Peat moss was used as "dressing cotton' for wounded soldiers. Peat is obtained
from Sphagnum.
Physcomitrella patens is increasingly used in biotechnology. Prominent examples are the
identification of moss genes with implications for **crop improvement or human health**
and the safe production of complex biopharmaceuticals in the moss bioreactor.
Mosses play an important role in controlling soil erosion. They perform this function by
providing ground cover and absorbing water.
Mosses are also indicators of air pollution. Under conditions of poor air quality, few mosses
will exist.
Peat is used as fuel to heat homes and generate electricity.*B ryophytes are among the first*
organisms to grow up in areas that have been destroyed by a fire or volcanic eruption.

Why Mosses are haploid in most of their lives?

Bryophytes commonly grow close together in clumps or mats in damp or shady locations. They do not have flowers or seeds, and their simple leaves cover the thin wiry stems. Please note that in Bryophytes, the dominant phase of life is *not the plant itself but one of its phases in reproduction called gametophytes*. The only thing you need to remember is that gametophyte contains a single set of Chromosome and that is why the "*Bryophytes are in Haploid state in most of their lives*".

At certain times, mosses produce spore capsules, which may appear as beak-like capsules borne aloft on thin stalks. These gametophyte produces male or female or both gametes (term used for sperms or ovum lower plants) by mitosis. When male and female gametes fuse, they make a diploid zygote, which develops by repeated mitotic cell divisions into a multicellular *Sporophyte*. This *Sporophyte is diploid* because it is a product of fusion of two haploid gametes. This Sporophyte is NOT independent in Bryophytes and needs to get nutritional support from the gametophyte.

Now, this diploid phase Sporophyte again produces sex cells via meiosis, which are called spores.

During making of spores, the chromosome pairs are separated once again to form single sets. The spores are therefore once again haploid and develop into a haploid gametophyte. This is how the lifecycle of a Bryophyte goes on.

Pteridophytes

Pteridophytes are commonly known as *Ferns*. There are around 12,000 species of Ferns, many of them are generally used a *decoration / ornamental plants.*

Position of Pteridophytes in Evolution

In the evolutionary stages, Ferns are next advanced level after Bryophytes. Bryophytes don't have the vascular tissues, but the Ferns have *both xylem and phloem*, thus they are the *first vascular plants* in terms of evolution of plant species. They have stems, leaves, and roots like other vascular plants.

Further, in case of the Bryophytes, the dominant phase of life is gametophytes. This reverses from
Pteridophytes ONWARDS. Thus in Pteridophytes, Gymnosperms and Angiosperms, the dominant
phase of life is Sporophyte. This Sporophyte is NOT only independent but also long lived.
Pteridophytes differ from the advanced plants on the basis of the Reproduction procedures. They
differ from gymnosperms and angiosperms as they *do not have neither flowers nor seeds.*

Economic Importance

Most of the Pteridophytes have ornamental value; they are grown as ornamental plants in gardens
and homes. Some Pteridophytes such as Marsilea are rich source of starch and used as food material.
Parts of *Pteridium aquilinum* or *Pteridium esculentum*, are used as a cooked vegetable in Japan and are
believed to be responsible for the high rate of stomach cancer in Japan. It is also one of the world's
most important agricultural weeds, especially in the British highlands, and often poisons cattle and
horses. *Dryopteris filix-mas* is used an anti-helminth means anti worm, used in Pharmacy.

Biofertilizer

The smallest fern *Azolla* has the capability of Nitrogen Fixation is used as a biofertilizers, especially in
parts of Southeast Asia. Azolla has been used for thousands of years in China in paddy cultivation.
Azolla is also known as ***Mosquito fern*** because of a myth, that when this plant is in bloom, no
mosquito can cross its covering to the water in the water body to lay eggs.

Gymnosperms

Gymnosperms are called so because they *have naked ovules / seeds.* In terms of plant evolution, they
are first *seed-bearing plants.* They are *inferior to Angiosperms because* in Angiosperms, the ovules are
covered. Common gymnosperms include Conifers, Cycads, *Ginkgo,* and Gnetales.

Notable Points

Tallest plant of the world "Coast Redwood of California" is a gymnosperm.

Some Gymnosperms are called the "living fossils" because many of them represent the one of the few, if not the only, surviving members of a taxonomic group, with no close living relatives. Cycas and Ginkgo Biloba are examples of living fossils.

Canada Balsum, the sticky colourless and odourless liquid used in optical industry is obtained from a Gymnosperm.

Ephedrine is obtained from Ephedra which is a naturally growing Gymnosperm in Rajasthan.

Sago, which is a staple food in New Guinea and some other countries is obtained from *Cycas revoluta* and

Chilgoza is obtained from *Pinus gerardiana*, known as the Chilgoza Pine. Chilgoza is one of the most important cash crops of tribal people residing in the Kinnaur district of Himachal Pradesh, which seems to be the only place in India where Chilgoza pines are found.

Cedar wood is obtained from many species of the Gymnosperms. Similarly **Chir wood** is obtained from Chir Pine or *Pinus longifolia*. The Pinus species of Gymnosperms contain the "winged pollen grains".

Angiosperms

Angiosperms or flowering plants are the most advanced, most diverse and most dominant group of land plants. They are seed-producing plants and can be distinguished from the gymnosperms by a series of derived characteristics such as flowers, endosperm within the seeds, and the production of fruits that contain the seeds. They have developed from Gymnosperms over the period and replaced them as most dominant group of plants some 100 million years ago.

Main Features of Angiosperms

Benefit of Flowers

Due to Flowers, Angiosperms were able to adapt a wider range of ecological niches, making them largely dominate terrestrial ecosystems.

Reduced Male and Female Parts

Instead of cones in Gymnosperms, the Angiosperms have stamens, reduced male parts and an
enclosed ovule. The Stamens are much lighter than the corresponding organs of gymnosperms and
have contributed to the diversification of angiosperms through time with adaptations to specialized
pollination methods. In some advanced species, the Stamens were modified to prevent selffertilization,
enabling further diversification.

Dominant Sporophyte

The main plant of Angiosperms is a Diploid Sporophyte which is divided into roots, stems and
leaves. The male gametophyte in angiosperms is significantly reduced in size compared to those of
gymnosperm seed plants. The smaller pollen decreases the time from pollination — the pollen grain
reaching the female plant — to fertilization of the ovary; in gymnosperms, fertilization can occur up
to a year after pollination, whereas, in angiosperms, the fertilization begins very soon after
pollination. The shorter time leads to angiosperm plants' setting seeds sooner and faster than
gymnosperms, which is a distinct evolutionary advantage.

Double Fertilization

Double Fertilization is a rule on Angiosperms. This means that the Fertilization in Angiosperms
involves the joining of a female gametophyte (megagametophyte, also called the embryo sac) with
two male gametes (sperm).

Pollination in Angiosperms

In flowering plants, pollination refers to transferring pollen grains from the male anther of a flower
to the female stigma.

Pollination taking place in a single flower is called self pollination, while pollination taking place
between two flowers is called cross pollination. If the cross pollination is between flowers of a same
plant, it will be called Geitonogamy, while if it takes place between two separate plants, it will be

called as Xenogamy. In some plants, the flowers are bisexual and closed called Cleistogamous. Here
only self pollination takes place.
Insects (Entomophily) can facilitate the pollination, similarly can Wind (anemophily), Water
(Hydrophily), Animals (Zoophily). Further, Hummingbirds, bats, monkeys, marsupials, lemurs,
bears, rabbits, deer, rodents, lizards and other animals are common animals that carry pollens and
help in pollination.

Pollination by Bats

Pollination done by Bats is called *chiropterophily*. Many fruits are dependent on bats for pollination,
such as mangoes, bananas, and guavas. Bat pollination is an integral process in tropical communities
with 500 tropical plant species completely, or partially, dependent on bats for pollination.

Pollination by Birds

The term ornithophily is used to describe pollination specifically by birds.*H ummingbirds, sunbirds,
honeyeaters, flowerpeckers, honeycreepers, and bananaquits* are examples. Plants pollinated by birds often
have brightly colored diurnal flowers that are red, yellow, or orange, but no odor because birds have
a poor sense of smell. Other characteristics of these plants are that they have suitable, sturdy places
for perching, abundant nectar that is deeply nested within the flower. Often flowers are elongated or
tube shaped. Also, many plants have anthers placed in the flower so that pollen rubs against the birds
head/back as the bird reaches in for nectar.

Pollination by Lizards

Although lizard pollination has historically been underestimated, recent studies have shown lizard
pollination to be an important part of many plant species' survival. Not only do lizards show
mutualistic relationships, but these are found to occur most often on islands. The lizard
Hoplodactylus is only attracted by nectar on flowers, not pollen.

Monocots and Dicots

Angiosperms are classified into two categories viz. monocots and dicots. In monocots, seed has only
one cotyledon while in dicots, seed has two cotyledons.
The key comparisons of these two groups are as follows:
The roots of monocots are lesser developed in comparison to dicots.
The petals in flowers of monocots are 3 or multiples of 3. The petals in flowers of dicots are
four or five; it's their multiples.
No secondary growth is found in monocots because their vascular tissue has no cambium. Secondary
growth is found only in dicot plants.
Examples of monocots include grasses, bamboo, sugarcane, cereals, bananas, palms, lilies,
orchids etc. Examples of Dicots include all the hardwood tree species, pulses and the most
fruits, vegetables, species beverage crops and ornamental flowering plants.

Roots and root modifications

Roots of Angiosperms always move opposite to the sunlight. The soft parts of roots and root hairs
absorb water and mineral salts from the soil. The root transports water and mineral salts to the stem
and ultimately to the leaves. Some roots like of carrot, radish etc. store foods and in contingency
plants use these foods. The roots are of following types:
Tap root: The radical of such root develops itself and forms a main root and such roots exist
in dicotyledonous plants.
Conical shape: This type of root is thickened towards base but thin near the side of the
plant. Example-carrot.
Napiform: This type of root is extremely thickened and becomes inflated spherical at the
base (bottom) but it becomes extremely thin at the top of the plant. Examples-turnip, beet
root etc.
Fusiform : This type of root is inflated in the middle portion, while towards bottom and top
it becomes thinned. Example is Radish.
Pneumatophores : This type of root is found in salty soil of the sea and for the respiratory

activities it undergoes towards negative geotropic. Examples are Rhizophora, etc.

Adventitious Roots

Adventitious roots originate from the stem, branches, leaves, or old woody roots, rather than the normal root system. For example in Strawberry and Willow. These roots develop to avoid stress or fight with the problem of nutrition deficiency or to get sufficient oxygen, or avoid too much oxygen.

One more important work of these roots is to help in vegetative propagation in many plants. This ability of plant stems to form adventitious roots is utilized in commercial propagation by cuttings.

Understanding of the physiological mechanisms behind adventitious rooting has allowed some progress to be made in improving the rooting of cuttings by the application of synthetic auxins as rooting powders and by the use of selective basal wounding.

Adventitious roots *develop near the existing vascular tissue*, so that they can connect to the xylem and phloem. There are several kinds of modifications such as:

Tuberous roots are without any definite shape; example: Sweet Potato.

Fasciculated root (tuberous root) occur in clusters at the base of the stem; example: asparagus, dahlia.

Nodulose roots become swollen near the tips; example: turmeric.

Stilt roots arise from the first few nodes of the stem. These penetrate obliquely down in to the soil and give support to the plant; example: maize, sugarcane.

Prop roots give mechanical support to the aerial branches. The lateral branches grow vertically downward into the soil and acts as pillars; example: banyan.

Climbing roots these roots arising from nodes attach themselves to some support and climb over it; example: money plant.

Modifications of adventitious roots

Roots	Examples
Fibrous root	Onion
Leafy root	Briophylem
Climbing root	Betel leaf, pothos
Buttress root	Terminolia
Sucking root	Cuscuta
Respiratory root	Juicia
Epiphytic root	Orcede

Aerial root	Orcede
Assimilatory root	Tinspora
Parasitic root	Kascutta
Moniliform root	Grapes, bitter guard
Nodulose root	Mango turmeric
Prop root	Banyan tree
Stilt root	Maize, sugarcane
Fasciculated root	Dahlia

Stem in Angiosperms

On the basis of the position of the soil, stems are of three types:

Underground stem: The branch or part of the stem which intruses inside the soil is called underground stem. These stems store the food in the stem, node, internode, bud and scale leaf are found. Examples- banana, potato, colocasia etc.

Sub aerial stem : If a few part of stem is inside the soil and rest is in air then such stem is called subaeriala stem. Examples-Grass root, water plant, etc.

Aerial stem : The stem which is completely confined and localized in air and entirely outside from the soil then it is called aerial stem. In this type of stem branches, leaves, node,

internodes, buds flower-fruit etc are found. Examples-Grapes, lemons, roses etc.
To perform some specific works, stems sometimes do exclusive works other than common work
then shapes and sizes of the stems are changed and it is called modifications of stems. Usually there
exists three types of modifications in the stems-

Underground modifications

In the diverse conditions, underground stems store their food inside the stems and become thickened
and tuberous. There are various types of modifications occur in underground stem-
Stem tuber- Potato
Bulb – Onion, garlic, tulips, lilies etc.
Corm – Gladiolus, crocus, saffron etc.
Rhizome—Ginger, turmeric, arrow root etc.

Sub aerial modifications

There are various types of modifications exists in such types of stem-'
Runner – Grass root, mereilia etc.
Stolon – Mint, jasmine, straberi etc.
Offset – Water plant, pestia etc.
Sucker – Roses, gilly flower etc.

Aerial modifications

There also occur various types of aerial modifications-
Stem tendril – Grape.
Stem thorn – Lemon, roses, jujube, plum or Chinese date.
Phylloclade – Cactus.
Bublis – Ruscus.

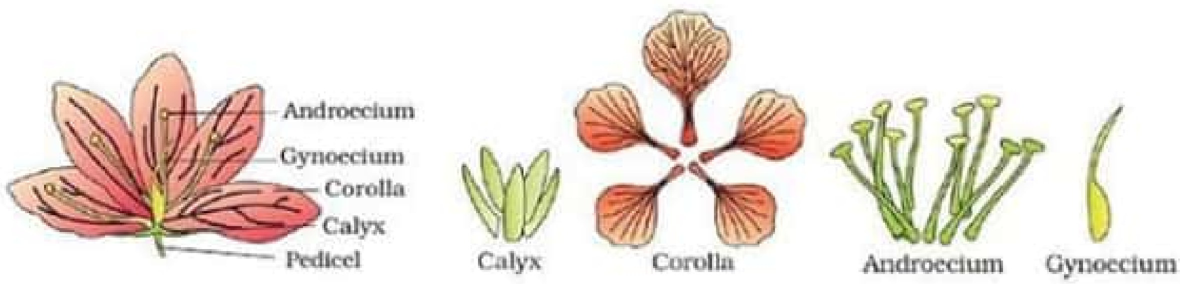
Leaf in Angiosperms

Leaves prepare food for the plants. Respiratory activities are performed by the leaves through
stomata. Leaves perform the vascular and execratory activities of foodstuffs. Leave help in
performing conducive reproduction and pollination. Some leaves work to store food-stuffs.
Leaves undergo through various modifications like the following—
Leaf spines : In this class of modification leaves transform into spines. Examples-Cactus,
lemon etc.

Floral leaves : In this class of modification floral activities like calyx, corolla etc are
performed by the leaves.
Bract : In this class of modification leaves become colored and fascinate the insects towards
themselves.
Scaly leaves: Sometimes leaves modified themselves to protect buds and other soft organs of
the plant, called scaly leaves. Sometimes scaly leaves also store the food-stuffs. Example-
Garlic, onion, etc.
Leaf root : In this class of modification, leaves transform into roots. Example- Briophylem
etc.
Leaf tendril : In this class of modification leaves take the form of tendrils. Example-Pea
plant.
Storage leaves : In this class of modification leaves store foodstuffs and become thickened
and tuberous.
Picher : In this class leaves accommodate to trap the insects and modified themselves in the
form of bags. Example-Pitcher plant.
Bladder : In this class of modification, leaves transform themselves in the form of bladder to
trap the aquatic insects like utriculeria etc.
Leaf hooks : In this class of modification leaves turn like nails. Example-bignonia etc.
Phyllode : Australian acacia etc.

Main parts of a Typical Flower

A Flower is a composite system of *modified leaves and knots*, which directly participates in the
reproductive activity and produces fruits and seeds. Usually a flower is composed from four modified
leaves which are attached to the thickened receptacle thalamus. This receptacle thalamus has four
types of cycle- calyx, corolla, androecium and gynoecium.



The flower which *has all four cycles is called complete flower*, while if any cycle be absent then it is called incomplete flower. The organelles calyx and corolla and called auxiliary organelles, while androecium and gynoecium and called necessary organelles.

Calyx

This is an extremely outer cycle of the flower and it is green coloured cycle of sepals. The main work of calyx is to protect the soft parts of buds and performs photosynthesis. In some flowers, it becomes coloured and its main function to attract insects for the pollination.

Corolla

This is the second cycle of the flower which is confined inside the organelle calyx. Corolla is mainly composed from 2-6 petals and it is also colored whose main function to fascinate insects for the pollination.

Androecium

This is the third cycle of sepals which is the made from stamens. The stamen is the male sex organ of the flower. Each and every stamen has its three parts viz. Filament, Anther and Connective. The vital component of androecium is basically stamen and in which pollen grains are found in pollen sac.

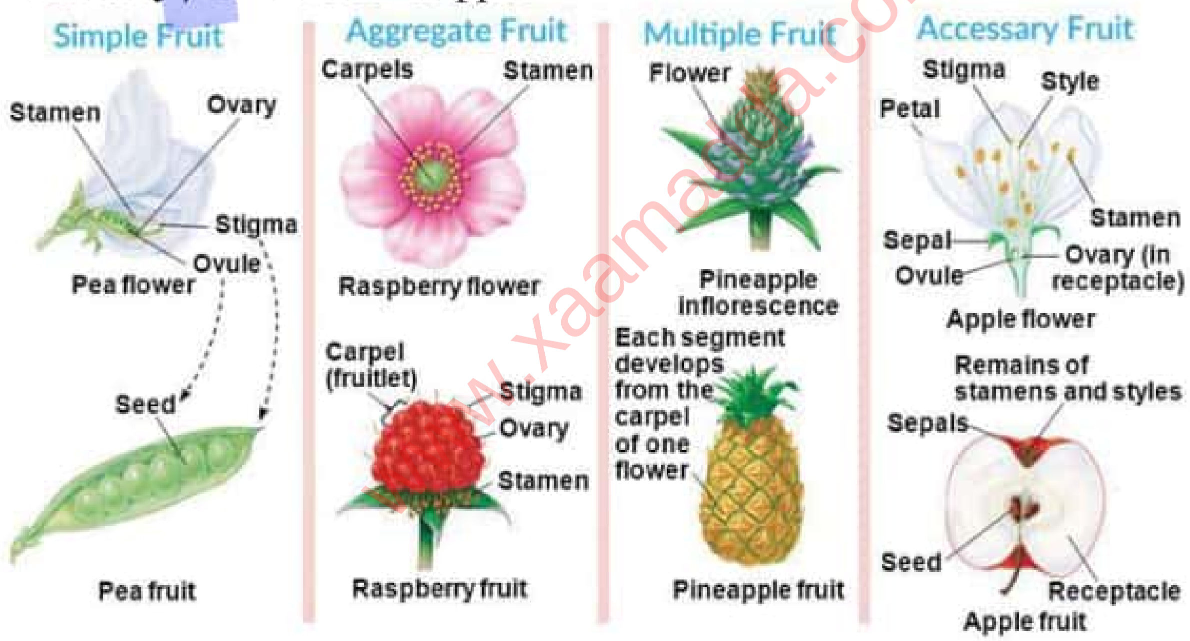
Gynoecium

This is the central part (fourth cycle) of the flower and it is the female sex organ of the flower. Each and every gynoecium is made from one or more carpels and it produces female ovule. The carpel is made from three components- ovary, style and stigma.

Fruit in Angiosperms

The fruit is usually formed in the ovary of the plant and pericarp is formed from the mature ovary

walls. But in the formation of some fruits like apple, jack fruit etc, *calyx, corolla, thalamus etc participate*
and such fruits are called false fruits.
Usually pericarp has three layers outermost layer is called *epicarp*. Middle Layer is called *mesocarp*,
while innermost layer is called endocarp. *Please note that Coconut coir is Mesocarp.*
On the basis of fertilization of the flower there are two types of fruits-
True fruit – The fruit forms in the ovary of the flower by the process of fertilization and
zygote formation is called true fruit.
False fruit : When fruit formation occurs other than ovary and flowers organelles like calyx,
corolla, thalamus etc take place then it is called false fruit. Examples- Apple, jack fruit, pear
etc.
But in angiosperms too much diversities are found in their fruits, thus on macro level there are three
classes in them.
Simple fruit – bean, mustard, mango, lemon etc.
Aggregate fruit- strawberry, lotus, raspberry, custard apple etc.
Composite (multiple) fruit- jack fruit, mulberry, banyan, fig etc.
Accessory / False Fruit: Apple



Here is a list of some common Fruits and their edible parts. This list is important.

Fruits	Edible parts
Mango	Mid. Pericarp
Apple	Thalamus
Pear	Thalamus
Tomato	Pericarp and perisperm
Litchi	Pulpy aerial
Coconut	Endosperm
Guava	Pericarp
Ground nut	Seed leaves and embryo
Wood apple	Mesocarp and endocarp
Grape	Pericarp
Jack fruit	Sepals, bract, seeds
Wheat	Endosperm and embryo

Fruits	Edible parts
Coriander	Thalamus and seeds
Custurd apple	Pericarp
Water chest nut	Seed leaves
Lemon	Juicy pore
Chinese date	Epicarp and mesocarp
Mulberry	Bract, sepals and seeds

In some plants without fertilization, fruits are produced through ovary and the process of this nonfertilization is called *parthenocarpy* and *such fruits are seedless*. Examples-banana, papaya, orange, grapes, etc.

Other Important Topics

Stomata in Plants

There exist various tiny openings (called pores) on the surface of the skin of stems and leaves called stomata which are surrounded by two kidney shaped *guard cells*. In a leaf the number of stomata vary from 14 to 1040mm². These stomata *exchange the moisture and help in transpiration activities* in the plants.

Annual rings in age determination

The branch of botany under which annul a rings of the plant are studied is called dendrochronolgy.

By the elevation of number of annual rings in the plants or trees, the ages of the plants or trees are
estimated exactly. Please note that dendrochronolgy is applicable only to a period of a few thousand
years and only in the few areas where old wood samples have been preserved, radiocarbon dating can
date events up to sixty thousand years old.

How does it work?

Due to the chronological, climatic changes the core activities of the cambium of any plant that of any
place is regularly changed. In spring season this *activity is increased,* while in the winter season it is
decreased, consequently distinct annual rings form which is the indicative parameter of the year
growth.

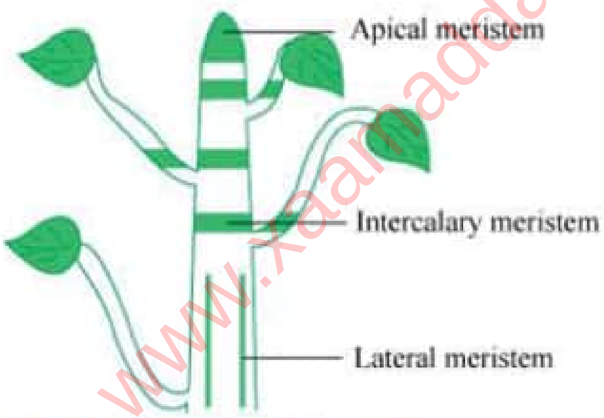
Plant Physiology Topics

Plant Tissues

In plants, there are two kinds of tissues viz. *Meristematic tissues* and *Permanent Tissues.*

Meristematic Issue

The Meristematic tissues are divisible and cells in these tissues retain the power of division, so that
plant keeps growing. These tissues are found in the regions of plant growth such as apical tissues,
buds, nodes, side of branches etc.



Apical Dominance by Meristematic Tissues

Apical Dominance means that in plants, one Meristem {regions of growth / Meristematic tissues}
inhibits the growth of other Meristems. The result of this is that a plant has one clearly defined main

trunk. The tip of the main trunk bears the dominant Meristem and grows rapidly. It is not shadowed
by branches. If the dominant Meristem is cut off, one or more branch tips will assume dominance.
The branch will start growing faster and the new growth will be horizontal. *To get a bushy growth, the*
tip of the main trunk is removed. This mechanism is based upon *Auxin hormone* which is produced in
the apical Meristem and transported towards the roots in the cambium.

Permanent Tissue

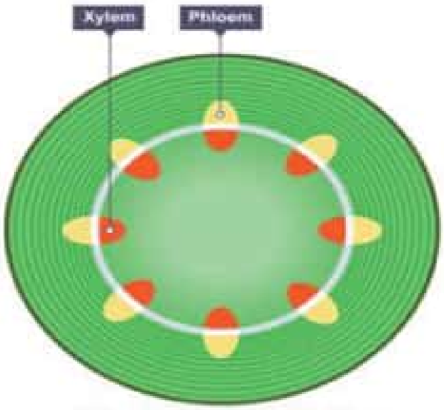
Permanent tissues are formed by the cells which lose the power of division. Cells in permanent tissue
are either living or dead. These cells have thick cell walls. These tissues are either simple {made of
similar types of cells} or complex {made of different types of cells, working as single unit}.

Simple Tissues

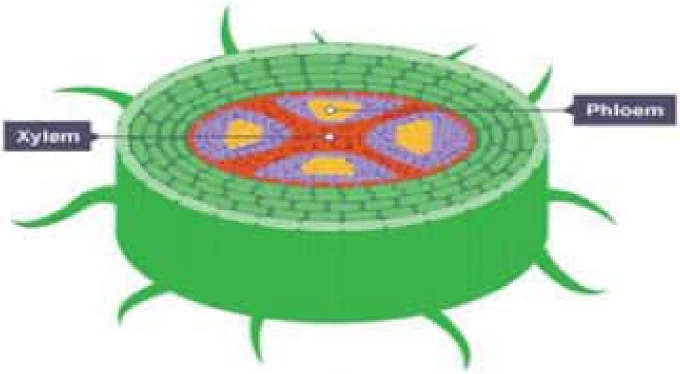
Simple permanent tissues are of three kinds viz. parenchyma, collenchyma and sclerenchyma.
Parenchyma tissues are the most vital parts and centers of important physiological functions such as
respiration, photosynthesis, storage, secretion etc. These tissues help in growth and repair, wound
healing, formation of adventitious roots. In succulent plants(Succulent plants are water-retaining
plants adapted to arid climate or soil conditions, such as Carissa carandas or Karonda), these tissues
store water; while in aquatic plants they store air. The collenchyma tissue also has living cells but
these cells are with thick cell walls and provide tensile strength. It works both as vital and mechanical
tissues. *Sclerenchyma* is made of dead cells and it works as mechanical tissues.

Complex Tissues

In plants, the complex tissues are Xylem and Phloem. Xylem (wood) conducts water and minerals
from root to leaves and also provides mechanical strength. It remains at inner side in the root and in
the form of wooden columns in stems as shown below:



Xylem and Phloem in Stem



Xylem and Phloem in Root

Phloem or wood conducts the prepared food material from the leaves to the storage organs and
growing organs. Generally Phloem is found outside the vascular cambium, but in some plants it may
be found inside the pith also in the form of intraxylary phloem.
Why plants die when bark is removed?
Here we note that when bark of a tree is removed in a circular fashion all around near
its base, it gradually dries up and dies because roots are starved of energy. This is
because removal of bark means removal of phloem and absence of phloem would
block transport of soluble organic material made during photosynthesis in leaves to
root of the plant.

Other Tissues in Plants

Plants also have secretory tissues such as water stomata or hydathodes. The water stomata release
water via a process called *guttation* in aquatic plants. Pistia (also called water cabbage / water lettuce)
is one such aquatic plant that has water stomata. Further, some plants are insectivorous (example
Nepenthes, Pitcher plant) which have secretory tissues that release some poisonous material to kill
the insects. Further, in Rubber plants (*Ficus elastica* and *Havea brasiliensis*), the laticiferous tissue
secretes latex, which is dried and processed to produce natural rubber.

Photosynthesis

Plants have the amazing ability to harvest energy from the sun using chlorophyll and convert it into
carbohydrates. These carbohydrates serve as chief energy source for almost all living beings in the
world, including plants themselves.
Photosynthesis is the process through which the food is prepared by the plant from chlorophyll,
carbon dioxide (CO_2) and water (H_2O) in the presence of sunlight. The chemical involve in the
photosynthesis is –
$6CO_2 + 12H_2O$ ——- $C_6H_{12}O_6+6H_2O+6O_2$
Most organisms that utilize photosynthesis to produce oxygen use visible light to do so, *although there
are plants which use infrared radiation* too. Photosynthesis occurs in Chloroplats of plants and it done
by Chlorophyll pigment. Magnesium is found in the chlorophyll of plant leave and in the nucleus of
the chlorophyll on atom of the magnesium exists. The chemical substance chloroplast is called the
nucleus of the photosynthesis.

Factors influencing photosynthesis

Light

Mainly, ***violet, blue and red light***portion of sunlight is used for photosynthesis. Further,
photosynthetic activity is maximum in low intensity light; as the intensity of the light increases
photosynthetic activity *decreases*.

Temperature

As the process of photosynthesis is the complex chemical reaction of the various enzymes and these
enzymes only being normal to participate in the chemical reaction up to a moderate and optimum
temperature. Thus photosynthetic activity increase from 0°C to 37°C but 37°C onwards such activity
decreases abruptly.

Carbon dioxide (CO_2)

Up to a definite level on increasing the concentration of CO_2, photosynthetic activity increases, but
after the certain limit, the increase of its concentration does not affect the photosynthetic activity.

Water (H_2O)

Due to the lack of water, the photosynthetic activity abruptly decreases because of steep fall of the rate of evaporation. In fact, the pores of the plant leaves become partially closed and ultimately the translocation of CO_2 is disrupted through the leaves.

Why Peepal tree releases Oxygen all the time?

Most plants largely uptake Carbon dioxide (CO^2)and release oxygen during the day (photosynthesis) and uptake oxygen and release CO^2 during the night (respiration).

Some plants such as Peepal tree can uptake CO^2 during the night as well because of their ability to perform a type of photosynthesis called Crassulacean Acid Metabolism (CAM). However, they don't release large amounts of oxygen during the night. CAM is one of the three types of photosynthesis pathways occurring commonly in plants; the other two being C3 and C4 pathways.

Plant Hormones

Plant hormones are signal molecules produced within the plant, and occur in extremely low concentrations. Hormones regulate cellular processes in targeted cells locally and, when moved to other locations, in other locations of the plant. Hormones also determine the *formation of flowers, stems, leaves, the shedding of leaves, and the development and ripening of fruit*. Plants, unlike animals, lack glands that produce and secrete hormones. Instead, each cell is capable of producing hormones. They affect which tissues grow upward and which grow downward, leaf formation and stem growth, fruit development and ripening, plant longevity, and even plant death. Hormones are vital to plant growth, and, lacking them, plants would be mostly a mass of undifferentiated cells.

There are various types of plant hormones.

Auxins

Auxin is a group of plant hormones that produce a number of effects, including plant growth,
phototropic response through the stimulation of cell elongation (photopropism), stimulation of
secondary growth, api¬cal dominance, and the development of leaf traces and fruit. An important
plant auxin is indole-3-acetic acid. (IAA and synthetic auxins such as 2,4-D and 2,4,5-T are used as
common **weed killers**.)
They are basically weak organic acids which actively participate in the cell division and the
cell elongates consequently thus plants growth occurs.
If some auxins hormones be applied on the flower of the plants then without fertilization and
without seeds formation ovary wall becomes tuberous and forms the fruit. This is called the
artificial parthenocarpy

Agent Orange

2,4-dichlorophenoxyacetic acid (2,4-dichlorophenoxyethanoic acid) is a synthetic auxin frequently
used as a weed killer of broad-leaved weeds. When two herbicides 2,4,5-T and 2,4-D and mixed in
equal parts, it is called Agent Orange, which was used by US in Vietnam war.

Gibberellins

Gibberellins, or GAs, include a large range of chemicals that are produced naturally within plants and
by fungi. They were first discovered when Japanese researchers, including Eiichi Kurosawa, noticed
a chemical produced by a fungus called *Gibberella fujikuroi* that produced abnormal growth in rice
plants.
Gibberellins are important in seed germination, affecting enzyme production that mobilizes
food production used for growth of new cells. This is done by modulating chromosomal
transcription. In grain (rice, wheat, corn, etc.) seeds, a layer of cells called the aleurone layer
wraps around the endosperm tissue.
Absoption of water by the seed causes production of GA. The GA is transported to the

aleurone layer, which responds by producing enzymes that break down stored food reserves
within the endosperm, which are utilized by the growing seedling. GAs produce bolting of
rosette-forming plants, increasing internodal length. They promote flowering, cellular
division, and in seeds growth after germination. Gibberellins also reverse the inhibition of
shoot growth and dormancy induced by ABA.

Cytokinins

Cytokinins or CKs are a group of chemicals that influence cell division and shoot formation.
They were called kinins in the past when the first cytokinins were isolated from yeast cells.
They also help delay senescence or the aging of tissues, are responsible for mediating auxin
transport throughout the plant, and affect internodal length and leaf growth.
They have a highly synergistic effect in concert with auxins, and the ratios of these two
groups of plant hormones affect most major growth periods during a plant's lifetime.
Cytokinins counter the apical dominance induced by auxins; they in conjunction with
ethylene promote abscission of leaves, flower parts, and fruits.
The correlation of auxins and cytokinins in the plants is a constant (A/C = const.).

Ethylene

Ethylene is a gas that forms through the *Yang Cycle* from the breakdown of methionine, which is in
all cells. Ethylene has very limited solubility in water and does not accumulate within the cell but
diffuses out of the cell and escapes out of the plant.
Its effectiveness as a plant hormone is dependent on its rate of production versus its rate of
escaping into the atmosphere. Ethylene is produced at a faster rate in rapidly growing and
dividing cells, especially in darkness. New growth and newly germinated seedlings produce
more ethylene than can escape the plant, which leads to elevated amounts of ethylene,

inhibiting leaf expansion.
As the new shoot is exposed to light, reactions by phytochrome in the plant's cells produce a signal for ethylene production to decrease, allowing leaf expansion. Ethylene affects cell growth and cell shape; when a growing shoot hits an obstacle while underground, ethylene production greatly increases, preventing cell elongation and causing the stem to swell. The resulting thicker stem can exert more pressure against the object impeding its path to the surface. If the shoot does not reach the surface and the ethylene stimulus becomes prolonged, it affects the stem's natural geotropic response, which is to grow upright, allowing it to grow around an object.

Abscisic Acid

Abscisic acid (ABA) hormone activates the vascular cambium during mitosis cell divison and its presence slows down the stems growth. This hormone can be used in preventing the sprouting activities in seeds and buds. In dry stem it provokes the pores to close and consequently a downfall in the rate of evaporation takes place. **The role of Abscisic acid in abscission of leaves** is doubtful and not proved, please note it.

General Science-3: Animal Kingdom

Introduction

Note: In UPSC or state level examinations, questions are not asked directly regarding classification of the animals in GS Paper. The questions are generally odd man out type, which are easy and low hanging fruits if you have basic idea about various taxonomical groups given in this module. Two Example questions are given here:
Q-1: Consider the following:
1. Sea Cow
2. Sea Horse

3. Sea Anemone
Which of the above is / are mammals?
{In this question Sea Cow (Dugong) is a mammal, while Sea Horse is a Fish. Sea Anemone is a
Cnidarian; so correct answer is Only 1}
Q-2: Among the following organisms, which one does not belong to the class of other three?
{CSE-2014}
1. Crab
2. Mite
3. Scorpion
4. Spider
{The above question is asking you to differentiate between Arachnids and Crustaceans among
Arthropoda. This is discussed in this module}. Some more example Questions have been given in the
end of this module.

Animal Kingdom

The kingdom Animalia is the animal kingdom. The kingdom Animalia is normally subdivided into
invertebrates and vertebrates. There are nine phyla {Phyla is plural of Phylum}in Kingdom Animalia viz.
Porifera (poriferans), Cnidaria (cnidarians), Platyhelminthes (flatworms), Nematoda (roundworms),
Annelida (annelids), Mollusca (molluscs), Arthropoda (arthropods), Echinodermata (echinoderms)
and Chordata (chordates).

Phylum – Porifera

Sponges are the members of Porifera, called so because they have pores all over their bodies. They
are found in mostly in marine but also in freshwater. They have asymmetrical bodies. Most
physiological activities take place at cellular level in them.

Phylum Cnidaria

Cnidarians include *Hydra, Corals, Sea Anemones, Jelly Fishes, Sea Pens* etc. They have tentacles to catch preys and special cells called Cnidoblasts that secret some poison in their prey.

Corals

Corals are Cnidarians that *live in colonies* in oceans. Individual coral in a colony is called Polyp. Many of them feed upon the small fish and plankton using the stinging cells in their tentacles. However, many others get their energy and nutrients come via a symbiotic relation with photosynthetic dianoflagellates called *Symbiodinium*. These dianoflagellates live within coral tissues. The symbiotic corals need sunlight to grow and that is why they best and grow in clear, shallow water.

Sea Anemones

Sea anemones are also predatory animals closely related to corals, jellyfish and Hydra. Some sea anemones form symbiotic relationships with dinoflagellates. They are sold worldwide as ornamental things for aquariums.

Phylum – Platyhelminthes

Platyhelminthes is a phylum of the *flatworms*. Most of these are endo-parasites in animals and humans. Common examples of Platyhelminthes include Tapeword, Liver fluke etc.

Phylum Nematoda

Phylum Nematoda is a group of Nematodes or Round worms . They live as freeliving, aquatic, terrestrial or as parasites in plants and animals. Common examples are Round worm, Filiaria worm, Hookworm etc.

Phylum – Annelida

Phylum Annelida is of Annelids or Ringed worms. The body is divided into several segments called metameres. Earthworms and Leeches are common examples of this group.

Phylum – Arthropoda

Arthropoda is the *largest phylum of animal kingdom* because around 2/3rd of all the named species on Earth belong to this phylum.

Ants, mosquitoes, flies, cockroaches, shrimp, crabs, spiders, scorpions etc. are examples of arthropods. There are three main classes of arthropods as follows:

Insects: This includes mosquitoes, cockroaches, ants, flies, bees, moths, grasshoppers, beetles and butterflies

Crustaceans: This includes crabs, lobsters, shrimp and barnacles

Arachnids: This includes scorpions, spiders and mites

Further, a few other classes are onychophorans (velvet worms), diplopods (millipedes) and chilopods (centipedes).

Key features of Arthropods

Members of this phylum are invertebrates; have an exoskeleton made of chitin, segmented body and articulated (jointed) legs.

Molting in Arthropods

Due to the presence of the exoskeleton, the growth of arthropods is periodical. During the growth period, the animal loses the exoskeleton, grows and develops a new exoskeleton. This process is called *ecdysis* or *molting*. We note here that the in the exoskeleton of arthropods, there is a layer of

waterproof wax. This feature was fundamental in allowing primitive arthropods from the sea to
survive on dry land without losing excessive water to the environment.

Malpighian Tubules

Another key feature of Arthropoda is that the excretion in these animals takes place through so
called *Malpighian tubules*.

Extracorporeal digestion

The Arachnids (scorpions, spiders and mites) inject poison to paralyze or kill their prey by using
structures called chelicerae. *The prey is partially digested outside the body of the arachnid by digestive*
enzymes injected together with the venom or afterwards. After this extracorporeal digestion, they eat and
digest their prey.

Respiration

In Crustaceans (crabs, lobsters, shrimp and barnacles), gills are found for respiration. In terrestrial
insects, respiration is tracheal whereby gases flow inside small tubes on animal's external surface.
Further, in arachnids (scorpions, spiders and mites) so called *Book Lungs* may also exist to aid in respiration.

Blood and Circulation

All arthropods have a heart. The respiratory system is open (lacunar). Blood, also known as
hemolymph, is pumped by the heart and enters into cavities (lacunas), irrigating and draining tissues.
In place of Haemoglobin, respiratory pigment called Haemocynanin is found in arthropods. We note
here that although the circulatory system of insects works at a sluggish pace, they are ableto perform
extremely fast and exhaustive movements because of *separation of circulatory system from respiration.*
Gas exchange is carried out with great speed and efficiency by the tracheal system that puts cells in direct
contact with air. Muscles can then work fast and hard.

Embryonic development

In crustaceans, some species undergo direct development whereas others undergo indirect

development. In insects, some species do not have a larval stage, whereas others go through indirect
development beginning with an egg stage followed by a nymph stage. Moreover, other insects go
through indirect development beginning with a larval stage. The transformation of a larva into an
adult insect is called *metamorphosis*.
Insects have two common types of metamorphosis.
Grasshoppers, crickets, dragonflies, and cockroaches have incomplete metamorphosis. The
young (called a nymph) usually look like small adults but without the wings.
Butterflies, moths, beetles, flies and bees have complete metamorphosis. The young (called a
larva instead of a nymph) is very different from the adults. It also usually eats different types
of food. There are four stages in the metamorphosis of butterflies, moths and housefly viz.
egg, larva, pupa, and adult.
In some insects such as butterflies and silk moth, larva makes a cocoon (chrysalis, pupa) where it
lives until transforming into the adult form. The period during which the larva is within its cocoon
is a *time of intense biological activity* since the larva is being transformed into an adult insect.

Main Differences between the Classes of Arthropods

Wings are found only in Insects (mosquitoes, cockroaches, ants, flies, bees, beetles and
butterflies). There are no wings in Crustaceans (crabs, lobsters, shrimp and barnacles) and
Arachnids (scorpions, spiders and mites).
Crustaceans have *two pairs of antennae*; *insects have one pair*; *arachnids do not have antennae.*
In crustaceans and arachnids, the head is fused with the thorax to form the cephalothorax.
Their body is therefore divided into cephalothorax and abdomen. Insects have a head, thorax
and abdomen.
Most crustaceans have *five pairs of limbs. Insects have three pairs* and *arachnids have four pairs of
limbs.*

Phylum – Mollusca

Phylum Mollusca is the *second largest animal phylum* after Arthropoda. They are terrestrial or aquatic
(both marine and freshwater). Members of this phylum include snails, octopuses, squids, oysters etc.

Soft body of Molluscs

The word "mollusc" means "soft thing". Molluscs have soft bodies and this explains the name of the
phylum. Since their body is soft, they are fragile and find it difficult to support their body in
terrestrial environment. Many molluscs solve these problems by secreting a calcareous shell, which
functions as exoskeleton and prevents dehydration.

Major classes

There are five main classes of Phylum Mollusca includes Bivalves, Gastropods, Cephalopods,
scaphopods (tooth shells) and Polyplacophora (Chitons). Bivalves, Gastropods and Cephalopods are
commonly known mollusc animals.

Bivalves

This group includes molluscs which have a *calcium carbonate* shell made of two, usually similar parts
called valves. These two valves are joined together with the help of a ligament at a point called hinge.
Members of this class include clams, oysters, cockles, mussels, scallops etc.

Bivalvia {Examples of Bivalve Molluscs}

Gastropods

All kinds of snails and slugs, big or small, marine or freshwater or land snails are put in class
Gastropoda. This class of Molluscs has ane *xtraordinary diversity of habitats*. They are found in
gardens, woodlands, deserts, mountains, lakes, small ponds, estuaries, mudflats, beaches, abyssal

depths of oceans etc. They are called *Gastropods because they have their feet in their ventral region*. Body
of gastropods is divided into three main portions: the head, the visceral mass and the foot.

Gastropoda (Snail and Slug)

Snail Slug Snail Shells

Cephalopods

Cephalopods (headfeet) are another class of molluscs which have a prominent head and a set of arms
/ tentacles (muscular hydrostats). These arms are modified feet. The Cephalopods are colloquially
called *inkfish*, because of their ability to squirt ink. The Octopus, Squids and Cuttlefish are some of
the common examples of Cephalopods.

Cephalopods

Octopus Squid Cuttlefish

Salient Notes on Molluscs

Molluscs have a complete digestion system with mouth and anus. They also have extracellular
digestion which is not found in any phylum below them in taxonomical hierarchy.

A few molluscs have a tongue like structure that is used to scrape food. It is called Radula.

Study of Molluscs is known as *Malacology* while that of Cephalopods is known as *Teuthology*.

Aquatic molluscs respire through gills, while terrestrial molluscs have a primitive lung.

Shell of Molluscs: The Molluscs, particularly bivalves and gastropods secrete an external

Calcareous cell made of Calcium Carbonate. This secretion is done by mantle, a fold in their epidermis.

Ecological and Economic Importance of Molluscs

Molluscs play an important role in several food chains in ecosystems. Many marine molluscs are a part of a common human diet, such as octopuses and squids, which are very popular in Asia, and oysters and mussels, which are consumed all over the world. In addition to molluscs that are a part of the food industry, pearls made by oysters have a large commercial value.

Formation of Natural and Artificial Pearls

Pearls are made from small foreign particles that are deposited between the shell and the mantle of an oyster. These particles trigger a defense process in the organism and are gradually covered by layers of calcium carbonate secreted by the oyster, thus producing pearls.
In the artificial production of pearls, a small fragment of shell covered with mantle pieces is inserted between the shell and the mantle of an oyster and a pearl is formed around the graft.

Phylum – Echinodermata

Members of Echinodermata (Spiny bodied) have an endoskeleton of calcareous ossicles. Starfish, sea cucumbers (holothurians), sea urchins and brittle stars are examples of echinoderms. All echinoderms are marine animals. They live in salt water.

Echinoderms

Star Fish   Sea Cucumber   Sea Urchin   Brittle Star Fish

Salient notes on Echinoderms

Thorny Animals

In Latin, *Echino* means spiny**.** Echinoderms, as their name indicates are creatures with spines that stick out from an endoskeleton. Their endoskeleton is made of calcareous plaques that, in addition to spines, contain pedicellaria, small pincers used to clean the body and to help capture prey.

They suck their prey

The system that allows echinoderms to move and to attach to substrates is called the ambulacral
system. In these animals, water enters through a structure called the madreporite, passes through
channels and reaches the ambulacral feet along the under surface of the body. In the ambulacral
region in contact with the substrate, there are tube feet which empty and fill with water, thus acting
as suckers. The ambulacral hydrovascular system also carries out the tasks of circulatory and
respiratory system.

Pentaradial Symmetry

Adult echinoderms have *Pentaradial symmetry*; the radial symmetry in these animals is present only
in adults.

Aristotle's Lantern

Sea urchins have a teeth-like structure attached to the mouth and made of five teeth connected to
ossicles and muscle fibers. This structure, known as Aristotle's lantern, is use to scratch food, mainly
algae, from marine rocks.

Phylum – Chordata

Chordates are the most advanced animals in terms of evolution. Out of the 65000 species of
Chordates, half belong to a class of bony fishes. All chordates posses a notochord *at one time in their*
life cycle (including embryonic development). All Chordates have *branchial clefts* in the pharynx (in some
species present only in the embryo). In humans, the branchial clefts located in the anterior region of
the pharynx (also known as pharyngeal clefts) and are present only during the embryonic stage and
disappear later.

Phylum Chordata has been divided into subdivisions viz*P.r otochordates* and *Vertebrates*. In
Protochordates, the notochord remains throughout the life while in vertebrates; it has been replaced

by spine in vertebrates. Balanoglossus, Amphioxus or Lancelet are notable examples of protochordates. Vertebrates are a well-known group of animals that includes mammals, birds, reptiles, amphibians, and fish.

Vertebrates

With currently 64000, species, majority of the members of Phylum Chordata belong to sub-phylum Vertebrata. All vertebrates possess notochord during the embryonic period only and later it is replaced by bony vertebral column. Further, the vertebrates have a ventral muscular heart with two, three or four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs.

Vertebrata has been divided into two divisions on the basis of jaws i.e. whether or not they have jaws. Those who lack jaws, have been placed in *Agnatha* while those possessing jaws have been placed in *Gnathostomata*. The Agnatha division has only one class called Cyclostomata whose members include Lampreys and Hagfishes. Lamprey are toothed (but jawless) vertebrates which have a sucking mouth. *Many of these are known for boring into the flesh of other fishes to suck their blood.* They can attack humans also. *Hagfishes are known as Ocean scavengers.*

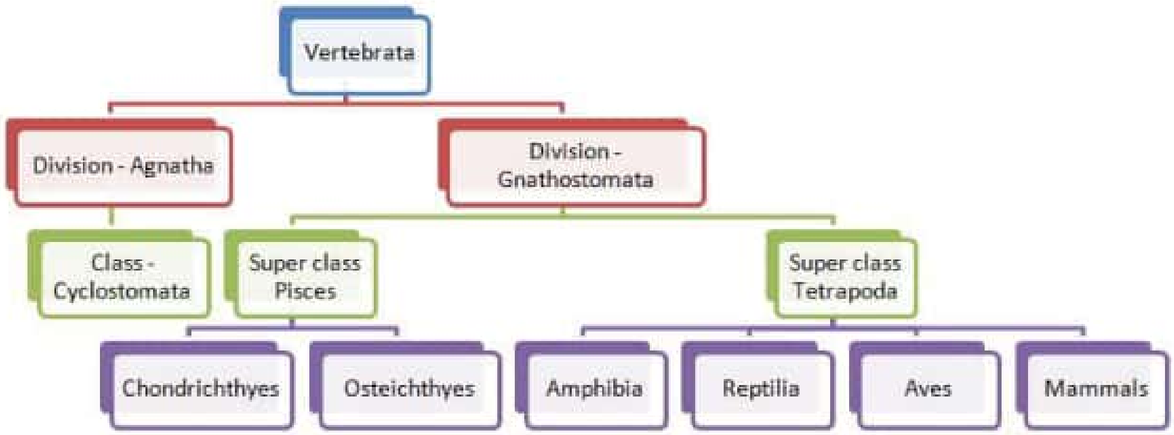
Agnatha (Jawless Chordates)

Leprey

Lemprey (as parasite on Fish)

Hagfish

The Chordates that bear jaws have been placed in a division called Gnathostomata. It has been divided into two super-classes viz. Pisces (fishes) and Tetrapoda (that bear limbs). This division is shown in below graphics.



Class – Pisces (Fishes)

All the true fishes have been classified into two main classes as follows:

Chondrichthyes: These are the fishes with soft cartilaginous skeletons. Examples are *sharks, rays, dog-fish, skates, sturgion*

Osteichthyes: These are fishes with bony skeleton. Examples are Tuna, Sardines, Codfish, Salmon, Trouts, Herring etc.

Examples of Cartilaginous and Bony Fishes

Cartilaginous Fishes Bony Fishes

Fish are all aquatic animals and, as a result, have a hydrodynamic and elongated body suitable for moving underwater, without limbs and with fins. This habitat is also related to their branchial respiration.

Gas Bladder / Swim Bladder

Bony fish have a specialized organ called a gas bladder, or swim bladder, whose interior can be filled

with gas released from gas glands. The swim bladder works as a hydrostatic organ, since it produces
variations in the relative density of the body, thus regulating the buoyancy and the depth of the fish
in water. Such swim bladders are not found in the Chondrichthyes. Due to this, *they must continuously*
move their body to keep swimming and to maintain their depth in water. This is the reason that Sharks need to
move their body to swim while bony fishes do not.
Further, when the swim bladder is filled with gas, it reduces the density of the body of the fish and,
when it is emptied, this density is increased. As a result, this mechanism controls the depth of the
fish under water.

Gills

Respiration in Fishes takes place via Gills, the highly vascularized organs specialized in gas exchange
underwater. Apart from fishes, gills are also found in marine annelids, crustaceans, Molluscs, tadpole
etc. *Gills are covered in bony fishes while not covered in cartilaginous fishes.*

Fish Heart

The Fish Heart has only two consecutive chambers called atrium and ventricle.

Excretion

Fish have Kidneys has excretory organs. While Bony fishes excrete ammonia, cartilaginous fishes
excrete Urea as nitrogenous waste.

Lateral Line

Lateral lines of bony fish are sensory organs that extend along both sides of their body. They contact
the environment by a series of specialized scales that transmit information about pressure variation
and vibrations in the surrounding water.

Class – Amphibia

Amphibians were the *first vertebrates to venture out onto land.* Early amphibians retained many fish-like
characteristics but during the Carboniferous period amphibians diversified. Even today, Amphibians

live a dual life. They are totally aquatic during their larval stage and partially terrestrial animals as
adults. Because of this, they are considered intermediate organisms in the evolutionary passage of
vertebrates from an aquatic to terrestrial. Amphibians are also the first tetrapod animals; that is, the
first with two pairs of limbs, a typical feature of terrestrial vertebrates. The name "amphibian" comes
from the double life (aquatic as larvae and partially terrestrial as adults) of these animals.

Common Amphibians

Bufo (Toad), Rana (Frog), Hyla (Tree frog), Salamandra (Salamander), Ichthyophis (Limbless
Amphibia), Newt are some of the common frogs.

Salient Features

There are several features of amphibians that make them dependent on water to survive. These
include a permeable skin; a body subject to dehydration, external fertilization, eggs without shells
and a larval stage with branchial respiration.

Respiration

In the fishes, the gas exchange is carried out via the direct contact of water with the gills, while in
adult amphibians; the gas exchange is carried out through their moist and permeable skin. This kind
of respiration is called *cutaneous respiration*. Further, they also have lungs. During larval (tadpole)
stage, they respire only through gills and this is the reason that frogs and other amphibians need
water to survive.

Amphibian Heart

While the fish heart only has two chambers; amphibians have three chambers (two atrium and one
ventricle).

Excretion

The adult amphibians have kidneys to excrete nitrogenous wastes as Urea. However, their larvae (Tadpole) are aquatic and excrete ammonia.

Reproduction in Amphibians

In most amphibians, fertilization is external. However, despite the external fertilization, amphibian males and females copulate to stimulate the release of sperm and egg cells. However, females release eggs in water and males also release the sperms in water only.

Amphibians to Higher Vertebrates: Adaptations to Terrestrial environments

Transition of vertebrates from aquatic environment to terrestrial environment needed to solve some problems. *Firstly,* they needed to avoid dehydration. This problem was solved by a thicker, impermeable skin which allows to less water. While Amphibians have semi-permeable skin which helps them in respiration also, higher vertebrates have impermeable skin. *Secondly,* they needed to eliminate waste with less amount of water available. We note here that Ammonia is highly soluble in water and essentially excretion of ammonia is feasible only in aquatic animals. When they are on ground, they need to save water. This was possible by excreting nitrogenous wastes as Urea or Uric Acid as they need less water to dissolve. In amphibians, while their larvae release ammonia (thus called Ammonotelic), the adult amphibians need economy of water and thus excrete Urea. In Birds, the system is even more efficient as they excrete Uric Acid which needs least water. *Thirdly,* they needed to protect themselves against the harmful solar radiation. This was done was skin pigments, feathers, hair, fur or whatever means to filter the harmful radiation. While amphibians have skin pigments, other higher vertebrates have other means for the same purpose. *Fourthly,* they needed to solve the problem of fertilization. Hitherto animals had a media (water) which allowed the mixing of male and female gametes. In amphibians also male and female release the gametes in water.

However, in higher vertebrates this problem was solved by internal fertilization.

Class – Reptilia

Reptiles are the first entirely terrestrial vertebrate class, totally independent from the aquatic habitat for

survival. They have excellent evolutionary innovation to get them rid of water life. Their skin is

keratinized and impermeable to water whereas amphibian skin is permeable. Due to keratinized skin,

the hitherto cutaneous respiration became impossible and respiration became dependent on internal

organs such as airways and lungs. Snakes and lizards shed their scales as skin cast.

Distribution and sub-groups

Reptiles are found in all continents except Antarctica. There are several sub-groups such as:

Testudines: This includes some 400 species of turtles, terrapins and tortoises.

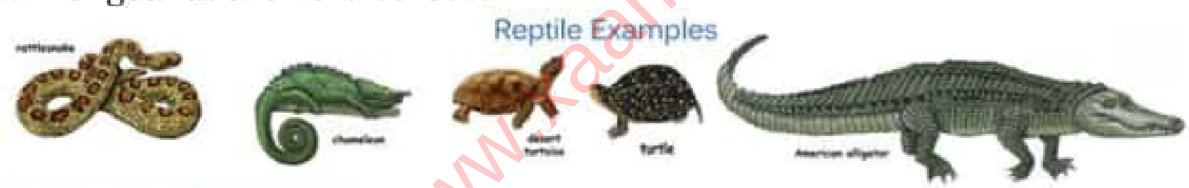
Sphenodontia: This includes only two species of tuatara (found in New Zealand)

Squamata: This is largest group of reptiles having some 9600 species of lizards and snakes

Crocodilia: This group has some 25 species of crocodiles, gavials, caimans, and alligators.

Reptiles are both carnivorous and herbivorous. For example, snakes, crocodiles etc. are carnivorous

while Iguanas are herbivorous.



Pulmonary Respiration

Since reptiles have no permeable skin, they need to respire using internal organs. Thus, like birds

and mammals, reptiles also have pulmonary respiration.

Heart of Reptiles

Like amphibians, the reptile heart has three chambers (two atria and one ventricle). However, their

heart is advanced from amphibians because ventricular separation (process of having two ventricles)
appears in their heart. *Further, Heart is four-chambered in crocodiles.*

Greater mobility

Reptiles have larger and more powerful legs. The placement of the reptilian legs beneath the body
(instead of at the side as in amphibians) enabled them greater mobility.

External Ear

Reptiles do not have external ear openings. ***Tympanum*** represents ear.

Body temperature

Fish, amphibians as well as Reptiles are hetero-thermic animals; which means that they are unable to
maintain the body temperature. They are also called Cold blooded animals or poikilothermic or
ectothermic animals. This is the reason that
Reptiles are rarely found in polar regions.
They need an external heat source to warm their bodies.
They are more active during the day, a period when they can use the sun's heat to warm their
bodies.

Excretion

Evolution of reptiles happed around water economy. They excrete uric acid which is less toxic than
both ammonia and urea and needs least water.

Reproduction

In reptiles, birds and mammals, fertilization is internal by means of copulation between male and
females. Reptiles are oviparous and they lay eggs with shell. The embryo develops outside mother's
body. Some reptiles also show ovovivipary in which mother keeps the eggs in its body until it
hatches. However, it is different from vivipary as there is no trophic / placental connection between
embryo and parent.
Further, the embryonic development is direct in reptiles, which means that there are no tadpoles or
larvae.

Class – Aves

Sometime during the early Jurassic, two groups of reptiles gained the ability to fly and one of these

groups later gave rise to the Aves (birds). They developed a range of adaptations that enabled flight
such as feathers, anterior limbs transformed into wings, pneumatic bones and horny (corneous)
beaks and endothermy i.e. birds are warm blooded animals.

Bird Adaptations for Flight

There are several features of birds that allow them to fly*F.i rstly,* their anterior limbs have
transformed into wings attached to a well-developed pectoral musculature*S. econdly,* they have
lightweight bones with internal spaces filled with air. These bones are called pneumatic bones. This
feature reduces the density of body of the animal, facilitating flight. *Thirdly,* they have no colon or
bladder to accumulate feces or urine. Their excretion is Uric acid which requires least water and least
storage place. Lastly, Birds have an aerodynamic body and lungs with specialized air sacs.

Heart of Birds

The heart of birds is more developed then reptiles and has 2 atria and 2 ventricles. There is no
mixture of venous and arterial blood like mammals.

Excretion in Birds

Birds are uricotelic, meaning that, like reptiles, they excrete uric acid. This substance needs less water
to be eliminated and it helps to reduce body weight, making flight easier.

Similarities between Birds and Reptiles

In terms of external coverage, birds are similar to reptiles in that they present impermeable
keratinized outside. In terms of reproduction, fertilization is internal in both and the embryo
develops within a shelled egg. In terms of excretion, both excrete uric acid.

Reproduction in Birds

Birds reproduce sexually. Embryos develop within shelled eggs and embryonic development occurs
outside the mother's body. The eggshell is made of calcium carbonate. The white, or albumen, is
composed by albumin, a protein. The yolk is predominantly made up of lipids, but also contains
proteins and vitamins.

Body Temperature Control in Birds

While Reptiles are heterothermic, as they do not control their body temperature; birds are the first homoeothermic (endothermic) animals, as they are able to maintain a constant body temperature.

This is the reason that many birds live in regions of intense cold. Penguins are an example of birds that live in polar region.

Other important Facts

Modern Birds don't have teeth. They possess beak.

The digestive tract of birds has additional chambers, *the crop and gizzard.*

Class – Mammalia

Both birds and mammals have evolved from a reptile ancestor. In terms of evolution, mammals are most advanced organisms found in almost all habitats in Earth's biosphere including polar ice caps, deserts, mountains, forests, grasslands and dark caves.

Common features of all mammals

All mammals have six things in common. *Firstly,* all mammals are vertebrates and have a backbone. *Secondly,* all mammals have lungs and breathe dry air. *Thirdly,* all mammals are endothermic i.e. warm blooded. animals. *Fourthly,* all mammals have some fur or hair on their bodies. The hair or fur may differ in proportion. *Fifthly,* all mammals have two pairs of limbs. *Sixthly,* the most unique mammalian characteristic is the presence of milk producing glands (*mammary glands*) by which the young ones are nourished.

Monotremes / Marsupials / Placentals

Mostly female mammals give birth to the young ones but there are only a few mammals that lay eggs.

On this basis, Mammals have been divided into three groups viz. Monotremes (prototheria), Marsupials (metatheria) and Placentals (Eutheria).

Monotremes (prototheria)

Monotremes or Prototherians are egg laying (oviparous) mammals. They are them *ost primitive mammals.* Currently, only three species of Monotremes are extant viz. Duckbilled Platypus and two

species of Echidnas. Monotremes *are found only in Australia and New Guinea.*
The word "monotreme" means "one opening" which denotes that Monotremes have *only one*
cloaca that is used as anus, unitary tract as well as for reproduction.
They lay egg which has leathery shell.
The young ones get their milk from mammary glands found on mother's belly. No nipples are
found in Monotremes.
While platypus lays eggs on bank of stream; echidnas lay a single egg in a temporary
protective pouch on mother's belly.
Monotremes don't have a placenta also.

Marsupials (Metatheria)

Marsupials include kangaroos, wallabies, koala, possums, opossums, wombats, numbat etc. There are
around 330 species of Marsupials distributed in three continents viz. Australia South America and
North America (only two species are found north of Mexico).

Most (70%) are found Australia continent which includes Australia, New Zealand, New Guinea and neighbouring islands in the Pacific Ocean. Remaining is mostly found in South America and Central America.

Key Features

The term marsupium means a pouch. Marsupials give birth to a relatively undeveloped young, which often resides in the pouch with the mother for a certain time after birth. This also implies that they have a *relatively short gestation*

Marsupials have different ecological niches, ranging from moles to insect eaters to plant eaters.

They first evolved in South America some 100 million years ago when Australia, South America and Antarctica were joined together. Gradually, these three continents separated and the marsupials got isolated. They freely evolved in isolation.

Most Marsupials are nocturnal and they have best sense of smell and hearing.

Small Kangaroos are called wallabies. Red Kangaroo is largest Marsupial of the world.

Further, Kangaroos are able to move more efficiently at high speed in comparison to low speed because of tendons in their hind legs and tail acts as pendulum.

Kangaroos are able to withstand dry periods and little rainfall and can survive without water for many months.

A male kangaroo is called a boomer, a female kangaroo a flyer, and a baby kangaroo a joey.

Placentals (Eutheria)

There are nearly 4000 described species in Placental mammals, of which most are rodents and bats.

The Placental mammals give birth to live young. Before birth, the embryo is nourished in mother's uterus via a specialized organ connected to uterus called placenta. We note that Marsupials also have a placenta but it is very short lived and does not make any substantial contribution in the nourishment of the foetus.

The placental animals have been divided into several orders as enumerated below:
Artiodactyls are mammals with an even number of fingers in claws or paws like. These include
cows, sheep and giraffes.
Perissodactyls or *ungulates* (hooved), are large animals with an odd number of fingers on each
paw, such as horses and rhinos.
Carnivorous mammals are predators with canine teeth such as dogs, lions and tigers.
Cetaceans are aquatic mammals without posterior limbs, such as whales and dolphins.
Edentates are mammals with rare or absent teeth, such as sloths, armadillos and anteaters.
Lagomorphs are small-sized mammals with three pairs of continuously growing incisor teeth
specialized in gnawing, such as rabbits and hares.
Primates are characterized by their large cranium and well-developed brain, such as humans
and apes.
Proboscideans are large animals whose nose and upper lip form a trunk (snout), such as
elephants
Chiropterans are flying nocturnal mammals, this group includes bats.
Rodents are animals with two pairs of continuously growing incisor teeth, such as mice, rats,
beavers and squirrels.
Sirenians are freshwater aquatic mammals lacking of posterior limbs, such as dugongs (Sea
Cows) and manatees.

Example Questions on Animal Taxonomy

Sample Questions for Module

1. Which among the following is closest to corals in terms of evolution of animals?

[A] Sea Cow
[B] Sea Horse
[C] Sea Lion
[D] Sea anemone

Answer: [D] Sea anemone

Sea anemones, Corals, jellyfish, tube-dwelling anemones, and Hydra are members of Phylum
Cnidaria.

2. Which among the following is a matching set in taxonomy?

[A] Leech, Locust, Sea urchin, Lobster
[B] Star Fish, Jelly Fish, Cuttle Fish, Octopus
[C] Milliped, Crab, Centipede, Cockroach
[D] Round Worm, Earthworm, Flatworm, Silk worm

Answer: [C] Milliped, Crab, Centipede, Cockroach

3. Which among the following is / are warm blooded animals?

1. Mammals
2. Birds
3. Fishes
4. Reptiles

Choose the correct option from the codes given below:

[A] 1 Only
[B] 1 & 2 Only
[C] 1, 2 & 3 Only
[D] 1, 2, 3 & 4

Answer: [B] 1 & 2 Only

With a few exceptions, all mammals and birds are warm-blooded, and all reptiles, insects,
arachnids, amphibians and fish are cold-blooded.

4. Which among the following is homologous to a human arm?

[A] Wing of an insect
[B] Leg of a lobster
[C] Lateral Fin of a whale
[D] Front leg of a reptile

Answer: [C] Lateral Fin of a whale

The lateral fin of the whale consists of the same bones as a human's arm, the radius, ulna, and
humerus. These structures are considered to be homologous because the underlying structure is
similar and, therefore, humans and whales share a common ancestor. The lobster's leg, the reptile's
front leg, and the insect's wing are analogous to the human's arm. They have a common function
but no common structure, and they do not share a common ancestor.

5. How Alligators are different from Crocodiles?

1. While Alligators and Crocodiles belong to same family of reptiles, their orders are different
2. While Alligators prefer a freshwater habitat, crocodiles prefer to live in brackish water or
saltwater.
3. While the salt glands are non functional in Alligators, they work in Crocodiles
Select the correct option from the codes given below:
[A] Only 1 is correct
[B] Only 2 & 3 are correct
[C] Only 2 is correct
[D] 1, 2 & 3 are correct
Answer: [B] Only 2 & 3 are correct
Both these reptiles belong to same order Crocodilia, alligators are classified under Alligatoridae
family, whereas crocodiles are members of the Crocodylidae family. In regards to the habitat
comparison of alligators and crocodiles, both spend their life in and near water bodies and lay their
eggs on land. But the difference is alligators prefer a freshwater habitat, while crocodiles prefer to
live in brackish water or saltwater. Alligators have a broader 'U' shaped snout, whereas the snout
shape of crocodiles is narrow and form a V towards the end.
The tooth placement is also a distinguishing feature to demarcate alligators and crocodiles. The
jaw placement of an alligator is such that the upper jaw is wider and covers the lower jaw
completely. In case of a crocodile, the width of the upper and lower jaw are the same, hence, the
teeth in the lower jaw become apparent after the mouth is closed.Dermal Pressure Receptors
(DPRs) are small, black, sensory pits that help in detecting changes in the water pressure. Both in
alligators and crocodiles, DPRs serve as an important organ for locating their prey. In alligators,
DPRs are present only around the jaw, whereas in crocodiles, these sensory organs are present in
nearly every scale of the body.

Both alligators and crocodiles have structurally modified salivary glands (salt glands) in the tongue.
The crocodiles use these salt glands for excreting excess salt from the body, whereas in alligators,
these salt glands are non functional. This is the reason as to why, a crocodile can tolerate saline
water, whereas an alligator cannot. (Buzzle.com)
6. The birds not have respiratory trouble at the time of flying at high altitude. What is the reason for
this?
[A] The size of lungs of birds is larger in comparison to their body
[B] At higher altitudes birds fly inactively
[C] Birds have extra air sacs
[D] None of the above is a correct reason
Answer: [C] Birds have extra air sacs
Because flying takes a tremendous amount of energy, birds need to get lots of oxygen. The air sacs
in their lungs help them to keep fresh air flowing in, unlike mammals, where the "old" air within
the trachea and mouth (which has low oxygen content and high CO_2 levels) in inhaled each time.
Birds eliminate this "anatomical dead space" problem by using air sacs.
7. Taxonomically, which among the following is closet to Sea Corals?
[A] Sea Lettuce
[B] Sea Horse
[C] Sea Anemone
[D] Sea Urchin
Answer: [C] Sea Anemone
As cnidarians, sea anemones are related to corals, jellyfish, tube-dwelling anemones, and Hydra.
8. Which among the following is most distantly related to other three animals?
[A] Walrus
[B] Sea Lion
[C] Seals
[D] Sperm whale
Answer: [D] Sperm whale
Seals, Walruses and Sea lions are Mammals belonging to a single taxonomic group (a clade) called

Pinnipedia, which means fin footed. All of them are semi-aquatic marine mammals. They belong
to the order Carnivora and their closest living relatives are bears.
They are characterized by modification of limbs to flippers. Pinnipeds are mammals with four
flippers — one pair in front and one at the back.
They are warm-blooded, nurse their young, breathe air and have hair. The sea lion has small, tiny
external ear flaps. Seals have no flaps.
The front flippers of sea lions are long, have no hair and nails. Seals' front flippers are short, blunt,
covered with hair with nails on the ends.
Sea lions can turn their hind flippers forward to move on land but seals cannot do so.
9. Select species of animals enters into the state of animal dormancy to avoid damage from adverse
season. Which among the following are included in such animals?
1. Polar Bear
2. Tortoises
3. Crocodiles
4. Salamanders
Select the correct option from the codes given below:
[A] Only 1 & 2
[B] Only 2, & 3
[C] Only 1, 2 & 3
[D] 1, 2, 3 & 4
Answer: [D] 1, 2, 3 & 4
Many animals go under the ground during winter. This process is called hibernation. During this
period metabolic rate is reduced. In fact, it is a mechanism of survival. Amphibians like toad and
frog undergo hibernation. Hybernation is also seen in female polar bears. Aestivation is an
opposite process of hibernation. Some animals go under the ground during the dry season of
summer. In zoology it is a state of inactivity and reduced metabolic activity that occurs during the
dry season in species such as lungfish and snails.
10. From the point of view of evolution of living organisms, which of the following set of animals is

a correct sequence of evolution?
[A] Whale, Kangaroo, Echidna
[B] Echidna, Whale, Kangaroo
[C] Kangaroo, Whale, Echidna
[D] Echidna, Kangaroo, Whale
Answer: [D] Echidna, Kangaroo, Whale
The correct sequence of the evolution would be Monotremes, Marsupials and Eutheria. Since,
Whale is in subclass Eutheria, it is the latest in the evolution. So the correct sequence is Echidena
(Monotreme), Kangaroo (Marsupials) & Whale (Eutheria).Echidna are the only surviving
members of the Monotremata order and are the only living mammals that lay eggs.

General Science-4: Human Body

Animal Tissues
In all the animals, tissues develop from the embryonic germ layers during the blastula (early stage of
embryonic development) phase. On the basis of germ layers, all animals except Porifera and
Protozoa; there are either two or three germ layers.
The animals which develop from two germ layers (ectoderm and endoderm) are called Only
Ctenophores (comb jellies) and Cnidarians *(Hydra, Corals, Sea Anemones, Jelly Fishes, Sea Pens)*
have this feature.
The animals which develop from three germ layers viz. ectoderm, mesoderm and endoderm
are called *triploblastic*. All animals from Platyhelminthes to Humans are triploblastic.
Types of Animal Tissues
There are 4 categories of animal tissues viz. Epithelial Tissue, Connective Tissue, Muscular Tissue
and Nervous Tissue.
Epithelial Tissue

Epithelial tissue makes the covering of the internal organs as well as our body. This is the simplest
and non specialized tissue. Epithelial tissue originates from all the three embryonic layers viz.
Ectoderm, Mesoderm and Ectoderm.

Connective Tissue

The tissues that bind several tissues in the body are called connective tissues. They do the function of
supporting the organs and packaging of the organs. Please note that except muscles all the connective
tissue is derived from the mesoderm of the embryonic blastula. 30% of the body by mass is composed
of connective tissue. This tissue includes connective tissue proper, skeletal issue and fluid tissue.

Collective tissue proper includes the below two types:

Collagen fibres which make *tendons that connect muscles to bones*. We note here that
Vitamin C helps in synthesis of Collagen and lack of vitamin C causes a deficiency of
connective tissue called "Scurvy".

Yellow elastic fibres which make *ligaments that connect bones to bones*. Yellow elastic
fibres are also present in arteries to provide elasticity to them. We note here that
Yellow Elastic Fibre is resistant to chemical change, though it loses elasticity with
aging. Resistance to chemical change is also evident from the fact that when mummies
are dissected, arteries are among the internal organs that might be found in most
intact condition!

Skeletal Tissue is *derived from the mesoderm of embryonic blastula* {this question is frequently
asked in UPSC and state exams}. There are two types of skeletal tissues viz. cartilage and
bone.

Cartilage is softer, elastic tissue that makes joints between bones, rib cage, ear, nose,
bronchial tubes, intervertebral discs etc.

Bone is a highly mineralized tissue in which connective tissue part is 1/3rd while
mineral part is 2/3rd portion.
Fluid Connective Tissue includes Blood, Lymph and Cerebrospinal fluid(CSF). Blood and
Lymph circulate in the body and help in transportation of the metabolites. They have a
common matrix called plasma. They have various kinds of cells which are called "corpuscles.
There are no fibers or matrix in fluid connective tissue.

Nervous Tissue

Nervous Tissue is the main component of brain; spinal cord and peripheral nerves. It helps in the
regulation and control of body functions and activities and allows us to see and perceive the world. It
is made of neurons {nerve cells}, and Neuroglia, which helps in propagation of the nerve.

Muscular Tissue

These tissues are made of muscle fibres whose contractions and relaxations provoke the movement
and locomotional activities.

Digestive System

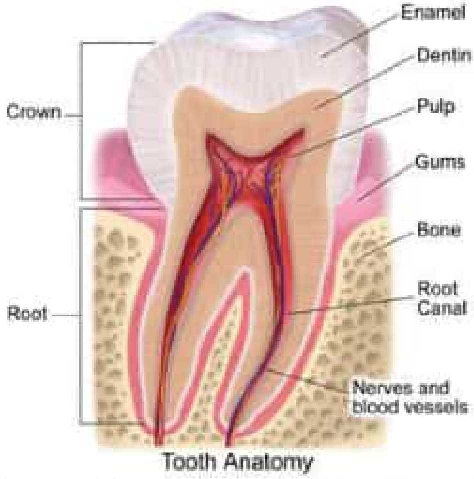
The digestive system is made up of the digestive tract and other organs that help the body break
down and absorb food. Organs that make up the digestive tract include mouth, oesophagus, stomach,
small intestine, large intestine (also known as colon rectum) and anus. Inside these hollow organs is a
lining called the mucosa.

Mouth / Oral Cavity

The oral cavity has a number of teeth and a muscular tongue.

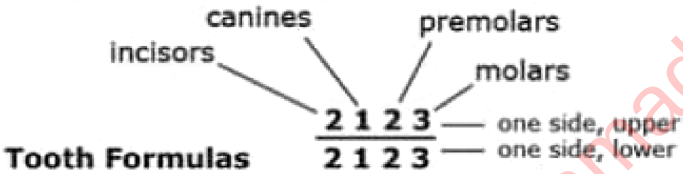
Teeth

Each tooth is embedded in a socket of jaw bone. Most of the animals including humans have two sets
of teeth during their life. First set is of temporary milk or deciduous teeth, which is replaced by a set
of permanent or adult teeth. Adult human has 32 permanent teeth which are of four different types
viz. Incisors, Canines, Premolar and Molars.



Tooth Anatomy

Incisors are the eight front teeth (4 up, 4 down). Canines are another four teeth on either side of
incisors in both sides (2 up, 2 down). Beyond canines are eight premolars (4 up, 4 down). These teeth
have two pointed cusps on their biting surface and are sometimes referred to asb *icuspids*. Beyond
Premolars are 12 molars (6 up and 6 down) thus making a set of 32 teeth in humans. The three pairs
of molars in upper or lower jaw are denoted as first, second and third molars. Third molar is also
known as wisdom teeth that come up in 30s. The above system is arranged in the form of a dental
formula, which is 2123/2123 in humans.



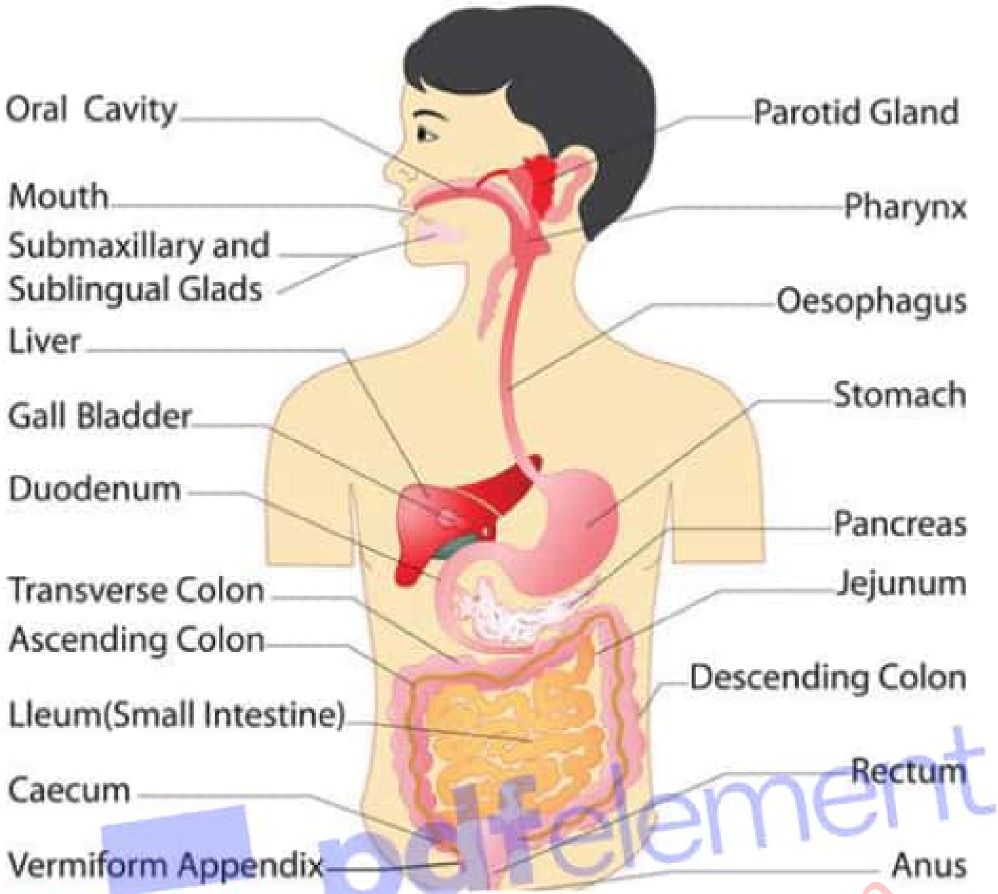
In children, there are only 20 deciduous teeth or ***milk teeth***. They begin to develop before birth and
begin to fall out when a child is around 6 years old. The dental formula for milk teeth is 2102. *We
note here that Children don't have premolars.* Their premolar is called by dentists as first molars rather.
These baby molars are replaced by adult premolars.
Human teeth are made up of four different types of tissues viz. pulp, dentin, enamel, and cementum.

Pulp is the innermost portion of the tooth and consists of connective tissue, nerves, and blood vessels, which nourish the tooth. Pulp is surrounded by Dentin, a hard yellow substance that makes up most of the tooth and is as hard as bone. Enamel which covers the dentin is *hardest tissue in the body* and forms the outermost layer of the crown. A bony layer of cementum covers the outside of the root, under the gum line, and holds the tooth in place within the jawbone. Cementum is also as hard as bone.

Steps in Digestion

The digestive system performs four functions viz. ingestion, digestion, absorption and elimination.

Ingestion is intake of food. Digestion is of two types viz. mechanical (food is broken down into smaller pieces, this begins as soon as we put food in our mouth) and chemical (use of enzymes and acids to break down consumed food). Absorption is the assimilation of digested food in cells while elimination is passing out of what we cannot digest. The entire digestive system is made of alimentary canal and accessory digestive organs. Alimentary canal is made of salivary glands, Pharynx, Oesophagus, stomach, small intestine and large intestine. Accessory digestive organs are liver, gallbladder and pancreas.



Digestion in Mouth Cavity

Salivary glands release saliva in mouth cavity which contains *Salivary Amylaze* enzyme that digests
starch into sugars. Further, another enzyme called lingual lipase also begins digestion of the lipids /
fats in mouth cavity only. *Thus, while digestion of carbohydrates and lipids begins in mouth cavity,*
digestion of proteins begins only in stomach in highly acidic environment. Mouth cavity leads to pharynx
that is common passage for food and air. When we swallow the food, the windpipe is closed by a flap
of cartilage behind the root of the tongue. This flap is called epiglottis. Beyond epiglottis is
Oesophagus, a food pipe which ends in stomach. At the junction of the oesophagus and stomach,
there is a ring like muscle, called the ***oesophageal sphincter*** that relaxes and allows the food to pass
through to the stomach. No digestion takes place in oesophagus.

Digestion in stomach

The ***Stomach*** has three mechanical tasks. To store the swallowed food, to mix up the food, liquid, and
digestive juice produced by the stomach and to empty its contents slowly into the small intestine.
Digestion of carbohydrates, proteins as well as fats takes place in stomach. We note here that least
time is needed to digest carbohydrates, more for protein and maximum for fats.

Key Enzymes in Stomach

The main gastric enzyme is *Pepsin* which is secreted in inactive form called Pepsinogen. It is activated
by stomach acid (HCl). It breaks protein into peptide fragments and amino acids. Here, Hydrochloric
acid plays role to denture the proteins and kill any bacteria or viruses in the food. Another stomach
enzyme is *Gastric lipase*. It works in acidic environment {other lipases such as pancreatic lipase work
in alkaline environment} digests fats and lipids.

How stomach saves itself from acids secreted?

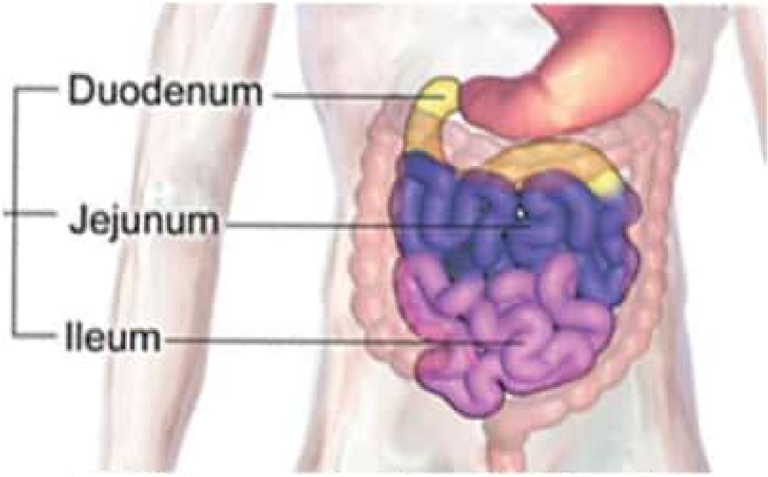
Stomach has highly acidic environment. To protect its own lining from digestion by digestive juices,
it secrets Mucin and carbonate from its mucous cells. This is one way to save its own cells. Another
way is a high turnover of stomach cells.

Function of Gastrin Hormone

Gastrin is an important hormone of G-cells of stomach. It stimulates stomach cells to produce
hydrochloric acid (HCl) and another chemical called Intrinsic factor (IF).

Digestion in Small Intestine

Small intestine is largest part of digestive system (around 6 meters) and divided into three parts viz.
the duodenum, jejunum and ileum.



By the time food is ready to leave the stomach, it has been processed into a thick liquid called ***chyme***.
A walnut-sized muscular valve at the outlet of the stomach called the***p ylorus*** keeps chyme in the
stomach until it reaches the right consistency to pass into the small intestine. Once entered into
duodenum, the chyme comes into contact with pancreatic juice with a pH of approximately 8.5.
Thus, the hitherto acidic environment of stomach (pH near 2) is turned into alkaline environment.
Here we note that the neutralization of the acidity of the chyme is *necessary* for the functioning of the
digestive enzymes that act in the duodenum. Further, without neutralization of the acidity of the
chyme, mucous membrane of the intestine would be damaged.
What happens here is that the acidity of chyme stimulates production of a hormone called *secretin in*
the duodenum. Secretin stimulates the pancreas to release pancreatic juice and also signals the
gallbladder to expel bile in the duodenum. The pancreatic secretion, rich in bicarbonate ions, is
released in the duodenum and neutralizes the chyme acidity; this acidity is also neutralized by the
secretion of bile in the duodenal lumen.
Further, most of the chemical digestion of fats begins only in duodenum via so called *emulsification*
process.

Role of Liver: Bile Juice and Emulsification

Bile, an emulsifier liquid, is made by the liver and later stored in the gallbladder and released in the duodenum. Bile is composed of bile salts, cholesterol and bile pigments. Bile salts are detergents, amphiphilic molecules, or rather, molecules with a polar water-soluble portion and a non-polar fatsoluble portion. This feature allows bile salts to enclose fats inside water-soluble micelles in a process called emulsification. Through this process, fats come into contact with intestinal lipases, enzymes that break them down into simpler fatty acids and glycerol.

Why patients with gall stones are not allowed to take fatty foods?

Bile is concentrated and stored in the gallbladder. When foods high in fat are ingested, the gallbladder contracts to release bile into the duodenum. This is the reason why patients with gallstones are advised to not to eat fatty foods, because the reactive contraction of the gallbladder may move some of the stones to the point of blocking the duct that drains bile into the duodenum, causing pain and other complications.

Other functions of Liver

Apart from making bile for releasing in small intestine, Liver is also a site for storing, processing and inactivating poisons in food. This work is done by a network of veins in the liver called mesenteric circulation. Liver also polymerizes glucose and stores it as Glycogen. It stores many vitamins and the iron absorbed in the intestine. It detoxifies poisonous substances such as alcohol, nicotine, drugs etc.

Role of Pancreas

The ***pancreas*** produces enzymes that help digest proteins, fats, and carbohydrates. It also makes a substance that neutralizes stomach acid. The pancreatic juice is released into the mixture that contains the following enzymes to help chemically digest fats and carbohydrates:

Pancreatic Lipase breaks apart fat molecules into fatty acids and glycerol.

Pancreatic amylase breaks long carbohydrates into disaccharides, which are short chains of two

sugars. The disaccharidases then break apart into monosaccharides that can be absorbed by
the cells lining the small intestine.
Trypsin and chymotrypsin are enzymes that break apart peptide fragments. After they break
the peptides down into small chains, amino peptidases finish them off by breaking apart the
peptides into individual, absorbable amino acids.

Intestinal Villi and Microvilli

After digestion, the next step is absorption by cells of the mucous membrane of the intestine. For this
to happen, a large absorption surface is needed. This is done by two ways. *Firstly,* intestine itself is
long and tubular and closely folded and numerous loop. *Secondly,* a more efficient process is done by
intestinal Villi and the microvilli of the mucosal membrane cells. These are like gloved fingers which
scale up the process of absorption by increasing absorption area manifold.
The majority of water, vitamins and mineral ions are absorbed by the small intestine.

Digestion in Large Intestine

The large intestine is not responsible for digestion but only for reabsorption of nearly 10% of
ingested water, a significant amount that gives consistency to feces. If there is some disease in colon,
water will not be absorbed and person will suffer from diarrhoea.

How food is assimilated?

The sugars, amino acids, mineral salts and water are taken from the capillary vessels of small
intestine to mesenteric circulation. The blood from the mesenteric circulation distributes nutrients
to tissues in body.

Role of vegetable fibres

Plant fibers are not absorbed by the intestine but play an important role in its functioning. They
retain water inside the bowels and therefore contribute to the softening of the feces. Softer feces are
easier to eliminate during defecation. People who eat less dietary fiber may suffer from hard stool
and constipation.

Intestinal Microflora

Bacteria that live inside intestine play an important role in digestion. Some polysaccharides such as cellulose, hemicelluloses and pectin are not digested by digestive enzymes secreted by the body; instead, they are broken down by enzymes released by bacteria in the gastrointestinal tract. Intestinal bacteria also produce substances vital to the functioning of the bowels, facilitating or blocking the absorption of nutrients and stimulating or reducing peristalsis. Further,*g ut bacteria are themain source of vitamin K for the body* and, as a result, they are essential for the blood clotting process.

Special features of Birds digestive system

The digestive system of birds contains special structures called crop, the proventriculus and the gizzard. Crop works as temporary storage of ingested food. Proventriculus is the chemical stomach of birds, in which food is mixed with digestive enzymes. Gizzard is a muscular pouch that serves as a mechanical stomach, in which food is ground up to increase the exposure area of the food particles to digestive enzymes.

Mutualistic Digestion of cellulose in Ruminants

Herbivorous animals eat large amounts of cellulose, which is not digested by their digestive enzymes. In such animals, one region of the digestive tract is colonized by microbes that digest cellulose. This type of digestion is found in horses, cows, and rabbits and also in some insects, such as termites. Further, food ingested by cows and other ruminant animals first passes through two compartments of the digestive tract called the rumen and the reticulum. Within them, the food is subject to the action of digestive enzymes released by microorganisms that live there in a mutualistic digestion. In the reticulum, the food is broken down. After passing through reticulum, the food (cud) is regurgitated to the mouth to be chewed and swallowed once again in a process called rumination.

Disorders of Digestive System

Appendicitis, an inflammation of the appendix, most often affects kids and teens between 11 and 20 years old, and requires surgery to correct. The classic symptoms of appendicitis are abdominal pain, fever, loss of appetite, and vomiting.

Gastrointestinal infections can be caused by viruses, by bacteria (such as Salmonella, Shigella, Campylobacter, or E. coli), or by intestinal parasites (such as amebiasis and giardiasis).

Abdominal pain or cramps, diarrheal, and sometimes vomiting are the common symptoms of gastrointestinal infections.

Inflammatory bowel disease (IBD) is chronic inflammation of the intestines that affects older kids, teens, and adults.

Hepatitis, a condition with many different causes, is when the liver becomes inflamed and may lose its ability to function.

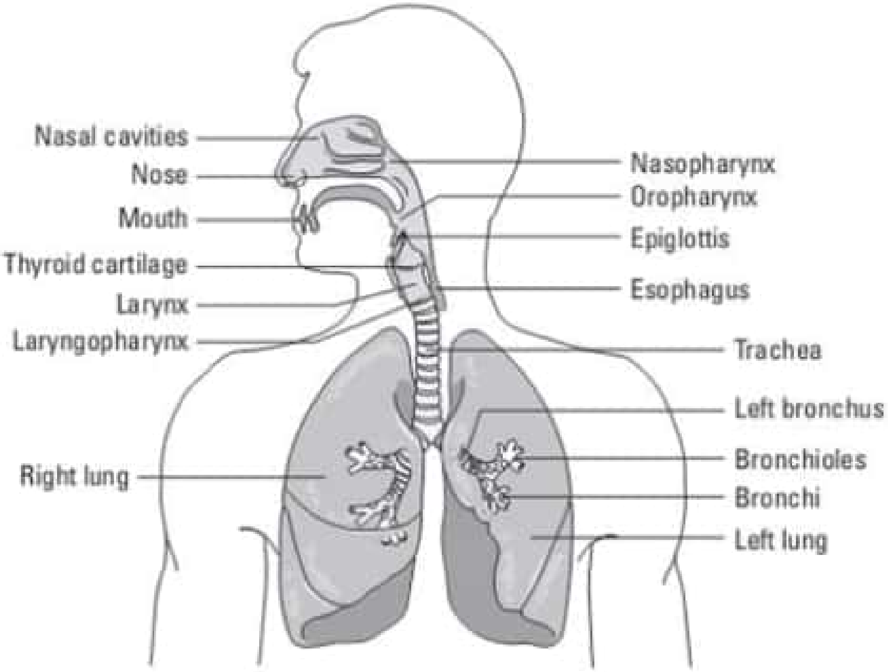
Respiratory System

Respiration is the entire process of taking air in, exchanging needed gases for unnecessary gases, using the needed gases, and releasing the waste form of gases. The Human respiratory system consists of the following parts, divided into the upper and lower respiratory tracts.

Upper Respiratory Tract

Mouth, nose & nasal cavity

The nostrils act as the air intake, bringing air into the nose, where it's warmed and humidified. Tiny hairs called cilia protect the nasal passageways and other parts of the respiratory tract, filtering out dust and other particles.



Pharynx

Pharynx is part of the digestive system as well as the respiratory system because it carries both food
and air.

Larynx

This is also known as the voice box as it is where sound is generated. It also helps protect the trachea
by producing a strong cough reflex if any solid objects pass the epiglottis.

Lower Respiratory Tract

Trachea (Wind Pipe)

It carries air from the throat into the lungs. The inner membrane of the trachea is covered with cilia.
The trachea is surrounded by 15-20 C-shaped rings of cartilage at the front and side which help
protect the trachea and keep it open.

Bronchi

The trachea divides into two tubes called bronchi, one entering the left and one entering the right
lung.

Bronchioles

Tertiary bronchi continue to divide and become bronchioles, very narrow tubes, less than 1 millimetre in diameter. There is no cartilage within the bronchioles and they lead to alveolar sacs.

Alveoli

Individual hollow cavities contained within alveolar sacs. Alveoli have very thin walls which permit the exchange of gases Oxygen and Carbon Dioxide. They are surrounded by a network of capillaries, into which the inspired gases pass.

Thorax or the chest cavity

It is the airtight box that houses the bronchial tree, lungs, heart, and other structures. The top and sides of the thorax are formed by the ribs and attached muscles, and the bottom is formed by a large muscle called the diaphragm.

Diaphragm

It is located below the lungs. It is a large, dome-shaped muscle that contracts rhythmically and continually, and most of the time, involuntarily. Upon inhalation, the diaphragm contracts and flattens and the chest cavity enlarges which pulls air into the lungs. Upon exhalation, the diaphragm relaxes and returns to its domelike shape, and air is forced out of the lungs.

Steps in Respiration

Respiration involves the following steps:

1. Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.
2. Diffusion of gases (O_2 and CO_2) across alveolar membrane.
3. Transport of gases by the blood.
4. Diffusion of O_2 and CO_2 between blood and tissues.
5. Utilisation of O_2 by the cells for catabolic reactions and resultant release of CO_2.

The process of Respiration

In a process called diffusion, oxygen moves from the alveoli to the blood through the capillaries (tiny blood vessels) lining the alveolar walls. Blood has a massive capacity to dissolve oxygen – much more oxygen can dissolve in blood than could dissolve in the same amount of water. This is because blood

contains Haemoglobin – a specialized protein that binds to oxygen in the lungs so that the oxygen
can be transported to the rest of the body. This oxygen-rich blood then flows back to the heart,
which pumps it through the arteries to oxygen-hungry tissues throughout the body.
In the tiny capillaries of the body tissues, oxygen is freed from the hemoglobin in the blood and
moves into the cells. Carbon dioxide, which is produced during the process of diffusion, moves out
of these cells into the capillaries, where most of it is dissolved in the plasma of the blood.
Blood rich in carbon dioxide then returns to the heart via the veins. From the heart, this blood is
pumped to the lungs, where carbon dioxide passes into the alveoli to be exhaled.

Circulatory System

Circulatory system is responsible for movement of nutrients, gases and wastes within blood vessels.

Open and Closed Circulatory Systems

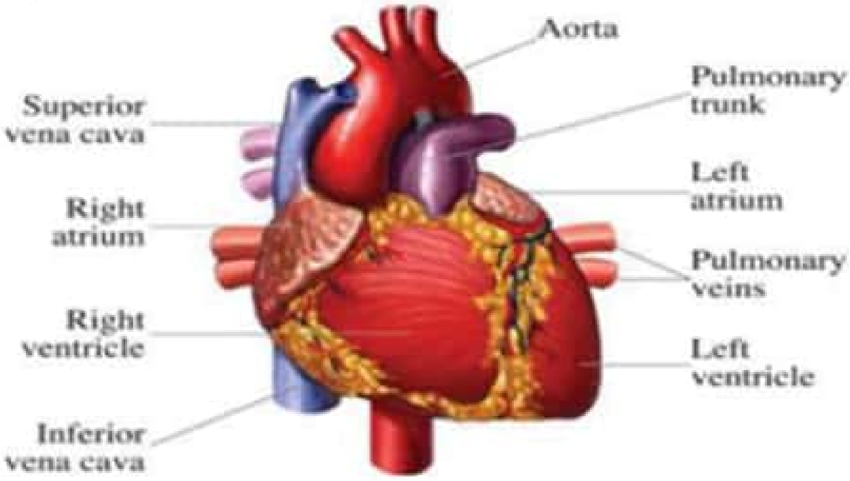
Circulatory system is not found in Porifera, Cnidaria, Platyhelminthes, Nematodes and Echinoderms.
An open circulatory system is found in arthropods, gastropods, bivalves and protochordates. In open
circulatory system blood (called hemolymph) flows *in vessels as well as open in body cavities*. Such
circulatory system has low blood pressure.
In annelids, Cephalopods and Vertebrates, closed circulatory system in found in which blood
circulates only inside blood vessels. Due to this, the blood pressure is high in these organisms and
thus blood can travel greater distances to the organs and tissues. Further, higher circulatory speed
also increases the capacity to distribute large supplies of oxygen.

Human Heart and Circulatory system

The main components of human circulatory system include blood vessels (arteries, veins and
capillaries), heart, blood, lymph and lymphatic system.

Human Heart

Human heart has four chambers viz. right atrium & right ventricle and left atrium & left ventricle
through which blood passes.



We note that two sides of our heart are anatomically and functionally separate pumping units. The
cardiovascular system is composed of these two circulatory paths.

Pulmonary Circulation

Pulmonary circulation or circuit refers to the movement of deoxygenated blood from heart to lungs,
getting oxygenated in lungs and then coming back to heart.

Systematic Circulation

Systemic circulation or circuit is the movement of blood from the heart through the body to provide
oxygen and nutrients, and bringing deoxygenated blood back to the heart.
Notable points about the above two circulations are as follows:
The *right side of heart pumps blood through the* **pulmonary circulation**, while the *left side of the*
heart pumps blood through the ***systemic circulation***.
Usually, arteries carry oxygen rich blood. But the pulmonary artery (which takes blood from
heart to lungs) carries deoxygenated blood. Similarly, usually veins carry deoxygenated blood,
but pulmonary veins carry oxygenated blood.

Systole and Diastole

Systole and diastole are the two stages into which the cardiac cycle is divided. Systole is the stage
when the contraction of ventricular muscle fibers occurs and the ventricles are emptied. Diastole is

the stage of the cardiac cycle when the ventricular muscle fibers expand and the ventricles are filled
with blood. When ventricles contract (systole), the blood is sent to pulmonary and systemic
circulation. To prevent the flow of blood backwards into the atria during systole, the atrioventricular
valves close, creating the sound (lubb). When the ventricles finish contracting, the aortic
and pulmonary valves close to prevent blood from flowing back into the ventricles. This is what
creates the second sound (dubb). Then, the ventricles relax (called diastole) and fill with blood from
the atria, which makes up the second phase of the cardiac cycle. This is how sounds of our heart are
represented as lubb-dubb-pause-lubb-dubb-pause.

Heart Beat Rate

The normal heart beat is 70-72 per minute in males and 78-82 per minute in females. The heartbeat
of a child is more than that of an adult at around 140/min.

Coronary Circulation

The coronary arteries supply blood to the heart muscle. These vessels originate from the aorta
immediately after the aortic valve and branch out through the heart muscle. The coronary veins
transport the deoxygenated blood from the heart muscle to the right atrium.

Arteries, Veins and Capillaries

Arteries carry blood from the heart to various body parts. All arteries carry oxygenated blood from
the heart *except pulmonary artery*. Arteries have thick elastic muscular walls; they don't have valves
and blood in them flows under high pressure. *Arteries are pulsating blood vessels*. The arterial pulse can
be felt during a medical examination, for instance through the palpation of the radial artery in the
internal-lateral face of the wrist near the base of the thumb.

Veins carry blood from the various body parts to the heart. All veins carry deoxygenated blood from
the various body parts *except pulmonary vein*. They have thin non elastic walls and they consist of

valves to prevent back the backward flow of blood. Blood flows under low pressure in veins.

Capillaries

Capillaries are fine branching blood vessels that form a network between the arteries and veins.

They help to enable the exchange of water, oxygen, carbon dioxide, and many other nutrients and
waste substances between the blood and the tissue.

Blood

Blood comprises of around 9% of body mass in adult human. In an average man, blood is 90 milliliter
per kg of body weight and in an average woman blood is 65 milliliter per kg of body weight. Its
specific gravity {specific gravity means Relative density) is 1.060 {this means slightly more than
water} and average pH is 7.4 {means blood is little alkaline). Its osmotic pressure at room
temperature is 7.6 atmospheres. Hemoglobin in normal healthy adult is 14-16 gm per 100 milliliter.

Blood is a connective tissue and means of substance transportation in body. It distributes nutrients,
oxygen, hormones, antibodies and cells specialized in defense to tissues and collects waste such as
nitrogenous wastes and carbon dioxide from them. It is made of two portions viz. fluid part (plasma)
and cellular part (blood cells or corpuscles).

Plasma

Plasma is 55% of the blood by volume and constitutes 5% of the body weight. Plasma is a pale yellow
transparent clear fluid which consists of 90-92% water and 8-10% organic and inorganic substances.

Organic substances are mainly plasma proteins viz. albumin, globulin, prothrombin and fibrinogen.

Albumins are responsible for maintenance of osmotic pressure of Blood. Globulins are chief sites for
formation of antibodies; while prothrombin and fibrinogen are essential for clotting of blood.

Inorganic substances in plasma include Glucose, Fructose, cholesterol, nucleosides, Vitamins, hormones, uric acid etc. and gases such as oxygen and carbon dioxide in dissolved phase.

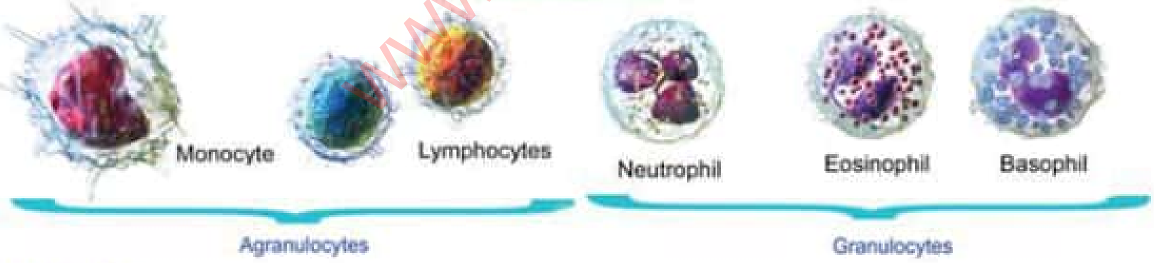
Red Blood Corpuscles

RBCs or Erythrocytes *are biconcave cells which don't have a nucleus.* They are responsible for
transporting oxygen from the lungs to tissues with the help of respiratory pigment hemoglobin,
which is main constituent of RBCs.
In the embryonic stage RBC are produced in Liver, spleen and Lymph nodes (all the three). Up to 20
years of age, they are produced in bone marrow of long bones such as femur. After 20 years they are
produced in the bone marrows of membranous bones. RBCs complete a circulation in the body in 20
seconds. Their life span is 100-120 days. Their main constituent Hemoglobin is made o*fof ur*
polypeptide chains and four heme (iron) groups. The *spleen is the main organ where old red blood cells are*
destroyed. During the destruction of red blood cells, the heme groups turns into bilirubin and this
substance is then captured by the liver and later excreted to the bowels as a part of bile.

White Blood Corpuscles

White Blood Cells leukocytes are specialized in the defense of the body against foreign agents and are
part of our immune system. There are several types of WBCs such as lymphocytes, monocytes,
neutrophils, eosinophils and basophils. Out of them, the neutrophils, eosinophils and basophils are
called granulocytes because their cytoplasm looks containing granules when viewed under
microscope. Lymphocytes and monocytes are called agranulocytes.

White Blood Cells



Monocytes

Monocytes are largest WBCs and have a horse shoe shape. They are most powerful phagocytes {cells which eat other cells} which work as scavengers. Monocytes make around 5% of the total WBC count.

Lymphocytes

Lymphocytes make around 25% of the WBC count and they are made in lymph nodes and lymphatic tissues in spleen, liver etc. They are able to show some amoeboid movement. Their function is to make antibodies.

Neutrophils

Neutrophils are WBCs with multi-lobbed nucleus. They ingest and destroy the bacteria or other foreign bodies. Wherever there is some infection, neutrophils pass out from the blood streams and accumulate creating puss by eating debris and bacteria.

Eosinophils

The main function of histamine rich eosinophils is to combat the multicellular parasites and certain infections. Along with the mast cells, they also control mechanisms associated with allergy and asthma. Thus, their number increases during chronic bronchitis, asthma or allergic conditions.

Basophils

Basophils appear during inflammatory reactions which cause allergy. They contain anticoagulant heparin, which prevents blood from clotting too quickly.

White blood cells perform several functions in the body as:

Leucocytosis

Leucocytosis and leukopenia are clinical conditions in which a blood sample contains an abnormal count of leukocytes. When the leukocyte count in a blood sample is *above the normal* level for the individual, it is called leukocytosis. When the leukocyte count is lower than the expected normal level, it is called leukopenia. Leukocytosis generally happens when body is suffering from infections

or in cancer of these cells. Leukopenia, occurs when some diseases, such as AIDS, attack the cells or
when immunosuppressive drugs are used.

Platelets and Hemostasis

Platelets or thrombocytes are fragments of large bone marrow cells called megakaryocytes. Through
their properties of aggregation and adhesiveness, they are directly involved in blood clotting as well
as release substances that activate other hemostatic processes. When tissue wound contains injury to
a blood vessel, the platelets and endothelial cells of the wall of the damaged vessel release substances
(platelet factors and tissue factors, respectively) that trigger the clotting process.

Blood Clotting

Blood clotting is basically a sequence of chemical reactions whose products are enzymes that catalyze
the subsequent reactions. This is the reason that clotting reactions are called cascade reactions. In
plasma, thromboplastinogen transforms into thromboplastin, a reaction triggered by tissue and
platelet factors released after injury to a blood vessel. Along with calcium ions, thromboplastin then
catalyzes the transformation of prothrombin into thrombin. Thrombin then catalyzes a reaction that
produces fibrin from fibrinogen. Fibrin, as an insoluble substance, forms a network that traps red
blood cells and platelets, thus forming the blood clot and containing the hemorrhage.

Clotting factors

Clotting factors are substances (enzymes, coenzymes, reagents) necessary for the clotting process to
happen. In addition to the triggering factors and reagents already described (tissue and platelet
factors, thromplastinogen, prothrombin, fibrinogen, calcium ions), other substances participate in
the blood clotting process as clotting factors. One of these is factor VIII, the deficiency of which
causes hemophilia A, and another is factor IX, the deficiency of which causes hemophilia B. Most

clotting factors are produced in the liver. Vitamin K participates in the activation of several clotting
factors and is essential for the proper functioning of blood coagulation.

Lymphatic System

The lymphatic system is a network of specialized vessels with valves, which drains interstitial fluid
called lymph. The lymphatic system is also responsible for the transport of chylomicrons (vesicles
that contain lipids) produced after the absorption of fats by the intestinal epithelium.
Along lymphatic vessels are ganglial-like structures called lymph nodes, which contain many
immune system cells. These cells filter impurities and destroy microorganisms and cellular waste.
The lymphatic vessels drain to two major lymphatic vessels, the thoracic duct and the right lymphatic
duct, which in turn drain into tributary veins of the superior vena cava.
The lymph nodes, or lymph glands, have lymphoid tissue that produces lymphocytes (a type of
leukocyte). In inflammatory and infectious conditions, it is common to see the enlargement of lymph
nodes in the lymphatic circuits that drain the affected region due to the reactive proliferation of
leukocytes.

Blood Related Diseases

Sickle-cell disease

Sickle-cell disease (SCD) is an autosomal recessive genetic blood disorder with overdominance,
characterized by red blood cells that assume an abnormal, rigid, sickle shape. Sickling decreases the
cells' flexibility and results in a risk of various complications. The sickling occurs because of a
mutation in the haemoglobin gene. Red Blood Cells alter shape and threaten to damage internal
organs.

Anemia

Anemia refers to low RBC count or low hemoglobin or abnormality of the RBCs. It is characterized
by low oxygen transport capacity of the blood.

Pernicious anemia is an autoimmune disease in which body lacks intrinsic factor required to absorb vitamin B12 from food. Vitamin B12 is needed for the production of hemoglobin.

Aplastic anemia is caused by the inability of the bone marrow to produce blood cells. Pure red cell aplasia is caused by the inability of the bone marrow to produce only red blood cells.

Thalassemia

Thalassemia results in the production of an abnormal ratio of hemoglobin subunits. It's a genetic disease.

Malaria link of Sickle-cell disease and Thalassemia

Malaria parasite spends big part of its life-cycle in Red Blood Cells. During this period it feeds on the hosts hemoglobin and then breaks them apart. This causes fever at several intervals. Both sickle-cell disease and Thalassemia are more common in malaria prone areas, because these mutations convey some protection against the parasite.

Leukemia

A great increase in abnormal leukocytes may occur for unknown reasons, resulting in the diseases known as the leukemias. These range in severity from the chronic lymphocytic leukemia, in which a person may live for many years, to devastating acute leukemia, often causing death within months.

Thromboembolic Disease

This disease results in abnormal clotting in the blood vessels. It is caused by a relatively inactive lifestyle, or by a person's confinement to bed, is one of the most common causes of death in middleaged and elderly persons.

Arteriosclerosis

The single major cause of artery disease is the thickening and hardening of arterial walls by deposits of fatty materials, known as *arteriosclerosis*. In major vessels such as the aorta, this process is called *arthrosclerosis*. These are common cause of coronary heart disease, including heart attacks.

Bypass surgery, the surgical replacement of the narrowed segment of artery with a vein taken from
elsewhere in the body, is a common medical treatment for arterial narrowing in coronary arteries.
Another medical therapy, *angioplasty*, is the dilation of the narrowed segment with a tiny balloon
delivered by catheter.

Aneurysms

Other major diseases of the aorta include true aneurysms and so-called dissecting aneurysms. The
former are balloon-like swellings that result from weakening of the aorta wall, most commonly
because of atherosclerosis.

Vein Diseases

The most common peripheral vascular disease of the veins is***th rombophlebitis or phlebitis***. This
disorder involves the formation of a blood clot (or clots) in large veins, usually in the leg or pelvis. A
distressing but usually minor disorder of the veins, known as ***varicose veins***, results from a failure of
valves in the veins to keep blood flowing back toward the heart.

Hypertension

High blood pressure is a common disorder among the adult population. By far the most common
type is essential hypertension, the causes of which are medically unknown. The remaining cases of
high blood pressure are secondary to at least 30 different conditions.

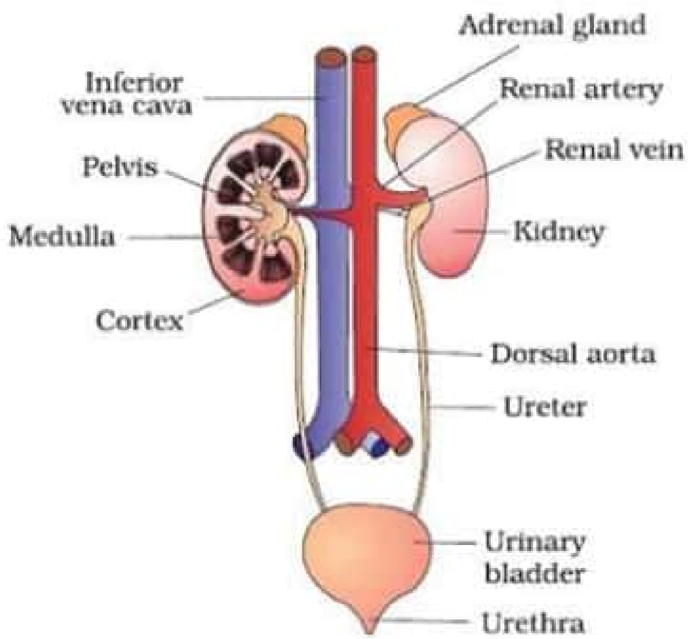
Stroke

Stroke, also known as Cerebro-Vascular Accident (CVA), involves damage to the brain because of
impaired blood supply and causes a sudden malfunction of the brain. Some stroke risk factors include
increasing age, gender (more men have strokes), diabetes mellitus, prior stroke, and family history of
stroke, hypertension, heart disease, cigarette smoking, and transient ischemic attacks (TIAs), or little
strokes. Strokes are of three kinds viz. Ischemia, Haemorrhage and Heart Failure. Ischemia is the
narrowing or blockage of an artery by means of atherosclerosis or by an embolus.

About 63% of strokes are ischemic. Atherosclerosis, or progressive hardening of the arteries,
produces ischemia by obstruction of vessels with fatty deposits. Another form of ischemia is
thrombosis, or blockage resulting from an embolus.
About 22% of all strokes are caused by cerebral hemorrhage or bleeding in the brain. The
most common causes of spontaneous intracranial hemorrhage, commonly called *apoplexy*, are
hypertension and aneurysm.
Heart Failure is a condition in which the heart fails to maintain an adequate output, resulting
in diminished blood flow and congestion in the circulation in the lungs and/or the body. The
causes of heart failure are high blood pressure and heart disease. To properly manage heart
failure the underlying heart disease must be treated.

Excretory System

Several kinds of wastes, including sweat, carbon dioxide gas, feces (stool), and urine are produced by
our body. These wastes exit the body by
Sweat is released through pores in the skin.
Water vapor and carbon dioxide are exhaled from the lungs.
Undigested food materials are formed into feces in the intestines and excreted from the body
as solid waste in bowel movements.
In humans, the excretory system consists of a pair of kidneys, one pair of ureters, a urinary bladder
and a urethra.



Kidneys

The kidneys are located just under the ribcage in the back, one on each side. The right kidney is
located below the liver, so it's a little lower than the left one.
The functional unit of Kidney is a Nephron. Each Kidney has around 1 million Nephrons that work
as tiny filtering units which remove the harmful substances from the blood. Each of the nephrons
contains a filter called the **glomerulus,** which contains a network of tiny blood vessels known as
capillaries. Blood travels to each kidney through the **renal artery. Once in Nephrons,** it is filtered
by glomerulus then travels down a tiny tube-like structure called a **tubule,** which adjusts the level of
salts, water, and wastes that are excreted in the urine. Filtered blood leaves the kidney through the
renal vein and flows back to the heart. The continuous blood supply entering and leaving the kidneys
gives the kidneys their dark red color.

Urine

Urine is a concentrated solution of waste material containing water, urea (a waste product that
forms when proteins are broken down), salts, amino acids, by-products of bile from the liver,

ammonia, and any substances that cannot be reabsorbed into the blood. Urine also contains **urochrome,** a pigmented blood product that gives urine its yellowish color.

Antidiuretic hormone

Antidiuretic hormone (ADH) from the pituitary promotes water retention by the kidneys, and its secretion is regulated by a negative feedback loop involving blood water and salt balances.

Other functions of Kidney

The kidneys also secrete the hormone erythropoietin, which stimulates and controls red blood cell production. In addition, the kidneys help regulate the acid-base balance (or the pH) of the blood and body fluids.

Skeletal and Muscular System

The main organs and tissues of the musculoskeletal system in humans are bones, cartilages and muscles. These systems provide support and protection to organs; maintain structure of the body; help in movement of organs and limbs; and store nutrients {muscles store glycogen; while bones store calcium and phosphorus}. Further bones also have function of Hematopoiesis {making of blood cells} in bone marrow (mainly within flat bones).

Bone

Bone is a highly mineralized tissue in which connective tissue part is 1/3rd while mineral part is 2/3rd portion. Apart from providing mechanical strength, the bones work as homeostatic reservoir for ions such as calcium, magnesium and phosphorous. Thus, bones have a very important function in acid base balance in the body. There are 270 bones in a new born baby and 206 in an adult human.

Bone as connective Tissue

Formation of bones is called Osteogenesis or Ossification. Bones are made of three types of specialized cells called *osteoblasts, osteocytes and osteoclasts*. Osteoblasts make the bone while Osteoclasts break / remodel the osteous tissue. They create canals in bones. Osteocytes provide

support.
The intercellular part between Osteocytes is made of casein protein and inorganic phosphates. We
note here that *bony tissue is highly vascular and has greater regenerative power than any other tissue of the*
body except Blood. Bones have narrow tubes called *Haversian Canals* and *Volkmann's Canals* apart from
the network of blood vessels.

Number of Bones

An adult human has 206 bones while a new born baby has 300 bones. 94 bones fuse as a baby grows.
The total number of bones in human skull is 29. The face of a man is made up of 14 bones. Largest
and longest bone is femur (thigh bone).The shortest bone in the human body is stapes or stirrup
bone in the middle ear.

Cartilage

Cartilage is softer, elastic tissue that makes joints between bones, rib cage, ear, nose, bronchial tubes,
intervertebral discs etc.

Muscles

The human body has more than 650 muscles, which make up half of a person's body weight. Humans
have three different kinds of muscle: Skeletal, Involuntary and Cardiac muscles.

Skeletal muscle

These are voluntary muscles that hold the skeleton together, give the body shape, and help it with
everyday movements. They are striated because they are made up of fibers that have *horizontal stripes*
when viewed under a microscope. They can contract quickly and powerfully, but they tire easily and
have to rest between workouts.

Involuntary or smooth muscle:

It is also made of fibers, but looks smooth, not striated and they're controlled by the nervous system
automatically. Walls of the stomach and intestines, walls of blood vessels are the examples of
involuntary muscles. Smooth muscles take longer to contract than skeletal muscles but they can stay

contracted for a long time because they don't tire easily.

Cardiac muscle

It is an involuntary type of muscle found in the heart. Its rhythmic, powerful contractions force blood out of the heart as it beats. Cardiac muscle contraction is totally involuntary, meaning it occurs without nervous stimulation and doesn't require conscious control.

Sarcomeres

Sarcomeres are the functional units of muscle fibers. Within them, the blocks of actin and myosin molecules are placed in an organized manner. Sarcomeres are the contractile units of muscle tissue, formed of alternating actin blocks (thin filaments) and myosin blocks (thick filaments).

Myoglobin

Myoglobin is a pigment similar to hemoglobin which is present in muscle fibers. Myoglobin has a large affinity to oxygen. It keeps oxygen bound and releases the gas under strenuous muscle work.

Therefore, myoglobin acts as an oxygen reserve for muscle cells. If oxygen from hemoglobin or myoglobin is not enough to supply energy to the muscle cells, the cell begins to use *lactic fermentation* in an attempt to compensate for that deficiency. Lactic fermentation releases lactic acid and this substance causes muscle fatigue and predisposes the muscles to cramps.

Joints

Joints are structures where two bones are attached so that bones can move relative to each other.

Bones are held together at joints by ligaments, which are strong, fibrous, connective tissues. Joints are classified into three groups:

Immovable (fibrous) joints, e.g. skull bones;

Slightly movable (cartilagenous) joints, e.g. intervertebral discs;

Freely movable (synovial) joints, e.g. limb joints.

Synovial joints permit the greatest degree of flexibility and have the ends of bones covered with a connective tissue (synovial membrane) filled with joint (synovial) fluid.

Vertebral Column

The spinal cord runs along the dorsal side of the body and links the brain to the rest of the body.
Vertebrates have their spinal cords encased in a series of (usually) bony vertebrae that comprise the
vertebral column. Our back is composed of 33 bones called vertebrae, 31 pairs of nerves, 40 muscles
and numerous connecting tendons and ligaments running from the base of your skull to your
tailbone. Between our vertebrae are fibrous, elastic cartilage called discs known as shock absorbers.

Nervous System

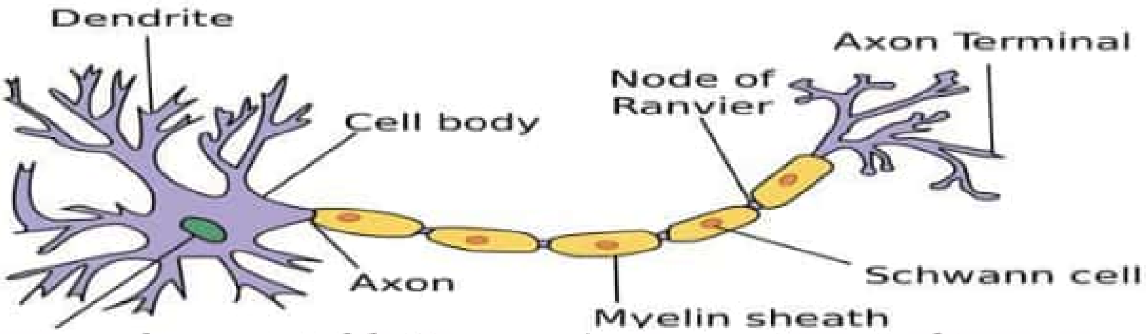
The nervous system is made of two parts viz. Central Nervous System (CNS) and the Peripheral
Nervous System (PNS). CNS is made of Brain {cerebrum, brainstem and cerebellum} and spinal cord.
The PNS is made of nerves and neural ganglia. Further, the meninges {three membranes that
envelop the brain and spinal cord) are also a part of the nervous system.

Cells of the Nervous System

The main cells of the nervous system are neurons. In addition to neurons, the nervous system is also
made up of glial cells. Neurons are cells that have the function of receiving and transmitting neural
impulses. Glial cells support, feed and electrically insulate the neurons. One common example of
Glial cells are the so called "Schwann cells" that produce the myelin sheath of the peripheral nervous
system.

Neuron

The neuron is the functional unit of the nervous system with 3 parts viz. Dendrite, Cell Body and
Axon. Dendrites receive information from another cell and transmit the message to the cell body.
The cell body contains the nucleus, mitochondria and other organelles typical of eukaryotic cells.
The axon conducts messages away from the cell body.



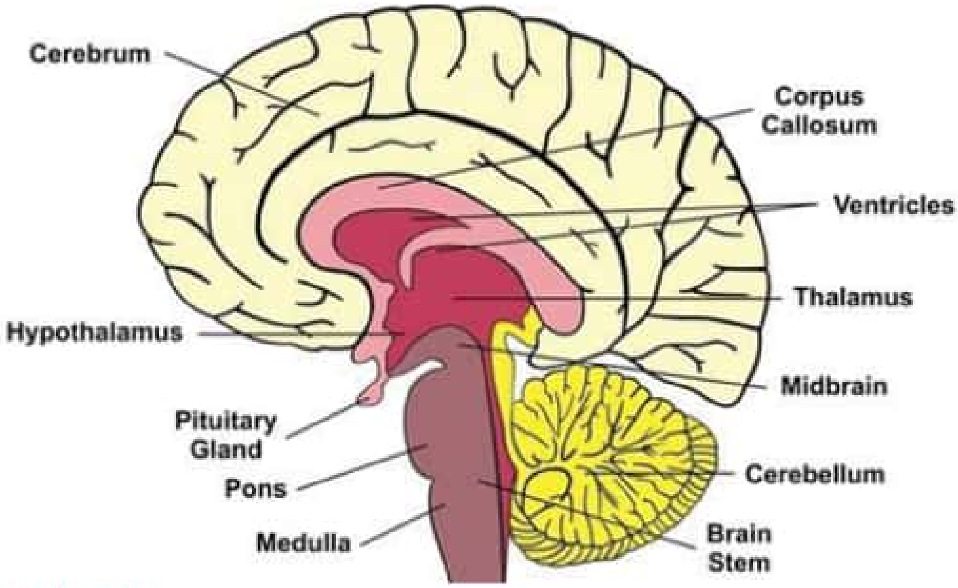
There are three types of the Neurons viz. Sensory, Motor and Inter. Sensory neurons carry messages
from sensory receptors to the central nervous system. Motor neurons transmit messages from the
central nervous system to the muscles. Inter neurons are found only in the central nervous system
where they connect neuron to neuron.
Some axons are wrapped in a myelin sheath by specialized glial cells known as ***Schwann cells.*** The gap
between Schwann cells is known as the ***Node of Ranvier***, and serves as points along the neuron for
generating a signal.

Synapses

Synapses are the structures that transmit a neural impulse between two neurons. When the electric
impulse arrives, the presynaptic membrane of the axon releases neurotransmitters that bind to the
postsynaptic receptors of the dendrites of the next cell. The activated state of these receptors alters
the permeability of the dendritic membrane and the electric depolarization moves along the plasma
membrane of the neuron to its axon.

Brain

The brain is made up of three main sections: the forebrain, the midbrain, and the hindbrain.



Forebrain

The forebrain is the largest and most complex part of the brain. It consists of the ***cerebrum*** and some other structures beneath it. The cerebrum contains the information that essentially makes us who we are: our intelligence, memory, speech, ability to feel etc. Specific areas of the cerebrum are in charge of processing these different types of information. These are called lobes, and there are four of them: the *frontal, parietal, temporal, and occipital lobes.*

The cerebrum has right and left halves, called hemispheres, which are connected in the middle by a band of nerve fibers (corpus collosum) that enables the two sides to communicate.

The left side is considered the logical, analytical, objective side. The right side is thought to be more intuitive, creative, and subjective.

The outer layer of the cerebrum is called the ***cortex*** (also known as "gray matter"). Information collected by the five senses comes into the brain from the spinal cord to the cortex. This information is then directed to other parts of the nervous system for further processing.

In the inner part of the forebrain sits the thalamus, hypothalamus, and pituitary gland.

The ***thalamus*** carries messages from the sensory organs like the eyes, ears, nose, and fingers to

the cortex.
The ***hypothalamus*** controls the pulse, thirst, appetite, sleep patterns, and other processes in
our bodies that happen automatically.
It also controls the ***pituitary gland***, which makes the hormones that control our growth,
metabolism, digestion, sexual maturity, and response to stress.

The Midbrain

The midbrain, located underneath the middle of the forebrain, acts as a master coordinator for all the
messages going in and out of the brain to the spinal cord.

The Hindbrain

The hindbrain sits underneath the back end of the cerebrum, and it consists of the cerebellum, pons,
and medulla.
The cerebellum — also called the "little brain" because it looks like a small version of the cerebrum —
is responsible for balance, movement, and coordination.
The pons and the medulla, along with the midbrain, are often called the brainstem. The brainstem
takes in, sends out, and coordinates all of the brain's messages.
It also controls many of the body's automatic functions, like breathing, heart rate, blood pressure,
swallowing, digestion, and blinking.

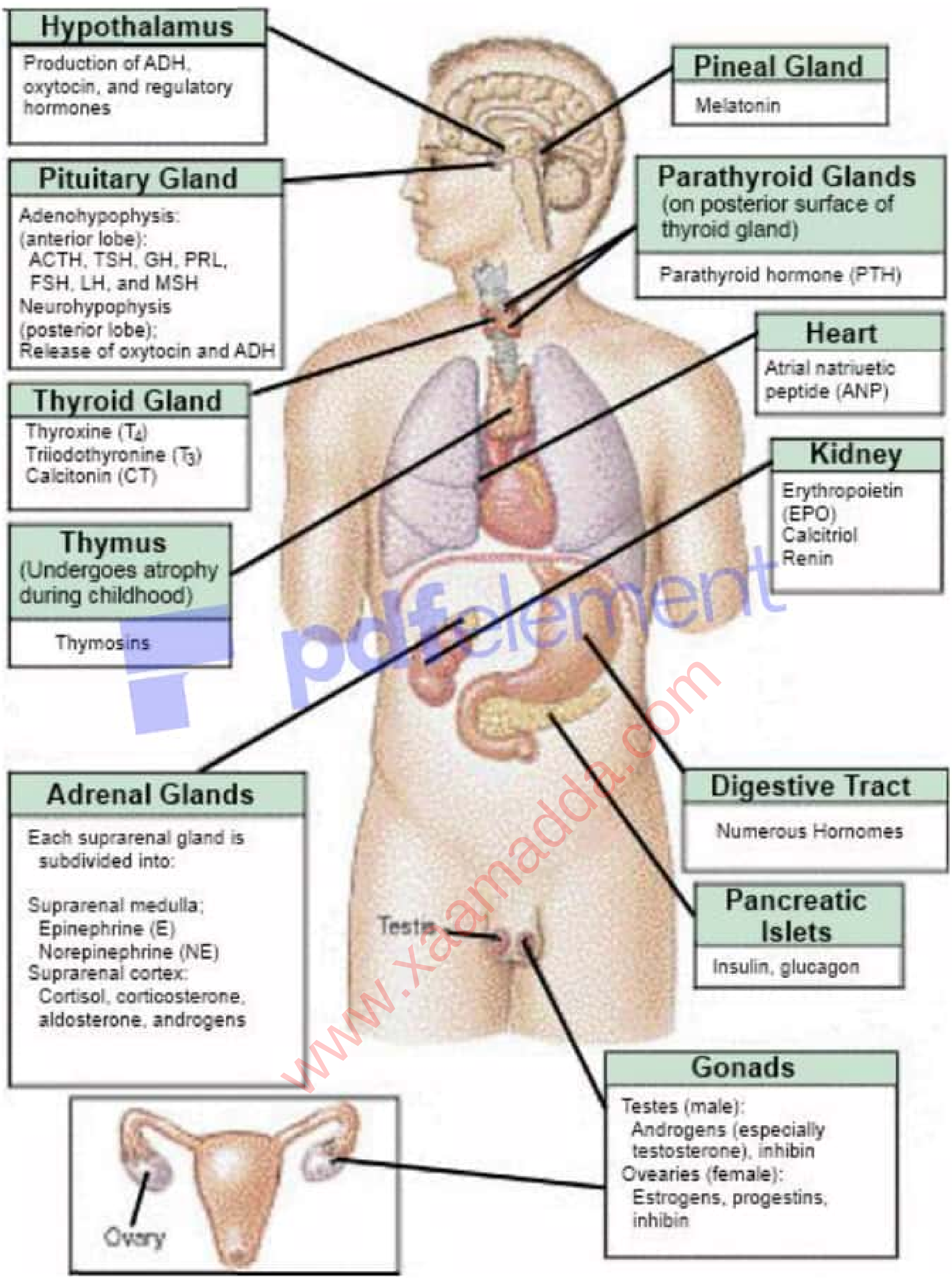
Spinal cord

The spinal cord is a long bundle of nerve tissue about 18 inches long and ¾ inch thick. It extends
from the lower part of the brain down through spine. Along the way, various nerves branch out to
the entire body. These are called the peripheral nervous system. Both the brain and the spinal cord
are protected by bone: the brain by the bones of the skull, and the spinal cord by a set of ring-shaped
bones called vertebrae. They're both cushioned by layers of membranes called meninges as well as a
special fluid called cerebrospinal fluid.

Endocrine System

Endocrine system is a collection of glands that work interdependently and produce hormones that

regulate the body's growth, metabolism, and sexual development and function. The Endocrine
system influences almost every cell, organ, and function of our bodies. It is instrumental in
regulating mood, growth and development, tissue function, metabolism, and sexual function and reproductive processes.


Hypothalamus
Production of ADH, oxytocin, and regulatory hormones
Pineal Gland
Melatonin
Pituitary Gland
Adenohypophysis: (anterior lobe): ACTH, TSH, GH, PRL, FSH, LH, and MSH
Neurohypophysis (posterior lobe): Release of oxytocin and ADH
Parathyroid Glands
(on posterior surface of thyroid gland)
Parathyroid hormone (PTH)
Heart
Atrial natriuetic peptide (ANP)
Thyroid Gland
Thyroxine (T_4)
Triiodothyronine (T_3)
Calcitonin (CT)
Kidney
Erythropoietin (EPO)
Calcitriol
Renin
Thymus
(Undergoes atrophy during childhood)
Thymosins
Adrenal Glands
Each suprarenal gland is subdivided into:
Suprarenal medulla;
Epinephrine (E)
Norepinephrine (NE)
Suprarenal cortex:
Cortisol, corticosterone, aldosterone, androgens
Digestive Tract
Numerous Hormones
Pancreatic Islets
Insulin, glucagon
Testis
Gonads
Testes (male):
Androgens (especially testosterone), inhibin
Ovearies (female):
Estrogens, progestins, inhibin
Ovary

Hormones

Hormones, the chemical messengers are carried in the bloodstream to a target tissue elsewhere in the body, where they must be absorbed into the tissue before they can have an effect. There are two groups of Hormones viz. Peptide Hormones and Steroid Hormones. **Peptide hormones**, such as insulin, are short chains of amino acids. Peptide hormones are hydrophilic (water loving), so they don't pass easily through cell membranes. The receptors for peptide hormones are embedded in the plasma membranes of target cells. **Steroid hormones**, such as testosterone and estrogen, are lipids, so they're hydrophobic (water fearing) and can pass easily through the hydrophobic layer of the plasma membrane and enter cells. Thus, the receptors for steroid hormones are located inside the cell.

The Pineal Gland

The pineal gland or pineal body or **epiphysis** is located in the center of the head. It secretes the hormone *melatonin*, a hormone produced at night and related to the regulation of circadian rhythm (or the circadian cycle, the wakefulness-sleep cycle). Melatonin may also regulate many body functions related to the night-day cycle.

Pituitary Gland

The pituitary gland or hypophysis is located in one of the bones at the base of the skull. It has two portions viz. anterior hypophysis and posterior hypophysis. The anterior part produces two hormones that work directly viz. growth hormone (GH) and prolactin; and four tropic hormones {tropic hormones regulate the other endocrine glands} viz. adrenocorticotropic hormone (ACTH), thyroid-stimulating hormone (TSH), luteinizing hormone (LH) and follicle-stimulating hormone (FSH). The posterior part releases two hormones produced in the hypothalamus viz. oxytocin and antidiuretic hormone (ADH or vasopressin).

Growth Hormone (GH) acts on bones, cartilage and muscles to promote the growth of these tissues. During childhood, GH secretion deficiencies may lead to dwarfism. Excessive production of GH in children may cause exaggerated bone growth and gigantism.
Prolactin stimulates the production and secretion of milk by the mammary glands in women.
ACTH stimulates the cortical portion of the adrenal gland to produce and secrete cortical hormones called glucocorticoids.
TSH stimulates the activity of the thyroid gland, increasing the production and secretion of its hormones T3 and T4.
FSH is a gonadotropic hormone {gonadotropic means it stimulates the gonads} and acts on the ovaries to induce the growth of follicles and, in men, it stimulates spermatogenesis.
LH is also a gonadotropic hormone; it acts upon the ovaries of women to stimulate ovulation and the formation of the corpus luteum (which secretes estrogen); in men, it acts on the testicles to stimulate the production of testosterone.
Oxytocin is secreted in women during delivery to increase the strength and frequency of uterine contractions and therefore to help the baby's birth. During the lactation period, the infant's sucking action on the mother's nipples stimulates the production of oxytocin, which then increases the secretion of milk by the mammary glands.
Vasopressin, or ADH, participates in the regulation of water in the body and therefore in the control of blood pressure, since it allows the reabsorption of free water through the renal tubules. As water goes back into circulation, the volume of blood increases.

Thyroid Gland

The thyroid is located in the anterior cervical region (frontal neck), in front of the trachea and just below the larynx. It is a bilobed mass below the Adam's apple. It secrets thyroxine (T4),

triiodothyronine (T3) and calcitonin.
T3 and T4 act to increase the cellular metabolic rate of the body (cellular respiration,
metabolism of proteins and lipids, etc.) Goiter. the abnormal enlargement of the thyroid
gland, can occur as a result of hypothyroidism or hyperthyroidism. Endemic goiter is caused
by a deficiency in iodine consumption. Hypothyroidism caused by deficient iodine ingestion
is more frequent in regions far from the coast because sea food is rich in iodine.
Calcitonin inhibits the release of calcium cations by bones, thus controlling the level of
calcium in the blood.

Parathyroids

The parathyroids are four small glands, two of which are embedded in each posterior face of one lobe
of the thyroid. The parathyroids secrete parathormone, a hormone that, along with calcitonin and
vitamin D, regulates calcium levels in the blood.

Pancreas

Pancreas is a mixed gland because it produces both endocrine and exocrine secretions. It releases
pancreatic juice as exocrine gland while *insulin, glucagon and somatostatin hormones*as endocrine
gland. These hormones are produced in so called *"islets of Langerhans"*.

Glucose Regulation

For normal body functions, the Blood glucose levels must be maintained. If blood glucose levels are
abnormally low, it shall not be able to supply the energy metabolism of cells. If it is too high, it causes
severe harm to peripheral nerves, the skin, the retina, the kidneys and other important organs, and
may cause cardiovascular diseases.
The pancreatic hormone Glucagon increases blood glucose while Insulin reduces it. Glucagon
stimulates glycogenolysis, thus forming glucose from the breakdown of glycogen. Insulin is
the hormone responsible for the entrance of glucose from blood into cells.

When glucose is low (for example during fasts), glucagon is secreted and insulin is inhibited.
When glucose is high (for example after meals) glucagon is inhibited and insulin secretion is
increased.
While glucagon targets the liver, insulin works in all cells. Somatostatin inhibits both insulin and
glucagon secretions.

Diabetes Mellitus

Diabetes mellitus is caused by deficient production or action of insulin and, as a result, characterized
by a low glucose uptake by cells and a high blood glucose level. This diseases is identified by a so
called *diabetic triad* called polyuria (excessive urine) , polydipsia (excessive thirst) and polyphagia
(excessive hunger). Diabetic persons are advised to take less carbohydrates because these substances
are broken down into glucose and this molecule is absorbed in the intestines.

Type-I and Type-II diabetes

Type I or juvenile diabetes or insulin-dependent diabetes is the impaired production of insulin by the
pancreas and is caused by destruction of the cells of the islets of Langerhans by autoantibodies
(autoimmunity). Type II diabetes occurs adults. In this, the pancreas secretes normal or low levels of
insulin, but the main cause of the high glucose sugar is the peripheral resistance of the cells to the
action of the hormone.
Type I diabetes is treated with the parenteral administration of insulin. Insulin must be administered
intravenously or intramuscularly because, as a protein, it will be digested if ingested orally. In type II
diabetes, treatment is done with oral drugs that regulate glucose metabolism or, in more severe cases,
with parenteral insulin administration. The moderation of carbohydrate ingestion is an important
aid in diabetes treatment.
Diabetes insipidus is the disease caused by deficient ADH secretion by the **pituitary gland.** In diabetes

insipidus, blood lacks ADH and, as a result, the reabsorption of water by the tubules in the kidneys is reduced, and a large volume of urine is produced. The patient urinates in large volumes and many times a day.

Adrenal Glands

Each adrenal gland is located on the top of each kidney (forming a hat-like structure on the top of the kidneys). Each adrenal gland has two parts viz. outer cortical portion and inner adrenal cortex.

Further, there is a central part called adrenal medulla.

Adrenal medulla releases adrenaline (aka epinephrine) and noradrenaline (aka norepinephrine). These two hormones increase the breakdown of glycogen into glucose, thus increasing blood sugar and metabolic rate. They are released during situations of danger (fight or flight response) and they intensify the strength and rate of the heartbeat and selectively modulate blood irrigation in some tissues.

The adrenal cortex releases cortical hormones viz. glucocorticoids, mineralocorticoids and cortical sex hormones. Glucocorticoids stimulate the formation of glucose and as immunosuppressive role, meaning that they reduce the action of the immune system and for this reason are *used as medicine to treat inflammatory and autoimmune diseases* and the rejection of transplanted organs.

Mineralocorticoids regulate the concentration of sodium and potassium in the blood and, as a result, control the water level in the extracellular space.

Cortical sex hormones are Androgens. They promote secondary male and female features.

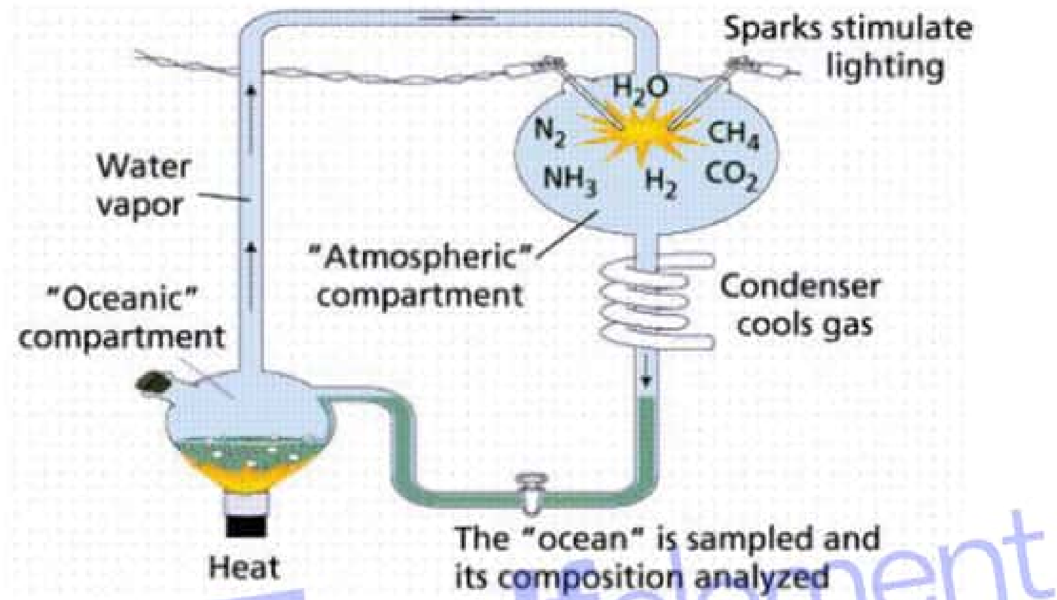
General Science-5: Evolution and Genetics Basics

Evolution

Scientific Hypotheses about Origin of Life

Earth is believed to be some 4500 million years old. Life on earth is believed to have originated after
around 1 billion years of Earth's birth i.e. 3500 million years ago. Various theories, mostly
mythological tried to explain the origin of life on earth. Currently, this scientific problem remains
unsolved.
However, there is a general agreement among scientists that all life has evolved from common
descent from a single primitive life form. Further, it is also believed that some kind of Chemical
evolution happened before biological evolution.
However, which came first –*metabolism or genetics*? – This question also remains unsolved. There are
two main hypotheses in this context viz. *RNA World Hypothesis* and *Protein World Hypothesis*. The
RNA world hypothesis, which came in 1980s, says that genetics came first. The primitive life had only
RNA as genetic material and structural molecules, and later it turned into DNA and proteins. The
logic behind this theory is that RNA predates DNA and it can work both as catalyst as well as
enzyme. The *Protein World Hypothesis* says that first proteins evolved which worked as enzymes and
metabolism. It formed amino acids and then all other things followed.
Both of the above hypotheses are based upon the primitive atmosphere of Earth. Currently, Earth's
atmosphere is composed mainly of molecular nitrogen and oxygen. Presence of molecular oxygen in
the primitive atmosphere was extremely rare. Oxygen became abundant with emergence of the
Photosynthetic organisms. Further, the water cycle was also much faster that what it is today due to
extremely high temperature, characterized by harsh storms and intense electrical charge. Moreover,
it is believed that there was no ozone layer protection from ultraviolet rays from Sun.
In summary, electricity, radiation and heat were the main available of sources of energy. In 1953,

Stanley Miller arranged something of this kind of environment in his laboratory. He heated a
mixture of methane, ammonia, hydrogen and circulating water that, when heated, was transformed
into vapour.



Miller made this mixture subject to a continuous bombardment of electrical discharge. After a few
days, he obtained a liquid residual within which he discovered organic molecules. Among these
organic molecules were amino acids glycine and alanine, which are most abundant components of
the proteins. This experiment was reproduced by other researchers who were able to make possible
formation of organic molecules such as lipids, carbohydrates and nucleotides!
This theory put full stop on all mythological theories regarding origin of life and brought forward
the natural organic synthesis concept for the origin of life on earth.

Origin of Photosynthesis and Aerobic Life

Another related and unsolved question in context with the origin of life is - who came first –
autotrophic or heterotrophic organisms? The heterotrophic hypothesis has got little more weight here.
This theory claims that first living organisms were *fermenting heterotrophs*. They released CO2 via

fermentation and then the atmosphere became rich in this gas. Through mutation and natural selection, organisms capable of using CO_2 and light to synthesize organic material appeared. These would have been the first photosynthetic organisms. These were called *fermenting autotrophs* because oxygen was not in abundance in the atmosphere. When Molecular oxygen became available, some organisms developed aerobic respiration, a highly efficient method to produce energy.

Further, it is believed that the prokaryotes appeared before Eukaryotes. Life first originated in water because protection from UV radiation was not available on land in primitive earth. Life on land was possible only when there was enough oxygen in atmosphere and ozone layer was formed to filter the UV rays from sun.

Theory of Evolution

The theory of evolution tries to solve the question – *how different living organisms on earth appeared?*

This question also has numerous mythological answers. One theory is *fixism*, which proposed that there is no evolution at all, and all species on earth were identical to species in last and no change has taken place into them. The religious version of fixism is *creationism*, which has its own different forms. The basic idea behind creationism is that God created all the organisms.

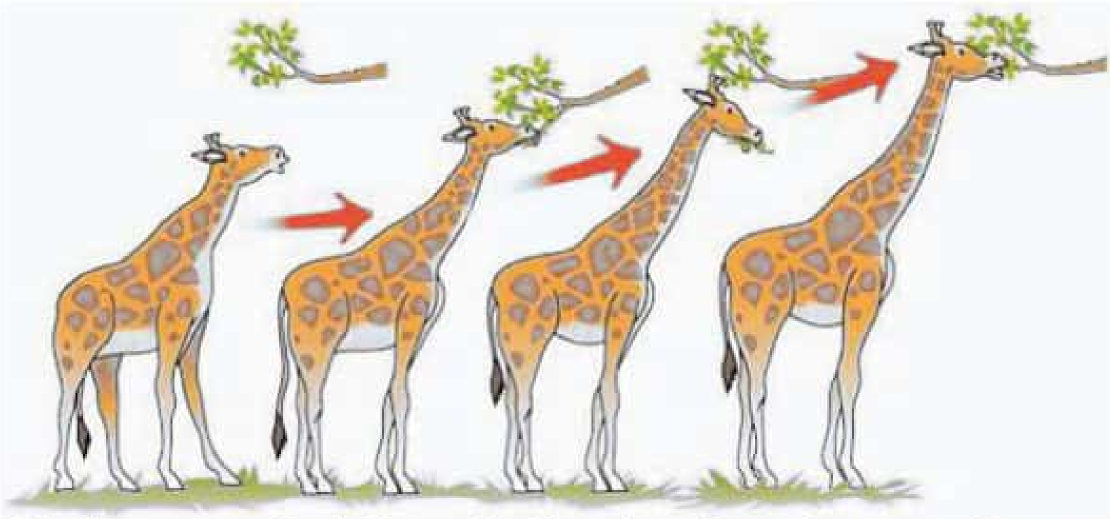
However, science is in favour of evolution of species. There are many evidences in favour of evolution. *First,* there is paleontological evidence which shows gradual change in fossils from different periods. *Second,* evidence is of the comparative anatomy, such as the existence of residual organs or other structures with same origin and function (For example, Darwin theorized that the appendix in humans and other primates was the evolutionary remains of a larger structure, called a cecum, which was used by now- extinct ancestors for digesting food) that reveal relationships among

species. *Third evidence is of* comparative embryology. There are similarities between structures and
developmental processes among embryos of related species. *Fourth* evidence is of molecular biology,
which shows the existence of a large percentage of similar nucleotide sequences in the DNA of
species with common ancestors.

Evolutionary theories

The two main evolutionary theories were *Lamarckism* and *Darwinism*. Prior to that we need to
understand what were *law of use and disuse* and *law of transmission of acquired characteristics*.

The *law of use and disuse* says that the characteristics of a body vary depending on whether it is used
more or less. This rule is valid for features such as muscle mass and the size of the bones, for
example. The *law of the transmission of acquired characteristics* believed that the parents could transmit
characteristics acquired by the use and disuse to their offspring. In 19th century, French Naturalist
Lamarck proposed a theory by combining these two laws. Lamarckism says that individuals do not
only pass on the things they received from their parents, but also some things they experienced
during their lifetime. To support his theory, he gave an example of Giraffes, which have long necks.
He argued that Giraffe must have evolved from ancestors with much shorter necks. Since the adults
needed to stretch their neck to reach leaves from high branches; their children inherited longer necks.



This theory was albeit doomed to be rejected; was important because it was proposed at a time when fixism and creationism dominated. In fact, Lamarck must be hailed for his bravery to introduce an evolutionary theory based on natural law in those times.

Darwinism

Charles Darwin is considered the father of the theory of evolution. When he was about 23 years old, he had embarked on a ship called *Beagle* as volunteer scientist for a five year expedition to the South American coast and the Pacific. During the voyage, the most famous part of which was the stop in the Galapagos Islands, Darwin collected data that he used to write his masterpiece*The Origin of Species in 1859*. In this work, the principles of the common ancestry of all living organisms and natural selection as the force that drives the diversity of species were described.

Natural selection

The original name of Darwin's work was "*Origin of Species by Means of Natural Selection*". The core idea behind natural selection is that species which are *less adapted to environment* are eliminated.

Natural selection is when the organisms with favourable traits are more likely to reproduce. In doing so, they pass on these traits to the next generation and over the time; this process would allow organisms to adapt to their environment. This is because the frequency of genes for favourable traits

increases in the population.
Darwin noted that within on particular species, there are individuals with different characteristics.
Such differences could lead to different survival and reproduction chances for each individual.
Therefore, he discovered the importance of the effect of the environment on organisms and the
preservation of those with characteristics more advantageous for survival and who are more able to
generate offspring. This is how he described the basis of the principle of natural selection.
Natural selection explains why living organisms change over time to have the anatomy, the functions
and behaviour that they have. It works like this:
1. All living things have such fertility that their population size could increase rapidly forever.
2. Actually, the size of populations does not increase to this extent. Mostly, numbers remain
about the same.
3. Food and other resources are limited. So, there is competition for food and resources.
4. No two individuals are alike. Therefore, they do not have the same chance to live and
reproduce.
5. Much of this variation is inherited. The parents pass the traits to the children through their
genes.
6. *The next generation comes from those that survive and reproduce*. The elimination is caused by the
relative fit between the individuals and the environment they live in. After many generations,
the population has more helpful genetic differences, and fewer harmful ones.
In summary, the Natural selection is really a continuous *process of elimination*.

Industrial revolution in England – An example of natural selection

One of the classic examples of natural selection is the moths of industrial zones of England at the end
of the 19th century and the beginning of the 20th century. As the industrial revolution advanced, the

bark of the trees that moths landed on became darker due to the soot released from factories. The
population of light moths decreased and was substituted by a population of dark moths, since the
mimicry of the dark moths in the new environment protected them from predators, meaning that
they had an adaptive advantage in that new environment. Light moths in turn suffered the negative
effect of natural selection because they had become more visible to predators, and were almost
eliminated. In the open forest far from factories, however, it was experimentally verified that light
moths maintained their adaptive advantage and the dark moths continued to be more easily found by
predators.

Comparison of Lamarckism vs. Darwinism

Both Lamarckism and Darwinism are evolutionary theories opposed to fixism and, both admit the
existence of processes that caused changes in the characteristics of living organisms in the past.
However, these two theories have different explanations for those changes. Lamarckism combines
the law of use and disuse with the law of the transmission of acquired characteristics to explain the
changes. Darwinism defends the effect of natural selection.

Neo-Darwinism

The modern Darwinist theory that incorporates knowledge from genetics and molecular biology is
called neo-Darwinism. It is also known as *synthetic theory of evolution*. It argues that the variation of
inherited characteristics is created by *alterations in the genetic material of individuals*, and *more precisely
by modifications or recombination of DNA molecules*. Small changes in genetic material accumulate and
new phonotypical characteristics emerge. The carriers of these characteristics are then subject to
natural selection.

Modern science has established that the genetic variability occurs from various thins such as

recombination of chromosomes during sexual reproduction; DNA mutation in germ cells and
gametes etc. Such variability creates individuals which are carriers of some new features compared to
their ancestors. These individuals are submitted to environmental pressure and can be more or less
well-adapted concerning survival or reproduction. Those better adapted transmit their genetic
heritage to a *larger number of descendants*, thus increasing the frequency of their genes in the
population. Those less well-adapted tend to transmit their genes to a smaller number of descendants,
thus decreasing the frequency of their genes in the population or even becoming extinct.

Neo-Darwinism and Antibiotic Resistance

The appearance of multi drug resistant strains of pathogenic parasites such as bacteria or superbugs
can be explained by the synthetic theory of evolution. As in any environment, TB bacteria in
hospitals undergo changes in their genetic material. *In the hospital environment, however, they undergo*
continuous exposure to antibiotics. Many of them die from the effect of the antibiotics but *carriers of*
mutations that provide resistance to those antibiotics proliferate freely. These resistant microorganisms,
when subject to other antibiotics, once again undergo natural selection and those which became
resistant to these other drugs are preserved and proliferate. This is how MDR, XDR kinds of TB and
NDM-1 *(New Delhi metallo-beta-lactamase* 1) types of super bugs develop. The use (and overuse) of
antibiotics is a factor that promotes natural selection and the emergence of multi-resistant bacteria.

Reproductive isolation

Reproductive isolation refers to various mechanisms by which different species cannot cross-breed
among themselves; or even if they cross-breed would produce infertile offspring. This is an
important phenomena because it defines the concept of a species. These mechanisms are as follows:

Spatial Isolation

If two populations are either at a great distance from each other or inhabit different parts of same area, it is called spatial isolation.

Geographical Isolation

If there is a physical barrier between two species such as water bodies, mountains, deserts etc. then it would prevent interbreeding between them and the process of natural selection would occur independently on both the sides. A common example of Geographical isolation is Darwin's finches on Galapagos Islands.

Ecological or Habitat Isolation

In this case, the populations are not separated by great distances but occupy different habitats within the same area. Brown bears and polar bears are a good example of habitat isolation.

Temporal Isolation

Temporal isolation is when two species are ready to mate at different times. For example, one species active during day and another at night; or one species mates in different season than other.

Behavioral Isolation

In some species, there are certain courtship displays and rituals needed for mating. These include courtship calls, songs, dances or other such rituals.

Mechanical Isolation

When mating is physically impossible because of incompatible genitalia, it is called mechanical isolation. Such isolation is common in insects whereby the genitalia work like locks and keys.

Gametic Isolation

When gametes (sperms and eggs) are unable to fuse and fertilize, then it is called gametic isolation.

Apart from the above, there is some Post-Mating mechanism also which prevent hybrid formation even if all premating mechanisms given above fail. These are as follows:

Gametic mortality

In this case, the sperms fail to fertilize the egg due to various reasons such as adverse climate (in case of external fertilization) or sperm death in female genital tract (in case of internal fertilization)

Zygotic mortality

Zygotic mortality is when egg and sperm have met and fused, but the zygote dies without further
development.

Hybrid inviability

This is a post-zygotic barrier in which Hybrid does not mature into a healthy and fit adult. The
relatively low health of these hybrids in comparison to pure-breed individuals would prevent gene
flow between species.

Hybrid sterility

In this case, the hybrids are sterile. Sterility is mainly because of incompatibility of the
Chromosomes. Mules and Hinnies are examples of this kind of barrier.

Hybrid breakdown

Hybrid breakdown is when the hybrids are fertile but their progeny abnormal or sterile. The
interspecific hybrids of cotton (Gossypium) are common example of Hybrid breakdown.

Speciation

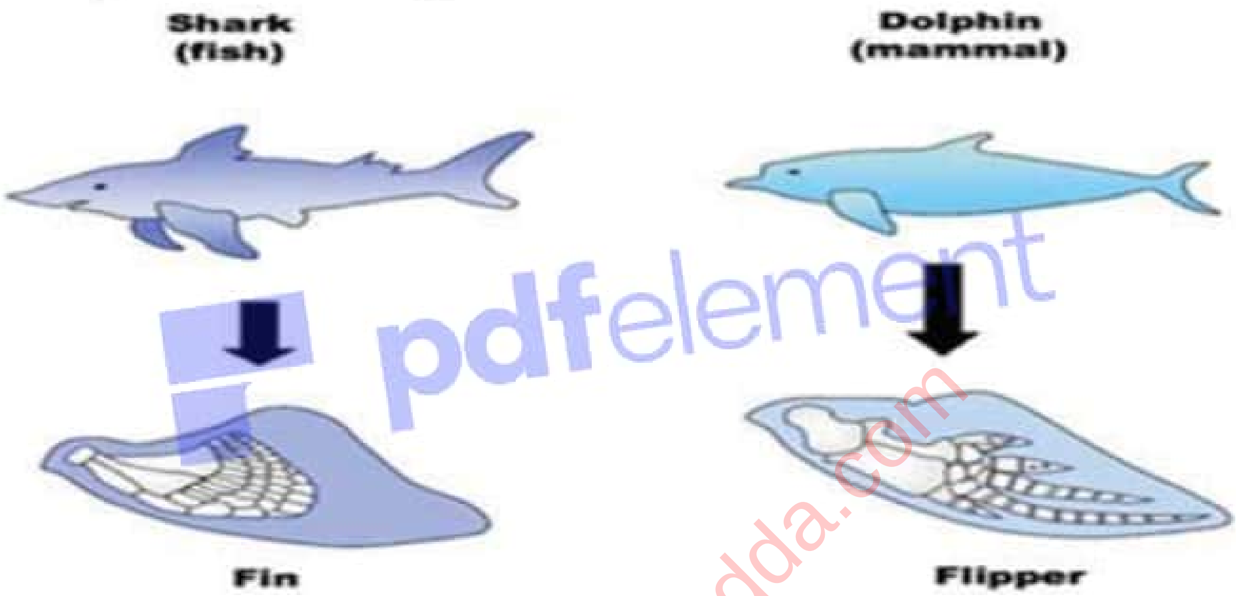
Speciation refers to the process by which different species emerge from a common ancestor.

Speciation generally begins when populations of the same species become geographically isolated, for
example when they are separated by some physical barrier that disallows cross-breeding between
individuals from one population and individuals of another population. The basic theory in
speciation is that the groups which are kept in geographical isolation for a long time, tend to
accumulate different phenotypical (appearance) characteristics from each other by means of genetic
variability (i.e. mutations and recombination) and natural selection. Speciation is considered to have
occurred when they reach at a point where cross breeding between these two groups becomes
impossible.

Adaptive Convergence and Adaptive Radiation

Adaptive Convergence

Adaptive convergence refers to a phenomenon in which living organisms that face similar
environmental pressures or problems might incorporate similar solutions (structures in their bodies)
during evolution. Such similar structures are called analogous to each other. A common example of
this is fins and hydrodynamic body of Shark (Fish) and Dolphin (Mammal), Taxonomically and
phylogenetically, they are distant animals but they have similar organs and shape because they need
to adapt to similar environments.



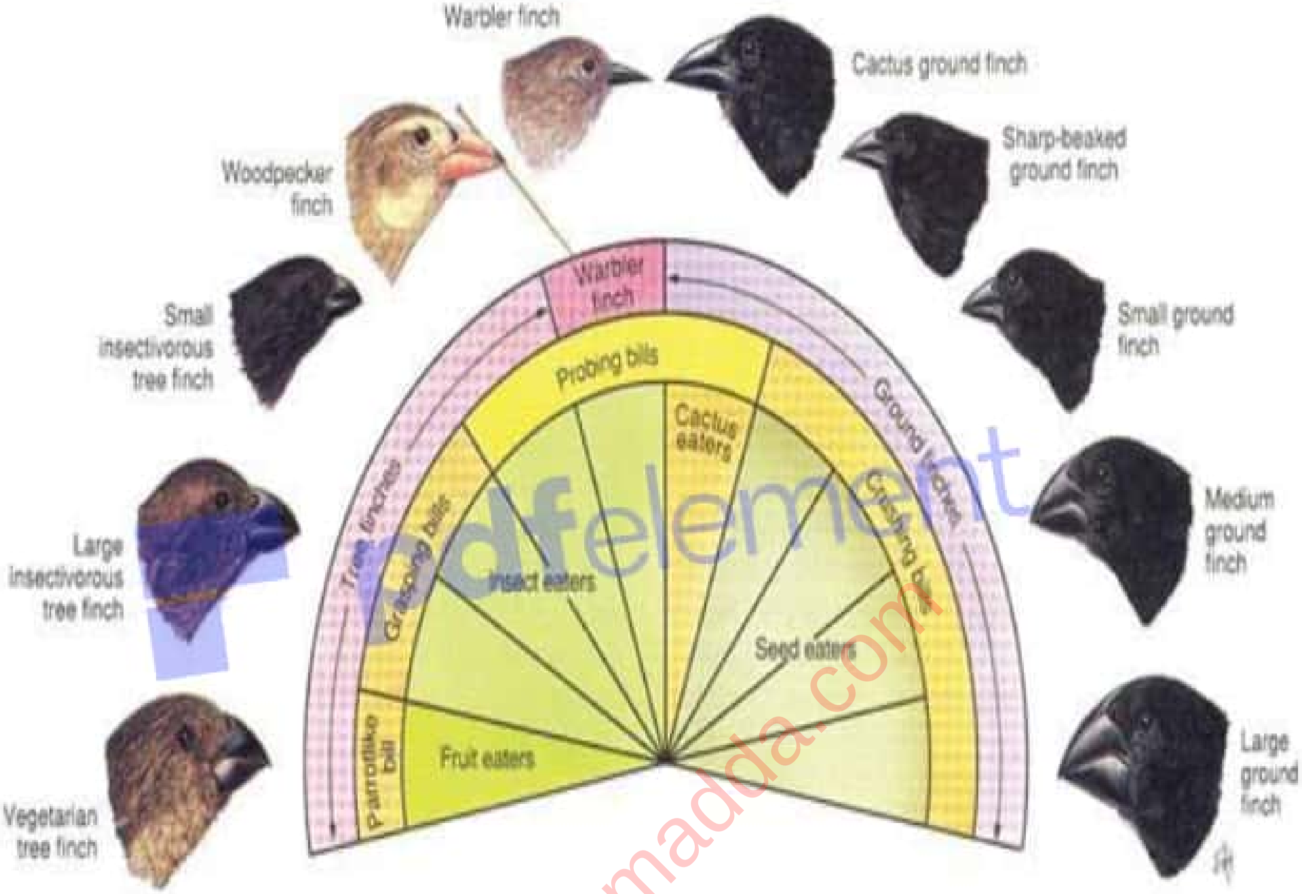
Adaptive Radiation

Adaptive radiation is when a single ancestral form diversifies into several or many different types
because they spread to various regions or environments. It is also known as Divergent Evolution.

Adaptive Radiation in Darwin's Finches

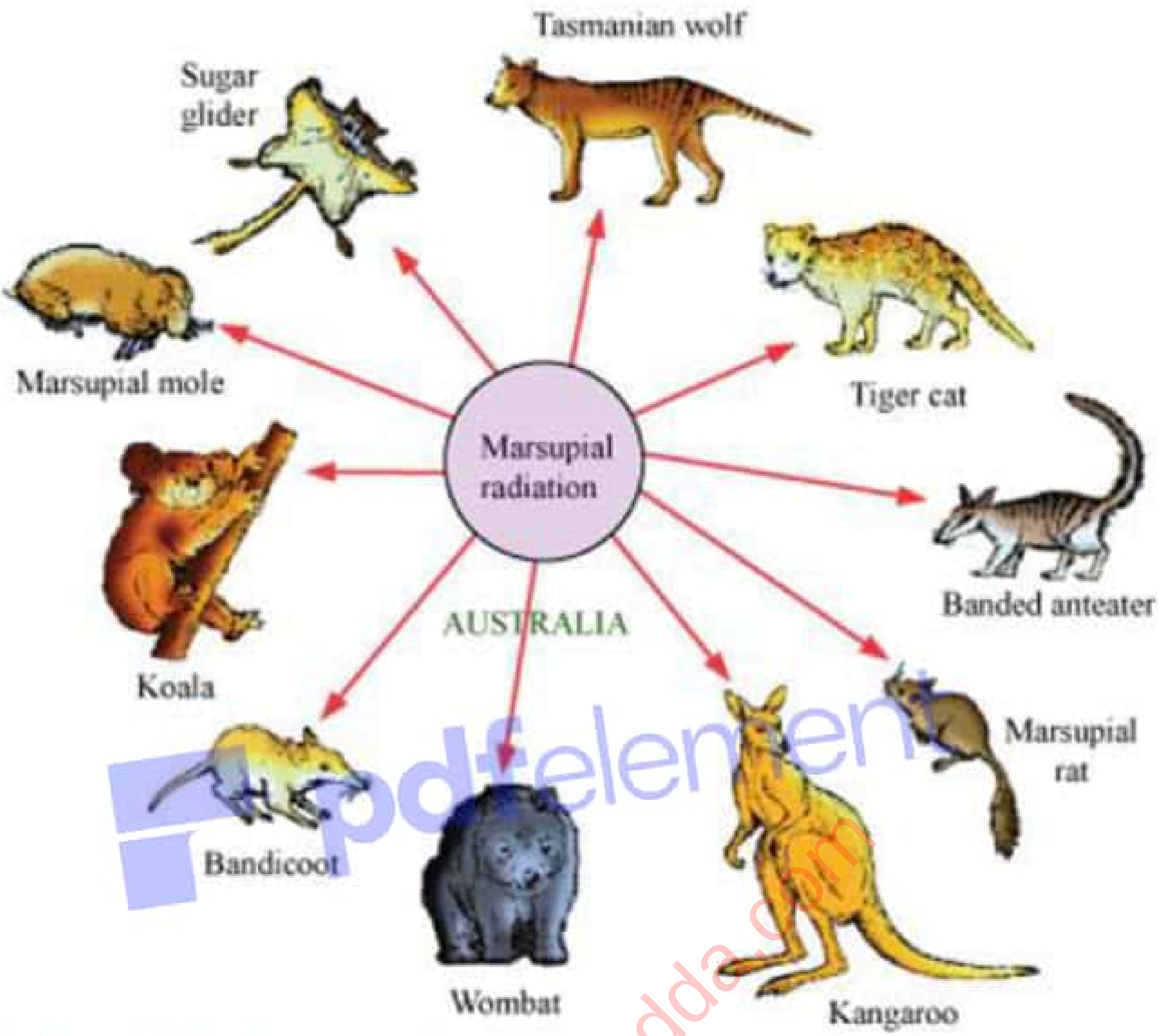
The classic example of Adaptive Radiation is the finches of Galapagos Islands, also called Darwin's
Finches. During his five weeks there, Darwin noticed that Finches differed from one island to
another. When he returned to England, his speculation on evolution deepened after experts

informed him that these were separate species, not just varieties, and famously that other differing
Galápagos birds were all species of finches. All the 15 finches observed by Darwin are thought to
have been radiated from a common seed eating ancestor. They occupy different ecological niches as
well as habitats.



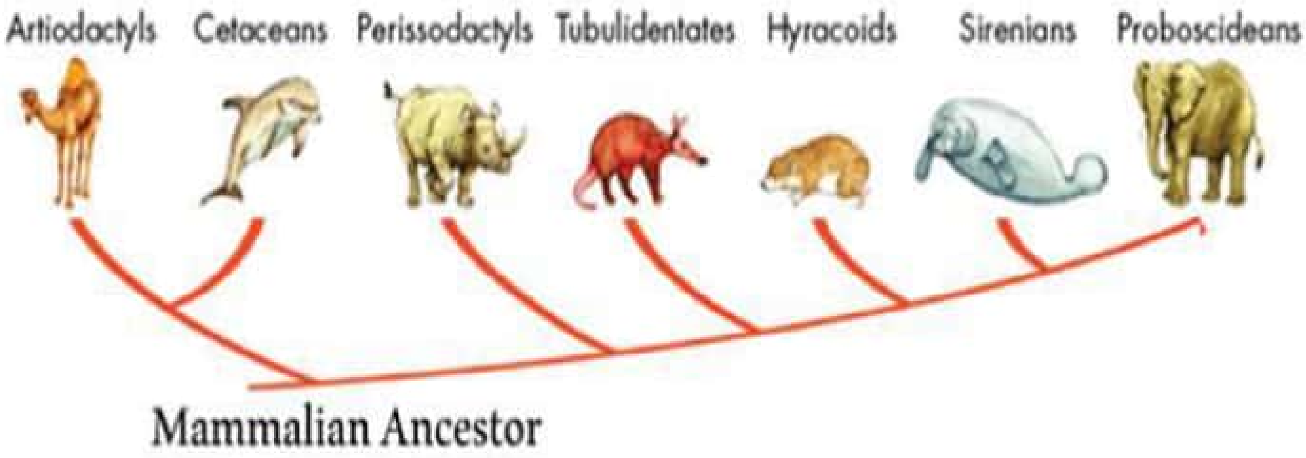
Adaptive radiations in Marsupials

There are lots of species that have evolved from Marsupials via adaptive radiation. This is also called
Marsupial Radiation.



Adaptive radiations in mammals:

Around 65 Million years ago at the end of the Cretaceous period, only few lineages of the Eutherians were present. It is believed due to a vacuum created by the disappearance of dinosaurs, there was a rapid evolution of new mammalian types during the Eocene and Oligocene periods due to moving into different habitats and ecological niches. This is how different kinds of mammals originated from common ancestor.



The above theory also proposes that the primitive common ancestor might be a insect eater like a
common shrew.

Analogous and Homologous Organs

Organs of different species are said to be analogous when they have the same biological function. For
example, wings of bats and the wings of insects.

Organs of different species are called homologous when they have the same biological origin, or
when they are the products of the differentiation of the same characteristic of a common ancestor.

The forelimbs of various vertebrates such as humans, dogs, birds and whales are examples of
homologous organs. Each of them has a different function, they have similar bone structure; and
have that originated from the same embryonic tissue. This is considered as an evidence for descent
from a common ancestor.

Genetics

Genetics is the branch of science that deals with mechanism of inheritance.

Gene and Chromosome

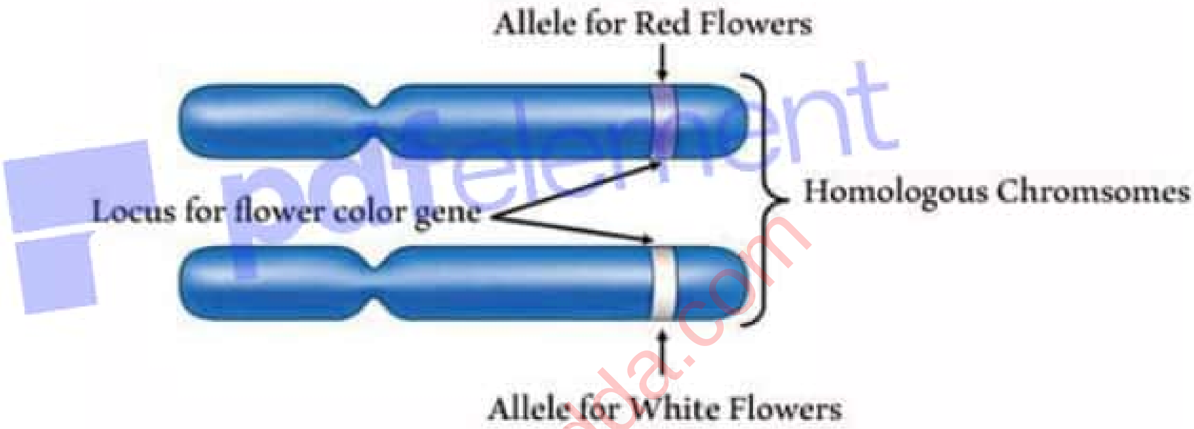
A gene is a *portion of a DNA* molecule that codifies a specific protein. A gene is made of several
triplets of DNA nucleotides with their respective nitrogen-containing bases, such as AAG or CGT. A
chromosome is a DNA molecule that may contain several different genes as well as portions of DNA

that are not genes. A gene locus (locus means place) is the location of a gene in a chromosome; or
rather, the position of the gene in a DNA molecule.

Alleles and Genes

Most of the genes exist in more than one form; and when expressed, they result in different
characteristics. These different forms of genes are termed alleles. This implies that an allele is *one of
the at least two alternative forms of genes.*

Alleles are similar in type but their genetic instructions produce visible different organisms. This
visible difference is called **Phenotype.** For example, a single gene may be a controller of flower color
in a plant. Its two alleles may be such that one produces red flowers while other produces white
flowers.



As shown in the above graphics, alleles are located at corresponding locations on the Chromosomes,
which constitute a chromosomal pair. All diploid organisms (animals and plants) have two alleles at a
given location on a pair of chromosome. On the other hand, the gametes (for example sperms or
eggs) contain only one allele of a particular gene. After fertilization, when the diploid condition is
restored, one allele of the two may dominant or recessive resulting in the phenotypes.

We can understand this by human example. I have 23 pairs of chromosomes. Each pair has two homologous chromosomes (one from my mother and one my father). Both of these contain information related to production of same proteins (except sex chromosomes, which are heterologous). Whether I look more like my father or my mother – is an example of a phenotype.

We note here that naturally one allele comes from father and another from mother, it is not obligatory always. In clones, both alleles would come from a single parent.

Further, there may be three or more copies of the chromosome rather than the expected two copies in some cases called Polysomy. In this case, additional alleges would be found in organism. For example, three alleles would be found in trisomy whole four in tetrasomy.

Phenotype and Genotype

A phenotype is observable characteristic, while a genotype nucleotide sequences contained in the chromosomes. Thus, a phenotype is biological manifestation of genotype. If a gene of a diploid species has two different alleles, such as A and a; then there may be three possible genotypes viz. Aa, AA, and Aa. These three genotypes manifest in three different kinds of phenotypes. Aa and AA are called Homozygous while Aa is called heterozygous.

The alleles may be dominant and recessive. In this example, if the allele A is dominant over the allele a, the phenotype A will be manifest; whether it's AA, or Aa. a will manifest only if genotype is aa.

A recessive allele can remain hidden because it may be present in the genotype but is not expressed in the phenotype. When this allele is transmitted to the offspring and forms a homozygous genotype with another recessive allele from another chromosomal lineage, the phenotypical characteristics that appear reveal its existence.

Mendel's Laws

Gregor Mendel (1822–84) is known as the "father of modern genetics". Ironically, his work was discovered and recognized only 16 years after his death. He was an Austrian *Friar* {Friars are members of some

secular religious orders who practice the principles of monastic life and devote themselves to the service of humanityH}. e carried out experiments and
studies on heredity on pea plants and postulated the Mendel's laws.

Selection of Pea plant for experiments

Mendel used pea plants in his experiments for two main reasons. First, the Pea plants reproduce
sexually; and second that these plants are self-pollinating (the male and female organs are enclosed in
the same flower). This ensured true breeding of the plants. Mendel used self-fertilization in peas
over several generations for the purpose of obtaining individuals with the desired characteristics and
to ensure that parent pea plants were pure or homozygous.
Once such pure lines were obtained he cross bred them and obtained their hybrid offspring. He again
crossbred the hybrids and called them F1 or First Filial generation. When again the offspring
crossed, he called them F2 or second Filial generation. The results he obtained were postulated as
Mendel's two laws of heredity. These are as follows:
First Law is also known as *Law of segregation or also law of purity of gametes*. It says that a trait
of an individual is always determined by *two factors*, one inherited from the father and the
other from the mother. When gametes are produced, these two factors separate and a gamete
only receive one or the other.
Second law is called *Law of Independent Assortment. This law says that a*lleles of different genes
separate independently of one another when gametes are formed. So Mendel thought that
different traits are inherited independently of one another. We now know this is only true if
the genes are not on the same chromosome, in which case they are not linked to each other.
Ironically, Mendel was ahead of times in his research. His work was only identified later and
understood properly when study of cells developed and scientists knew about the nucleus,

chromosomes, genes, mitosis, meiosis etc. properly.

Non-Mendelian Inheritance

What Mendel called as "Factors" was later identified as Genes. It was later understood that the phenotype is determined by the genotype and dominant alleles. However, it was also observed later that there are many types of inheritance that don't exactly follow the Mendelian pattern. These included Polysomy (multiple alleles), gene interactions; gene linkages etc.

Other concepts

Incomplete Dominance

Incomplete dominance is when heterozygous individual presents an intermediate phenotype between the two types of homozygous ones. Example of incomplete dominance is Sickle Cell Anaemia. In Sickle Cell Anaemia, the heterozygous individual produces some sick red blood cells and some normal red blood cells.

Codominance

In codominance, heterozygous individual has a phenotype totally different from the homozygous one, and not an intermediate form. Example of Codominance is MN blood group system.

Pleiotropy

Pleiotropy is when a single gene manifests in several different phonotypical traits.

Lethal Genes

Lethal genes are genes with at least one allele that, when present in the genotype of an individual, cause death. There are recessive lethal alleles and dominant lethal alleles.

Multiple Alleles

Multiple alleles is when same gene has more than two different alleles (in normal Mendelian inheritance, the gene only has two alleles). In multiple alleles, relative dominance among the alleles may exist. Common example of Multiple alleles is ABO blood group system, in which there are three alleles (A, B or O, or IA, IB and i). IA is dominant over i, which is recessive in relation to the other IB allele. IA and IB lack dominance between themselves.

Complementary Genes

In complementary genes, a phenotypic trait is manifested by two or more genes.

General Science-6: Everyday Chemistry

States of Matter

Four States of Matter

Matter can exist in at least four fundamental states viz. solid, liquid, gas and plasma. There are other states also such as Bose–Einstein condensate, quark-gluon plasmas etc. which don't exist in our natural environment.

Basic difference between Solid, Liquid and Gas

In solids, the constituent particles are held very close to each other in an orderly fashion and there is not much freedom of movement. In liquids, the particles are close to each other but they can move around. In gases, the particles are far apart as compared to those present in solid or liquid states and their movement is easy and fast.

Because of such arrangement of particles, solids have definite volume and definite shape; the Liquids have definite volume but not the definite shape. They take the shape of the container in which they are placed. The Gases have neither definite volume nor definite shape. Gases completely occupy the container in which they are placed. These states of matter are interconvertible by changing the conditions of temperature and pressure.

Plasma

Plasma is one of the four fundamental states of matter. Plasma is basically *ionized molecules or atoms.*

The Ionization can be induced by heat or strong electromagnetic field applied with a laser or microwave generator. When this is done, the molecular bonds dissociate to give rise to Plasma.

Difference between Gas and Plasma

Like gas, plasma *does not have a definite shape or a definite volume*unless enclosed in a container.

However, unlike gas, plasma can form structures such as filaments, beams and double layers under the influence of a magnetic field.

Plasma in Universe

Plasma is most common state of matter in universe and most of it is found as rarefied inter-galactic plasma. It is found in stars and galaxies.

Plasma in appliances

In everyday life, plasma can be found in many electronic instruments such as Plasma TV, Neon Lights, Static Electric sparks etc. Further, *the area in front of a spacecraft's heat shield during re-entry into the atmosphere is a plasma.* The electric arc in an arc lamp, an arc welder or plasma torch is also plasma. Laser-produced plasmas (LPP) are created when high power lasers interact with materials.

Magnetically induced plasmas (MIP) are typically produced using microwaves as a resonant coupling method.

Concepts Related to Atoms

Atomic Number and Mass Number

Atomic Number is the *number of Protons* in nucleus of an Atom. Mass number of an element is the number of nucleons viz. Neutrons and Protons. The atomic mass number is represented by a super index in left side such as 238U. The number 238 denotes that it has total 238 of nucleons (neutrons and Protons).

Difference between Atomic Mass and Mass Number

While mass number is total number of nucleons, atomic mass is relative mass of an atom to another.

Earlier, atomic mass of Hydrogen was fixed at 1 without any units and other atoms were assigned masses relative to it. Currently, atomic mass is defined as 1/12 of a mass of an atom of the carbon-12 (12C) isotope. This is called atomic mass unit (amu) or a Dalton. On this basis, the mass of Hydrogen atom is 1.0080 amu. Mass of oxygen – 16 (16O) atom is 15.995 amu.

Nuclear Binding Energy

All the protons have a similar charge that is positive charge. To keep all the protons together which
are similarly charged (positive), a nuclear force exists which is a very short range force and works
within the nucleus. This is called Nuclear Binding energy and is released when nucleus is broken
apart via nuclear fission. Thus, the energy required to break apart or split the nucleus of the atom
into its component nucleons viz. Neutrons and Protons is also called Nuclear Binding Energy.
Due to nuclear binding energy the *mass of the atomic nucleus is always less than the sum of the individual*
masses of the nucleons. This gives an explanation to the non whole number of the atomic mass. For
example the mass of 19F is 18.9984032 u. This mass difference is called *Mass defect*. Please note that
nuclear binding energy is millions of times more than the electron binding energy.

Molecular Mass

Molecular mass is the sum of atomic masses of the elements present in a molecule. It is obtained by
multiplying the atomic mass of each element by the number of its atoms and adding them together.
For example, molecular mass of methane which contains one carbon atom and four hydrogen atoms
can be obtained as follows:
Molecular mass of methane,
(CH4) = (12.011 u) + 4 (1.008 u)
= 16.043 u
Similarly, molecular mass of water (H2O)
= 2 atomic mass of hydrogen + 1 atomic mass of oxygen
= 2 (1.008 u) + 16.00 u
= 18.02 u

Mole

One mole is the amount of a substance that contains as many particles or entities as there are atoms
in exactly 12 g (or 0.012 kg) of the 12C isotope. It may be emphasised that the mole of a substance
always contain the same number of entities, no matter what the substance may be. In order to

determine this number precisely, the mass of a carbon-12 atom was determined by a mass
spectrometer and found to be equal to 1.992648 10–23 g.

Chemical Reactions

Chemical and Physical Changes

In a physical change, substances don't change; only their molecules are rearranged. No new substance
is formed in a physical change. In Chemical Change, a chemical reaction takes place and new
substances are formed. Such reaction either takes energy or releases energy.

Examples of Physical Change

Any change in state of matter in solid, liquid or vapour and vice versa is a physical change.
For example, heating water would turn it into vapour while cooling it would turn it into ice.
Sublimation of iodine or salt; melting of gold, silver or other metals.
Absorption of water into a towel, Crumpling a piece of paper, Pulling copper into a thin wire,
cutting wood, breaking glass, ripping a paper of tin foil etc.
Dissolving sugar in water is also an example of Physical change because sugar molecules are
dispersed within the water, but the individual sugar molecules are unchanged.

Examples of Chemical Changes

Rusting of Iron (Iron reacts with Oxygen and turns into Iron Oxide)
Burning of all kinds of fuels results in release of energy and gases such as CO_2
Cooking of egg would denature the protein molecules; which uncoil and create cross links to
become solid white.
Fermentation in which yeast converts Carbohydrates to alcohol, CO_2 and other by products.
Souring of Milk results in production of lactic acid from lactose sugar
Burning of Camphor
Explosive reaction of sodium with water and phosphorous with moist air
Setting of cement
A change is considered to be chemical reaction only if chemical bonds are broken in reactants and
new bonds are formed in products. *In other words, chemical reaction is a bond breaking and bond making*

process. In some cases, the products of a reaction recombine to form the reactants back. These are called reversible reactions. Others are irreversible reactions.

During chemical changes, there is a rearrangement of atoms that makes or breaks chemical bonds. In a chemical reaction, bonds are broken and new bonds are formed between different atoms.

Dissolving salt into water is a Physical Change or Chemical Change?

Sometimes, changes are difficult to categorize into physical or chemical changes. One definition of Physical change is that may result in re-arrangement of molecules but the molecules should not be broken apart. Although dissolving salt in water involves the breaking of chemical bonds, yet is described as physical change.

Burning of Candle is a Physical Change or Chemical Change?

Burning of candle is example of both physical and chemical change. Physical change is melting and solidifying of the wax. Chemical change is the production of heat by consuming oxygen.

Rate of Chemical Reaction

The rate of a chemical reaction is defined as the change in the concentration of the reactant or product per unit time. The Factors affecting the rate of reaction are summarized as below:

Concentration of Reactants

The rate of reaction generally increases with increase in concentration of the reactants.

Temperature

Generally increase in temperature increases the rate of reaction. When the temperature increases, the reactant molecules acquire higher energy and can easily form the products. Cooked food gets spoilt quickly during summer than winter. Souring of milk is faster in summer. These are all due to the fact that the chemical reactions responsible for these changes take place faster at higher temperatures.

Presence of Light

There are certain reactions which take place or are accelerated by the absorption of light by the reactants. Such reactions are known as photochemical reactions. These reactions do not occur if the reactants are shielded from light. The combination of hydrogen and chlorine to produce hydrogen chloride does not take place at measurable rate in the dark. The plants prepare starch from carbon dioxide and water in the presence of sunlight by the process of photosynthesis. This reaction is slow in dim sunlight but it is much faster in bright sunlight.

Presence of Catalyst

A catalyst is a substance which is added to a reaction mixture to alter the rate of chemical reaction where the mass and the chemical composition of the catalyst remain unchanged at the end of the reaction. Many industrially important reactions such as manufacture of ammonia, sulphuric acid, nitric acid and polythene are carried out using suitable catalysts.

Chemical Equilibrium

In reversible chemical reactions, there is a point when forward and backward reactions proceed simultaneously at the same rate. This is called Chemical Equilibrium. For instance when hydrogen and iodine are taken in a closed vessel maintained at 717 K, hydrogen molecule combines with iodine molecule to form hydrogen iodide.

$H_2(g) + I_2(g) \longleftrightarrow 2HI(g)$

Since the reaction is reversible in nature, the molecules of hydrogen iodide formed begin to dissociate to form hydrogen and iodine.

Exothermic and Endothermic Reactions

The chemical reactions which proceed with the evolution of heat energy are called exothermic reactions. Heat evolved is expressed in Joules (J) or kilo Joules (kJ).

All combustion reactions are exothermic. These reactions proceed with the evolution of heat energy.

An important exothermic reaction occurs in our body cells which is nothing but respiration. During

respiration, glucose in food burns in oxygen and gives out heat energy. Another example is
formation of ammonia. When nitrogen combines with hydrogen in the presence of iron catalyst to
form ammonia, a lot of heat is produced. Thus, the formation of ammonia is an exothermic reaction

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + \text{Heat}$

The chemical reactions which proceed with the absorption of heat energy are called endothermic
reactions.

Why heat is evolved or absorbed in chemical reactions?

Chemical reaction involves the rearrangement of atoms. During the reaction, certain bonds are
broken while certain new bonds are formed between the atoms. If the energy required to break the
bonds is more than the energy released during the formation of bonds, then there is net absorption
of energy and the reaction is endothermic. Both exothermic and endothermic reactions are due to
the internal (intrinsic) energy that is stored within the structural units of every substance. When
nitrogen and oxygen are heated to a very high temperature, they combine to form nitrogen
monoxide and a lot of heat is absorbed in this reaction. Thus, the formation of nitrogen monoxide is
an endothermic reaction.

$N_2(g) + O_2(g) + \text{Heat} \longleftrightarrow 2NO(g)$

What is impact of Temperature on Exothermic and Endothermic Reactions?

Increase in temperature favours endothermic reactions and decrease in temperature favours the
exothermic reactions.

Acids and Bases

The term acid is derived from the Latin word *acidus* meaning sour. Bases are bitter in taste. An acid is
a substance that has the tendency to lose a proton and a base is a substance that has the tendency to
accept a proton. An acid in water gives hydrogen ions. A base in water gives Hydroxyl ion.

Key Features of Acids

Acids can be defined in many ways but generally their aqueous solutions have the following
properties.
They are sour in taste.
They turn blue litmus red.
They react with certain metals and liberate hydrogen gas.
They react with oxides and hydroxides of metals forming salt and water.
Their aqueous solutions conduct electricity

Key features of Bases

Bases are defined in various ways but generally substances having the following characteristics are
called bases.
They have a *bitter taste.*
Their aqueous solutions have a soapy touch.
They turn red litmus blue.
They react with acids to form salt and water.
Their aqueous solutions conduct electricity.

Weak and Strong acids and bases

Acids such as Hydrochloric Acid (HCl), Sulphuric Acid (H_2SO_4) and Nitric Acid (HNO_3)
which are almost *completely ionised* in aqueous solution are termed as strong acids. Acids such
as acetic acid (CH_3COOH) is partially ionised and is called a weak acid.
Similarly, bases like NaOH and KOH are almost completely ionised in aqueous solution and
are therefore called strong bases. Ammonium Hydroxide is partially ionised and is called a
weak base.

Important Notes on Acids and Bases

Acid-base indicators are dyes or mixtures of dyes which are used to indicate the presence of
acids and bases.
Acidic nature of a substance is due to the formation of $H^+(aq)$ ions in solution. Formation of
$OH^-(aq)$ ions in solution is responsible for the basic nature of a substance.
When an acid reacts with a metal, hydrogen gas is evolved and a corresponding salt is
formed. When a base reacts with a metal, along with the evolution of hydrogen gas a salt is
formed which has a negative ion composed of the metal and oxygen.

When an acid reacts with a metal carbonate or metal hydrogen carbonate, it gives the
corresponding salt, carbon dioxide gas and water.
Both acidic and basic solutions in water conduct electricity because they produce hydrogen
and hydroxide ions respectively.

pH Scale

The acidity or basicity of a solution is usually expressed in terms of function of the hydrogen ion
concentration. This function is called pH of a solution. pH of a solution may be defined as the
negative logarithm (to the base 10) of hydrogen ion concentration expressed in moles per litre.

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

For pure water and neutral solutions, at 298 K, concentration of hydrogen ions is 1×10^{-7} mol L^{-1}.
These hydrogen ions are formed by ionisation of some of the water molecules.

$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

Thus, for pure water at 298 K,

$[H^+] = [OH^-] = 1 \times 10^{-7}$ mol L^{-1}

Sp pH of distilled water is :

$-\log(1 \times 10^{-7}) = 7$

The approximate values of pH for some familiar solutions are as follows:

Solutions	pH
Blood	7.3 - 7.5
Saliva	6.5 - 7.5
Urine	5.5 - 7.5
Coffee	4.5 - 5.5
Tomato juice	4.0 - 4.4
Vinegar	2.4 - 3.4
Lemon juice	2.2 - 2.4
Gastric juice	1.0 - 3.0
Soft drinks	3
Milk	6.5
Sea water	8.5

Red Cabbage Juice as Acid Base Indicator

Red cabbage juice is known as an acid/base indicator because it has pigments in it that react differently to acids and bases. These pigment change color when exposed to an acid or a base.

Cabbage juice is naturally neutral and it has a purplish color. *When acid is added to it, it turns pink. If a base is added, it turns green.*

For example, the juice will turn pink when lemon juice is added to it. It changes to green when toothpaste is mixed with it, because toothpaste is basic in nature. *The tooth paste should be basic due to the reason, that some acids are formed by the bacteria in our mouth and these are neutralized by the bases present in the tooth paste.*

Periodic Table

Elements

Elements are pure chemical substances consisting of one type of atom. Elements can be metals, metalloids or non-metals. Examples: carbon, oxygen (non-metals), silicon, arsenic (metalloids), aluminium, iron, copper, gold, mercury, and lead (metals).

As of now, 118 elements have been defined of which 98 are known to occur naturally and 80 are
stable. Others are either radioactive, decaying into lighter elements over various timescales from
fractions of a second to billions of years or synthesized.

Most abundant elements

Hydrogen and helium are by far the most abundant elements in the universe. However, iron is the
most abundant element (by mass) making up the Earth. Oxygen is the most common element in the
Earth's crust.

Isotopes

Isotopes have different number of neutrons but same number of protons. The number of protons is
called atomic number so all isotopes have same atomic number but different number of nucleons
(neutron + proton) due to different number of neutrons. For example C12, C13 & C14 are isotopes.
Each of them has 6 protons. But they have 6, 7, 8 neutrons. So their atomic weights vary. The 80
elements with stable isotopes have atomic number of 1 to 82.
The two elements between this atomic number range elements 43 and 61 (technetium and
promethium) have no stable isotopes.
83rd element is Bismuth and from Bismuth onwards all undergo radioactive decay. They
don't have stable nuclei but are found in nature.
Remaining 24 are artificial or synthetic elements.
The first synthetic element was technetium. Technetium is found in trace amounts in nature
and was discovered in 1925 but it was synthesized in 1937.

Allotropes

Some chemical elements are known to exist in two or more different forms because the atoms are
bounded together in different manners. Most common example is Carbon which exists in Diamond,
graphite, fullerenes etc. Allotropy is for elements and NOT for compounds. For example water and
ice are not allotropes. The changes in state between solid, gas and liquid is NOT allotropy.

Oxygen has two allotropes viz. Oxygen and Ozone. These allotropes can stay in all the liquid, gaseous
and solid phases. Phosphorus has many allotropes but when melted, all return to the P4 form. The
different structural forms of the same element lead to the allotropes to show different physical
properties and chemical behaviours.

Some allotropes

Allotropes of Carbon:

Carbon has allotropes such as Diamond which is extremely hard, transparent crystal in which
atoms are arranged in a tetrahedral lattice.

Another allotrope is **Lonsdaleite** which is also known as hexagonal diamond. It has a
hexagonal lattice in comparison to the diamond which has tetrahedral crystal structure. It is
less hard than diamond (Diamond has Mohs hardness 10 while the Lonsdaleite has 7-8). It's a
brown color substance.

Another allotrope is Graphite which is soft, black and flaky and a moderate electrical
conductor. In graphite the C atoms are bonded in flat hexagonal lattices layered in sheets.
Each lattice is called a Graphene.

Amorphous carbon is another allotrope. It has no crystalline structure.

Fullerenes are other allotropes of Carbon. The fullerenes exist in various shapes such as
hollow sphere, ellipsoid, or tubes. Accordingly they have been named buckyballs (for
spherical) and buckeytubes for tube fullerenes. Tube fullerenes are the carbon nanotubes.

The first fullerene discovered was **C60 in 1985** and it was called buckministerfullerene.

Carbon nanotubes display extraordinary properties that make them potentially useful in
many applications including in nanotechnology, electronics, optics and other fields of
materials science. They exhibit extraordinary strength and unique electrical properties, and

are efficient thermal conductors. They are either single-walled nanotubes (SWNTs) and
multi-walled nanotubes (MWNTs).

Allotropes of Phosphorus

The crystalline solid phosphorous is P4 which is called white phosphorus.
The Red phosphorus is polymeric.
There are scarlet phosphorus, Violet Phosphorus, Black Phosphorus and Diphosphorus.
Black Phosphorous is a semiconductor which is very much equivalent to Graphite.

Allotropes of Oxygen

Oxygen has two allotropes Dioxygen O2, which is colourless and Ozone O3 which is blue.
Apart from this there is tetraoxygen O4 which is also called oxozone and it is metastable.
The solid oxygen is Octaoxygen which exists in 6 phases under various pressures and
temperatures; it is also called Red Oxygen.

Allotropes of Nitrogen

N2 is stable isotope. Another is unstable Polynitrogen molecule N4.

Allotropes of Sulfur

Sulfur is amorphous polymeric solid which is calledp **lastic Sulfur**, then there are S8
molecules which are large crystalline structures called Rhombic Sulfur.
Another form is fine needle like structures called monoclinic Sulfur.
Apart from that there are other ring molecules such as S7 and S12.

Periodic Table

Periodic classification attempts to arrange the chemical elements on the basis of fundamental
properties. The practice started in 19th century when Dmitri Mendeleev propounded the Mendeleev
law. This law states that the *physical and chemical properties of the elements are periodic functions of their*
atomic weights. Thus, as per this law, if the elements are arranged in the order of increasing atomic
weights; then after certain definite number there would be the elements which would have almost
same properties.
He arranged the known elements in a table and created the Periodic table. Via this table, he predicted

discovery of new elements and kept black space for them.
The periodic table of Mendeleev was modified several times later. Currently, periodic table has 7 horizontal rows (periods) and 18 vertical columns (groups). Please note that there is an extended version of the periodic table which contains 8th period. No element of the eighth period has yet been synthesized.

Group #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
* Lanthanoids			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
** Actinoids			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Periods

When we go from left to right in a period
size of atomic radius, metallic property decrease.
Electron affinity, Electron negativity, ionization potential increase
Chemical reactiveness first decreases and then increases till halogens. However, this is not applicable to last group of Nobel gases.

Groups

When we move from top to bottom in a group:
The metallic property in a group increases from top to bottom.
The chemical reactiveness of the metallic elements increases from top to bottom, while decreases in the case of non-metallic elements.

Valency is same in all groups (there are some exceptions)
Values of the electron affinity decreases from top to bottom in a group.
Values of ionization potential decreases from top to bottom.
The size of the atomic radius increases from top to bottom.

Alkali metals

The metals of First group of periodic table are alkali metals. They include Lithium (Li), Sodium (Na),
Potassium (K), Rubidium (Rb), Caesium (Cs), And Francium (Fr). Hydrogen is also a member of
group 1 but is not an alkali metal.

Key features:

They are highly reactive and are never found in elemental forms in nature.
They are usually stored immersed in mineral oil or kerosene (paraffin oil) because of their
high reactive nature.
They have low melting points and densities.
All alkali metals have silver color except caesium which has a golden color.
They react with halogens and make salts for example NaCl (table salt)
They react with water and make Hydroxides for example NaOH
Potassium and rubidium are naturally weakly radioactive elements and they each contain a
long half-life radioactive isotope.
Under standard conditions Lithium is the lightest metal and the least dense solid element.
Lithium carbonate is used in use in psychiatry
Organolithiums are also used in polymer synthesis and for creating carbon-carbon polymers.
Lithium batteries are disposable (primary) batteries with lithium metal or lithium compounds
as an anode, while the Lithium ion batteries are high energy-density rechargeable batteries.
Al-Li alloys are used in aeronautics.
The sodium vapour lamp uses sodium in an excited state to produce light.
Alkali metal as the Na+ ion is vital to animal life.
Molten sodium is used as a coolant in some types of nuclear reactors.
It decreases in blood pressure and decreases in sodium concentration sensed within the
kidney result in the production of rennin which in turn helps in secretion of anti diuretic hormones

Animal cells, potassium ions are vital to cell function. They participate in the Na-K pump and
in helping to restore the body's total amount of fluid.
Sodium is the chief cation in fluid residing outside cells in the mammalian body
Low sodium intake may lead to sodium deficiency which is known as hyponatremia.
About 93% of the world potassium production is consumed by the fertilizer industry
Potassium chloride is used in execution by lethal injection.
Potassium vapour is used in several types of magnetometers
Caesium is one among the five metals which are liquid at room temperature. These are
Mercury (melting point −39 °C), Francium (27 °C) caesium (28 °C), Gallium (30 °C) &
rubidium (39 °C)
Caesium has been used in the petroleum Industry exploration as caesium formate.
The caesium atomic clocks use the resonant vibration frequency of caesium-133 atoms as a
reference point. Precise caesium clocks measure frequency with an accuracy of from 2 to 3
parts in 1014, which would correspond to a time measurement accuracy of 2 nanoseconds per
day, or one second in 1.4 million years.

Alkaline Earth Metals

Group 2 of the periodic table is known as Alkaline earth metals and it includes the Beryllium
(Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra).
Beryllium has very low absorption for X-rays and its most important applications are in
radiation windows for X-ray tubes.
Magnesium ions are essential to all living cells, where they play a major role in manipulating
important biological polyphosphate compounds like ATP, DNA, and RNA. Hundreds of
enzymes thus require magnesium ions to function.
Magnesium is also the metallic ion at the center of chlorophyll, and is thus a common

additive to fertilizers.
Magnesium hydroxide is an inorganic compound with the chemical formula $Mg(OH)_2$. As a
suspension in water, it is often called milk of magnesia because of its milk-like appearance it
is used as an antacid and laxative.
Magnesium has three stable isotopes: ^{24}Mg, ^{25}Mg and ^{26}Mg, all are in significant amount.
Magnesium is the third most commonly used structural metal. The two most commonly used
are iron and aluminum.
It has a low weight and used in Electronic devices.
Calcium has four stable isotopes (^{40}Ca and ^{42}Ca through ^{44}Ca).
New Rocks: The uplift of mountains exposes Ca-bearing rocks to chemical weathering and releases Ca^{2+} into surface water. This Ca^{2+} eventually is transported to the ocean where it
reacts with dissolved CO_2 to form limestone. Some of this limestone settles to the sea floor
where it is incorporated into new rocks.
Dissolved CO_2, along with carbonate and bicarbonate ions, are referred to as Dissolved
Inorganic Carbon (DIC).
Making of cheese, where calcium ions influence the activity of rennin in bringing about the
coagulation of milk.
Calcium plays an important role in building stronger, denser bones early in life and keeping
bones strong and healthy later in life.
Approximately ninety-nine percent of the body's calcium is stored in the bones and teeth.
Vitamin D is added to some calcium supplements. Proper vitamin D status is important
because vitamin D is converted to a hormone in the body which then induces the synthesis of
intestinal proteins responsible for calcium absorption.
Strontium is named after a village in Scotland where it was first discovered.
The ^{90}Sr isotope is present in radioactive fallout and has a half-life of 28.90 years
Barium sulphate is used for its heaviness, insolubility, and X-ray opacity.

133Ba, is routinely used as a standard source in the calibration of gamma-ray detectors in
nuclear physics studies
Barium sulphate is used as a radio contrast agent for X-ray imaging of the digestive system
("barium meals)
The most stable isotope of radium is 226Ra, has a half-life of 1601 years and decays into
radon gas.
Radium is over one million times more radioactive than the same mass of uranium, Handling
of radium has been blamed for **Marie Curie's death due to aplastic anaemia.**

Metals versus Non-Metals

On the basis of their properties, the elements are broadly classified into metals and non-metals. The
metals have been placed on the left hand side and in the centre of the periodic table, whereas nonmetals
have been placed on the right hand side. There are certain elements which show the
properties of both metals and non-metals and these are called metalloids. The metals and non-metals
in the periodic table are separated by a zig-zag line of metalloids. The metalloids are bismuth, silicon,
germanium, arsenic, antimony, tellurium and polonium.
The following table differentiates between metals and non metals with their general properties.

Metals	Non Metals
Except mercury, all metals all solids at room temperature	Non-metals can be solids, liquids or gases. For example bromine is a liquid.
Metals are hard and malleable and can be beaten into thin sheets.	Non-metals are brittle
They are generally lustrous	They are generally not lustrous (Iodine, graphite and diamond are lustrous)
They are ductile and can be stretched into wires.	They are generally non ductile except some as Carbon fibre
They are sonorous and clang if they are hit.	Non-sonorous
They are good conductors of heat and electricity.	Except some examples such as Graphite, Non-metals are bad conductors of heat and electricity
Generally hard (except sodium and potassium) and have high tensile strength	Generally soft exception diamond.
Generally high density	Generally low density
Generally high melting and boiling points (except sodium and potassium)	Generally low melting and boiling points (exception graphite)
Metals react with oxygen and forms metal oxides. which are mostly basic in nature. Aluminium and zinc oxides exhibit acidic as well as basic properties. Such metal oxides are known as amphoteric oxides.	Non-metals react with oxygen and form acidic or neutral oxides. Carbon and sulphur form acidic oxides. Hydrogen forms a neutral oxide

Minerals

A mineral is a naturally occurring substance that is solid and stable at room temperature, representable by a chemical formula, usually abiogenic, and has an ordered atomic structure. It is different from a rock, which can be an aggregate of minerals or non-minerals, and does not have a specific chemical composition. There are around 5000 known minerals. The diversity and abundance of mineral species is controlled by the Earth's chemistry. Silicon and oxygen constitute approximately

75% of the Earth's crust, which translates directly into the predominance of silicate minerals.
Minerals are distinguished by various chemical and physical properties. Differences in chemical
composition and crystal structure distinguish various species, and these properties in turn are
influenced by the mineral's geological environment of formation.
The general definition of a mineral encompasses the following criteria: Naturally occurring
Stable at room temperature
Represented by a chemical formula
Usually abiogenic
Ordered atomic arrangement
As the composition of the Earth's crust is dominated by silicon and oxygen, silicate elements are by
far the most important class of minerals in terms of rock formation and diversity. However, nonsilicate
minerals are of great economic importance, especially as ores. Non-silicate minerals are
subdivided into several other classes by their dominant chemistry, which included native elements,
Sulfides, halides, oxides and hydroxides, carbonates and nitrates, borates, sulphates, phosphates, and
organic compounds. The majority of non-silicate mineral species are extremely rare (constituting in
total 8% of the Earth's crust), although some are relative common, such as calcite, pyrite, magnetite,
and hematite.

Minerals versus Ores

The Inorganic elements or compounds of various metals found in nature, associated with their
earthly impurities are called Minerals. For example, sodium chloride – NaCl, potassium chloride –
KCl, calcium carbonate, – $CaCO_3$, magnesium carbonate – $MgCO_3$, zinc sulphide – ZnS, cuprous
sulphide – Cu_2S etc., which are found in nature are minerals. Some minerals may contain a large
percentage of metals whereas others may contain only a small percentage. All the minerals cannot be

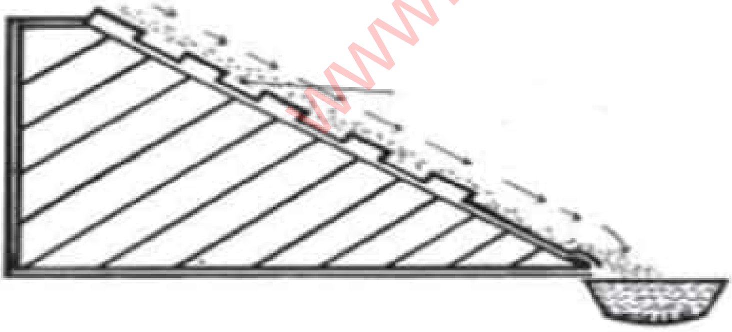
used to extract metals. Those minerals from which metals can be extracted profitably and
conveniently are called Ores.
There are four types of Ores
Oxide ores: Bauxite $Al_2O_3.2H_2O$, Cuprite Cu_2O, Zincite ZnO, Haematite Fe_2O_3, Pyrolusite
MnO_2
Sulphide ores : Copper pyrites $CuFeS_2$, Argentite Ag_2S, Zinc blende ZnS, Cinnabar HgS,
Galena PbS and Copper glance Cu_2
Carbonate ores : Limestone $CaCO_3$, Calamine $ZnCO_3$.
Halide ores : Rock salt $NaCl$, Fluorspar CaF_2
Basics of Metallurgy
The process of extracting metals from their ores followed by refining is known as metallurgy. The
four steps usually employed in metallurgy are :
Concentration of ore (or enrichment of ore)
Conversion of concentrated ore into metal oxide.
Reduction of metal oxide to metal
Refining of impure metal.

Concentration of ores

Ores are usually associated with unwanted earthly matter called gangue (sand, clay etc.,) and the
removal of this unwanted impurity is called concentration. Concentration of ores is generally carried
out by any one of the following processes

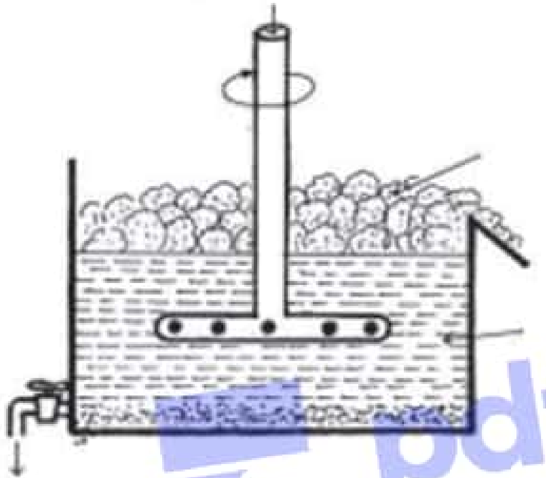
Gravity separation

The method is generally used for the concentration of oxide ores. The ore is thoroughly crushed,
sieved and levigated in a stream of water. The heavier ore particles stay back while the lighter earthly
impurities are washed away.



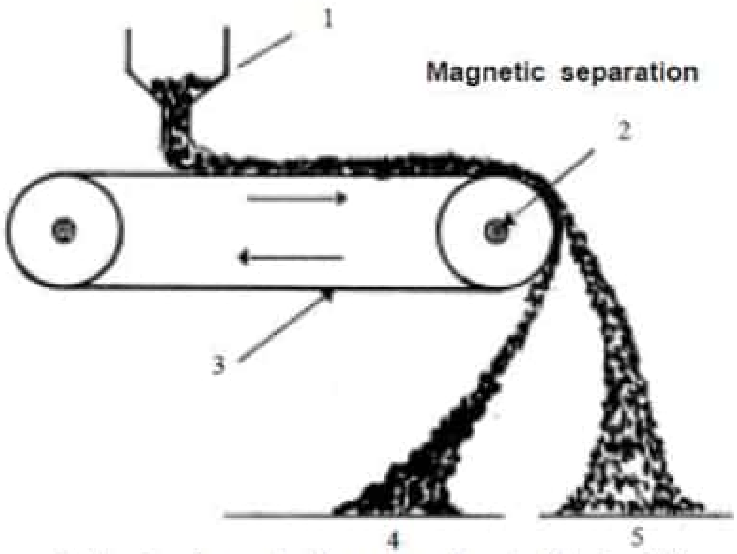
Froth floatation process

The process is commonly employed for the concentration of sulphide ores, which are preferentially wetted by oils. The well powdered ore is added to a mixture of pine or eucalyptus oil and water and agitated by flowing air into the mixture. The ore which is wetted by oil comes to the surface with the froth while the impurities go to the water layer below.*For example, Zinc sulphide and Galena are concentrated by this method.*



Electromagnetic separation

If one of the impurities present is magnetic in nature, it can be removed by this method. Thus, tinstone, an ore of tin, contains *Wolframite as an impurity, which is paramagnetic (i.e., attracted by a magnet).* To remove wolframite the powdered tinstone ore is dropped over a travelling belt passing over electromagnetic rollers. Wolframite being paramagnetic is attracted and collected in a heap near the magnets while tinstone is dropped away from the roller and forms another separate heap.



1. Powdered ore 2. Magnetic roller 3. Moving belt
4. Magnetic impurities 5. Non-magnetic ore particles

Conversion of concentrated ore into metal oxide

Calcination

It is the process of heating the concentrated ore in the controlled supply of air at a temperature sufficient to melt the ore.

$$FeCO_3 \xrightarrow{\Delta} FeO + CO_2 \uparrow$$

$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$$

During calcination process, the moisture and volatile impurities are removed from the concentrated ore and the mass becomes porous. Decomposition of the ores may also take place. Thus, in the case of oxide ores water is lost from the ores and Carbonate ores undergo decomposition with the evolution of carbon dioxide leaving behind a porous oxide ore.

Roasting

Roasting is the name of process of heating the concentrated ore strongly in the presence of excess air.
Usually, sulphide ores are subjected to roasting. For example, zinc sulphide gives zinc oxide on roasting.

$$2\ ZnS + 3O_2 \xrightarrow{\Delta} 2\ ZnO + 2SO_2 \uparrow$$

Reduction of metallic oxide to the metal

Reduction is carried out either by electrolysis or by smelting.

Electrolysis

Electrolysis is the process employed for highly electropositive metals which cannot be reduced by reducing agents such as carbon, carbon monoxide, hydrogen etc., Electrolysis is carried out on fused metallic salts (halides or oxides) resulting in deposition of metal ions at cathode. Oxides of potassium, sodium, calcium, magnesium and aluminium are reduced to metals by electrolysis of their fused metallic salts.

Smelting

The calcined or roasted ore is reduced to the metallic form. The high temperature reduction process in which the metal is usually obtained in a molten state is called smelting. The smelting operations are usually carried out in the presence of a flux.

Metallic oxides are reduced to metals by coke, carbon monoxide or hydrogen. Zinc oxide is reduced by coke. Oxides of Iron, lead and copper are reduced by carbon, carbon monoxide or hydrogen.

Oxides of Mercury and silver are reduced by thermal decomposition.

Refining of metals

The metals obtained by any of the methods described above need further purification as they may contain other metals, dissolved oxides, carbon, phosphorous etc. The following methods are employed for refining.

Distillation

This is employed for purifying volatile metals like zinc and mercury. On heating, pure metal is vaporised, condensed and gets collected and non-volatile impurities remain behind.

Liquation

It is used for refining easily fusible metals having low melting point like tin. Impure metal is placed on the inclined bed of a furnace and heated. When the metal melts, it flows down leaving the nonfusible impurities behind.

Oxidation

If the impurities present in a metal can be easily oxidised, then the metal is refined by stirring the
molten mass thoroughly in the presence of air. During this process, the impurities come to the
surface in the form of a scum and can be skimmed off.

Electrolytic refining

The impure metal to be refined is made as anode and the cathode consists of a piece of pure metal in
an electrolyte which is a suitable salt of the impure metal. Pure metal gradually passes from the anode
to the cathode while the impurities settle to the bottom. Copper, tin, lead, aluminium etc., are
purified by this method.

Some basic terms related to Metallurgy

Gangue or matrix

The ore mined from the earth's crust contains some unwanted substances or impurities such as sand,
rocky or clay materials. These substances are called gangue or matrix. The gangue has to be removed
before the extraction of metals.

Flux

A flux is a substance that is added to the furnace charge (roasted or calcined ore and coke) during the
process of smelting to remove the non-fusible impurities present in the ore.

Slag

Flux combines with non-fusible impurities to convert them into fusible substances known as slag. It
is being light, floats over the molten metal and is removed from there. Impurities present in metal
oxides may be acidic or basic. For acidic impurities, such as silica or phosphorus pentoxide (SiO_2 or
P_2O_5), calcium oxide is added as a flux to the mixture during smelting. If basic impurities such as
manganese oxide are present, silica is added as a flux.

Important Inorganic Compounds

Sodium Carbonate / Washing Soda

Washing soda is sodium carbonate decahydrate, $Na_2CO_3.10H_2O$. Sodium carbonate was made from

the ash of sea weeds, once upon a time. It was also found to occur as an efflorescent deposit (Trona,
$Na_2CO_3.\ NaHCO_3.2H_2O$) in Egypt. In India, an efflorescent soil called **Sajimati**, which is a mixture
of sodium carbonate, sodium bicarbonate, sodium sulphate and clay is found in places such as
Dehradun, Mathura and Varanasi.
Sodium carbonate is one of the most important industrial chemicals. First, anhydrous sodium
carbonate is manufactured by the Solvay process (ammonia-soda process) and then it is converted
into sodium carbonate decahydrate which is called washing soda.

Why washing Soda Effloresce in water?

Washing soda is a transparent, crystalline solid, soluble in water and the solution is found to be
alkaline as it turns red litmus blue. Washing soda, the decahydrate of sodium carbonate effloresces in
air forming sodium carbonate monohydrate. Efflorescence is the process of losing water of
crystallization from a hydrated salt when kept exposed to air for a long time.

$Na_2CO_3.10H_2O \rightarrow Na_2CO_3.H_2O + 9H_2O$

The so formed monohydrate, $Na_2CO_3.H_2O$ is a white amorphous solid, which is stable in air.

How Soda Ash is obtained from Washing Soda?

On heating, washing soda gives **anhydrous sodium carbonate** called soda ash.

$Na_2CO_3\ .10H_2O \rightarrow Na_2CO_3 + 10H_2O$

Major applications of Sodium Carbonate

Sodium carbonate is used
In the manufacture of paper, soap, textiles, paints, etc.
In laundry as washing soda and as a cleaning agent for domestic purposes.
As an important laboratory reagent both in qualitative and quantitative analysis.
In softening of hard water.

Role of Sodium Carbonate in Softening of hard water

Hardness of water is due to the presence of soluble salts of calcium and magnesium. When washing
soda is dissolved in hard water, calcium and magnesium salts which cause hardness, react with

washing soda and gets precipitated as insoluble solids, thus leaving the water soft.

$Na_2CO_3 + MgSO_4 \rightarrow Na_2SO_4 + MgCO_3$

Baking Soda

Sodium Bicarbonate $NaHCO_3$ is known as baking soda. It is also manufactured by Solvay process. In

Laboratory, it can be prepared by saturating aqueous solution of sodium carbonate with carbon

dioxide.

$Na_2CO_3 + CO_2 + H_2O \rightarrow 2NaHCO_3$

Baking soda is a white solid. It is sparingly soluble in water and the solution is slightly alkaline which

turn red litmus blue.

Baking powder is a mixture of sodium bicarbonate and tartaric acid. Baking powder is used in

aerated drinks and as an additive in food stuff to make it soft. Sodium carbonate produced during

baking is neutralised by tartaric acid present in baking powder.

How baking soda helps in baking?

When it is heated, it decomposes with the evolution of carbon dioxide gas. Hence, it is used as a

constituent of baking powder to soften the dough and to aerate the drinks. The evolution of carbon

dioxide also makes it useful for fire extinguishers.

$$2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2\uparrow + H_2O$$

It gives brisk effervescence with acids due to the liberation of carbon dioxide

$$NaHCO_3 + HCl \longrightarrow NaCl + CO_2\uparrow + H_2O$$

Bleaching Powder

Bleaching powder is chemically, calcium oxychloride ($CaOCl_2$). Bleaching powder is manufactured

using Backmann's plant in which slack lime and Chlorine are made to react to create Bleaching

Powder.

Bleaching powder is a yellowish white powder with a strong smell of chlorine. When exposed to air,

bleaching powder gives a smell of chlorine. This is because bleaching powder reacts with carbon

dioxide from the atmosphere to produce calcium carbonate and chlorine.

$CaOCL_2+CO_2 \rightarrow CaCO_3 + Cl_2$

Working of Bleaching Powder

In the presence of a very small amount of dilute acid, it gives nascent oxygen. Due to the evolution of
nascent oxygen, it acts as an oxidising and a bleaching agent.

$2CaOCl_2 + H_2SO_4 \rightarrow CaCl_2 + CaSO_4 + 2HOCl$

$2HOCl \rightarrow 2HCl + 2\,[O]$

When it is treated with excess of dilute acids, chlorine is evolved. Chlorine gas produced in this way
is known as, "available chlorine" which is responsible for the bleaching action of bleaching power.

Available chlorine in bleaching powder is usually 35 – 38% by weight. The strength of bleaching
powder is estimated on the basis of available chlorine content.

$CaOCl_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O + Cl_2$

$CaOCl_2 + 2HCl \rightarrow CaCl_2 + H_2O + Cl_2$

Bleaching powder is used to bleach cotton and linen in textile industry and wood pulp in paper
industry. It is also used to bleach washed clothes in laundry. Bleaching powder is also used as a
disinfectant and germicide, ***since it liberates chlorine***on exposure to the atmosphere which
destroys the germs. It is also used for disinfecting water for the same reason. It is also used as an
oxidising agent in many chemical industries

Plaster of Paris

Plaster of Paris is calcium sulphate hemihydrates. The formula is given as, $CaSO_4.1/2H_2O$ or
$(2CaSO_4).H_2O$. The powder is called plaster of Paris, because the gypsum which was used to get the
powder was mainly found in Paris. POP is prepared by heating gypsum at 373K in rotary kilns,
where it gets **partially dehydrated**.

$$CaSO_4 . 2H_2O \xrightarrow{373K} CaSO_4 . \tfrac{1}{2}H_2O + 1\tfrac{1}{2} H_2O$$

gypsum plaster of Paris

$$2(CaSO_4 . 2H_2O) \xrightarrow{373K} (2CaSO_4) . H_2O + 3H_2O$$

If the temperature is not maintained carefully, further dehydration will take place at higher temperature and setting property of the plaster will be partially reduced.

$CaSO_4.2H_2O \rightarrow CaSO_4 + 2H_2O$

How POP works?

Plaster of Paris is a white powder. When it is mixed with water (1/3rd of its mass), gypsum is obtained back. It initially forms a plastic mass with the evolution of heat and then sets to a hard solid mass within 5 to 15 minutes. Setting of plaster of Paris is accompanied by a slight expansion (about 1%) in volume which makes it suitable for making casts for statues, toys, etc. The setting of plaster of Paris can be catalysed by adding sodium chloride to it.

Cement

Cement was first discovered by an English brick layer named Joseph Aspdin in 1824. He called it Portland cement for the reason that the cement he discovered, resembled the limestone found in Portland. The approximate composition of Portland cement is given below

Lime (CaO) : 60 – 70%
Silica (SiO_2): 20 – 25%
Alumina (Al_2O_3): 5 – 10%
Ferric oxide (Fe_2O_3): 2 – 3 %

The raw materials used for the manufacture of Portland cement are limestone (provides CaO) and clay (provides SiO_2 , Al_2O_3 and Fe_2O_3) which are finely powdered and then mixed in the ratio 3 : 1 by mass. The mixture is again ground to a fine powder and water is added. The finely ground powder called **slurry** is heated to 1773 K in a rotary kiln. On heating, lime, silica, alumina and ferric oxide react together and produces a mixture of dicalcium silicate, tricalcium silicate and tricalcium aluminate called **clinker**. The clinker is cooled and a small amount of gypsum (2 – 5%) is added to it, **to delay the setting time of cement.** The mixture of clinker and gypsum is then ground to a fine powder which is called cement. It is stored in tall structures called silos. The cement is then packed in water-proof bags and sold in markets.

When cement is mixed with water, it becomes hard over a period of time. This is called setting of cement. Gypsum is often added to Portland cement to prevent early hardening or "flash setting", allowing a longer working time.

Glass

The approximate composition of ordinary glass is given by the formula, $Na_2O.CaO.6SiO_2$. The raw materials required for the manufacture of ordinary glass are sodium carbonate, calcium carbonate and silica. The raw materials are ground separately to a fine powder, weighed accurately and mixed in a definite proportion. The mixture is called batch.

A specific amount of cullet (broken pieces of glass) is added to increase the fusibility of the glass produced The mixture is heated in fire clay pots or in a tank furnace. The pots (or tanks) are heated by using producer gas. The burning of gases produces a high temperature of about 1673 K in the furnace. The raw materials present in the batch melt at this high temperature and react with one another to form glass. **Carbon dioxide is evolved during the reaction**.

Annealing of Glass

The **slow and uniform cooling** of Glass is called Annealing. The glass articles are made by pouring molten glass into moulds and then cooling. If the glass is cooled rapidly, it becomes very brittle and cracks easily and if it is cooled very slowly, it becomes opaque. Therefore, it should be cooled neither very slowly nor very quickly. In the annealing process, the hot glass articles are placed on a slow

moving belt which passes through a long narrow chamber in which the temperature is regulated
carefully so that it is hot at the starting point and at room temperature at the other end. It takes
several days for completion.

Soda glass or soda-lime glass

It is the most common variety of glass. It is prepared by heating sodium carbonate and silica. It is
used for making windowpanes, tableware, bottles and bulbs.

Coloured Glass

Small amounts of metallic oxides are mixed with the hot molten mixture of sand, sodium carbonate
and limestone. The desired color determines the choice of the metallic oxide to be added, as different
metallic oxides give different colors to the glass.

Chemicals Used in Making of Colored Glass

Iron oxide is used to produce bluish-green glass (used in beer bottles). Chromium along with
Iron Oxide gives richer green color, used for wine bottles.
Sulfur + Carbon + Iron salts make iron polysulfides, which give amber glass ranging from
yellowish to almost black.
In borosilicate glasses rich in boron, sulfur imparts a blue color. With calcium it yields a deep
yellow color
Manganese is added to remove the green tint given by iron. Manganese dioxide, which is
black, is used to remove the green color from the glass; in a very slow process this is
converted to sodium permanganate, a dark purple compound.
In New England some houses built more than 300 years ago have window glass which is
lightly tinted violet because of the above chemical change; and such glass panes are prized as
antiques
Small concentrations of cobalt (0.025 to 0.1%) yield blue glass.
2 to 3% of copper oxide produces a turquoise color.
Nickel, depending on the concentration, produces blue, or violet, or even black glass.
Lead crystal with added nickel acquires purplish color.

Nickel together with a small amount of cobalt was used for decolorizing of lead glass.
Uranium (0.1 to 2%) can be added to give glass a fluorescent yellow or green color. Uranium
glass is typically not radioactive enough to be dangerous, but if ground into a powder, such as
by polishing with sandpaper, and inhaled, it can be carcinogenic. When used with lead glass
with very high proportion of lead, produces a deep red color.

Safety glass

It is made by placing a sheet of plastic such as celluloid between sheets of glass.

Laminated glass

It can also be called bulletproof glass. Several layers of safety glass are bound together with a
transparent adhesive.

Flint Glass

Optical glass is softer than any other glass. It is clear and transparent. Potassium and lead silicates are
used in making optical glass. It is also called flint glass. The main use of flint glass is in the
manufacture of lenses, prisms and other optical instruments.

Pyrex glass

Pyrex glass is highly heat resistant. In ordinary glass, silica is the main constituent. In pyrex glass
some of the silica is replaced by boron oxide. **Boron oxide expands very little when heated,**
thus, pyrex glass does not crack on strong heating. Pyrex glass is also called borosilicate glass. It
has a high melting point and is resistant to many chemicals. Laboratory equipment and ovenware are
made of pyrex glass.

Photo-chromatic glass

Photochromatic pr Photochromic glass acquires a darker shade when exposed to bright light and
returns to its original lighter shade in dim light. This happens becauses **ilver halides (iodide or**
chloride) is added to this glass. Plastic photochromic lenses rely on organic photochromic

molecules (such as oxazines and naphthopyrans) to achieve the reversible darkening effect.

Lead crystal glass

Lead crystal glass has high refractive index, and so has the maximum brilliance. It sparkles and is used for high quality art objects and for expensive glassware. It is also called cut glass because the surface of the glass objects is often cut into decorative patterns to reflect light. In order to increase the refractive index, **lead oxide is used as flux in crystal glass**, therefore it is also called **lead crystal glass.**

Organic Compounds

Carbon Compounds

Cells in our body are made of proteins. The fossil fuels are the important energy resources. The life saving antibiotics and drugs play a vital role in our day to day life. In recent years, many synthetic polymer products like polyethylene terephthalate (PET) polyethylene, nylon, terylene, bakelite, etc. are widely used in various fields.. Soaps, detergents and many cleansing agents are useful for domestic and industrial purposes. The above mentioned products namely, proteins, fossil fuels, antibiotics, drugs, synthetic polymers, soaps and detergents are compounds of carbon. Carbon exhibits a characteristic property called catenation by which carbon atoms can attach themselves with one another and due to this property, a large number of carbon compounds are existing. The role of carbon and its compounds in our daily life shows the importance of the study of these compounds.

Carbon forms a large number of compounds with hydrogen. Compounds containing only carbon and hydrogen are called Hydrocarbons. Many carbon compounds, in addition to hydrogen, also contain some elements like oxygen, nitrogen, halogens (chlorine, bromine and iodine) and sulphur.

Defining Organic Molecule

The difference between organic and inorganic molecules has been a subject of debate. An organic
molecule is considered to be a molecule that plays role in organic activities.
All organic molecules have Carbon.
Oxygen may or may not be present, for example CH3 (methane) is organic despite not having
Oxygen.
The presence of C–C and C–H bonds are also not needed in some important molecules to call
them organic. For example, Urea has no C–H bond. The same is with Oxalic Acid.
Then C–C bond is neither present in methane, nor in Carbon Tetra Chloride.
Thus, there is no "official" definition of an organic compound. Some textbooks define an organic
compound as one containing one or more C-H bonds; others include C-C bonds in the definition.
Others state that if a molecule contains carbon-it is organic. One more definition is that except
hydrocarbons, **organic compounds** consists of two parts, namely a reactive part which is known as
Functional group and a skeleton of carbon and hydrogen atoms called alkyl radical**F. unctional
group** may be defined as an atom or group of atoms which is responsible for the characteristic
properties of the compound. The chemical properties of an organic compound are determined by the
functional group and the physical properties of an organic compound are determined by the
remaining part of the molecule.

Classification of organic compounds based on functional groups

Alcohols

Organic compounds containing -OH as the functional group are known as Alcohols. For example,
methanol (CH_3OH), ethanol (C_2H_5OH), propanol (C_3H_7OH), Butanol (C_4H_9OH) etc., are alcohols.
Most of the characteristic properties of alcohols are due to the presence of the -OH group.

Aldehydes

Organic compounds containing –CHO as the functional group are known as aldehydes. For example, methanal (HCHO), ethanal (CH_3CHO), propanal (CH_3CH_2CHO), butanal ($CH_3CH_2CH_2CHO$) etc., are aldehydes.

Ketones (>C=O)

Organic compounds containing >C=O as the functional group are known as ketones. For example, propanone (CH_3COCH_3), Butanone ($CH_3CH_2COCH_3$) are ketones.

Carboxylic acids

Organic compounds containing carboxyl group (-COOH) as the functional group are known as carboxylic acids. For example, methanoic acid (HCOOH), ethanoic acid (CH_3COOH), propanoic acid (CH_3CH_2COOH), butanoic acid ($CH_3CH_2CH_2COOH$) etc., are carboxylic acids.

Saturation in Organic Chemistry

In organic chemistry, a saturated compound has **no double or triple bonds or ring**. In saturated hydrocarbons, every carbon atom is attached to two hydrogen atoms, except those at the ends of the chain, which bear three hydrogen atoms. In the case of saturated ethane, each carbon centre has four single bonds as is characteristic of other saturated hydrocarbons, alkanes. In contrast, in alkenes such as ethylene (C_2H_4), double bonds are common. Thus, like other alkenes, ethylene is unsaturated. The degree of unsaturation specifies the amount of hydrogen that a compound can bind. The term is applied similarly to the fatty acid constituents of fats, which can be either saturated or unsaturated, depending on whether the constituent fatty acids contain carbon

carbon double bonds. Unsaturated is used when any carbon structure contains double or occasionally triple bonds. Many vegetable oils contain fatty acids with one (monounsaturated) or more (polyunsaturated) double bonds in them. The bromine number is an index of unsaturation.

Alkanes

Chain compounds in which all carbon-to-carbon bonds are only simple single bonds (C-C) are called
ALKANES. They are also called saturated hydrocarbons, because each carbon-to-carbon bond is a
single bond, and the valence of the carbon atom is, therefore, saturated.
No more atoms can be bonded to the atoms in the compound, without breaking the compound into
two or more fragments. If it contains one or more bonds which can react with hydrogen it is called
an unsaturated hydrocarbon. Almost all other organic compounds can be named as derivatives of
these simple hydrocarbons. Alkanes which have long carbon chains are often called paraffins in
chemical industry. The general formula of alkanes is C_nH_{2n+2}.
The simplest alkane is the gas methane, whose molecular formula is CH_4. Methane exists as a
tetrahedral shape, but it is often represented by a flattened structure as are most organic compounds.
Flattened structures for the three simplest alkanes are given in the adjacent figure. In many cases the
structures can be further simplified without loss of information by omitting all single bonds and
writing the letter symbol of the element close to the letter symbol of the element to which it is
attached.
Thus the representation of methane as CH_4, ethane as H_3CCH_3 (rather than as C_2H_6), and propane
as $H_3CCH_2CH_3$ (rather than as C_3H_8) is a representation of structure as well as of molecular
composition.
The alkanes above propane are named by giving the number of carbons (in Greek) with the ending -
ane added. If an alkane is not a straight chain, then the longest straight chain in it is used as the basis
of the name and the shorter side chains are considered to be substituents; thus names such as
methylpropane and methylbutane are derived.

Name	Molecular Formula	Structural Formula	Boiling Point (°C)
Methane	CH_4	CH_4	-161.0
Ethane	C_2H_6	CH_3CH_3	-88.5
Propane	C_3H_8	$CH_3CH_2CH_3$	-42.0
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$	0.5
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	36.0
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	68.7
Heptane	C_7H_{16}	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	98.5
Octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$	125.6
Nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$	150.7
Decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$	174.1

Saturated hydrocarbons occur in three forms: **straight-chain forms** , **branched chain forms** and cyclic forms which are known as cycloalkanes. The cycloalkanes contain only single bonds, and have the general formula CnH2n. Cyclomethane and cycloethane obviously cannot exist, but cyclopropane can; it is a triangular stable structure, though somewhat reactive because the bond angles are somewhat strained to form the triangular structure. The bond angles in cyclopropane are those of an equilateral triangle, 60 degrees, as compared to the tetrahedral bond angle of 109.5 degrees.

Cyclobutane is a square structure; it is less reactive than cyclopropane because the bond angle strain is less, 90 degrees compared to the tetrahedral bond angle of 109.5 degrees. Cyclopentane and larger cycloalkanes are, like the normal alkanes, quite unreactive; there is no significant bond angle strain in these molecules.

Notable Observations about Alkanes

Alkanes occur in nature in various ways; biologically they are not among the essential materials.

Musk of the Musk dear contains Cycloalkanes with 14 to 18 carbon atoms.

Methanogens are the bacteria that are found in the guts of cows, produce large quantities of methane by the metabolism of carbon dioxide or other oxidized organic compounds. The energy is released by the oxidation of hydrogen as follows:

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

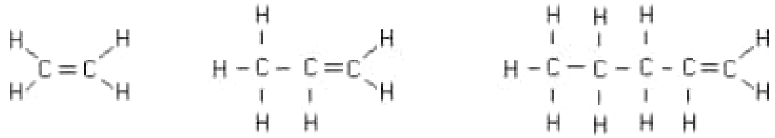
First four alkanes are used mainly for heating and cooking purposes and in some countries
for electricity generation. Methane and ethane are the main components of natural gas; they
are normally stored as gases under pressure. It is, however, easier to transport them as liquids:
This requires both compression and cooling of the gas.
Propane and butane can be liquefied at fairly low pressures, and are well known as liquefied
petroleum gas (LPG). Propane, for example, is used in the propane gas burner and as a fuel
for cars, butane in disposable cigarette lighters. The two alkanes are used as propellants in
aerosol sprays.
From pentane to octane the alkanes are reasonably volatile liquids. They are used as fuels in
internal combustion engines, as they vaporise easily on entry into the combustion chamber
without forming droplets, which would impair the uniformity of the combustion. Branchedchain
alkanes are preferred as they are much less prone to premature ignition, which causes
knocking, than their straight-chain homologues. This propensity to premature ignition is
measured by the **octane rating** of the fuel, where 2,2,4-trimethylpentane (isooctane) has an
arbitrary value of 100, and heptane has a value of zero.
Apart from their use as fuels, them iddle alkanes are also good solvents for nonpolar
substances.
Alkanes from nonane to hexadecane (C16) are liquids of higher viscosity, less and less suitable
for use in gasoline. They form instead the major part of diesel and aviation fuel. Diesel fuels
are characterized by their **cetane number**, cetane being an old name for hexadecane.
However, the higher melting points of these alkanes can cause problems at low temperatures
and in Polar Regions, where the fuel becomes too thick to flow correctly.

Alkanes from hexadecane upwards form the most important components of fuel oil and
lubricating oil. In the latter function, they work at the same time as anti-corrosive agents, as
their hydrophobic nature means that water cannot reach the metal surface. Many solid
alkanes find use as paraffin wax, for example, in candles. This should not be confused
however with true wax, which consists primarily of esters.
Alkanes with a chain length of approximately 35 or more carbon atoms are found in bitumen,
used, for example, in road surfacing. However, the higher alkanes have little value and are
usually split into lower alkanes by cracking.
Some synthetic polymers such as polyethylene and polypropylene are alkanes with chains
containing hundreds of thousands of carbon atoms. These materials are used in innumerable
applications, and billions of kilograms of these materials are made and used each year.

Alkenes

An alkene, olefin, or olefine is an unsaturated chemical compound containing at least one carbon-tocarbon
double bond.. Thus, Alkenes are the simplest of the unsaturated hydrocarbons, hydrocarbons
which will react with hydrogen.
<blockquote>An alkene may be distinguished from an alkane by shaking the hydrocarbon with
bromine water. Bromine water is reddish-brown, and will decolorize with an alkene but not with
an alkane. Bromine adds across the double bond of an alkene to form a colourless dibromo alkane.
This is an example of an addition reaction. An addition reaction occurs when two or more reactants
join together to form a single product.
Alkenes contain one or more reactive double bonds between carbon atoms, and are easily indicated
by the symbol =. Since a double bond requires two carbon atoms, the simplest alkene is C2H4 or

$H_2C=CH_2$, ethene. The presence of a double bond is indicated by the change of ending from -ane to -ene. An older form of the name, ethylene, is used in chemical industry. The general formula is C_nH_{2n}. All alkenes have at least one double bond.



Ethene Propene Pentene

C_2H_4 C_3H_6 C_5H_{10}

Alkenes and Cycloalkanes have the same general formula, C_nH_{2n}. Therefore, the general formula does not identify the structure as an alkene nor a cycloalkane. To further become problematic there are alkenes which contain more than one double bond. Those with two double bonds have the formula, C_nH_{2n-2}.

The physical properties of alkenes are comparable with those of alkanes. The main differences between the two are that the acidity levels of alkenes are much higher than the ones in alkanes. The physical state depends on molecular mass. The simplest alkenes, ethene, propene and butene are gases. Linear alkenes of approximately five to sixteen carbons are liquids, and higher alkenes are waxy solids.

Alkenes are relatively stable compounds, but are more reactive than alkanes. Some common reactions related to alkenes are as follows:

Hydrogenation

Hydrogenation of alkenes produces the corresponding alkanes. The reaction is carried out under pressure at a temperature of 200 °C in the presence of a metallic catalyst. Common industrial catalysts are based on platinum, nickel or palladium.

Oxidation

Alkenes are oxidized with a large number of oxidizing agents. In the presence of oxygen, alkenes burn with a bright flame to produce carbon dioxide and water.

Ozonolysis

Ozonolysis is the cleavage of an alkene or alkyne with ozone to form organic compounds in which
the multiple carbon–carbon bond has been replaced by a double bond to oxygen. The outcome of the
reaction depends on the type of multiple bond being oxidized and the workup conditions. Alkenes
can be oxidized with ozone to form alcohols, aldehydes or ketones, or carboxylic acids.

Notable Points about Alkenes

Alkenes are unsaturated hydrocarbons with one double bond (R-C=C-R). They are from a
homologous series with the general formula CnH2n. The 1st member to possess this functional
group is ethane, C2H4. Ethene is an important raw material for the petrochemical industry.

Alkenes are extremely important in the manufacture of plastics. All plastics are in some way related
to alkenes. The names of some plastics (Polythene or Poly Ethene, Polypropene), relate to their
alkene partners. Plastics are used for all kinds of tasks, from packaging and wrapping, to clothing and
outdoor apparel.

Lower alkenes are used as fuel and illuminant. These may be obtained by the cracking of
kerosene or petrol.

For the manufacture of a wide variety of polymers, e.g., polyethene, polyvinylchloride (PVC)
and teflon etc.

As raw materials for the manufacture of industrial Chemicals such as alcohols, aldehydes, and
etc.

Besides, alkenes also used for artificial ripening of fruits, as a general anesthetic, for making
poisonous mustard gas (War gas) and ethylene-oxygen flame.

Alcohols

Alcohols are compounds which contain carbon, hydrogen and oxygen. Alcohols can be derived from alkanes, if a hydrogen (–H) in alkane is replaced by a hydroxyl group (–OH). For example,

$$\underset{\text{methane}}{CH_4} \xrightarrow[\text{}]{\text{Replace} \atop -H \text{ by} -OH} \underset{\text{methanol}}{CH_3OH}$$

$$\underset{\text{ethane}}{CH_3\,CH_3} \xrightarrow[\text{}]{\text{Replace} \atop -H \text{ by} -OH} \underset{\text{ethanol}}{CH_3CH_2OH}$$

Generally alcohols are represented as R–OH where R is an alkyl group and –OH is the functional
group and the general formula of alcohol is given as CnH2n + 1 OH, where 'n' is the number of carbon atoms. There are two ways of naming organic compounds namely Common and IUPAC
system. The common names of alcohols are derived when the last letter '-ane' in the name of the
parent hydrocarbon is replaced by '-yl' and it is combined with the word 'alcohol'.
According to IUPAC system, the last letter '-e' in the name of the parent hydrocarbon is replaced by
'ol'.
Alcohols are classified into primary, secondary (sec), and tertiary (tert), based upon the number of
carbon atoms connected to the carbon atom that bears the hydroxyl group. The primary alcohols
have general formulas RCH2OH; secondary ones are RR'CHOH; and tertiary ones are RR'R"COH,
where R, R', and R" stand for alkyl groups. Ethanol and n-propyl alcohol are primary alcohols;
isopropyl alcohol is a secondary one.

Chemical Formula	IUPAC Name	Common Name
CH3OH	Methanol	Wood alcohol
C2H5OH	Ethanol	Grain alcohol
C3H7OH	Isopropyl alcohol	Rubbing alcohol
C4H9OH	Butyl alcohol	Butanol
C5H11OH	Pentanol	Amyl alcohol
C16H33OH	Hexadecan-1-ol	Cetyl alcohol
C2H4(OH)2	Ethane-1,2-diol	Ethylene glycol
C3H6(OH)2	Propane-1,2-diol	Propylene Glycol
C3H5(OH)3	Propane-1,2,3-triol	Glycerol
C4H6(OH)4	Butane-1,2,3,4-tetraol	Erythritol, Threitol
C5H7(OH)5	Pentane-1,2,3,4,5-pentol	Xylitol
C6H8(OH)6	Hexane-1,2,3,4,5,6-hexol	Mannitol, Sorbitol
C7H9(OH)7	Heptane-1,2,3,4,5,6,7-heptol	Volemitol
C3H5OH	Prop-2-ene-1-ol	Allyl alcohol
C10H17OH	3,7-Dimethylocta-2,6-dien-1-ol	Geraniol
Chemical Formula	**IUPAC Name**	**Common Name**
C3H3OH	Prop-2-in-1-ol	Propargyl alcohol
C6H6(OH)6	Cyclohexane-1,2,3,4,5,6-hexol	Inositol
C10H19OH	2 - (2-propyl)-5-methyl-cyclohexane-1-ol	Menthol

Common Applications of Alcohols

Alcoholic beverages

Alcoholic beverages, typically containing 5% to 40% ethanol by volume, have been produced and consumed by humans since pre-historic times.

Antifreeze

A 50% v/v (by volume) solution of ethylene glycol in water is commonly used as an antifreeze.

Antiseptics

Ethanol can be used as an antiseptic to disinfect the skin before injections are given, often along with iodine. Ethanol-based soaps are becoming common in restaurants and are convenient because they do not require drying due to the volatility of the compound. Alcohol based gels have become common as hand sanitizers.

Fuels

Some alcohols, mainly ethanol and methanol, can be used as an alcohol fuel. Fuel performance can be increased in forced induction internal combustion engines by injecting alcohol into the air intake after the turbocharger or supercharger has pressurized the air. This cools the pressurized air, providing a denser air charge, which allows for more fuel, and therefore more power.

Preservative

Alcohol is often used as a preservative for specimens in the fields of science and medicine.

Solvents

Alcohols have applications in industry and science as reagents or solvents. Because of its relatively low toxicity compared with other alcohols and ability to dissolve non-polar substances, ethanol can be used as a solvent in medical drugs, perfumes, and vegetable essences such as vanilla. In organic synthesis, alcohols serve as versatile intermediates.

Methanol

Methanol or methyl alcohol, **wood alcohol**, **wood naphtha** or **wood spirits**, is a chemical with

the formula CH_3OH. Methanol acquired the name "wood alcohol" because it was once produced
chiefly as a by-product of the destructive distillation of wood. Modern methanol is produced in a
catalytic industrial process directly from carbon monoxide, carbon dioxide, and hydrogen. It smells
slightly sweeter than Ethanol. Methanol is produced naturally in the anaerobic metabolism of many
varieties of bacteria, and is ubiquitous in small amounts in the environment. As a result, there is a small fraction of methanol vapour in the atmosphere. Over the course of
several days, atmospheric methanol is oxidized with the help of sunlight to carbon dioxide and water.

Methanol burns in oxygen (including open air), forming carbon dioxide and water:

$2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$

Methanol ingested in large quantities is metabolized to formic acid or formate salts, which is
poisonous to the central nervous system, and may cause blindness, coma, and death. Because of these
toxic properties, methanol is frequently used as a denaturant additive for ethanol manufactured for
industrial uses.

Applications of Methanol

Methanol is a common laboratory solvent.

The largest use of methanol by far is in making other chemicals. About 40% of methanol is
converted to formaldehyde, and from there into products as diverse as plastics, plywood,
paints, explosives, and permanent press textiles.

Methanol is used to produce a gasoline additive methyl tert-butyl ether (MTBE).

In addition to direct use as a fuel, methanol (or less commonly, ethanol) is used as a
component in the transesterification of triglycerides to yield a form of biodiesel.

Methanol derived Dimethyl ether (DME) has replaced chlorofluorocarbons as an aerosol
spray propellant. Dimethyl ether (DME) also can be blended with liquified petroleum gas

(LPG) for home heating and cooking, and can be used as a diesel replacement for
transportation fuel.
Methanol is used on a limited basis to fuel internal combustion engines. It is not widely used
as a fuel because , using high concentrations of methanol (and other alcohols, such as ethanol)
in fuel is the corrosivity to some metals, particularly to aluminium. Methanol, although a
weak acid, attacks the oxide coating that normally protects the aluminum from corrosion
Methanol is a traditional denaturant for ethanol, the product being known as "denatured
alcohol" or "methylated spirit". This was commonly used during the Prohibition to discourage
consumption of bootlegged liquor, and ended up causing several deaths.
As an antifreeze in pipelines and windshield washer fluid.In some wastewater treatment
plants, a small amount of methanol is added to wastewater to provide a carbon food source
for the denitrifying bacteria, which convert nitrates to nitrogen to reduce the nitrification of
sensitive aquifers.
Methanol is also a widely used fuel in camping and boating stoves. Methanol burns well in an
unpressurized burner, so alcohol stoves are often very simple, sometimes little more than a
cup to hold fuel. This lack of complexity makes them a favorite of hikers who spend extended time in the wilderness.
Methanol is mixed with water and injected into high performance diesel and gasoline engines
for an increase of power and a decrease in exhaust gas temperature in a process known as
water methanol injection.

Ethanol

Ethanol is the second member of the alcoholic series. Ethanol is commonly known as alcohol. It is a
constituent of all alcoholic beverages namely beer, wine, whisky, some cough syrups, digestive syrups

etc. In industries, alcohol is produced by the fermentation of sugar present in molasses. Molasses is a
by-product of sugar industry in India. In our country, most of the ethanol is prepared from molasses.

Fermentation

The slow chemical change taking place in an organic compound by the action of enzymes leading to
the formation of smaller molecules is called Fermentation. In our daily life, there are many instances
of fermentation. For example, the change of milk into curd, souring of kneaded flour, etc., are due to
fermentation. The fermentation of sugar is a process in which the sugar molecules are broken down
into ethanol and carbon dioxide by the action of enzymes called invertase and zymase present in
yeast.

Manufacture of Ethanol from Molasses

Molasses is a dark colored syrupy liquid left after the crystallization of sugar from the concentrated
sugar cane juice. Molasses still contain about 30% sucrose which could not be separated by
crystallization. Molasses is converted into ethanol by the following steps.

Dilution

Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10
percent.

Addition of Ammonium salts

Molasses usually contains enough nitrogenous matter to act as food for yeast during fermentation. If
the nitrogen content of the molasses is poor, it may be fortified by the addition of ammonium
sulphate or ammonium phosphate.

Addition of yeast

The solution from step (2) is collected in large 'fermentation tanks' and yeast is added to it. The
mixture is maintained at about 303K for a few days. During this period, the enzymes invertase and
zymase present in yeast bring about the conversion of sugar into ethanol. During this process, the

liquor froths owing to the evolution of CO_2 which is recovered and used for preparing aerated
drinks. The fermented liquid is technically called **wash**.

Distillation of wash

The fermented liquid containing 15 to 18 percent alcohol and the rest water is now subjected to
fractional distillation. The main fraction drawn is an aqueous solution of ethanol which contains
95.6% ethanol and 4.4% water. This is called Rectified spirit. This mixture is then heated under reflux
over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On distillation of this
mixture, pure alcohol (C_2H_5OH = 100%) is obtained. This is called Absolute alcohol.

Physical Properties of Ethanol

Ethanol is a colorless liquid having a pleasant smell and a burning taste.
It is a volatile liquid having a low boiling point of 78° C (351 K).
It is miscible with water in all proportions.
Ethanol does not contain any ions, as it is a covalent compound and has no effect on litmus
paper.
The boiling point of alcohols is, in general, much higher than the corresponding alkanes.
This is because in alcohols there is intermolecular association of a large number of molecules
due to Hydrogen bonding which is absent in alkanes.

Chemical Reactions of Ethanol

Reaction with oxygen or combustion

Ethanol is a highly inflammable liquid (it catches fire easily). It burns with a blue flame to form
carbon dioxide and water.

$C_2H_5OH + 3O_2 \rightarrow 2CO_2\uparrow + 3H_2O\uparrow$

Reaction with Sodium Metal

When a small piece of sodium metal is put into ethanol in a dry test tube, brisk effervescence is
produced. When a burning splinter is brought near the mouth of the test tube, the gas burns with a
'pop' sound, which is a characteristic property of hydrogen gas. This shows that the gas produced by

the action of sodium metal on ethanol is hydrogen. Ethanol reacts with sodium to produce sodium
ethoxide and hydrogen.
$2C_2H_5OH + Na \rightarrow 2C_2H_5ONa + H_2\uparrow$

Esterification

Ethanol reacts with acetic acid in the presence of Concentrated Sulphuric Acid H_2SO_4 to form an
ester, ethyl ethanoate and water. The ester formed has sweet smell and the reaction is known as
esterification

Inflammability

An ethanol-water solution that contains 40% ABV (alcohol by volume) will catch fire if heated to
about 26 °C (79 °F) and if an ignition source is applied to it. This is called its flash point. The flash
point of pure ethanol is 16.60 °C (61.88 °F), less than average room temperature.

Applications of Ethanol

Ethanol is used in the following:
Manufacture of paints, varnishes, lacquers and medicines.
In the preparation of organic compounds like ether, chloroform and iodoform.
As an antiseptic to sterilize wounds and syringes in hospitals and dispensaries.
In alcoholic drinks (beverages) like whisky, wine, beer and other liquors. Beer contains
around 3 to 6% ethanol, whisky contains 30% ethanol and wine contains 8 to 10% ethanol.
In spirit lamps as methylated spirit (contains ethanol mixed with a small amount of methanol
and water).
As power alcohol to generate power in internal combustion engines. Power alcohol is a
mixture of 25% absolute alcohol and 75% petrol and it is a good fuel for motor cars. In the
present days, due to scarcity of petrol and petrolatum products, power alcohol can be used as
a substitute for petrol in motor cars which may also reduce pollution of air.

Carbonyl Compounds

Aldehydes and ketones are called carbonyl compounds as they contain the carbonyl group, >C=O.
The functional group of an Aldehydes is -CHO and that of the ketones is >C=O. Both Aldehydes and
ketones have the same general formula, CnH2nO. The general formula for Aldehydes is R-CHO,
where R is an alkyl group and the general formula for ketones is R-CO-R¢, where R and R' are alkyl
group which may or may not be the same.

Aldehydes

The common names assigned to Aldehydes are based on the names of acids produced by their
oxidation. For example, formaldehyde and acetaldehyde are so called because on oxidation they
produce formic acid and acetic acid respectively.

Formaldehyde

Formaldehyde or Methanal is the first member of the aldehyde series. The chemical formula of
methanal is HCHO. It is prepared by the controlled oxidation of methanol (CH3OH) at 873 – 923K
using silver, iron oxide or molybdenum oxide as catalyst

$$\underset{\text{methanol}}{2CH_3OH} + O_2 \xrightarrow{873-923\text{ K catalyst}} \underset{\text{formaldehyde}}{2HCHO} + 2H_2O$$

Properties of Formaldehyde

Formaldehyde is a colorless, pungent smelling gas. It is highly soluble in water. It can be easily
condensed into liquid. The liquid HCHO boils at 252K. It causes irritation of skin, eyes, nose and
throat. Its solution acts as an antiseptic and a disinfectant.

Applications of Formaldehyde

Formaldehyde is oxidized to methanoic (Formic) acid in the presence of oxidizing agents like
alkaline potassium permanganate or Ammoniacal silver nitrate**F. ormic Acid occurs
naturally, most notably in the venom of bee and ant stings**.
A major use of formic acid is as a preservative and antibacterial agent in livestock feed
An aqueous solution of formaldehyde is called Formalin which contains about 40% HCHO. It

is a powerful disinfectant and antiseptic. It is used for preserving dead bodies, biological specimens and sterilising surgical instruments.

It is used in the manufacture of paints and dyes.

Formaldehyde is condensed with phenol in the manufacture of bakelite, a plastic which is used for making electrical switches.

Formaldehyde is condensed with ammonia to produce urotropine, $(CH_2)_6N_4$ which is an important medicine in urinary ailments.

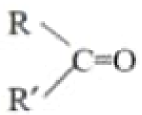
Acetaldehyde

Acetaldehyde or ethanal occurs widely in nature and being produced on a large scale industrially.

Acetaldehyde occurs naturally in coffee, bread, and ripe fruit, and is produced by plants as part of their normal metabolism. It is also produced by metabolism of Alcohol in our body and is popularly believed to be a cause of hangovers from alcohol consumption. Pathways of exposure include air, water, land or groundwater as well as drink and smoke. Acetaldehyde derived from the consumption of ethanol binds to proteins to form DNA adducts. This DNA adduct is what causes Cancer linked to alcohol overuse. Acetaldehyde is a probable or possible carcinogen in humans. Many microbes produce acetaldehyde from ethanol in our body which lead to stomach and colon cancer.

Ketones

Like aldehydes, ketones also contain carbonyl group, >C=O. Therefore, ketones are also known as carbonyl compounds. Ketones have two alkyl groups attached to carbonyl carbon

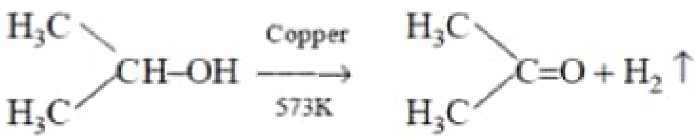


where R and R' are alkyl groups.

Acetone

Acetone is the first member of the ketone series. Its IUPAC name is propanone. The chemical

formula of acetone is CH3COCH3. It is prepared by the dehydrogenation of isopropyl alcohol using
heated copper.



isopropyl alcohol acetone

Properties & Applications of Acetone

Acetone is a colourless, inflammable, volatile liquid with characteristic pleasant smell. Its
boiling point is 329 K. It is miscible with water, alcohol and ether in all proportions. It
specific gravity is 0.792 g/ml at 293K
About a third of the world's acetone is used as a solvent, and a quarter is consumed as acetone
cyanohydrin a precursor to methyl methacrylate, which is further used to create plastic called
polymethyl methacrylate (PMMA)
Acetone is a good solvent for most plastics and synthetic fibers including those used in
laboratory bottles made of polystyrene, polycarbonate and some types of polypropylene. It is
ideal for thinning fiberglass resin, cleaning fiberglass tools and dissolving two-part epoxies
and superglue before hardening. It is used as a volatile component of some paints and
varnishes. As a heavy-duty degreaser, it is useful in the preparation of metal prior to painting;
it also thins polyester resins, vinyl and adhesives. It is also useful for high reliability soldering
applications to remove solder rosin after soldering is complete. This helps to prevent the
Rusty bolt effect from occurring due to dirty solder contacts.
It is also used in the synthesis of rubber, in the manufacture of artificial leather, to clean and
dry the parts of precious equipments and as a nail polish remover.

Carboxylic Acids

Carboxylic acids are a class of organic compounds which contain carboxyl group (–COOH) as the functional group. This group is structurally represented as follows:

$$\begin{array}{c} O \\ \| \\ -C-OH \end{array}$$

Common names of monocarboxylic acids have been derived from the Latin name of the products / organisms in which they are found naturally. For example,
Formic Acid $HCOOH$ is found in the sting of Ants. Ants are called Formica in Latin.
Acetic Acid CH_3COOH is found in Vinegar. Vinegar is called Acetum in Latin.
Butyric Acid $CH_3CH_2CH_2COOH$ is found in Butter. Butter is called butyrum in Latin

Acetic Acid

Acetic acid is the second member of the carboxylic acid series after Formic Acid. The formula of acetic acid is CH_3COOH and the IUPAC name of acetic acid is ethanoic acid. A dilute solution of acetic acid in water is called vinegar. Vinegar contains 6 to 10% acetic acid. Acetic acid is manufactured in the form of vinegar by the bacterial oxidation of ethanol. Ethanol is oxidised by the oxygen in air in the presence of Bacterium *Mycoderma aceti* to form a dilute solution of acetic acid called vinegar.

$$CH_3CH_2OH + O_2 \rightarrow CH_3COOH + H_2O$$

Acetic Acid is an important chemical reagent and industrial chemical, mainly used in the production of cellulose acetate mainly for photographic film and polyvinyl acetate for wood glue, as well as synthetic fibres and fabrics. In households, diluted acetic acid is often used in descaling agents. In the food industry, acetic acid is used under the food additive code E260 as an acidity regulator and as a condiment. The major use of acetic acid is for the production of vinyl acetate monomer (VAM).
VAM is further polymerized to polyvinyl acetate or to other polymers, which are components in paints and adhesives. The acetates of metals such as Sodium, Magnesium etc. have wide usage such as

preservatives, food inudustry, fungicides, dyes etc.

Soaps & Detergents

Soaps are sodium or potassium salts of some long chain carboxylic acids. Sodium salts of fatty acids are known as hard soaps and potassium salts of fatty acids are known as soft soaps. Hard soaps are prepared from cheap oils, fats and sodium hydroxide. They contain free alkali and are used for washing purposes. Soft soaps are prepared from good oils and potassium hydroxide. They do not contain free alkali, produce more lather and are used as toilet soaps, shaving creams and shampoos.

Soap is prepared by heating vegetable oil or animal fat containing Glyceryl stearate with concentrated sodium hydroxide solution. Hydrolysis of fat takes place and a mixture of sodium salts of fatty acids and glycerol is formed. The salts of fatty acids thus formed are used as soap. The alkaline hydrolysis of oils and fats forming soaps is commonly known as saponification.

$$\underset{\text{(animal fat)}}{\text{Glyceryl stearate}} + \text{sodium hydroxide} \longrightarrow \underset{\text{(soap)}}{\text{Sodium stearate}} + \text{Glycerol}$$

Hardness of water and soaps

The big disadvantage of soapy detergents is that their washing action is reduced by hardness in water. Water that contains calcium and magnesium compounds is said to be hard. These compounds destroy the soap **by reacting with it and converting into insoluble compounds called scums that float to the surface**. In hard water, a lot of soap is needed to get a good lather and a lot of scum is formed as well. This difficulty is overcome by detergents.

Detergents are sodium salts of benzene sulphonic acids. Thus instead of -COOH group in soaps, detergents contain $-SO_3H$ group. **The detergents do not form precipitates with metal ions such as Ca^{2+} and Mg^{2+} present in hard water**. Therefore, the cleansing action of detergents is better than soaps. Detergents are prepared by treating hydrocarbons obtained from petroleum with

conc. sulphuric acid. The corresponding sulphonic acids are then converted into their sodium salts.
Washing powders available in the market contain about 15 to 30 percent of detergents by weight.
Some other chemicals which are added to detergents for specific cause are as follows:
Sodium sulphate and sodium silicate added to keep the washing powder dry.
Sodium carbonate is added to maintain alkalinity which helps in removing dirt and also in
softening water.
Carboxy-methyl cellulose (CMC) added to keep the dirt suspended in water.
A mild bleaching agent such as sodium perborate is added to produce whiteness in clothes.

Soaps Versus Detergents

Soap	Detergents
Soaps are sodium salts of long chain fatty acids	Detergents are sodium salts of sulphonic acids.
The ionic part of a soap is -COO- Na+	The ionic part in a detergent is -SO3 - Na+
They are biodegradable	Some detergents are not biodegradable.
They are prepared from animal fats or vegetable oils.	They are prepared from hydrocarbons obtained from coal and petroleum.
Soaps form insoluble salts called scums with calcium and magnesium ions which are present in hard water and hence cannot be used in hard water.	Calcium and magnesium salts of detergents are soluble in water and therefore can be used even in hard water.

How soaps work?

When used for cleaning, soap allows otherwise insoluble particles to become soluble in water and
then be rinsed away. A soap molecule contains two chemically distinct parts that interact differently
with water. One part is a long hydrocarbon chain, which is non-polar and water hating
(hydrophobic), while the other part is charged carboxylate group -COONa which is polar and waterloving
(hydrophilic). The hydrophilic part makes the soap soluble in water. So, a soap molecule can
be thought of as one having a long tail made of hydrocarbon and a short head made of carboxylate

group. The long tail is dirt-loving and water-hating and the short head is water-loving. The
hydrophobic part of the soap
molecule traps the dirt and the hydrophilic part makes the entire molecule soluble in water. When a soap or detergent is dissolved in water, the molecules join together as clusters called miscelles. Their
long hydrocarbon chains attach themselves to the oil and dirt. The dirt is thus surrounded by the
non-polar end of soap molecules. The charged carboxylate end of the soap molecules make the
miscelles soluble in water. Thus, the dirt is washed away with soap.

Advantages of Detergents over Soap

Detergents can be used even in hard water whereas certain amount of soap gets wasted if water is
hard. Detergents can be used even in acidic medium as they are the salts of strong acids and are not
decomposed in acidic medium.
For example: oil/fat is insoluble in water, but when a couple of drops of dish soap are added to the
mixture the oil/fat apparently disappears. The insoluble oil/fat molecules become associated inside
micelles, tiny spheres formed from soap molecules with polar hydrophilic (water-loving) groups on
the outside and encasing a lipophilic (fat-loving) pocket, which shielded the oil/fat molecules from
the water making it soluble. Anything that is soluble will be washed away with the water. Synthetic
detergents operate by similar mechanisms to soap. The type of alkali metal used determines the kind
of soap produced. Sodium soaps, prepared from sodium hydroxide, are firm, whereas potassium
soaps, derived from potassium hydroxide, are softer or often liquid. Historically, potassium
hydroxide was extracted from the ashes of bracken or other plants. Lithium soaps also tend to be
hard—these are used exclusively in greases.
Soaps are derivatives of fatty acids. Traditionally they have been made from triglycerides (oils and
fats). Triglyceride is the chemical name for the triesters of fatty acids and glycerin. Tallow, i.e.,

rendered beef fat, is the most available triglyceride from animals. Its saponified product is called
sodium tallowate. Typical vegetable oils used in soap making are palm oil, coconut oil, olive oil, and
laurel oil. Each species offers quite different fatty acid content and, hence, results in soaps of distinct
feel. The seed oils give softer but milder soaps. Soap made from pure olive oil is sometimes called
Castile soap or Marseille soap, and is reputed for being extra mild. The term "Castile" is also
sometimes applied to soaps from a mixture of oils, but a high percentage of olive oil.
Soap is an emulsification agent. Oil and grease are not soluble in water (they don't dissolve in water),
which is why, for instance, oil and water will separate when combined. This is because oils are nonpolar
molecules, but water is a polar molecule, and non-polar things do not mix well with polar
things. In order to remove oil from clothes or from your dishes with water, the oils must be made
soluble by the process of emulsification.
The non-polar end adsorbs the oil or other hydrophobic dirt. The ionic end is highly soluble in
water. This allows for an emulsion to be formed. The alkali metal (sodium or potassium ion) does
not play a role in the action of the soap.
Soap use is not a chemical reaction, but a physical one. Under normal conditions, the soap does not
react with the dirt chemically. If "hard water" minerals are present (magnesium or calcium) these can
chemically react with the soap and lessen its effectiveness by removing the soap from solution.
The structure of the emulsion is such that the oil or oily dirt is surrounded by soap molecules with
the ionic part of the molecules toward the outside where water will react with the ionic end (by
hydrogen bonding) and keep the oil in "solution." Hot water helps in the formation and suspension
of the emulsion.

Other additives are sometimes added to soap for antibacterial or antifungal effects, but these are not
the main ingredients — they just enhance the primary function of emulsifying oils in water.

Miscellaneous Topics

Zeolites

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents.
Zeolites are widely used in industry *for water purification, as catalysts, for the preparation of advanced*
materials and in nuclear reprocessing. They are used to extract nitrogen from air to increase oxygen
content for both industrial and medical purposes. Their biggest use is in the production of laundry
detergents. They are also used in medicine and in agriculture.

Zeolites and Permanent Hardness of water

Hardness in water is due to the presence of carbonates and biocarbonates of Calcium or Magnesium
(when it is temporary hardness) or sulphates and chlorides of Calcium and Magnesium (when it is
permanent hardness). Temporary hardness of water can be removed easily by boiling water or by
adding washing soda (Sodium Carbonate-hydrated). Permanent hardness cannot be removed by
merely boiling or adding washing soda. A complex salt called sodium aluminium silicate (zeolite) is
used to remove permanent hardness in water.
Permotit or zeolite is packed into a column and the hard water is allowed to flow through it. Double
decomposition occurs and calcium aluminium silicate is formed. Eventually the permotit is
completely converted into its calcium salt. It can be made fit for use again by pouring a strong
solution of common salt through the column.
Sodium Aluminium Silicate (zeolite)+ Calcium Sulphate (salt causing hardness of water)→ Calcium
Aluminium Silicate+ Sodium Sulphate (zeolite)
After adding salt water:-
Calcium Aluminium Silicate + Sodium Chloride (common salt) →Sodium Aluminium silicate

(zeolite) + Calcium Chloride
In the above reaction the tower is revived and reset for use again, thus the zeolite is not wasted. The
principle of the permutit process has been greatly extended to modern synthetic ion-exchange resins.
These can be used to remove all metallic and acidic ions from water and provide a cheap and
convenient way of making high purity water purer even than the best distilled water. Another
application is in the preparation of drinking water from sea water

Use of Barium and Iodine based materials as contrast media in X-Ray

The production of X-ray images depends on the differences between the X-ray absorbing powers of
various tissues. This difference in absorbing power is called contrast and is directly dependent on
tissue density. To artificially enhance the ability of a soft tissue to absorb X-rays, the density of that
tissue must be increased. The absorption by targeted soft tissue of aqueous solutions of barium
sulfate and iodized organic compounds provides this added density through the heavy metal barium
and the heavy nonmetal iodine.

Brinjal and Apples become dark when they are kept open

This is mainly because of so called *Climacteric Rise*. In many fruits, especially the fleshy types, there
are marked changes in their `respiration rate' after they mature. In certain fruits, there is a
considerable increase in the respiration rate at the time of `ripening', which is known asc *limacteric
rise*. Even after the fruits are harvested, they continue to respire, which leads to consumption of food,
water and other cellular fluids. This results in the breakdown of tissues eventually and causes the
perishability of fruits. The onset of fruit ripening happens due to the release of ethylene (C_2H_2).

Dry Cleaning Materials

Dry cleaning uses non-water solvents such as highly vaporising organic solvents. Many dirt, soil or stains producing substances on the fabric are organic in nature (sticky oily compounds). In dry cleaning, cleansing is achieved by the action of a solvent, which dissolves out the sticky matter due to its like nature. Dry cleaning fluids serve as a vehicle to carry away the soil*C. amphene, naphtha, benzene, benzol, petrol, carbon tetrachloride, trichloroethylene and tetrachloroethylene*are some of the frequently used dry cleaning fluids.

Teer Gas

Tear gas, formally known as a lachrymatory agent or lachrymator stimulates the corneal nerves in the eyes to cause tears, pain, and even blindness. Common lachrymators include OC, CS, CR, CN (phenacyl chloride), nonivamide, bromoacetone, xylyl bromide and syn-propanethial-S-oxide (from onions).

Tear gas is a noxious gas. It is also called as war gas since it is used to disperse soldiers in a battle and an attacking mob. It is one kind of Lachrymator.

Deodorants and Antiperspirants

Deodorants mask the smell of body odour, which is actually caused by bacteria, where as antiperspirants block the pores of the skin to stop us from perspiring.

There are two types of glands in our underarms, apocrine and eccrine. The eccrine glands are by far the most numerous sweat glands and are responsible for producing most of the sweat in our underarms, as well as in our entire body.

Most antiperspirants contain *aluminium chlorohydrate/ aluminium chloride or aluminium zirconium,* which are highly soluble and readily absorbed into the skin. Once in the body, the aluminium passes freely across cell membranes and is readily absorbed. The aluminium ions are taken into the cells that line the eccrine-gland ducts at the opening of the epidermis, the top layer of the skin. When the aluminium ions are drawn into the cells, water passes in with them. As more water flows in, the cells begin to swell, squeezing the ducts closed so that sweat can't get out.

Knocking of Engine

An Internal combustion engine under load develops `pinging' or `knocking', where the fuel mixture starts exploding due to compression before the right time, causing rough running, stalling going up hills, and so on.

Tetra Ethyl Lead (TEL) is one such component that is added to petrol to reduce its tendency to `ping' under compression. TEL breaks down to lead at upper cylinder temperatures. Lead atoms spread around and combining with the free radicals and slowing down the reaction.

However, `Leaded' petrol was a grave danger to the environment, as lead is a poison when it is absorbed into the body.

But reason for going completely unleaded is different. The reason is to reduce other pollutants, the unburned hydrocarbons and nitrogen oxides. To achieve this, catalytic exhausts have been adopted, and they cannot stand even the residual lead, which will affect the platinum catalyst. It was discovered that passing the exhaust gases through a filter of platinum caused a catalytic conversion of the oxides to other products, which could then be prevented from escaping into the greenhouses, used for food production.

Lead Alternates

There are three main groups of substances oil companies use instead of lead to improve octane number.

Aromatics: organic compounds based on the benzene ring, a 6-carbon ring with 3 delocalised double bonds e.g., benzene, toluene, xylene,

Olefines: organic compounds, which have, double bonds. After combustion, one critical byproduct is 1,3-butadiene.

Oxygenates: organic compounds containing oxygen molecules such as methane, ethane or MTBE (methyl-tertiary-butyl ether).

As benzene and 1,3-butadiene are the top toxic air pollutants. They are both highly carcinogenic

substances, MTBE is the most popular additive in unleaded petrol. The third group of alternative
octane-raising substances mentioned above are the oxygenates. A major by-product of their
combustion is acid aldehyde — the first substance the body produces in the alcohol-detoxifying
process. So the oxygenates are less toxic than benzene and 1, 3-butadiene. Another advantage of
oxygenates is that, because they contain oxygen molecules, they cause the fuel to burn more
efficiently-and thus lowering the levels of all pollutants from car emissions.

Chlorination and Ozonation of Water

Chlorine, Iodine and Bromine can be used for disinfecting water but not fluorine because it is too
reactive. Chlorine is often chosen simply because it is cheap, readily available and relatively easy to
handle. Disinfection relies on disrupting a harmful organism's metabolism or structure. That can be
achieved by oxidation and non-oxidising chemicals which have similar effects, as well as by nonchemical
processes such as ultraviolet (including sunlight), X-rays, ultrasound, heat (as in
pasteurisation), variations in pH and even storage to allow organisms to die naturally. Chlorine gas
consists of molecules of two chlorine atoms but no oxygen. When added to water, one of the atoms
forms a chloride ion. The other reacts with water to form hypochlorous acid, an oxidising agent.
Disinfection comes from the hypochlorous acid reacting with another molecule, most probably in
the bacterial cell wall, in an oxidation-reduction reaction. If this happens enough times, the
organism's repair mechanisms are overwhelmed and it dies. So concentration of disinfectant and the
length of time pathogens are exposed to it are important factors. Disinfection needs to be carried out
under closely controlled pH conditions, ideally between 7 and 7.6. If the pH is too low — less than 6.8
— there is a tendency for nitrogen compounds, especially urea (a common pool contaminant) to

degrade via another route to chloramines. The worst of these is nitrogen trichloride, which irritates
the eyes and creates the so-called chlorine smell associated with poorly run or overused swimming
pools.

Best time of Chlorination of Swimming Pool is Night Hours.

Chlorine, or more commonly a substance containing hypochlorite ion, is added to pools as a
disinfectant. However, sunlight rapidly destroys hypochlorite, drastically reducing the effectiveness
of the sanitizer. Hence, the effectiveness of the disinfectant is maximized when added in the evening
hours.

Ozonation Versus Chlorination

Ozonation of water has strong virucidal effect. It inactivates viruses in a matter of seconds. Many
countries around the world are using ozone for water treatment. Ozone has no residual germicidal
effect, but in the case of chlorination there is residual effect over the germs. Combined treatment of
water with ozone and chlorine effectively sterilise the water. 0.2 to 1.5 mg of ozone is necessary to
sterilise one litre of water. As ozone destroys all micro organisms and it removes disagreeable
odours, the resultant water is absolutely safe, pure, fresh and healthy. Ozonised water is colourless
and odourless.

Sodium Vapour Lamp and Mercury Vapour Lamp

Difference	Sodium Vapour Lamp	Mercury Lamp
Light Source	Works by electric discharge (passage of electricity through sodium vapours at high/low pressure)	Works through the combined effect of electric discharge through mercury vapours and fluorescence from phosphors (luminescent materials).
Process of Lightning	Filaments of the lamp sputter fast moving electrons, which hit the sodium atoms (vapour) causing the valence electrons of the sodium atoms to excite to higher energy levels and the electrons thus excited relax by emitting the characteristic monochromatic bright yellow light (589nm).	The mechanism in mercury vapour lamp is more involved and sequential. The sputtered electrons from the filaments, after having been accelerated by high voltage, hit the mercury atoms. Here also, the excited electrons of mercury atoms relax by emitting characteristic but ultraviolet (254nm, invisible) light.

		The photons of this ultraviolet light fall on the fluorescent layer on the inner walls of the tube and excite the molecular bonds of the fluorescent material to various electronic and vibrational energy states. Hence, the light from the mercury vapour lamp is white.
Applications	Although sodium vapour lamps produce much higher light output (about 90 lumens/watt) they cannot be used in lighting applications where colour-rendering property is very crucial. This is because most of the light emitted from a sodium vapour lamp is concentrated in the yellow part of the visible spectrum (around 580-590 nm).	Mercury vapour lamp is quite suitable for lighting applications. This is because, the mercury vapour lamp can feed almost the entire visible region (380-780 nm) of the human visual system

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Colors in Fireworks

Pyrotechnics is the art of making fireworks, which produce different colours when lit. The art involves the intimate mixing of a fuel (burnable material) that is in a fine state of subdivision and an oxidising agent using a binder. This burning coincides with the fuel oxidizer interaction. The binder also burns in air and that adds to flame formation. The effects, so produced owe their selective light emission to the presence of the various elements and compounds. These are summarized below:
Aluminium is used to produce silver and white flames and sparks. It is a common component of sparklers.
Barium is used to create green colors in fireworks.
Carbon is one of the main components of black powder, which is used as a propellant in

fireworks. Carbon provides the fuel for a firework.
Calcium is used to deepen firework colors. Calcium salts produce orange fireworks.
Chlorine is an important component of many oxidizers in fireworks. Several of the metal
salts that produce colors contain chlorine.
Cesium compounds help to oxidize firework mixtures. Cesium compounds produce an indigo
color in fireworks.
Copper produces blue-green colors in fireworks and halides of copper are used to make
shades of blue.
Iron is used to produce sparks. The heat of the metal determines the color of the sparks.
Potassium nitrate, potassium chlorate, and potassium perchlorate are all important oxidizers.
The potassium content can impart a violet-pink color to the sparks.
Lithium is a metal that is used to impart a red color to fireworks.
Magnesium burns a very bright white, so it is used to add white sparks or improve the overall
brilliance of a firework.
Phosphorus burns spontaneously in air and is also responsible for some glow in the dark
effects.
Sulfur is a component of black powder, and as such, it is found in a firework's propellant/fuel.
Strontium salts impart a red color to fireworks.
Zinc is a bluish white metal that is used to create smoke effects for fireworks.

Silver Tarnish

Silver tarnish is the discoloration that occurs on silver. Silver is not appreciably affected by dry or
moist air that is free from ozone, halogens, ammonia, and sulphur compounds. The presence of
hydrogen sulphide in any material that silver comes into contact with is one of the prime reasons for
silver tarnish. The hydrogen sulphide reacts with the silver to form silver sulphide.
$2Ag + H_2S \rightarrow Ag_2S + H_2$
Silver sulphide is black. When a thin coating of silver sulphide forms on the surface of silver, it

darkens the silver. Rubber contains sulphur, which will cause silver to tarnish. Certain foods like
eggs, mayonnaise, mustard, table salt, olives, salad dressing, vinegar, fruit juices and onions also
hasten the silver tarnish process. The sulphur in these foods will corrode silver. Flowers and fruits
can etch the silver containers due to the acid produced as they decay.

Ice Cubes are Cloudy on the Inside

Water contains both dissolved gases (e.g., oxygen) from the atmosphere and dissolved minerals (e.g.,
calcium and magnesium salts). The presence of these substances affects the temperature at which
water freezes. Pure water freezes at 0~ water with dissolved gases and mineral salts freezes at a lower
temperature. The higher the concentration of dissolved gases and minerals, the lower the freezing
point of water. As water cools, the first layer of ice that forms is at the interface with air. As ice
forms, pure water solidifies, leaving the dissolved gases and salts in solution. Thus, the freezing
process concentrates the dissolved species in smaller and smaller volumes of liquid solution,
effectively increasing their concentration. With a higher concentration of dissolved material, the
temperature at which additional ice will form is lowered. The cloudiness in the center of an ice cube
thus is the consequence of the concentration of dissolved gases and minerals that refract light and
create an opaque appearance.

Free Flowing Salts and Desiccants

Calcium silicate ($CaSiO_3$), a commonly used anti-caking agent, added to e.g. table salt, absorbs both
water and oil. This white powder has the incredible ability to absorb liquids and still remain a fleeflowing
powder. In general, calcium silicate absorbs 1 to 2.5 times its weight of liquids. For water, its
total absorption power is estimated as 600%, that is, absorbing 600 times its weight of water.

Desiccants – Silica Gel

A desiccant is a hygroscopic substance that induces or sustains a state of dryness (desiccation) in its local vicinity in a moderately well-sealed container. Some commonly used desiccants are: silica gel, activated charcoal, calcium sulfate, calcium chloride, montmorillonite clay, and molecular sieves such as Zeolites. These desiccants remove water by a variety of physical and chemical methods: adsorption, a process whereby a layer or layers of water molecules adhere to the surface of the desiccant; capillary condensation, a procedure whereby the small pores of the desiccant become filled with water; and chemical action, a procedure whereby the desiccant undergoes a chemical reaction with water.

Montmorillonite clay is a naturally occurring adsorbent that swells to several times its original volume when water adsorption occurs.

The most commonly used desiccant is silica gel (SiO_2. H_2O), an amorphous form of silica manufactured from sodium silicate and sulphuric acid. The porous nature of silica gel forms a vast surface area that attracts and holds water by both adsorption and capillary condensation, allowing silica gel to adsorb about 40% of its weight in water. Zeolites or "molecular sieves" are rigid, hydrated crystalline aluminosilicate minerals that contain alkali and alkaline earth metals. Zeolites possess a three-dimensional crystal lattice structure that forms surface pores of uniform diameter and contain numerous regular internal cavities and channels. Water molecules are readily incorporated within the pores and cavities.

Copper & Brass cleaning by Vinegar

Copper is a metallic element; brass is an alloy or mixture of the metallic elements copper and zinc.

The surfaces of copper and brass items tamish with prolonged exposure to air, particularly in moist environments with high carbon dioxide (CO_2) or sulfur dioxide (SO_2) concentrations. The

compounds that form on the surface, ranging in color from black to blue to dark green, dissolve
readily in acidic solutions. Vinegar contains acetic acid, ketchup contains tomatoes rich in ascorbic
acid (Vitamin C), and onions contain malic acid and citric acid. All of these foods provide variable
amounts of acid to dissolve the tamish on copper surfaces.

List of Chemical Compounds with Common Names

Common Name	Chemical Name
Alum	Ammonium aluminium sulphate
Aspirin	Acetyl salicyclic acid
Battery acid or oil of vitriol	Sulphuric acid
Blue vitriol	Copper sulphate
Baking soda	Sodium bicarbonate
Bleaching powder	Calcium chlorohypochlorite
Borax	Sodium tetraborate

Butter of tin	Stanic chloride
Caustic soda	Sodium hydroxide
Caustic potash	Potassium hydroxide
Carbolic acid	Phenol
Chile saltpeter	Sodium nitrate
Carborundum	Silicon carbide
Corrosive sublimate	Mercuric chloride
Colomel	Mercuric chloride
Dry ice	Carbon dioxide (solid)
Formalin	Formaldehyde (40% solution)
Grain alcohol (spirit)	Ethyl alcohol
Green vitriol	Ferrous sulphate
Gypsum	Calcium sulphate
Gammexane (bhc)	Benzene hexachloride
Corrosive sublimate	Mercuric chloride
Colomel	Mercurous chloride
Dry ice	Carbon dioxide (dolid)

Grain alcohol (spirit)	Ethyl alcohol
Green vitriol	Ferrous sulphate
Gypsum	Calciumm sulphate
Gammexane	Benzene hexachloride
Butter of tin	Stanic chloride
Caustic soda	Sodium hydroxide
Caustic potash	Potsssium hydroxide
Carbolic acid	Phenol
Chile saltpetre	Sodium nitrate
Carbrundum	Silicon carbide
Corrosive sublimate	Mercuric chloride
Hydrolith	Calcium hydride
Hypo (antichlor)	Sodium thio sulphate

Indian nitre	Potassium nitrate
Lime stone	Calcium carbonate
Lunar caustic	Silver nitrate
Laughing gas	Nitrous oxide
Litharge	Lead monoxide
Muratic	Hydrochloric acid
Mohr's salt	Ferrous ammonium sulphate
Milk of magnesia	Magnesium hydroxide
Microcosmic salt	Sodium ammonium hydrogen posphate

Marsh gas (damp-fire)	Methane
Oleum	Sulphuric acid(fuming)
Oxone	Sodium peroxide
Plaster of paris	Calcium sulphate hemihydrate
Philosppher's wool	Zinc oxide
Phosgene	Carboxyl chloride
Pearl ash	Potassium carbonate
Pyrene	Carbon tetrachloride
Picric acid	2, 4, 6, trinitrophenol
Quick lime	Calcium oxide
Red lead (minium)	Lead tetroxide
Sugar	Sucrose
Salked lime(milk of lime)	Calcium hydroxide

Sal ammoniac	Ammonium chloride
Sugar of lead	Lead acetate
Sand	Silicon dioxide
Table salt (common salt)	Sodium chloride
Tel	Tetra-ethyl lead
Tear gas	Chloropicrin
Washing soda	Sodium carbonate
Water glass	Sodium silicate
White vitriol	Zinc sulphate

General Science-7: Everyday Physics

Measurement and Units

Measurement refers to comparison of a physical quantity with its standard unit. The standard unit
should be easily reproducible and internationally accepted.

Fundamental Units and Derived Units

The units which are independent of each other are known as Fundamental Units. Derived Units are
derived from Fundamental Units. For example, meter is a fundamental unit of length and second is a
fundamental unit of time. However, meter per second (ms-1) is a derived unit of velocity. There are
seven fundamental units as given in the below table:

No.	Quantity	Fundamental Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	S
4.	Temperature	Kelvin	kg
5	Electric current	ampere	A
6	Luminous intensity	candela	cd
7	Amount of substance	mole	mol

Apart from the above seven, there are two supplementary fundamental units viz. Radian and
Steradian. While Radian (Rad) is used to measure plane angle, Steradian (Sr) is used to measure Solid
Angle.
The derived units are derived from fundamental units. Examples of derived units are velocity
(meter/second), acceleration (meter /second^2) etc.

Kilogram

At present, a kilogram is defined by a cylindrical piece of platinum-iridium kept at the office of
International Committee on Weights and Measures in Paris. However, that lump has lost 50
microgram since 1879 and that is why scientists are looking for ways of expressing a kilogram in
terms of the fundamental constants of nature, rather than a man-made object.

Meter

Earlier meter was calibrated as the distance between two “Xs” on a platinum Iridium metal bar kept
in Paris at a temperature of 0°C. Later, it was fixed as length of the path travelled by light in vacuum
during a time interval of 1/299,792,458 of a second. Currently, one meter contains 1650763.73
wavelength of orange-red light of Kr-86.

Second

Earlier, second was the length of a mean solar day divided by 86,400. Since 1967, a second has been
classified time in which caesium atom vibrates 9192631770 times in an atomic clock.

Kelvin

One Kelvin is the 1/273.16 part of the thermodynamics temperature of the triple point of water.

Candela

Candela is the luminous intensity, in a given direction, of a source that emits monochromatic
radiation of frequency 540×1012 hertz and that has a radiant intensity in that direction of 1683 watt
per steradian.

Ampere

1 ampere is the electric current which it maintained in two straight parallel conductor of infinite
length and of negligible cross-section area placed one metre apart in vacuum will produce between
them a force 2 x 10-7 N per metre length.

Mole

One mole is the amount of substance of a system which contains a many elementary entities (may be
atoms, molecules, ions, electrons or group of particles, as this and atoms in 0.012 kg of carbon
isotope 6C12.

A complete set of units, both fundamental and derived is known as System of Units. There are four
commonly used systems of units' viz. CGS, FPS, MKS and SI systems. CGS refers to centimetre,
gram and time; FPS refers to foot, pound and second; MKS refers to meter, kilometer and second
while SI system uses the seven fundamental units as mentioned above.

Motion

Horizontal Motion

Motion is when an object changes its position with respect to its surroundings with time. If the
object does not change its position with respect to its surroundings with time, it is called to be at rest.
Being is rest and motion are relative and depend on reference frames. This implies that an object
may be in rest in one frame of reference while in motion in another frame of reference. For example,
if I am standing on ground, that is my frame of reference. Motion of anything would be compared to
reference point of ground. However, if I am in a moving Bus, then moving Bus is my reference
point. Any other person in Bus will be in rest for my, while for anyone standing on ground Bus and
everything within that will be in motion.

One, Two and Three Dimensional Motions

Motion can be either one dimensional or two dimensional.
In one dimensional motion, only one out of three coordinates specifying the position of
object changes. Example: object falling under gravity.
In two dimensional motion, only two out of three coordinates specifying the position of the
object change. Example: Circular motion.
In three dimensional motion, all the three coordinates specifying the position of object
change with respect to time. Example: A flying bird, kite or aeroplane.

Distance and Displacement

Distance refers to the actual path traversed by an object. Distance is a scalar quantity and it can be
never zero or negative. Distance is measured by meter. Displacement is the shortest distance
between initial and final positions of any object during motion. Displacement is a vector quantity
and can be either positive or negative or zero. Displacement is also measured in meter.
Can displacement be greater than distance?
Kindly note that magnitude of displacement can NEVER be greater than distance. This

is because displacement is the shortest route connecting two positions of the particle.

Speed

Speed refers to the rate of change of position of the object in any direction with respect to time.
Speed (v) = Distance travelled (s) / Time taken (t)
The unit of speed is meter / second and it's a scalar quantity. If the object covers equal distance in
equal intervals of time, it would be *uniform speed*. If the object covers unequal distances in equal
intervals of time, it is called *non-uniform speed*.

Average Speed

Average speed is the total distanced travelled divided by total time taken. When an object moves in a
straight line at a steady speed, we can calculate its average speed if you know how far it travels and
how long it takes. The below equation shows the relationship between average speed, distance
moved and time taken:

$$average\ speed = \frac{distance\ moved}{time\ taken}$$

where **average speed** is measured in metres per second, m/s; **distance moved** is measured in
metres, m; and **time taken** is measured in seconds, s
For example, a car travels 300 m in 20 s. Its average speed is: 300 ÷ 20 = **15 m/s**

Velocity

Velocity is the rate of change of displacement of an object in particular direction. Thus, Velocity is
Displacement / time taken. The unit of velocity is also meter per second. However, unlike speed,
velocity is a vector quantity both in magnitude and direction. Thus, velocity of an object can be
positive or negative or zero.
If an object undergoes equal displacements in equal intervals of time, it would be called uniform
velocity; while if it undergoes unequal displacements in equal intervals of time, it would be called
non-uniform velocity. Relative velocity is the time rate of change of relative position of one object

with respect to another object. The average velocity is ratio of total displacement to total time taken.

Acceleration

The rate of change in velocity per unit of time is called acceleration.

$$acceleration\ (metre\ per\ second\ squared) = \frac{change\ in\ velocity\ (metre\ per\ second)}{time\ taken\ (second,\ s)}$$

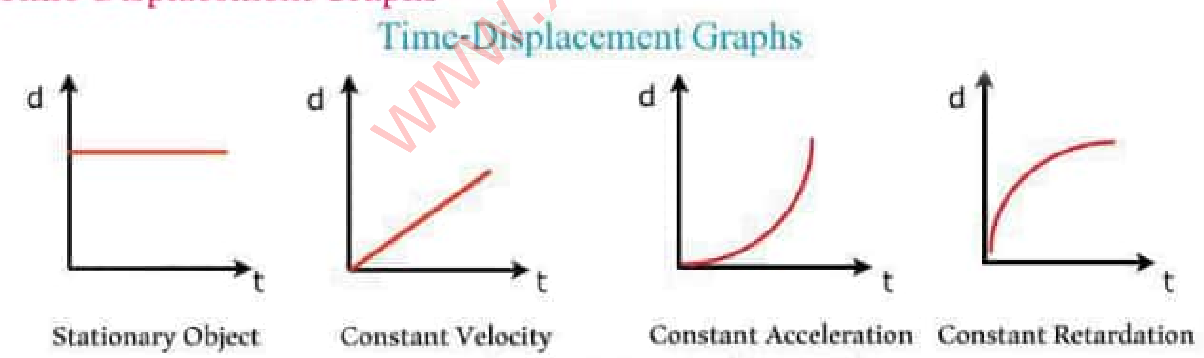
The units for acceleration are commonly written as m/s/s or m/s2. The equation for acceleration can
also be represented as:
$a=(v-u)/t$
where **a** is acceleration in m/s2; **v** is final velocity in m/s; **u** is initial velocity in m/s and **t** is time in s
For example, a car accelerates in 5 s from 25 m/s to 3 5m/s. Its velocity changes by 35 – 25 = 10 m/s.
Therefore its acceleration is 10 ÷ 5 = 2 m/s2

Deceleration / Retardation / Negative Acceleration

Deceleration, or negative acceleration, is observed when an object slows down. The units are the
same as for acceleration but the number has a negative symbol before it. For example, the car slowed
down at -1 m/s2. For example, a car decelerates in 5 s from 35 m/s to 25 m/s. Its velocity changes by
25 – 35 = -10 m/s. Therefore its acceleration is -10 ÷ 5 = -2 m/s2
Acceleration is also a vector quantity and can be positive, negative or zero. Positive acceleration
means velocity is increasing with time, zero acceleration means velocity is uniform while negative
acceleration means velocity is decreasing with time. Negative acceleration is also known as
retardation.

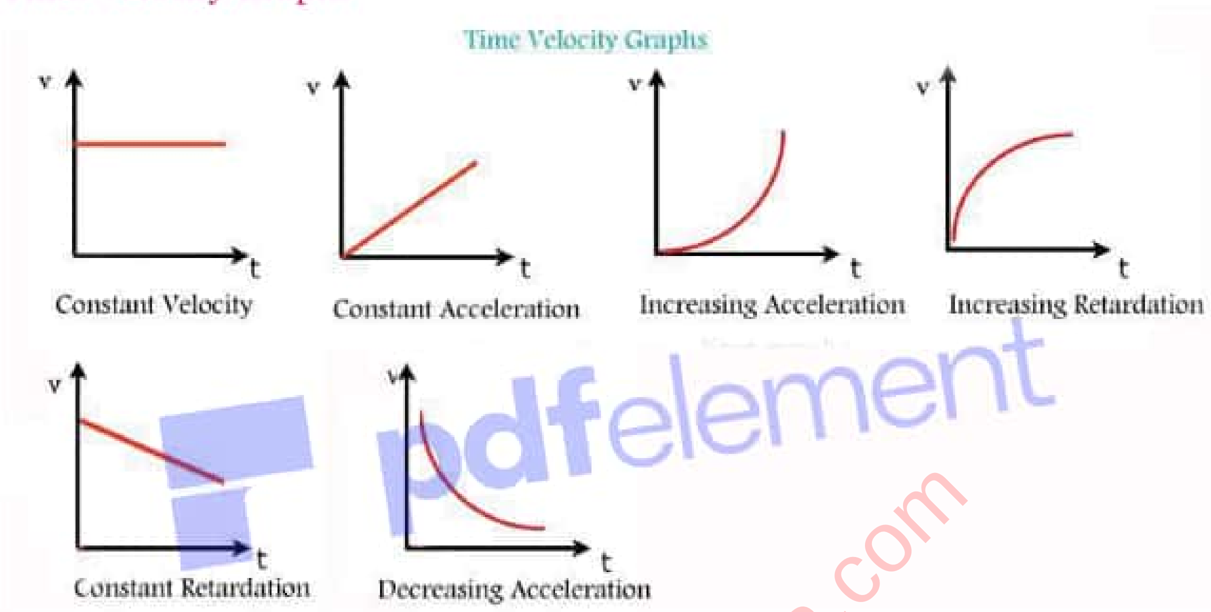
Various Graphs

Time-Displacement Graphs

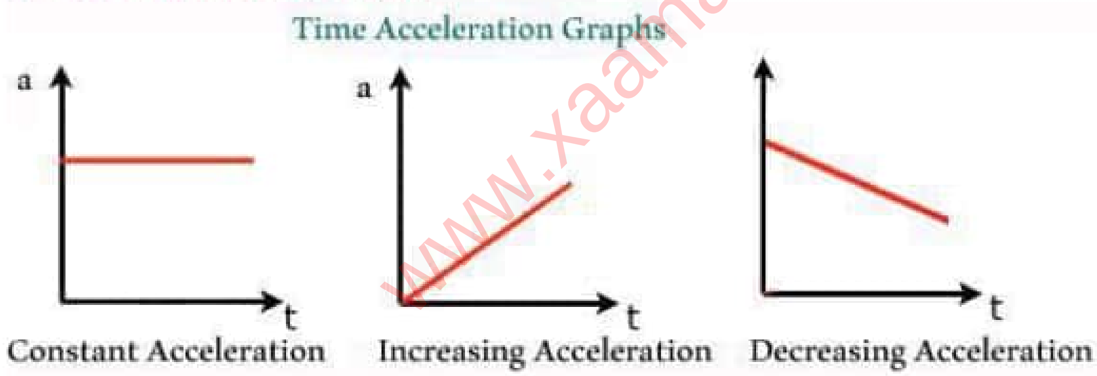


In the above graphics, first graph from left is of a stationary body because there is no change in displacement with time. Second graph denotes constant velocity because equal distance is being covered in equal time intervals. Third graph is of constant acceleration because more distance is being covered as time lapses. Fourth graph is constant retardation because less distance is being covered as time lapses.

Time-Velocity Graphs



Time Acceleration Graphs



Important Basic Equations

If a body starts with velocity (u) and after time t its velocity changes to (v), if the uniform

acceleration is a and the distance travelled in time t in s, then following would be the equations of
uniformly accelerated motion.
Formula to get final velocity:
v = u + at
Formula to get distance covered:
s = ut + 1/2 at2
Relation between v, u, a and s
v2 = u2 + 2as
Distance travelled in nth second.
Sn = u + a / 2(2n – 1)
If a body moves with uniform acceleration and velocity changes from u to v in a time interval, then
the velocity at the midpoint of its path:
√u2 + v2 / 2
Example:
A is running after a bus. The bus is travelling at an average speed of 5 m/s. The man
runs 25 m in 6 s. Does he catch the bus?
Answer: No. The man's average speed is 25 ÷ 6 = 4.2 m/s. So he will not catch a bus
moving at 5 m/s.

Identify if the below statement is true or false

Two persons sitting face-to-face at the two ends of a railway compartment running at a constant
acceleration toss a ball to each other with the same muzzle velocity and at the same inclination to the
horizontal. The time intervals for the toss are equal in both directions.

Answer:

This is a false statement. The horizontal component of the velocity of the two balls will be equal but
opposite, hence one of the ball will get accelerated while the other retarded with respect to the train,
so their times of flight will be different.

Motion under Gravity

Under gravity, acceleration is 9.8 m/s^2 and is denoted by g. When an object is falling freely under
gravity, then the above equations would be adjusted as follows:
v = u + gt
h = ut + 1/2 gt2

$V^2 = u^2 + 2gh$

In the above equation, + is replaced by – if the body is thrown upwards.

Maximum Height attained

Let a body be projected vertically upwards with an initial velocity u. As it moves upwards its

acceleration is taken as –g. As the body goes up its velocity decreases and finally becomes zero (v = 0)

when it reaches maximum height. Now the above equation (3) becomes:

$-u^2 = -2gh$

From the above, we can derive that: $h = u^2/2g$.

Time of Ascent (t_1)

The time taken by a body thrown up to reach maximum height is called its time of ascent. Let t_1 be

the time of ascent. At the maximum height its velocity v = 0. Equation (1) becomes

$0 = u - gt_1$

$t_1 = u/g$

Time of descent (t_2)

After reaching the maximum height, the body begins to travel downwards like a freely falling body.

The time taken by a freely falling body to reach the ground is called the time of descent (t_2). In this

case $u = 0$ and g is positive. Equation (2) becomes

$$h = 0 + \frac{1}{2} g t_2^2$$

$$t_2^2 = \frac{2h}{g}$$

$$t_2 = \sqrt{\frac{2h}{g}}$$

By Equation (4)

$$h = \frac{u^2}{2g}$$

$$\therefore\ t_2 = \sqrt{\frac{2}{g} \times \frac{u^2}{2g}}$$

$$= \sqrt{\frac{u^2}{g^2}}$$

$$= \frac{u}{g}$$

The above discussion makes it clear that time of ascent is equal to the time of descent in the case of
bodies moving under gravity.

Time of Flight

The time of flight is the time taken by a body to remain in air and is given by the sum of the time of
ascent (t_1) and the time of descent (t_2).

$$t_f = t_1 + t_2$$

$$= \frac{u}{g} + \frac{u}{g}$$

$$t_f = \frac{2u}{g}$$

Velocity of a body dropped from a height

When a body is dropped from a height h its initial velocity u is zero. Let the final velocity on
reaching the ground is v.

Equation (3) becomes

$v^2 = 2gh$

$$v = \sqrt{2gh}$$

At the same time, from Equation (4) we note that

$$u = \sqrt{2gh}$$

This means that:

Velocity of the body falling from a height h on reaching the ground is equal to the velocity with

which it is projected vertically upwards to reach the same height *h*. Hence the upward velocity at any
point in its flight is the same as its downward velocity at that point.

Numerical Example

1. A coin was thrown vertically upwards and it rose to a length of 10 metre. What is the velocity with which the body was thrown upwards?

Answer: In this question: h = 10 m, v = 0, u = ?, g = -9.8 ms^{-2}

Using equations: $v^2 - u^2 = 2gh$

$0 - u^2 = -2 \times 9.8 \times 10$; $u^2 = 196$; u = 14 m/s

2. A coin was thrown vertically upwards and it rose to a length of 10 metre. What was the time taken by the body to reach the highest point?

Answer: From the first question u = 14 m/s, v = 0, t = ?

v= u – gt

0 = 14 – 9.8 x t

t = 1.43 second

Practical Questions

When we drop a coin and a feather simultaneously in a tube fill with air and evacuated tube, which one will reach the bottom first?

When we drop a coin and a feather simultaneously in a tube fill with air and evacuated tube, we get
the following observations.

When the tube has air, coin which is heavier than the feather reaches the bottom of the tube
more rapidly while the feather flutters down slowly.

When there is no air in the tube, coin and the feather to fall together.

From this experiment we understand that air resistance affects the motion of a falling body. The air
resistance on a falling body depends on its shape, size and speed.

Is it possible for the acceleration to be decreasing while the velocity increasing during the same interval of time?

Yes, it's possible. If the acceleration acts in the direction of motion, it will always cause increment in
the velocity. If the acceleration is decreasing but acting in the same direction, the rate, of increase of
velocity will decrease. Consequently the velocity will continue to increase slowly. For example, in

case of a sphere falling in a viscous liquid, the net acceleration decreases but the velocity increases till
the sphere attains its terminal velocity.

A beaker is left out in the rains. Will the rate at which the beaker is filled be altered if a
horizontal wind starts to blow?

Answer: No. Beaker will be filled with the same rate because filling of beaker depends on vertical
component of the rain.

Two balls of different masses are thrown vertically upwards with the same speed. They
pass through the point of projection in their downward motion with the same speed
(neglect air resistance). This statement is true or false?

Answer: True. In absence of air resistance a ball will return to the point of projection with the same
speed.

Terminal Velocity

When a body falls, it accelerates due to gravity and the retarding force of air resistance increases with
speed. This continues till the force of air resistance equals the weight of the object. Now the object
no longer accelerates but falls with a constant speed called the terminal velocity. The terminal
velocity is about 200 km/hr for a skydiver with an unopened parachute. While falling, the skydivers
use a "spread-eagle" position to increase the air resistance and prolong the time of fall. When the
parachute is opened, the fall is slowed by the additional resistive force.

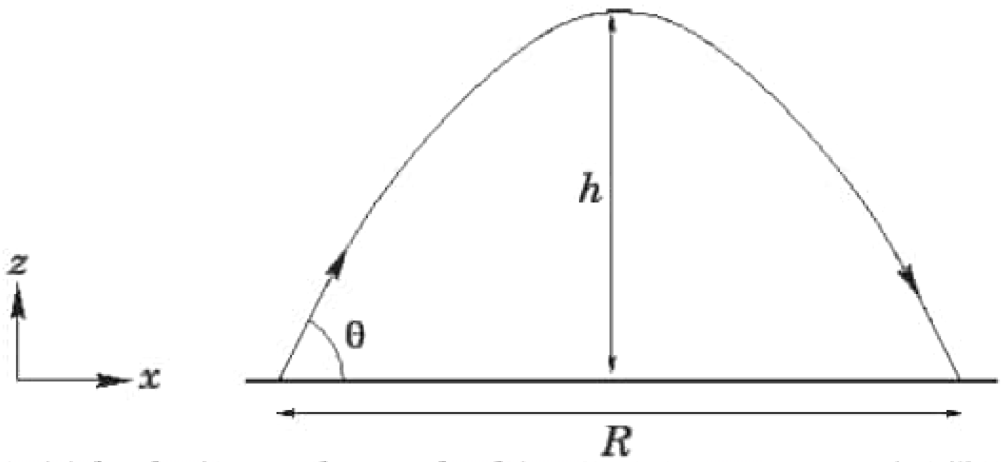
Horizontal Projectile Motion

When an object is thrown from horizontal at an angle θ except 90°, then it will follow a trajectory
and the motion is called projectile motion. A horizontally thrown ball and a bullet fired from a rifle
held horizontally are the examples of projectiles in the horizontal direction. For this type of
projection there is an initial velocity u only in the horizontal or x-direction. But there is no initial
velocity in the vertical or y-direction.

However, there is acceleration in the downward direction due to gravity. Since there is no
acceleration or force in the x-direction after it is projected, the projectile moves in this direction with
a constant speed (u).
As the object moves horizontally, it also falls in the downward direction due to gravity. In the
downward direction, the motion is the same as that of a dropped object.
Let us consider a body A which is allowed to fall freely and another body B projected horizontally
with a velocity u from the same height and at the same time. The body B possesses simultaneously:
Uniform horizontal velocity u
A non-uniform vertical velocity v.
As the body B travels down its vertical velocity (v) increases due to acceleration due to gravity. **But
the horizontal velocity u remains constant.** Hence the body A which is freely falling and the
body B projected horizontally from the same height at the same time will strike the ground
simultaneously at different points. But the two bodies at any instant will be at the same vertical
height above the ground. Thus the motion of a freely falling body is same as that of a horizontally
thrown projectile. A stone released from a moving train behaves like the horizontal projectile B. As
the path of B is a parabola, a stone released from a moving train also follows a parabolic path.

Oblique projection Motion

Consider a body which is projected at an angle with the horizontal. Let u be the initial velocity of the
projectile and θ be the angle of projection.



Initial velocity can be resolved into two components viz. (i) the horizontal component u cos θ and
(ii) the vertical component u sin θ. The path of the projectile ACB is a parabola and CD (h) is the
maximum height reached by it. The time (t) taken by the projectile to reach the maximum height is
given by

$$t = \frac{u \sin \theta}{g} \quad \ldots (1)$$

The maximum height reached is given by

$$h = \frac{u^2 \sin^2 \theta}{2g} \quad \ldots (2)$$

The time of flight (tf) of a projectile is defined as the time taken by it to reach the horizontal plane
after its projection. It s given by

$$t_f = \frac{2u \sin \theta}{g} \quad \ldots (3)$$

The distance between the point of projection A and the point B where the projectile strikes the
horizontal plane again is called its range (R). It is given by

$$R = \frac{u^2 \sin 2\theta}{g} \quad \ldots (4)$$

Equation (4) shows that the range is maximum when θ = 45° (because sin 90°= 1). This is a
consideration in several sports
Events such as shot-put, javelin and golf where maximum ranges are desired. The player is expected
to throw at an angle of 45° to achieve maximum range.

Circular Motion

When an object moves in circular path, it is called circular motion. If the speed of the object in circular motion remains constant, then it is called *uniform circular motion*. If the speed is not constant, then the motion is non-uniform circular motion. In circular motion, an acceleration acts on the body, whose direction is always towards the centre of the path. This acceleration is called centripetal acceleration or radial acceleration. Further, the Centripetal force is the force which makes the body to move in a circular path. Centripetal force is the force that is *directed toward the center of an orbital path*/spinning object which keeps the revolving object in its orbit. This is in opposition to the "centrifugal force" – a kind of fictitious force that appears to try to pull the object away from the center of the orbit (due to inertia).

Important Observations on Circular Motion

Artificial Satellites

An artificial satellite orbiting around the earth does not fall down. This is so because the attraction of earth provides the necessary **acceleration** for its motion. This acceleration is "constant" in magnitude but "changing in direction". By the launch rocket, immediately before the satellite is established in the predetermined orbit, the speed given to it is 30, 000 km/hr. The speed must be great enough so gravity doesn't bring the satellite back to Earth, but not so great that the satellite escapes gravity out into space. This means that the speed, which is provided by the rocket is the source of the centrifugal force, and the attraction of the earth holds it from moving away from this centrifugal force.

Working of Washing Machines

Both Centripetal Force and Centrifugal Force play role in working of a **Washing Machine.**

The spin dryer of a washing machine removes excess water from the clothing by rotating at a high speed. The high speed of rotation creates a high *centrifugal force* for the water in the clothing which causes it to be pulled to the outside of the spinning portion of the washing machine and away from the clothes. However, it is the Centripetal force that keeps the clothes themselves away from the outer portion of the washing machine. This is provided by the walls of the rotating spin dryer. Since there is insufficient centripetal force affecting the water (only friction & surface tension holding it to the clothes), it flows to the outer walls and is separated from the clothes, which removes the excess water.

Vehicles

Wheel of an automobile spins in mud because the centripetal force is not enough to hold the mud on tyre. When vehicles turn around at a turn, the centripetal force is provided by the friction between tyres and road.

The less desirable case of lack of centripetal force is when the rear wheel of an automobile spins in mud. The adhesion of the mud to the wheel which is the centripetal force in this case is not enough to hold the mud on the tyre. So it comes off tangentially to the tyre's circular motion.

If a vehicle moves at very high speed over a curved path, the *centrifugal force makes it topple*. This is because the centrifugal force overcomes the frictional force between the road and the tyres of the vehicle. To prevent this, the curved tracks are always banked. It means that the outer edge of the road is slightly elevated at an angle. This angle of elevation is given by

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

Where g is acceleration due to gravity.

Due to banking of curves the centrifugal force balances with frictional force and equilibrium is reached. Thus toppling of vehicles is prevented on curved roads. This is known as banking of tracks.

The racing track is designed like a concave disc for the same reason.
In circus there during the cage of death event, a motor cyclist drives a motor cycle at a high speed on the inner walls of a spherical cage of iron. But he does not fall off the motor cycle even when he is upside down. The centrifugal force keeps the motor cyclist glued to his seat while driving his motor cycle inside the cage.

Other Notes

Total work done by the *centripetal force is always zero*because the centripetal force and displacement are at right angles to each other.
During orbital motion of the planets, centripetal force is provided by the gravitational force between planet and sun.
During orbital motion of electron around nucleus in an atom, the centripetal force is provided by *Electrostatic force* between electron and nucleus.
When we swing a stone tied to a string, the centripetal force is provided by tension in the string.
Centrifugal force is in opposite direction to Centripetal force. On earth, it is minimum at poles and maximum at equator.
In centrifuges, heavier particles move away from the centre while lighter particles remain near axis of rotation.
When a sample of blood is centrifuged, the red blood cells accumulate at the bottom, because red blood cells are heavier than White Blood Cells.
Cream from milk is separated by centrifuges in dairy separators. Ultra centrifuges with speeds of the order of 5 x 105 rpm are used to **concentrate viruses in solution**.
Centrifuges are used in **Uranium enrichment**.
Sugar crystals are separated from molasses with the help of a centrifuge. **Honey is also separated from bees wax** with the help of a centrifuge.

Laws of Motion

Inertia

The property of an object by virtue of which it cannot change its state of rest or of uniform motion
along a straight line its own, is called **inertia.** Inertia is basically a measure of mass of the body. Thus,
greater is the mass, greater is its inertia and vice versa.
When a bus or train starts to move suddenly, the passengers sitting in it falls backward. This
is due to inertia called *inertia of rest*.
When a moving train stops suddenly, the passengers sitting in it jerk in forward direction.
This is due to inertia called *inertia of motion*.
We are able to protect ourselves from rains using an umbrella because rain drops cannot
change their direction on their own. This is called *inertia of direction*.

Force

Force refers to a push or pulls which tries to change the state of rest, motion, size or shape of an
object. Its SI unit is Newton. 1 Newton is equal to 1 kg m/s2. There are two types of forces viz. *Contact
forces* and *Action at distance forces*. Examples of Contact Forces include Frictional force, Tensional
Force, Spring Force etc. The Forces in action at distance include magnetic force, electrostatic force,
gravitational force etc.
Further, the forces which act on an object for a short interval of time but change large change in
momentum is called impulsive force. Momentum is the total amount of motion present in a body.
Change in Momentum is called Impulse.

Newton's First Law of Motion

Newton's first law of motion says that a body continues to be in its state of rest or in uniform motion
along a straight line unless an external force is applied on it. This explains:
Why when a beat a carpet with stick, dust particles separate out of it.
Why passengers feel sudden jerk forward when a moving Bus or train stops suddenly.

Newton's Second Law of Motion

Newton's second law of motion says that the rate of change of linear momentum is proportional to

the applied force and change in momentum takes place in the direction of applied force. This
explains:
Why it is easier to push empty cart than full cart
Why adult is able to push or pull a cart easily than a child
The second law of motion is called real law of motion because first and third laws of motion can be
obtained by it.

Newton's Third Law of Motion

Third law of motion says that "For every action there is an equal and opposite reaction and both acts
on two different bodies." Swimming is possible because of this law. This explains why jerk is
produced in a boat when bullet is fired from it. *A person is hurt on kicking a stone due to reaction only.*

Law of Conservation of Linear Momentum

This law says that if no external force acts on a system, then its total linear momentum remains
conserved. In equation form, Momentum=mass*velocity. To increase the momentum of an object,
we need to either increase its mass or velocity or both.
Rockets work on law of conservation of momentum. As momentum in one direction is given
to the rocket's exhaust gases, momentum in the other direction is given to the rocket itself.

Weight (w)

Weight refers to a force with which a body is pulled towards the centre of the earth due to gravity. It
has the magnitude mg, where m is the mass of the body and g is the acceleration due to gravity, thus
$w=mg$
When a lift is either at rest or moving with a constant speed, then apparent weight of a
person standing in it is equal to his actual weight. Thus, $R = mg$
When a lift is accelerating upward, then apparent weight would be $R_1=M(g+a)$. Thus
weighing machine would read the apparent weight more than the actual weight.
When a lift is accelerating downward, then apparent weight would be $R_2=m(g-a)$. Thus, the

weighing machine would read less than actual weight.
When the lift is falling freely under gravity then apparent weight $R3=m(g-g) =0$. In this case,
machine will read zero.
If lift is accelerating downward with an acceleration *greater than g*, then the person will lift
from floor to the ceiling of the lift.

Friction

Friction is force acting on the *point of contact of the objects*, and which opposes the relative motion.
Friction always works parallel to the contact surfaces. Frictional forces are produced due to
intermolecular interactions acting between the molecules of the bodies in contact.
There are three kinds of friction viz. static friction, limiting friction and Kinetic friction.
Static friction is the opposing force which works when one body tends to move over the surface of
the other body but actual motion is not taking place. This makes harder for two objects to slide
alongside one another. Glass on Glass is an example of static friction. Static friction results from the
interlocking irregularities present on the two surfaces in contact. This force will increase in response
to an attempt to move the objects until it is overcome at the threshold of motion. The maximum
value of static friction when body is at the verge of starting motion is called Limiting Friction. The
friction that occurs after the point where motion is achieved is referred to as kinetic friction.

Common examples of Friction:

We can hold a pen while writing due to the force of friction. Friction is needed in this case
for better grip. If there is no friction, it would be really difficult to write.
If there was no friction, walking on the road would become impossible. It is friction that
allows us to walk.
After a shower, it becomes difficult to drive a car at high speed on the wet road because
friction decreases.

Angle of sliding or angle of repose is the minimum angle of inclination of a plane with the horizontal in such a way that the body placed on it begins to slide down. It depends upon limiting friction.

Further, when a body moves on an inclined plane then several forces work on it viz. normal reaction of plane, friction force acting in opposite direction of motion, gravitation force vertically down etc.

Pushing or pulling an object

To pull an object (such as lawn mower) is always easier than to push whenever the *force is applied at an angle to the object*. This is because horizontal component of force will act to move the object. so:

If we push, then the vertical component of force will press the object downward and the friction will be more.

If we pull then the Vertical component of force will act upward and the friction will be less.

Work, Power and Energy

Work

Work is said to have been done when a force acts on an object and the object actually moves in the direction of force. Work done is equal to the product of the *force and the displacement* of the object in the direction of force.

Work = Force X Displacement

SI unit of work is Joule (J) which is equivalent to SI base units 1 kg.m2/s2. Thus, 1 Joule of work is said to have been done when a force of 1 N causes a displacement of 1 m.

Notable Examples regarding work:

No work is done by a man rowing a boat upstream but is at rest with respect to the bank.

This is because when the man is rowing a boat upstream, it is at rest with respect to the bank.

So, the displacement of the boat is zero. Hence, no work is done by the boat.

No work is done if I apply all the force upon a wall and is not able to move it. Similarly, I will do no work if I am a coolie and I just standing with a load on my head but not moving. {work

is done in this case if I lift a luggage from ground to place it on my head}
Work can be positive, zero or negative. Negative work implies that the displacement is in
opposite side of the force. Negative Work is done when brakes are applied to a moving
vehicle and vehicle stops.
When a ball is projected vertically upward and it comes back due to force of gravity, work is
done by both ball and gravity in opposite directions.

Work done in Circular Path

Work done depends only on the initial and final Positions and not on the actual path followed
between initial and final positions. When a body moves in a circular path no work is done. This is
because centripetal force acting on the body is always at right angles to the displacement of the body
along the circular path. Since $\cos 90° = 0$, so $W = F \cos 90° \times S = 0 \times S =$ Zero.
Similarly, when a satellite revolves around the earth in a circular orbit, the work done by force of
gravity is also zero because it acts at right angles to the direction of displacement of the satellite.

Power

Power is the time rate of work done by a body. Thus if work done is divided by time taken, we get
power.
Power =Work done / Time taken
The SI unit of power is Watt which is equal to 1 joule per second. 1 Horse power is equal to 746
watt. Power is a scalar quantity.

Energy

Energy of a body refers to its capacity of doing work. Energy is a scalar quantity. SI unit of Energy is
erg. 1 erg = 10^{-7} J
There are several types of energies for example, mechanical energy, chemical energy, light energy,
heat energy, sound energy, nuclear energy, electric energy etc.

Mechanical Energy

Kinetic Energy and Potential Energy are called Mechanical Energy. The sum of kinetic and potential

energies at any point remains constant throughout the motion. It does not depend upon time. This is
known as law of conservation of mechanical energy.

Kinetic Energy

The energy possessed by any object by virtue of its motion is called its kinetic energy.
Kinetic energy of an object is given by **k = 1 / 2 mv2**
where m = mass of the object, and v is its velocity.
So it's obvious that Kinetic energy is zero in stationary objects as v=0.
The above formula shows that the Kinetic Energy is a product of half the Mass and velocity Squared.
When the velocity is doubled, the Kinetic energy would go up four times. If velocity is tripled, kinetic energy
would go up nine times. If velocity is increased by 1.5 times the Kinetic energy would go up by
1.5×1.5=2.25 times.
Further, since kinetic energy is a product of mass and velocity squared, a tennis ball and a football
don't have equal kinetic energy if they have equal velocities. To get equal kinetic energy, the tennis
ball needs to have few times higher velocity than a football.
Energy in a running horse, Speeding car, fired bullet, oscillating pendulum, flowing water, flying
bird are examples of Kinetic energy.

Potential Energy

The energy possessed by any object by virtue of its position or configuration is called its potential
energy. There are three important types of potential energies viz. gravitational, elastic and electric.
If a body of mass m is raised through a height h against gravity, then it ha*gsr avitational*
potential energy. It would be equal to E=mgh
If a spring of spring constant k is stretched through a distance x, then *elastic potential energy* of
the spring would be E=1/2 kx2
Examples of Potential Energy include: a stretched bow and arrow system; a wound up spring of a
watch; water stored high up in reservoirs; stone lying on the top of the roof.

Work-Energy Theorem

Work energy theorem says that the work done by a force in displacing a body is equal to change in
its kinetic energy. When we move an object (i.e. we do work on it), we increase its*k inetic energy*.
When we bring a moving object to rest, we also do work on the object, but in this case we are
decreasing its kinetic energy. Regardless of whether we are increasing or decreasing an object's
kinetic energy, the *amount of work done is equal to the change in energy*.

Mass-Energy Equivalence

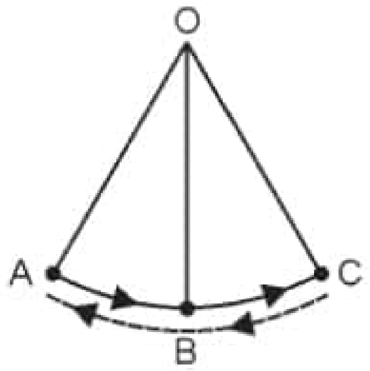
Einstein showed us the way that mass can be transformed into energy. When Δm is converted into energy, the energy produced is equal to $E = \Delta mc^2$, where c is the speed of light
in vacuum.

Principle of Conservation of Energy

This says that sum of all kinds of energies in an isolated system remains constant at all times.
The law of conservation of mass and energy states that the total energy (Rest mass energy + kinetic
energy + potential energy) of a closed system is constant; that is, energy or mass can neither be
created nor destroyed.

Principle of Conservation of Mechanical Energy

For conservative forces the sum of kinetic and potential energies of any object remains constant
throughout the motion. An object may have both kinetic and potential energy at the same time but
total of them would be same. For example, a flying aeroplane, an oscillating pendulum, a stone
thrown upwards have both kinetic and potential energy.
A swinging pendulum has maximum kinetic energy and minimum potential energy when it is at the
middle of the arc i.e. at its lowest point. However, when it is at highest point on either side, its
kinetic energy is zero and all energy is potential energy. Throughout its swing, the total mechanical
energy remains same.



At A	At B	At C
P.E. = Max	P.E. = 0	P.E. = Max
K.E. = 0	K.E. = Max	K.E. = 0

Practical examples on Energy

Q-1: A rubber ball dropped from 24 m height and after impact it loses its kinetic energy by 25%. What is the height to which it rebounds?

Answer: In this question, all the potential energy of ball (by virtue of its being at a height of 24 m) is converted into kinetic energy when it reaches to the ground. However, the ball has lost 25% of its kinetic energy (due to inelastic collision). What remains with the ball is 75% of the kinetic energy. So it would rebound only 75% of 24 meters i.e. 18 meters.

Q-2: What kind of Energy is stored in Tides in Oceans?

Tides in the sea have stored in them combination of Hydraulic energy, Kinetic energy as well as Gravitational potential energy.

Q-3: **Which of the following four objects has the least kinetic energy: an object of mass (m) moving with speed (4v), an object of mass (3m) moving with speed (2v), an object with mass (4m) moving with a speed of (v), or an object of mass (2m) moving with speed (3v)?**

Answer:

Let $1/2mv^2$ be X, so:

Kinetic energy of first mass is 16X

Second is 12X

Third is 4X

and fourth is 18X

Thus, least Kinetic energy is of third one.

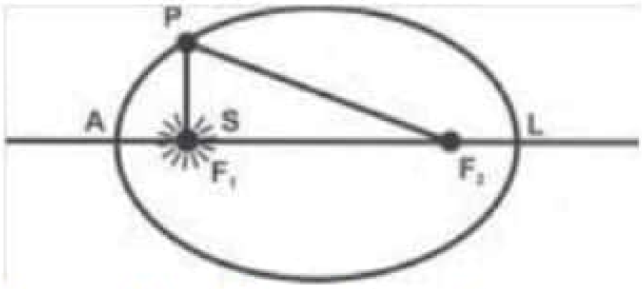
Gravitation and Artificial Satellites

Kepler's Laws

In the early 1600s, Johannes Kepler proposed three laws of planetary motion as follows:

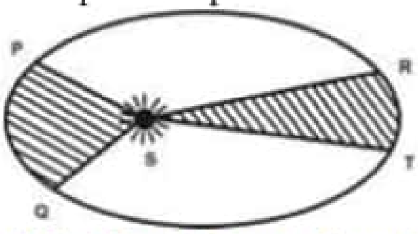
Kepler's First law (Law of orbits)

Each planet moves around the sun in an elliptical orbit with the sun at one of its foci. An ellipse is a closed curve such that the sum of the distances from any point P on the curve to two fixed points (F_1, F_2) remains constant.



Second law (Law of areas)

As the planet moves in its orbit, a line drawn from the sun to the planet sweeps out equal areas in equal intervals of time. Let PQS and RST be the areas swept by the line joining the planet and the sun in equal intervals of time. Kepler found that these areas are equal. Hence the speed of the planet around sun must be maximum at the perihelion position and minimum at the aphelion position.



Third law (Law of periods)

The squares of the periods of revolution of the planets are proportional to the cubes of their mean distances from the sun. If R is the mean distance of the planet from the sun and T is the period of its revolution the third law states that $T^2 \propto R^3$. As per this law, the planets with the mean distances from the sun, their orbital periods and velocities are listed in the table.

Planet	Time Period (Earth Years	Mean Distance from Earth ($x10^9$ m)	Mean Velocity (x 10^3 m/s)	T^2 / R^3 ($x10^{-25}$) $years^2 /km^3$
Mercury	0.241	57.91	47.875	2.991
Venus	0.615	108.21	35.056	2.985
Planet	Time Period (Earth Years	Mean Distance from Earth ($x10^9$ m)	Mean Velocity (x 10^3 m/s)	T^2 / R^3 ($x10^{-25}$) $years^2 /km^3$
Earth	1	149.6	29.806	2.987
Mars	1.881	227.94	24.144	2.988
Jupiter	11.862	778.3	13.072	2.985
Saturn	29.458	1427	9.651	2.986
Uranus	84.015	2869	6.804	2.99
Neptune	164.788	4498	5.438	2.984
Pluto	248.4	5900	4.732	3.004

A century later, Newton demonstrated that Kepler's laws were the consequence of a simple force that
exists between any two masses. Newton's law of gravitation and laws of motion, provide the basis for
the motion of planets and satellites.

Newton's universal law of gravitation

Everybody in the universe attracts every other body with a force which is directly proportional to the
product of the masses of the two bodies and inversely proportional to the square of the distance
between them. If m1 and m2 are the masses of two bodies separated by a distance r, the force of
attraction F between them is given by:

$$F = \frac{G m_1 m_2}{r^2}$$

where G is the universal constant of gravitation. The value of G = 6.67 x10-11 N m2 Kg-2 . The force of
gravitation is directed along the line joining the two bodies. If m1 = m2 = 1 kg and r = 1 m then F =
G. Thus the gravitational constant is equal to the force of attraction between two bodies each of mass
1 kg separated by a distance of 1 metre.

Artificial Satellites

Satellite refers to any project that is orbiting earth, sun or other planetary bodies. Satellites can be
artificial or natural. The artificial satellites basically work on principle of projectiles. The only force
that works on satellites is gravity. Once launched in an orbit, gravity is the only force governing the motion of the satellite.

Important Concepts

Selection of tangential speed is very much important in case of launch artificial satellite
launches. They are projected with such a speed that the "radius" of their curved path is
"greater" than the radius of earth. However, not such a high speed that the satellite leaves the
orbit and gets lost in space.

The speed of an artificial satellite does NOT depend upon its mass. This implies that at a
particular distance from earth, all objects would move at same speed of revolution.

Higher the orbit is, lower is its speed, so when a satellite moved from higher orbit to lower
orbit, its speed increases.

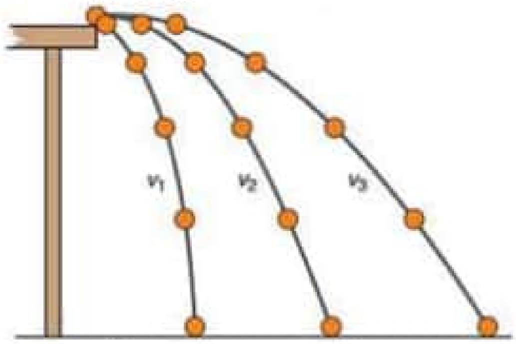
If we throw the satellite of a speed lesser than 7900 meters per second or 28500 kilometers
per hour, it will simply fall on earth. The speed higher than this willp roduce an elliptical
orbit. However if this speed is more than 11.2 kilometers per second, it will escape the earth's
gravitation field and will never come back.

Equator or the places near to equator are found suitable for launching the satellites as it will
save efforts.

Satellites are launched in Eastward direction, it also saves efforts.

Basics

When we throw a stone with some speed in the horizontal direction, it will follow a curved path and
fall on the ground. When we throw the stone with a greater speed, it will follow a curved path that is
even bigger than the previous one. Thus, greater is the speed, greater is the radius of the curved path
as shown below:



Now, if we have such a powerful device to throw this stone with such a tremendous speed that
radius of the curved path it follows becomes little bigger than the radius of earth, we cannot expect it
to return to earth. Rather, it will keep on revolving around the earth. This is how the artificial
satellites work. **They are projected with such a speed that the "radius" of their curved path is "greater" than the radius of earth.** Gravitational pull of earth would provide the necessary centripetal force that is needed to keep it in
its particular orbit. Here, we should note that **speed of the satellite is carefully chosen** so that it
provides necessary force to keep it revolving. This implies that:

F (Gravitational) = F (centripetal)

$$\text{So } m\frac{v^2}{r} = mg$$

$$v^2 = rg$$

$$V = \sqrt{rg}$$

From the above formula, we first note that there is no place for **m** , which means that the **speed of**

an artificial satellite does NOT depend upon its mass. This implies that at a particular distance
from earth, all objects would move at same speed of revolution.
But the above formula says that v is dependent upon r. The above formula now we derive again as
follows:
F (Gravitational) = **F** (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

In the above formula, G is the universal gravitational constant and M is the mass of earth. We arrive
at v as follows:

$$m\frac{v^2}{r} = \frac{GMm}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

Here we come to two conclusions:

- v is dependent upon r because V= $\sqrt{rg}$
- **v is inversely proportional to r because** $v = \sqrt{GM/r}$

Here we conclude that higher the orbit is, lower is its speed. When we whirl a small string with an
small object tied at one of its and also allow to get it rolled around our finger, we find that the smaller
the radius of the circle is, higher is its speed.
So, when a satellite moved from higher orbit to lower orbit, its speed increases.
Since, g= 9.8 square meters per second and radius of earth is 6.4 x 106 meters, we conclude that

V = $\sqrt{rg}$ = $\sqrt{6.4 \times 10^6 \times 9.8}$ = 7.9 x 10^3 meters per second = 7.9 kilometers per second

Thus, if we throw the satellite of a speed lesser than 7900 meters per second or 28500 kilometers per
hour, it will simply fall on earth. But the speed higher than this will produce an elliptical orbit.
However if this speed is more than 11.2 kilometers per second, it will escape the earth's gravitation
field and will never come back.

This value of 11.2 kilometers per second is known as escape velocity and it explains why we have the
gaseous atmosphere which does not go away from earth. On moon the escape velocity is 1.9
kilometers per second and molecules of any gas formed on moon would have velocity more than this
value and that is why moon has not gaseous atmosphere.
Launching a satellite needs tremendous forces, because providing it an speed of 28500 kilometers per
second is not an easy task.

Launching a satellite on Equator versus Poles

Earth is not round and we all know that its radius on poles is smaller than its radius on equators. The
away we move from centre of earth, lower is the gravitational force and this is the reason that the
gravitational pull is minimum at Equator. So, **Equator or the places near to equator are found**
suitable for launching the satellites as it will save efforts.

Launching a satellite in eastward versus westward direction

We know that Earth rotes from west to east, the satellites are launched in Eastward direction so that
the speed of earth's rotation which comes nearly 462 meters per second will provide it additional
push. (40000 x 1000 ÷24÷60÷60=462 (though exact speed is 465.1 meters per second))

Geostationary and Geosynchronous Orbits

The core principle of an orbit is that as a satellite or object moved tangentially, it falls toward the
earth / other body, but it moved so quickly that earth / body will curve away beneath it. Thus we can
understand that gravity pulls this object into a curved path as it attempts to fly off in a straight line. A
satellite has enough tangential velocity to miss the orbited object, and will continue falling
indefinitely.
In other words, when the satellite is moving in the orbits, it stays in position because the centripetal
force on the satellite balances the gravitational attractive force of the earth. This balance depends on
the following:

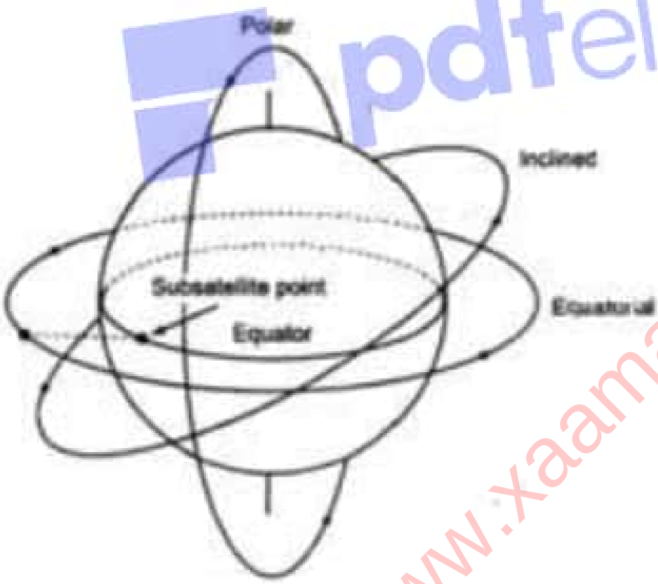
Distance from the earth
Tangential speed of the satellite
Earth's radius
Gravitational force of the earth.
But it does not depend upon:
Mass of the satellite
Size of the Satellite

Key Concepts

An artificial satellite is always falling towards earth, but it has enough tangential velocity to
continue fall indefinitely.
Centripetal force on the satellite balances the gravitational attractive force of the earth. This
balance does not depend upon the mass and size of the satellite.

Types of Orbits

There are three major types of orbits viz. **Polar, Inclined and Equatorial**. The Polar Orbits cover the poles, Equatorial are above the equator and inclined orbits are inclined
from the equatorial orbit. They are shown as below:



Geostationary Orbit (GEO)

If we need a satellite for the purpose which needs this satellites to remain at a particular distance
from earth at all the time, then we need **circular orbits so all the points on circular orbit are at**

equal distance from earth's surface. The **circular equatorial orbit** is exactly in the plane of
equator on the earth. If the satellite is moving in the circular-equatorial orbit and its angular velocity
is equal to earth's angular velocity, the satellite is said to be moving along with the earth. This
satellite would appear stationary from the earth and this orbit would be called **Geostationary Orbit**.

Features of geostationary satellite

The orbit is circular
The *orbit is in equatorial plane* i.e. directly above the equator and thus inclination is zero.
The *angular velocity of the satellite is equal to angular velocity of earth*
Period of revolution is equal to period of rotation of earth.
Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1
seconds
There is ONLY one geostationary orbit.

Geosynchronous Orbit

There is a difference between the geostationary and geosynchronous orbits. We should note that
while other orbits may be many, there is ONLY ONE Equatorial orbit, i.e. the orbit which is directly
above the earth's equator. Sometimes we send a satellite in the space which though has a period of
revolution is equal to period of rotation of earth, but its orbit is **neither equatorial nor Circular**.
So, this satellite will finish one revolution around the earth in exactly one day i.e. 23 hours, 56
Minutes and 4.1 seconds, yet it does NOT appear stationary from the earth. **It looks oscillating** but
NOT stationary and that is why it is called **Geosynchronous**.

Features of a geosynchronous satellite

The orbit is **NOT circular**
The orbit is **NOT in equatorial plane**e. directly above the equator, it's **in inclined orbit**
The **angular velocity of the satellite is equal to angular velocity** of earth
Period of revolution is equal to period of rotation of earth.

Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1
seconds
There are **many geosynchronous orbits**.
Please note that it is practically NOT possible to achieve an absolute geostationary orbit. So, the
terms geostationary and geosynchronous are used alternatively.

Advantages of GEO satellites

Most communications satellites in use today for commercial purposes are placed in the
geostationary orbit, because one satellite can cover almost 1/3 of Earth's surface, offering a
reach far more extensive than what any terrestrial network can achieve.
The geosynchronous satellites remain stationary over the same orbital location, users can
point their satellite dishes in the right direction, without costly tracking activities, making
communications reliable and secure
GEO satellites are proven, reliable and secure – with a lifespan of 10-15 years.
GEO systems have significantly greater available bandwidth than the Low Earth Orbit -LEO
and Medium Earth Orbit -MEO systems. This permits them to provide two-way data, voice
and broadband services that may be unpractical for other types of systems.
Because of their capacity and configuration, GEOs are often more cost-effective for carrying
high-volume traffic, especially over long-term contract arrangements. For example, excess
capacity on GEO systems often is reserved in the form of leased circuits for use as a backup to
other communications methods.

Disadvantages of GEO Satellites

GEO systems, like all other satellite systems, *require line-of-sight communication paths between*
terrestrial antennae and the satellites. But, because GEO systems have fewer satellites and these
are in a fixed location over the Earth, the opportunities for line of sight communication are
fewer than for systems in which the satellites "travel" across the sky. This is a significant

disadvantage of GEO systems as compared to LEO and MEO systems, especially for mobile
applications and in urban areas where tall buildings and other structures may block line-ofsight
communication for hand-held mobile terminals.
There are concerns with the transmission delays associated with GEO systems, particularly
for high-speed data. However, sophisticated echo cancellation and other technologies have
permitted GEOs to be used successfully for both voice and high-speed data applications.

Height of Geostationary Satellites

Key Points

The height of the geostationary orbit is 35786 kilometers above earth
In Geostationary Orbit, the satellite moves with an orbital speed of 11068 km per hours.
A minimum of three satellites are needed to cover the entire earth
Super synchronous orbit is a disposal / storage orbit above GSO. From earth, they would
seem drifting in westerly direction.
Sub synchronous orbit is a orbit close to but below GSO and is used for satellites undergoing
station, changes in an eastern direction.

Calculation of Height

For circular motion of a planet, the condition is that:
F (Gravitational) = F (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

V is the speed. Now, we know that the speed v of the planet in its orbit is equal to the circumference
of the orbit divided by the time required for one revolution T. so v=2πr/T. So, the above formula
becomes as follows:

$$\frac{GMm}{r^2} = m\frac{\left(\frac{2\pi r}{T}\right)^2}{r}$$

From the above formula, we can derive the value of T2 as follows

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$

The above mathematical derivation is suitable for circular as well as elliptical orbits. Now we know
that geostationary satellite follows a circular, equatorial, geostationary orbit, without any inclination,
so we can apply the Kepler's third law to determine the geostationary orbit. Since, the path is circle,
its semi-major axis will be equal to the radius of the orbit.
Now, it has already been calculated that Earth completes one rotation on its polar axis in 23 hr 56
min and 4.09 sec, which comes out to be 86164.09 seconds. So, the period of rotation of the
Geostationary satellite should be 86164.09 seconds.
This means that
T=86164.09 seconds
Now we use this formula:

$$\frac{r^3}{T^2}=\frac{GM}{4\pi^2}$$

$$r^3=\frac{GM}{4\pi^2}$$

$$r^3=\frac{6.67x10^{-11}x5.983x10^{24}x86164.09}{4\pi^2}$$

$$r^3=7.546x10^{22}$$

$$r = 4.23\ x10^{7}\ \text{Meters}$$

$$r = 42300\ kilometers$$

The above derivation gives the height of the Geostationary orbit. Now, please note that the above
height includes radius of Earth which is 6,384 km. When we deduct it from the calculated height we
get 35916 Kilometers. The precise height is altitude of 35,786 km (22,236 mi) above ground.
Orbital speed (how fast the satellite is moving through space) is calculated by multiplying the angular
speed by the orbital radius:

$$v = \omega r \approx 3.0746\ \text{km/s} \approx 11068\ \text{km/h} \approx 6877.8\ \text{mph}.$$

Orbiting at the height of 22,282 miles above the equator (35,786 km), the satellite travels in the same

direction and at the same speed as the Earth's rotation on its axis, taking 24 hours to complete a full
trip around the globe. Thus, as long as a satellite is positioned over the equator in an assigned orbital
location, it will appear to be "stationary" with respect to a specific location on the Earth.

Inclined Orbit

An inclined orbit is used to cover the Polar Regions. It's not a very popular orbit and used not very
frequently. The height of the inclined orbit is kept such that it covers the required area of the region
of interest. The time for which the satellite is visible to the point on the earth is also controlled.
Satellite cannot remain in continuous contact with the point on the earth if rotating in inclined orbit.
Sometimes the inclined orbit is also called elliptical inclined orbit.

Clarke Orbit

Please note that a single geostationary satellite can view approximately **one third of the Earth's**
surface. If three satellites are placed at the proper longitude, the height of this orbit allows almost
the Earth's entire surface to be covered by the satellites. It was first of all conceptualized by world
famous science fiction writer Arthur C. Clarke. The arrangement which was suggested by Clarke is
shown in the following figure:

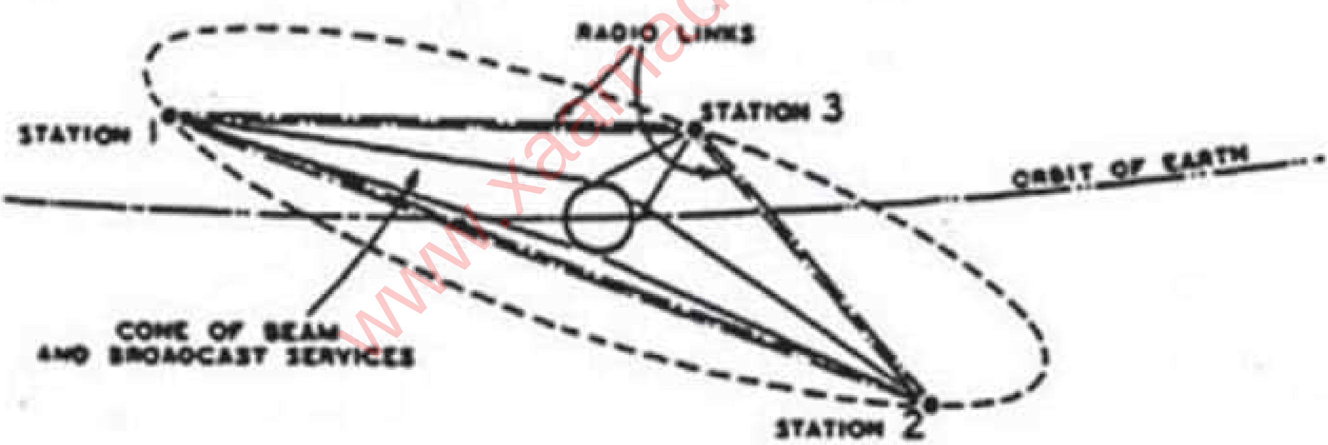


Fig. 3. Three satellite stations would ensure complete coverage of the globe.

The stations would be arranged approximately equidistantly around the earth and the following
longitudes appear suitable:
30°E – Africa & Europe
150°E – China & Oceania
90° W- The Americas
The station chain would be linked by radio or optical beams and thus any broadcast service could be
provided. The geostationary orbit is now sometimes referred as the Clarke Orbit or the Clarke Belt
in his honor.

Low Earth Orbits

A satellite can also be placed in Low Earth Orbits (about 1,000 kilometers above the Earth (between
400 miles and 1,600 miles)). However, satellites in LEO need a higher velocity than Geostationary
orbits. For example, a satellite which is placed in an orbit at altitude of 200 kilometers will need an
orbital velocity of approximately 29000 kilometer per hour. Similarly, a satellite placed in an orbit at
around 1730 kilometers will need a speed of 25,400 kilometers per hour.

Key Features of LEO

Unlike GEOs, the LEO satellites appear travelling across the sky from earth. A typical LEO satellite
takes one and half hours to orbit the Earth, which means that a single satellite is "in view" of ground
equipment for a only a few minutes. As a consequence, if a transmission takes more than the few
minutes that any one satellite is in view, a LEO system must "hand off" between satellites in order to
complete the transmission. In general, this can be accomplished by constantly relaying signals
between the satellite and various ground stations, or by communicating between the satellites
themselves using "inter-satellite links."

International Space Station

The International Space Station is in a LEO that varies from 320 km (199 mi) to 400 km (249 mi)
above the Earth's surface

Applications of Low Earth Orbit Satellites

LEO systems are designed to have more than one satellite in view from any spot on Earth at any given time, minimizing the possibility that the network will lose the transmission. Because of the fast-flying satellites, LEO systems must incorporate sophisticated tracking and switching equipment to maintain consistent service coverage. The need for complex tracking schemes is minimized, but not obviated, in LEO systems designed to handle *only short-burst transmissions.*
The advantage of the LEO system is that the satellites' proximity to the ground enables them to transmit signals with no or very little delay, unlike GEO systems. LEO satellites rotate the earth and currently deliver significant voice quality over the Geosynchronous (GEO) satellite systems. Now days, LEO Satellites are used in constellations such as Globalstar and Iridium constellations. In addition, because the signals to and from the satellites need to travel a relatively short distance, LEOs can operate with much smaller user equipment (e.g., antennae) than can systems using a higher orbit. In addition, a system of LEO satellites is designed to maximize the ability of ground equipment to "see" a satellite at any time, which can overcome the difficulties caused by obstructions such as trees and buildings.

Orbital Decay

The satellites particularly in the LEO are subject to a drag produced by an atmosphere due to frequent collisions between the satellite and surrounding air molecules. The amount of this drag keeps increasing or decreasing depending upon several factors including the solar activity. The more activity heats of the upper atmosphere and can increase the drag. This drag in a long duration causes a reduction in the altitude of a satellite's orbit, which is called orbital decay.
So, the major cause of the orbital decay is Earth's atmosphere. The result of the drag is increased heat

and possible reentry of satellite in atmosphere causing it to burn. Lower its altitude drops, and the lower the altitude, the faster the decay. Apart from Atmosphere, the Tides can also cause orbital decay, when the orbiting body is large enough to raise a significant tidal bulge on the body it is orbiting and is either in a retrograde orbit or is below the synchronous orbit. Mars' moon Phobos is one of the best examples of this.

LEO systems Pros and Cons

It requires less energy to place a satellite into a LEO and the LEO satellite needs less powerful amplifiers for successful transmission, LEO is still used for many communication applications.

However, since these LEO orbits are not geostationary, a network (or "constellation") of satellites is required to provide continuous coverage.

The transmission delay associated with LEO systems is the lowest of all of the systems.

Because of the relatively small size of the satellites deployed and the smaller size of the ground equipment required, the LEO systems are expected to cost less to implement than the other satellite systems.

The small coverage area of a LEO satellite means that a LEO system must coordinate the flight paths and communications hand-offs a large number of satellites at once, making the LEOs dependent on highly complex and sophisticated control and switching systems.

LEO satellites have a shorter life span than other systems. There are two reasons for this: first, the lower LEO orbit is more subject to the gravitational pull of the Earth and second, the frequent transmission rates necessary in LEO systems mean that LEO satellites generally have a shorter battery life than others.

Medium Earth Orbit

MEO systems operate at about 8,000-20,000 km above the Earth, which is lower than the GEO orbit
and higher than most LEO orbits. The MEO orbit is a compromise between the LEO and GEO
orbits. Compared to LEOs, the more distant orbit requires fewer satellites to provide coverage than
LEOs because each satellite may be in view of any particular location for several hours. Compared to
GEOs, MEOs can operate effectively with smaller, mobile equipment and with less latency (signal
delay).
These orbits are primarily reserved for communications satellites that cover the North and South
Pole. Although MEO satellites are in view longer than LEOs, they may not always be at an optimal
elevation. To combat this difficulty, MEO systems often feature significant coverage overlap from
satellite to satellite, which in turn requires more sophisticated tracking and switching schemes than
GEOs.Typically, MEO constellations have 10 to 17 satellites distributed over two or three orbital
planes.Most planned MEO systems will offer phone services similar to the Big LEOs. In fact, before
the MEO designation came into wide use, MEO systems were considered Big LEOs. Examples of
MEO systems include ICO Global Communications and the proposed Orblink from Orbital Sciences.
Unlike the circular orbit of the geostationary satellites, MEO's are placed in an elliptical (oval

shaped) orbit

Polar Orbit

The Polar Orbit is not much suitable for communication purposes because it moves in a different
direction than that of direction of earth's rotation. So, the use of Polar satellites depends upon their
arrival at a particular point on earth at a particular point. The Polar orbits are used for special

applications like navigational satellites.

Key features of Polar Orbits

Polar orbits are useful in earth mapping

A satellite in polar orbit would pass over equator on different longitude in successive times.

No one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit,

however, to make them work on a particular area, they are launched in highly elliptical orbit

with its apogee over that area

In a polar orbit, the satellite passes above or nearly above both poles of the earth being orbited on

each revolution. So, we can say that the inclination of such orbit is almost 90 degrees to the equator.

The Polar orbits are used for earth-mapping, earth observation, and reconnaissance satellites, as well

as for some weather satellites. However, Iridium satellite constellation also uses a polar orbit to

provide telecommunications services.

Some important notes about Polar orbits

Except for polar geosynchronous orbit, a satellite in a polar orbit will pass over the equator at

a different longitude on each of its orbits.

No one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit,

this is its biggest drawback.

The polar orbit can be manipulated also. If we want a satellite in polar orbit to remain

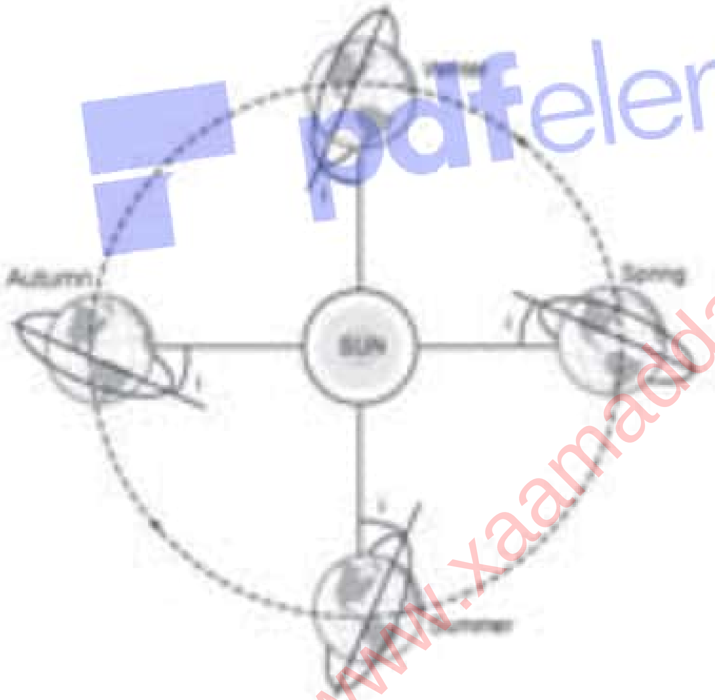
hovering over a certain area for larger time**, it can be placed in a highly elliptical orbit**

with its apogee over that area.

Sun-synchronous orbit

Sun-synchronous orbit or a heliosynchronous orbit very important because of its particular importance to satellites intended for remote sensing and military applications. A sun-synchronous orbit is one that lies in a plane that maintains a fixed angle with respect to the Earth-sun direction. In other words, it combines altitude and inclination in such a way that an object on that orbit ascends or descends over any given point of the Earth's surface at the same local mean solar time.

We can say that the orbital plane in such a case has a fixed orientation with respect to the Earth-sun direction and the angle between the orbital plane and the Earth-sun line remains constant throughout the year. It is shown by the below diagram:



Features of Sun Synchronous Orbits

The satellite passes over a given location on Earth every time at the same local solar time.

Thus, it guarantees the same illumination condition, which varies only with seasons.

The orbit is *Quasi-polar in nature and so ensures coverage of the whole surface of the Earth*
Every time a sun-synchronous satellite completes one revolution around earth, it traverses a thin
strip on the surface of the Earth. During the next revolution it traverses another strip as shown in
the diagram.

Frozen Orbits

We all know that Earth is not perfectly round. This means the gravitation is not exactly same at all
the places. Apart from that there is gravitational pull from Sun and Moon too, followed by the solar
radiation pressure, air drag and so many other forces. In other words, most satellites experience
noticeable variations in orbital eccentricity.
But, fortunately, the distorting impacts of these issues can be induced to cancel each other by expert
satellite planners. They choose optimum Orbital altitude, inclination, eccentricity and argument of
perigee. The satellites whose orbital parameters are controlled by such techniques is said to be in Frozen Orbits.
Thus we can say that:
Frozen orbit is a Sun-synchronous orbit in which the precession of the orbital plane around
the polar axis of the Earth caused by the oblateness of the Earth is utilized to the benefit of the
mission by choosing correct orbital parameters.
The Earth observation satellites ERS-1, ERS-2 and Envisat are all operated in Sunsynchronous
"frozen" orbits

Other Orbits

Super synchronous orbit is a disposal / storage orbit above GSO. From earth, they would
seem drifting in westerly direction.
Sub synchronous orbit is a orbit close to but below GSO and is used for satellites undergoing
station, changes in an eastern direction.
Graveyard orbit is a Supersynchronous orbit where spacecraft are intentionally placed at the
end of their operational life.

Elasticity

Elasticity refers to that property of an object by virtue of which it regains its original configuration
after removal a deforming force. Deforming force is the force which causes a change in configuration
of an object when applied to it.

Important Notes on Elasticity

The upper limit of the deforming force up to which a body regains its original configuration
completely is called *Elastic Limit*. Beyond elastic limit, the body will lose its property of
elasticity and will deform permanently.
If a body regains its original configuration immediately and completely after removal of the
deforming force, it would be called Perfectly Elastic Body. There is no perfectly elastic body
but *quartz fibre and Phosphor bronze are examples of near perfect elastic bodies.*
If a body does not regain its original configuration at all after the deforming force is removed,
it is called perfectly plastic body. Examples of near perfect plastic bodies are wax, putty etc.
When a ball falls, it is temporarily deformed. Because of elasticity, the ball tends to regain its
original shape for which it presses the ground and bounces up.
The materials which show large plastic range beyond elastic limit are called ductile materials,
e.g., copper, silver, iron, aluminum, etc. Ductile materials are used for making springs and
sheets. The materials which show very small plastic range beyond elastic limit are called
brittle materials, e.g., glass, cast iron, etc.
The materials for which strain produced is much larger than the stress applied, with in the limit of elasticity are called elastomers, e.g., rubber, the elastic tissue of aorta, the large vessel
carrying blood from heart. etc. Elastomers have no plastic range.
Elasticity of steel is more than that of copper and so for equal applied force, the elongation of
steel spring is less than that of copper for same initial length. This implies that the steel spring

can bear a larger tension before the elastic limit is crossed. Further, steel recovers its original state quicker than copper after the deforming force is removed. Due to this reason, steel is preferred in making springs in comparison to steel.

Glass is more elastic than rubber because for a given applied force per unit area, the strain produced in glass is much smaller than produced in rubber.

Working of Crazy Balls

Rubber is a common visco-elastic material which means it is both viscous and elastic.

Further, Rubber is also characterized by another property called resilience. Resilience is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading. Higher the resilience, higher is the bounce in a rubber ball, which means higher elasticity and lesser viscosity. We note here that the butadiene rubber has highest resilience property, followed by natural rubber.

Fluids and Pressure

Fluids refers to the substances which can flow when an external force is applies to them. Both liquids and gases come under the category of fluids. Fluids don't have a finite shape and take the shape of the vessel containing them. The total normal force exerted by liquid at rest on a given surface is called *thrust of liquid*. Thrust of the liquid is measured in Newton.

Pressure Exerted by the Liquid

Pressure of liquid or its *hydrostatic pressure* refers to the normal force exerted by it per unit area of the surface in its contact. Pressure exerted by a liquid column is given by $p = h\rho g$

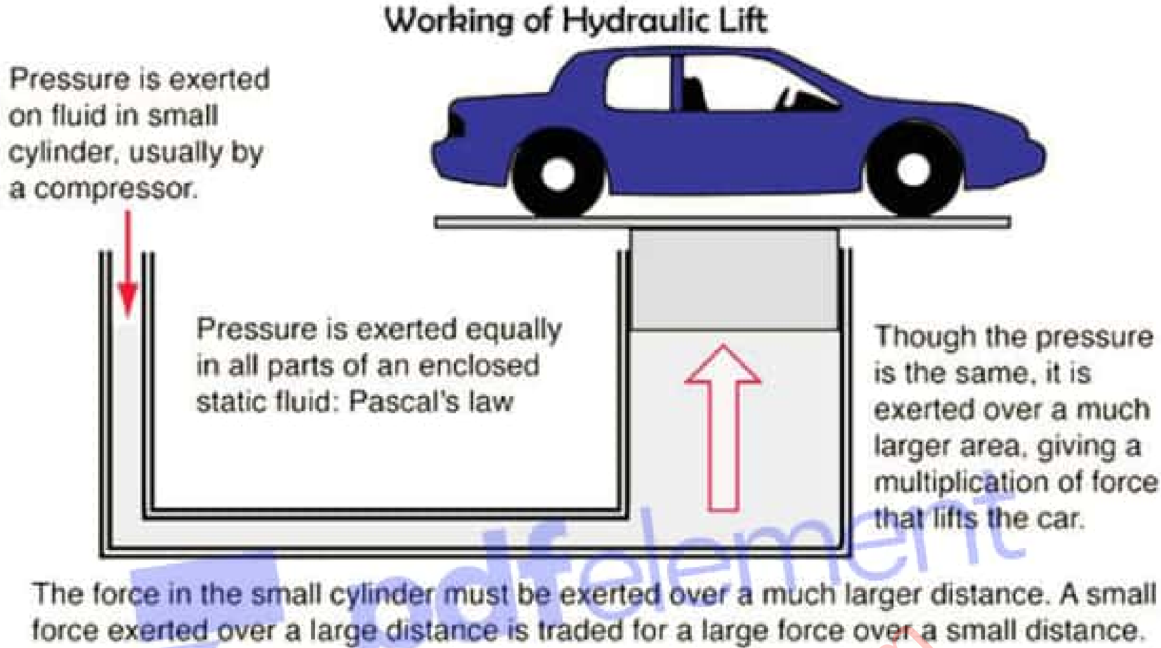
Where, h = height of liquid column, ρ = density of liquid and g = acceleration due to gravity

We note here that mean pressure on the walls of a vessel containing liquid up to height h is $(h\rho g / 2)$.

Pascal's Law

In 1647 the French scientist Blaise Pascal (1623–1662) discovered that water exerts the *same pressure in all directions*. This statement is known as Pascal's Principle.

Pascal's law states that increase in pressure at a point in the enclosed liquid in equilibrium is
transmitted equally in all directions in liquid and to the Walls of the container. The working of
hydraulic lift, hydraulic press and hydraulic brakes are based on Pascal's law.



Atmospheric Pressure

Barometric, or atmospheric, pressure is the force exerted on a surface by the weight of the air above
that surface, as measured by an instrument called a barometer.
Pressure is measured in *Pounds Per Square Inch* or *Newton per M^2* (also called Pacal). It is also measured
in toor and bar. 1 torr is equal to 1 mm of mercury column, while 1 bar = l05 Pa.
Pressure is greater at lower levels because the air's molecules are squeezed under the weight of the air
above. So while the average air pressure at sea level is 14.7 pounds per square inch {100000 N/m2 }, at
1,000 feet (304 meters) above sea level, the pressure drops to 14.1 pounds per square inch (around
about half of the figure at sea level). Changes in air pressure bring weather changes. High pressure
areas bring clear skies and fair weather; low pressure areas bring wet or stormy weather. Areas of

very low pressure have serious storms, such as hurricanes.

Atmospheric Pressure at sea level is equal to:

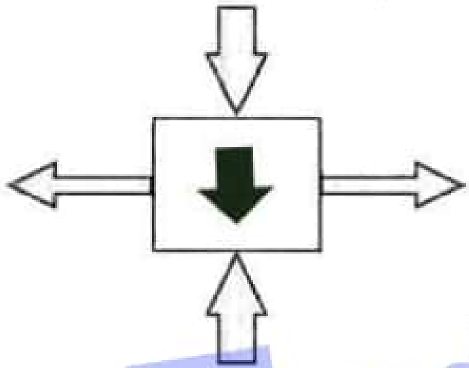
76 cm of mercury column
980 dyne/cm2
100000 N/m2

Why atmospheric Pressure does not crush over body?

The atmospheric pressure does not crush our body because the pressure of the blood flowing through our circulatory system balances this pressure.

Pressure in water

We can understand this by imagining a small cube of water as shown below:



In the above cube, the middle black arrow shows force of gravity on the cube. This implies that the total downward force of the cube is larger than the upward force. Thus, pressure increases with the depth of the water. This explains why or ears hurt when we dive to the bottom of the swimming pool. It also explains why dams thicker at the bottom than at the top. Also, in Hydro power stations, the generator is placed at the lower part so that the pressure of the water is high enough to drive the turbine.

Blood Pressure

Blood pressure refers to the pressure that our blood exerts on our arteries. The fluid dynamics of blood play a major role in blood pressure. The device used to measure blood pressure is the sphygmomanometer. It is placed around the upper arm (Brachial artery), inflated, and then deflated, while a meter measures the pressure passing through that section of the arm and either a person using a stethoscope or an electronic sensor detects the pulse. The cuff is inflated until no pulse can be heard. It is then slowly lowered. As the pressure falls below the systolic pressure the pulse can be heard. When it's below the diastolic pressure the pulse gets weaker. Also note that the Blood Pressure 120/70 means that the systolic pressure is 120 torr and the diastolic pressure 70 torr.

Why blood Pressure is taken from upper arm?

We have discussed above that pressure of a liquid is dependent on the depth of the fluid. Thus, to get the blood pressure correctly, it should be measured at a height of our heart. It cannot be measured around the heart so brachial artery in the upper arm provides convenient location. *If a person is laying down, the blood pressure can be taken from any artery.*

Where is the water pressure greater, in a lake 20 meters deep or in the ocean at a depth of 10 meters

In the lake, because pressure depends on height.

Where is the water pressure greater, in a lake 10 meters deep or in the ocean at a depth of 10 meters?

At similar depth, Ocean water will exert more pressure because saltwater is denser than freshwater and more pressure should be applied by seawater at same distance.

Buoyancy

When a body is partially or fully immersed in a fluid an upward force acts on it, which is known as buoyant force or simply buoyancy. The buoyant force acts at the *centre of gravity of the liquid displaced* by the immersed part of the body and this point is called the centre of buoyancy.

Archimedes' Principle

The exclamation 'Eureka!' is famously attributed to the ancient Greek scholar Archimedes (c. 287–c. 212 BC), who is known to have devised the way to check purity of a gold crown without breaking it apart. He gave the principle that: When a body is partially or fully immersed in a liquid, it loses some

of its weight and that lost weight is equal to the weight of the liquid displaced by the immersed part
of the body.
If T is the observed weight of a body of density σ when it is fully immersed in a liquid of density p,
then real weight of the body
$w = T / (1 - p / \sigma)$

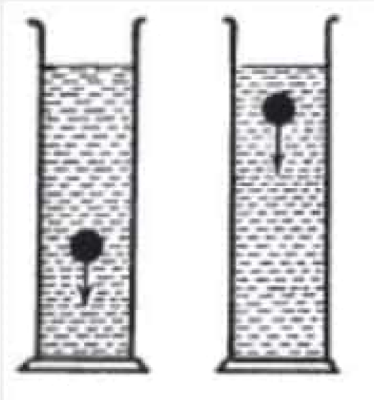
Laws of Floatation

A body will float in a liquid, if the weight of the body is equal to the weight of the liquid displaced by
the immersed part of the body. If W is the weight of the body and w is the buoyant force, then
If W > w, then body will sink to the bottom of the liquid.
If W < w, then body will float partially submerged in the liquid.
If W = w, then body will float in liquid if its whole volume is just immersed in the liquid,
Further, the floating body will be in stable equilibrium if meta-centre (centre of buoyancy) lies
vertically above the centre of gravity of the body. The floating body will be in unstable equilibrium if
meta-centre (centre of buoyancy) lies vertically below the centre of gravity of the body. The floating
body will be in neutral equilibrium if meta-centre (centre of buoyancy) coincides with the centre of
gravity of the body.

Viscosity & Bernoulli's Theorem

Viscosity

When we move our fingers through any liquid we experience a resistance. This is because liquid
offers a frictional force. The resistance offered by fluids (liquids as well as gases) to relative motion
between its different layers is called viscous force. This property is called viscosity. The viscous
forces are similar to frictional forces which resist relative motion between two bodies in contact. To
observe this, we can take two long cylinders, one filled with water while the other filled with
glycerine.



We take two identical lead shots and drop one in water and the other in glycerine at the same time.
We see that the lead shot dropped in water comes down more quickly and the lead shot in glycerine
descends slowly. This implies that the viscous force is more in the case of glycerine than that in the
case of water.

Flow of liquid through Pipes

There are two types of flows viz. streamlined flow and turbulent flow.
If all the particles of the liquid pass across a point with the same velocity, the flow is said to be
stream lined. In this flow, a particle follows the same path throughout its motion.
If the particles pass across a point with different velocities, the flow is turbulent. In this flow,
a particle does not follow the same path throughout its motion.
When a liquid flows slowly and steadily through a pipe, the velocity of the layer of the liquid in
contact with the walls of the pipe is zero. As we move towards the axis of the tube, the velocity of the
layers gradually increases and reaches a maximum value along the axis of the tube. In the case of
streamlined flow of a river, the velocity is maximum for water on the upper layer (surface) of river .
The velocity is minimum for water in the bottom most layer. When two parallel layers of a liquid are
moving with different velocities, they experience tangential forces which tend to retard the faster
layer and accelerate the slower layer. These forces are (F) called viscous forces. Newton found that

the viscous force is:
Directly proportional to the common area (A) of the liquid layers in contact.
Directly proportional to their relative velocity (v1 – v2).
Inversely proportional to the distance (x) between them.
This can be represented by the following formula:

$$F = \eta A \frac{(v_1 - v_2)}{x}$$

Where η is a constant known as coefficient of viscosity of the liquid and (v1-v2)/x is called the
velocity gradient. The unit of coefficient of viscosity is N s m-2 or **Poise**. The values of coefficient of
viscosity are different for different liquids as shown in the below table:

Fluid	η (poise)
Glycerine	13.4
Castor oil	9.86
Olive oil	0.84
Turpentine	0.015
Water	0.018
Mercury	0.0015
Honey	0.2
Blood	0.0027
Air	0.019×10^{-3}

Applications of Viscosity in Everyday Life

The motion of falling raindrops is opposed by the viscous force offered by air. Hence the rain
drops falls slowly.
The viscosity of sea water makes the waves subside during a storm.
The motion of objects in fluids depends upon the viscosity of the fluids.

The viscous force of water or air opposes the motion of ships, cars, aeroplane etc. hence their shapes
are streamlined in order to minimise the viscous drag on them.

Working of Lubricants

Friction reduces the efficiency of a machine by converting mechanical energy into heat energy and
causes much wear and tear of the moving parts. Friction is reduced by using lubricants. High
molecular weight compounds such as hexanol are added as viscosity index improvers. The lubricant
forms a thin layer between the two surfaces in contact. It also fills the depressions present in the
surfaces of contact and reduces friction considerably. In light machinery, thin oils (e.g., clock oil)
with low viscosity are used. In heavy and fast moving machinery solids or thick highly viscous oils
(e.g., grease) are used. By adding **long chain polymers with lubricating oil, its coefficient of
viscosity is kept constant even at high temperatures**.

Properties of Good Lubricants

A good lubricant should have the following properties:
It should be able to spread and fill up the minute depressions in the surfaces.
It should be chemically inert and should not undergo any decomposition at high temperature.
It should be capable of conducting away the heat produced by friction.

Viscosity of Blood

If the arteries and veins of human body contract and become hard, their diameters decrease. Hence
the flow of blood is affected due to the viscosity of blood and the blood pressure increases. This
affects the functioning of heart. When the temperature of human body increases during fever, the
coefficient of viscosity of blood decreases. This increases the blood circulation and the normal heart
functioning is maintained.

Bernoulli's Theorem

When air is blown over the top of a sheet of paper, the paper rises in the air stream. This happens
because the pressure falls above the paper where the air is moving faster. We take a table tennis ball

and place in a funnel and hold it with the mouth sloping upwards. When we blow it, we can blow
the ball out. Similarly, two balls are suspended side by side and air is blown up through the space
between them. As the air flows through the narrow space between the balloons, the pressure falls.
The atmospheric pressure from the sides brings the balls together.
The above observations lead us to conclude thatt **here is a relation between pressure and**
velocity of air. Bernoulli's equation is a fundamental relation in fluid mechanics. It can be derived
from the work-energy theorem. The work-energy theorem says that the work done by the resultant
force acting on a system is equal to the change in kinetic energy of the system. Any moving liquid has
three kinds of energies:
Kinetic energy by virtue of its motion
Potential energy by virtue of its position
Pressure energy when it is subject to pressure
The work-energy theorem states that the work done by the resultant force acting on a system is
equal to the **change in kinetic energy of the system.** Let **m** be mass of the liquid and v be its
velocity in motion.
Then its kinetic energy will be

$$= \frac{1}{2} mv^2$$

The kinetic energy per unit mass will be:

$$= \frac{1}{2} v^2$$

Similarly, Let h be the height of the liquid above the earth's surface.
Then its potential energy = **mgh**
Potential energy per unit mass = gh
Similarly, Let P be the hydrostatic pressure exerted by a liquid, r be its density and V be its volume.
Then its pressure energy = PV

$$= P\left(\frac{m}{\rho}\right)$$

Pressure energy per unit mass $= \frac{P}{\rho}$

These three types of energies possessed by a liquid under flow are mutually convertible one into
another. Bernoulli's theorem says that the *sum of the energies possessed by a flowing, non-viscous,*
incompressible liquid at any point throughout its flow is constant ***when the flow is streamlined.***
This implies that:
Pressure Energy + Kinetic Energy + Potential Energy = Constant.
For a unit mass of liquid:

$$\frac{p}{\rho} + \frac{1}{2}v^2 + gh = \text{constant}$$

If the pipe is horizontal, then h also is constant so:

$$\therefore \frac{P}{\rho} + \frac{v^2}{2} = \text{constant.}$$

The above equation makes it clear that when the velocity of the fluid increases, the pressure of the
fluid decreases and vice versa. This principle can be illustrated by numerous demonstrations.

Everyday applications of Bernoulli's Theorem

Venturimeter, atomiser and filter pump

Bernoulli's principle is used in venturimeter to find the rate of flow of a liquid.
It is used in a carburettor to mix air and petrol vapour in an internal combustion engine. Bernoulli's
principle is used in an atomiser and filter pump.

Wings of Aeroplane

Wings of an aeroplane are made tapering. The upper surface is made convex and the lower surface is made concave. Due to this shape of the wing, the **air currents at the top have a large velocity than at the bottom**. Consequently the pressure above the surface of the wing is less as compared to the lower surface of the wing. This difference of pressure is helpful in giving a vertical lift to the plane.

How storms blow off the roofs?

Due to strong wind, storm or cyclone, the roofs are blown off. When a strong wind blows over the roof, there is lowering of pressure on the roof. As the pressure on the bottom side of the roof is higher, roofs are easily blown off without damaging the walls of the building.

How a moving train attracts a person standing nearby on a platform?

A suction effect is experienced by a person standing close to the platform at railway station when a fast train passes the person. This is because the fast moving air between the person and train produces a decrease in pressure and the excess air pressure on the other side pushes the person towards the train.

Surface Tension & Capillary Action

Surface tension of a liquid is defined as the tangential force per unit length acting at right angles on an imaginary line drawn on the surface of the liquid. Its unit is Newton per Metre.

Understanding Surface Tension

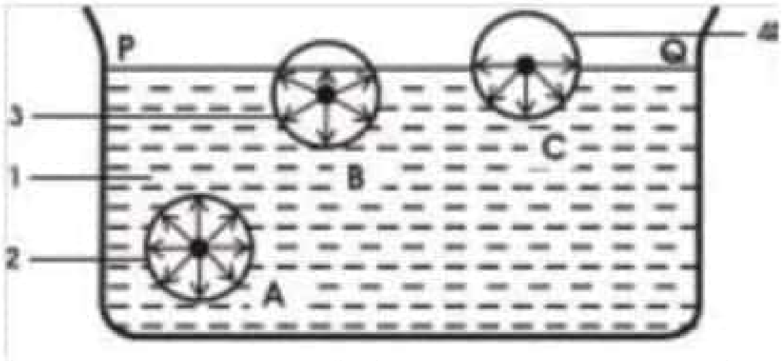
Insects like ants, water-spider are able to walk on the surface of water. Mosquitoes sit and move freely on the surface of stagnant water. When we sprinkle water at the roots of trees and shrubs, the sprinkled water gradually rises to their branches upwards. All these observations can be explained on the basis of a property of liquids called surface tension. When we take a clean glass plate and place a very small amount of mercury on the plane surface, we observe that the mercury assumes the form of a spherical drop. However, when we place large amount of mercury on the plane surface, we observe that now mercury assumes ellipsoidal shape. Similarly, when we place a greased sewing needle carefully on a water surface, the sewing needle makes a small depression in the surface and keeps floating even though the density of the needle is very much greater than that of water. A tumbler is filled to the brim with water. Some nails are put inside the water so that water is displaced upwards. A few more nails are added carefully. It is found that water surface rises well above the edge of the tumbler but water does not overflow. This is because the water surface stretches as water is displaced upwards. If a brush is dipped in water its bristles spread out. If it is taken out the bristles come closer and cling together.

The conclusion from the above observations is that there exists a tension on the surface of a liquid which tends to contract the surface to a minimum area. This property of the liquids is known as surface tension.

Adhesive and Cohesive Forces

Surface Tension is essentially a molecular phenomenon. There are two types of molecular forces of attraction viz. adhesive force and cohesive force. Forces between molecules of different substances are called **adhesive forces.** The adhesive force is different for different pairs of substances. Gum or glue is an adhesive. The force of attraction between gum and paper is an adhesive force. Forces between molecules of the same substances are called **cohesive forces.** *The cohesive forces are short range forces and therefore they are effective only up to a very small distance*. The adhesion of water to glass is stronger than the cohesion of water. On the other hand, the cohesion of mercury is greater than its adhesion to glass. The maximum distance at which the molecules can attract each other is called molecular range. The molecular range is of the order of 10–8 cm.

How Surface Tension works?



A sphere drawn with the molecule as centre and radius equal to the molecular range is called the
sphere of molecular influence. The molecular forces are effective within this sphere of molecular
influence. Therefore all the molecules lying within this sphere of molecular influence exert a force of
attraction on the molecule at the centre. These molecular forces are responsible for surface tension.

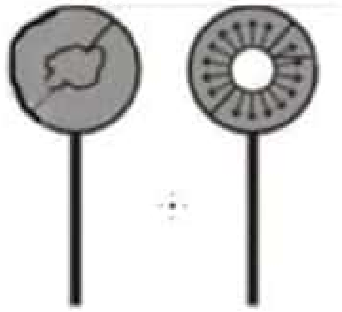
On the basis of this, Laplace gave an explanation of the surface tension.

In the above diagram, PQ represents the free surface of a liquid in a container. Let A, B and C
represents molecules with their spheres of influence drawn around them. The sphere of influence
around the molecule A is well within the free surface PQ. Hence it is equally attracted in all
directions by the molecules in the sphere of influence. Therefore the resultant force acting on the
molecule A is zero.

In the case of molecule B the sphere of influence is partly outside the liquid surface PQ. The number
of molecules in the upper half is less than that in the lower half. Thus the resultant force on B acts in
the downward direction.

The molecule C is exactly on the free surface PQ. The sphere of influence around the molecule C is
exactly half outside and half inside the liquid.**H ence this molecule C is attracted in the
downward direction with maximum force.**Thus we conclude that the **molecules in the
surface PQ are pulled downwards due to the resultant cohesive force**. This makes the free of

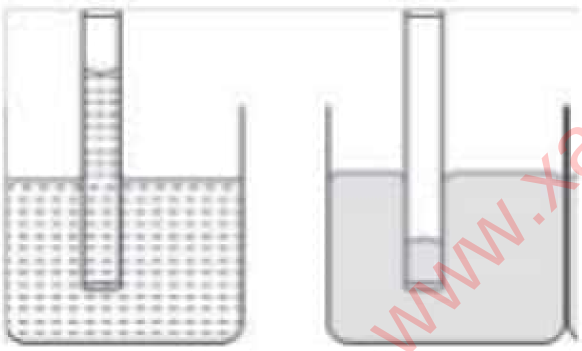
the liquid at rest behave like a stretched elastic membrane. This force gives rise to the surface tension
of the liquid.



To understand this, we can make a circular wire ring in which a loop of thread is attached as shown
in the adjacent diagram. The wire and thread are dipped in a soap solution and taken out gently. We
see that a film of the soap solution is formed across the ring. The zig-zag loop of the thread lies on
the film. If the film inside the loop of thread is punctured with a needle, then the loop takes the shape
of a circle due to surface tension. The surface of the liquid film pulls the thread radially outward as
shown by the arrows.

Capillary Action

A glass tube with a very fine uniform bore is called a capillary tube. When a capillary tube is dipped
vertically into a liquid contained in beaker, the liquid immediately rises or falls in the tube.



The rise or fall of a liquid in a very narrow capillary tube is given by

$$h = \frac{2T\cos\theta}{r\rho g}$$

Where:

T is the surface tension of the given liquid.
r is the radius of the capillary tube
ρ is the density of the liquid
g is acceleration due to gravity
θ is the angle of contact for the given pair of solid and liquid
The angle of contact is defined as the angle between the tangent to the liquid surface at the point of
contact and the solid surface inside the liquid. The angle can be acute or obtuse. If the angle of
contact is acute, the level of liquid inside the capillary tube is higher than that in the beaker. This
capillary rise is observed in the case of water. If the angle of contact is obtuse, the level of liquid
inside the tube is lower than that in the beaker.
This capillary fall is observed in mercury (θ =140°).
For water in silver tube, θ =90° and h = 0. The level of liquid remains the same.
For pure water and clear glass θ = 0°

Applications of Capillary Action in daily life

The rise of sap in trees and plants: The Xylem or Bark has such structure that the water rises
to reach from roots to leaves via capillary action, although some other theories also persist to
explain this.*When the bark of a tree (Xylem) is removed in a circular fashion all around near its
base, it gradually dries up and dies because water from soil cannot rise to aerial parts.*
The rise of kerosene or oil in the wick of an oil lamp or stove.
The absorption of ink in a blotting paper.
Sandy soil is gets drier earlier than clay: *The interspaces between the particles of the clay form finer
capillaries and water rises to the surface quickly.*
*The purpose of applying soap to clothes is to spread it over large area. When soap is dissolved in water
the surface tension of water is lowered. Surface tension always opposes the spreading of a liquid. By
reducing surface tension we facilitate the liquid to spread over larger surfaces. This is why soap is used
for washing.*

For the same reason the paste spreads more freely in the mouth and facilitates cleaning of the mouth.
When we pour oil on the surface of water it lowers the surface tension of water. Hence the mosquito breed sinks down and perishes.
In voyage at the high seas, when there are violent waves the sailors pour tins of oil around their boats or ships. Due to oil the surface tension of sea water is reduced thereby the height of water waves is also reduced.
A pen nib is split at the tip to provide the narrow capillary and the ink is drawn upto the tip continuously.
When molten lead is allowed to fall through the end of a narrow tube, lead drops assume spherical shape due to surface tension. In factories lead shots are manufactured in this way.
Rain drops assume spherical shape due to surface tension of water.

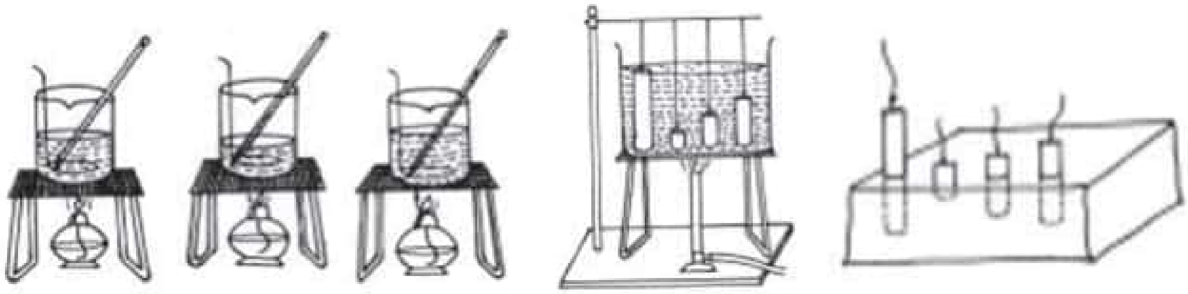
Heat Related Concepts

Heat is the most common form of energy. Heat can be transferred from one place to another by means of **conduction, convection and radiation**. It can be converted into other forms of energy.
Sun is the main source of heat energy for Earth. Fuels such as wood, petrol, coal and gas are other sources of heat energy. For the survival of all living things, heat energy is essential.
The temperature of a body is a measure of its hotness or coldness. It is a measure of the kinetic energy of the particles of the body.
Change in temperature, change of state and thermal expansion in a body, are some of the main

observable physical effects of heat energy. Heat energy plays a major role in determining the climatic and weather conditions.

Specific Heat Capacity

We take three identical glass beakers and fill them with equal mass of water, kerosene and coconut oil. We first note down their initial temperatures and then heat them one by one by same lamp for 5 minutes each; we find that the rise in temperature of each of them is different.



We take four cylindrical blocks of aluminium, lead, copper and iron of equal mass having the same area of cross section. Now, we suspend the cylindrical blocks fully inside boiling water. After few minutes, take out the blocks simultaneously and place them on a thick paraffin cake side by side.

What we observe is that depths of sink are different for different materials.

We take a stone and water of same mass. Place them in the hot sun for about half an hour. Now touch the stone with one hand and water with the other hand. What we observe is that the stone is hotter than water.

When a substance is heated, it absorbs heat energy and its temperature rises. The **amount of heat energy absorbed** by the substance (Q) is directly proportional to mass of the substance (m) and the change in temperature (Δt)

$Q = m s\Delta t$

Here s is a constant called Specific Heat Capacity. The value of the specific heat capacity depends on the nature of the substance. In the above equation, If m = 1 kg and Δt = 1 K then Q = s. This implies that:

The specific heat capacity of a substance is the amount of heat energy required to raise the
temperature of 1 kg mass of the substance by 1 K. Its unit is J kg-1 K-1. **It is a measure of thermal
inertia of a substance.**
The heat capacity of a substance is defined as the amount of heat required to raise the temperature of
the substance through 1 K.
Thus:
Heat capacity = mass x specific heat capacity.
Its unit is J/K.
The following table shows the specific Heat Capacity of some common materials.

Sr. No.	Substance	Specific Heat Capacity (J kg^{-1} K^{-1})
1.	Lead	128
2.	Mercury	138
3.	Copper	386
4.	Aluminium	899
5.	Wood	1755
6.	Kerosene	2090
7.	Ice	2130
8.	Water	4180

Among the liquids, the specific heat capacity is maximum for water, hence water is used as a coolant in radiators of automobile engines and mercury is used as a thermometric liquid.

Thermal Expansion

Thermal expansion takes place in all states of matter. The gases expand more than liquids and liquids
expand more than solids for the same amount of heat. Thermal expansion plays an important role in
many engineering applications.

When an object is heated its **molecules vibrate more violently because they have more**
kinetic energy. They also need more space around them. This causes the material to expand.

Increase in length due to heating is calledl **inear expansion**. Increase in area ass **uperficial**
expansion and that of volume as **volume expansion or cubical expansion**. The thermal
expansion is **different for different substances.**

Every day applications of thermal expansion of solids

If we find difficult to remove the stopper from a glass bottle, we can heat the neck of the
bottle. Now the neck of the bottle expands and the stopper comes out easily.

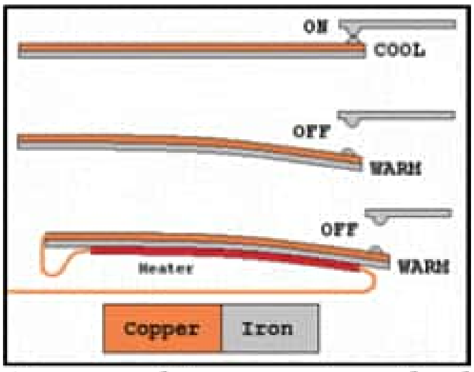
The principle of thermal expansion is used in fixing iron rim with the wooden wheel firmly.

Rivets are used to hold steel plates together very tightly. A very hot rivet is pushed through
the two plates and its end is hammered over. When the rivets cools down it pulls the two
plates together very tightly.

To avoid bursting of soft drink bottles containing gas, due to thermal expansion, their walls
are made very thick.

Bimetallic Strip

A bimetallic **strip** consists of two different metals such as brass and iron joined together.

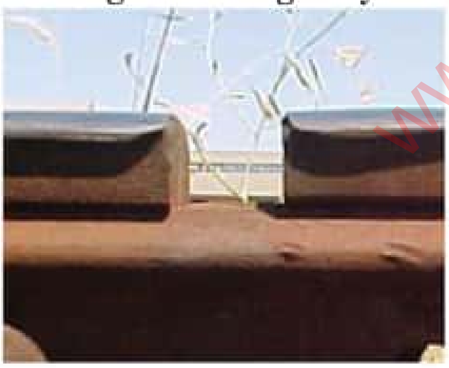


At normal temperature the bimetallic strip is straight. As it is heated the brass expands more than the iron. So the brass forms the outside of a curve with the iron on the inside. Such a bimetallic strip can be used in a thermostat to break an electrical circuit. A thermostat is used to maintain a steady temperature in a system. As the temperature increases the strip bends and breaks electrical contact in the heater circuit. When the temperature decreases, the bimetallic strip returns to its original position and shape. Thus contact is restored.

Some of the problems created by thermal expansion is the changing of shape and dimensions of objects such as doors, Wall collapsing due to bulging, cracking of glass tumbler due to heating and bursting of metal pipes carrying hot water or steam.

Thermal Expansion and Railway Lines

Rails are made of steel which expands on heating and contracts on cooling. A gap is left between two ends of the rails at the joint. If no gaps are left, due to expansion in summer the rails get distorted causing derailment. For the same reason, gaps are left in the concrete slabs of bridges and Highways.



Clock Pendulums

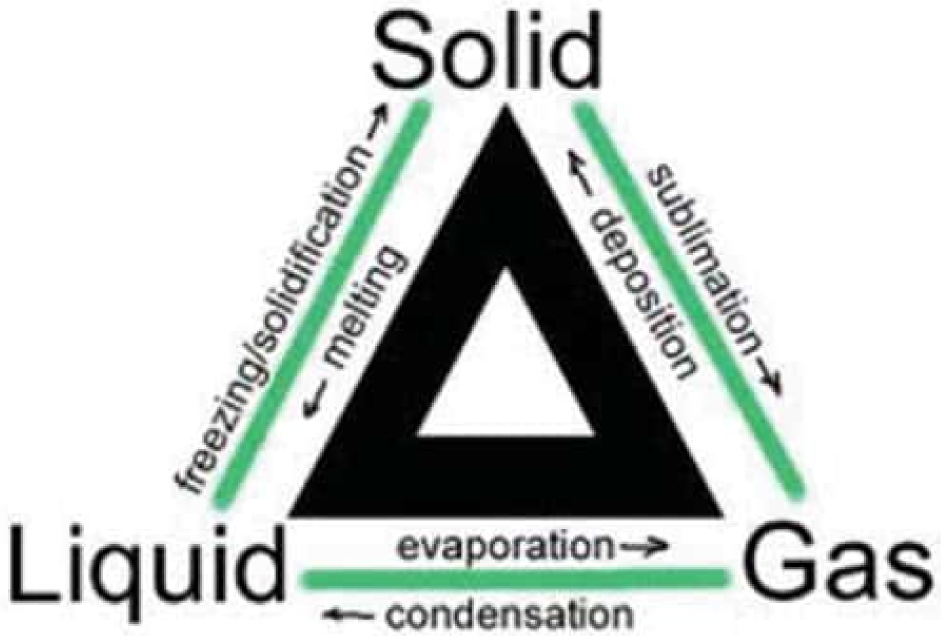
The period of oscillation of a pendulum in a clock depends on its length. When the temperature changes, the length also changes. Hence the clock loses time in summer and gains it in winter. This can be compensated by using a bimetallic pendulum against the effect of thermal expansion.

Change in state of mater

Matter exists in three states viz., solid, liquid and gas. The change from one state to another can be brought about by the application or withdrawal of heat.

Change in State of Matter

The water can be in the form of solid ice or liquid water or gaseous steam. The process in which a solid changes into liquid on heating is called melting. For example, ice changes into water. The change of a liquid into a solid on cooling is known as freezing. The process in which a liquid changes into vapour on heating is called vaporisation. e.g., water changes into water vapour or steam. Some materials may change directly from a solid to a gas. This is called sublimation. Solid carbon dioxide changes to carbon dioxide gas as it warms up. Another substance which sublimes is Iodine. When vapour condenses to form a liquid the change of state is called condensation. Steam changes to water as it condenses.



Latent Heat

The latent heat of a substance is defined as the amount of heat absorbed by a unit mass of the
substance to change its state without change of temperature. The heat absorbed during the change of
state of a substance is used to overcome the force of attraction between the molecules of a substance.
The kinetic energy of the molecules does not increase and hence there is no raise in temperature
during the change of state of the substance. Two of the more common forms of latent heat (or
enthalpies or energies) encountered are latent heat of fusion (melting or freezing) and latent heat of
vaporization (boiling or condensing). These names describe the direction of energy flow when
changing from one phase to the next: from solid to liquid, and to gas.

Cooling due to evaporation

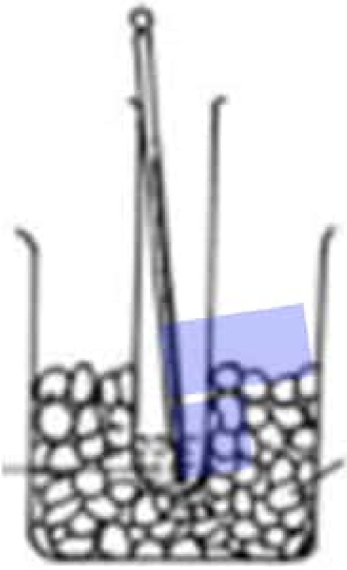
When we put a little ether or petrol at the back of our hand and wave it around, we observe
that the spirit evaporates rapidly and our hand feels very cold. The sprit takes the heat of
vaporization from our hand. The hand loses heat and gets cooled. Similarly, water vaporizing
from the leaves of the trees cools the surrounding air.

A liquid evaporates when it changes into gas. Evaporation occurs at the surface of a liquid.
During evaporation, only high energy molecules overcome the attraction of their
neighbouring molecules and leave the liquid. In this way, the liquid loses its most energetic
molecules, while the less energetic molecules are left behind.
The average kinetic energy of the remaining molecules is therefore, reduced. This results in a
fall of temperature of the liquid which gets cooled. The rate of evaporation of a liquid
depends on its surface area, temperature and the amount of vapour already present in the
surrounding air.
On a rainy day, wet clothes take longer time to dry, because large amount of vapour already
present in the air, slows down the evaporation. Similarly, during high fever, a cloth soaked in
cold water is kept on the forehead the water evaporates rapidly and takes heat from the head
and the body.
Dogs keep their tongue usually out in summer. Water evaporates from the tongue and keeps
it cool. Water in an earthen pot remains cool in summer. Water comes out of the pores of
the vessel and evaporates. Therefore water remains cool in an earthen vessel by evaporation.
After sometimes, when the pores get blocked by the dissolved material in water, the earthen
pot becomes useless.
Evaporation of sweat or perspiration from our skin causes a cooling effect.

Fusion of Ice Experiment

We take a test tube with clean water and a thermometer is placed in the test tube. The test tube is
placed in a freezing mixture bath. The water level in the test tube is well below the level of the
freezing mixture. While stirring water slightly and carefully, the thermometer readings for every 30
seconds are recorded till the temperature falls a few degrees below 0 °C. A graph is drawn by taking

time along the X-axis and temperature long the Y axis. The portion AB represents the liquid state. At
B the change of state takes place from liquid to ice at 0 °C. At C entire liquid is changed to ice. Here
during the change of state the temperature remains constant. Below C it is in the solid state (ice).
The flat portion of the graph represents the time during which the water solidifies. Here both solid
and liquid states exist together. This is the melting or freezing point. During this time heat continues
to be lost from the substance as it changes from liquid to solid but there is no fall in temperature.



When water changes into solid; its volume increases. When a substance melts, heat is gained. When
it freezes, heat is lost

Working of Refrigerators

When a liquid evaporates it takes in heat energy and cools its surroundings. When the gas condenses
back to a liquid, the latent heat is released. This is used to take heat from inside a fridge, and release it
outside. A liquid which evaporates easily is called volatile liquid. Freon is a volatile liquid used in
most fridges. The liquid evaporates in the coils around the ice box or cold plate inside the fridge.

This causes cooling. The Freon gas formed is pumped away and pressurised in the condenser on the back of the fridge. Here the Freon gas condenses back into liquid. As it condenses it releases the heat energy it has taken in. So heat energy has been taken from food and other things inside the fridge and released outside it.

If we leave the fridge door open, the pump has to work hard and more heat will be released into the kitchen which will eventually become hotter.

Freezing Mixtures

A mixture of compounds that produces a low temperature is called freezing mixture. A freezing mixture consists of powdered ice, common salt and ammonium nitrate. Temperatures lower than 0° C can be produced by mixing certain salts such as Sodium Chloride, Ammonium Chloride, Magnesium Sulphate etc. with ice. When salt is mixed with ice, some ice melts taking heat from the salt. The temperature of the mixture decreases. Now salt gets dissolved in the water formed. The necessary heat for this is extracted from the mixture itself and consequently the temperature of mixture falls below zero. With the freezing mixture of salt and ice in the ratio 1 : 3, temperatures as low as -13°C can be obtained

Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert unit mass of the solid at its melting point to the liquid state at the same temperature. The S.I unit of Latent heat is J kg-1.

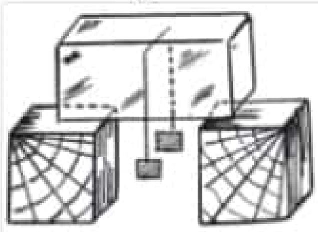
Ice at 0°C is more effective in cooling a substance than water at 0°C. This is due to the fact that for melting at 0°C each kilogram of ice takes its latent heat of 3.34 x105 J from the substance and hence cools the substance more effectively. On the other hand water at 0°C cannot take latent heat from the substance. This concept is valid for most of the liquids and their solids.

Latent heat of vaporization

Latent heat of vaporization of a liquid is the amount of heat required to convert unit mass of a liquid
at its normal boiling point into vapour at the same temperature.
The burns caused by steam are much more severe than those caused by boiling water though both of
them are at the same temperature of 100°C. This is due to the fact that steam contains more heat in
the form of latent heat (2.26 x 106 J/kg) than boiling water. Here we note that the latent heats of
fusion is maximum for ice and latent heat is maximum for steam. Hence steam and ice can be
considered to be the best source and sink of heat respectively in a heat engine.

Impact of pressure Melting Points

When we take two pieces of ice and apply pressure and release them; we observe that the two pieces
freeze together. This implies that melting point of a substance can be lowered by applying pressure.
We take a slab of ice is and a put a metal wire over it. Two equal weights (5 kg) are fixed to its ends.
The wire passes through ice slab due to the load applied to it. Just below the wire, ice melts at a lower
temperature due to increase in pressure. When the wire has passed, the water above the wire freezes
again. Thus the wire passes through the slab and the slab does not split. This phenomenon of
refreezing is called **regelation**.



Here, we have to note down that if a substance contracts on melting, as in the case of Ice, its melting
point is lowered by an increase of pressure. If a substance expands on melting, as in the case of a
paraffin wax, its melting point is raised by an increase of pressure.

Skates, Sledges and Snowballs

Since the edges of the skates are fine, the pressure applied on ice is sufficient to melt it. Water thus formed due to melting acts as a lubricant and enables the skates to move freely over ice. Due to regelation the water formed is again converted into ice. Thus free motion of skates with good grip is achieved. The same explanation holds good for sledges and snow balls.

Impact of impurities on Melting Points

We put some salt or other impurity into a beaker of water and heat it until it boils. Measure the boiling point and observe that it is above 100°C. It shows that the boiling point of liquid is raised by adding impurities. Again, we take some pieces of ice in a beaker and sprinkle some salt on the ice. Stir until the ice melts and measure its temperature. We observe that it is less than 0°C. The presence of impurity lowers the melting point.

Impact of Pressure on Boiling Points

The boiling point of a liquid is lowered under reduced pressure and increased under increased pressure. The atmospheric pressure is less on the top of a mountain and therefore water boils at a lower temperature. This temperature is too low to cook food properly.

It means that a longer time is required for cooking in hill stations. The time required for cooking vegetables and other foods can be greatly reduced if the boiling point of water is raised. This can be done by the use of a pressure cooker. A pressure cooker consists of a strong vessel of an aluminium alloy or stainless steel sealed so tightly that steam can be confined inside it with a pressure of about 2 atmospheres. The boiling point of water at this pressure will be about 120°C. When foods are cooked under these conditions there is a considerable saving of fuel and time. Since the cooking time is reduced the food value (vitamins and minerals) is retained better. Any possible oxidation of food material is also prevented because cooking takes place in an atmosphere of steam instead of air. The pressure cooker solves cooking problems at high altitudes also.

Humidity and Relative Humidity

Humidity is the amount of water vapour present in atmosphere. The amount of water vapour in atmosphere changes with time and weather. The air containing water vapour is called humid air.

The amount of vapour present per unit volume of air is called the humidity of air. Humidity is generally measured in kg/m3.

The knowledge of humidity helps us to predict weather. When the amount of water vapour in the air is small, the air appears to be dry and the humidity is low. When the amount of water vapour in the air is large, the air appears to be wet and the humidity is high. The degree of wetness of air is expressed in terms of its relative humidity.

Relative Humidity

The ratio of the mass of water vapour actually present in certain volume of air (m) to the mass of
water vapour (M) required to saturate the same volume of air at the same temperature is called
relative humidity (R.H)

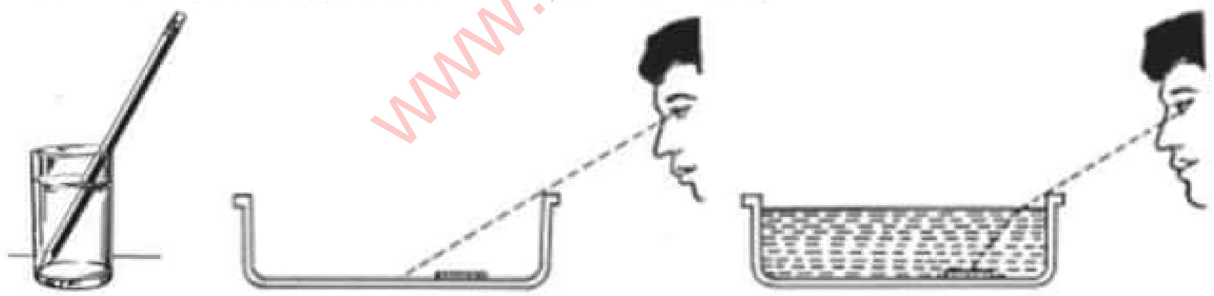
$$\text{Relative humidity} = \frac{m}{M} \times 100\%$$

If the air contains the maximum amount of water vapour its R.H is 100%. In such a case, water on
earth cannot vaporate at all. If the relative humidity is less than 100% but still high, the rate of
evaporation will be slow and the clothes do not dry up easily in such weather. The relative humidity
varies from season to season. During rainy season, as the amount of water vapours in air increases,
the relative humidity becomes more (R.H = 100%) More R.H is a permanent feature of coastal areas.
Due to more R.H perspiration from our body does not evaporate and we feel sultry.

Light

Refraction of light

When we place a pencil in a beaker containing water, we observe that the pencil appears to be bent
at the point where it just enters water. Again, when we put a coin in the bottom of an empty cup and
position our head so that the coin is just off sight, we can bring it into our view without moving
head or the cup, by just pouring water in the cup.



The above two observations lead us to conclude that the ray of light bends at the boundaries of air
and water medium. The phenomenon of bending of light as it passes from one medium to another is
known as the refraction of light.
Refraction is the change in direction of a wave **due to a change in its medium**. It is essentially a
surface phenomenon.
The phenomenon is mainly in governance to the law of conservation of energy and momentum. Due
to change of medium, the **phase velocity of the wave is changed but its frequency remains**
constant. Refraction of light is the most commonly observed phenomenon, but any type of wave
can refract when it interacts with a medium, for example when sound waves pass from one medium
into another or when water waves move into water of a different depth. Refraction is described by
Snell's law, which states that for a given pair of media and a wave with a single frequency, the ratio of
the sines of the angle of incidence θ_1 and angle of refraction θ_2 is equivalent to the ratio of phase
velocities (v_1 / v_2) in the two media, or equivalently, to the opposite ratio of the indices of refraction
(n_2 / n_1):

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}.$$

An easy way to remember Snell's law is that

$$\left(\begin{array}{c}\text{refractive index}\\ \text{of the medium}\end{array}\right) \times \left(\begin{array}{c}\text{sine of the angle}\\ \text{in the medium}\end{array}\right) = \text{constant}$$

The refractive index of the medium with respect to air (or vacuum) is called the absolute refractive
index of the material. The refractive index for light going from first medium to second is equal to the
reciprocal of the refractive index for light going from second to first medium.

$$_1\mu_2 = \frac{1}{_2\mu_1}$$

The refractive index of glass with respect to water is equal to the ratio of refractive index of glass and
refractive index of water with respect to air.

$$_{water}\mu_{glass} = \frac{_{air}\mu_{glass}}{_{air}\mu_{water}}$$

Similarly, the refractive index of water with respect to glass is:

$$_{glass}\mu_{water} = \frac{_{air}\mu_{water}}{_{air}\mu_{glass}}$$

The refractive index of the medium gives the light bending ability of that medium. Glass has higher
refractive index than air. So more bending of light rays take place in glass. Glass is said to be optically
denser medium and air is an optically rarer medium. The following table shows the refractive index
of some common materials with respect to air or vacuum:

Substance	Refractive Index
Air	1.0029
Ice	1.3
Water	1.33
Ethanol	1.35
Sulphuric acid	1.43
Kerosene	1.44
Quartz	1.46
Glycerine	1.48
Benzene	1.5
Crown glass	1.52
Flint glass	1.65
Canadian balsm	1.53
Sodium chloride	1.54
Ruby	1.71
Diamond	2.42

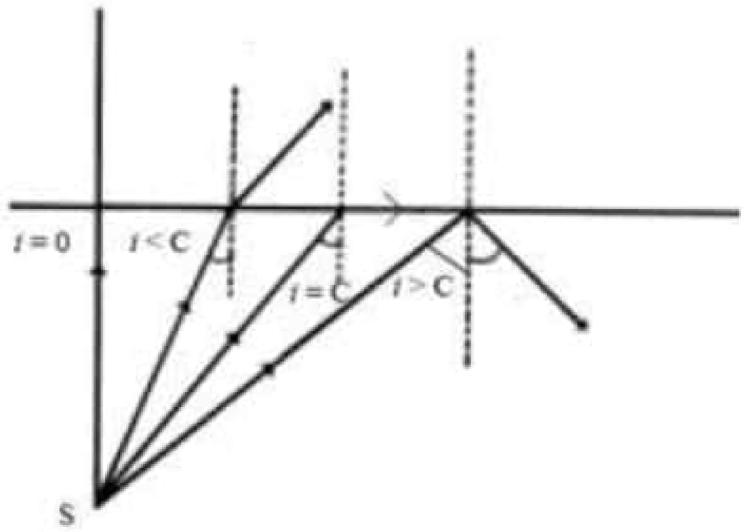
Measuring Refractive Index

The simplest way to measure the refractive index of a liquid is to measure its apparent depth and its real depth. We can place a scale inside a glass beaker containing liquid. Take another scale and hold it outside of the beaker by stand. View the scale from the top and adjust the outside scale until the bottom ends of both scales appear to be at the same level. Measure the heights h1 and h2 of the level of water surface on both scales. h1 and h2 are the real and apparent depth respectively. The refractive index of the liquid with respect to air.

$$_{air}\mu_{water} = \frac{\text{realdepth}}{\text{apparent depth}} = \frac{h_1}{h_2}$$

Total Internal Reflection

When a ray of light passes from an optically denser medium into a rarer medium; the refracted ray is bent away from the normal. A ray of light incident normal to the surface passes without any deviation. As the angle of incidence increases, the angle of refraction also increases and at a certain angle of incidence the refracted ray just grazes surface of water. This angle of incidence within a denser medium for which angle of refraction becomes 90° is called the critical angle. If the angle of incidence is increased beyond the critical angle, the ray bends inside the denser medium. This is called total internal reflection.



Relation between critical angle and refractive index

We know that

$$_{w}\mu_{a} = \frac{1}{_{a}\mu_{w}}$$

$$\frac{\sin C}{\sin 90^{o}} = \frac{1}{_{a}\mu_{w}}$$

$$\sin C = \frac{1}{_{a}\mu_{w}} \quad (\because \sin 90^{o} = 1)$$

$$_{a}\mu_{w} = \frac{1}{\sin C}$$

The above implies that refractive index of any medium with respect to air is the reciprocal of the sine
of the critical angle.

Example:

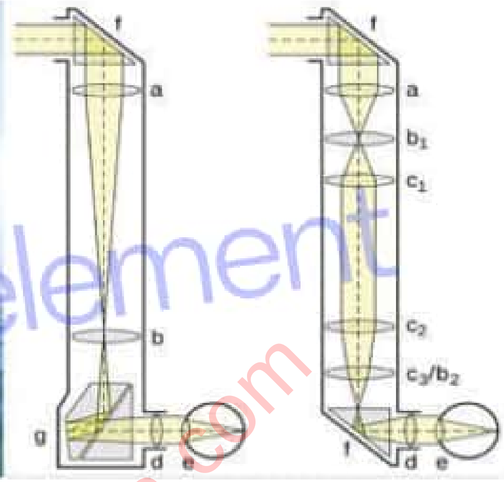
The critical angle of diamond is 24.4°. So C= 24.4° and μ=?

airμdiamond = 1/sinC

airμdiamond = 1/sin 24.4° = 2.42

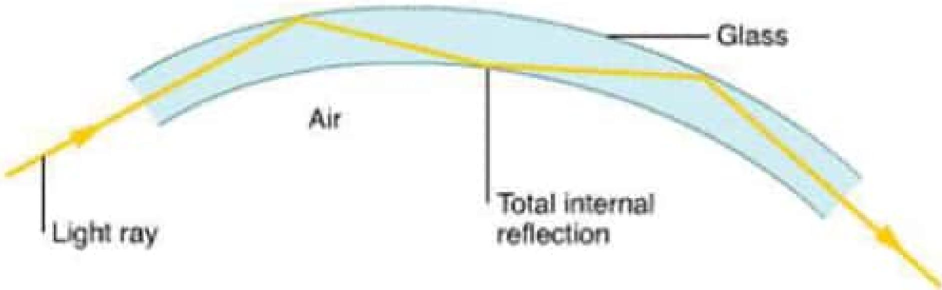
Working of a Periscope

There are two essential conditions for Total Internal Reflection. One is that the light must proceed from denser medium to a rarer medium. Second is that the angle of incidence in the denser medium must be greater than the critical angle. For example, a prism having an angle of 90° between its two refracting surfaces and the other two angles each equal to 45° is called a totally reflecting prism, because 45° is greater than the critical angle for glass (42°). Totally reflecting prisms are used in the construction of periscope. Periscope is used in the submarines to see objects above the surface of water.



Optical Fibres

An optical fibre is a device based on total internal reflection by which a light signal can be transmitted from one place to other with negligible loss of energy. An optical fibre is a long glass rod of only a few millimeters thick and it is quite flexible. The fibre glass consists of a cylindrical inner core that carries light and an outer concentric shell called cladding. The refractive index of inner core (m = 1.7) is relatively greater than that of cladding (m = 1.5). The rays of light travelling along the fibre cannot escape because they are totally reflected from the core-cladding interface. So the fibre of solid glass can be used as a light pipe.

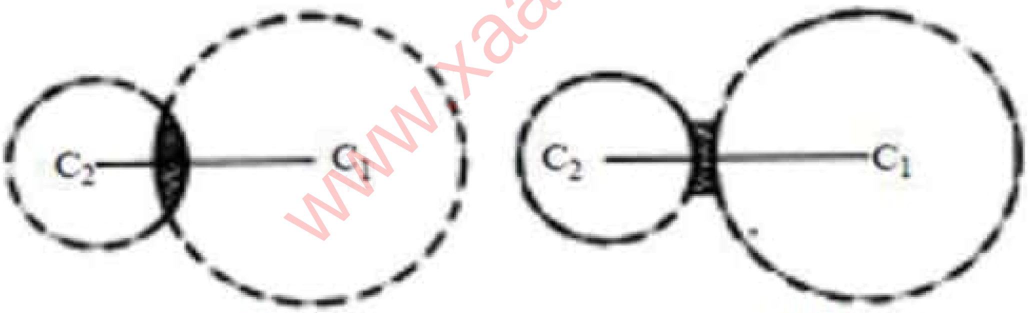


Optical fibres can carry light round bents. This allows doctor to see inside our body. (endoscopy).
Optical fibres can also carry information in the form of a digital code of light pulses with minimum
loss. They carry telephone messages and computer data. Fibre optics technique is used to destroy
tumours in solid organ like liver.

Lenses

A lens is a thin piece of a transparent material bounded by two spherical surfaces or by one spherical
and other plane surface. The width or diameter of a lens is called the **aperture of the lens**. The
geometric centre of a lens is known as its **optic centre** (O). The centre of curvature (C) is the centre
of the sphere of which its surface forms a part. The radius of curvature (R) of a surface is the radius
of the sphere of which the surface forms a part. The line passing through the centres of curvature of
the two surfaces and optic centre of a lens is called the **principal axis.**

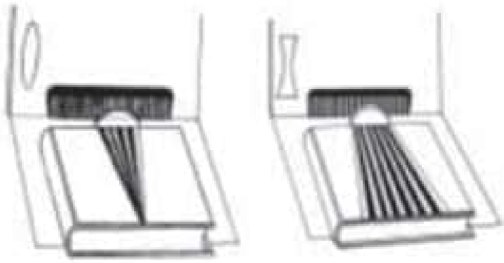
Radius and Centres of curvature of lenses



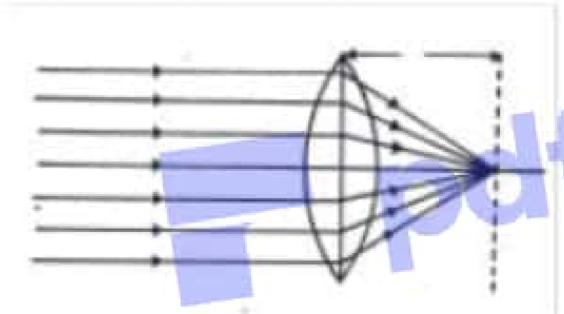
(i) Convex lens

(ii) Concave lens

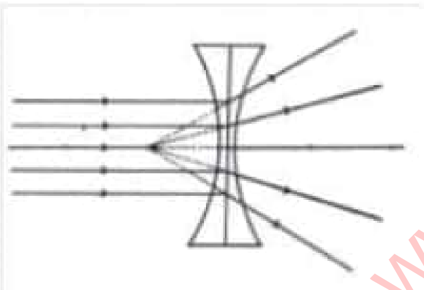
When we place a comb in between the torch light and the convex lens and adjust the lens, we
observe that the light rays converge at a point. In the case of concave lens, the rays appear to diverge
from a point.



A beam of rays parallel to the principal axis after refraction through the lens actually converges at a
point on the principal axis. This point is called **principal focus of a convex lens**.



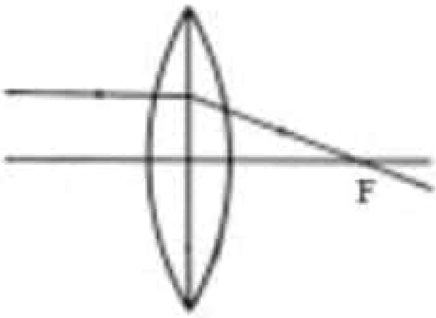
A beam of rays parallel to the principal axis after refraction through a concave lens appear to diverge
from a point on the principal axis. This point is called **principal focus of a concave lens**.



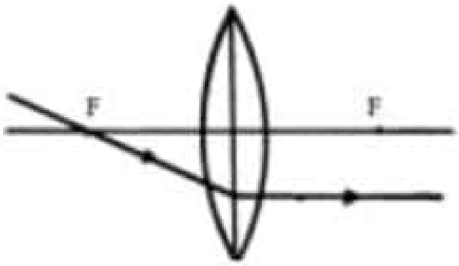
The focal length of a lens is the distance between optic centre and principal focus of the lens.

Behavior of Rays in Convex Lens

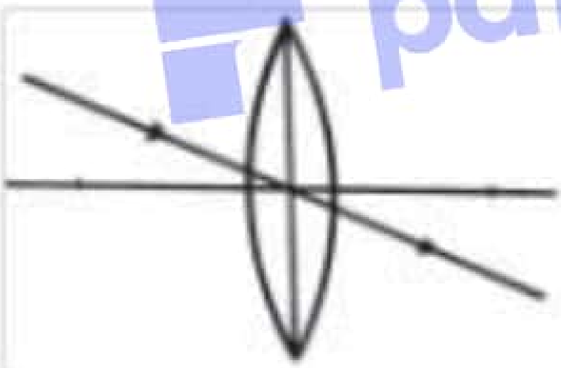
An incident ray which is parallel to the principal axis, after refraction, passes through the principal focus on the other side of the lens.



An incident ray which passes through the principal focus, after refraction, emerges parallel to the principal axis

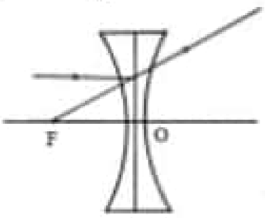


An incident ray which passes through the optic centre goes straight without deflection.

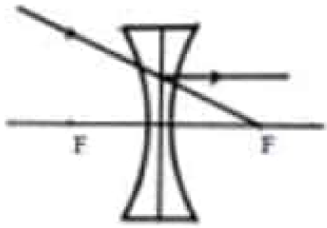


Behavior of Rays in Concave Lenses

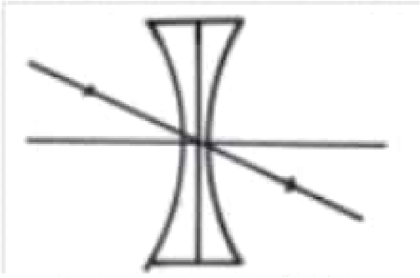
An incident ray which is parallel to the principal axis, after refraction, appears to diverge from the
principal focus on the same side of the lens as the incident light.



An incident ray which proceeds towards the principal focus, after refraction, emerges parallel to the
principal axis.



An incident ray which passes through the optic centre goes straight without deflection.



Real Images and Virtual Images

The image formed by the actual intersection of refracted rays through a lens is called the real image.

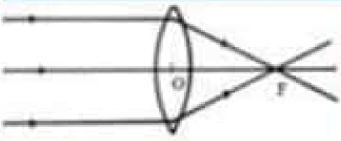
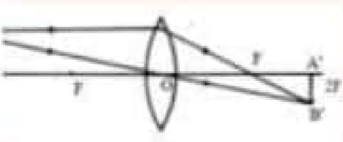
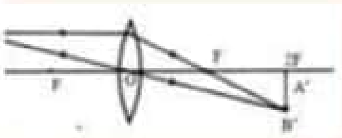
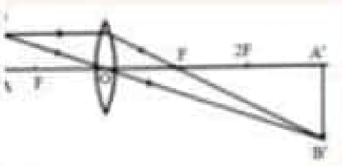
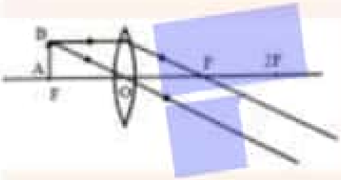
The real images can be caught on the screen and they are inverted.

The images that appear without actual intersection of the refracted rays are called virtual images.

Convex Lens

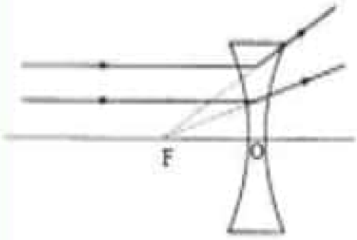
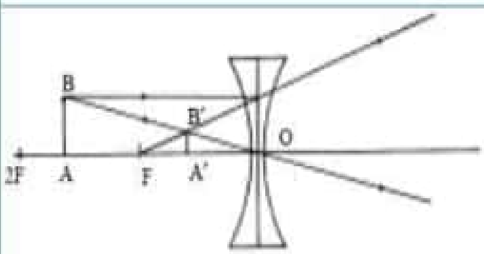
As the object is moved closer to the lens, the image distance increases and the image size increases.

At 2F, the object distance equals the image distance. As the object distance approaches one focal
length, the image distance and size approach infinity. When the object distance is one focal length,
there is no image. When the object distance is less than one focal length, the images are virtual erect
and located on the same side of the object. Finally, if the object distance approaches zero, the image
distance also becomes zero. The image size ultimately becomes equal to the object size.

Ray Diagram	Position of Object	Position of Image	Nature and Size of Image	Practical Application
	at infinity	at F	real, point-sized	Telescope objective lens
	beyond 2F	between F and 2F	real, diminished inverted	Camera
	at 2F	at 2F	real, same sized, inverted	Terrestrial telescope invert the image so that it is upright.
	Between 2F and F	beyond 2F	real, enlarged inverted	Projector
	at F	at infinity	real, infinitely large, inverted	Spotlights
	between F and O	on the side of the object	virtual, enlarged, erect	Magnifying Glass

Concave Lens

When an object is moved closer to the concave lens, the image distance decreases and the image size
increases with respect to that of previous image. As the object approaches the lens, its virtual image
on the same side of the lens also approaches the lens and image size increases. If the object is placed
at the optic centre, the virtual erect image of same size will be formed at the optic centre itself.

Ray Diagram	Position of Object	Position of Image	Nature and Size of Image
	at infinity	at F	Virtual, Point-Sized
	between infinity and O	between F and O	Virtual, Erect And Diminished

Lens Formula & Power of the Lens

The relationship between the object distance (u), the image distance (v) and the focal length (f) of the lens is called lens formula.

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

From the above formula, Focal length of a lens is obtained as follows:

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

The power of a lens is the measure of its ability to produce convergence or divergence of a parallel beam of light. The power of a lens depends on its focal length. The power of a lens is defined as the reciprocal of its focal length in metres. The unit of power of a lens is dioptre (D).

If two lenses of focal length f1 and f2 are in contact, then:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

And

$P = P_1 + P_2$
For example, if a lens has a focal length of 40 cm, its power would be: 1/40 x10-2= 100/40 = 2.5D

Twinkling of Stars

Heat energy radiated by the earth changes the density of the atmospheric layers continuously. This changing density of the air layers near the ground affects its refractive index. Due to the refraction of light rays from the star, path of these rays goes on varying. Hence the eye some times receives more light with the result that the star appears brighter and sometimes it receives only a few rays or no rays which make the star appear fainter. The brighter and fainter appearance of the star with varying time is called the twinkling of the stars.

Mirage

A mirage is an optical illusion observed in deserts or over hot extended surfaces like a coal tarred road. During hot days the lower layers of air near the earth's surface are hotter and lighter than the upper layers away from the earth's surface. Cold air is more dense than warm air and has therefore a greater refractive index. As light passes from colder air across a sharp boundary to significantly warmer air, the light rays bend away from the direction of the temperature gradient. When light rays pass from hotter to cooler, they bend toward the direction of the gradient. If the air near the ground is warmer than that higher up, the light ray bends in a concave, upward trajectory. Hence light from an object (say the top of a tree) undergoes a series of refraction and total internal reflections and bends upwards. Once the rays reach the viewer's eye, the visual cortex interprets it as if it traces back along a perfectly straight "line of sight". This line is however at a tangent to the path the ray takes at the point it reaches the eye. The result is that an "inferior image" of the sky above appears on the ground. The viewer may incorrectly interpret this sight as water which is reflecting the sky, which is,

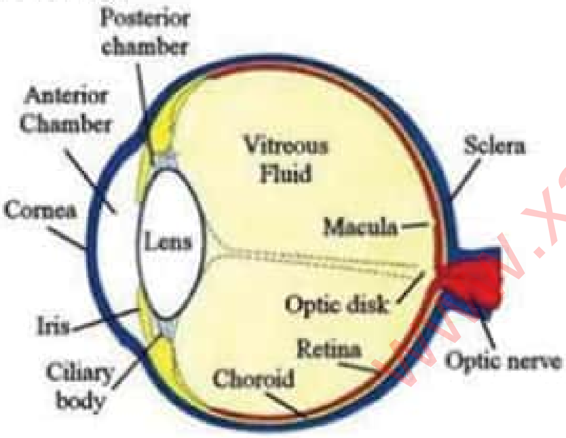
to the brain, a more reasonable and common occurrence. In the case where the air near the ground is
cooler than that higher up, the light rays curve downward, producing a "superior image". **Superior Image is common in polar areas, which is known as Looming.**
Due to the mirage, a traveller sees shimmering pond of water some distance ahead of him. This
optical illusion is called mirage. Thus, *Mirage is due to the combination of Refraction as well as Total Internal Reflection of light.*

Human Eye & Eye Defects

Our eyeball is nearly spherical with white outer layer called the sclera. Here is a short description of
how our eye works.

Working of Human Eye

The light enters the eye through a curved transparent tissue called **Cornea**. In humans, the refractive
power of the cornea is approximately 43 dioptres. While the cornea contributes most of the eye's
focusing power, its ***focus is fixed***. The curvature of the lens, on the other hand, can be adjusted to
"tune" the focus depending upon the object's distance. *The cornea has no blood supply; it gets oxygen directly through the air. Oxygen first dissolves in the tears and then diffuses throughout the cornea to keep it healthy.*



Behind the cornea, is a circular diaphragm called iris which has a central hole called pupil. The size of the pupil aperture is adjusted by muscle action and controls the amount of light entering the eye. The converging crystalline lens composed of glassy fibres is situated behind the iris. The shape and curvature of the crystalline lens is controlled by ciliary muscles. The images are formed on the retina by adjusting and changing the curvature of the lens. This is called accommodation of the eye. The eye ball contains a fluid in front of the lens and a gelatinous material in the space behind it. The retina of the eye consists of two types of photo sensitive rods and cones. *The more numerous rods have a greater sensitivity to light, but do not respond to colour. Rods work well when the light is dim. The cones are sensitive to bright light and colour. They are helpful to us to see things in colour*.Special optical nerves carry the messages from retina to the brain which interprets the images as erect images. The functioning of the eye is similar in many ways to that of a camera. Both have a lens but eyes are advanced because curvature of the camera lens cannot be changed.

The points between which the eye can see distinctly are called far point and near point. The far point is normally without limit (infinity) and near point depends on the accommodation of the crystalline lens.

When we move a pencil slowly towards our nose. At some points, we observe that the pencil appears blurred. This is the near point. For a normal human eye, the near point is 25 cm from the eye.

The near point increases with the age as shown below:

Short-sightedness or Myopia

The inability to see the distant objects clearly and distinctly is called short sightedness. This defect arises when the image is formed infront of the retina. A short sighted person can see near objects clearly. This may arise due to either excessive curvature of the cornea or elongation of the eyeball.

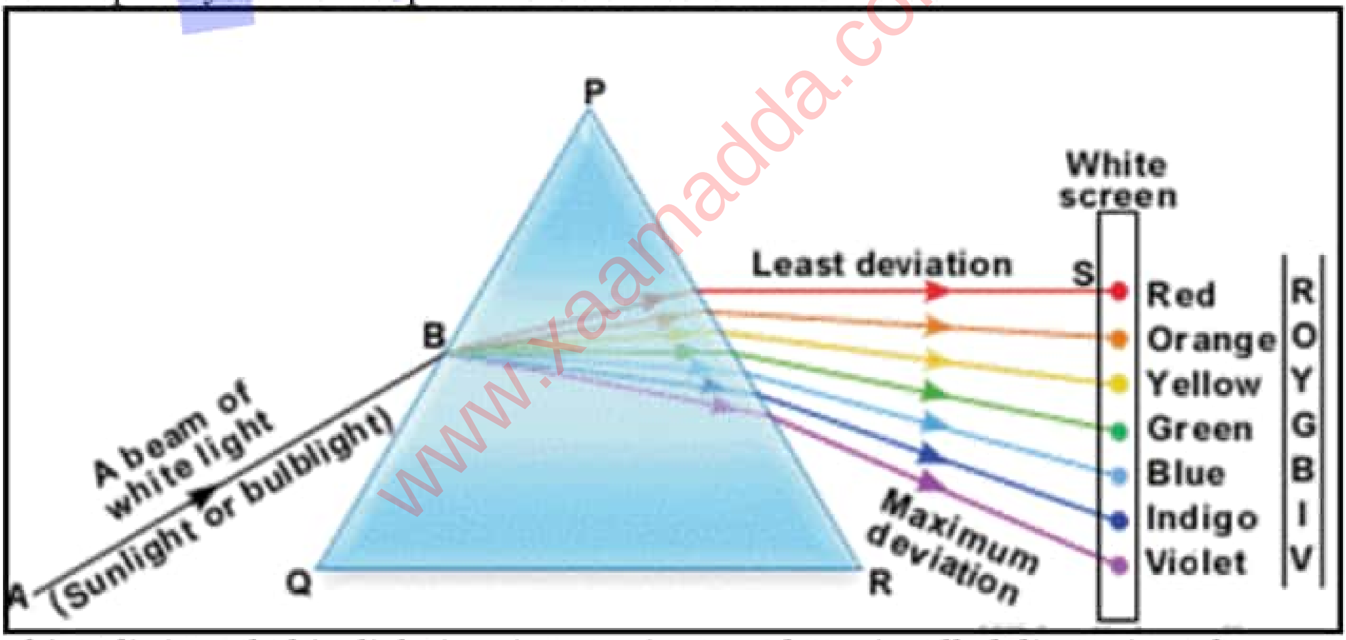
This defect is corrected by wearing glasses with a concave lens.

Long sightedness (or) Hypermetropia

The inability to see near objects clearly and distinctly is called long sightedness. This defect arises
when the image is formed behind the retina. This defect may arise due to shortening of eye ball. A
long sighted person can see the distant objects clearly. This defect is corrected by wearing spectacles
with convex lens (converging) of appropriate focal length. A converging lens will correct this defect
by converging the incoming rays so that the image is formed on the retina.
Longsightedness occurs naturally with age. As we grow old, our ciliary muscles weaken, and the
crystalline lens looses its elasticity or hardens which limits the eye's accommodation. Some persons
may have both Longsightedness and short sightedness defects. They should wear glasses consisting
of both converging and diverging lenses on the same piece of glass. This is called bifocal glass. The
bifocal lens was invented by Benjamin Franklin.

Dispersion of Light

When a beam of white light is passed through a prism, white light splits up into different colours.
Consequently a coloured pattern is obtained on the screen.



This splitting of white light into its constituent colours is called dispersion of light. The coloured

patent obtained on the screen is called a spectrum. The colours are not in strips but change gradually
through many different shades of colour. The colours of the spectrum of white light are violet,
indigo, blue, green, yellow, orange and red (VIBGYOR). The white light is a mixture of different
colours. Each colour is associated with light of a particular wavelength. Red light has longer
wavelengths than the blue light. The angle of deviation by a prism is not the same for all the
wavelength (colours) of light. Hence the prism disperses white light into its constituent colours. **The
red is deviated least and the violet most.**

Color wavelength

Violet 400 - 440
Indigo 440 - 460
Blue 460 - 500
Green 500 - 570
Yellow 570 - 590
Orange 590 - 620
Red 620 - 720

Color of Objects

The colour of an object depends upon the colour of light it reflects. If all colours are reflected the
object appears white. If some colours are reflected, the object appears coloured. The colour seen by
the eye is the colour of the reflected light. A ball appears red when it is seen through a piece of red
glass. White objects reflect all colour and black objects absorb all colours. Red objects reflect red only
and absorb other colours.

Primary Colors, Secondary colors and Complimentary Colors

Primary colours are sets of colours that can be combined to make a useful range of colours. For
human applications, three primary colours are usually used, since human colour vision is
trichromatic. For additive combination of colours, as in overlapping projected lights or in CRT
displays, the primary colours normally used are red, green, and blue. For subtractive combination of

colours, as in mixing of pigments or dyes, such as in printing, the primaries normally used are cyan, magenta, and yellow, though the set of red, yellow, blue is popular among artists. The colours obtained by mixing of any two primary colours are called secondary colours. Two colors are called complementary if, when mixed in the proper proportion, they produce a neutral color (grey, white, or black). The common complimentary colors are:

red + green + blue

yellow + blue

magenta + green

cyan + red

Sound Related Topics

Sound waves come from vibration of material objects. For example, vibrations of vocal cards in the larynx, and the vibrating strings of the sitar produce sounds. The frequency of the sound wave is same as the frequency of the vibrating source. A medium such as air, liquid or solid is required for transmission of sound. Solids and liquids are good conductors of sound whereas air is a poor conductor. Sound waves cannot travel in vacuum. Sound waves are longitudinal waves in gases and liquids, but they can be either longitudinal or transverse waves in solids.

Key Features of Sound

Pitch and Frequency

The sensation of a frequency is referred as pitch of a sound. *A high pitch sound corresponds to a high frequency sound wave and a low pitch sound corresponds to a low frequency sound wave.*The human ears are sensitive detectors to sounds with frequencies between 16 and 20,000 Hz. Any sound with a frequency below 16 Hz is known as infrasonic and above 20,000 Hz is known as ultrasonic. Cats and dogs are capable of hearing sounds of frequencies higher than 20,000 Hz. Dolphins can produce high pitched sounds of frequency as high as 1,00,000 Hz.

Loudness

The loudness of a sound wave depends on the *amplitude of the wave*. The bigger the amplitude, the louder the sound. The loudness of a sound is measured in decibels (db). Exposure to a noise level of 85 db or above can damage or impair hearing.

Whenever there is a need to increase loudness of a sound, it can be achieved by setting a greater mass of air into vibration. For example, instruments such as violin, guitar, sitar etc. have sound boxes attached to increase the loudness. In a loudspeaker, the vibrating cone has a large surface area and a large mass of air in contact with the cone is set into vibration to produce a loud sound.

The Speed of Sound

The speed of a sound does not depend on its pitch and loudness. At 0°C in dry air, the speed of sound is about 331 meters per sound and at room temperature in air it is 344 meters per second. Sound waves travel faster through warm air than cold air. It is calculated that for each degree rise in temperature, the speed of sound is increases by 0.61 metre per second. The speed in air slightly increases with presence of water vapour i.e. the speed of sound increases with humidity. The speed of sound also depends on the medium. It is high in solids, less in liquids, and the least in gases. For example, in steel the speed of sound is nearly 15 times as great as in air. The speed of sound is much less than the speed of light. This is the reason why thunder is heard much after the flash is seen. Similarly, the sound from an airplane does not appear to come from the plane at all, but from a point far behind it.

Reflection of Sound, Echo

Whenever waves meet an obstacle, they have the property of being reflected. When a sound wave reflects after hitting a distant object such as a wall, an echo is heard. But the minimum distance of the reflecting surface from the source of sound to hear an echo is 17 metres. If the distance is less than 17 metres, then the echo reaches us in less than 0.1 second and the echo cannot be distinguished as a separate sound. It gives the impression of the original sound being prolonged. This is called reverberation. Reverberation can also occur when a series of echoes are heard due to more than one reflecting surface.

The speed of sound can be measured by using an echo. For example, echoes of ultrasonic waves can be used to measure depth of sea-beds or finding the location of submerged objects. Ultrasonic waves are also used for finding faults in the interiors of solids and mapping of underground structures for oil and mineral deposits. Bats produce ultrasonic waves and use echoes to determine distance of the objects on their way. Ultrasonic waves are also used in medical diagnosis and treatment. Sound waves pass through various tissues, and from the pattern of echoes, tumours, lesions and other defects are detected.

Refraction of Sound

The character of sound waves to travel faster in warm air than in cold air causes bending of sound waves when they pass through successive layers of air that have different temperatures. This bending property is called refraction. On warmer days, the air near the ground is warmer than the air above and due to this the speed of sound waves near the ground is higher. It results in bending of the sound away from the ground. On colder days, the reverse will happen and the sound waves bend towards the earth. This is reason for hearing of sounds over longer distances on a cold day.

Resonance

Depending on the factors such as the elasticity and shape of the object, each vibrating object has a natural frequency. A resonance occurs when an object oscillates at its natural frequency, as a result of impulses received from some other system vibrating with the same frequency. Resonance can

happen in different kinds of systems: acoustical, mechanical, electrical and optical. Resonance leads to
increased amplitude of vibration. In some cases, the amplitudes that result from resonance can be
disastrous. This is the reason for ordering soldiers to break up while crossing a suspension bridge.
The resonant vibrations caused by the marching may severely damage the bridge. Oscillations also
occur in an electrical circuit. A radio receiver is tuned to a particular frequency when the oscillating
electrical circuit inside the radio is set into resonance with incoming signals.

Doppler Effect

The frequency of a wave changes depending on the motion of the source or observer. This is known
as Doppler Effect. When the source approaches the listener, the frequency of a sound appears to be
higher and vice versa.
Radar guns used by the police to check the speeding vehicles use Doppler Effect. The radar gun sends
out a radio pulse and wait for the reflection. Then it calculates the Doppler shift in the signal to
determine the speed of the vehicle. In astronomy, Doppler Effect is used to find out whether a star is
approaching us or receding away from us. When a star is receding from us the light emitted from the
star appears redder. Doppler Effect is also used to detect the rotation of a star or for tracking a
moving object, such as a satellite, from a reference point on the earth.

Sonic Boom

A sonic boom is an impulsive noise similar to thunder caused by a supersonic (faster than sound)
aircraft that produces a cone of sound called a shock wave.

Musical Scale

A musical scale is a group of pitches arranged in an ascending order. The diatonic scale includes the
notes with frequencies: sa (256), re (288), ga (320), ma (341.3), pa (384), dha (426.7) and ni (480).
The next note denoted by sa' has a frequency 512, twice that of sa. The interval sa-sa' is called an
octave (8).

Noise Reduction in Recording Media

Music recording company Dolby Laboratories Inc. has developed techniques to reduce noise levels in
recorded music. Dolby noise reduction works in tandem to improve the signal-to- noise ratio. Dolby
A, Dolby B, Dolby C, Dolby SR and Dolby S are the noise reduction systems developed by the
company.

Magnetism Basics

A simple magnet is a magnetised bar of iron. It attracts and holds iron pieces but does not attract
pieces of copper. Those materials attracted by a magnet comes under magnetic materials and those
not attracted are described as non-magnetic. Examples for strong magnetic materials include iron,
nickel, cobalt and certain alloys whereas copper, glass, wood, etc. are non-magnetic materials.

However, in presence of strong magnets, even non-magnetic substances show feeble magnetism. A
bar magnet when suspended with a thread tied exactly in its middle, after oscillating for a little it
comes to rest in the north-south direction. The end pointing to north direction is called north pole
of magnet and the end pointing to south direction is called south pole of magnet. Like poles of two
magnets repel and unlike poles of two magnets attract.

Earth's Magnetism

Earth also has magnetism however its origin is still not clear. It is believed that the motion of charges
in the molten outer core creates the magnetic field. Earth's magnetism may be due to heat arising
from the earth's inner core. The heat may be responsible for cause of convection currents in the
molten outer core.The flow of ions and electrons would produce a magnetic field. It is probably the
combination of such convection currents with the rotational effects of the earth are source of the
earth's magnetic field.The South Pole of the Earth is located upon the Antarctic Continent in the

southern hemisphere.The North Pole is located in the middle of the Arctic Ocean. At any place on
the earth, the magnetic north is not usually in the direction of the geographic north. The angle
between the two directions is called the declination. Mariners using compasses must allow for
declination in determining the true north. The angle made by a freely suspended bar magnet with
the horizontal is called the dip of the place. On the equator, the dip is zero and on the poles it is 90°.

Magnetic Resonance Imaging (MRI)

MRI is a non-invasive medical test that uses a magnetic field and pulses of radio wave energy to take
images of internal organs of the body.The images are examined on a computer monitor, printed or
copied on a compact disc. MRI does not use x-rays.

Electricity Related Topics

Static electricity refers to an imbalance of electric charges within or on the surface of a material. The
charge remains until it is able to move away by means of an electric current or electrical discharge.

Electricity by Friction

Friction produces the electric effects. The well-known example is, a hard rubber comb attract small
pieces of paper after using it on a dry hair. It is because after rubbing, the comb becomes charged
with electricity. The same effect is noticed when a plastic pen is rubbed on a coat sleeve. Static
electricity is the electricity produced by friction between two dissimilar objects. Based on the nature
of the objects, one object becomes a positive charge and the other an equal negative charge. For
example, when a glass rod is rubbed with silk, the rod becomes positive charge and the silk an equal
negative charge. Like charges repel and unlike charges attract.
Electrification by friction involves transfer of electrons (negatively charged particles of an atom). In
the example of a glass rod rubbed with silk, some electrons from the rod transferred the silk. By

losing electrons, the glass becomes positively charged and by gaining the same number of electrons
silk acquires an equal negative charge.
In case of hollow metallic conductors, when they are charged with static electricity it is found that
the charge remains on the outside of the conductor; the inner surface remains uncharged. This is the
reason for when a car is struck by lightning, persons sitting inside are shielded from the electricity as
the charge remains on the outer surface. In case of a pear-shaped conductor, the charge is
concentrated on and near the pointed end. When the charge on the conductor is increased, the
pointed end starts losing charge. A pointed end also acts as a collector of charge. The lightning
conductor works on this principle.

Lightning Conductor

Lightning involves heavy discharge of electricity between two charged clouds or between a charged
cloud and the earth. Lightning conductors are used in tall buildings for protection from lightning. A
lightning conductor is a thick copper strip fixed to an outside wall of the building. The upper end of
the strip consists of several sharp spikes reaching above the highest part of the building and the
lower end is connected to a copper plate buried in the earth. When lightning occurs, the lightning
conductor accepts any electric discharge.

Insulators, Conductors, Superconductors and Semiconductors

All the substances can be arranged based on their ability to conduct electrical charge. Almost all
metals are good conductors and most non-metals are poor conductors or insulators. Metals conduct
electricity as they have a large number of free electrons whereas insulators have no free electrons.
With decreasing of temperature, the resistance of metals to flow of electricity reduces. At near
absolute zero temperatures, metals have almost zero resistance and become superconductors. It is

also discovered that certain ceramics can behave as superconductors at relatively high temperatures of above 100K. Currently, scientists are working on in the field of high temperature superconductivity hoping to achieve it at room temperatures. Materials such as silicon and germanium have electrical resistivity in between those of conductors and insulators. Such materials are called as semiconductors. They are good insulators in their pure crystalline form but their conductivity increases by adding small amounts of impurities. After the addition of impurities, they become n-type and p-type semiconductors.

Transistors

Transistors used in radios, televisions, computers and other devices are composed of both n-type and p-type semiconductors. They need very little power and in normal use they work indefinitely.

Integrated Circuits (IC)

An integrated circuit is an arrangement of multifunction semiconductor devices. It consists of a single-crystal chip of silicon containing both active and passive elements and their interconnections.

Current Electricity

Electric current is different from static electricity and it involves the flow of electric charge. The flow of electrons in solid conductors, and the flow of ions and electrons in liquids constitute the current.

To maintain continuous flow of current in a circuit, it is essential to have an electromotive force that can be provided by a cell or a generator.

Electrical Resistance

Conductors such as a metallic wire offer some obstruction when electric current flows through it.

This character of conductors to offer obstruction is called its electrical resistance. The resistance (R) of a wire of a given material depends on its length (l) and area of cross-section (a).

$R = \rho (l/a)$; ρ is a constant called the resistivity of the material of the wire.

With increasing temperature, resistivity of a good conductor increases whereas resistivity of a
semiconductor decreases.

Electric Cell

In cells, chemical energy is converted into electrical energy. Cells are of two types viz. primary and
secondary. Examples of primary cells include torches, radios, etc. The constituents of a dry cell are a
negative electrode, a positive electrode and an electrolyte. The negative electrode is made with zinc
as it is the outer shell of the cell. A carbon rod surrounded by a mixture of carbon and manganese
dioxide acts as the positive electrode. The electrolyte is a mixture of ammonium chloride and zinc
chloride in the form of a paste. A dry cell produces about 1.5 volt.
Lead cells which are used for ignition and lighting on motor car are secondary cells. Secondary cells
are used as storage cells or accumulators. Due to their low internal resistance, secondary cells are
capable of giving large currents. They can be recharged after they discharged. They are used in
emergency lights in hospitals and other buildings.

Car Battery

In a car battery, there is a combination of 6 lead-acid secondary cells each with 2.04 volts. These cells
use lead plates as electrodes and sulphuric acid as the electrolyte. The car battery provides large
currents for a short time as large currents are required to start the engine. After engine started, the
alternator provides power to the car.

Effects of Electric Current

Magnetic Effect

When current flows through a wire, a magnetic field is developed around it. If a current-carrying
wire is brought near to a bar of iron, it gets magnetised and when the current flow is stopped, the
iron bar loses its magnetism. Electromagnets produced in this way have lot of applications. They are
used for lifting and transporting steel plates, scrap iron etc. They are also used in electric bells,

telephone receivers, etc.

Chemical Effect, Electrolysis

When electric current passes through a solution, it results in decomposition of the solution into
negative and positive ions. Positive ions are collected at the negative electrode i.e. cathode and
negative ions are collected at the positive electrode i.e. anode. This process is called electrolysis. This
process is widely used in electroplating.

Heating Effect

When electric charge flows through a conductor, it results in heating of the conductor i.e. electric
energy is converted into heat energy. The heating effect is used in a wide variety of appliances such
as geyser, room heater, etc. These appliances use coils of nichrome, which are heated with flow of
current. In an electric iron, the heating element is placed between two thin sheets of mica, which is
highly insulating and can withstand high temperatures.

Motor Effect

If a current-carrying conductor is placed at right angles to a magnetic field, a force acts on the
conductor. When a current-carrying rectangular coil is placed in a magnetic field, the coil starts
rotating as a couple acts on the coil. This is the mechanism used in an electric motor i.e. in an electric
motor, electric energy is converted into mechanical energy. Electric motors are used in electric fans,
washing machines etc. In loudspeakers, energy is transferred from electric current into mechanical
energy of vibration.

Electric Generator (Dynamo)

The electric generator works on the principle identical to that of an electric motor. In a generator,
the armature is rotated in the magnetic field and an emf is generated in it due to electromagnetic
induction. Thus a generator converts mechanical energy into electrical energy. With a minor change
in construction, a generator can produce alternating emf or direct emf. The corresponding currents

produced are called alternating Current (ac) and direct Current (dc).

Inverter

An inverter converts DC to AC. The inverters for home and office purpose are designed to convert DC from a battery to AC, and also to charge the battery. If there is a power failure, the inverter automatically switches on the AC, converted from the battery's DC. After the mains supply is restored, the inverter automatically switches to a mode where it starts charging the battery.

Power Generation and Transmission

Power stations generate electricity of 11 kilovolts (kV) and it is stepped up to 132 kV for transmission to main substations. In a high voltage power transmission, there is little power-loss in the transmission cables. In the main substations, the voltage is stepped down to 33 kV.This voltage is further stepped down and consumers are supplied at 220V. As the voltage is alternating, 220 is the effective value of the voltage.The frequency of a.c. is 50 Hz (cycle per second).

Domestic Electric Installation

Electricity is supplied to houses by using two cables, the "live" cable and the "neutral" cable. A third cable is also used for safety purposes. It is called the "earth" and is connected to the earth terminal provided in the building. From the meter installed in a house, connections are made to the distribution board through a main fuse and a main switch.

Fuse

A fuse is a short piece of wire that has a low melting point. It is generally made of a tin-lead alloy.

Fuse melts and breaks whenever there is short circuiting, overloading, voltage fluctuation, etc. This will protect the electrical appliances and also prevents fire accidents.Fuses are always connected in the live wire. Nowadays, miniature circuit breakers (M CBs) are replacing fuses.

A circuit breaker automatically protects an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, a circuit breaker need not be replaced. It needs to be reset manually to resume normal operation.

Earth

The earth wire is used for safeguarding of electrical appliances against shocks.

Flexible Cables

All electrical appliances comes with three-core flexible cables. The cables insulations are coloured red or brown (for live connection), black or light blue (for neutral connection), and green or yellow (for earth connection).

Plugs, Sockets and Switches

In a three pin plug, one pin is longer and thicker, and the other two are similar. The longer pin is used for earthing and it is connected to the green wire of the appliance. The other pins are connected to the red (or brown) and the black (or blue) wires. As the earth pin is longer, an appliance is always first earthed before it is connected to the live circuit. In a socket, the lower right hole is used for the live connection and the left hole is for the neutral connection, and the top bigger hole is for the earth.All switches in a house are connected to the live wires. If they are connected in the neutral wire, the sockets would remain live even if the switches are in off position.

Electric Light

Incandescent Lamp or Filament Lamp

In electric lamps, electrical energy is converted to light energy. In electric lamps, a tungsten filament is connected between two lead-in wires. The tungsten filament is heated with passage of current and emits light.The reason for use of tungsten is it has a high melting point of 3,400°C. The electric lamp also contains a small quantity of argon (an inert gas) to prevent evaporation of tungsten. Air is not used as it would oxidise the tungsten.

Fluorescent Tubes

A fluorescent tube consists of mercury vapours at low pressure. When electricity flows through the

tube, the mercury vapours emit invisible ultraviolet rays. These ultraviolet rays fallon the fluorescent
coating on the inside of the tube and emit visible light. In a fluorescent tube very little heat is
produced, so almost all the electrical energy is converted to light energy. The fluorescent tubes are
cheaper and efficient.

Compact Fluorescent Lamps

In incandescent light bulbs, lot of electricity is wasted in the form of heat. A CFL (compact
fluorescent lamp) is a miniature fluorescent tube that works 4 to 6 times more efficient than an
incandescent bulb. A 15W fluorescent bulb can produce the same amount of light as a 60W
incandescent bulb. Mercury used in the fluorescent lamps is a hazardous substance. Most light
sources including fluorescent bulbs emit a small amount of UV, but it is far less than the amount
produced by natural daylight.

Cost of Electricity

Electricity consumption is measured in the unit kWh. From the power rating of electrical appliances,
we can calculate the consumption of electrical energy. By knowing the rate per unit, one can work
out the cost of consumption.

Working of Some Electronic Devices

TV Remote Control

A TV or music system remote control contains a chip (an integrated circuit) and other components,
such as a diode, a transistor, capacitor, etc. When a key is pressed, remote control translates it into
infra-red signals which are received by the electronic circuit in the TV, and the desired operation is
performed.

Cordless Phone

Cordless phones are directly plugged into an existing telephone socket that essentially serves as a
wireless extension to the existing phone wiring. A cordless phone has two parts viz. a base unit and a

hand set. The hand set can communicate with a number of frequencies (channels) in the 46-48 MHz
bands. Based on the quality, a cordless phone can permit mobility (range) up to 100 m.