General Knowledge Today

General Science-1-Biochemistry and Cell Biology

Target 2016: Integrated IAS General Studies

Last Updated: January 27, 2016

Published by: GKTODAY.IN

Contents

Model Questions

Prelims MCQ Topics

Basic Features of Life, Living and Nonliving properties of Viruses, Comparison of Carbon and Silicon in terms of life, Polarity of Water and its implications for life, Role of Cations and Anions in our body, Hypernatremia, Hyponatremia, Types of Carbohydrates, Lipids, Unsaturated Fat and Saturated Fat; Trans and Cis Fats; Good Fats or Bad Fats, Thermal Properties of Fats and Lipids; Cholesterol-Importance, Sources, Types and control; Proteins-Types and Composition, Amino Acids, Peptide Bonds, Examples of Common Proteins, Enzyme-Functions and Industrial Uses, DNA & RNA Differences, Basics on how do they work; Various Vitamins; Deficiency diseases, Cell-structure and major organelles, Prokaryotic and Eukaryotic cells, Difference between Plant cells and Animal cells, Mitosis and Meiosis

Biochemistry

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 self-assembly 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 (CH4) or carbon dioxide (CO2). 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 bio-organic 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 called *hydrolysis*. 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; *oxygen 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 polar, it 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. Fat-soluble 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.

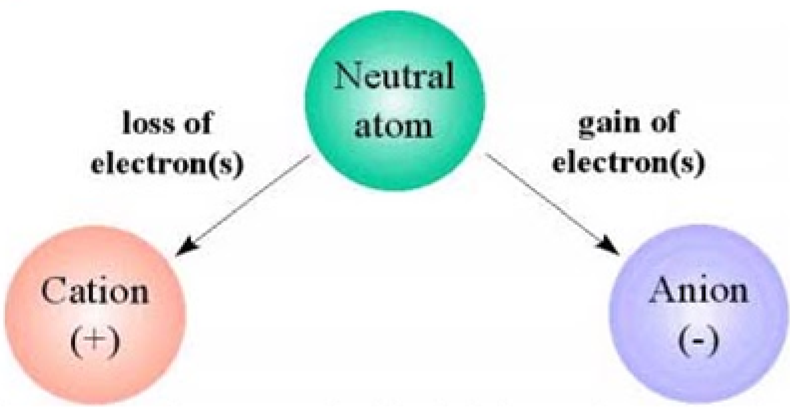
Mineral Salts and Ions

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 non-solubilized 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 (PO_4^-), bicarbonate (HCO_3^-), nitrate NO_3^-) and sulphate (SO_4^-).



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. St*orage 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.

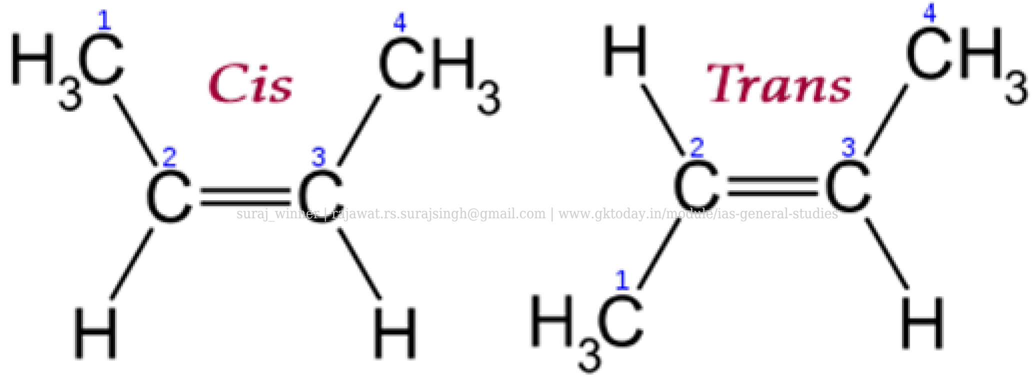
Hydrogenation: Converting Unsaturated Fat to Saturated Fat

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 and not 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.

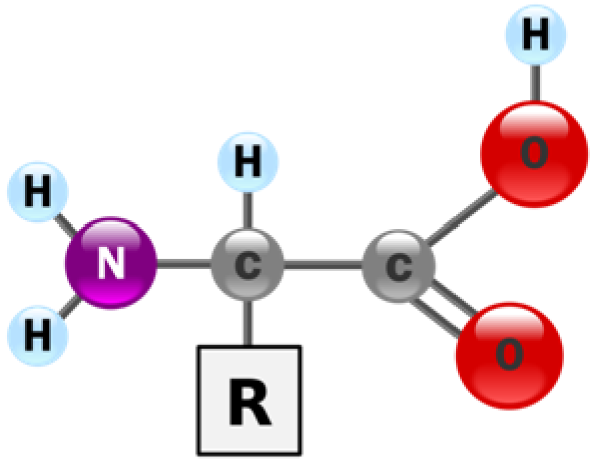
Functional Versatility of Proteins

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:

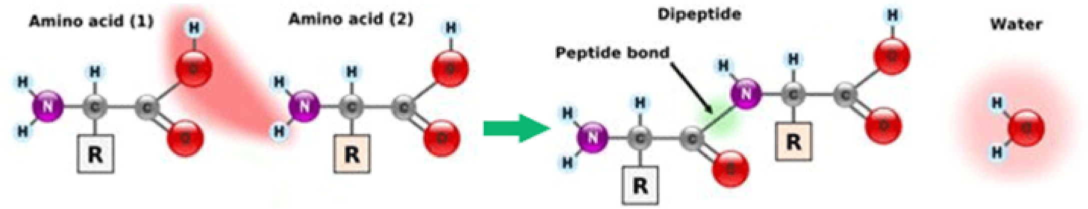
- *Defensive Proteins:* Antibodies that respond to invasion
- *Enzymatic Protein:* Increase the rate of reactions, build and breakdown molecules
- *Hormonal Proteins:* Insulin and glucagon, which control blood sugar
- *Receptor Proteins:* Cell surface molecules that cause cells to respond to signals
- 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

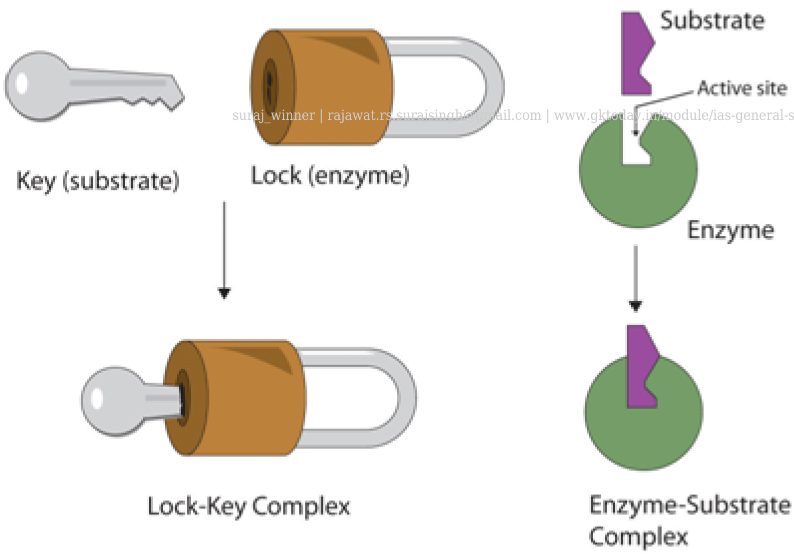
- Myosin protein when bound to actin produces a muscle contraction.
- CD4 is a membrane protein in some lymphocytes, the cells that are infected by HIV.
- Albumin is an energy storage protein and also an important osmoregulator of blood.
- Keratin is a protein with a structural function and which is 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 *Lactose 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 enzyme-substrate 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.

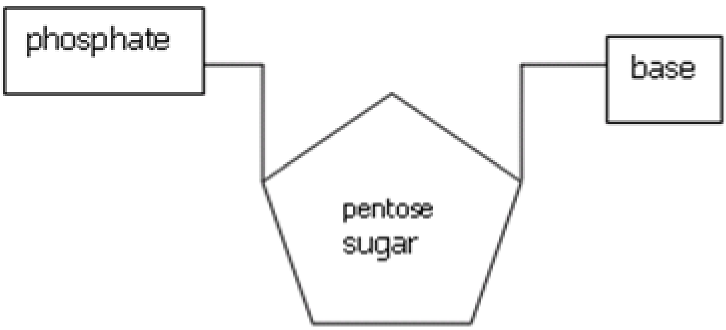
DNA and RNA molecules are responsible for hereditary information that controls the protein synthesis in living organisms. They are called nucleic acids because they were first discovered within the nucleus of the cell by a Swiss biochemist Friedrich Miescher.

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.

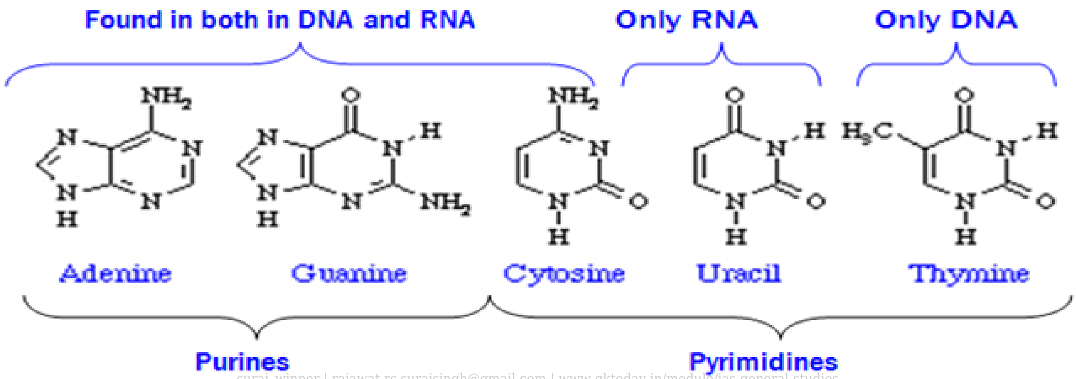
Composition of DNA and RNA

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).

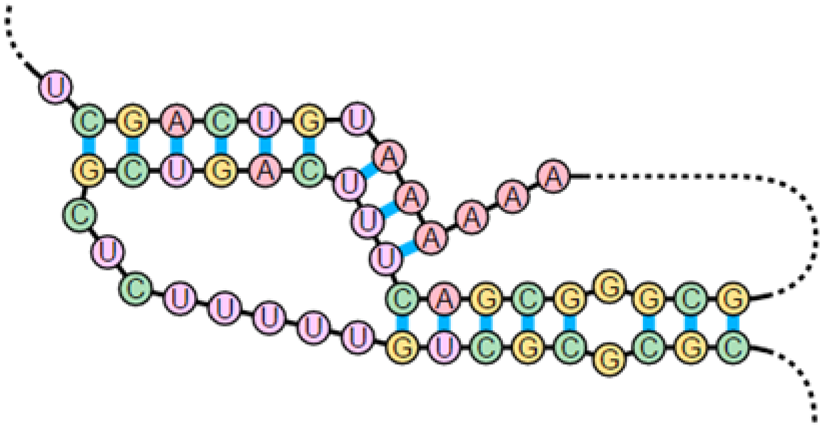
Out of them, adenine and guanine are called Purines (because they have fused ringed structure), while cytosine, thymine and uracil are called Pyrimidines (because they have single ring structure). Further, while both DNA and RNA consist of adenine, guanine and cytosine; *thymine is only found in DNA* and *uracil in RNA*. This is shown in below image:



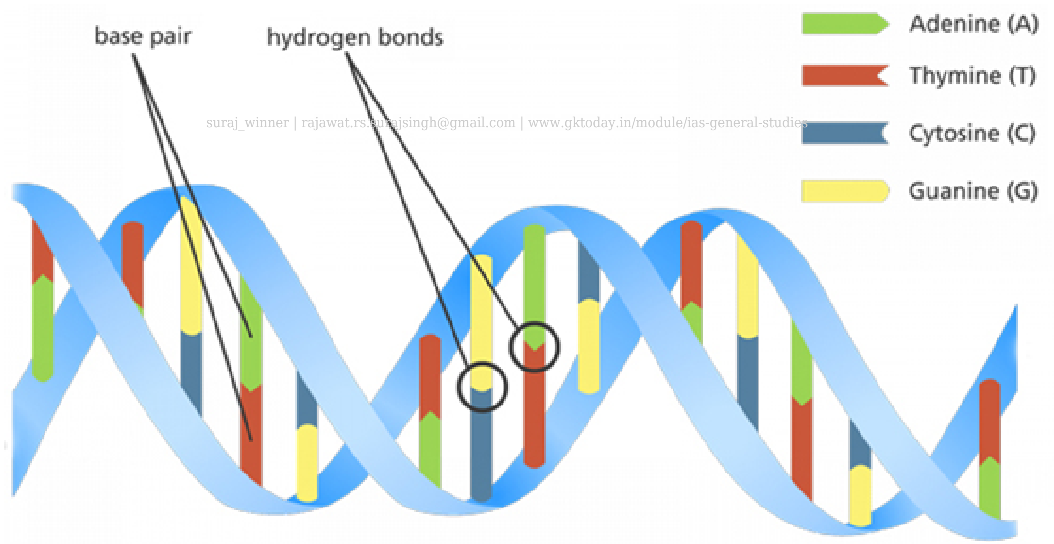
The nucleotides are joined together supported by the backbone of the sugar and phosphate. These nucleotide chains are long and may be either single stranded, or single stranded folded onto itself or double stranded. Whenever the strand folds onto itself or two strands come together for making a double 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 called *ribosome*. 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 activity, *not 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. *Dry 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.

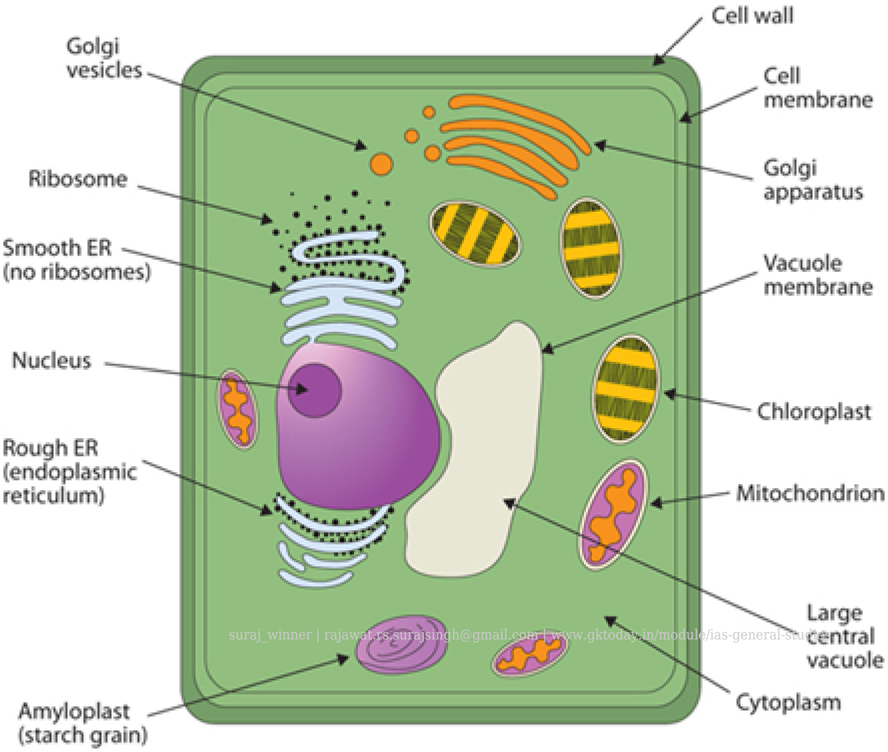
Prokaryotic and Eukaryotic cells

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. The 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. This envelope 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. This Vitamin A + Opsins bond is the chemical basis of vision.

The Carotenoids also get converted to another type of Vitamin A called Retinol. Retinol is fat-soluble 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 is directly 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. *This 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. They 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
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 a prerequisite for sexual 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. *Meiosis 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.