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# General Studies Manual for UPSC and State Public Services Examinations 2014

## Everyday Science and Technology
## Module-3: Select Notes in Everyday Biology

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## Chapter 1. Introduction to Life Molecules

### Basic Features of Life

Any contiguous living system is called an organism. Scientific evidence suggests that life began on Earth approximately 3.5 billion years ago by variously proposed mechanisms. Life is considered a characteristic of organisms that exhibit all or most of the following

#### Homeostasis

It refers to regulation of the internal environment to maintain a constant state. For example, electrolyte concentration or sweating to reduce temperature.

#### Organization

Being structurally composed of one or more cells — the basic units of life.

#### Metabolism

Transformation of energy by converting chemicals and energy into cellular components (anabolism) and decomposing organic matter (catabolism). Living things require energy to maintain internal organization (homeostasis) and to produce the other phenomena associated with life.

#### Growth

Maintenance of a higher rate of anabolism than catabolism. A growing organism increases in size in all of its parts, rather than simply accumulating matter.

#### Adaptation

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: A response 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

The ability to produce new individual organisms, either asexually from a single parent organism, or sexually from two parent organisms.

### Are Viruses Living Organisms?

***Model Question 1.***

Which among the following features of Viruses is / are common with other living organisms?

1. Presence of genes
2. Evolution
3. Replication
4. Metabolism

Choose the correct option from the codes given below:

Answer: [1]

Viruses are most often considered replicators rather than forms of life. They have been described as "organisms at the edge of life," because

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[Answer1] 1, 2 & 3

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- 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.

## Carbon Bonds – The Basic Feature of Life on Earth

In the chemistry document, we have studied that there are three major types of chemical bonds viz. **covalent, Ionic, and hydrogen**. The form of bond that is established is determined by a specific arrangement between the electrons.

- **Ionic bonds** are formed when electrons are exchanged between two atoms. The resulting bond is relatively weak. An ionic bond is found in salt for example Sodium and Chloride in common salt are joined together by an ionic bond.
- **Covalent bonds** occur when electrons are shared between atoms; this form of bond is strongest and is found in both energy-rich molecules and molecules essential to life. Thus, it is the covalent bond that makes the base on which life rests.
- **Hydrogen bonds** are temporary but they are important because they are crucial to the shape of a particular protein and have the ability to be rapidly formed and reformed. For example, in the case of muscle contraction. Hydrogen bonds are bonds between oppositely charged regions of molecules that have covalently bonded hydrogen atoms.

***Model Question 2.***

Life on Earth is Carbon based, while some opine the view that it could be Silicon based also. Why Carbon is superior to Silicon in this context__:

1. Carbon can sustain more bonding patterns than Silicon
2. Carbon is more abundant in nature than silicon
3. Carbon compounds are more reactive than Silicon

Which among the above is / are correct statements?
Answer: [2]

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Life on earth is Carbon Based and that is why we humans are told to be **Carbon Based Bipedal descended from Apes**! ☺

This is 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. We must 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. Then Carbon wins the competition on many accounts. 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

[2] 1 & 2 only

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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!

## Bioorganic Molecules

***Model Question 3.***

Consider the following:

1. Nucleic Acids
2. Proteins
3. Carbohydrates
4. Lipids

Which among the above is / are biopolymers?

Answer: [3]

**Four molecules** are referred to as bio-organic because they are essential to living organisms and contain carbon. These are:

- Nucleic Acids
- Proteins
- Carbohydrates
- Lipids.

These molecules are all large, and they are formed by a specific type of smaller molecule known as a monomer. These "giant" polymers made from the chemical linkage of smaller units called monomers. To be considered a macromolecule, a molecule has to have a molecular weight greater than 1,000 daltons.

Bonds are important to the structure of bio-organic molecules. Because chemical reactions actually involve electron activity at the subatomic level, shape determines function.

*For example, morphine has a shape similar to an endorphin, a natural molecule in the brain. Endorphins are pain suppressant molecules; thus morphine essentially mimics the function of endorphins and can be used as a potent pain reliever.*

These four kinds of Macromolecules are quite diverse in terms of structure, size, and function, the same mechanisms build and break them down. 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.

[3] 1, 2, 3, & 4. A macromolecule is a very large molecule commonly created by polymerization of smaller subunits. In biochemistry, the term is applied to the three conventional biopolymers (nucleic acids, lipids, proteins and carbohydrates), as well as non-polymeric molecules with large molecular mass such as lipids and macrocycles. The individual constituent molecules of macromolecules are called monomers (mono=single, meros=part). Some examples of macromolecules are bio-polymers (DNA, carbohydrates, proteins, and lipids), synthetic polymers (plastics, synthetic fibers, and synthetic rubber), graphene, and carbon nanotubes. (wikipedia)

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- ✓ 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."
- ✓ A hydrogen atom (H) is removed from one monomer and a hydroxide (OH) group is removed from the next monomer in line. Atoms on the ends of the two monomers will then form a covalent bond to fill their electron shells, thereby building a polymer.
- ✓ All polymers are broken down by the same method, hydrolysis. Hydrolysis means "breaking with water." By adding $H_20$, which contains hydrogen and hydroxide groups, back to the monomers, the bond is broken and the macromolecule separates into smaller pieces.

**Model Question 4.**

Consider the following statements:

1. Among Fats, Carbohydrates and Proteins, the last resort as a source of Energy is Protein
2. Among Fats, Carbohydrates and Proteins, the highest comparative value of energy is of Fats

Which among the above statements is / are correct?

Answer[4]

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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

## Polar Molecules

Polar Molecules are very essential for life. Polar molecules have opposite charges at either end. "Polar" refers to the positive and negative sides of the molecule. 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 dissolve in water, the shape of a protein, and the complex helical structure of DNA.

*Water is the most common example of a polar molecule and that is also the reason that when you put a potato in a paper plate in a microwave, potato gets hot but not the paper plate. If you put the potato in a wet paper plate, it would get cooked along with Potato ☺*

## Difference between a Lipid and a Fat

Fats consist of a wide group of compounds that are generally soluble in organic solvents and generally insoluble in water. Chemically, fats are triglycerides, triesters of glycerol and any of several fatty acids. Lipids is a biochemical term used for fats and lipids are essentially **hydrophobic**. This implies that they do not mix with or dissolve in water. Each fat molecule is

[4] Both 1 & 2 are correct.

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comprised of a glycerol (alcohol) molecule and at least one fatty acid (hydrocarbon chain with an acid group attached).

## Good Fats and 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."

## Types of Carbohydrates

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 polysaccharide) or function . Examples of functional definitions are

- storage polysaccharides (glycogen and starch) which store energy
- structural polysaccharides (cellulose and chitin) which provide support for organisms without a bony skeleton

## Cholesterol

***Model Question 5.***

In context with Cholesterol in Human Body, consider the following statements:

1. It is synthesized in Human Body
2. It is essential for life
3. It is precursor for the biosynthesis of Vitamin D
4. The level can of cholesterol in body can be controlled by Statins

Which among the above statements is / are correct?

Answer: [5]

Cholesterol refers to **a subclass of lipids** **known as steroids.** Steroids have a unique chemical structure. They are built from **four carbon-laden fused ring structures**.

The human body uses cholesterol to **maintain the strength and flexibility of cell membranes**. Cholesterol is also the molecule from which steroid hormones and bile acids are built.

Here are some of the derivatives of Steroids:

- **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

[5] All are correct

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- **Testosterone, estrogens, progesterone:** Maintain sex characteristics. Allow reproduction to occur.

**Important Observations Cholesterol**

- Cholesterol is a steroid of fat, an essential structural component of mammalian cell membranes and is required to establish proper membrane permeability and fluidity and is thus manufactured by every cell.
- It serves as a precursor for the biosynthesis of steroid hormones, bile acids, and vitamin D.
- Cholesterol is the principal sterol synthesized by animals; in vertebrates it is formed predominantly in the liver.
- Since cholesterol is essential for all animal life, each cell synthesizes it from simpler molecules. For a man of about 68 kg (150 pounds), typical total body-cholesterol synthesis is about 1 g (1,000 mg) per day, and total body content is about 35 g, primarily located within all the membranes of all the cells of the body.
- This apart, the food also supplements Cholesterol in body. But the ingested cholesterol is esterified, and esterified cholesterol is poorly absorbed. That is why that the cholesterol intake in food has little effect on total body cholesterol content or concentrations of cholesterol in the blood.
- The liver excretes it in a non-esterified form (via bile) into the digestive tract. Typically about 50% of the excreted cholesterol is reabsorbed by the small bowel back into the bloodstream.
- Cholesterol is an important precursor molecule for the synthesis of vitamin D and the steroid hormones, including the adrenal gland hormones cortisol and aldosterone, as well as the sex hormones progesterone, estrogens, and testosterone, and their derivatives.
- Animal fats are complex mixtures of triglycerides, with lesser amounts of phospholipids and cholesterol. As a consequence, 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.
- From a dietary perspective, cholesterol is not found in significant amounts in plant sources.Plant products such as flax seeds and peanuts contain cholesterol-like compounds called phytosterols, which are believed to compete with cholesterol for absorption in the intestines.
- 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.

**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: 1) They block an enzyme that is needed for cholesterol production. 2) They increase LDL membrane receptors in the liver

## Proteins

Proteins, consisting of one or more chains of amino acids, make us see and experience the life as we do it. They are the enzymes that are required for all metabolic reactions. They are also important to structures like muscle and act as both transporters and signal receptors.

So, there are several types of Proteins which do specific functions.

These are 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

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Proteins have very complex structural patterns. They require up **to four levels of structure** in order to be functional. 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*. 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.

## 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.

## ATP

ATP (adenosine triphosphate) is the universal energy currency of a cell. Its secret lies in its structure. ATP contains three negatively charged phosphate groups. When the bond between the outermost two phosphate groups is broken, ATP becomes ADP (adenosine diphosphate). This reaction releases 7.3 kcal/mole of ATP, which is a great deal of energy by cell standards. Each cell in the human body is estimated to use between one to two billion ATP's per minute. With 100 trillion cells in the human body, 200 Kg ATP is produced by the human body in a day !

*This is the unit of energy in intracellular energy transfers. It can be compared to a unit of currency in the whole currency market of a body. ATP is a nucleotide. Another nucleotide which serves as a source of chemical energy is guanosine triphosphate or GTP. As the name suggests ATP has three Phosphate groups. The ATP is created out of ADP and AMP which is Adenosine Diphosphate and Adenosene Monophosphate. The conversion of ATP to ADP and AMP is reversible and so the making of ATP is a continuous process. This continuous process is supported by an enzyme called ATP synthase .*

## Catabolic and anabolic reactions and Krebs cycle

Catabolic and anabolic reactions are metabolic processes. Both the capture and use of energy by organisms involves a series of thousands of reactions (metabolism). A catabolic reaction is one that breaks down large molecules to produce energy; an example is digestion. An anabolic reaction is one that involves creating large molecules out of smaller molecules; an example is when our body

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makes fat out of extra meal we eat. The Krebs cycle or the citric acid cycle is central to aerobic metabolism. It is an adaptation that allows cells to gain increased energy from glucose. The process is critical to the development of multicellular organisms, and is essential to the harvesting of high energy electrons during the final breakdown of the glucose molecule. By-products of this cycle are carbon dioxide and water.

## Enzymes and their shapes

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). 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**. The enzymes are three dimensional. 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.

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 thier name from older system when this 'ase' nomenclature was not adopted. Examples are trypsin and pepsin, both digestive enzymes that breakdown protein.

***Model Question 6.***

Consider the following enzymes and their application in respective industries:

1. Proteases – Biscuits Production
2. Rennin – Cheese Production
3. Lignases – Paper Production

Which among the above is / are correct matches?

Answer: [6]

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### 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

[6] All are correct

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- 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.

## 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 B3** | Niacin, niacin amide | 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 |

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| | | | | |
|---|---|---|---|---|
| **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 Observations about 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 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)

Well-known syndromes caused by thiamine deficiency include 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. All animals either make it, eat it, or else die from scurvy due to lack of it.

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 (cats and dogs cannot synthesize vitamin D and must receive it in their diet). In the liver vitamin D is converted to calcidiol, which is the specific vitamin D metabolite that is measured in serum to determine a person's vitamin D status.

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Part of the calcidiol is converted by the kidneys to calcitriol, the biologically active form of vitamin D. Calcitriol circulates as a hormone in the blood, regulating the concentration of calcium and phosphate in the bloodstream and promoting the healthy growth and remodeling of bone. Vitamin D deficiency causes osteomalacia (called rickets when it occurs in children).

### 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.

**Vitamin E and Skin Health**

The generation of free oxygen radicals is believed to play an important pathogenic role in the development of various disorders. More than other tissues, the skin is exposed to numerous environmental chemical and physical agents such as ultraviolet light causing oxidative stress. In the skin this results in several short- and long-term adverse effects such as erythema, edema, skin thickening, wrinkling, and an increased incidence of skin cancer or precursor lesions. However, accelerated cutaneous aging under the influence of ultraviolet light, usually termed photoaging, is only one of the harmful effects of continual oxygen radical production in the skin. Others include cutaneous inflammation, autoimmunological processes, keratinization disturbances, and vasculitis. Vitamin E is the major naturally occurring lipid-soluble non-enzymatic antioxidant protecting skin from the adverse effects of oxidative stress including photoaging. Its chemistry and its physiological function as a major antioxidative and anti-inflammatory agent, in particular with respect to its photoprotective, antiphotoaging properties, are described by summarizing animal studies, in vivo tests on human skin and biochemical in vitro investigations (Source: http://www.ncbi.nlm.nih.gov)

### 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.

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### 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 one of five vitamins (when lacking in human diet) associated with a pandemic deficiency disease: niacin deficiency (pellagra), vitamin C deficiency (scurvy), thiamin deficiency (beriberi), vitamin D deficiency (rickets), vitamin A deficiency (night blindness and other symptoms).

Niacin has been used for over 50 years 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 (folic acid and folate) is essential to numerous bodily functions. The human body needs folate to synthesize DNA, repair DNA, and methylate DNA as well as to act as a cofactor in certain biological reactions.

It is especially important in aiding rapid cell division and growth, such as in infancy and pregnancy. Children and adults both require folic acid to produce healthy red blood cells and prevent anemia. Deficiency can result in many health problems, the most notable one being neural tube defects in developing embryos.

## Saturated, Unsaturated Fats

Fat is a type of lipid molecule constructed by glycerol and three fatty acids. The molecular structure of the fatty acids determines whether the fat is saturated or unsaturated.

Fats with hydrogen atoms but without double bonds are "saturated." Unsaturated fatty acids have double bonds, and therefore have fewer hydrogen atoms. The process of hydrogenation can convert an unsaturated fatty acid into a hydrogenated fatty acid. It is achieved by adding extra hydrogen atoms to unsaturated fat. Hydrogenation is the process that allows unsaturated vegetable oils to be turned into margarine. This method prevents 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.

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*Unsaturated fat is a fat molecule containing one or more double bonds between the carbon atoms. Since the carbons are double-bonded to each other, there are fewer bonds connected to hydrogen, so there are fewer hydrogen atoms, hence the name, 'unsaturated'. 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 the cis arrangement, the hydrogens are on the same side of the double bond. In the trans arrangement, the hydrogens are on opposite sides of the double bond.*

## Cis Fats and Trans Fats

**Model Question 7.**

In context with the Trans-Fats, consider the following statements:

1. They are always unsaturated
2. They increase level of LDL (i.e. Bad Cholesterol) however they don't impact at the level of HDL (i.e. Good Cholesterol)

Which among the above statements is / are correct?

Answer: [7]

The term "trans" fat refers to the arrangement of hydrogen atoms around the carbon backbone of the fatty acid. A trans-fatty acid is a molecule that has a carbon backbone with hydrogen atoms attached in a manner that is not normally found in nature. Most naturally occurring fatty acids have their hydrogen arranged in the "cis" form. In trans fats, some of these hydrogens are attached on opposite sides of the fatty acid molecule in what is known as a "trans" (as opposed to "cis") formation.

However, Trans fats do exist in nature (For example in the milk and body fat of ruminants (such as cattle and sheep) ) and also occur during the processing of polyunsaturated fatty acids in food production. Please note that only unsaturated fats can be trans or cis fat, since only a double bond can be locked to these orientations. Saturated fatty acids are never called trans fats because they have no double bonds, and, therefore, all their bonds are freely rotatable.

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 fatty acids are not essential and provide no known benefit to human health", whether of animal or plant origin.
- While both saturated and trans fats increase levels of LDL cholesterol (so-called bad cholesterol), trans fats also lower levels of HDL cholesterol (good cholesterol), thus increasing the risk of coronary heart disease.

## Trans fats: Notable Observations

- They are found in nature
- They are always unsaturated
- They increase level of LDL (i.e. Bad Cholesterol)

[7] Only 1

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- They decrease the level of HDL (i.e. Good Cholesterol)
- 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.

## Chapter 2. Fundamentals of Cell Biology

### Who discovered a Cell?

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".

### What are the 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.

### What is 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.

### What are Prokaryotic and Eukaryotic cells?

***Model Question 8.***

In terms of evolution of organisms, the prokaryotes are considered to be primitive because their cells :

1. Lack well defined nucleus
2. Lack important cell organelles
3. Lack DNA and RNA

Which among the above statements is / are correct?

Answer: [8]

There are two groups of cells. All cells are either prokaryotic or eukaryotic.

[8] 1 & 2 are correct

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- Prokaryotic cells are primitive and don't possess a well defined nucleus. The nuclear membrane is absent and DNA material remains scattered in the Cytoplasm. The cells organelles like mitochondria, chloroplasts, Golgi Bodies are absent in the prokaryotic cells.
- The cytoplasm of the prokaryotic cells has no cytoskeleton while the cytoplasm of the Eukaryotic cells possesses the Cytoskeleton which is made up of protein Filaments.
- The ribosome in prokaryotic cells are of **70S** type while those in the Eukaryotic cells is **80S** type.
- The DNA is circular, scattered in the prokaryotic cell and not associated with the histones. While in Eukaryotic cells the DNA is long and associated with the histones.
- The 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.
- The examples of prokaryotic cells is bacteria, blue green algae and mycoplasms. The example of Eukaryotic cells are green algae and higher plants and animals.

## What is 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 was 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.

## What is composition & functions of Cell Wall?

***Model Question 9.***

Consider the following:

1. Wood Pulp
2. Diatomaceous Earth
3. Agar
4. Carrageenan

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Which among the above is / are obtained from cell walls of various plants?
Answer: [9]

- The major function of the cell wall is to act as a pressure vessel, which prevents the over-expansion when water enters the cell and creation of a stable osmotic environment by preventing osmotic lysis and helping to retain water.
- Cell walls are found in plants, bacteria, fungi, algae etc. and absent in animals and protozoa.
- Major component of the cell wall is Cellulose, which is a carbohydrate and organic compound with the formula $(C_6H_{10}O_5)_n$. It's a polysaccharide consisting of a linear chain of several hundred to over ten thousand D-glucose units.
- In industrial used the cellulose is mainly obtained from wood pulp and cotton and used to produce the textiles and paper.
- The cell walls of diatoms are composed of silicic acid. Other than cellulose the cell wall is made up of hemicelluloses and pectin.
- The Bacterial cell walls are made of peptidoglycan which is also called murein. The peptidoglycan is a polysaccharide chains cross-linked by unusual peptides containing D-amino acids.

## What is composition and Functions of Cell membrane?

Cell membrane is found around all cells and is selectively-permeable and controls the movement of substances in and out of cells. Main function is to protect the intracellular components from the extracellular environment.

The cell membrane is often differentially permeable and able to regulate what enters and exits the cell. The cell membrane facilitates the transport of materials needed for survival. The movement of substances across the membrane can be passive, occurring without the input of cellular energy, or active, requiring the cell to expend energy in moving it.

### Functions:

- **Permeability:** this is the most important function which allows the selective movement of particles inside and outside the cells.
- **Respiration:** The cell membrane plays an important role in the respiration and electron transport chains.
- **Cell secretion:** The Golgi apparatus or body is important in the function of process and package macromolecules, such as proteins and lipids, after their synthesis and before they make their way to their destination; it is particularly important in the processing of proteins for secretion.

[9] 1, 2, 3 & 4. Alginic acid is common polysaccharide in the cell walls of brown algae. Sulfonated polysaccharides common in red algae include agarose, carrageenan, porphyran, furcelleran and funoran.

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- This secretion is carried out with the help of cell membranes. The Golgi vesicles containing the secreted products from the endoplasmic reticulum fuse with the plasma membranes and releases the products to the outside of the cell.
- Exocytosis and endocytosis: These are the processes by which the materials are taken in or out of a cell.

## What is Cytoplasm?

Part of a cell that is enclosed within the cell membrane except the nucleus is cytoplasm. Contents of the cell nucleus are not part of the cytoplasm and are instead called the nucleoplasm. Cytoplasm contains organelles, such as mitochondria, Golgi bodies etc. Cytoplasm is the site where most cellular activities occur, such as metabolism, glycolysis, and cell division.

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.

## What are 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. There are nonliving substances as well and they are called ergastic substances. These 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.

## What are different types of Plastids?

These 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. Plastids have the ability to differentiate, or re-differentiate, between the above forms & and many shapes. This means that the above plastids are interchangeable. For example due to continuous absence of the sunlight the green chloroplast may turn to colorless 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:

- Amyloplats: which store the carbohydrates.
- Elaioplasts: which store the fats

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- Aleuroplats: which store proteins

Chloroplasts have a green pigment in them which is 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 chlorophylls are pigments responsible for Photosynthesis. 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 colors. 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.

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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.

## How Mitochondria is related to metabolism?

**Model Question 10.**

Which among the following cells most likely have the highest content of mitochondria?

1. Hen Egg Cell
2. Cow Skin Cell
3. Human Arm Muscles Cell
4. Human Kidney Cells

Answer: [10]

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 also implies that we find more mitochondria 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.

## What is 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 which 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.

## What are functions of 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

[10] C is most correct answer

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are parallel to each other. They are of two types, Rough endoplasmic reticulum 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.

### What are functions of Golgi apparatus?

These are named after Camillo Golgi who identified them in 1898. These are not present in the Prokaryotic cells. 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.

### What are Lysosomes and why they are called Suicide Bags?

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.

### What are Ribosome and how they are classified as per Svedberg Unit?

Ribosomes were discovered by Palade in 1955. They are not enclosed by any unit membrane. They are made up of RNA and proteins. There are two basic types of Ribosomes - 70S and 80S. The 70S Ribosomes are present in the prokaryotic cells and chloroplast and mitochondria of the Eukaryotic cells. The 80S Ribosomes are found in cytoplasm.

65% part of a Ribosome is ribosomal-RNA and 35% part of a ribosome is ribosomal proteins. These proteins are also known as a ribonucleoprotein or RNP. The 80S and 70S ribosome are differentiated by their S Units. S units are Svedberg Units. This unit is named after the Swedish chemist Theodor Svedberg who was given Nobel Prize in chemistry in 1926 for his work in the chemistry of colloids and his invention of the ultracentrifuge. The Ribosomes are distinguished by their behavior in sedimentation processes such as centrifugation.

The 80S and 70S Ribosomes are consisted of smaller units as follows:

- 70S : 50S + 30S
- 80S : 60S + 40S

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Please note that Svedberg unit is not a scale and that is why the 50S+30S are not 80S but 70S. This basically shows the behaviour of the smaller units in comparison to the Bigger Units. These smaller units are called sub units. The sub units unite and disintegrate before and after the protein synthesis. In the Reunion and separation process the magnesium $Mg^{++}$ plays a very important role.

### akrishan and his Ribosomal Study

Venkatraman Ramakrishnan an Indian-born American structural biologist, who shared the 2009 Nobel Prize in Chemistry with Thomas A. Steitz and Ada E. Yonath, did so" for studies of the structure and function of the ribosome". In 1999, Ramakrishnan's laboratory published a 5.5 Angstrom resolution structure of the 30S subunit. The following year, his laboratory determined the complete molecular structure of the 30S subunit of the ribosome and its complexes with several antibiotics. This was followed by studies that provided structural insights into the mechanism that ensures the fidelity of protein biosynthesis. More recently, his laboratory has determined the atomic structure of the whole ribosome in complex with its tRNA and mRNA ligands. Ramakrishnan is also known for his past work on histone and chromatin structure.

He was awarded Nobel Prize for studies of Ribosomes functions and structures.

### What are utilities of Peroxisomes, Glyoxisomes, Spherosomes and Centrioles in Cell?

- **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.

### What are 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.

### Which human cells have no Nucleus?

The credit of discovery of nucleus is given to Scottish Botanist Robert Brown in 1833. He saw the nucleus as opaque area in the cells of an orchid flower. Among all the organelles, Nucleus is most distinct and was the first cell organelle to be discovered. It was seen by Antonie van Leeuwenhoek in the red blood cells of salmon fish but called it a "Lumen". *Mammalian red blood cells have no nucleus.*

### What are structure and functions of Nucleus?

A distinct nucleus is absent in the prokaryotic cells and that is why they are called Prokaryotic (karyos: center). Nucleus is the master of a cell. It controls the cell functions such as metabolism, reproduction and development. It consists of Nuclear membrane, Nuclear Sap, Nucleolus and

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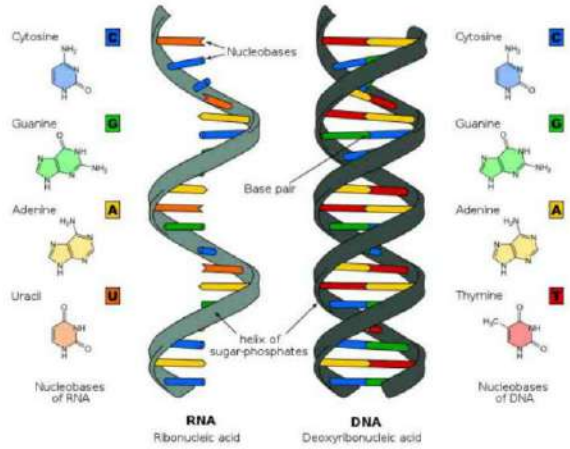
Chromatin. The nuclear membrane is again a double membrane and the space between the two membranes is called pronuclear space. The outer membrane is continuous with the endoplasmic reticulum which indicates its firm position in the cell. During the cell division the membrane disintegrates and reappears once the division is almost complete. Nucleoplasm is a transparent and gel like matrix. It contains the nucleolus, chromatin threads and Ribosomes. 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.

## What are Chromatins?

Chromatins are long thread like structures, which are *inter-coiled and intermingled*. This network has been named Chromatin Reticulum. It consists of DNA, RNA and Histones.

## What are Chromosomes?

All Eukaryotes possess multiple large linear chromosomes contained in the cell's nucleus. Each chromosome has one Centromere, with one or two arms projecting from the centromere. Each chromosome is part of a pair that contains the same genes or information just a different version. These pairs are called homologous chromosomes. When there are two copies of each chromosome in the nucleus of a cell that chromosome number is referred to as diploid and designated.




Each species has a specific number of chromosomes. Human cells have 23 pairs of large linear nuclear chromosomes (22 pairs of autosomes and one pair of sex chromosomes), giving a total of 46 per cell.

Gametes (sperm and egg) contain half the number of chromosomes of somatic cells (Human gametes have 23 chromosomes).

All chromosomes are made up of Nucleic acid and Protein. Hence they are called Nucleoproteins. Nucleic acid is the polymers of Nucleotide. Each Nucleotide is composed of 3 components: Nitrogen base, Pentose sugar and Phosphate group.

- Nitrogen base are of 5 types: Purine bases: Adenine(A), Guanine(G); Pyrimidine bases: Thymin(T), Cytosine(G), Uracil(U).
- Pentose sugars are of two types: Deoxy Ribose & Ribose
- The type of nucleotide i.e DNA or RNA is decided based on the composition nitrogen bases and pentose sugars. DNA = [A,G,C,T] + Deoxy Ribose sugar + Phosphate group
- RNA = [A,G,C,U] + Ribose sugar + Phosphate group.
- DNA was first identified by Friedrich Meische. A double helical structure of DNA is given by Watson & Crick. It explains the DNA as stranded, helical, spiral, staircase.

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- RNA is of 3 types: m RNA: messenger RNA – single stranded linear; t RNA: transfer RNA - single stranded linear; r RNA: ribosomal RNA – clover leaf shaped.

## Cell Division

### What are Mitosis and Meiosis?

The cell division is of two types. Mitosis and Meiosis. In mitosis chromosomes separates and form into two identical sets of daughter nuclei, and it is followed by Cytokinesis (division of cytoplasm). Basically, in mitosis the mother cell divides into two daughter cells which are genetically identical to each other and to the parent cell. The Chromosomes separate and for into two identical sets of daughter nuclei during the Karyokinesis and it is followed by Cytokinesis. Meiosis is also called reductional cell division and 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.

### What is significance of Mitosis?

*Mitosis occurs exclusively in eukaryotic cells*. In the prokaryotic cells, there is no Nucleus and cell division takes place by a process called binary fission. Further, in animals there is Open Mitosis which means that nuclear envelope breaks down before the chromosomes separate. In some kinds of fungi, such as *Aspergillus*, the process is "Close Mitosis", in which the nucleus remains intact while the chromosomes divide.

The cell cycle in mitosis is divided into interphase, Mitosis and Cytokinesis. Further, the interphase is divided into 3 stages viz. G1 stage, S stage and G2 stage.

Significance:

- 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.

### What is 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.*

The main phases in Meiosis are similar to those in mitosis, but the outcome of the process is entirely different. Since, the chromosome number of the parent cell gets reduced in the Meiosis; four daughter cells are produced, each with one-half the chromosome number of the parent cell. Each daughter cell contains only one chromosome from each homologous pair.

Thus, Meiosis has been divided into two divisions called Meiosis I and Meiosis II. Meiosis I is also known as heterotypic division or reduction division and in this phase the Chromosome number is

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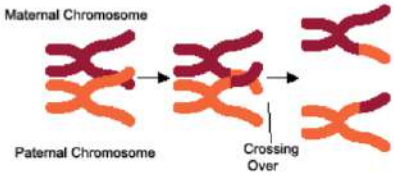
reduced to half. In meiosis II, the reduced number of Chromosomes is reproduced and total result is 4 cells.

### Meiosis : significance:




- The 4 cells formed as a result of meiosis contain the half number of Chromosomes.
- During sexual reproduction, the doubling of the Chromosomes takes place. Meiosis keeps the number of Chromosomes constant from generation to generation.
- By meiosis, new combinations of Chromosomes and genes are produced. This new combination occurs during crossing over and random distribution of paternal and maternal chromosomes occurs in the daughter cells.

## What is 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:**

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.

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### 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 diarrhea.

## Chapter 3. Viruses

*Virus* is a Latin word whose literal meaning is poison. A virus is not a living thing in first instance but they posses some properties of the both. *It is nor a cell nor able to reproduce independently*. A Virus is an extreme micro, parasitic non-cellular **nucleoprotein particle** which can persist only if it inside any living organism. This means that all viruses are parasites.

> Viruses were discovered by the Russian scientist **Dimitri Ivanovsky** in 1892 during the investigation of plant disease called **tobacco mosaic.** So, the TMV or **Tobacco Mosaic Virus** was the first Virus that was discovered.

Viruses naturally grow and reproduce in the living cells of more complex organisms, where they may cause diseases. The study of the viruses is called virology. Viruses undergo reproductive activities through multiplication. In plants , the viruses transmit generally through phloem, while in the animals through the blood / fluid of the body. *Viruses have **DNA and RNA but not both together** and these are composed from **nucleoproteins**.* Virus affects only a certain species and exhibits the properties of living and non-living both, as shown in the following table:

| 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. |

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| | |
|---|---|
| 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 |

## Structure of Virus

There are three main constituents or components of the structure of the virus-protein capsid, nucleic acid and a thick outer layer. Around a virus there is a closed frame of protein and which acts as genetic carrier. Generally, nucleic acid RNA is present in the plant virus, while in the animal virus nucleic acid DNA is present. On the basis of parasitic nature there are three types of virus-

- **Plant virus:** ***This is nucleic acid of RNA***. Examples are Tobacco Mosaic Virus and YMV (Yellow Mosaic Virus).
- **Animal virus :** *The animal Viruses contain either RNA or DNA* and are **usually spherical** in shape. Examples are influenza, mumps etc.
- **Bacteriophage:** The viruses that are parasites on a bacterial cell are called Bacteriophage.

Please note that in Bacteriophage ONLY DNA is present and they can destroy NOT ONLY Bacteria BUT also other viruses.

## 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:

**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.

- 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.

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- 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.

## Viral Plant Diseases

The mosaic diseases of plants such as Tobacco, Papaya, Banana, Lady Finger etc. are caused by Viruses. In Tomato, the Twisted leaf disease, In lemon, the yellowing of veins, the streak pattern of Almond and Twisted apex of Beet Root are all caused by Viruses. 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.

## Viral Animal Diseases

**Some Animal Viral Diseases**

| Diseases | Animals | Viruses |
|---|---|---|
| Herpes | Cow | Herpes virus |
| Blue tongue Disease | Cow | Blue tongue virus |
| Small pox | Cow | Variola vaccinia |
| Small pox | Buffalo | Poxverdi orthopox |
| Rabies | Domestic animals dog | Rabdovergi vasculo virus stereit virus |
| Mouth and gland infection | Cow and buffalo | Picornaverdi aphtho virus |
| Renderpest disease. | Cow and buffalo | Paramixoverdi morbeli virus |

- **Foot-and-mouth disease virus** (FMDV) causes acute systemic vesicular disease that affects cattle worldwide, foot-and-mouth disease. FMDV is a highly variable and transmissible virus. It's an RNA Virus.
- **Pestiviruses** causes diseases in animals such as Classical swine fever (CSF) and Bovine viral diarrhea / Mucosal disease (BVD/MD).

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- **Arteriviruses** are small, enveloped, animal viruses that infect animals such as Horses, Rabbits, Mice etc.
- **Influenza is caused by RNA viruses** and affects birds and mammals. Wild aquatic birds are the natural hosts for a large variety of influenza A viruses. Occasionally viruses are transmitted from this reservoir to other species and may then cause devastating outbreaks in domestic poultry or give rise to human influenza pandemics.
- **Bluetongue virus (BTV)** causes serious disease in livestock (sheep, goat, cattle). BTV is a complex non-enveloped virus with seven structural proteins and a RNA genome consisting of 10 double-stranded (ds) RNA segments of different sizes.
- **Porcine Circoviruses (PCV)** are the smallest viruses replicating autonomously in eukaryotic cells. They cause Postweaning Multisystemic Wasting Syndrome (PMWS), a new emerging and multifactorial disease in swine.
- **Herpesviruses** are highly successful pathogens infecting animals and man.

## Foot and Mouth Disease

Foot-and-mouth disease or hoof-and-mouth disease also known as Aphtae epizooticae , affects cloven-hoofed animals such as cattle, water buffalo, sheep, goats, pigs, antelope, deer, and bison. The virus causes a high fever for two or three days, followed by blisters inside the mouth and on the feet that may rupture and cause lameness. This disease is highly infectious and can spread quickly. The control methods include the vaccination, strict monitoring, trade restrictions and quarantines, and elimination of millions of animals. Epidemics of FMD have resulted in the slaughter of millions of animals, despite this being a frequently nonfatal disease for adult animals (2-5% mortality), though young animals can have a high mortality. Please note that not all the animal species affected by this virus spread it, for example, elephant has been shown to be contracted with this virus, but not spreading it to other elephants.

**FMD and Humans**
Humans can be infected with foot-and-mouth disease through contact with infected animals, but this is extremely rare. Some cases were caused by laboratory accidents. Because the virus that causes FMD is sensitive to stomach acid, it cannot spread to humans via consumption of infected meat, except in the mouth before the meat is swallowed.

In mid of 20th century, the disease was widely distributed throughout the world. In 1996, endemic areas included Asia, Africa, and parts of South America; as of August 2007, Chile is disease free, and Uruguay and Argentina have not had an outbreak since 2001. North America and Australia have been free of FMD for many years. New Zealand has never had a case of foot-and-mouth disease. Most European countries have been recognized as disease free, and countries belonging to the European Union have stopped FMD vaccination, though there was a serious outbreak of FMD in Britain in 2001.

## Dengue

Dengue is a mosquito-borne seasonal viral infection caused by any of four closely related viruses (DENV 1-4). The virus is transmitted by a bite of female mosquito of any of two species of

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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. It occurs **widely in tropical and subtropical areas** in Asia, Africa, Central and South America. 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. WHO estimates that there may be 50 million dengue infections worldwide every year. A severe form of the infection is known as dengue hemorrhagic fever (DHF). DHF **can be fatal if not detected.**

### Symptoms of Dengue

After its entry into patient's body, the virus multiplies to reach sufficient numbers to cause the symptoms. This process might take 4-6 days after which the symptoms become visible. The main symptoms of dengue are high fever (103-105 degrees Fahrenheit), severe headache (mostly in the forehead), severe pain behind the eyes, joint pain, muscle and bone pain, rashes, and mild bleeding from nose or gums. Because of the severe joint pain, dengue is also known as **break-bone fever**. Typically, younger children and those with their first dengue infection have **a milder illness than older children and adults**.

- 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.

### Treatment of Dengue:

- Like in most viral diseases, there is **no specific cure** for dengue. Antibiotics do not help and paracetamol is the drug of choice to bring down fever and joint pain.
- Other medicines such as Aspirin and Ibuprofen or any medicine that can decrease platelet count should be avoided since they can increase the risk of bleeding.
- As it has no specific medication, most dengue patients can be treated at home.

## Polio

Poliomyelitis, often called polio or infantile paralysis, is an acute viral infectious disease. Polio virus is an enterovirus which means that the route of entry of this virus is through the gastrointestinal system. *Polio Virus is 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.

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## Symptoms of Polio

- The virus makes its way into the body of humans through the faecal-oral route and divides within gastrointestinal cells for about a week, from where it spreads to the tonsils and then widely distributed throughout the body. It affects the CNS (Central Nervous System) reflected as inflammation (of Spine) and this is called the non-paralytic Polio.
- The incubation period for polio is commonly 6–20 days, with a range of 3–35 days. Surprisingly, 95% of all individuals infected with polio have no apparent symptoms.
- Another 4%–8% of infected individuals have symptoms of a minor, non-specific nature, such as sore throat and fever, nausea, vomiting, and other common symptoms of any viral illness. About 1%–2% of infected individuals develop nonparalytic aseptic (viral) meningitis, with temporary stiffness of the neck, back, and/or legs.
- Less than 1% of all polio infections result in the classic "flaccid paralysis," where the patient is left with permanent weakness or paralysis of legs, arms, or both.
- In this case, the Virus spreads along certain nerve fiber pathways, preferentially replicating in and destroying motor neurons within the spinal cord, brain stem, or motor cortex resulting in flaccid paralysis. This has made polio a feared disease for hundreds of years. Of people with paralytic polio, about 2%–5% of children die and up to 15%–30% of adults die.

## Cure

- There is no "cure" for polio. People infected with polio need supportive therapy, such as bed rest and fluids. Standard precautions should be taken to avoid passing on the virus through any contamination from the patient's stool.
- Since, there is no cure known for the disease, and so the best strategy is prevention. Immunization is the only way to prevent Polio and it is done at prescribed intervals and en-masse vaccinations.

## Polio Eradication Efforts

- In 1988, the World Health Organization (WHO) adopted the goal of global polio eradication. Although the initial target date of 2000 was not met, substantial progress has been made. The efforts of WHO and Rotary International have reduced the number of annual diagnosed cases by 99%; from an estimated 350,000 cases in 1988 to a low of 483 cases in 2001, after which it has remained at a level of about 1,000 cases per year (1,606 in 2009).
- Unfortunately, rumors about the safety of polio vaccine in 2003, and subsequent refusal of vaccine by many parents in Nigeria, led to an increase in cases and spread of the virus to nearby countries that had previously been polio free.
- Many organizations have been working hard toward eradicating polio including WHO, the United Nations Children's Fund (UNICEF), the Centers for Disease Control and Prevention (CDC), Rotary International, the Bill and Melinda Gates Foundation, and many other international and national groups. Strategies include house-to-house vaccination and

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National Immunization Days, where even warring factions have called temporary cease fires to allow children to be vaccinated.

- Today, Polio is rare in Western world, but still endemic to Afghanistan, Pakistan and Nigeria. Polio is one of only two diseases currently the subject of a global eradication program, the other being Guinea worm disease. So far, the only diseases completely eradicated by humankind are smallpox in 1979 and rinderpest in 2010. In eradication of Polio also, a number of milestones have already been reached, and several regions of the world have been certified polio-free. The Americas were declared polio-free in 1994. *In 2000 polio was officially eliminated in 36 Western Pacific countries, including China and Australia. Europe was declared polio-free in 2002. As of 2012, polio remains endemic in only three countries: Nigeria, Pakistan, and Afghanistan. Since January 2011, there were no reported cases of the disease in India, and hence in February 2012, the country was taken off the WHO list of polio endemic countries.*

### Polio Vaccines

- The first polio vaccine was an **inactivated, or killed, vaccine (IPV)** developed by **Dr. Jonas Salk** and licensed in 1955. In 1961, a live attenuated (e.g., weakened) vaccine was developed by Dr. Albert Sabin. This vaccine was given as an oral preparation instead of as a shot.
- By 1963, this oral vaccine had been improved to include protection against three strains of polio and was licensed as "**trivalent oral poliovirus vaccine**" (OPV). OPV was the vaccine of choice for the most countries of the world from 1963. However In some developed countries including US, there was a policy change later on.
- In 1988, an enhanced-potency IPV formulation became available and by 1997 had become part of the routine schedule for infants and children, given in a sequential combination with OPV. IPV is also available in combination with other vaccines (e.g., DTaP-HepB-IPV, DTaP-IPV/Hib, or DTaPIPV). Thus, two types of Vaccines are employed today: -
  - **Inactivated Polio Vaccine or IPV** used since 1955 contains the inactivated polio virus. The vaccine is administered as a shot in the leg or the arm. Common in United States.
  - The **Oral Polio Vaccine or OPV**, employed since 1961, contains a mild form of the live polio virus and is administered as 'drops' orally. Common in India.

### Why United States discontinued OPV?

OPV became controversial in medical circles due to a rare but serious side effect associated with the use of the vaccine - **vaccine derived paralytic poliomyelitis and Vaccine associated paralytic poliomyelitis**. This culminated in the ban on OPV in United States.Oral polio vaccine (OPV) is its

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known ability to revert to a form that can achieve neurological infection and cause paralysis. This is known as Vaccine Derived Polio Virus or VDPV.

Though VDPV is rare event, but outbreaks of vaccine-associated paralytic poliomyelitis (VAPP) have been reported, and tend to occur in areas of low coverage by OPV, presumably because the OPV is itself protective against the related outbreak strain.

In simple words, for a few people (about one in 2.4 million), **OPV actually causes polio.** Since the risk of getting polio in the United States is now extremely low, experts believe that using oral polio vaccine is no longer viable. It has been proved that the polio shot (IPV) does not cause polio.

### OPV and India

In India, OPV is the backbone of Polio Vaccination Programme. The children need to be administered **four doses of Polio vaccine** during the period from infancy **till 5 years of age**.

- In India, the initiative against polio began in 1978 under the project called, the **Expanded Programme on Vaccination (EPV).** This programme brought more than 40% of the infants under its cover to avail 3 doses of Oral Polio Vaccine.
- Upon success of the first en-masse initiative, this programme was expanded to include many districts in the country.
- The **Pulse Polio Immunization (PPI)** Programme commenced in 1995-96 to *include all children below age of 3*. Please note that 'PULSE' stands for *Post-Resuscitation and Initial Utility in Life Saving Efforts*. In order to accelerate the pace of polio eradication, the target age group was increased from 1996-97 to all children under the age of **5 years**.

**Oral Polio Vaccine and Digestive System**

Some viruses are enveloped in a lipid layer that can be destroyed by the lipolytic agents present in the digestive system. The lipid layer cannot withstand the stomach's digestive system as it is sensitive to alcohol, acid and other enzymes in the digestive system. Examples are influenza and HIV viruses. However, there are other types of viruses, which are non enveloped, called naked viruses, like the polio virus, which cannot be destroyed by acid, bile or other proteolytic enzymes present in the digestive tract. Therefore the polio vaccine that contains attenuated strains of live polio virus, when given orally, cannot be destroyed by the digestive acids and enzymes and survives in the intestinal tract and induces local immunity in the intestinal tract.

## Chapter 4. Bacteria

The living beings (organisms) of all the prokaryotic cells which are extremely microscopic and simplified found everywhere come under kingdom Monera. Monera is a prokaryotic cell which has an incipient nucleus and under it. Bacteria and blue green algae have been kept in Monera. Bacteria are the most important member of Kingdom Monera.

### Features of Bacteria

Bacteria are simplified microbes having **prokaryotic cells lacking of chlorophyll**. The bacteria are unicellular microorganisms which were first observed and reported by **Anton Von Leeuwenhoeck** in 1676 and he described them as animalcules. The term "bacterium" was

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introduced **Christian Gottfried Ehrenberg** in 1838 and in 1859, Louis Pasteur demonstrated that the fermentation process is caused by the growth of microorganisms, and that this growth is not due to spontaneous generation. This gave rise to the germ theory of disease and **Robert Koch** pioneered the medical microbiology and worked on cholera, anthrax and tuberculosis. For his germ theory, Koch was awarded a Nobel Prize in 1905.

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.
- Bacterial cells have no chlorophyll, no mitochondria
- Respiratory activities are performed by the misosomes.
- All spores producing bacteria are gram positive and on colouration they become purple, while the cellular walls of such bacteria are made of murine.
- Louis Pasteur had invented the inoculation of the rabies and the pasteurization of the milk.

## How Pasteurization works?

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.

## What are different shapes of Bacteria?

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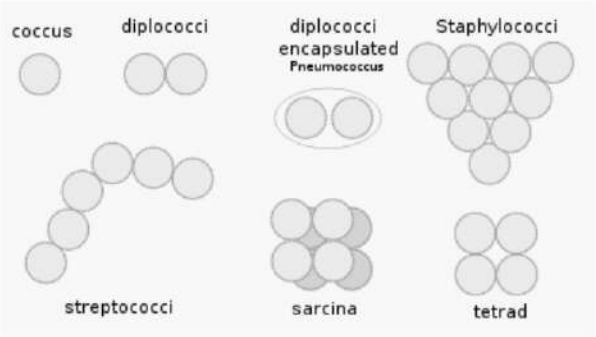
Bacteria are the monocellular microorganisms which are found in almost places in singleton form or in group. The cellular wall of the bacteria is thick and it is made from chitin, Murine etc. They have different shapes such as:




## Coccus

These are spherical bacteria. They can be

- Monococcus: single spherical bacterium
- Diplococcus: Occurs always in pairs
- Streptococcus : chains of bacteria arranged in a single row
- Sarcina: Cocci which are arranged in cubes of 8.
- Staphylococcus: irregular shapes.

## Bacillus

These are rod shaped bacterium. They can be

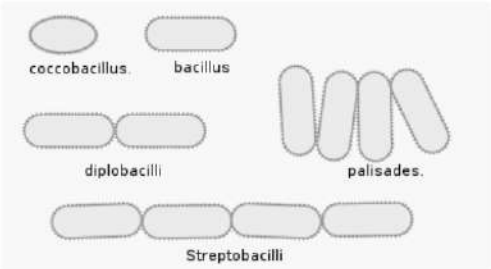
- Monobacillus: Single rod shaped bacterium
- Diplobacillus : Rod shaped bacteria arranged in pairs.
- Streptococcus: Chain of rod shaped bacteria

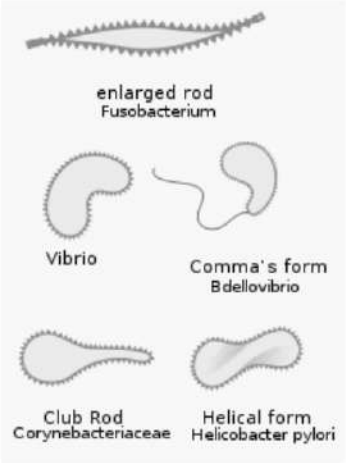
## Vibrio

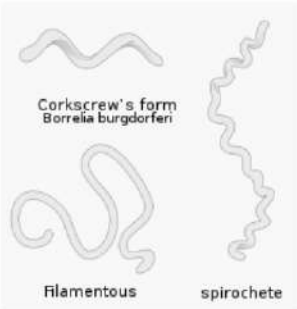
These are coma shaped bacteria.

## Spiriullum

These are cork screw shaped or helically coiled bacteria.




Bacteria are saprophytic or parasitic. There are three common bacterial bodies-spherical (coccus forms), rod-shaped or cylindrical (Spiriullum forms) and spiral or screw (Spiriullum). Some species

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of the bacteria are branched thread like bodies, live in liquids, and have long thread like shape called **flagella**. Cell membrane is made from **protein and phospholipids**. Almost bacteria undergo the metabolic activities, like nutrition , reproduction etc.

## G+ and G- Bacteria

### What are gram negative and Gram Positive Bacteria?

Gram staining is the first stage in identification of the bacteria. It differentiates the bacteria on the basis of chemical properties of their Cell Wall. Hans Christian Gram was the inventor of Gram staining. Please note that NOT all bacteria can be classified by this technique and only those bacteria which can be classified by using this technique are called Gram variable. Otherwise they are called Gram indeterminate.

### How does it work?

The staining distinct two types of bacteria viz. Gram positive and Gram negative denoted by G+ and G-. The primary stain used in the technique is crystal violet. Crystal violet is followed by use of a trapping agent (Gram Iodine) and after that alcohol is used to decolorize and finally Safranin / Basic fushcin is used to counter stain. The crystal violet gets dissociated in CV+ and Cl- ions in water and these ions penetrate the cell walls.

The cell wall which is made up of Peptidoglycan as well as lipids gets violet due to the reaction of the CV+. After the decolorization with alcohol, the lipids gets dissolved and the bacteria with higher Peptidoglycan remain violet. These are called Gram Positive bacteria. The bacteria which lose the violet color are called Gram negative bacteria.

### Properties of Gram negative bacteria

- The cell wall is heterogeneous.
- Thickness of the wall is in the range of 10-15 nanometer
- The cell wall is 10-20% of the cell's dry weight
- Composition: Peptidoglycan (5-15%), Phospholipids 35% and proteins 15%. 50 % is lipopolysachharides.
- **Teichoic Acid , which provides the rigidity to the cell walls is absent** in gram negative bacteria.

### Properties of Gram Positive Bacteria

- Cell wall is homogenous.
- Thickness of the Cell wall is around 25-30 nanometer
- 20-40% of dry weight is made by Cell wall.
- 20 to 80% of the cell wall is made up of Peptidoglycan.
- The teichoic acid is present in the cell walls of Gram Positive bacteria.

### How certain bacteria move?

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.

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## Are bacteria autotrophic or heterotrophic?

If the bacteria absorb the inorganic substances from the environment and convert them into organic substances there are called **autotrophic** bacteria. They are similar to the green plants. If they cannot use the $CO_2$ and meet their carbon requirements from the organic substances such as Glucose and amino acids, they are called **heterotrophic** bacteria. Some bacteria contain chlorophyll and obtain energy from the sunlight, they are called **Photoautotroph.** It includes the Purple sulphur and Green sulphur bacteria.

Some of the bacteria such as Nonsulphur purple bacteria obtain energy from the sunlight but derive their Carbon requirement from the organic sources. So they are called **Photo-heterotrophs.** Some bacteria derive the carbon from the $CO_2$ but Energy from the oxidation of the inorganic substances. They are called **Chemo-autotrophs.** Some bacteria derive their carbon as well as Energy requirements form the organic substances such as Glucose and amino acids. They are called **Chemo heterotrophs**.

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.

## How bacteria reproduce?

In bacteria reproduction takes place by two methods viz. Asexual and Sexual.

- **Asexual reproduction:** Reproduction in bacteria is largely asexual and the most of the bacteria reproduce by binary fission. This is a simple process of cell division, in which one bacterium splits into two new ones. Asexual reproduction in bacteria is done by **conidia and endospore**.
- **Sexual reproduction :** Some bacteria also exhibits the reproduction by sexual method and members of such bacterial species contain a **virus like agent called fertility or F factor**. Sexual reproduction is of three types-
- **Conjugation** : Two cells fuse and a transfer of DNA takes place called conjugation.
- **Transduction:** A virus replaces DNA of any bacterium and this replaced DNA is fused with DNA of another bacterium, called transduction.
- **Transformation:** Sexual reproduction through which genetic profile of the bacteria is changed by absorbing DNA from the external medium called transformation.

## What are Hydrogen bacteria and Sulfur bacteria ?

Hydrogen bacteria use Hydrogen and as source of energy. There are examples such as sulfate reducing and acetogenic bacteria which are commonly called **Hydrogen bacteria.** They have a membrane bound *Hydrogenase* which can oxidize the Hydrogen and convert it into various quinones and cytochromes.

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### Sulphur bacteria

Sulphur bacteria are capable of oxidation of the reduced Sulphur compounds such as Hydrogen Sulphide ($H_2S$), Inorganic Sulphur etc. They create Sulphuric Acid. Examples are *Beggiatoa* and *Paracoccus.*

### Ferrous bacteria

*Acidithiobacillus ferooxidans* and *Leptospirrillum ferrooxidans* are example of such bacteria which use Ferrous Iron and oxidize them. Since Ferrous Iron is stable at a very low pH, these bacteria are essentially acidophilic.

## What is role of 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 ($NO_{3-}$).

## What is role of Bacteria in Biological Nitrogen Fixation?

The Nitrogen Fixation is the procedure by which Nitrogen in the atmosphere is converted into ammonia. It 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.** The Nitrogen fixation is one of the important components of the Nitrogen cycle

### 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):

$$N_2 + 8H^+ + 8e^- + 16\ ATP = 2NH_3 + H2 + 16ADP + 16\ Pi$$

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 N2 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 N2, producing HN=NH. There are two more cycles and each requires electrons donated by ferredoxin) HN=NH is reduced to H2N-NH2, and this in turn is reduced to $2\mathbf{NH_3}$ .

### 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

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- Please note that BNF can be done by both **anaerobic bacteria as well as the aerobic bacteria** but the process occurs **in absence of Oxygen** and **thus is anaerobic process**. 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.
- 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.

The examples of all kinds of bacteria that are able to fix nitrogen are shown below:

| Examples of nitrogen-fixing bacteria | | | |
|---|---|---|---|
| **Free living** | | Symbiotic with plants | |
| **Aerobic** | Anaerobic | Legumes | Other plants |
| *Azotobacter* | *Clostridium* | *Rhizobium* | *Frankia* |
| *Beijerinckia* | *Desulfovibrio* | | *Azospirillum* |
| | Purple sulphur bacteria | | |
| | Purple non-sulphur bacteria | | |
| | Green sulphur bacteria* | | |

## Legume Plants

Plants that contribute to nitrogen fixation include the legume family – Fabaceae – with taxa such as clover, soybeans, alfalfa, lupines, peanuts, and rooibos. They contain symbiotic bacteria called **Rhizobia** within nodules in their root systems, producing nitrogen compounds that help the plant to grow and compete with other plants.

The fixed nitrogen is released only when the plant dies. This helps to fertilize the soil.

## Applications of Bacteria in Dairy Industry

*Lactobacillus* are found in the milk which through the process of fermentation (anaerobic respiration) with lactose of the milk form lactic acid and that's why milk becomes sour. In the milk a protein namely casein is found and with these protein bacteria of lactic acid transforms the milk into the curd (dahi). The bacteria used in dairy industry are *Streptococcus lactis, Leuconostoc cremoris, Megatherium* etc. The bacteria such as *Streptococcus lactis, Leuconostoc cremoris, Lactobacillus bulgaricus* are useful in the Dairy Industry. Some as *Lactobacillus, Acetobacter,* etc are bacteria which work as **Fermentation starter** in making of Cheese. The other Fermentation starters are fungi (yeasts and molds) such as Rhizopus, Aspergillus, Mucor, Amylomyces, Endomycopsis, Saccharomyces, Hansenula anomala. These bacteria (and the enzymes they produce) also play a large role in the eventual **flavor of aged cheeses.** Most cheeses are made with starter bacteria from the *Lactococci, Lactobacilli, or Streptococci* families.

### Why there are holes in Emmental cheese?

**Emmental cheese is** also known as **Swiss Cheese**, and is a cheese from Switzerland. It is unique because of the characteristic large holes in it as shown in this pic. These holes are due to a bacteria called *Propionibacterium*

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*freudenreichii,* which consumes the lactic acid excreted by the other bacteria, and **releases carbon dioxide gas**. The Gas is trapped and is not able to get released thus forming the bubbles that make holes.

## Bacteria in Industries (Don't cram the names of specific bacteria)

- The *Bacillus megatherium* bacterium is used in the Flavoring of Tea and Tobacco.
- *Acetobacter aceti* is used in preparation of vinegar from Alcohol
- *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 work as natural scavangers as they are able to decay huge amount of plan, animal and human waste.
- 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.
- Similarly vinegar is prepared by the decomposition of sugar solution through Acetobacter aceti bacteria.
- Bacteria, often 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.
- 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.
- 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 lives 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. This bacterium is used as a Lepidopteran-specific insecticide under trade names such as Dipel and Thuricide. Because of their specificity, these pesticides are regarded as environmentally friendly, with little or no effect on humans, wildlife, pollinators, and most other beneficial insects.
- Bioremediation techniques such as Oil zapper use bacteria.
- Bacillus megatherium is used in flavoring of tea and tobacco.
- Clostridium acetobutylicum can produce acetone from acetic acid and butanol from butyric acid.
- In Biogas plants, the Methanobacterium produces methane.
- Bacteria are used in retting of Flax, Jute and Hemp.
- Bacteria work as natural scavengers.
- Antibiotics
- 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* |
| Erythromycin | *S.Erythreus* |
| Tyrothrycin-A | *Bacillus brevis* |
| Polymyxin-B | *Bacillus polymixa* |
| Bacitracin | *B.Subtilis, Bacillus Licheniformis* |

## Role of bacteria in Soil Formation & 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 specially of plants *Rhizobium* bacteria are found in the roots of the plants

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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.

## Chapter 5. Microbial Diseases

### Common plant diseases caused by bacteria

| Diseases | Pathogens bacteria |
|---|---|
| Potato wilt | *Pseudomonas solanacearum* |
| Blight of rice | *Xanthomonas orzae* |
| Citrus canker | *Xanthomonas citri* |
| Bean blight | *Xanthomonas phaseoli* |
| Potato scab | *Streptomyces scabies* |
| Black arm of cotton | *Xanthomonas malvacearum* |
| Fire flight of apple | *Agrobacterium tumefacines* |

### Common Human and animal diseases caused by bacteria

| Disease | Pathogens bacteria |
|---|---|
| Leprosy | *Mycobacterium leprae, Corynobacterium diphtheriae* |
| Pneumonia | *Diplococcus pneumonia* |
| Cholera | *Vibrio cholera* |
| Typhoid | *Eberthalla typhosa* |
| Dysentery | *Shiquella dysenteriae* |
| Tetanus | *Clostridium tetani* |
| Tuberculosis | *Mycobacterium tuberculosis* |
| Whooping | *Hemophilous* |
| Cough | *Pertusis* |
| Plague | *Pasteurella pestis* |
| Gonorrhea | *Gonoccus* |
| Syphilis | *Treponema pallidium* |

### Animal diseases

| Diseases | Pathogens bacteria |
|---|---|
| Black leg of animals anthrax of sheep | *Clostridium chauvei, Bacillus anthracis* |

### Is diarrhoea caused only by Bacteria?

Diarrhea can be caused by all sorts of parasites such as viruses, Bacteria, protozoa and others. Most common virus causing Diarrhoea in adults is **Norovirus.** Most common virus causing Diarrhoea in children below 5 years **is rotavirus.** A *rotavirus vaccine* has the potential to decrease rates of diarrhea, and is under studies. Most common bacteria causing Diarrhoea is *campylobacter*, others are *salmonellae, shigellae and some strains of Escherichia coli (E.coli).*

### What agents causes 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 **viral infection.** The most common cause of the disease in developed countries is infection with a bacillus of the *Shigella* group (causing bacillary dysentery). Infection with the amoeba *Entamoeba histolytica* can cause amoebic dysentery

### Which Bacteria cause Typhoid and Whooping Cough?

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

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### Whooping Cough

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

## Tuberculosis

Tuberculosis is caused by various strains of **mycobacterium**, 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 MTB 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. 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. An estimated 1.7 million people died from TB in 2009. The highest number of deaths was in the 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.

### Drug resistant TB

Until 50 years ago, there were no medicines to cure TB. Now, strains that are resistant to a single drug have been documented in every country surveyed; what is more, strains of TB resistant to all major anti-TB drugs have emerged. Drug-resistant TB is caused by inconsistent or partial treatment, when patients do not take all their medicines regularly for the required period because they start to feel better, because doctors and health workers prescribe the wrong treatment regimens, or because the drug supply is unreliable. A particularly dangerous form of drug-resistant TB is multidrug-resistant TB (MDR-TB), which is defined as the disease caused by TB bacilli resistant to at least isoniazid and rifampicin, the two most powerful anti-TB drugs. Rates of MDR-TB are high in some countries, especially in the former Soviet Union, and threaten TB control efforts. (WHO website).

### Stop TB Strategy of WHO

In 2006, WHO had launched the new Stop TB Strategy. The heart of this strategy is **DOTS**, the TB control approach launched by WHO in 1995. Since its launch, 41 million patients have been treated under DOTS-based services. The new six-point strategy builds on this success, while recognizing the key challenges of TB/HIV and MDR-TB. It also responds to access, equity and quality constraints, and adopts evidence-based innovations in engaging with private health-care providers, empowering affected people and communities, to help strengthen health systems and promote research.

The six components of the Stop TB Strategy are:

- High quality DOTS expansion to even the remotest areas.
- Addressing TB/HIV, MDR-TB and the needs of poor and vulnerable populations.

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- National TB control programmes must contribute to overall strategies to advance financing, planning, management, information and supply systems and innovative service delivery scale-up.
- Engage all care providers. TB patients seek care from a wide array of public, private, corporate and voluntary health-care providers. To be able to reach all patients and ensure that they receive high-quality care, all types of health-care providers need to be engaged.
- Empower people with TB, and communities through partnership via Community TB care projects.
- Enable and promote research. While current tools can control TB, improved practices and elimination will depend on new diagnostics, drugs and vaccines.

## BCG Vaccine

Tuberculosis was declared a global emergency by the WHO in 1993. Control of this disease relies upon prevention through **Bacillus Calmette-Guérin** (BCG) vaccination or "preventive therapy" (chemoprophylaxis), and the ascertainment and treatment of cases, in particular employing the "**directly observed therapy - short course**" (DOTS) approach.BCG, or Bacille Calmette-Guérin, used for vaccination of infants in 192 countries. But not widely used in the United States, because TB is uncommon in US. BCG was the first vaccine for TB that was discovered after 1905, when Albert Calmette and Camille Guérin worked at the Institut Pasteur de Lille and the Pasteur Institute in France developing BCG, administering the first human trials in 1921. Original BCG vaccine was derived from an isolate of *M. bovis* at the Institut Pasteur in Lille.

- *M bovis* ,that has lost its virulence in humans by being specially cultured in an artificial medium for years is still used for producing BCG Vaccine. However, please note that BCG does not always protect against people from getting TB. At best, the BCG vaccine is 80% effective in preventing tuberculosis for a duration of 15 years.

## Why BCG vaccine shows variable efficacy?

This is the most controversial issue of the BCG administration. It has been shown that the BCG shows variable efficacy, which depends upon geography. The studies have almost concluded that the efficacy of BCG appears to fall the closer one gets to the equator.

Many hypothesis have been postulated so far. One such theory says that in areas where there is high levels of background exposure to tuberculosis, every susceptible individual is already exposed to TB prior to BCG, that 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 is less prevalent. One document of WHO says that in South Africa, the country with the highest prevalence of TB, BCG is given to all children under age three,. but since BCG is less effective in areas where mycobacterium are less prevalent; it is not given to the entire population in these countries. In United States, BCG vaccine is not recommended except for people who meet specific criteria.

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Another theory says that Variable efficacy is because of the Genetic variation in BCG strains . In this context, a WHO document says that a so-called RD-2 region, which encodes the **mpt-64 gene**, is present in the "primitive" BCG strains but is absent from those sub-strains derived from the original BCG Pasteur strain after 1925. However, full details are unavailable.

## TB and India

Tuberculosis in India takes a toll of 1,000 per day or one every minute. It is estimated that there are 14 million TB cases in our country out of which 3.5 million are sputum positive. About 1 million sputum cases are added every year.

## National Tuberculosis Control Programme

National Tuberculosis Control Programme was started in 1962 on a 50:50 sharing basis between Centre and State. The objectives of the Programme were to reduce the morbidity and mortality; to reduce disease transmission and to diagnose as many cases of tuberculosis as possible and to provide free treatment. The programme was a flop show mainly due to incomplete treatment as treatment completion rate was less than 40 per cent along with some other causes such as inadequate budget; shortage of drugs; emphasis on x-ray diagnosis; poor quality sputum microscopy and multiplicity of treatment regimens.

## Revised National TB Control Programme

The National TB Control Programme was later expanded to cover additional 100 million population in 100 districts/reporting units. For the first time in India, a web-based resource centre was developed for preparing TB communication materials. The heart of this programme is DOTS and that is why DOTS is known as the Revised National TB control programme (RNTCP) in India.

## How DOTS Therapy Works?

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. As it is the only strategy effective in controlling TB on a mass basis, nearly 100 countries are following it.

DOTS has five components:

- ✓ Government commitment (including both political will at all levels, and establishing a centralized and prioritized system of TB monitoring, recording and training)
- ✓ Case detection by sputum smear microscopy
- ✓ Standardized treatment regimen directly observed by a healthcare worker or community health worker for at least the first two months
- ✓ A regular drug supply
- ✓ A standardized recording and reporting system that allows assessment of treatment results

**Isoniazid**
Isoniazid / Laniazid or Nydrazid) is the classic antituberculosis medication, first discovered in 1912. It was found to be effective against tuberculosis in 1950s. However, Isoniazid is never used on its own to treat active tuberculosis because resistance quickly develops.

**Rifampicin**
Rifampicin is a bacteriocidal antibiotic drug. It has been used for TB along with isoniazid, ethambutol, pyrazinamide and streptomycin etc.

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The technical strategy for DOTS was developed by Dr. Karel Styblo in the 1980s primarily in Tanzania.

In 1989, the World Health Organization and the World Bank began investigating the potential expansion of this strategy. In July 1990, the World Bank, under Richard Bumgarner's direction, invited Dr. Styblo and WHO to design a TB control project for China. By the end of 1991, this pilot project was achieving phenomenal results, more than doubling cure rates among TB patients. China soon extended this project to cover half the country.

In India, Government had adopted the revised strategy for TB in the form of DOTS. Since 1993, DOTS has been pilot tested in 20 sites in India as RNTCP.

In RNTCP the proportion of TB cases confirmed in the laboratory is double that of the previous programme, and the cure rate is nearly triple that of the previous programme. The operational feasibility of DOTS in the Indian context has been demonstrated, with 8 out of 10 patients treated in the programme being cured as compared to three out of 10 under the previous regime.

DOTS has also been shown to prevent the emergence of multi-drug resistant tuberculosis (MDRTB) and to reverse the trend of MDRTB in communities in which it has emerged. Also DOTS can cure TB even in HIV-positive patients. Entire country has been covered under DOTS Strategy by March 2006. The international Joint Monitoring Mission (JMM) in October 2006, has hailed it as the fastest expansion of DOTS in the world.

## What are MDR-TB 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 drug-resistant 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.

Thus, Extensively-drug resistant TB (XDR-TB) is a sub-set of MDR-TB which is further resistant to at least two more drugs which are second line drugs and is thus virtually incurable. XDR TB was first described in March 2006 following a joint survey of laboratories by the WHO, IUATLD, and CDC, Atlanta.

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## Leprosy

Leprosy or Hansen's disease is caused by the bacteria Mycobacterium leprae and Mycobacterium lepromatosis. Leprosy has affected humanity for over 4,000 years and was well-recognized in the ancient China, Egypt, and India. The primary symptom is skin lesions and if left uncured , it can be progressive, causing permanent damage to the skin, nerves, limbs and eyes.

- ✓ BCG helps against Leprosy also.

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. Human Rights Council had adopted the Resolution 8/13 – "Elimination of discrimination against persons affected by leprosy and their family members", as proposed by the Japanese Government.

### Treatment of Leprosy

Some drugs such as rifampicin, clofazimine, and dapsone are used to treat Leprosy. In 1993, the WHO had recommended two types of standard MDT regimen be adopted. One was a 24-month treatment for multibacillary (MB or lepromatous) cases using rifampicin, clofazimine, and dapsone. Another was a six-month treatment for paucibacillary (PB or tuberculoid) cases, using rifampicin and dapsone.

## 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.

## 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. In later half of 2010, 41 deaths in Rayagada district and 8 deaths in Kalahandi district occured due to acute diarrhoeal diseases in Orissa.It was concluded a cholera outbreak. Similarly, After the 2010 Earthquake in Haiti, Cholera had again spread recently in Haiti. The pandemic probably spread from the water of the Artibonite river, Haiti. More than 2000 people have killed in Haiti in the latest Outbreak of Cholera as per the reports published in newspapers. A new kind of strain of the Cholera bacteria Vibrio Cholerae known as El Tor was making news in this context. El Tor is known as V. cholera biotype eltor. It is differentiated from the classic strain on the genetic level and known to produce the Hemolysins. It was first found in 1905 in El Tor in Egypt. In early 1900s 6 major Cholera pandemics had spread the word. The 7th outbreak was caused by this new strain in 1961 in Indonesia. It spread rapidly elsewhere.

### Why Curd is easy to digest than Milk?

Curd is made by mixing a few spoonfuls of commercial yoghurt made with live cultures of bacteria into pasteurised milk. A mixed culture of *Lactobacilus bulgaricus* and *Streptococcus thermophilus*

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consumes the milk sugar or lactose for energy and excretes lactic acid which curdles the milk. Curds retain the fat, mineral and vitamin content of milk, but have only one-third to two-thirds the amount of lactose. Curds are, therefore, more digestible than milk for lactose intolerant people.

## What are Probiotics?

A microbe that **protects its host and prevents disease is called Probiotic.** The best-known Probiotic is *Lactobacillus acidophilus*, found in yogurt, and other dairy supplements. Probiotic counter the destruction of helpful intestinal bacteria by antibiotics. They are useful in preventing antibiotic-associated diarrhea. Billions of bacteria inhabit the digestive system. These bacteria, also referred to as **'gut flora'**, are required to break down food remains that have not been digested and to discourage harmful bacteria and yeasts from invading the body. The gut flora consists of as many as 400 species of bacteria. Many produce vitamins and fatty acids and provide nutrients to the body. They maintain low pH level in the large intestine. Ayurveda has been using this concept for centuries.

## What are QWERTY tummy & Delhi Belly?

Qwerty tummy and Delhi Belly are alike. It is Enterotoxigenic ***Escherichia coli*** which causes a Traveler's diarrhea known as **Delhi Belly**.

Similarly, a bad tummy brought on by the use of a filthy computer keyboard is called QWERTY tummy. Some studies say that a keyboard has five times more bacteria than a toilet seat. The keyboard user could inadvertently put a finger in the mouth and suffer acute food poisoning. It all starts when people eat while working, leaving crumbs on the keyboard, which attract mice. Then there are others who don't wash their hands after using the restroom.

## Why there is a 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.

## What is Oil Zapper?

'Oilzapper' technology has been developed by ONGC-Teri Biotech Ltd (OTBL), a joint venture between Oil and Natural Gas Corporation Ltd and The Energy and Resources Institute. In OTBL, Teri has 47 per cent equity, while ONGC has 49 per cent. The remaining 2 per cent is with financial institutions.

Oilzapper is a microbial product wherein microbes that feed on oil are created. 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

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of birds. The company has bid in past (2009) for cleaning the huge oil spill left over from the Gulf War in 1991 in Kuwait. Same technology made news again as TERI carried out the bioremediation process by using the 'oilzapper' technology at the Awas beach at Alibaug, in 2010, in the wake of oil contamination by MS Chitra Oil Spill in Mumbai.

### What is special about the 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 cold-active bacteria collected from Antarctica and the other low temperature areas.**

## Chapter 6. Fungi

The 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.

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## What are 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* does 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:** 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.
- ✓ **V**itamins : Various vitamins like vitamin B is prepared from *Streptomyces griseus*.
- ✓ Bioremediation by means of Fungi is called **Mycoremediation**. 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.
- ✓ *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.

## What are common fungal diseases in Plants?

The fungi act as disease causal organisms for the various plants animals and human beings.

| Disease (plants) | Causal organisms (fungal) |
|---|---|
| Wart disease of potato | *Synchytrium endobioticum* |
| Late blight of potato | *Phytophythora infestans* |
| Green ear disease of bajra | *Sclerospora gramicola* |
| Rust of wheat | *Puccinia graminis tritici* |
| Loose smut of wheat | *Ustilogo nuda tritici* |
| Tikka disease of groundnut | *Corcospora personata* |

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| | |
|---|---|
| Red rot of sugarcane | *Collectotrichurn falcatum* |
| Brown leaf spot of rice | *Helmin thosporium oryzea* |
| Ergot disease of rye | *Cleviceps purpurea* |
| Powdery mildew of wheat | *Erysiphe graminis tritici* |

### What are common Fungal diseases in Humans?

| Diseases | Casual organism (fungus |
|---|---|
| Athlete's foot scabies | *Taenia pedis* |
| Scabies | *Acarus scabies* |
| Ring worm | *Trichophyton* |
| Meningitis | *Cryptococcus neoformans* |
| Asthma | *Aspergillus fumigates* |
| Baldness | *Taenia capitis* |
| Aspergillosis | *Aspergillus fumigatus* |

## Lichens

Lichens are composite organisms consisting of a symbiotic association of a fungus (the mycobiont) with a photosynthetic partner (the photobiont or phycobiont), usually either a green alga (commonly Trebouxia) or cyanobacterium (commonly Nostoc). Thus Lichens are associations of fungi and algae and the study of lichens is called Lichenology. The fungi facilitate water, minerals, vitamins, etc to the algae and algae prepare carbohydrate by the process of photosynthesis and supply the food to the fungi. Lichens coexist with fungi and algae as symbiotic and it is called **helotism**. Lichens are most commonly found on the trees.Lichens are useful and by the help of these various economic activities can be observed. Lichens like Reindeer mosses, Iceland moss etc are utilized as food stuffs.

### How Lichens such as Reindeer moss work as an environment Indicator?

Lichens are extremely vulnerable to habitat alteration, so habitats with the highest lichen species diversity are the remnants of ancient forests and other undisturbed ecosystems. The association between high diversity of lichens and pristine habitats is so clear that scientists use lichens as indicators of ecosystem continuity -- to help them identify areas that should be protected. Certain lichen species grow primarily (or even exclusively) in undisturbed habitats. Most lichens are extremely vulnerable to air pollution. When lichens disappear, they give early warning of harmful conditions. Scientists are using lichens to monitor air quality often compare current lichen inventories with past records.

Reindeer mosses were originally named for their value as a food source for reindeer and caribou in the plant's northern range. Reindeer moss is really a lichen - a combination of a fungus and an alga, which share a symbiotic relationship and form a new plant. A short, stubby ground cover grows in pillow-like mats in sandy soil. There are about 40 species in the southeast, which range in color from gray-green to green-yellow to just gray. Because the common forms of reindeer moss are nitrogen fixers, they help form new soil, stabilize eroding sand, and create habitat for other plants and animals. The plant has the ability to absorb moisture and nutrients

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from the air through cells on its surface. However, this makes reindeer moss susceptible to pollutants in the environment. **It is sometimes used as an indicator of environmental health.**

Native Americans relied on the moss as a survival food in hard times. It is low in protein, but high in carbohydrates and vitamins A and B. It was also used in powder form to thicken soups, stews and desserts.

Reindeer moss is spongy and rubbery when moist, but becomes dry and brittle in times of little rain and will crunch if stepped on. It is slow to recover after a burn.

## Chapter 7. Algae

Algae are chiefly water plants, dwelling in oceans, seas, lakes, ponds, rivers etc which have moist environment and which are not subjected to direct sunlight. Usually algae are chlorophylous, non-vascular, autotrophic thalloid like microorganisms. Some species are found on rocks. The study of Algae is called Phycology. While father of Phycology is **F E Fritch,** father of **Indian Phycology is MO P Iyengar.**

### Chief characteristics of algae

- ✓ The cell walls of the cell of algae are made from cellulose.
- ✓ Usually sex organs of the algae are uniceller.
- ✓ Algae store their food in the form of starch.

### Reproduction

There exist three types of reproduction in the algae-

- ✓ Vegetative reproduction
- ✓ Asexual reproduction
- ✓ Sexual reproduction: There are three types of sexual reproduction -----Isogamous, Anisogamous and Oogamous.

### Classes of Algae

There are several classes of Algae. Rather than studying the taxonomy, I am mentioning some of the important classes of algae.

- ✓ **Chlorophyceae:** They are Green algae, which have unicellular plant body, with chloroplast. *Chlamydomonas, Volvox, Spirogyra, Ulothrox, Oedogonium and Char*a are some example.
- ✓ **Phaeophyceae:** They are commonly called brown algae. **Kelps arepopular brown algae.** One important characteristic is that they store food in the form of **laminarin** and **mannitol.** *Ectocarpus, Laminaria, Sargassum* is common algae.
- ✓ **Rhodophyaceae:** They are Red algae. They are red because of the presence of a pigment called Phycoerythrin. Most of them are found in marines. They store food in Floridean starch. Common examples are Gracilaria, Porphyra etc.
- ✓ **Cyanophyceae:** These include the Blue Green algae, and are most primitive algae which reproduce only asexually.

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### How algae are useful in everyday life?

- ✓ Agar is obtained from the Red algae *Gracilaria* and *Gelidium.* Agar is used as a culture medium for growing of microbes in labs. Agar is also used in Food and Pharmaceuticals.
- ✓ The unicellular alga ***Chlorella*** is rich in proteins and vitamins and is considered a food for future. Chlorella is also source of an antibiotic *Chlorellin.*
- ✓ **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.
- ✓ *Cephaleuros virescens* is a pathogenic algae which causes **Red Rust in tea.**
- ✓ Some of the Blue green algae overgrow in the stagnant water and give rise to the water blooms. These include the Anabena, Microcystis, Ocilatoria etc.
- ✓ **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.
- ✓ **Macrocystis** is an algae which is source of Potash. It's a brown algae (phaeophyceae ) and is largest algae among all.

## Chapter 8. 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 India, **S R Kashyap** did a commendable job in the studies of Bryphytes and that is why is called Father of Indian Bryology.

### Why Mosses are called Amphibians of Plant Kingdom?

***Model Question 11.***

Which among the following are the amphibians of Plant world?

A. Algae and Fungi
B. Mosses and Liverworts
C. Ferns
D. Gymnosperms

Answer: [11]

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Bryophytes are called the "amphibians" of the plant kingdom. They can live on land but for reproduction and fertilization, need water essentially.

[11] Correct answer is Mosses and Liverworts

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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. You must know that in World War I, it 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. Bryophytes are among the first organisms to invade 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.

## Chapter 9. Pteridophytes

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Pteridophytes are commonly known as **Ferns**. There are around 12,000 species of Ferns, many of them are generally used a **decoration / ornamental plants.** In the evolutionary stages, Ferns are next advanced level after Bryophytes.

As we read above the Bryophytes don't have the vascular tissues, but the Ferns have **BOTH xylem and phloem**, thus they are the **first vascular plants**. They have stems, leaves, and roots like other vascular plants.

They 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**.

As we read above that in case of the Bryophytes , the dominant phase of life is gametophytes. This reverses from Pteridophytes ONWARDS.

This means that in Pteridophytes the dominant phase of life is Sporophyte. This Sporophyte is NOT only independent but also long lived.

The plant, like the advanced plants is divided into root, stem and leaf. But some of the primitive Pteridophytes have false roots, means they cannot be called true roots. The stem is dichotomously branched which means two branches emerge from one branch as shown in the figure.

The leaves can be small as well as big making them either microphyllous or megaphyllous. If leaves are small, the stem would be generally large and if leaves are big, the stem would be generally small.

The Xylem and Phloem are the vascular tissues but they are primitive. This means that the Xylem lacks the Vessels and Phloem lacks the companion cells.

The reproduction in Ferns is generally asexual but they have sexual reproduction also. Sexual Reproduction causes the alternation of generations, characterized by a diploid Sporophyte and a haploid gametophyte phase. Unlike the gymnosperms and angiosperms, the **ferns' gametophyte is a free-living organism**.

### What is Importance of Azolla?

The Pteridophytes have vascular tissues and so have the Gymnosperms and Angiosperms. So they all together are called Vascular Plants or Tracheophytes or Tracheophyta.

### Nitrogen Fixation & Biofertilizers

- ✓ The smallest fern is *Azolla*. We must note that Azolla has the capability of Nitrogen Fixation and this has led to *Azolla* being widely used as a biofertiliser, especially in parts of southeast Asia. Indeed, the plant has been used to bolster agricultural productivity in China for over a thousand years.
- ✓ When rice paddies are flooded in the spring, they can be inoculated with Azolla, which then quickly multiplies to cover the water, suppressing weeds. The rotting plant material releases nitrogen to the rice plants, providing up to nine tonnes of protein per hectare per year.

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- ✓ In addition to its traditional cultivation as a bio-fertilizer for wetland paddy (due to its ability to fix nitrogen), azolla is finding increasing use for sustainable production of livestock feed. Azolla is rich in proteins, essential amino acids, vitamins and minerals. Studies describe feeding azolla to dairy cattle, pigs, ducks, and chickens, with reported increases in milk production, weight of broiler chickens and egg production of layers, as compared to conventional feed. One FAO study describes how azolla integrates into a tropical biomass agricultural system, reducing the need for inputs.

### What are other useful ferns?

- ✓ Osamunda regalis is known as Indian Royal Fern.
- ✓ *Dryopteris filix-mas* is used an anti-helminth means anti worm, used in Pharmacy.
- ✓ 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.

## Chapter 10. Gymnosperms

Gymnosperms are called so because they have naked seeds. Therefore, they are superior to Pteridophytes because they are **seed-bearing plants**. They are **inferior to Angiosperms** or Flowering plants because their ovules are in an unenclosed condition means naked. In the flowering plants or Angiosperms, the ovules are covered. The plants in this group are the conifers, cycads, *Ginkgo,* and Gnetales. Since both angiosperms and gymnosperms have seeds, both of them are placed in **Spermatophytes**.

- ✓ Generally, the plants of Gymnosperms are woody trees, shrubs and climbers. Many of them are xerophytes means they can survive where there is no water such as deserts.
- ✓ **Gymnosperms have tap roots.** Tap roots are somewhat straight to tapering plant root that grows vertically downward. It forms a center from which other roots sprout laterally. One common example of Tap root in Angiosperms is Carrot. Please note that plants which have tap roots are difficult to relocate or transplant.
- ✓ The roots of many Gymnosperms have **symbiotic relations with algae or fungi (mycorrhiza)**. For example, the roots of Pinus have mycorrhizal relations with a fungus.
- ✓ The stem is erect and similar to advanced plants. It may or may not be branched. Leaves are **either green or brown.** The Xylem has bordered pits BUT there are NO vessels. Vessels in Xylem are found in ONLY Angiosperms. There are no companion cells in Phloem. Companion cells in Phloem is found in ONLY Angiosperms.

### Life Cycle

The dominant phase of life is **Sporophyte as in all other vascular plants.** The gametophyte is relatively short-lived. Two spore types, microspores and megaspores, are, in general, produced in pollen cones or ovulate cones, respectively, which can be called male cones and female cones. Male

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cone is small and short-lived. Female cone is large and long-lived. A short-lived multicellular haploid, gamete-bearing phase (gametophyte) develops inside the spore wall. Pollen grains (microgametophytes) mature from microspores, and ultimately produce sperm cells; megagametophyte tissue develops in the megaspore of each ovule, and produces multiple egg cells. Thus, megaspores are enclosed in ovules (unfertilized seeds) and give rise to megagametophytes and ultimately to egg cells. During pollination, pollen grains are physically transferred between plants, from pollen cone to the ovule, being transferred by wind or insects. Whole grains enter each ovule through a microscopic gap in the ovule coat (integument) called the micropyle. The pollen grains mature further inside the ovule and produce sperm cells.

Two main modes of fertilization are found in gymnosperms. Cycads and Ginkgo have motile sperm that swim directly to the egg inside the ovule, whereas conifers and gnetophytes have sperm with no flagella that are conveyed to the egg along a pollen tube. After fertilization (joining of the sperm and egg cell), the zygote develops into an embryo (young Sporophyte). More than one embryo is usually initiated in each gymnosperm seed. Competition between the embryos for nutritional resources within polyembryonic seeds produces programmed cell death to all but one embryo. The mature seed comprises the embryo and the remains of the female gametophyte, which serves as a food supply, and the seed coat (integument).

## What are economically Important Gymnosperms?

- ✓ Coast Redwood of California, which we know as the tallest plant / trees of the world are Gymnosperms. Its botanical name is *Sequoia sempervirens spp. gignatica*. The height is 420 fits and they are long living plants can live up to 1200-1800 years. The plant is an important timber.
- ✓ Many Gymnosperms are called the "living fossils". This is 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. Well known example of a living fossils are Cycas and Ginkgo Biloba, a tree which is literally in a class by itself. Like many other living fossils, Ginkgo is also remarkably similar anatomically to older relatives in the fossil record.
- ✓ **Canada balsam** is obtained from *Abies balsamea*, a Gymnosperm. This is the resin of the plant, very sticky, colorless and odorless. It has high optical quality and was used once upon a time in making the invisible-when-dry glue for glass. Similarly, it was used as a glue for prisms. Today it is used to fix the scratches in the glasses and also in cough syrups.
- ✓ **Ephedrine**, which is used in Medicines as stimulant, appetite suppressant, concentration aid, decongestant, and to treat hypotension associated with anaesthesia, is obtained from *Ephedra distachya*, which is also a Gymnosperm. It has been used in the treatment of asthma and bronchitis for centuries. Please note that Ephedra is a naturally growing Gymnosperm in Rajasthan.

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- ✓ **Sago** is a major staple food for the lowland peoples of New Guinea and the Moluccas. It is traditionally cooked and eaten in various forms, such as rolled into balls, mixed with boiling water to form a paste, or as a pancake. Sago is often produced commercially in the form of "pearls". Sago pearls can be boiled with water or milk and sugar to make a sweet sago pudding. It is obtained from *Cycas revoluta* and *Metroxylon.* Please note that **Sabudana,** which is used as a staple food in India, particularly in Hindu rituals and Vratas is NOT obtained by Cycas BUT is obtained from **tapioca roots which is an Angiosperm of family Euphorbiacae.**
- ✓ **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". Pinus aristata is oldest living Gymnosperm.

## Chapter 11. Angiosperms

Angiosperms, flowering plants, or **Magnoliophyta**, are the most advanced, most diverse and most dominant group of land plants. They are seed-producing plants like the gymnosperms 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 self-fertilization, 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

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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). It begins when a pollen grain adheres to the stigma of the carpel, the female reproductive structure of a flower. The pollen grain then takes in moisture and begins to germinate, forming a pollen tube that extends down toward the ovary through the style. The tip of the pollen tube then enters the ovary and penetrates through the micropyle opening in the ovule. The pollen tube proceeds to release the two sperm in the megagametophyte. One sperm fertilizes the egg cell and the other sperm combines with the two polar nuclei of the large central cell of the megagametophyte. The haploid sperm and haploid egg combine to form a diploid zygote, while the other sperm and the two haploid polar nuclei of the large central cell of the megagametophyte form a triploid nucleus (some plants may form polyploid nuclei). The large cell of the gametophyte will then develop into the endosperm, a nutrient-rich tissue which provides nourishment to the developing embryo. The ovary, surrounding the ovules, develops into the fruit, which protections the seeds and may function to disperse them. **Please note that in Double Fertilization, five nuclei are involved.**

Generally, the endosperm formation begins after fertilization and before the first division of the zygote. Endosperm is a highly nutritive tissue that can provide food for the developing embryo, the cotyledons, and sometimes the seedling when it first appears.

Please note that **Endosperm which is formed after fertilization is Triploid** (3n). This is a major difference with Gymnosperms because in Gymnosperms, the Endosperm is always Haplod (n).

- Pollination can be self-pollination or cross-pollination. Insects (Entomophily) can facilitate the pollination, similarly can Wind (anemophily), Water (Hydrophily), Animals (Zoophily).
- The common animals that are careers of Pollens are:
  - *Hummingbirds, bats, monkeys, marsupials, lemurs, bears, rabbits, deer, rodents, lizards* and other animals. Bat pollination is 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.

  - The term ornithophily is used to describe pollination specifically by birds. *Hummingbirds, sunbirds, honeyeaters, flowerpeckers, honeycreepers, and bananaquits* are examples. Plants pollinated by birds often have brightly

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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.

- *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.

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.

## What are Monocots and Dicots?

Angiosperms are classified into two categories –

- **Monocotyledonae (monocot):** In the seed of monocotyledonaeic plant, one cotyledon is found. The roots of these plants are not developed. The plant flower has three parts or its multiples. In the vascular pool, **cambium doesn't exist**. So, they don't so secondary growth. Today, at least more than 50,000 monocot species are known. **Monocot leaves are much longer than they are broad and their veins usual run in the same direction**. Some examples are grasses, bamboo, sugarcane, cereals, bananas, palms, lilies, orchids etc.
- **Dicotyledonae (dicot)** : In the seed of dicotyledonaeic plant **two cotyledons** are found. In the vascular pool cambium exists. The flower of the plant has multiples of four or five petals. They show **secondary growth**. While the monocots have only one seed leaf in the embryo, the dicots have two seed leaves. Dicots have veins forming a network in their leaves. Dicots have almost all the hardwood tree species, pulses and the most fruits, vegetables, species beverage crops and ornamental flowering plants.

## What are different Kinds of Roots in Angiosperms?

Roots of Angiosperms always move opposite to the sunlight towards the land. There are no root nodes and internodes as that in stems of these plants. 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:

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- **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.

## What are Adventitious Roots?

Adventitious roots develop necessity if circumstances. All I wanted to say is that these 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.

The first thing about the Adventiuous roots you must note is that **they 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 |

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| | |
|---|---|
| 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 |

## What are the Common Modifications of Stems 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-

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- Stem tendril – Grape.
- Stem thorn – Lemon, roses, jujube, plum or Chinese date.
- Phylloclade – Cactus.
- Bublis – Ruscus.

## What are Common Modifications of leaves in Angiosperm Plants?

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.

## What are mains 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.

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The flower which have 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 cycle of the flower and it is green colored cycle of sepals. The main work of calyx is to protect the soft parts of buds and performs photosynthesis. In some flowers, it becomes colored and its main function to fascinate 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-
    - Filament
    - Anther
    - Connective
- **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 females ovule. The carpel is made from three components- ovary, style and stigma.
- **Ovary :** Above the pedicel, there exists a thickened tuberous structure called ovary and inside of there exists some very small knots like structure and these are called ovules. In these ovules female embryo sac exists and in the various plants and number of ovules are fixed.
- **Style** : This is basically the upper lengthened and thinned part above the ovary.
- **Stigma :** This is the uppermost sticky part of the style.

Please note that the vital component of androecium is basically stamen and in which pollen grains are found in pollen sac.

## Some Important Observations

- The edible portion of the coconut is endosperm.
- In some dicots, cotyledons absorb entire store foodstuffs from endosperm and due to it endosperm is completely destroyed and these seeds are called **non-endospermic**. Example-Pea, gram, beans etc.
- In some plants without fertilization, fruits are produced through ovary and the process of this non-fertilization is called **parthenocarpy** and **such fruits are seedless**. Examples- banana, papaya, orange, grapes, etc.

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## What are True Fruits and False Fruits?

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 fruit-** jack fruit, mulberry, banyan, fig etc.

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 embrya |
| **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 |

## What is role of 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 1040mm$^2$. These stomata **exchange the moisture and help in transpiration activities** in the plants.

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### What is the role of 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.

## Chapter 12. Photosynthesis

The `food' for **plants is sunlight, water and air (carbon dioxide and oxygen)**. Plants have the amazing ability to harvest energy from the sun using chlorophyll and convert it in to chemical energy.

They then utilize it to produce carbohydrates such as sugars and starch (`photosynthesis'). These carbohydrates serve as chief energy source for almost all living beings in the world, including plants themselves. Nutrients such as nitrogen, phosphorus, potassium and other micronutrients are taken up by plants in very simple forms and used directly.

*Plant cells oxidize the sugars to release carbon dioxide and energy and utilize the energy to drive reactions for normal functions of the cell.*

In addition, cells use carbohydrates and derived products as building blocks for proteins and lipids (fat). Carbohydrates, proteins and lipids are the chief components of several sub-cellular organelles (parts of a cell).

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. Thus, the living cells of the plant by the help of chlorophyll and sunlight absorb $CO_2$ from atmosphere and then in the presence of water ($H_2O$) carbohydrate is formed. The chemical involve in the photosynthesis is –

$$6CO_2 + 12H_2O \text{ ---------- } C_6H_{12}O_6+6H_2O+6O_2$$

The above reaction happens in presence of sunlight and can be written generally as follows:

Carbon dioxide + electron donor + light energy → carbohydrate + oxidized electron donor

- ✓ Photosynthesis occurs in two stages. In the **first stage, light-dependent** reactions or light reactions capture the energy of light and use it to make the energy-storage molecules ATP and NADPH. During the second stage, the light-independent reactions use these products to capture and reduce carbon dioxide.
- ✓ Most organisms that utilize photosynthesis to produce oxygen use visible light to do so, **although there are plants which use infrared radiation** too.

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Here are some more details about the two stages of the Photosynthesis:

- ✓ **Photochemical reaction:** This process (reaction) **occurs in the grana** of the chlorophyll and the reaction involves is called **hill reaction.** In this process water ($H_2O$) disassociates and forms H+ and electron and for this decomposition of water ($H_2O$) energy is obtained from light. Ultimately, APT and NADPH are emancipated in the form of energy.
- ✓ **Chemical dark reaction :** This process (reaction) occurs in the **stroma of the chlorophyll** and for this reaction **energy is supplied by the photochemical reaction** and that's why it is called dark reaction. In this reaction, the produced energy in the forms APT and NADPH are utilized in the synthesis of carbohydrates from $CO_2$.

### Factors influencing photosynthesis

- ✓ **Light :** The process of photosynthesis **only occurs for violet, blue and red light**, while it doesn't occur for **ultraviolet, green, yellow and infrared light**. For the low intensity light photosynthetic activity is maximum, but 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.
- ✓ The metal 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.

## Chapter 13. 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.

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There are various types of plant hormones.

## How Auxins are important?

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 activily 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 technique.

## How Gibberellins are important ?

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.

## How Cytokinin is important as a plant hormone?

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.

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- The correlation of auxins and cytokinins in the plants is a constant (A/C = const.).

### How Ethylene is important as a plant hormone?

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.

### How Abscisic acid is important as a Plant hormone?

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.

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