General Knowledge Today

General Science-2: Plant Kingdom

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Biological Classification

When we classify the organisms into hierarchical series of groups on the basis of their evolutionary relationships, it is called *Systematics*. Classification is a subtopic of Systematics which deals with ordering of organisms into groups and *taxonomy* is the study of principles and procedures of classification. Nomenclature is the process of naming an organism so that this particular organism is known by same name all over the world. Currently, the scientists follow binomial nomenclature in which any organism is denotes by a name with two components viz. Genus and Species. For example, Mango is named as *Mangifera indica*, whereby, *Mangifera* is its Genus and *indica* is its species. While first letter of Genus is always capitalized, first letter of species is always in lower case. For example:

- Tomato → Solanum lycopersicum
- Potato → Solanum tuberosum
- Brinjal →Solanum melongena

In the above example, Tomato, Potato and Brinjal belong to same genus while they are different species. We note here that for plants, scientific names are based on agreed principles and criteria, which are provided in International code for Botanical Nomenclature (ICBN). Animal taxonomists have evolved International Code of Zoological Nomenclature (ICZN).

Taxonomical Hierarchy

Species is the smallest taxonomical unit and refers to a group of individual organisms which interbred among themselves and produce fertile offspring when they interbred. The group of related species is called Genus. Related Genera {General is plural of Genus} are kept in a family, related families are kept in Order. Related Orders are kept in classes. Classes comprising animals like fishes, amphibians, reptiles, birds, mammals etc. constitute the next higher category called *Phylum*. Generally animals are subdivided into phyla, while plants are subdivided into *Divisions*. All animals/plants belonging to various phyla/divisions are assigned to the highest category called Kingdom. The below graphic shows position of humans in above taxonomic ranks:

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

Five Kingdom Classification

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

- All the prokaryotes were kept in Monera. This Kingdom comprises mainly Bacteria and blue green algae.
- All unicellular eukaryotes were kept in Protista. This kingdom comprised of Algae and Protozoa.
- All fungi were kept in Kingdom Fungi while multicellular plants and animals were kept in Plantae and Animalia respectively.

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

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

Viruses

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

Salient Features

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

Viruses have been excluded from the biological classification because they are not living things in

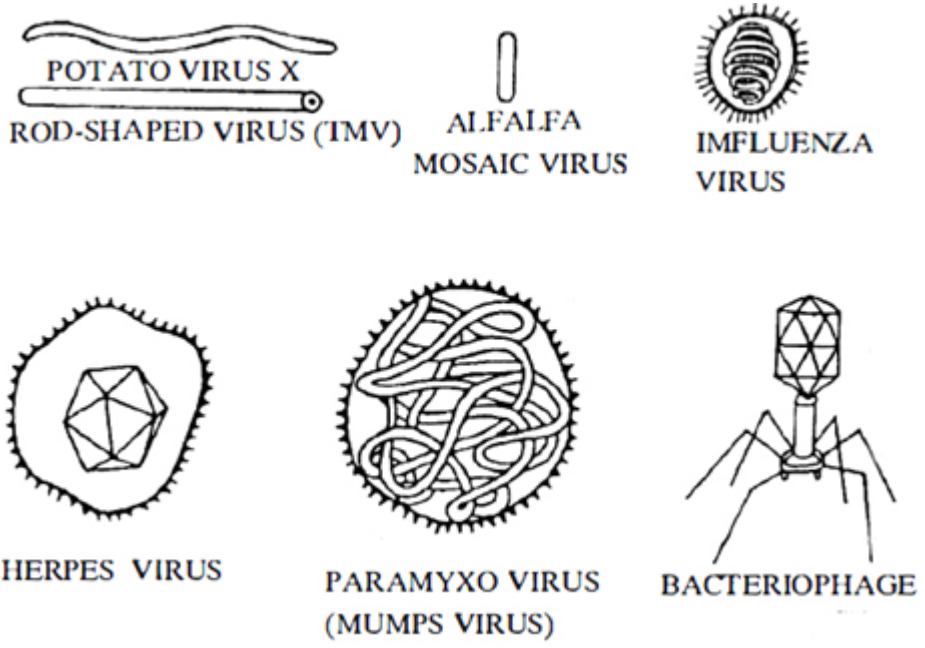
first instance. However, they do posses some properties of the both *living and non-living.*

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

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

Structure

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



A virus is made of three components viz. a protein capsid, nucleic acid and a thick outer layer. *Viruses*

may contain either DNA or RNA but not both together. Generally, plant viruses are RNA viruses while animal viruses are DNA viruses. Further, Bacteriophage is always a DNA virus. Viruses produce diseases in plants, animals and human beings.

Plant Viral Diseases

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

Use of TMV in Research

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

Animal and Human Diseases

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

Human Viral Diseases

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

Flu

Flu is caused by influenza virus, which is a highly mutant virus. Influenza generally spreads through air via cough or sneezes. There are three species of Influenza Virus viz. Influenza-A, Influenza-B, and Influenza-C. Out of them, Influenza A infects birds and mammals. It has very high rate of mutation, and this is the reason that so many different strains of influenza virus are found. In a first, they don't infect humans, but if they do so, they cause devastating pandemics. The common Influenza outbreaks caused by Influenza-A strains include H1N1 (swine flu) in 2009; and H5N1 (Bird

Flu) in 2004. H1N1 is the same strain which causes seasonal outbreaks of flu in humans on a regular basis. Since doctors have found it very hard to predict who will develop complications, it has been dubbed a "*Jekyll and Hyde*" virus.

Meaning of H and N in Flu

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

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

Hepatitis / Jaundice

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

- A is acute (*acute means short term*), B is acute as well as chronic (*Chronic means long term*) while C is almost chronic.
- A spreads easily, B spreads relatively less easily and C spreads rarely.
- A spreads via food, water etc. and can infect many people at once. For example, a food handler in a restaurant can spread Hepatitis A to many people at once; B spreads by blood or other body floods. C spreads only by blood.
- A gets better on its own but can be serious in older people; B is common in India, Asia and Africa. We note here that Amitabh Bachchan has recently revealed that he has lost 75% of is liver to Hepatitis B. C is even more dangerous.
- A and B can be prevented by vaccination, but not C. However, there are medicines available to treat C.

AIDS

Human immunodeficiency virus (HIV) also known as human T-lymphotropic virus-III (HTLV-III), lymphadenopathy-associated virus (LAV), and AIDS-associated retrovirus (ARV) is a retrovirus. {Retrovirus means it replicates via reverse transcription} in host cell. It transmits via anal, vaginal or oral sex, blood transfusion, contaminated hypodermic needles, exchange between mother and baby during pregnancy, childbirth, breastfeeding or other exposure to one of the above bodily fluids.

Due to weakened immune system the person is attacked by infections caused by bacteria, viruses, fungi and parasites that are normally controlled by the elements of the immune system that HIV damages.

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

The term AIDS applies to the most advanced stages of HIV infection. The Center for Disease Control (CDC) definition of AIDS includes all HIV-infected people who have fewer than 200 CD4+

T cells per cubic millimetre of blood. (Healthy adults usually haveCD4 + T cell count of 1,000 or more.) The definition also includes 26 clinical conditions (mostly opportunistic infections) that affect people with advanced HIV disease.

Opportunistic infections are common in people with AIDS. HIV affects nearly every organ system. People with AIDS may develop various cancers such as Kaposi's sarcoma, cervical cancer and cancers of the immune system known as lymphomas. Besides the people infected with AIDS often have systemic symptoms of infection like fevers, sweats (particularly at night), swollen glands, chills, weakness, and weight loss.

Smallpox

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

Chickenpox

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

Poliomyelitis

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

Measles

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

Rubella or German measles

Rubella (German measles) spreads when infected person coughs or sneezes. It causes a rash, a slight fever, aching joints, headaches, runny nose and red eyes. The virus spread by sneezes or coughs can lead to serious birth defects if contracted by pregnant woman. In 2015, the North and South America region have become the first region of the world to eradicate Rubella. There are no home-grown cases in five years.

Dengue

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

genus Aedes.

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

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

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

A severe form of the infection is known as dengue hemorrhagic fever (DHF). DHF can be fatal. Because of the severe joint pain, dengue is also known as **break-bone fever**.

DHF is characterized by a fever that lasts for 2 to 7 days, with general signs and symptoms consistent with dengue fever. In addition to these symptoms, *if a patient suspected with dengue experiences decrease in platelets or an increase in blood haematocrit, it becomes more certain that the patient is suffering from the infection. Platelets are cells in blood that help to stop bleeding, while haematocrit indicates thickness of blood. The smallest blood vessels become excessively permeable allowing fluid component to escape from blood vessels to organs of the body.* This may lead to failure of circulatory system, which might also cause death.

Chikungunya

This disease is caused by Chikungunya virus transmitted by both Aedes aegypti and *Aedes albopictus*. The mosquitoes usually transmit the disease by biting infected persons and then biting others. The infected person cannot spread the infection directly to other person.

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

Rabies

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

Yellow Fever

Yellow fever is a viral infection that occurs mainly in Central Africa and in the Amazon region of South America. It is prevented through vaccination and is transmitted by many species of mosquitoes of the *Aedes* genus, including *Aedes aegypti*. The infection causes clinical manifestations that range from asymptomatic cases to lethal fulminant cases. Generally, the disease

begins a with fever, chills, discomfort, headache and nausea and evolves to jaundice (increase of bilirubin in blood, after which the disease is named), mucosal and internal hemorrhages, hemorrhagic vomiting and kidney failure.

Prevention is done by regular mass vaccination and the vaccination of travelers to endemic areas. The fight against the vector mosquito is also an important prophylactic measure.

Acute Encephalitis Syndrome

Encephalitis refers to acute Inflammation of the brain. There are two main types of encephalitis viz. viral encephalitis and Japanese encephalitis. While Viral encephalitis is caused by water-borne enterovirus; Japanese encephalitis is caused by mosquito *Culex tritaeniorhynchus* and *Culex vishnui*. Every monsoon sees an outbreak of acute encephalitis syndrome, or AES, diseases. Japanese encephalitis and viral encephalitis diseases; and both of these make the Acute encephalitis syndrome, or AES. This disease is called a poor man's disease and affects largely to paddy farmers.

Other Notes on Viral Diseases

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

Industrial and Scientific Applications of Viruses

Since Viruses contain the characteristics of both living and non-living organisms, they are utilized in the field of *Biotechnology research*. Bacteriophage can be used in water preservation as it can destroy the bacteria and keep water fresh. Here are some other applications of Viruses:

- Molecular Biology, Cellular Biology, Molecular genetics, such as DNA replication, transcription, RNA processing, translation, protein transport, and immunology.
- Virotherapy uses viruses as vectors to treat various diseases, as they can specifically target cells and DNA. It shows promising use in the treatment of cancer and in gene therapy.
- The viruses represent largest reservoirs of unexplored genetic diversity on Earth. They can be used as alternative to the antibiotics because of the high level of antibiotic resistance now found in some pathogenic bacteria.
- Viruses contain protein and this property can be used in production of various proteins such as vaccine antigens and antibodies.
- In nanotechnology, viruses can be regarded as organic nanoparticles. Because of their size, shape, and well-defined chemical structures, viruses have been used as templates for

organizing materials on the nanoscale.

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

Virus and Aquatic Ecosystem

A teaspoon of seawater contains about one million of Viruses, making them the most abundant biological entity in aquatic environments. They are useful in the regulation of saltwater and freshwater ecosystems. The Bacteriophage, which is harmless to plants and animals, play the most important role here. They infect and destroy the bacteria in aquatic microbial communities, comprising the most important mechanism of recycling carbon in the marine environment. However, the organic molecules released from the bacterial cells by the viruses stimulate fresh bacterial and algal growth. Viruses are useful for the rapid destruction of harmful algal blooms that arises generally from the Blue Green algae and often kills other marine life. Viruses INCREASE the amount of Photosynthesis in Oceans and are responsible for reducing the amount of carbon dioxide in the atmosphere by approximately 3 gigatonnes of carbon per year.

Bacteria

General Information about Bacteria

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

Different shapes of Bacteria

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

G+ and G- Bacteria

Gram staining is a method to identify some of the bacteria on the basis of some chemical properties of their *cell wall.* Not all bacteria can be identified on the basis of gram method. If a bacterium can be

judged using this method, it would be called Gram variable otherwise Gram indeterminate. can be classified by using this technique are called *Gram variable*. What is basically done is to color the cell walls using a stain called Crystal violet. If a bacteria has lipids and peptidoglycan in its cell wall, it would appear violet in microscope and will be called gram positive. Otherwise, they would be called gram negative.

The cell wall of Gram positive bacteria is thicker and more peptidoglycan in comparison to gram negative bacteria. Further, a chemical called Teichoic acid is present in + and absent in – bacteria.

Movement

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

Nutrition in Bacteria

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

Reproduction

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

Applications of Bacteria

Pasteurization

Pasteurization is one of the methods of preservation of products such as milk, alcoholic beverages etc. at higher temperatures. Pasteurization is defined as the process of heating products to a particular temperature and holding it at that temperature for a particular time till the pathogenic (disease causing) micro-organisms are destroyed causing minimum change in composition, flavor and nutritive value of products such as milk.

- There are two methods of pasteurization (of milk) in general use. One is low temperature holding (LTH) method in which milk is heated to 62.8°C (145F) for 30 minutes in commercial pasteurizers (or) large closed vats which are heated by steam coils, hot water jackets etc.
- The other method (i.e.) high temperature short time (HTST) method in which the milk is heated to 71.7°C (161F) for 15 seconds.

The heating is accomplished by electricity (or) hot water and requires a heat exchange system, which preheats raw, cold milk and cools the hot pasteurized milk. Please note that Pasteurization conditions are not sufficient to destroy thermo-resistant spores (reproductive part of microorganisms). Thus, Pasteurization does not sterilize the products but kills only those organisms that grow most readily at low temperatures. The surviving organisms must be kept from multiplying by constant refrigeration.

Nitrogen Fixation

The Nitrogen Fixation is the procedure by which atmospheric Nitrogen is converted into ammonia. The Nitrogen fixation is one of the important components of the Nitrogen cycle.

Nitrogen fixation can be biotic or abiotic. The examples of abiotic processes are lightening, Industrial processes such as Haber-Bosch Process, and combustion. The biotic nitrogen fixation was discovered by *Martinus Beijerinck.*

How does it work?

Two molecules of ammonia are produced from one molecule of nitrogen gas, at the expense of 16 units of ATP and a supply of electrons and protons (hydrogen ions):

$N_2 + 8H+ + 8e- + 16\ ATP = 2NH_3 + H_2 + 16ADP + 16\ Pi$

Please note that *exclusively the prokaryotes do this reaction.* The enzyme used is called *nitrogenase.* The

nitrogenase enzyme has two kinds of proteins viz. Iron Protein, and Iron-Molybdenum protein. The 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 2NH3 .

Thus in summary

- 16 ATP are used in BNF (Biological Nitrogen Fixation)
- Two minerals viz. *Iron and Molybdenum* play important role in BNF.
- End product is *ammonia + Hydrogen*
- Enzyme used is Nitrogenase

Role of Bacteria

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

- Free living aerobic bacteria: Azotobacter
- Free living anaerobic bacteria: Clostridium, purple sulphur bacteria
- Symbiotic in legumes and pulses: Rhizobium (found in *root nodules*)
- Symbiotic in sugarcane: *Glucoacetobacter diazotrophicus* (found in *stem knots*)

- Symbiotic in other plants: Frankia, Azospirillum

Why BNF occurs only in anaerobic conditions?

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

BNF in Legume Plants

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

Bacteria in Nitrification

Nitrification is the process in which the ammonia is converted into Nitrate. Nitrification is a two step process and based upon these two steps, the bacteria are divided into Nitrosifying and Nitrite-Oxidizing bacteria. Example of Nitrosifying bacteria is *Nitrosomonas,* which converts the Ammonia (NH_3) into Nitrite (NO_{2-}). Example of Nitrite-Oxidizing bacteria is Nitrobacter which are able to oxidize the Nitrite and crate Nitrate (NO_{3-}).

Bacteria in Industry and Everyday Life

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

Dairy Industry

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

Food Industry

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

Industrial Uses

Clostridium acetobutylicum is able to produce acetone from acetic acid as well as butanol from butyric acid. In Biogas plants, the bacterium called *Methanobecterium* is used for production of Methane. Bacteria are useful in the Fibre ratting in which the fibres of Jute, hemp and Flax are prepared. Clostridium butyricum is used in the process and these bacteria hydrolyze the middle lamella of these plant fibres. Microbial mining, which is the bacteria and other microorganisms are cultured in

container and then used to bring these processes e.g., copper extraction, iron extraction; which involves bacteria called Ferro-oxidans.

Bacteria in soil formation and soil fertility

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

Other uses

- Bacteria work as natural scavengers as they are able to decay huge amount of plant, animal and human waste.
- Using biotechnology techniques, bacteria can also be bioengineered for the production of therapeutic proteins, such as insulin, growth factors or antibodies.
- Some bacteria living in the gut of cattle, horses and other herbivores secrete cellulase, an enzyme that helps in the digestion of the cellulose contents of plant cell walls. Cellulose is the major source of energy for these animals. generally plant cells contain cellulose.the bacteria present in the stomach of cattle will help in the digestion of cellulose.
- Escherichia coli that live in the human large intestine synthesize vitamin B and release it for human use. Similarly, Clostridium butyclicum is used for commercial preparation of riboflavin, and vitamin B.
- Bacillus thuringiensis (also called BT), a Gram-positive, soil dwelling bacterium is used for Pest Control and producing Bt crops.
- Bioremediation techniques such as Oil zapper use bacteria.
- Many antibiotics are used from bacteria. Some of them are Bacitracin, Polymyxin B, Streptomycine, Erythromycine, neomycin-B, Chloramophenicol etc.

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

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

Pleasant smell of the earth after the first shower

Pleasant smell of the earth after the first shower (earthy odour) is caused by the production of a series of streptomycete metabolites called geosmins.

These substances are sesquiterpenoid compounds and unsaturated compound of carbon, oxygen and hydrogen. The geosmins first discovered has the chemical name trans-1, 10-dimethyl-trans-9-decalol; however, other volatile products produced by certain species of Streptomyces may also be responsible for the characteristic smell.

Oil Zapper

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

Bacteria in the Bio-Digester Toilet

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

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

Bacterial Diseases

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

Diarrhoea

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

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

Dysentery

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

Typhoid

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

Whooping Cough

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

Tuberculosis

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

MDR and XDR TB

TB that is resistant at least to isoniazid and rifampicin the two most powerful first-line anti-TB drugs is called the Multi-drug-resistant tuberculosis (MDR-TB). It develops because the when the course of antibiotics is interrupted and the levels of drug in the body are insufficient to kill 100% of bacteria. This means that even if the patient forgets to take medicine, there are chances of developing MDR-TB. MDR-TB is treated with secondline of antituberculosis drugs such as a combination of several medicines called **SHREZ** (Streptomycin+isonicotinyl Hydrazine+Rifampicin+Ethambutol+pyraZinamide)+MXF+cycloserine.

XDR-TB

When the rate of multidrug resistance in a particular area becomes very high, the control of tuberculosis becomes very difficult. This gives rise to a more serious problem of extensively 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.

Extent of TB

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

HIV and TB

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

BCG

BCG (Bacillus Calmette-Guérin) was the first vaccine for TB that discovered in 1905 by Albert Calmette and Camille Guérin. Once WHO declared TB a global emergency, BCG vaccine along with DOTS was used in more than 192 countries as a preventive therapy. However, there was a controversial side of BCG vaccination that it showed variable efficacy, that depended on geography. It was concluded that BCG efficiency goes down as one gets closer to equator. There were several explanations to this phenomenon. One such theory said that in areas where there are high levels of background exposure to tuberculosis, every susceptible individual *is already exposed to TB prior to BCG*, which is why the natural immunizing effect of background tuberculosis duplicates any benefit of BCG. This means that BCG is less effective in the area where the Mycobacteria are less prevalent. Another theory says that Variable efficacy is because of the Genetic variation in BCG strains.

DOTs

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

Leprosy

Leprosy or Hansen's disease is caused by the bacteria *Mycobacterium leprae* and *Mycobacterium lepromatosis*. Leprosy has a high degree of stigma attached to it because of the fact that there was no cure for the disease till the eighties and also due to disfigurement caused by the disease.

Some drugs such as rifampicin, clofazimine, and dapsone are used to treat Leprosy.

Diphtheria

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

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

Cholera

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

Kingdom Fungi

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

Why Photosynthesis does not take place in Fungi?

Fungi lack chlorophyll and cannot prepare their own food and depend on other organism for nourishment. On the basis of nourishment the fungi are of three types –

- *Saprophytes:* The fungi which obtain their food or do nutrition from decayed moist leaves, moist dead wood or by some other useless rotten residues or organic substances. The fungi like *Rhizopus*, Penicillium etc are saprophytes.
- *Parasites:* The fungi which obtain their food by taking or sharing the food of any other organisms. The fungi like *Ustilago, Puccinia* etc that are harmful parasites.
- *Symbiotic:* The fungi, which coexist with other plants and facilitate water and mineral salt and plants prepare food for them. The microbe lichen is the best example of symobiotic fungus.

Benefits of Fungi

Soil Formation and Fertility

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

Food

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

Nitrogen fixation

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

Medicines

In the fungi there are various types of antibiotics which are utilized in making medicines like

chloromycetin, neomycin, streptomycin, teramycin etc.

Chemical Industry

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

Enzymes and Vitamins

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

Mycoremediation

Bioremediation by means of Fungi is called *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.

Pest control

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

Common fungal diseases

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

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

Lichens

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

Kingdom Plantae

Algae

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

Types of algae

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

Green Algae or Chlorophyceae

Green algae have chloroplast and chlorophyll in their cells. Examples are *Chlamydomonas, Volvox, Spirogyra, Ulothrox, Oedogonium and Chara* are some example.

Brown algae or Phaeophyceae

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

Red Algae or Rhodophyceae

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

Blue Green Algae or Cyanophyceae

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

Economic Importance of Algae

Benefits

Nitrogen fixation and Biofertilizers

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

Other Uses

- Many green algae such as Chlorella, Ulva, Caulerpa, Enteromorpha, etc. are used as food. Chlorella has about 50% protein and 20% of lipid and carbohydrates. Chlorella also yields an antibiotic chlorellin.
- Agar is obtained from the Red algae *Gracilaria* and Agar is used as a culture medium for growing of microbes in labs. Agar is also used in Food and Pharmaceuticals.
- *Carragineen* which is used in the Dairy industry is obtained from a red alga called *Chondrus crispus.* It is also used in cosmetics and Pharma.

- *Alginic acid,* which is used as a stabilizer and thickening agent is obtained from Laminaria, the brown algae.
- *Dynamite is* prepared with the cell walls of Diatoms.
- Brown algae Laminaria is a good source of Iodine.
- **Macrocystis** algae are source of Potash. It's a brown algae (phaeophyceae) and is largest algae among all.

Algal Hazards

Algal toxicity

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

Algal parasitism

The red alga Cephaleuros virescens causes Red Rust of Tea.

Algal blooms

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

Color of Red Sea

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

Bryophytes

The common word for Bryophytes is Moss, which are the first land plants in context with evolution of plants. The branch of science that deals with Bryophytes is called Bryology. Please note that Mosses don't have a vascular tissue such as Xylem and Phloem, which we find in plants of higher orders. Due to this, they are also known as Atracheates which means no trachea. In India, *S R Kashyap* did a commendable job in the studies of Bryphytes and that is why is called Father of Indian Bryology.

Amphibians of Plant Kingdom

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

The Bryophytes were the first plants in which alternation of generation was seen for the first time in the embryophytes as Gametophyte→Mitosis → gametes →Sporophyte → Spores → Meiosis →Gametophytes.

Bryophytes: Important Points

- One of the famous Bryophyte is **Peat Moss**. Its botanical name is *Sphagnum*. It grows in

swamps and damp areas. This is one of the most economically important Bryophyte. In World War I, Peat moss was used as "dressing cotton' for wounded soldiers. Peat is obtained from Sphagnum.

- *Physcomitrella patens* is increasingly used in biotechnology. Prominent examples are the identification of moss genes with implications for **crop improvement or human health** and the safe production of complex biopharmaceuticals in the moss bioreactor.
- Mosses play an important role in controlling soil erosion. They perform this function by providing ground cover and absorbing water.
- Mosses are also indicators of air pollution. Under conditions of poor air quality, few mosses will exist.
- Peat is used as fuel to heat homes and generate electricity. *Bryophytes are among the first organisms to grow up in areas that have been destroyed by a fire or volcanic eruption.*

Why Mosses are haploid in most of their lives?

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

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

Now, this diploid phase Sporophyte again produces sex cells via meiosis, which are called spores. During making of spores, the chromosome pairs are separated once again to form single sets. The spores are therefore once again haploid and develop into a haploid gametophyte. This is how the lifecycle of a Bryophyte goes on.

Pteridophytes

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

Position of Pteridophytes in Evolution

In the evolutionary stages, Ferns are next advanced level after Bryophytes. Bryophytes don't have the vascular tissues, but the Ferns have *both xylem and phloem*, thus they are the *first vascular plants* in

terms of evolution of plant species. They have stems, leaves, and roots like other vascular plants. Further, in case of the Bryophytes, the dominant phase of life is gametophytes. This reverses from Pteridophytes ONWARDS. Thus in Pteridophytes, Gymnosperms and Angiosperms, the dominant phase of life is Sporophyte. This Sporophyte is NOT only independent but also long lived.

Pteridophytes differ from the advanced plants on the basis of the Reproduction procedures. They differ from gymnosperms and angiosperms as they *do not have neither flowers nor seeds.*

Economic Importance

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

Biofertilizer

The smallest fern *Azolla* has the capability of Nitrogen Fixation is used as a biofertilizers, especially in parts of Southeast Asia. Azolla has been used for thousands of years in China in paddy cultivation.

Azolla is also known as ***Mosquito fern*** because of a myth, that when this plant is in bloom, no mosquito can cross its covering to the water in the water body to lay eggs.

Gymnosperms

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

Notable Points

- Tallest plant of the world "Coast Redwood of California" is a gymnosperm.
- Some Gymnosperms are called the "living fossils" because many of them represent the one of the few, if not the only, surviving members of a taxonomic group, with no close living relatives. Cycas and Ginkgo Biloba are examples of living fossils.
- **Canada Balsum**, the sticky colourless and odourless liquid used in optical industry is obtained from a Gymnosperm.
- Ephedrine is obtained from Ephedra which is a naturally growing Gymnosperm in Rajasthan.
- **Sago,** which is a staple food in New Guinea and some other countries is obtained from *Cycas revoluta* and
- **Chilgoza** is obtained from *Pinus gerardiana*, known as the Chilgoza Pine. Chilgoza is one of the most important cash crops of tribal people residing in the Kinnaur district of Himachal

Pradesh, which seems to be the only place in India where Chilgoza pines are found.

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

Angiosperms

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

Main Features of Angiosperms

Benefit of Flowers

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

Reduced Male and Female Parts

Instead of cones in Gymnosperms, the Angiosperms have stamens, reduced male parts and an enclosed ovule. The Stamens are much lighter than the corresponding organs of gymnosperms and have contributed to the diversification of angiosperms through time with adaptations to specialized pollination methods. In some advanced species, the Stamens were modified to prevent 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 angiosperm plants' setting seeds sooner and faster than gymnosperms, which is a distinct evolutionary advantage.

Double Fertilization

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

Pollination in Angiosperms

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

Pollination taking place in a single flower is called self pollination, while pollination taking place between two flowers is called cross pollination. If the cross pollination is between flowers of a same plant, it will be called Geitonogamy, while if it takes place between two separate plants, it will be called as Xenogamy. In some plants, the flowers are bisexual and closed called Cleistogamous. Here only self pollination takes place.

Insects (Entomophily) can facilitate the pollination, similarly can Wind (anemophily), Water (Hydrophily), Animals (Zoophily). Further, Hummingbirds, bats, monkeys, marsupials, lemurs, bears, rabbits, deer, rodents, lizards and other animals are common animals that carry pollens and help in pollination.

Pollination by Bats

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

Pollination by Birds

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

have brightly colored diurnal flowers that are red, yellow, or orange, but no odor because birds have a poor sense of smell. Other characteristics of these plants are that they have suitable, sturdy places for perching, abundant nectar that is deeply nested within the flower. Often flowers are elongated or tube shaped. Also, many plants have anthers placed in the flower so that pollen rubs against the birds head/back as the bird reaches in for nectar.

Pollination by Lizards

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

Monocots and Dicots

Angiosperms are classified into two categories viz. monocots and dicots. In monocots, seed has only one cotyledon while in dicots, seed has two cotyledons.

The key comparisons of these two groups are as follows:

- The roots of monocots are lesser developed in comparison to dicots.
- The petals in flowers of monocots are 3 or multiples of 3. The petals in flowers of dicots are four or five; it's their multiples.
- *No secondary growth is found in monocots because their vascular tissue has no cambium. Secondary growth is found only in dicot plants.*

- Examples of monocots include grasses, bamboo, sugarcane, cereals, bananas, palms, lilies, orchids etc. Examples of Dicots include all the hardwood tree species, pulses and the most fruits, vegetables, species beverage crops and ornamental flowering plants.

Roots and root modifications

Roots of Angiosperms always move opposite to the sunlight. The soft parts of roots and root hairs absorb water and mineral salts from the soil. The root transports water and mineral salts to the stem and ultimately to the leaves. Some roots like of carrot, radish etc. store foods and in contingency plants use these foods. The roots are of following types:

- **Tap root**: The radical of such root develops itself and forms a main root and such roots exist in dicotyledonous plants.
- **Conical shape:** This type of root is thickened towards base but thin near the side of the plant. Example-carrot.
- **Napiform:** This type of root is extremely thickened and becomes inflated spherical at the base (bottom) but it becomes extremely thin at the top of the plant. Examples-turnip, beet root etc.
- **Fusiform :** This type of root is inflated in the middle portion, while towards bottom and top it becomes thinned. Example is Radish.
- **Pneumatophores :** This type of root is found in salty soil of the sea and for the respiratory activities it undergoes towards negative geotropic. Examples are Rhizophora, etc.

Adventitious Roots

Adventitious roots originate from the stem, branches, leaves, or old woody roots, rather than the normal root system. For example in Strawberry and Willow. These roots develop to avoid stress or fight with the problem of nutrition deficiency or to get sufficient oxygen, or avoid too much oxygen. One more important work of these roots is to help in vegetative propagation in many plants. This ability of plant stems to form adventitious roots is utilized in commercial propagation by cuttings. Understanding of the physiological mechanisms behind adventitious rooting has allowed some progress to be made in improving the rooting of cuttings by the application of synthetic auxins as rooting powders and by the use of selective basal wounding.

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

- **Tuberous roots** are without any definite shape; example: Sweet Potato.
- **Fasciculated root** (tuberous root) occur in clusters at the base of the stem; example: asparagus, dahlia.
- **Nodulose roots** become swollen near the tips; example: turmeric.

- **Stilt roots** arise from the first few nodes of the stem. These penetrate obliquely down in to the soil and give support to the plant; example: maize, sugarcane.
- **Prop roots** give mechanical support to the aerial branches. The lateral branches grow vertically downward into the soil and acts as pillars; example: banyan.
- **Climbing roots** these roots arising from nodes attach themselves to some support and climb over it; example: money plant.

Modifications of adventitious roots

Roots	Examples
Fibrous root	Onion
Leafy root	Briophylem
Climbing root	Betel leaf, pothos
Buttress root	Terminolia
Sucking root	Cuscuta
Respiratory root	Juicia
Epiphytic root	Orcede
Aerial root	Orcede
Assimilatory root	Tinspora
Parasitic root	Kascutta
Moniliform root	Grapes, bitter guard
Nodulose root	Mango turmeric
Prop root	Banyan tree
Stilt root	Maize, sugarcane
Fasciculated root	Dahlia

Stem in Angiosperms

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

- **Underground stem:** The branch or part of the stem which intruses inside the soil is called underground stem. These stems store the food in the stem, node, internode, bud and scale

leaf are found. Examples- banana, potato, colocasia etc.

- **Sub aerial stem :** If a few part of stem is inside the soil and rest is in air then such stem is called subaeriala stem. Examples-Grass root, water plant, etc.
- **Aerial stem** : The stem which is completely confined and localized in air and entirely outside from the soil then it is called aerial stem. In this type of stem branches, leaves, node, internodes, buds flower-fruit etc are found. Examples-Grapes, lemons, roses etc.

To perform some specific works, stems sometimes do exclusive works other than common work then shapes and sizes of the stems are changed and it is called modifications of stems. Usually there exists three types of modifications in the stems-

Underground modifications

In the diverse conditions, underground stems store their food inside the stems and become thickened and tuberous. There are various types of modifications occur in underground stem-

- Stem tuber- Potato
- Bulb – Onion, garlic, tulips, lilies etc.
- Corm – Gladiolus, crocus, saffron etc.
- Rhizome—Ginger, turmeric, arrow root etc.

Sub aerial modifications

There are various types of modifications exists in such types of stem-'

- Runner – Grass root, mereilia etc.
- Stolon – Mint, jasmine, straberi etc.
- Offset – Water plant, pestia etc.
- Sucker – Roses, gilly flower etc.

Aerial modifications

There also occur various types of aerial modifications-

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

Leaf in Angiosperms

Leaves prepare food for the plants. Respiratory activities are performed by the leaves through stomata. Leaves perform the vascular and execratory activities of foodstuffs. Leave help in performing conducive reproduction and pollination. Some leaves work to store food-stuffs.

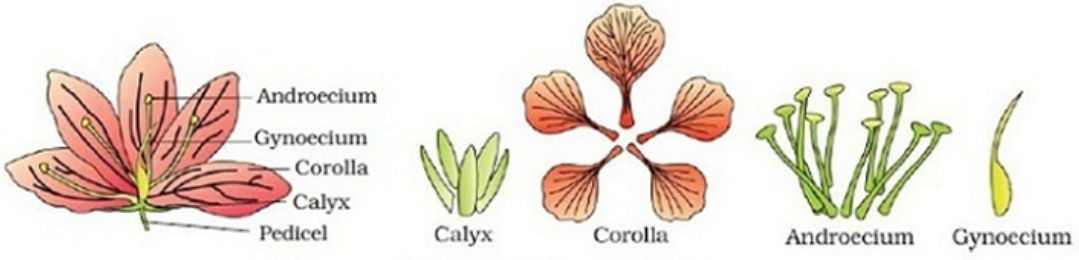
Leaves undergo through various modifications like the following—

- **Leaf spines :** In this class of modification leaves transform into spines. Examples-Cactus, lemon etc.

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

Main parts of a Typical Flower

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



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

Calyx

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

Corolla

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

Androecium

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

Gynoecium

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

Fruit in Angiosperms

The fruit is usually formed in the ovary of the plant and pericarp is formed from the mature ovary walls. But in the formation of some fruits like apple, jack fruit etc, *calyx, corolla, thalamus etc participate and such fruits are called false fruits.*

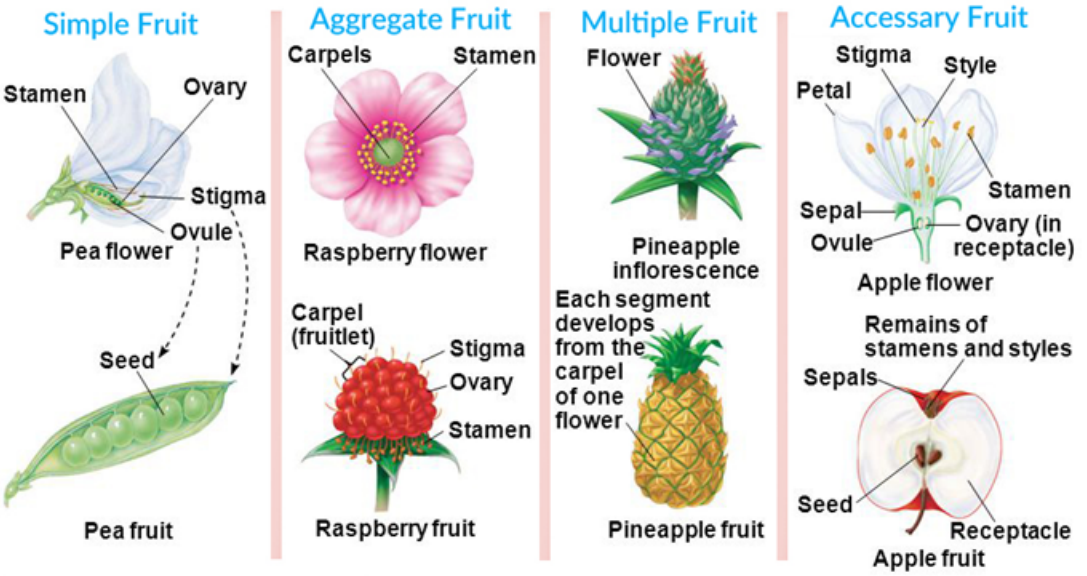
Usually pericarp has three layers outermost layer is called *epicarp*. Middle Layer is called *mesocarp*, while innermost layer is called endocarp. *Please note that Coconut coir is Mesocarp.*

On the basis of fertilization of the flower there are two types of fruits-

- **True fruit –** The fruit forms in the ovary of the flower by the process of fertilization and zygote formation is called true fruit.
- **False fruit :** When fruit formation occurs other than ovary and flowers organelles like calyx, corolla, thalamus etc take place then it is called false fruit. Examples- Apple, jack fruit, pear etc.

But in angiosperms too much diversities are found in their fruits, thus on macro level there are three classes in them.

- **Simple fruit** – bean, mustard, mango, lemon etc.
- **Aggregate fruit**- strawberry, lotus, raspberry, custard apple etc.
- **Composite (multiple) fruit**- jack fruit, mulberry, banyan, fig etc.
- **Accessory / False Fruit**: Apple



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

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

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

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

Other Important Topics

Stomata in Plants

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

Annual rings in age determination

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

How does it work?

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

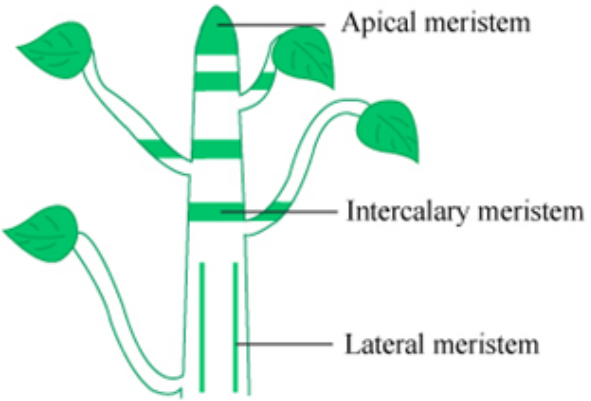
Plant Physiology Topics

Plant Tissues

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

Meristematic Issue

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



Apical Dominance by Meristematic Tissues

Apical Dominance means that in plants, one Meristem {regions of growth / Meristematic tissues} inhibits the growth of other Meristems. The result of this is that a plant has one clearly defined main trunk. The tip of the main trunk bears the dominant Meristem and grows rapidly. It is not shadowed by branches. If the dominant Meristem is cut off, one or more branch tips will assume dominance. The branch will start growing faster and the new growth will be horizontal. *To get a bushy growth, the tip of the main trunk is removed.* This mechanism is based upon *Auxin hormone* which is produced in the apical Meristem and transported towards the roots in the cambium.

Permanent Tissue

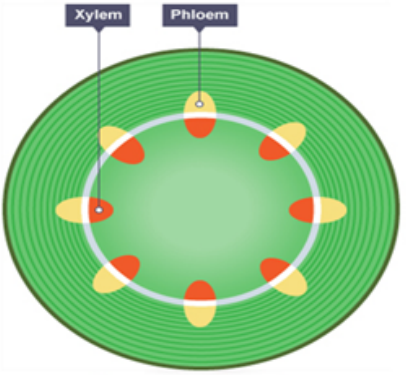
Permanent tissues are formed by the cells which lose the power of division. Cells in permanent tissue are either living or dead. These cells have thick cell walls. These tissues are either simple {made of similar types of cells} or complex {made of different types of cells, working as single unit}.

Simple Tissues

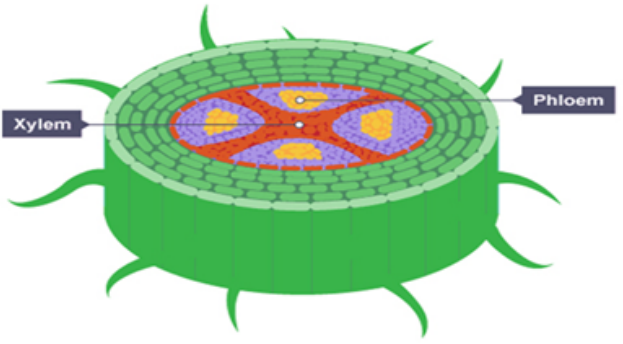
Simple permanent tissues are of three kinds viz. parenchyma, collenchyma and sclerenchyma. Parenchyma tissues are the most vital parts and centers of important physiological functions such as respiration, photosynthesis, storage, secretion etc. These tissues help in growth and repair, wound healing,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

Complex Tissues

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



Xylem and Phloem in Stem



Xylem and Phloem in Root

Phloem or wood conducts the prepared food material from the leaves to the storage organs and growing organs. Generally Phloem is found outside the vascular cambium, but in some plants it may be found inside the pith also in the form of intraxylary phloem.

Why plants die when bark is removed?

Here we note that when bark of a tree is removed in a circular fashion all around near its base, it gradually dries up and dies because roots are starved of energy. This is because removal of bark means removal of phloem and absence of phloem would block transport of soluble organic material made during photosynthesis in leaves to root of the plant.

Other Tissues in Plants

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

Photosynthesis

Plants have the amazing ability to harvest energy from the sun using chlorophyll and convert it into carbohydrates. These carbohydrates serve as chief energy source for almost all living beings in the

world, including plants themselves.

Photosynthesis is the process through which the food is prepared by the plant from chlorophyll, carbon dioxide (CO_2) and water (H_2O) in the presence of sunlight. The chemical involve in the photosynthesis is –

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

Most organisms that utilize photosynthesis to produce oxygen use visible light to do so, *although there are plants which use infrared radiation* too. Photosynthesis occurs in Chloroplats of plants and it done by Chlorophyll pigment. Magnesium is found in the chlorophyll of plant leave and in the nucleus of the chlorophyll on atom of the magnesium exists. The chemical substance chloroplast is called the nucleus of the photosynthesis.

Factors influencing photosynthesis

Light

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

Temperature

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

Carbon dioxide (CO_2)

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

Water (H_2O)

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

Why Peepal tree releases Oxygen all the time?

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

Plant Hormones

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

There are various types of plant hormones.

Auxins

Auxin is a group of plant hormones that produce a number of effects, including plant growth, phototropic response through the stimulation of cell elongation (photopropism), stimulation of secondary growth, api¬cal dominance, and the development of leaf traces and fruit. An important plant auxin is indole-3-acetic acid. (IAA and synthetic auxins such as 2,4-D and 2,4,5-T are used as common **weed killers**.)

- They are basically weak organic acids which actively participate in the cell division and the cell elongates consequently thus plants growth occurs.
- If some auxins hormones be applied on the flower of the plants then without fertilization and without seeds formation ovary wall becomes tuberous and forms the fruit. This is called the *artificial parthenocarpy*

Agent Orange

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

Gibberellins

Gibberellins, or GAs, include a large range of chemicals that are produced naturally within plants and by fungi. They were first discovered when Japanese researchers, including Eiichi Kurosawa, noticed a chemical produced by a fungus called *Gibberella fujikuroi* that produced abnormal growth in rice plants.

- Gibberellins are important in seed germination, affecting enzyme production that mobilizes food production used for growth of new cells. This is done by modulating chromosomal transcription. In grain (rice, wheat, corn, etc.) seeds, a layer of cells called the aleurone layer wraps around the endosperm tissue.

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

Cytokinins

Cytokinins or CKs are a group of chemicals that influence cell division and shoot formation.

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

Ethylene

Ethylene is a gas that forms through the *Yang Cycle* from the breakdown of methionine, which is in all cells. Ethylene has very limited solubility in water and does not accumulate within the cell but diffuses out of the cell and escapes out of the plant.

- Its effectiveness as a plant hormone is dependent on its rate of production versus its rate of escaping into the atmosphere. Ethylene is produced at a faster rate in rapidly growing and dividing cells, especially in darkness. New growth and newly germinated seedlings produce more ethylene than can escape the plant, which leads to elevated amounts of ethylene, inhibiting leaf expansion.
- As the new shoot is exposed to light, reactions by phytochrome in the plant's cells produce a signal for ethylene production to decrease, allowing leaf expansion. Ethylene affects cell growth and cell shape; when a growing shoot hits an obstacle while underground, ethylene production greatly increases, preventing cell elongation and causing the stem to swell. The resulting thicker stem can exert more pressure against the object impeding its path to the surface. If the shoot does not reach the surface and the ethylene stimulus becomes prolonged, it affects the stem's natural geotropic response, which is to grow upright, allowing it to grow around an object.

Abscisic Acid

Abscisic acid (ABA) hormone activates the vascular cambium during mitosis cell divison and its

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