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UG-TRB:BOTANY

(ENGLISH MEDIUM)

UNIT-1-VIRUS, BACTERIA,PHYCOLOGY AND MYCOLOGY

VIRUSES:

- The viruses are non-cellular obligate parasites that are characterized by having an inert crystalline structure outside the living cell.
- Once the viruses infect a cell, they kill the host cell and take over the machinery of the host cell to replicate themselves.
- The name virus that means venom or poisonous fluid was given by Pasteur. D.J. Ivanowsky.
- J. Ivanowsky recognized certain microbes as causal organism of the mosaic disease of tobacco, which were found to be smaller than bacteria because they passed through bacteria-proof filters.
- W. Beijerinek demonstrated that the extract of the infected plants of tobacco could cause infection in healthy plants and called the fluid as Contagium vivum fluidum.
- M. Stanley showed that viruses could be crystallized and crystals consist largely of proteins, which are inert outside their specific host cell.
- In addition to proteins viruses also contain genetic material that could be either RNA or DNA.
- Viruses that infect plants have single stranded RNA and viruses that infect animals have either single

~~or double stranded RNA or double stranded DNA.~~

- Bacteriophages are usually double stranded DNA viruses.
- The protein coat called capsid made of small subunits called capsomeres, protects the nucleic acid.

VIRIOIDS

- Viroids are smaller than viruses, which was found to be a free RNA.
- Virioids lacked the protein coat that is found in viruses, hence the name viroid.

Lichens

- Lichens are symbiotic associations between algae and fungi.
- The algal component is known as **phycobiont** and fungal component as
- Algae prepare food for fungi and fungi provide shelter and absorb mineral nutrients and water for its partner**.**
- Lichens are very good pollution indicators.

uses cause diseases like mumps**, small pox, herpes and influenza, AIDS.**

Three general hypotheses of the origin of viruses are taken into consideration.

(i) The ancestors of viruses were at one time cellular organisms. As a result of parasitic existence in other cells, they gradually lost more and more of their own cellular machinery until they eventually became reduced to their present form.

(ii) The ancestors of viruses were once free-living pre-cellular forms of life, which managed to survive after the evolutionary emergence of cellular organisms only by becoming parasitic on them.

(iii) The viruses have not evolved from organisms, either pre-cellular or cellular, but have arisen from detached fragments of the genetic material of cellular organisms. These genetic fragments, as a result of detachment from the rest of the genetic system, acquired the ability to multiply more rapidly than the other constituents of the cell, and their unregulated growth caused disease and death of the cell.

- Liberated after cell death, the genetic fragments were able to ensure their own perpetuation by entering adjacent healthy cells and again multiply there.
- Originally passed from cell to cell in the form of nucleic acid, they eventually acquired the capacity to

direct the simultaneous synthesis of the infected cell of a special protein, which served to enclose the nucleic acid fragments, and thus made their transfer from cell to cell a much less hazardous operation.

- The above hypotheses have not yet been supported by factual information.

Characteristics of Viruses:

- Viruses are a cellular, non-cytoplasmic infectious agents. Therefore, a unit of virus is referred to as 'a virus particle' ratherthan 'a virus cell'.
- They are smallerthan bacteria and can pass through bacteriological filter.
- They are consisting mainly of a nucleic acid surrounded by a protein envelope called capsid.
- They are devoid of the sophisticated enzymatic and biosynthetic machinery essential for independent activities of cellular life. Therefore, they can grow only inside suitable living cells.
- These virusesdo not grow, neitherrespire nor metabolize, butthey reproduce.
- Viruses may even be crystallized much like molecules although some kind of viruses can only be purified but not crystallized .
- A virus cannot contain both DNA and RNA. Therefore, virus is called either 'DNA virus' or 'RNA virus' depending on whetherit contains the nucleic acid DNA or RNA.
- Viruses are transmissible from disease to healthyorganisms.
- All viruses are obligate parasites and can multiply only within the living host cells.
- Viruses are host specific that they infect only a single species and definite cells of the host.
- They are highly resistantto germicides and extremes of physical conditions.
- Viruses are called connective link between living and non-living.

❖ The word virus is from Latin virus, a poison. As a preliminary working definition, viruses may be characterized as ultra-microscopic disease-producing entities, capable of being introduced into living cells of particular kinds of organisms, and capable of reproducing or being reproduced only within such cells. They cannot be made to multiply on artificial media.

❖ The viruses can, however, be seen with an electron microscope. Because they are able to pass through bacterial filters, they have been called filterable viruses. A typical virus particle apparently consists of

~~a core of nucleic acid, partly or wholly surrounded by a sheath of protein. Some of the viruses have~~ been isolated in a pure form and even crystallized.

- All thus far isolated have been found to be nucleoproteins of very large molecular size and weight.
- Plant viruses have not been definitely observed in plants other than flowering plants and bacteria, but this may be due to lack of study rather than a real absence. Again, animal viruses inhabit vertebrates, arthropods, and many other animals.
- Particles of both plant and animal viruses vary from spherical to slenderly rod- shaped, according to the kind of virus. Some animal viruses are brick-shaped. Some of the smallest viruses are only about 0·01 micron in length, while some of the largest ones approach 0.5 micron.
- The viruses are responsible for a large number of important plant and animal diseases. In many cases the virus is more or less latent (i.e., it exists and reproduces but causes no detectable harm) in a particular host and causes a recognizable disease only when introduced into some other kind of host.
- In general, the plant viruses are transmissible by sap, by grafting, or by insects. The virus diseases and infections in plants are recognized and described on the basis of symptoms and transmissibility.
- Viruses possess some of the qualities of living organisms they are able to reproduce, they occur in distinct strains or varieties, and they undergo changes similar to mutations. Unlike living organisms, they do not respire, nor do they possess cellular structures. Many Biologists regard viruses as intermediate between non-living matter and living organisms.
- The first known record of the existence and behaviour of virus is a variegation in the colour of tulips reported by Carolus Clusius in 1576. That the variegation might be due to a disease was suggested only in 1670. In 1715 an account of an infectious chlorosis of Jasminum was published. About fifty years later the so-called **'curl'** disease of potatoes came into prominence. But there was a great controversy over its cause.
- About 1886 Adolf Mayer described a disease of tobacco plant which occurred in the tobacco-growing regions of Holland, as Mosaikkrankheit which means mottling type of virus disease. He described the disease, and from the mosaic pattern common on leaves of affected plants, Mayer suggested the name **'mosaic'**.
- Mayer showed that this mosaic disease of tobacco could be communicated to a healthy tobacco plant by inoculation with the sap of the infected plant. But Mayer did not suggest that the diseased

condition was due to virus. Two years later, Erwin F. Smith showed that the disease **'peach yellows'** was also communicable and could be transmitted by transplanting a bud from a diseased tree to a healthy tree.

- The first scientific proof of the existence of a virus was given by the Russian Botanist DmitriIwanowski in 1892. Iwanowski working with the mosaic disease of tobacco, described by Mayer, proved that sap from such a diseased plant was capable of inducing the mosaic disease in healthy tobacco plants. He passed the sap through a bacteria-proof Chambeiland filter candle and found the filtrate to retain infectivity.

- It is the first record of the passage of either a plant or an animal virus through a bacteria-proof filter. Six years later in 1898 Loeffler and Frosch showed that the foot and mouth disease of cattle is caused by an agent which could pass through bacteriological filters. In 1892, a Dutch Bacteriologist Martinus Willem Beijerinck took up the study of tobacco mosaic.

- He found the sap of infected plant, when filtered through bacteria-proof filter, to be sterile but still infectious, which he designated as contaginm vivum fluidum and subsequently, referred it as a virus. Beijerinck confirmed the findings of Mayer and Iwanowski and claimed more emphatically than either of them that the causal agent was not a bacterium or any conceivable corpuscular material.

- The relationship between an insect and a plant virus has been experimentally established by a Japanese farmer, Hashimoto, who worked in 1894 with the dwarf disease of rice and the leafhopper Nephotettix apicalis var. cincticeps. In 1895 Takata in Japan transmitted virus by means of the leafhopper Deltocephalus dorsalis.

- During 1906-07, Ball, Adams, and Shaw working on curly top of sugar-beet established the leafhopper transmission of virus. Further evidences of leafhopper transmission of virus were put forward by Boncquet and Hartung in 1915. That aphids are also responsible for the transmission of virus was demonstrated by Allard in 1914.

- Iwanowski continuing his study of tobacco mosaic virus described in 1903 certain intracellular bodies in the tissues or diseased plants. One type was amoeboid, the other was in the form of crystalline plates. Holmes in 1929 described the primary infection lesion of tobacco mosaic virus and thereby he indicated the usefulness of the symptomatology.

- In the area of strain differences in viruses, McKinney (1926) is the pioneer worker. He suggested that strains arise by mutation. Takahashi and Rawlins in 1933 exhibited the physical phenomenon of tobacco mosaic virus. By 1935 it was evident that the virus was a particle distinct from any known living entity and comparable in many ways to larger molecules or colloidal particles.

- In 1935 Stanley for the first time isolated a crystalline protein in more or less purified condition possessing the properties of the tobacco mosaic virus. In his opinion, tobacco mosaic virus is an auto-catalytic protein which may be assumed to require the presence of living cells for multiplication. In the succeeding five years protein crystals were isolated from preparations of several plant viruses.

- These preparations were infectious and capable of producing the disease concerned upon inoculation into the respective host. Other pioneer workers in this line are Bawden and Pirie. They have shown that all virus proteins crystallized so far, are nucleoproteins.

Nature of Viruses:

- There has been some argument as to whether viruses should be considered to be living or non-living. True, viruses are individual organic compounds whose chemical composition resembles protoplasmic constituents. They behave as microorganisms only when in association with the complex mechanisms of living cells.

- Viruses reproduce in a host cell and are capable of mutation. They contain the true essence of life by the possession of an extremely potent complement of genes and behave as microorganisms only when in associated with the complex mechanisms of living cells.

- In their ability to reproduce themselves in living tissues they also resemble microorganisms. With the messages contained in the single strand of the nucleic acid, the virus is able to divert the enzyme systems of the host cells into new pathways and synthesize more virus particles instead of host substance.

- In this respect viruses seem to resemble self-duplicating genes and chromosomes, but they differ in that they are able to penetrate some unicellular of multicellular hosts from the outside.

- But on the other hand, viruses do not possess cellular structures. They by themselves do not carry on respiration, lack capacity for independent metabolism, and do not multiply by classical growth and fission methods from pre-existing virus particle. Those viruses which have been prepared in pure crystalline form and found to be nucleoproteins are not living organisms in the ordinary sense.

- Again the virus crystals are chemically inert and can apparently be kept indefinitely without significant change.

- Again viruses are often accepted as molecules having ability to duplicate themselves. But Stanley and others suggested the significant difference between viruses and other molecules pointing out that a virus comes to life the moment it infects a cell. Besides this, the term **'molecule'** implies a precise knowledge of the structure of a compound.

- Viruses are thus ultra-microscopic disease-producing particles of organic matter which can multiply only in living plants and animals and are responsible for a large number of important plant and animal diseases. It is apparent that furthermore is necessary before assigning any particular status to the viruses.

PROPERTIES OF VIRUSES:

1. They are non-cellular organisms, which is enclosed in a protective envelope.
2. The presence of spikes helps in attaching the viruses to the host cell.
3. These viruses do not grow, neither respire nor metabolize, but they reproduce.
4. They are surrounded by a protein coat – capsid and have a nucleic acid core comprising DNA or RNA.
5. They are considered both as living and non-living things. These viruses are inactive when they are present outside of host cells, but become active within host cells. These viruses cause several infections and reproduce within the host cell by using the enzymes and raw materials.

REPLICATION OF VIRUSES

- Viral populations do not grow through cell division, because they are acellular.

- Virus use the machinery and metabolism of a host cell to produce multiple copies of themselves.

- During the process of viral replication, a virus induces a living host cell to synthesize the essential components forthe synthesis of new viral particles.

❖ The particles are then assembled into the correct structure, and the newly formed virions escape from the cell to infect other cells.

❖ The host cell is forced to rapidly produce thousands of identical copies of the original virus.

❖ Replication between viruses is varied and depends on the type of genes involved.

❖ Most DNA viruses assemble in the nucleus;

❖ Most RNA viruses develop solely in cytoplasm.

❖ Viral life cycle differs greatly between species, but there are basic stages in their life cycle:

- Attachment
- Penetration
- Uncoating
- Replication
- Assembly
- Release

Classification of Viruses

- Viruses can be classified primarily on their phenotypic characteristics, core content, chemical composition, capsid structure, size, shape, genome structure and modes of replication.
- The Baltimore classification is the most commonly used for studying the system of virus classification. This system was developed by an American biologist David Baltimore in the 1970s, for which he was awarded the Nobel Prize.
- Virus classification is the process of naming viruses and placing them into a taxonomic system.
- Viruses do not fit into the established biological classification of cellular organisms. This is mainly due to pseudo-living nature of viruses.
- Initially, on the basis of their host range, clinical, epidemiological and pathological symptoms,

viruses were classified into the following four groups:

- Plant viruses : This group includes only plants virus
- Invertebrate viruses : This group includes only invertebrates virus
- Vertebrate Viruses : This group includes viruses infecting vertebrate.
- Dual-host viruses : Infects two different hosts mentioned above.

GENERAL ACCOUNT OF PLANT, ANIMALAND HUMAN VIRAL DISEASE

- The definition of a disease is an illness or sickness with specific, well-defined symptoms that affects a person, plant or animal.
- A condition of the living animal or plant body or of one of its parts that impairs normal functioning and is typically manifested by distinguishing signs and symptoms.
- A disorder of structure or function in a human, animal, or plant, especially one that produces specific symptoms or that affects a specific location and is not simply a direct result of physical injury.
- A disease is a particular abnormal condition that negatively affects the structure or function of all or part of an organism, and that is not due to any immediate external injury. Diseases are often known to be medical conditions that are associated with specific symptoms and signs.

Types of Causes of Diseases

- Airborne: Disease that is caused by pathogens and transmitted through the air.
- Food borne: Illness resulting from the consumption of food contaminated with
  - Bacteria
  - Toxins
  - Viruses
  - Prions
  - Parasites

- **Infectious:**

It is known as transmissible diseases or communicable diseases, comprise clinically evident illness (i.e., characteristic medical signs or symptoms of disease) resulting from the infection, presence and growth of pathogenic biological agents in an individual host organism. Included in this category are:

• **Contagious diseases**—commonly spreads from one person to another. Eg., influenza

• **Communicable diseases**—a disease that can spread from one person to another, but does not necessarily spread through everyday contact.

❖ **Lifestyle:**

A lifestyle disease is any disease that appears to increase in frequency as countries become more industrialized and people live longer, especially if the risk factors include behavioral choices like a sedentary lifestyle or a diet high in unhealthful foods such as refined carbohydrates, trans fats, or alcoholic beverages.

❖ **Non-communicable:**

A non-communicable disease is a medical condition or disease thatis nontransmissible. Non-communicable diseases cannot be spread directly from one person to another. Heart disease and cancer are examples of non-communicable diseases in humans.

Classification based on the presence of nucleic acid

DNA virus

- ♣ The virus, having DNA as its genetic material. There are two different types of DNA virus
- ♣ Single-stranded (ss) DNA virus: e.g. Picornaviruses, Parvovirus, etc.
- ♣ Double-stranded (ds) DNA virus: e.g. Adenovirus, Herpes virus, etc.

RNA virus

- ♣ The virus, having RNA as its genetic material. There are two different types of RNA virus
- ♣ Double-stranded (ds) RNA virus: e.g. Reovirus, etc.
- ♣ Single-stranded (ss) RNA virus. It is further classified into two Positive sense RNA (+RNA) and negative sense RNA (-RNA). Poliovirus, Hepatitis A, Rabies virus, Influenza virus are examples of single-stranded RNA virus.

Classification based on the structure or symmetry

1. Complex virus. E.g Poxvirus
2. Radial symmetry virus. E.g.Bacteriophage

3. Cubical or icosahedral symmetry shaped virus. E.g. Reovirus, Picornavirus

4. Rod or Spiral shaped or helical symmetry virus.E.g. Paramyxovirus, orthomyxovirus

Classification based on the replication properties and site of replication

Here, viruses invade into the host cell, where it replicates and assembly within the cell organelles.

1. Replication within the cytoplasm of the host cell.
   E.g. All RNA viruses except the Influenza virus.

2. Replication within the nucleus and the cytoplasm of the host cell.
   E.g. Influenza virus, Poxvirus, etc.

3. Replication within the nucleus of the host cell.
   All DNA viruses except Pox virus.

4. Replication of the virus through the double-stranded DNA intermediate.
   E.g. All DNA viruses, Retrovirus and some tumour causing RNA virus.

5. Replication of the virus through a single-stranded RNA intermediate.
   E.g. All RNA viruses except Reovirus and tumour-causing RNA viruses.

Classification based on the host range

Based on the type of host, there are four different types of viruses:

Animal viruses:

These viruses infect by invading the cells of animals, including humans. Prominent examples of animal viruses include the influenza virus, mumps virus, rabies virus, poliovirus, Herpes virus, etc.

Plant viruses:

These viruses infect plants by invading the **plant cells.** Well-known examples of plant virus include the potato virus, tobacco mosaic virus, beet yellow virus, and turnip yellow virus, cauliflower mosaic virus, etc.

Bacteriophage:

The virus which infects bacterial cells is known as bacteriophage. There are many varieties of bacteriophages, such as DNA virus, MV-11, RNA virus, λ page, etc.

Insect virus;

The virus which infects insects is known as Insect virus, also called the viral pathogen of insects. These viruses are considered as a powerful biocontrol agent in the landscape of modern agriculture. Ascovirus virions and Entomopox virus, are best examples for insect virus.

Classification based on the mode of transmission

1. Airborne infections – Transmission of the virus through the air into the respiratory tract. E.g. Swine flu, and Rhinovirus.

2. Fecal oral route – Transmission of the virus through the contaminated water or food. E.g. Hepatitis A virus, Poliovirus, Rotavirus.

3. Sexually transmitted diseases – Transmission of the virus through sexual contacts with the infected person. E.g. Retrovirus, human papillomavirus, etc.

4. Transfusion-transmitted infections- Transmission of the virus through the blood transfusion. E.g. Hepatitis B virus, Human Immunodeficiency Virus, etc.

5. Zoonoses -Transmission of the virus through the biting of infected animals, birds, and insects to human. E.g. Rabies virus, Alpha virus, Flavivirus, Ebola virus, etc.

List of Viral Diseases

Following is a list of virus diseases that have made a significant socioeconomic impact in the last few decades.

- AIDS (Acquired Immunodeficiency Syndrome)
- Ebola

- Influenza
- SARS (Severe Acute Respiratory Syndrome)
- Chikungunya
- Small Pox (Now eradicated)

WHAT ARE THE VIRUSES

❖ Viruses are simple and acellular infectious agents.

❖ Viruses are infectious agents having both the characteristics of living and nonliving.

❖ Viruses are microscopic obligate cellular parasites, generally much smaller than bacteria. They lack the capacity to thrive and reproduce outside of a host body.

❖ Viruses are infective agent that typically consists of a nucleic acid molecule in a protein coat, is too small to be seen by light microscopy, and is able to multiply only within the living cells of a host.

❖ Viruses are the large group of submicroscopic infectious agents that are usually regarded as nonliving extremely complex molecules, that typically contain a protein coat surrounding an RNA or DNA core of genetic material but no semipermeable membrane, that are capable of growth and multiplication only in living cells, and that cause various important diseases in humans, animals, and plants.

ORIGIN OF VIRUSES

❖ The origin of viruses is unclear because they do not form fossils.

❖ There are three main hypotheses that aim to explain the origins of viruses:

I-Regressive Hypothesis

- This is also called the 'degeneracy hypothesis‘ or 'reduction hypothesis'.
- Viruses may have once been small cellular organisms that parasitized larger cells.
- Over time, genes not required by them and they become simpler organisms which are the viruses we see today. Supporting Evidence: Rickettsia and Chlamydia are living cells that, like viruses, can

reproduce only inside host cells. They lend support to this hypothesis, as their dependence on parasitism is likely to have caused the loss of genes that enabled them to survive outside a cell.

II- Escaped Gene Theory

- Some viruses may have evolved from bits of DNA or RNA that "escaped" from the genes of a larger organism.
- The escaped DNA could have come from plasmids (pieces of naked DNA that can move between cells) and or transposons (molecules of DNA that replicate and move around to different positions within the genes of the cell).
- This is sometimes called the vagrancy hypothesis or the escape hypothesis. Supporting Evidence: Once called "jumping genes", transposons are examples of mobile genetic elements and could be the origin of some viruses. They were discovered in maize by Barbara McClintock in 1950.

Virus Induced Symptoms:

Effects of Viruses on Plants:

- Viruses are similar to obligate parasites in that they cannot be grown on non-living media. They are intimately associated with the host cell and few kill the infected plant although some cause severe distortion and dwarfing.

The changes brought about by viruses are treated as symptoms which may be:

- Morphological changes or external symptoms,
- Histological and cytological or internal symptoms, and
- Metabolic changes; but these are all correlated.
- The symptoms of the majority of plant virus diseases are most conspicuous on plants making rapid growth. Plants that are almost mature at the time of infection usually do not develop symptoms on any part except on new growths.
- Viruses being infectious induce a variety of symptoms covering a wide range of host reactions.

Some of the symptoms frequently encountered are mentioned below:

External Symptoms:

- The most common symptom in the green tissues of higher plants is the alteration in the normal development of chlorophyll— chlorosis. This may be accompanied with various other malformation. Besides this, necrosis of tissue and dwarfing, distortion of a particular organ or the entire plant are also common symptoms. The external symptoms may be primary or localized and systemic.

- The primary or initial symptom is a local reaction at the actual site of inoculation consisting of spots or rings of various types.

- They are usually necrotic but are occasionally chlorate and known as local lesions. There may also occur a second type of primary symptom known as clearing of the veins, a condition where the veins of the youngest leaves become yellow. Whereas, the systemic symptoms are of widespread occurrence in the host tissue.

Some of the external symptoms are described below:

Chlorosis:

- The dis-balance of normal development of chlorophyll leading to yellowing or formation of different shades of green without pattern is the chlorosis.

Mosaic:

- The interspersion of various degrees of chlorosis with the normal green colour of the leaf resulting in a mosaic pattern of yellow and green, forms the mosaic.

Meaning of Bacteria:

- Bacteria are microscopic organisms, which are often known as **'germs'** and **'microbes'**. They are among the simplest forms of life known, and, hence show the characteristics of both plants and animals. Their relationship to other living organism is very obscure.
- Though they are placed in the plant kingdom, this does not mean that they are more closely related to plants than to animals. Their inclusion under the plant kingdom is entirely for the sake of convenience.
- Their brilliant work revolutionized medicine and pioneered the field of antiseptic surgery paving the way for the development of the study of bacteria into independent science of bacteriology. It was Pasteur who disproved the theory of spontaneous generation by furnishing irrefutable evidence that microorganisms arise from pre-existing living entities.

General Characteristics of Bacteria:

- Bacteria are among the smallest of living organisms. They are unicellular (some nulticellular) or

thalloid living organisms, sometimes with some differentiation of cells, but without differentiated tissues. Bacterial cells are procaryotic possessing datively simple nucleus without any nucleous and nuclear membrane.

- Some species of bacteria are parasites. They attack the living cells of other plants or of animals and secure their food from that source. But most bacteria grow as saprophytes on dead remains or the products of plant and animal life without a direct relationship with living cells.

Economic Importance of Bacteria:

- Bacteria are of major importance to main kind for they include some of his most destructive enemies and also some of his greater benefactors. Injurious species include those responsible for disease of human beings and other animals and those that destroy food and reduce crop production by inducing various diseases of crop plants.

- Beneficial species liberate fertilizer elements for growing crops, destroy sewage and other wastes. Activities of many bacteria have been harnessed for various industrial purposes to produce valuable chemicals, medicines and various other products essential for human society.

Beneficial Activities:

Some of the beneficial activities of bacteria are:

1. Bacteria and soil fertility:

Of all the living organisms found in soils, bacteria are among the most active. They are especially abundant in the 'surface layers of soil, decreasing in numbers with depth of soil. These bacteria, along with other soil organisms, play a dominant role in soil fertility.

- Large quantities of the nitrogen from the soil which has been built into plant proteins of crop plants are removed from the field in the grain or other useful parts.

❖ There are two types of nitrogen-fixing bacteria:

(i) Non-symbiotic nitrogen-fixing bacteria live independently in the soil. Two prominent genera of this group are Azotobacter and Clostridium. These free-living bacteria fix independently atmospheric nitrogen in their body and convert to organic nitrogen compounds. When they die, the organic nitrogen compounds of their body are made available to higher plants through the activities of other bacteria.

(ii) Symbiotic nitrogen-fixing bacteria, consisting of species of Rhizobium, live symbiotically in small, swellings or nodules on the roots of various seed plants, chiefly leguminous plants. These bacteria fix atmospheric nitrogen to synthesize organic nitrogen compounds. When the leguminous plants are harvested, the roots with nodules containing bacteria are left in the soil.

When they decay, the organic nitrogen compounds made by bacteria become available as nitrates through the process of nitrification. A leguminous crop in a rotation thus possesses an advantage besides that of the crop itself, it increases the amount of nitrogen in the soil.

- Each type of leguminous plant requires a particular strain of nodule-forming bacteria in its roots. If this strain is not present in the soil, it can be added artificially by inoculating the seeds before they are sown. The relationship between nodule- forming bacteria and their leguminous plants is one of symbiosis.

- The bacteria secure food from the tissues of the leguminous plant, and the leguminous plant obtains nitrogen which is fixed by the bacteria.

- The nodule-forming bacteria are thus also known as symbiotic nitrogen-fixing bacteria. These bacteria are widely distributed in soils, so that even in the absence of seed inoculation with these bacteria, leguminous seedling roots sooner or later become infected with symbiotic nitrogen- fixing bacteria.

2. Bacterial Metabolism—its Commercial Importance:

- The metabolic processes and their products of bacteria have been utilized in many industries. In their metabolic activities bacteria excrete waste products some of which have exceedingly important commercial uses. The large-scale production of valuable substances from bacterial metabolism is a relatively new field in the economic utilization of bacteria, and, as such, is one in which new discoveries are frequent and often very startling.

(i) Source of Antibiotics:

- Soil is perhaps the most important source of microorganisms which produce antibiotic substances. These include filamentous bacteria (actinomycetes). Some of the antibiotic substances are secreted outside the cells and into the environment; others are retained largely within cells and must be separated by extraction.

- The modern period of antibiotics began in 1939 with the finding of tyrothricin, produced by a soil bacterium.

Prominent among the antibiotics from actinomycetes are:

- streptomycin, discovered in 1944 and obtained from Streptomyces griseus, strtptothricin from S. lavendulae; Chloromycetin, in 1947 obtained from S. venezuelae; aureomycin, in 1948 obtained from S. aureofaciens; neomycin, in 1949 obtained from S. fradiae and terramycin, in 1950 obtained from S. rimow.

- Besides these, bacitracin and polymyxin are antibiotics produced by Bacillus subtilis and Bacillus sp. respectively were reported long ago.

(ii) Fermentation—its Industrial Application:

- The process of bacterial fermentation and its products have been utilized in various industries. Some of them are: Clostridium acetobutylicum ferments carbohydrates producing acetone, methyl alcohol, and n-butyl alcohol, which have important industrial uses. Very recently, vitamin B_2, a commercially important product has been discovered as a product of fermentation of carbohydrates by this species of Clostridium. This vitamin has been one of the more expensive vitamins to obtain in quantity, is valuable as a preventive of certain nervous disorders and other diseases.
- The manufacture of vinegar is one of the oldest processes in human history which involves bacterial metabolism. Vinegar production begins with the fermentation of sugars in apple juice to alcohol by yeasts. In the presence of oxygen, the vinegar bacterium, Acetobacter aceli, oxidizes alcohol to acetic acid, which is responsible for the characteristic odour and flavour of vinegar.

- Lactic acid as one of the products resulting from the souring of milk, has many uses in the processing of foods, in pharmaceuticals and in the chemical industry. It is named after the milk constituent lactose, or milk sugar. It is probably the oldest known acid, having been discovered by Scheele in 1780.

- A group of bacteria designated as ‘lactic acid bacteria’, ferment lactose of milk to lactic acid. All these bacteria are classified in the family Lactobacteriaceae which includes the genera Lactobacillus, Leuconostoc, and Streptococcus.

- The dairy industry finds bacteria an essential aid in a number of processes. Butter is sometimes made

from cream which has been allowed to undergo 'ripening'—that is, a lactic acid fermentation, causing it to become sour. The cream is pasteurized, incubated and then churned. This fermentation eventually results in the formation of substances responsible for the characteristic odour of butter.

- The process of pasteurization was named after Louis Pasteur, the French scientist who developed it to prevent the spoilage of wines. It is chiefly associated with the treatment of milk to eliminate pathogenic bacteria. Two methods are used to pasteurize milk. In the older of these, the holding process; the milk is heated to 140°F. and held at that temperature for 30 minutes.

- Another short time, high temperature method, sometimes termed flash pasteurization, the milk, in thin layers is exposed to a temperature of 160°F. for a minimum of 15 seconds. The milk is then cooled as rapidly as possible to a temperature which retards bacterial growth. Pasteurization destroys pathogenic bacteria without appreciably affecting tie physical and chemical properties of the milk.

- The pasteurization of milk is widely recognized as one of the most important public health measures. It is not a process of sterilization. Spores of bacteria are not killed, and since the temperature falls far short of boiling, neither are all the vegetative cells. This is notably true of the lactic acid bacteria although the number of these is greatly reduced.

- Pasteurized milk will, therefore, be normally sour, as will raw milk, although more slowly. Besides all these processes, a number of complex processes involving lactic acid or other kinds of bacteria occur during the ripening of cheese.

(iii) Retting of fibres:

- Bacteria play an important role in the retting of jute, flax, and hemp fibres. They hydrolyze the pectic substances which act as cement like materials that bind the fibres together. Retting is carried out by immersing the stalks of jute, flax or hemp in water and weighing them down. Water is absorbed by the tissues, causing swelling and the extraction of water soluble substances.

- The water becomes highly coloured containing substances that have been extracted from the submerged stalks. This highly coloured water now becomes a good culture medium for the growth of many kinds of organisms. The aerobic organisms reduce the concentration of dissolved oxygen and create an environment suitable for the growth of anaerobes.

- The pectic substances are slowly fermented and dissolved by the anaerobes, leaving the fibres intact. During fermentation, various organic acids and gases are produced. The submerged stalks should be removed from water when the reaction has gone to completion; otherwise overrating will result.

- They are then thoroughly washed to remove the organic acids, odours, and other undesirable substances and the fibres removed from them are then spread out in the sun or air to dry. The dried material is then ready for dressing. Bacteria responsible for retting of fibres are: Bacillus subtilis, B. polymyxin, Clostridium tertium, and C. felsimium.

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