

Course No.: PATH 121
[Fundamentals of Plant Pathology]

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Chapter 1

Introduction

- Plants are the only higher organisms that can convert the energy of sunlight into stored, usable chemical energy in carbohydrates, proteins and fats. All animals including humans depend on these plant substances for survival.
- Plants whether cultivated or wild grow and produce well as long as the soil provides them with sufficient nutrients, moisture, sufficient light and temperature within a normal range.
- Plants however also get sick, grow and exhibit various types of symptoms and sometimes whole plant die. It is not known whether diseased plants feel pain or discomfort. If a plant is looking different from its community then it is equal to be diseased one. Any biotic or abiotic agent which induces the disease in plant is referred to as the cause of diseases.
- The causative agents of disease in plants are pathogenic such as fungi, bacteria, viruses, protozoa and nematodes and environmental conditions such as lack or excess of nutrients, temperature, light etc. presence of toxic chemical in air or soil.

Plant Pathology or Phytopathology :

It is a science that deals with the study of diseases of plants, their development and control.

Phytopathology :

Phyton = Plants, Pathos= Disease, logos= Science.

Plant disease :

A malfunctioning process that is caused by continuous irritation which results in some suffering-producing symptoms. The continuous irritation may be brought about by living and non living factors (environmental) because of which the particular process in metabolic and catabolic activity of plant cells is disrupted leading to development of symptoms as a reaction to such suffering. These may be brought about by utilizing host cell content, by death of tissue, excess production of enzymes, toxins, growth regulators, loss of nutrition and interference in translocation of food, minerals & water.

Diseases for plants have been known since ancient time.

Definitions.

Disease : is defined as a disturbance in the rhythmical equilibrium in the activities of host in respect of structure or physiology or both, leading to the death of a part or entire host, or reduce the economic value of the products.

OR

Disease : is a complex phenomenon, it is an interaction between the host, the pathogen and the environment.

OR

Disease : is malfunctioning process caused by continuous irritation, which results in some suffering producing symptoms.

Or

A structural abnormality or physiological disorder or both due to an organism or unfavorable conditions that may affect the plant or its parts or products or may reduce the economic value .

Plant diseases are caused by **biotic** agents like fungi, bacteria, actinomycetes, phytoplasma, viruses, nematodes, flowering parasites or by **abiotic** agents like unfavorable environmental conditions or nutritional deficiencies. Study of plant pathology includes the study of mycology, nematology, protozoology, phycology, unfavorable environmental factors, nutritional deficiencies and flowering plant parasites.

❑ Branches of Plant Pathology :

- Microbiology : Study of Micro organisms
- Mycology: Study of Fungi
- Bacteriology : Study of Bacteria
- Virology : Study of Viruses
- Nematology : Study of Nematodes
- Protozoology : Study of Protozoa
- Phycology : Study of Algae

❑ Objectives of Plant Pathology :

Plant Pathology or Phytopathology is one among the branches of Agricultural sciences that deals with cause, etiology, resulting the losses and management of plant diseases with following **four major objectives** .

- i. Study the disease (s) / disorders caused by biotic and abiotic agents (s)
- ii. Study the mechanism (s) of disease development by Plant Pathogens.
- iii. Study the interaction between plant and pathogen in relation to overall environment.
- iv. To develop suitable management strategies for managing the diseases and losses caused by them.

❑ Economic importance of Plant diseases:

The plant diseases are very important because they causes enormous losses to the cultivated crop. The losses due to plant diseases accounts around 26% in field, storage and transportation.

1. Impact of plant diseases on population :

- The **late blight of potato** is a famous example in history of plant pathology, the disease assume epidemic proportion in **Ireland in 1845** devastating the whole potato crop. The potato being the staple food of people & because of non availability of it, around 20 lakh people died due to starvation & migration of population to other lands including North American continent.
- ***Helminthosporium* leaf spot of rice** devastated rice crop in **west Bengal** in India during 1942-43 & thousands of people died because of hunger & migrated to other part of country.

2. Change in Agri Pattern :

The diseases like **coffee rust** in Ceylon had changed the economy of country & shifting to other plantation crop like tea.

In 1885 there was epidemic of coffee rust in Ceylon which devastated the entire coffee ,Due to the rust yield of coffee went down from 228 kg/acre to 101 kg/acre by 1878 & because of which by 1893 the coffee export of Ceylon reduced by 93% thus making huge loss. The coffee rust became so Severe that Ceylon has to shift itself to cultivation of tea.

3. Food Poisoning :

The poisoning of food due to plant disease is another evil. There is death of people & animal due to consumption of contaminated rye with **ergot**, which produces toxin fatal to human beings & animals.

Also production of **aflatoxin** by *Aspergillus flavus* in foodstuff is also fatal to human beings.

4. Impact on Industry : The certain agro industries are also affected due to supply of the diseased raw material. e.g. The disease red rot of sugarcane affects the sugar industries because of poor recovery of sugar from such infested material which in turn increases the cost of production.

5. Impact on science : The plant disease system had provided a great scope for expanding the areas of human knowledge regarding, Micro-organism, their taxonomy, ecology, physiology & biochemistry, genetic, molecular & cellular biology & managements practices for control of crop diseases.

6. Useful plant diseases : The man has commercially exploited the plant disease for economic gain & aesthetic value for ex. Tulip breaking the disease of flower of tulip which cause variegation in flower of tulip are much prized & covered in west.

The fungus *Cytosphaeria mangiferae* infecting the *Aquilaria agallocha* in Pakistan, produces a fragrant perfume known as 'uttar' in Indian subcontinent is commercially exploited

Chapter No. 2

History of Plant Pathology

By studying the history of science, we get a better perspective of the subject we come to know the contributions made in that fields the problems that are encountered and the manner in which they are tackled.

The history of Plant pathology is divided into different five eras.

1. Ancient era : Ancient to 5th Century (476 A.D.)
2. Dark era : 5th to 16th Century (476 A.D. to 1600)
3. Premodern era : 17th Century to 1853 (1600 to 1853)
4. Modern era : 1853 to 1906
5. Present era : 1906 onwards

1) Ancient era : Ancient to 5th Century (476 A.D.)

1. Diseases in plant have been known since ancient times
2. Rust, blight, mildews, smuts were familiar to Hebrews, Greeks, Romans, Chinese and Indians, Plant diseases were recorded in Vedas (Rugveda, Atharveda) as early as 1200 B. C.
3. Symptoms and control of disease have been mentioned in “VRIKSHAYURVED” by **Surapal** in ancient India.
4. Definite mention of plant diseases has been seen in Buddhist literature of 500 B.C.
5. **Theophrastus** (300 B.C.) a great botanist noted occurrence of crop diseases and suggested some remedies to control them. he also wrote about plant diseases in this era.
Lord pliny 100 A.D . He described plant diseases and suggested some remedies. He believed that disease originates from the plants or from the environment.

Plant pathology made very little progress during this era. Some Arabians like Ibn al-Awam described symptoms and control measures for some plant diseases

1440 : Printing was introduced in Europe and this reflected interest in learning science.

3. Premodern era 18th century to 1853 (1600 to 1853)

Robert Hooke (1665)

The father of cell theory . He had developed or **invented first compound microscope**. He reported that plant tissues are made up of minute units called as cells.

Antony Van Leeuwenhoek (1676)

A Dutch worker from Holland. He **invented first simple microscope with home ground lenses between two plates**. He described different types of protozoa and bacteria as "**Little animalcules**". All unicellular microorganisms (Protozoa, algae and bacteria) were firstly recorded by him.

P.A. Micheli -1729

An Italian Botanist studied several fungi and described their morphology for

John Needham -1743

Reported plant parasitic nematodes in wheat galls.

Carlous Linnaeus -1753

Established Latin Binomial system of Nomenclature of plants and animals in his book "Species Plant".

Tillet -1755

Proved that Bunt of wheat is contagious disease and can be controlled by seed treatment.

Prevost -1807

A French Botanist suggested CuSO_4 seed treatment for Bunt of Wheat.

This is known as autogenic or physiologic period , since plant diseases were distinctly physiologic with tendency towards the mycology. At the end of the period it was clear the fungi were very closely associated with diseases.

In 1845 late blight of potato (Irish Potato Famine) was appeared in Ireland , over one million people get died and one and half millions get migrated and the history entered the next era.

4.Modern era :1853 to 1906 .

This is known as pathogenic period which was devoted the study of role of fungi causing plant diseases.

Anton de Bary 1853 : He Proved that late blight of potato was caused by *Phytophora infestans*. Founder or Father of Plant Pathology.

T.J. Burril 1873 : American Plant Pathologist. He proved bacterial Nature of Fire Blight of Apple and Pear (*Erwinia amylovora*)

Robert Koch 1876 : Bacterial nature of Anthrax disease in animal (1881)
Gelatin is used as solidifying agent in culture media which is replaced by Agar Agar . He described the theory called “KOCH’S POSTULATES” .

Steps in Koch`s postulate – i Association ii Isolation iii Inoculation
iv .Reisolation

P.A.Millardet 1882-85 : Use of Bordeaux mixture(CuSO_4 + Lime) for control of Downey mildew of grapes.

Adolf Mayer 1886 : Described TMV and proved that TMV should be transmitted from diseased plant to healthy plants.

Jenson 1887 : Hot water treatment for loose smut of wheat.

E.F. Smith 1890: Father of Phytopathology. He worked on bacterial wilt of cucurbit and crown gall diseases.

Iwanowski 1892: Demonstrated that Tobacco Mosaic Virus (TMV) can pass through bacteria proof filters and proved filterable nature of viruses.

Cragie 1827: Showed function of *Puccinia* in rust fungi.

Biffen 1905: Pioneers in Genetic of Plant disease resistance.

5. Present era : 1906 onwards.

The present or current era commencing from 1906 has since remarkable discoveries.

J.C. Luthra 1931 : Solar heat treatment for loose smut of wheat.

W.M.Stanley 1935 :He proved crystalline nature of virus. He got Nobel Prize.

F.C. Bowden & Pierie 1936:Nucleoproteinous nature of virus.

G.H. Flor 1955:Gene for gene theory hypothesis.

Doi & Asuyama :Discovered mycoplasma like organisms(MLO) responsible for yellows type of disease.

Important Contribution of Indian Phytopathologists

E.J. Butler (1874-1943): Empirical mycologist at LARI, New Delhi Since 1905 to 1921 and trained many workers in Mycological and plant pathological Research, he wrote a Book “Fungi and Diseases in Plants” in 1918. He is called as the “**Father of Modern Plant pathology in India**”

K.C. Mehta (1892-1950) : Physiology & Epidemiology of cereal rusts in country. Monograph on further studies on cereal rusts in India in 1940.

B.B. Mundkar (1896-1892): Worked on cotton wilt in Bombay state, published **ustilaginales** in India. Pioneer in establishment of Indian phytopathological society (IPS) in 1947 and Indian phytopathology in 1918. He worked on Smut Fungi. He wrote a book “Fungi and Plant Diseases”.

J.F. Dastur : He worked on “Anthracnose of cotton”. Cotton wilt, pink disease of citrus, foot rot of Betelvine. He published 36 original papers & 4 books.

B.N. Uppal:He worked on Downey mildew of maize ,bajara and showed physiological specialization in *Sclerospora graminicola*. He worked on several fungal and bacterial diseases.

G.S. Kulkarni: Downey mildew of Sorghum and Pearl millet. Sorghum Smut.

V.P. Bhide:Bacterial Diseases of plant.

M.J. Thirumalachar:500 research papers, 20 genera and 300 species of fungi. He discovered antibiotic Aureofungin.

G. Rangaswami.:He worked on ,Nematode, bacterial and other diseases. Published 5 books of Microbiology and plant pathology and over 300 research papers.

P.N.Patel.: Bacterial diseases of Plants.

Lecture No. 3 & 4

Terms and concepts .

1.	Immunity	:	<ul style="list-style-type: none">* The state of being immune .* Freedom from a given disease due to lack of quantities permitting infection or possession of qualities that do not permit establishment of infection .* To develop resistance against infection
2.	Immune	:	<ul style="list-style-type: none">* Can not be infected by a pathogen .* Exempt from disease.
3.	Immunization	:	It is a process to make the host immune.
4.	Infection	:	The establishment of parasite within the host .
5.	Perpetuation	:	Survival of pathogen in absence of main host .
6.	Incubation period	:	The period of time between penetration of a host by a pathogen and the first appearance of symptoms on the host.
7.	Polygenic resistance	:	The resistance controlled by many genes .

8.	Setae (Singular) Seta (Plural)	:	Bristle like structures found in some fungal fruiting bodies .
9.	Antherezoid	:	A motile male gamete.
10.	Blastospores	:	A type of fungal spore produced asexually by budding process.
11.	Parasite		An organism living on or in another living organism (host) and obtaining food from it.
12.	Saprophyte	:	An organism living on dead organic matter
13.	Facultative parasite	:	Having a ability to be a parasite but it is ordinarily saprophyte .
14.	Facultative saprophyte	:	An organism that is ordinarily parasite but under certain conditions may be saprophyte
15.	Obligate parasite	:	A parasite that in nature can grow and multiply only on or in living organism/ host .
16.	Hyperparasite	:	A parasite parasitic on another parasite .
17.	Homothallic	:	A fungi producing compatible male and female gametes on the same mycelium .
18.	Heterothallic	:	Fungi producing compatible male and female gametes on the physiologically distinct mycelium .

19.	Holocarpic	:	An individual with thallus entirely converted in to reproductive structure .
20.	Eucarpic	:	An individual whose thallus is not entirely converted in to reproductive structure .
21	Dikaryosis	:	Mycelium or spores containing sexually compatible nuclei per cell. It common in basidiomycetes
22.	Plamogamy	:	Fusion of protoplasm .
23.	Karyogamy	:	Fusion of nuclei .
24.	Spore	:	* A one to several celled body, set apart for reproduction * A minute reproductive unit without a preformed embryo .
25	Haustoria (Haustorium)	:	Special branch of fungus hyphae, especially Intracellular hypha , within the living cell to absorb nutrients. Also root like absorbing organ connecting parasitic seed plant to the vascular system of the host.
26	Apresoria (Apresorium)	:	Swollen or flat end of mycelium , derives the nutrients from host .
27	Alternate host	:	* One of two kinds of plants on which a parasitic fungus (e.g. rust) must develop for completion of its life cycle . * Wild host of other family than the host are called as alternate host.

28	Collateral host	:	Wild host of same family of main host are called as collateral host These are mainly wild grasses e. g. Blast of paddy
29	Anamorph	:	The imperfect or asexual stage of a fungus.
30	Teliomorph	:	The sexual or so called perfect growth stage in fungi.
31	Signs	:	Signs are the experimental or scientific evidences of the diseases .
32	Symptoms	:	Symptoms are expression of diseased condition
33	Chronic symptoms	:	Symptoms that appears over a long period of time
34	Masked symptoms	:	Virus infected plant symptoms that are absent under certain environmental condition but can appeared when the host is exposed to certain condition of light and temperature .

35	Symptomless carrier	:	The infected plant showing no obvious symptoms, though its infected with pathogen.
36	Conjugation	:	A process of sexual reproduction involving fusion of two gametes. Also in bacteria, the transfer of genetic material from a donor cell to a recipient cell through direct cell to cell contact.
37	Horizontal resistance	:	Partial resistance equally effective against all races of a pathogen
38	Vertical resistance	:	Complete resistance to some races of a pathogen but not to others
39	Host	:	A plant that is invaded by a parasite and from which the parasite obtain its nutrients
40	Pathogen	:	An entity, usually a microorganism that can incite disease .
41	Hypersensitivity	:	Excessive sensitivity of plant tissue to certain pathogens. Affected cells are killed quickly, blocking in advance of obligate parasite

42	Inoculum	:	The pathogen or its parts that can cause infection. The portion (propogule) of individual pathogen that are brought in to contact with the host
43	Propagule	:	The part of an organism that can reproduce or regenerate and can be disseminated .
44	Resistance	:	The ability of an individual to exclude or overcome , completely or in some degree, the effect of a pathogen or other damaging factor.
45	Susceptibility	:	The plant without inherent capacity to resist the attack by a pathogen or disease .
46	Tolerance	:	The ability of a plant to sustain the effects of a disease without dying or suffering serious injury or crop loss.
47	Non host resistance	:	Inability of a pathogens to infect a plant because the plant is not a host of the pathogen due to lack of something in the plant that the pathogen needs.

48	Paraphysis	:	A sterile hyphae present in some fruiting bodies of fungi.
49.	Periphysis	:	Hair like growth or projection lining the inner wall of ostiole of stroma .
50.	Pathogenicity	:	The capacity of a pathogen to cause disease .
51.	Phytoalexin	:	Substance which inhibit the development of a fungus on hypersensitive tissue, formed when host plant cells come in contact with the fungus.
52	L. D. 50 (Lethal dose 50%) I..C.50(Inhibitory Concentration 50%)	:	The minimum concentration of toxic compound that kills 50% of the population, inhibition/ suppress 50% of spore germination or cause 50% inhibition of growth
53	Anemochory	:	The dispersion of plant pathogen by means of wind .
54	Hydrochory	:	The dispersion of plant pathogen propagules by means of water .
55.	Entomochory	:	The dispersion of plant pathogen propagules by means of insect .

Lecture No.5. CLASSIFICATION OF PLANT DISEASES

I. Classification of plant Diseases on the basis of causes: According to causes diseases are classified as **Non Infectious diseases & Infectious diseases.**

A. Non infectious diseases: Are due to abiotic causes / factors :

These includes mainly the deficiencies or excesses of nutrients, light, moisture, aeration , abnormalities in soil conditions, atmospheric impurities, etc

1. Due to unfavorable Soil conditions.

a. Physical composition:-Soil structure, soil moisture, soil aeration eg. Dieback and wilts.

b. Chemical composition:- Excess or deficiency of elements e.g. Mango tip rot or fruit necrosis, khaira disease of rice, Hollow and black heart of potato

2. Due to unfavourable climatic conditions:-

a. Temperature- High temperature effects- sunscald of vegetables &
Low Temp effects -freezing injury in apples..

b. Relative Humidity, rains and snow.

c. Wind and Hail

d. Light and lightening:- Etiolation of leaves.

3. Diseases due unfavourable practices, chemical and mechanical injury.

4. Diseases due to fumes, gases and smoke :-Hydrogen fluoride causes toxicity in tulip & corns.

5. Diseases due to plant metabolic products and storage.eg Black Heart of potato.

B. Infectious diseases/ Biotic causes / factors:

1. Mesobiotic causes / factors:

These are disease incitants which are neither living nor nonliving. They are considered to be threshold of life.

1. Viruses – These are infectious agents made up of one type of nucleic acid (RNA or DNA) enclosed in protein coat e. g. Potato leaf roll, leaf curl of tomato and Chilli mosaic.

2. Viroids – Naked infectious strands of nucleic acid e.g. spindle tuber of potato, citrus exocortis, and tomato bunchy top.

2. Virusoids, Prions and others.

2. Biotic causes: This category includes diseases caused by living or animate or cellular organisms.

1. Prokaryotes – A microorganism whose genetic material is not organized in to membrane bound nucleus.

a. Mollicutes – These are wall less prokaryotes that includes Mycoplasma like Organisms (MLO) and Spiro plasma, e. g. Grassy shoot of sugarcane, little leaf of brinjal, Sandal spike and Papaya bunchy top caused by Mycoplasma. Citrus stubborn and stunt disease – caused by Spiroplasma.

b. Rickettsia Like Bacteria (RLBs): These are very small, sometimes submicroscopic, walled bacteria e. g. Citrus greening and pierce`s disease.

c. True bacteria – e. g. Brown rot or wilt of potato, soft rot of potato, and vegetables. Leaf blight of rice, citrus canker, sugarcane ratoon stunting disease, Angular leaf spot of cotton.

2. Eukaryotes –

a. Fungi- Nearly 70% of disease (major and minor) in any plant species of economic important are caused by fungi e.g. Wart of potato, Cabbage club root , Potato late blight, Downy mildew, powdery mildew, rust and smut , red rot of sugarcane .

b. Protozoa – Heart rot of coconut palm, phloem necrosis of coffee.

c. Algae – Red rust of mango, papaya etc.

d. Metazoan animals (Nematodes) - Root knot of vegetables, Molya disease of wheat and barley, Ear cockle of wheat, citrus decline .

e. Flowering plant parasites – Besides microorganisms certain flowering plants also parasitize the cultivated crop plants.

1.**Cuscuta/Dodder**- complete stem parasite of Onion, Alfaalfa Linseed etc

2. **Loranthus/Giant Mistetoes**-Partial stem parasite of Mango, Citrus etc.

3.**Broomrape/Orobanche**- Complete root parasite of Tobacco, Tomato etc

4.**Striga/Witchweed**-Partial root parasite of Jowar, maize etc.

II. Classification of Plant diseases on the basis of occurrence & severity :

- 1. Endemic disease :** The word endemic means “prevalent in’ and confined to a particular country or district” and applied to disease. A disease is classified as endemic when it is constantly present in moderate to severe form and is confined to a particular country or district. e.g . Club root disease of cabbage is endemic in Nilgiri district. Alternaria leaf spot of Onion in Nasik district .
- 2. Epidemic or epiphytotic disease :** A disease usually occurs widely but periodically in a destructive form is referred as epidemic or Epiphytotic disease. e.g. Powdery mildew disease in grapevine.
- 3. Sporadic disease:** Sporadic disease is one which occur at irregular interval and locations and relatively fewer instances. In reality, sporadic diseases belongs to the epidemic group. e.g. Uredinia disease in rice , Angular leaf spot of cotton .
- 4. Pandemic diseases:** These occurs all over the world and result in mass mortality. e.g. Damping-off disease of Tomato ,Late blight of potato.

III. Classification of Plant diseases on the basis of symptoms produced:

- 1.Hypoplasia:** In these diseases there is under development of host tissue due to infection of the pathogen e. g. Bunchy top of Banana, Yellow vein mosaic of Bhendi or Okra.
- 2.Hyperplasia:** In these diseases there is over development of host tissue due to production of toxins or growth regulating substances e. g. Root gall, Leaf curl etc.
- 3.Teratological phenomenon:** In this case where the plant parts lose their original appearance & takes up different forms. This may be due to genetical or pathological factors e.g. Smut of Jowar, Rust of Wheat.
- 4.Necrotic:** Under such symptoms the host tissue is destroyed and killed e.g. Blight, Wilt Rots, Cankers, Spots, Damping-off, scab.

Chapter No.5

Concepts of Plant Disease and Diseases Triangle

Old concept of Plant disease:

Plant diseases were considered to be a curse and punishment to the people by god for wrong and since they had committed religious belief superstition .

The Greek philosopher **Theophrastus** (300 B.C.) was the first to study and write about diseases of trees, cereals and legumes. He wrote a book named "Enquiry in to Plants". In this book he mentioned his experiences about plant diseases. His experience was not based on experimentation. He being unable to explain diseases. He believed that God controlled the weather that brought diseases. Plant diseases were a manifestation of the worth of God. It is due to religious belief. , superstitions or it is the effect of star moon and bad wind.

This was continued for almost 2000 years after Theophrastus. After invention of compound microscope in the mid 1600 ,scientist enable to see many microorganisms associated with diseased plants and they come to believe that the mildews, rust and other symptoms observed on plants and microorganism found on diseased plant. Plant parts were the natural product of diseases than the cause and effect of diseases.

Louis Pasteur (1860-63) provided irrefusable evidence that microorganisms arise only from pre-existing microorganisms and fermentation is a biological phenomenon not just a chemical one.

New concept of Plant disease :

It is accepted that a plant is healthy or normal when it can carry out its physiological functions to the best of its genetic potentials.

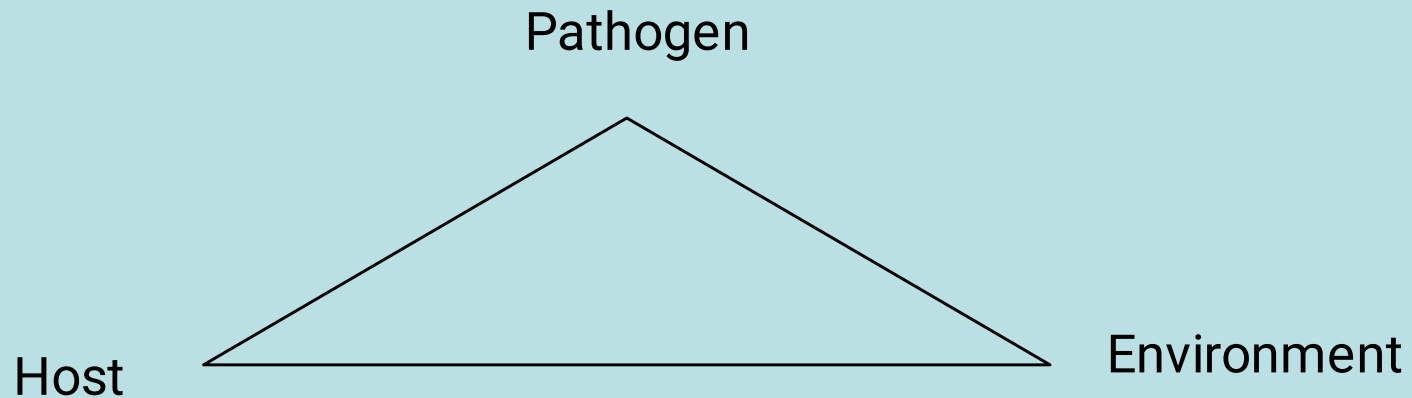
1. Cell division, differentiation and development.
2. Absorption of water and nutrients
3. Translocation of nutrients and water synthesis.
4. Photosynthesis.
5. Translocation and Metabolism or store the photosynthetic products.
6. Production of seed or reproductive organs or survival and multiplication.

Whenever the ability of the cells of a plant or plant part to carry out one or more of these essential functions is interfered other by a pathogenic microorganism or adverse environmental factor. The activities of the cells die or plants become diseased.

Pathogen may cause diseases in plant by :

1. Weakening the host by continuously absorbing food from the host cells for their own use.
2. Killing or disturbing metabolism of host cells through toxins enzymes or growth regulating substances, they secrete.
3. Blocking the transportation of food, mineral, nutrients and water through the conductive tissues.
4. Consuming the contents of the host cells upon contact.

Disease Triangle



Pathogen : Virulent , abundant and active

Host : Susceptibility, stage and density of crop

Environment : temperature, moisture and wind velocity.

Chapter 5

IMPORTANT PLANT PATHOGENIC ORGANISMS

Differences between Prokaryotic and Eukaryotic Cells

Sr. No	Particulars	Prokaryotic Cells	Eukaryotic Cells
1.	Group of organisms	Bacteria and BGA	Algae, protozoa, fungi, plants and animal cells.
2.	Size range	< 1-2 x 1-4 μ m	> 5 μ m in width or diameter
3.	Nucleus		
	i)	Not bounded by membrane	Bounded by membrane
	ii)	One circular chromosome without histones	One or more linear chromosomes containing histones
	iii)	No mitotic division	Mitotic nuclear division
4.	Sexuality	Zygote is partially diploid (merozygotic)	Zygote is diploid
5.	Mesosomes	Present	Absent

6.	Ribosomes	70 S	80 S arrayed on membrane as in endoplasmic reticulum , 70 S in mitochondria and chloroplast
7.	Mitochondria, golgi structures, chloroplasts, endoplasmic reticulum	Absent	May be present
8.	Cytoplasmic membrane	Generally does not contain sterols	Contains sterols
9.	Cell-wall	Peptidoglycan present	Peptidoglycan absent
10	Locomotion	Simple fibril	Multi-fibril
11	Metabolism	Wide, anaerobic energy yielding reactions. Some fix N2, some accumulate poly-hydroxybutyrate as reserve material	Glycolysis is the pathway for anaerobic energy yielding mechanism.

Groups of Microorganisms :

- 1) **Bacteria** :These are the unicellular, prokaryotic organisms or simple associations of similar cells. Cell multiplication is usually by binary fission.
- 2) **Fungi**: These are microbes devoid of chlorophyll, usually multicellular, but are not differentiated into roots, stems and leaves. They range in size from single celled microscopic yeasts to multicellular mushrooms and puff balls. The fungi reproduce by fission, budding or by means of spores borne on fruiting bodies.
- 3) **Algae** : These are relatively simple organisms; most primitive types are unicellular. All algal cells are capable of photosynthesis and are found most commonly in aquatic environments or in damp soils.
- 4) **Protozoa** : These are single celled, eukaryotic protists differentiated on the basis of morphological, nutritional and physiological characteristics. Some cause diseases in human beings and animals.
- 5) **Viruses** :They are very small parasites or pathogens of plants, animals and bacteria as well as some other protists. They can be seen only under electron microscope and can be cultivated only on living cells (obligate parasites).

1.BACTERIA

Bacteria are the microscopic, possess rigid cellwall, unicellular, prokaryotic protists lacking chlorophyll and divide chiefly by transverse binary fission. Among the major characteristics of bacterial cells are their size, shape, structure and arrangement, which constitute the morphology of the cell.

MORPHOLOGY OF BACTERIA

I. Size: Size of a bacterium is measured in terms of micrometer (μ).

$1/\mu\text{m} = 1000\text{th of one mm}$

The bacteria are minute, single celled organisms, ranging in size 0.75 to $1.25/\mu$ in diameter of a spherical cell and 0.5 to $1.25 \mu \times 2.0$ to 5.0μ of a rod shaped cells.

II) Shape of bacteria: Bacteria exhibit various types of shape, which are as

under :

1. Rod or cylindrical shaped – called as Bacilli.
2. Round or spherical shaped – called as Cocci.
3. Spiral shaped – called as Spirilla.

The short comma shaped cells are called “Vibrio”, short tightly coiled rods are called “Spirillum” and the very long cells with several curves and twists are called “Spirochete”.

- 4) Filamentous – Called as Trichobacteria : These are filamentous branched or unbranched (branching true or false) bacteria also called as Actinomycetes or ray fungi e.g. *Streptomyces* sp.
- 5) Involution forms or Bacteroides: These are unusual, abnormal or irregularly shaped cells produced by certain bacteria under modified conditions or in old cultures or in different habitat.

Morphology of Bacteria :

MORPHOLOGY



i

ii

iii

iv

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vii

viii

III. Cell Structure

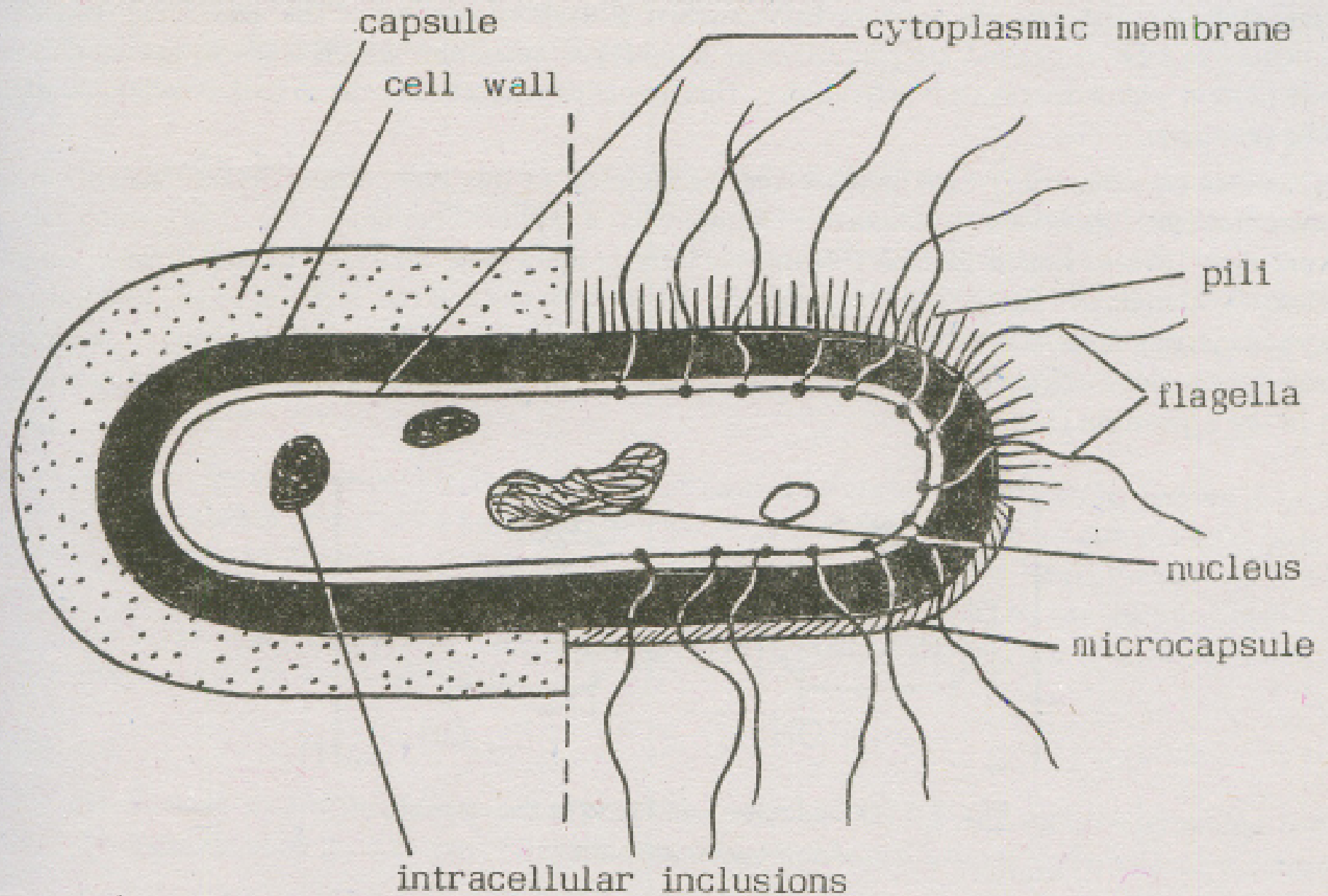


Fig. 3.4 A typical bacterial cell. Right to the dotted line represents the non-capsulated, flagellate rod.

❑ General structure of bacterial cell:

- A cell is surrounded by cell wall.
- Just underlying the cell wall there lies a thin membrane i.e. cytoplasmic membrane.
- Inner cavity of the cell is filled up with a cytoplasm, nuclear material and various bodies.
- The cell wall is surrounded with a mucilaginous slimy material called as capsule. It is a secretory product of the cell and not common in all.
- In some of the bacteria an organ of locomotion called as flagellum. It is very thin, slender and a whip like structure .

❑ The main components of a bacteria cell are :

(1) Capsule, (2) cell wall (3) Cytoplasmic membrane (4) Cytoplasm, (5) Nuclear region (6) Flagellum. (7) Pilli

1. Capsule

- In many bacteria cells develop an enclosing cover of gummy material forming a layer of considerable thickness. This layer is known as capsule or slime layer.
- Capsule serves as reservoir of food and site for disposal of waste substances.
- Chemically, it is polysaccharide in nature. It protects the bacterial cell during adverse condition.

Functions of capsule :

1. Provide a protective covering to the cell wall against harmful influence.
2. Many capsulated strains of pathogenic bacteria are not readily phagocytised by the leucocytes (WBC) thus, capsule contributes to the virulence of the organism.
3. Serve as a reservoir of stored food when the nutrients become limiting.
4. Serve as a site for disposal of waste substances.

2. Cell wall:

- It is a thin, sharply defined, and relatively firm structure beneath the capsule.
- Bacterial cell wall is rather stable and resistant to the action of most substances except strong acids and alkalis.
- All the food material which enters in to the cell must diffuse through the cell wall.
- It is composed of complex carbohydrates, cellulose, chitin, and other polysaccharides.
- Bacterial cell wall is rigid and gives definite shape to bacterial cell. Peptidoglycan, a polymer present in the cell wall determine the shape and offers rigidity to cell wall.
- Cell wall thickness ranges from 10 to 25 nm. Cell wall Constitutes 10 to 40 % dry

Bacterial cell wall has two functions.

- It gives definite shape to bacterial cell.
- It is essential for growth and division.
- Peptidoglycan is rigidly giving principle of cell wall. It is polymer of a) DPA-diaminopimelic acid b) Muramic acid and c) Techoic acid
- In addition to this it is also contains amino acid, amino sugars , carbohydrates and lipids. Above chemicals join to form polymer of Peptidoglycan.

❑ Major building blocks of Peptidoglycan are as below :

1. AGA (Acetyl glucose amine)
2. AMA (Acetyl muramic acid)
3. Peptide : containing four or five types of acids.

❑ On the basis of structure and chemical composition of cell wall, bacteria are divided in to two groups:

- 1 Gram +ve bacteria and 2 Gram -ve bacteria

1) Gram + ve Bacteria :

- Cell wall of such bacteria contains an insoluble polymer called Peptidoglycan.
- Peptidoglycan has major portion of teichoic acid and unipartite layered cell wall e.g. *Bacillus subtilis*.

2) Gram - ve Bacteria :

- In addition to **Peptidoglycan** such bacteria also have **lipopolysaccharide** in their cell wall, which is endotoxin and determines antigenicity, toxigenicity and sensitivity to **bacteriophage**.
- Chemically gram – ve bacteria cell wall being complex, contain higher **lipid portion** and more **amino acids**.
- Under electron microscope cell wall shows tripartite structure e.g. *Escherchia coli*.

Functions of cell wall :

- 1) Protection of protoplast.
- 2) Maintenance of elongate shape of bacilli.
- 3) Helps in flagellar motion.
- 4) Exerts selective permeability.

3. Cytoplasmic membrane or Plasma membrane:

Extremely thin but distinct membrane surrounding the cytoplasm. It functions as selective membrane, controls passage of nutrients and waste products. Responsible for gram staining reactions.

It is acidic in reaction due to the presence of RNA .

Functions of cytoplasmic membrane are as below .

1. Intake of nutrients
2. Elimination of byproduct of metabolism
3. Protection from harmful substance
4. Responsible for harmful substance
5. Semipermeability
6. Responsible for gram and id fast reaction
7. Act as electron transport organelle
8. It is biochemically active because it contains enzymes.

4. Cytoplasm

- Inside the cytoplasmic membrane there is a colloidal substance containing 70-90 percent water, known as cytoplasm.
- It is usually clear or watery or slightly viscous in consistency.

❑ Cytoplasmic inclusions consist of

1. Granules of stored food particles like carbohydrates.
2. Droplets of fat may be found distributed into cytoplasm.
3. Metachromatic granules of organic metaphosphate may also be present.
4. Elementary sulphur is also present in the cells of certain sulphur bacteria in the form of droplets. Cytoplasmic area – RNA and Nuclear area – DNA.

5. Nucleus

- Presence of nucleus has been established with certainty only a few years back.
- It has been shown that all bacteria contain intracellular bodies with the chemical properties expected of DNA which divide in co-ordination with the division of the cell.
- By following special staining methods with the help of electron microscope, it has been possible to demonstrate the bacterial nucleus.
- Although composition is still unsettled one.
- It is however shown that the nucleus consists of tiny granules of chromatin scattered through out the cytoplasm.

1. Morphologically distinct from cytoplasm
2. composed of mainly nucleoprotein,
3. Bears the hereditary characters of cell.
4. Nucleus is capable of further multiplication.

6. Flagella

- They are the **organs of locomotion**.
- Most commonly bacterial motility is due to the presence of hair like appendages known as **flagella**.
- The flagella vibrate actively and thus propel the organism forward.

7. Pilli (Fimbriae)

These are smaller, shorter, numerous, hair like structures as compared to flagella. They can not produce regular waves. They are visible only with electron microscope and are present in motile bacteria.

Pilli have following three functions:

- 1.They are helpful in adherence to host.
- 2 They make possible attachment of bacteriophage on bacterial surface.
- 3 Sex pilli serve as conjugation tube in sexual reproduction of bacteria
e.g. special 'F' pilus in *E. coli*.

Plasmid

In addition to chromosomal DNA many Bacteria contains **extra chromosomal DNA** in closed circular double strand form. This unit of genetic material is capable of independent replication is called as Plasmid .

Arrangement and Grouping of bacterial cells:

The bacterial cells are surrounded by a thin (rarely thick) layer of gelatinous material which tends to keep the cells together.

The grouping of cells largely depends upon the manner of multiplication and the direction of the planes of division. It is a general rule that the wall that divides bacterial cell into two daughter cells is formed at right angles to the longer axis. Since Cocci have no longest axis, cell division may occur in any direction.

Grouping in Cocci.

1. **Micrococcus** : When daughter cells separate out soon after their formation.
2. **Diplococcus** : When the cells remain attached in pairs.
3. **Streptococcus** : Here successive planes of division are constantly parallel and thus results in a chain of cells.
4. **tetrads** : four cells, cling together forming a square.
5. **Sarcina**: cells clinging together in cubes made up of eight or its multiple (Cell division in three)
6. **Staphylococcus** : When the cells remain attached in irregular masses resembling a bunch of grapes.

Grouping in Bacillus

The rod shaped bacteria may be long or short, usually straight, it may also be some what curved. It may have rounded ends or may be even concave.

Grouping is possible in bacillus because of the division is only in one plane.

1. Microbacillus : Separate rods.

2. Diplobacillus: Rods in pair.

3. Streptotacillus : Rods in chain

4. Pallisade: The cells form group in pallisade, like the matchsticks filled in matchbox e.g *Corynebacterium diptheriae*

this character much more readily than others e.g. Root nodule bacteria.

Diseases caused by bacteria

Examples of common bacterial diseases include blight, soft rot, canker, wilt, hairy root, tumors and galls.

Different morphological form of Bacteria :

- i Micrococci ii Diplococci iii Streptococci
- iv Staphylococci v. Sarchina
- vi Rod-shaped bacteria
- vii Sprilla
- viii Vibrios

Grouping in spirillum

No grouping in spirillum. They may be thin, broad, short or long.

Trichobacterium: Consists of long threads which may be branched or unbranched. Branching may be true or false.

Involution forms: Consistency of form is usually a marked feature of bacteria during its early stages of growth, but in old cultures and under certain conditions which are not favorable for the growth, bacteria may attain abnormal or unusual shapes such as thread like filaments, or club shape etc. these are termed as involution forms . Certain species of bacteria show

Types of flagella

Atrichous: Organisms without flagella.

Monotrichous: Organisms having a single flagellum at one end

Amphitrichous : Bacteria with a single flagellum at each end

Lophotrichous: Organisms with a cluster or tuft of flagella at one or both ends.

Peritrichous: Flagella on all over the body

Endospore Formation in Bacteria

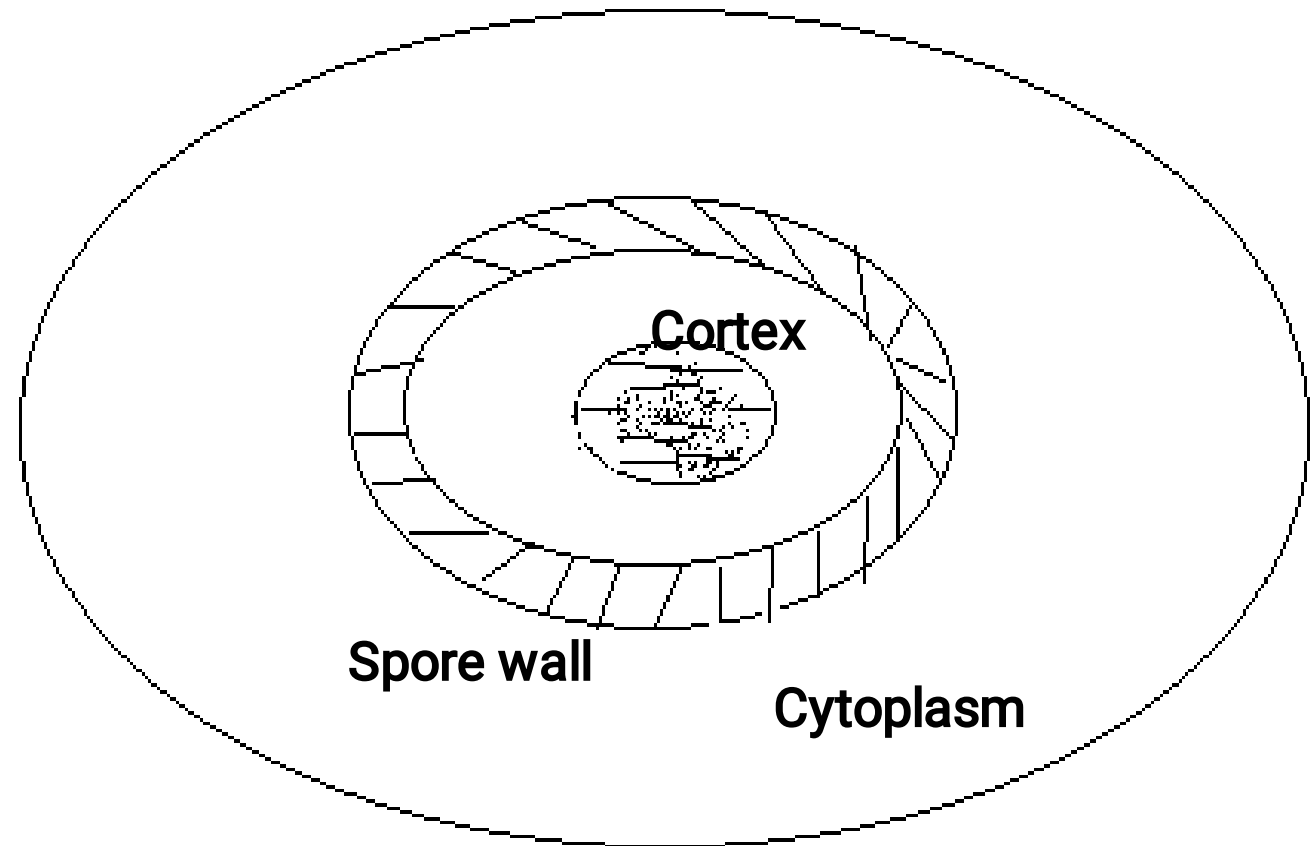
Certain bacteria produce spores inside (within) the cell called endospores. The spore is a metabolically dormant form which, under appropriate conditions, can undergo germination and outgrowth to form a vegetative cell. These structures are unique to bacteria. These are **thick-walled, highly retractile** bodies that are produced (only one per cell) by *Bacillus*, *Sporosarcina*, *Thermoactinomyces* (all aerobic), *Clostridium*, *Desulfotomaculum* (anaerobic) and a few other genera. The shapes of endospores and also their location within the cell vary depending on the species. Ex.

Bacillus cereus : Spores are elliptical and centrally located.

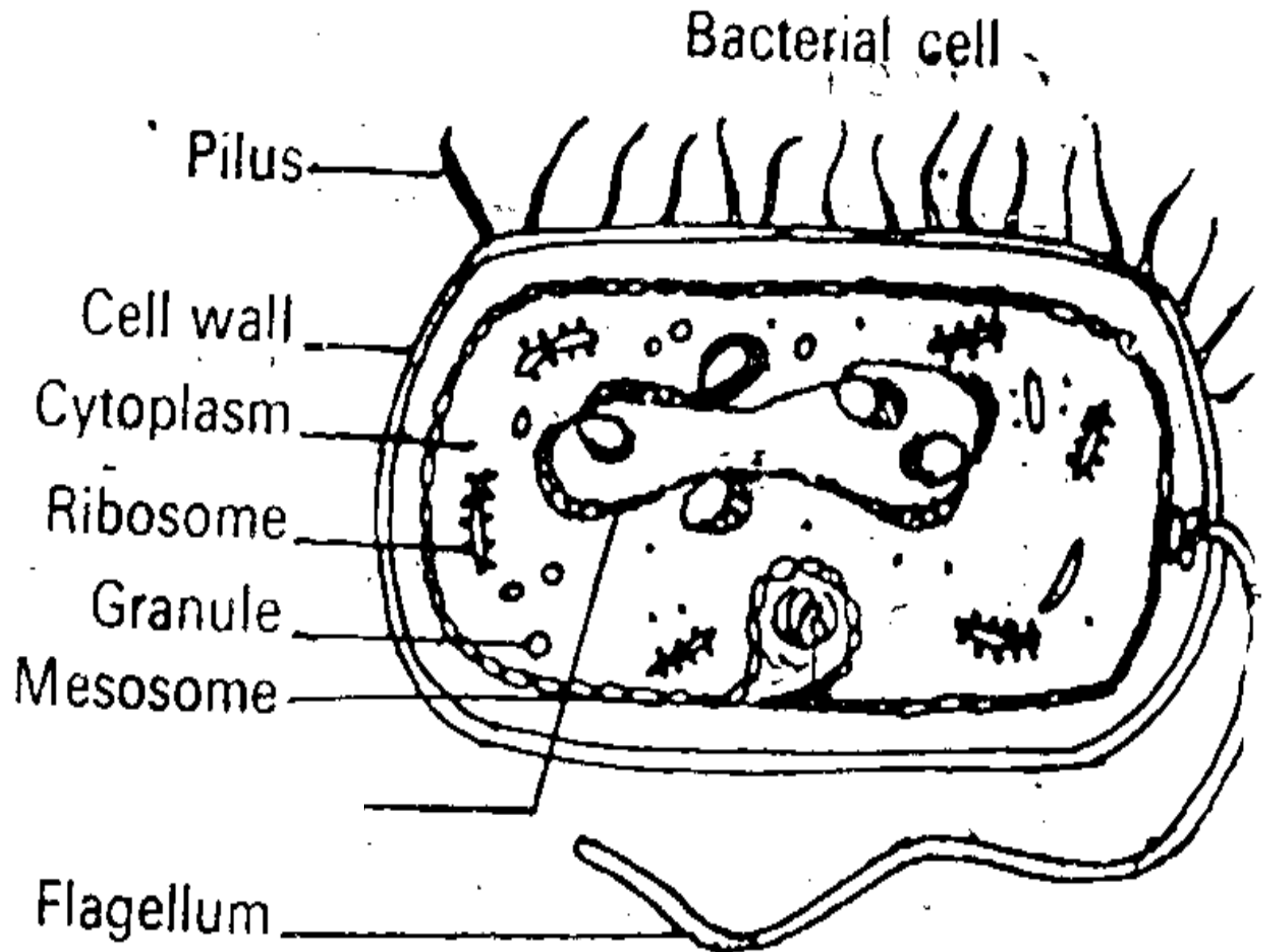
Clostridium tetani : Spores are spherical and terminally located.

Clostridium subterminale : Spores are ovoid and sub-terminally located.

Endospore



1. Bacteria :



Bacteria belong to kingdom prokaryotae

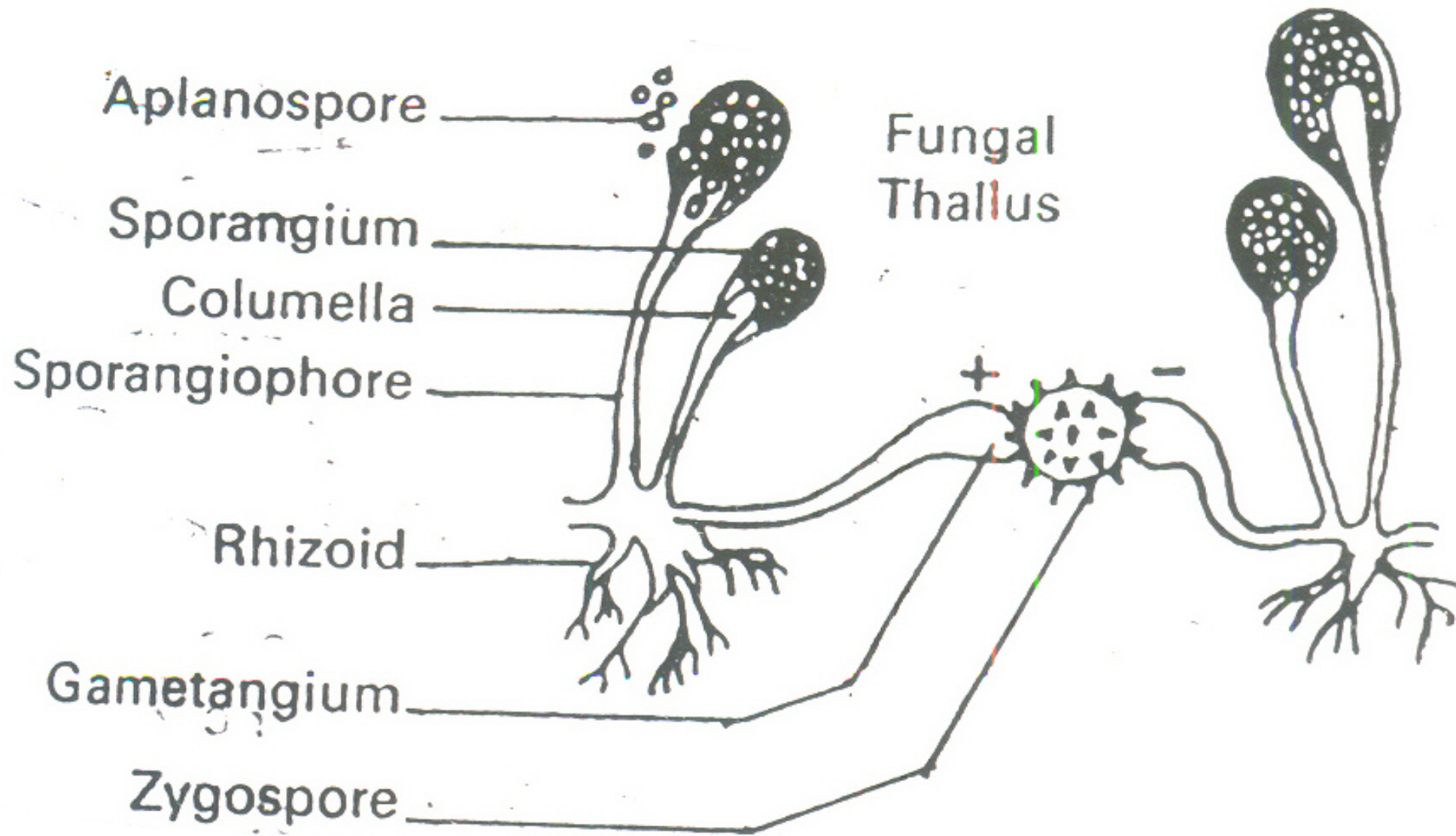
They are unicellular, microscopic, possess rigid cell wall without chlorophyll, reproducing by transverse or binary fission. Some possess organs of locomotion, which are called as flagella. They have various types of shapes such as rod or cylindrical, round or spherical, spiral, filamentous etc. The average size of bacteria is 0.5 to 2.0/ μm . They grow well on artificial medium, bacteria largely occur, in soil, air, milk etc.

They play an important role in the welfare of human beings. Some are useful in dairy industry some of them are capable of fixing atmospheric nitrogen.

Some cause diseases in plants and animals

Common genera are *Bacillus*, *Rhizobium*, *Azotobacter*, *Lactobacillus*, *Escherichia*, *Xanthomonas*, *Pseudomonas*.

Fungi:



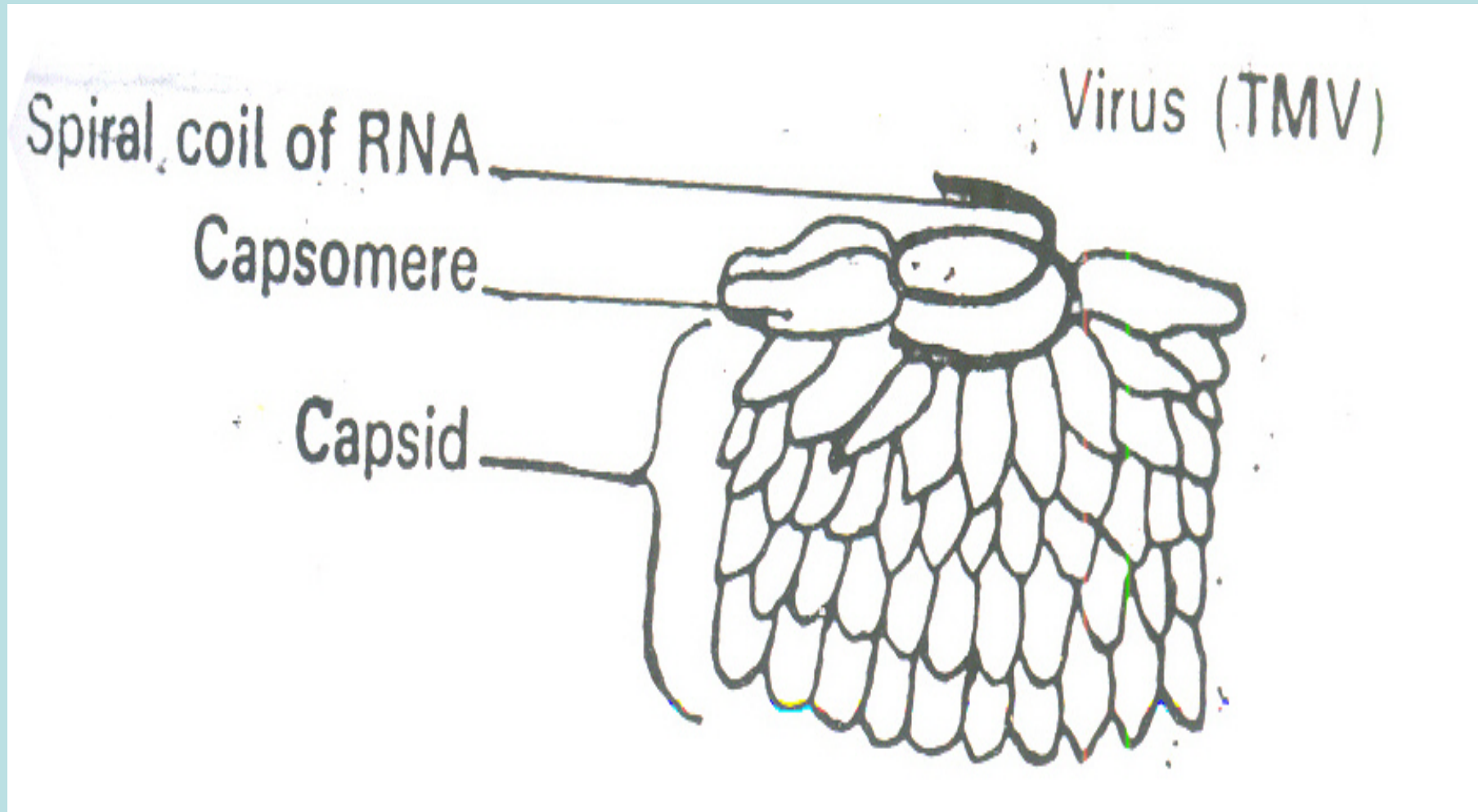
Fungi :

Common saprophytic (Growing on dead plant tissues) fungi are called mold. They are unicellular or multicellular, chlorophyll less, microscopic, thallophytic (undifferentiated into root, stem, branches, leaves, etc.) Fungi reproduce by sexual, asexual or by vegetative spores. Their body consists of filamentous or thread like structure, piece of such thread is known as **hypha**, while a group of hyphae is known as **mycelium**. Molds usually occur on slightly moist dead organic matter such as wood, leather, food, milk etc.

Economically they carry out various useful and harmful activities; they cause enormous loss to mankind by causing diseases in plants. They are also responsible for spoilage of paper, clothes, wood and food. At the same time they are useful in different industries such as production of antibiotics like penicillin. *Mucor*, *Aspergillus*, *Rhizopus*, *Penicillium* are some of the important genera of fungi.

Viruses:

Viruses are highly infectious, ultra microscopic, crystalline in form, obligate parasites, nucleoproteins, filterable in nature, reproduce by replication, ranging from 10 to 300 mu (millimicron). They cause infectious diseases in plants, animal and human beings. Viruses contains mostly RNA (Ribose Nucleic acid) only few cases like cauliflower mosaic contains DNA (Deoxyribose Nucleic acid). Infection of viruses is systemic in plants.



Diseases caused by Viruses

Viruses causes diseases in human, animals and plants.

Diseases in human : Small pox, AIDS(HIV), Hepatitis, Poliomyelitis (polio virus).

Diseases in animals : foot and mouth diseases (FMD).

Diseases in plants : Yellowing, Mosaic, Yellow mosaic, Yellow vein mosaic. Mottling, Chlorosis, Bunchy top, Sterility mosaic etc

Phytoplasma

- Ultramicroscopic
- Filterable
- Pleuomorphic organisms
- Without cell wall
- They can be grown on cultures media
- Various forms have been observed in the growth cycle viz. budding form, chain bodies, elongated and filamentous forms.
- They are susceptible to osmotic pressure and are able to pass through bacteria proof filters.
- Their growth is very slow and can be inhibited by specific anti sera.
- Both RNA and DNA are present.

Phytoplasma contd....

- They cause diseases like citrus greening, spike diseases of sandal, sesame Phyllody, little leaf of Brinjal, papaya bunchy top and several other yellowing type diseases.
- Phytoplasma infection mostly seen in phloem and parenchyma.
- Phytoplasma reported to grow on artificial medium. However, its growth is a slow, it is sensitive to antibiotic like Tetracycline or oxytetracycline.
- Instead of cell wall it possesses double layer membrane.
- Phytoplasma is a true prokaryotic microorganism.

Diseases caused by Phytoplasma :

- They are known to cause “Yellows” diseases in plant.
- Economically important plant diseases caused by mycoplasma are sandal spike, Aster yellows, Mulberry dwarf, grassy shoot of sugarcane, citrus greening, sesamum phyllody, little leaf of Brinjal etc.
- They causes diseases in human and animals e.g. pneumonia (M. pneumoniae)

Spiroplasma

- Spiroplasma are helical prokaryotes lacking a rigid cell wall, but bounded by unit membrane 8-10 μm in thickness, with RNA (ribosomes) and DNA strand in the nuclear region.
- They vary in shape form spherical to slightly ovoid to helical and branched non helical structure.
- Unlike phytoplasma, they can be cultured on artificial media, colonies on agar have 0-2 mm diameter and appears as granules but some have fried egg appearance.
- They do not have any flagella and reproduce by fission.
- They transmitted mostly by leaf hoppers.
- They are resistant to penicillin but inhibited by tetracycline.

Diseases Caused : Citrus stubborn (*Spiroplasma citri*), Leaf roll, Yellow dwarf of rice, Pear decline, Corn stunt, etc.

Protozoa

- These are single celled animal forms, motile by cilia, flagella or possess pseudopodia. They multiply by fission and sexual means. The size varies from 2 to 20 μm . Some cause diseases such as sleeping sickness, diarrhea etc. in human beings and animals. Common genera are Verticella, Paramocium, Amoeba etc. Plays important role in biological equilibrium.