Biyani's Think Tank

***Concept based notes***

# Microbiology, Mycology and Plant Pathology

*[B.Sc. Part-I]*

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# Preface

I am glad to present this book, especially designed to serve the needs of the students. The book has been written keeping in mind the general weakness in understanding the fundamental concepts of the topics. The book is self-explanatory and adopts the "Teach Yourself" style. It is based on question-answer pattern. The language of book is quite easy and understandable based on scientific approach.

Any further improvement in the contents of the book by making corrections, omission and inclusion is keen to be achieved based on suggestions from the readers for which the author shall be obliged.

I acknowledge special thanks to Mr. Rajeev Biyani, *Chairman* & Dr. Sanjay Biyani, *Director* (*Acad.*) Biyani Group of Colleges, who are the backbones and main concept provider and also have been constant source of motivation throughout this Endeavour. They played an active role in coordinating the various stages of this Endeavour and spearheaded the publishing work.

I look forward to receiving valuable suggestions from professors of various educational institutions, other faculty members and students for improvement of the quality of the book. The reader may feel free to send in their comments and suggestions to the under mentioned address.

**Author**

# Syllabus

## Unit I

Menaing and Scope of Microbiology: History and Development in the field of microbiology, General account of Eubacteria : occurrence, morphology (structure, shapes), flagella, capsule, nutritional types, endospore, reproduction (binary fission, transformation, conjugation, transduction), economic and biological importance. Cyanobacteria : *Oscillatoria* and *Nostoc*–occurrence, morphology, reproduction and importance.

**Mycoplasma** : occurrence, morphology, reproduction and importance.

## Unit II

**Virus** : General characteristics and importance. Structure of TMV and Pox virus, Structure and multiplication of Bacteriophage.

General characters and reproduction in Fungi : Economic importance of fungi. Classification of Fungi. (Aloxopolous and Ainsworth's). Important Symptoms of plant diseases caused by fungi, bacteria, viruses, MLO's (blights, mildew downy and powdery, rust, smut, canker mosaic, little leaf, galls etc.)

## Unit III

Brief account, structure, importance and life history and/or disease cycle and control of the following:

*Albugo* and white rust.
*Sclerospora* and Downy mildew/Green ear disease of Bajra.
*Aspergillus.*
*Claviceps* and Ergot.
*Peziza.*

## Unit IV

Brief account, structure, importance and life history and/or disease cycle and control of the following.

*Puccinia* and rusts of wheat (Black, orange, yellow).
*Ustilago* and loose smut of wheat and covered smut of barley.
*Agaricus.*
*Alternaria* and early blight of potato.

# Unit I

# Bacteria and Viruses

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**Q1 Give a detailed account of the habit , structure and Reproduction in Nostoc.**

**Ans Occurrence:**

It is filamentous form of both terrestrial and aquatic habitats . It does not occur in single filaments but grows in large colonies of closely packed trichomes embedded in a firm matrix of gelatinous material. Nostoc colony thus forms a mucilaginous lump or thallus which occurs floating or attached. The thalli are of various sizes and shapes and may be solid or hollow. They may be balls of a jelly – like substance or may be irregularly shaped. The colony may be olive green or blue green and the surface of the colony is warty and smooth. Terrestrial species, **Nostoc commune** grows on damp soil and forms leathery or rubbery sheaths. It is common in Arctic and alpine meadows. Aquatic species occur as free floating thalli in the sunny pools , ponds and lakes or lying at the bottom attached to submerged vegetation. A few species favour running water , especially fast flowing mountain streams. There they are found attached to stones along the stream beds. Nostoc also occurs in symbiotic association with fungi to form lichens. A certain species of Nostoc occurs in the thalli of Anthoceros. Some species of Nostoc have been reported to fix atmospheric nitrogen and tend to maintain fertility of paddy fields in which these forms regularly occur.

**Structure of the Colony:**

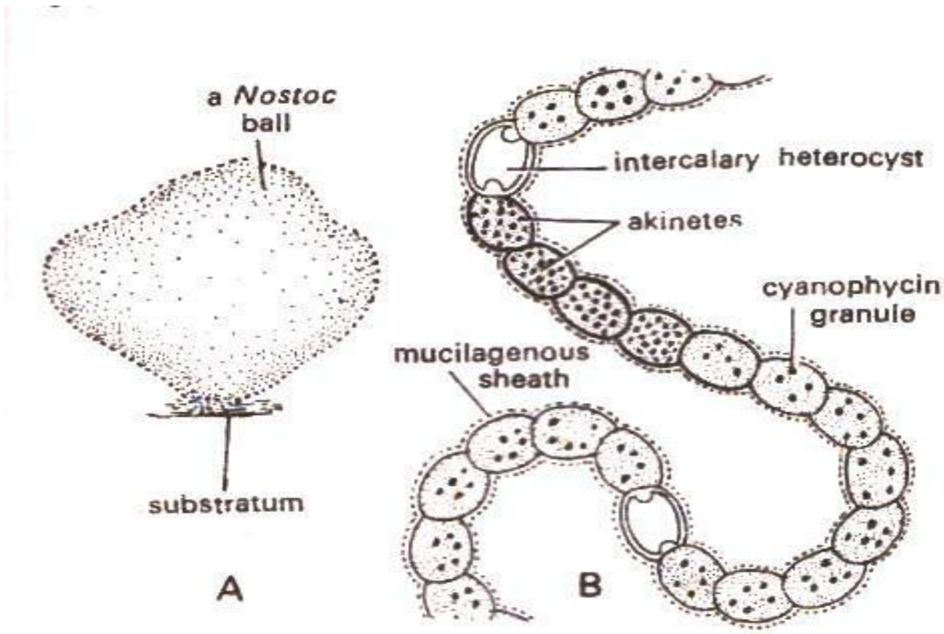
Innumerable chains of bead – like cells (trichomes) of varying lengths are intricately tangled in a copious gelatinous matrix to form a colony. Each trichome is usually enclosed by its own mucilaginous sheath and is called a **filament.** The numerous filaments in the colony are held together by a soft gelatinous envelope formed by the fusion of the individual trichome sheaths and also secreted copiously by the component cells. The mucilage lump is bounded externally by a firm, tough , pellicle –like bounding membrane to form a definite colony. Each colony appears like a bluish green or yellowish mass of jelly. Young colonies are small and microscopic. The mature ones are large. Enclosure of several colonies growing in the neighbourhood , within a common gelatinous mass results in the formation of a macroscopic , mucilaginous lump or thallus. It may be called a **compound colony.**

**Structure of the Trichome:-**

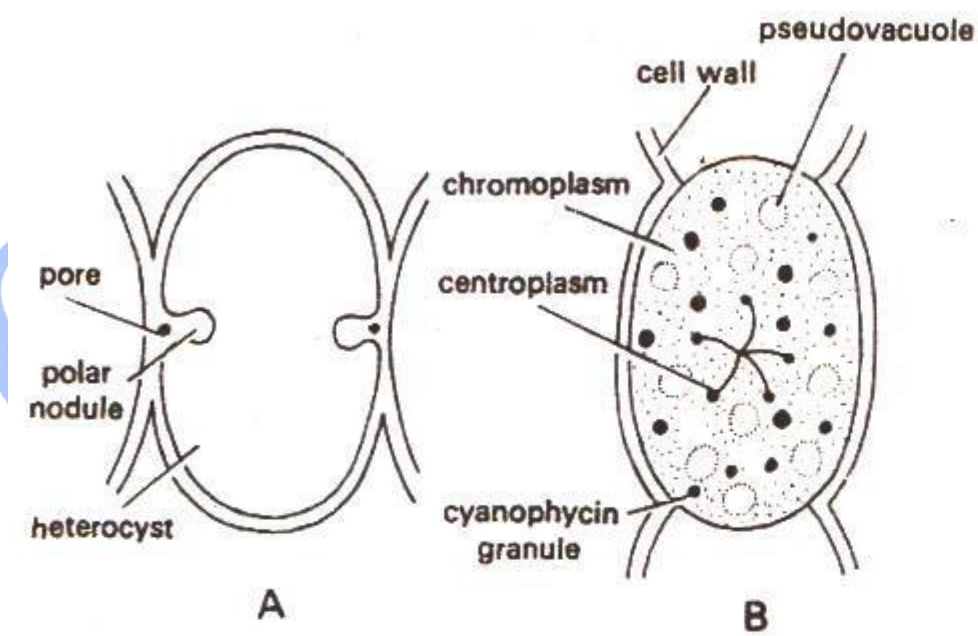
The trichomes are much contorted , moniliform and intertwined. They wind about in every direction in the gelatinous matrix. They are more crowded towards the periphery of the colony to form a dense limiting layer. Each trichome is composed of numerous rounded or oval cells. The cells are joined loosely from end to end into a trichome somewhat resembling a string of beads. At frequent intervals along with the trichome are found colourless ,empty looking , spherical or barrel shaped cells called the **heterocysts.** They are slightly large and have thicker walls than the vegetative cells and are intercalary , sometimes terminal.( N. linckia). They occur singly , sometimes in series. Each intercalary heterocyst , when first formed has two polar pores. Through these pores cytoplasmic connections are maintained with the adjacent vegetative cells.

**Cell Structure:-**

The cell consists of the **cell wall** surrounding the **protoplast.** The protoplast is vaguely defined into the outer pigmented cytoplasmic region called the **chromoplasm** and the inner colourless **centroplasm.** The chromoplasm has the usual pigments **(phycocyanin, chlorophyll a etc)** located in the lamellae which form a system of without lamellae. It also contains the colourless granules of myxophycean or cyanophycean starch and the cyanophycean granules of proteinaceous nature.




A-B. *Nostoc* : A. Gelatinous colony, B. Trichome.




A-B. *Nostoc* : A. Heterocyst, B. Cell structure as seen under light microscope.

**Reproduction:-**

Nostoc reproduces entirely vegetatively by the following methods:-

**(1) Colony Fragmentation:-**
The Nostoc colony as it gets larger frequently breaks into flat expanses as a result of storms and other disturbances. Each of these grows up to the size of the parent colony.

**(2) Hormogonia:-**
Hormogone formation is very common in Nostoc. The trichome ruptures at places where a heterocyst and the vegetative cells adjoin. This junction is the weakest link in the chain. In fact some algologists believe that heterocysts represent a mechanism for the fragmentation of the trichome. In this way short segments of living cells called the **Hormogonia** became isolated. The Hormogonia slip out of the enclosing gelatinous matrix and establish new colonies by division. The terminal cells of the Hormogonia differentiate as heterocysts. The intercalary cells then divide in a plane parallel to the axis of the trichome forming a jacket of cells.

**(3) Resting spores or Akinetes:-**
Under certain conditions any cell or some of the vegetative cells of the trichome become enlarged and each secretes a thick , highly resistant wall around it. They get gorged with reserve food materials. Such specially modified vegetative cells are called the **Akinetes** or **resting spores.** These are well adapted to survive unfavourable conditions such as water shortage and unsuitable temperature. It is not unusual to find all the cells between two heterocysts and occasionally the entire trichome converted into Akinetes. With the return of favourable season each akinete germinates to form a new filament of Nostoc.

**(4) Endospore formation:-**
Brand (1901) and Spratt (1911) reported that the contents of the heterocysts in **Nostoc commune** and **Nostoc microscopicum** divide to produce **endospores.** The endospores , on liberation , give rise to new filaments.

**Q2 Describe in detail the Morphology , reproduction and importance of Oscillatoria**

**Ans Occurrence:-.**

It is an exceedingly common , fresh water filamentous dark , blue green alga. It occurs in a wide variety of habitats. Usually it is found on damp soil , in temporary rain water pools and roadside ditches. Patches of entangled masses of filaments with the adherent mud are often found floating on the surface of fresh water channel. Bottoms of shallow temporary puddles and ditches , drains or sewers are usually covered with large patches of Oscillatoria.

**Thallus:-**

The thallus consists of free living trichomes which often form a compact , tangled floating mass or occur in the form of shiny mass on moist soil. It has a distinct filamentous texture. Occasionally , the trichomes occur singly. Each trichome is a long , very fine thread like unbranched structure. Most frequently it is naked or appears naked because the sheath around it is very delicate and poorly developed. The trichomes are usually smooth, sometimes constricted at the crosswall, straight and rigid or accurate. They are septate , the septa are faintly visible and often marked by rows of granules on either side. Except the end cell, all are alike and discoid. They are pressed flatly against one another in long rows. Due to mutual pressure the cells are shortly cylindrical. Some species of Oscillatoria have broader trichomes than the others. In the species with narrow trichomes the cells are as long as broad or longer than broad.

**Movements:-**

The striking characteristic of Oscillatoria is the slow , rhythmic but active movement of its trichomes. Under the electron microscope , the movements are seen to be of the following three types:-

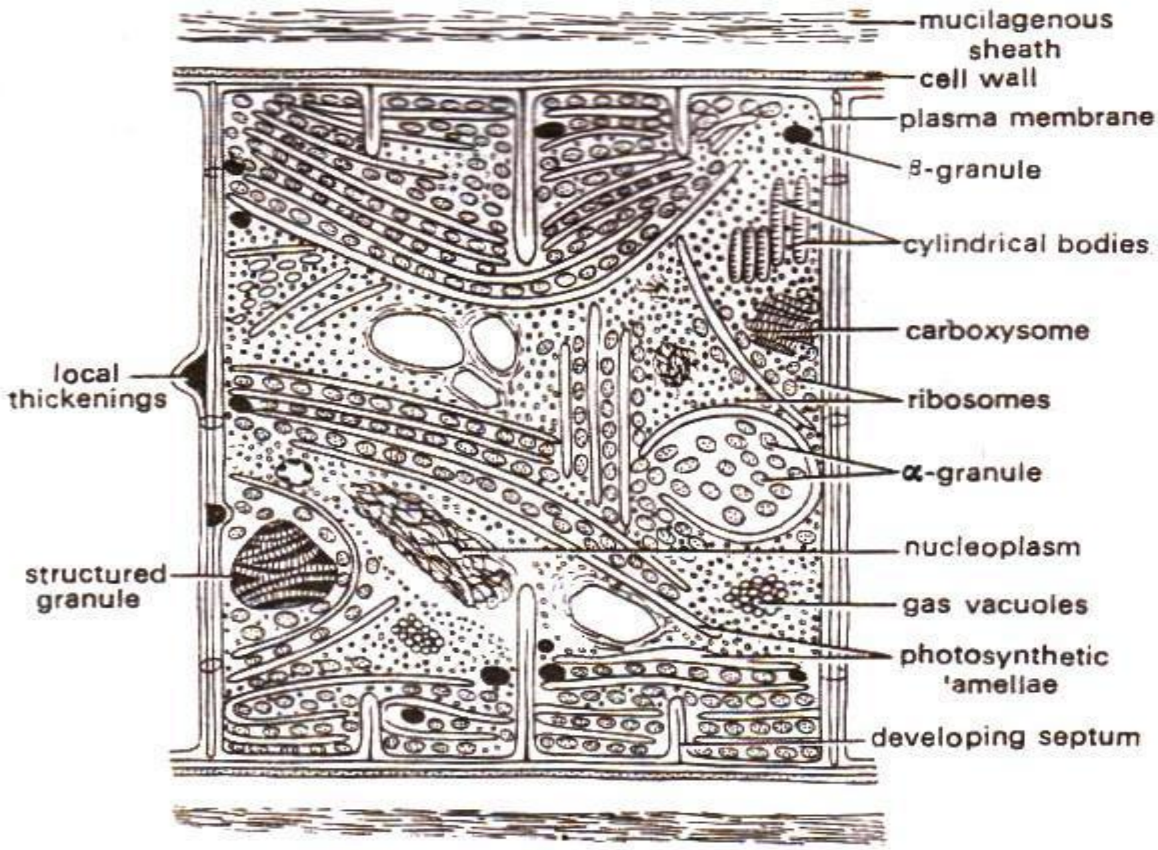
**(1) Gliding or creeping movements:-**
**Jarosch** defined gliding as the " active movement of an organism in contact with a solid substratum where there is neither a visible organ responsible for the movement, nor a distinct change in the shape of the organism. These rhythmic movements take place in the direction of the long axis of the trichome. They are called the **axial movements.**

**(2) Oscillatory movements:-**
**Oscillatoria** also exhibits slow varying movements. These are somewhat jerky , pendulum like oscillations of the front end , hence the generic name (**oscillare to swing) .**

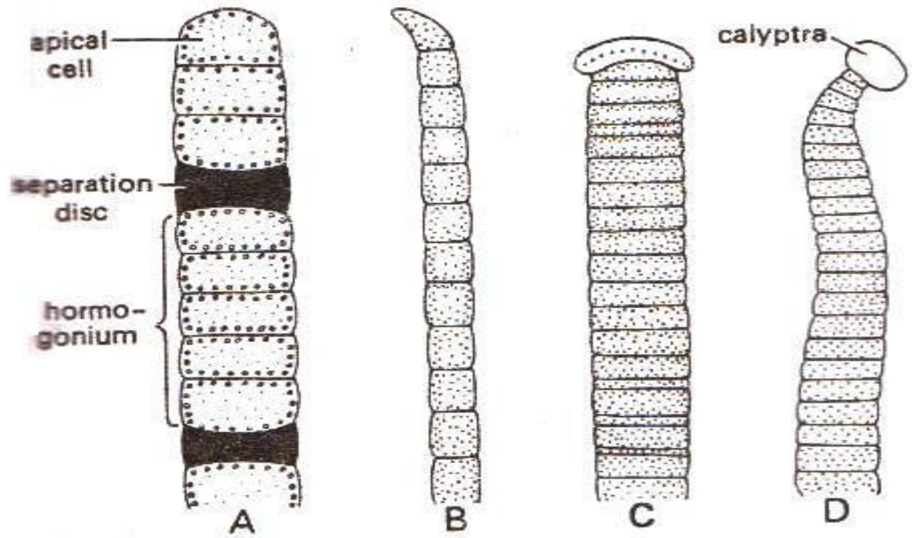
**Cell Structure:-**

All the cells in the trichome are similar in structure. The cell wall being stable there is hardly any conspicuous mucilaginous sheath external to it . According to **Halfen** and **Castenholtz** , the cell wall in **O. princeps** ultrastructurally consists mainly of a thick (2000 Å) structural layer external to the plasma membrane. Outside the structural layer is 160Å thick another layer. There is a third 90Åthick membrane – like layer loosely wrapped around the inner two. The 160Ålayer and the outer membrane are continuous over the trichome surface. They do not take part in the formation of the cross walls.

The cell protoplast shows distinction into an outer coloured cytoplasm, the **chromoplasm** which surrounds the colourless central area called the **centroplasm** or **central body .** The **chromoplasm** is invested by a two – layered plasma membrane. The protoplast lacks the plastids , mitochondria , endoplasmic reticulum and dictyosomes. The pigments are located in the flattened sac – like structures called the **lamellae** or **thylakoids** forming an array of parallel paired membranes embedded in the chromoplasm. The lamellae are not organized into grana. Besides the **Cyanophycean starch** and cyanophycean granules , the contents of the cell , especially in the planktonic species, may include **pseudo – vacuoles.** The central body represents the **incipient nucleus.** It consists only of a mass of scattered chromatin granules but lacks the **nuclear membrane`and the nucleoli.** Under electron microscope , the centroplasm is seen to consist of a faintly granular ground matrix in which are found embedded crystalline like bodies and clear areas.




*Oscillatoria* : Cell structure as seen under electron microscope.




A-D. *Oscillatoria* : Filaments showing different types of apices; A. *O. annae*, B. *O. acuminata*, C. *O. princeps*, D. *O. proboscidea*.

**Reproduction:-**

Oscillatoria reproduces vegetatively. The only known method is by the formation of **hormogones.** The hormogones are short sections or lengths or living cells separated from the trichomes. The break takes place where a **dead cell (necridium)** is situated.

During the growing season a cell here and there in the trichome will collapse. (dies). The protoplast of such cells changes into a transparent , viscous substance called the **mucilage.** The mucilage filled dead cells are called **necridia.** The dead cell loses its turgidity. The mutual pressure on the walls of the adjacent cells is released. They become convex so that the dead cell appears biconcave. These biconcave dead cells or separation discs provide weak links in the trichome and thus mark the points of disjunction of the trichome into **hormogones.** The mucilage swells and necridia break down releasing the hormogones. Each hormogone may consist of a few to several living cells. Sometimes a hormogone break off from the extremity of the trichome. The hormogones exhibit a greater capacity for a slow forward motion than the vegetative trichome.

**Q 3 What are Mycoplasmas? Describe their structure and comment briefly on their economic importance.**

**Ans** Mycoplasmas are the smallest known aerobic prokaryotes without a cell wall. These microorganisms were first discovered by **Pasteur** while studying the causative agent of pleuropneumonia in cattle ( bovine pleuropneumonia ). They were designated as PPLO ( pleuropneumonia – like organisms ). In 1898 , two French microbiologists , Nocard and Roux , were successful in obtaining pure cultures of these microorganisms in media containing serum. Mycoplasmas are frequent contaminants in tissue cultures rich in organic mater. They have also been found in hot – water springs and other thermal environments. They occur in soil, sewage water , different substrates and in humans , animals and plants.

**Structure of Mycoplasmas:-**

The absence of a true cell wall makes these organisms highly plastic and readily deformable, hence Mycoplasmas are irregular and variable in shape. The cells may be coccoid , granular , pear shaped , cluster like , ring like or filamentous. The filaments may be branched or unbranched. The cells are small , ranging in diameter between 0.3 and 0.9 µm.

These organisms are covered with a unit lipoprotein cytoplasmic membrane , 7.5 – 10 µm thick. The cytoplasm contains ribosomes and nucleoplasm – like structure. Though genetic material is composed of both DNA and RNA , it is less than half that usually occurs in other prokaryotes and is perhaps the lowest limit required for a cellular organism. The amount of DNA is up to 4 per cent and RNA about 8 per cent. The G+ C content in DNA ranges between 23 and 40 per cent. Mycoplasmas may be the simplest form of life capable of independent growth and metabolism.

Mycoplasmas are Gram – negative and stain slowly on long exposure to dyes. They are usually non – motile ; some forms , however , show gliding movements. They reproduce by budding or binary fission. They are sensitive to oxytetracycline, streptomycin, erythromycin and chloramphenicol. They do not have cell wall with peptidoglycans (like that of bacteria) and are insensitive to penicillin and some other antibiotics such as ampicillin and methicillin , which specifically affect peptidoglycan synthesis.

**Nature of Mycoplasmas:-**

Mycoplasmas can grow in a medium which contains no living tissues. They can also pass through many filters which cannot pass bacteria. Because of these two characteristics Mycoplasmas are considered to be intermediate between bacteria and viruses . Chemically , they are more close to bacteria than viruses.

**Some important Mycoplasmal diseases:-**

**Mycoplasmas** cause serious diseases in human beings , animals and plants. Some of these are described :-

**(I) Pathogenesis and diseases in human beings:-**

Pathogenic Mycoplasmas affect the respiratory organs , central nervous system , cardiovascular system and urogenital system in human beings. **Mycoplasma hominis ,** causes pleuropneumonia , inflammation of genitals , non – specific urethritis , endocarditis , prostatitis and other diseases.

Mycoplasma pneumoniae causes primary atypical pneumonia (PAP) , haemorrhagic laryngitis and vesicular inflammation of tympanic membrane. **Mycoplasma hominis** and **Mycoplasma fermentants** are known to cause infertility in man.

**(II) Pathogenicity for animals:-**

**Mycoplasma mycoides** causes pleuropneumonia in cattle. Some strains of Mycoplasma produce

**Q4 Define Virus? Give a detailed account of the morphology of Viruses?**

**Ans** Virus is a parasite in all types of organisms. They infect animals , plants , bacteria , algae , insects etc. Lwoff defined that ' Viruses are infectious , potentially pathogenic nucleoprotein with only one type of nucleic acid which reproduce from their genetic material , are unable to grow and divide and devoid of enzymes.

Luria and Darnell defined that Viruses are entities , whole genome of which are element of nucleic acid that replicate inside the living cells using the cellular synthetic machinery and causing the synthesis of specialized elements that can transfer the viral genome to other cell. While defining the microorganisms viruses are set apart on the basis of certain characters as given below by Lwoff and Tournier.:

**(i) They are all potentially infectious.**
**(ii) Presence of a single nucleic acid.**
**(iii) Incapability to grow the genetic material only.**
**(iv) Reproduction from the genetic material only.**

**(v) Absence of enzymes for energy metabolism (Lipman system).**
**(vi) Absence of ribosomes.**
**(vii) Absence of information for the production of enzymes in the energy cycle.**
**(viii) Absence of information for the synthesis of ribosomal proteins, and**
**(ix) Absence of information for the synthesis of ribosomal RNA and soluble tRNA.**

**II. Occurrence:**

Viruses occur on a very wide hosts such as plants ( angiosperms , gymnosperms, ferns , algae fungi) and animals ( protozoans , insects , fish , amphibians , birds , mammals , humans) . They cause very serious diseases in crop plants , ornamental plants and forest trees resulting in decreased growth , yield and mortality.

**III Morphology of Viruses:-**

**1 Shape:**

Viruses are of different shapes such as spheroid or cuboid ( adenoviruses) , elongated ( potato viruses ) , flexuous or coiled ( beet yellow ) , bullet shaped ( rabies virus) , filamentous ( bacteriophage M13 ) , pleomorphic ( alfalfa mosaic) etc.

**2.Size:**

Viruses are of variable sizes . Initially their sizes were estimated by passing them through membranes of known pore diameter. In recent years , their size is determined by ultracentrifugation and electron microscopy. Size vary from 20nm to 300 nm in diameter. They are smaller than bacteria ; some are slightly larger than protein and nucleic acid molecules and some are about of the same size. ( small pox virus) as the smallest bacterium and some virus ( virus of lymphogranuloma, (300 – 400 µm) are slightly larger than the smallest bacterium.

**3. Viral Structure:**

The complete assembly of the infectious particle is known as virion. A **virion** consists of a nucleic acid core surrounded by a protein coat or **capsid.** The complete set of virion is known as nucleocapsid. In turn the nucleocapsid may be naked or enveloped by as loose covering. The capsid is composed of a large number of subunits known as capsomeres.

Chemically the envelope is made up of proteins and glycoproteins

. Due to the presence of lipid the envelope seems flexible and loose. Envelope is composed of both the host and viral components i.e. protein ( virus specific) and carbohydrates ( host specific).

There are certain projections on the envelope known as spikes which are arranged into distinct units. The morphological types of virus observed through electron microscopy and crystallography have been categorized into the following three groups:

**(i) Helical ( cylindrical) Viruses:**

(a) Naked capsule e.g. TMV and the bacteriophage M13, etc.

(b) Enveloped capsid e.g. influenza virus.

**(ii) Polyhedral ( icosahedral ) Viruses:**

( a) naked capsid e.g. adenovirus , polio viruses etc.

(c) Enveloped capsids e.g. herpes simplex viruses etc.

**(iii) Complex Viruses:**

(a) Capsids are clearly identified e.g. vaccinia virus etc.

(b) Capsids to which some other structures are attached e.g. some bacteriophages etc.

**(i) Helical Viruses:**

The helical viruses are elongated , rod shaped , rigid or flexible. Their capsid is a hollow cylinder with a helical structure. Capsid consists of monomers arranged helically in a rotational axis. The helical capsule may be naked ( e.g. TMV) or enveloped. ( e.g. influenza virus).

**(a) Naked viruses:**

One of the examples of the naked viruses is the TMV. Stanley isolated TMV in the crystalline form from leaf sap of the infected tobacco plants. TMV virus is rod shaped measuring about 280 × 150 – 180 µm. It consists of a protein tube with a lumen of 20 Å which encloses a single stranded (ss) helix of coiled RNA. Protein coat of the virus contains a number of identical subunits ( monomers) which are arranged in a helical manner. A capsid consists of several capsomers each composed of a few monomers. Forty nine monomers ( each with molecular weight 12.000) take three turns of the helix and give a total of 2,130 subunits of the rod.

**(b) Enveloped viruses:**

When the helical viruses are enclosed within an envelope they are known as enveloped helical viruses , for example **Influenza virus.** The envelope is composed of a viral protein and the host cell components i.e. lipid and carbohydrates. The envelope consists of numerous spikes.

The helical capsid exists in folded form inside the envelope and sometimes may show pleomorphic appearance.

**(ii) Polyhedral (Icosahedral ) Viruses:-**

There are several animal , plant and bacterial viruses which have either naked or enveloped icosahedral shape. Polyhedral structure has the three possible symmetries such as tetrahedral , octahedral and icosahedral. The viruses are more or less spherical. Therefore, icosahedral symmetry is the best one for packing and bonding of subunits. An icosahedron is a regular polyhedron with 20 triangular faces and 12 corners. The capsomers of each face form an equatorial triangles and 12 intersepting points or corners.

Basically there are two types of capsomers , the pentamers and hexamers. The pentamer is a cluster of 5 monomers and the hexamer is a cluster of 6 monomers. The monomers are linked together by bonds. Thus, the capsomers are also linked together by bonds which are weaker than those of monomers due to their breaking into the capsomers during the purification of viral particles.

**(a) Naked icosahedral viruses:-**

Naked icosahedral viruses are turnip yellow mosaic virus (TYMV) , poliovirus, adenovirus and bacteriophage Ø× 174, QB etc. Adenoviruses are large ( 80 nm diameter) , icosahedral containing dsDNA. The capsid has the ring like capsomers each containing pentamers and hexamers. A total of 32 hexamers and 12 pentamers are found in the capsid. The hexamers are polygonal discs of 8nm diameter with a hole of 2.5 nm diameter in the centre.

At the surface of capsid these spike like structures form 12 points of the five fold symmetry. The capsomers are assembled to construct the capsid in a specific geometrical pattern where the pentamers form the corners of the icosahedron and the hexamers occupy the internal space.

**(b) Enveloped icosahedral viruses:-**

There are some of the enveloped icosahedral viruses, for example herpes virus where the capsid is enclosed inside an envelope of 30nm thickness that is made up of a glycoprotein – lipid complex. The envelope consists of spikes on its surface. The capsid is spherical and of about nm diameter enclosing a dense core of dsRNA molecule. The capsid contains 162 capsomers ( 12 pentamer capsomers at apices and 150 hexamer capsomers at the faces).

**( c) Complex Viruses:-**

The viruses which have the unidentifiable capsids or have the capsids with additional structures are called complex viruses, for example , vaccinia virus and T – even bacteriophages. In addition, the other variations in the structure of complex viruses are also found such as ( i) a definite capsid absent ( e.g. vaccinia virus , (ii) capsid present and consists of a tail . The second group consists of different types ,for example , tadpole shaped viruses ( with head and tail . e.g. T- even phage) , viruses with tail less head ( phage γ, $T_1$, $T_5$ ) , virus with brick shaped and devoid of flattened cylinder ( pox virus) , bullet shaped capsid viruses ( e.g. nuclear polyhedrosis or cytoplasmic polyhedrosis viruses).

**4 Envelope:-**

There are certain plants and animal viruses and bacteriophages , both icosahedral and helical , which are surrounded by a thin membranous envelope. This envelope is about 10 – 15µm thick. It is made up of protein, lipids and carbohydrates which are combined to form glycoprotein and lipoprotein. Lipids provide flexibility to the shape, therefore, viruses look of variable sizes and shapes. Protein component of the envelope is of viral origin and lipid and carbohydrates may be the features of the host membrane i.e. nuclear or cytoplasmic. The ssRNA viruses after replication in hosts cytoplasm are released by budding through plasma membrane . During release these are enveloped by a part of the membrane of the host cell which resembles a typical membrane. The membrane is made up phospholipid bilayer in which proteins are embedded. The spikes attached to the outer surface of the envelope is made up of glycoproteins. Spikes have agglutination proteins. In other group of viruses e.g. dsDNA bacteriophage, PM2 , dsRNA bacteriophage Ø6, iridescent dsDNA insect viruses and the pox viruses , the lipid bilayer is not derived from the host membrane. The lipids present in viral envelope fall under the four classes (i) phospholipids ( e.g. sphingomyelin, phosphatidyl choline , phosphatidyl serine and phosphatidyl inositol), ( ii) cholesterol (iii) fatty acid and (iv) glycolipids ( e.g. glycosphingolipids made up of sphingosine , fatty acid and carbohydrates).

**5 Nucleic acids:-**

Viruses contain either single or double stranded DNA or RNA molecules. The nucleic acids may be in linear or circular form, and have plus or minus polarity. Nucleic acids of several plant viruses occur in their respective particles in one pieces. However, the reovirus is known to contain the nucleic acid in 10 segments . The segmented nucleic acids is also found in wound tumour virus and influenza virus.

**6 Proteins:-**

Proteins found I viruses may be grouped into the four categories: (i) envelope protein, (ii) nucleocapsid ( structural ) protein ( iii) core protein and ( iv) viral enzymes.

**(i) Enveloped Protein:-**

Envelope of the viruses consists of proteins specified by both virus and host cell. Membranes of all classes of enveloped viruses contain glycoprotein . In influenza virus the main protein is the carbohydrate free protein which comprises of 50% of envelope protein and 35 – 40% of virion protein as a whole. Herpes viruses , poxviruses and leukoviruses do not contain protein in the envelope specified by them. It has been found that the envelope proteins are enclosed by the genome of arboviruses, rhabdoviruses and myxoviruses. In addition, the glycoproteins differ from virus to virus. For example, one glycoprotein in rhabdoviruses , two glycoproteins in paramyxoviruses and four glycoprotein in orthomyxoviruses have been found.

**(ii) Nucleocapsid Protein :**

The viral capsids are made up totally of proteins of identical subunits ( promoters) . The helical capsids contain single type of protein and icosahedral capsid contains several types of proteins. For example , TMV contains single protein types, adenovirus contain 14 protein types. T**4**bacteriophage contains 30 protein types etc.

**(iii) Core Protein:**

Protein found in nucleic acid is known as core protein . for example nucleoproteins of influenzavirus and proteins V and VI of adenoviruses.

**(iv) Viral Enzymes:-**

In animal viruses especially in the enveloped viruses , many virion specific enzymes have been characterized , for example , RNAase and reverse transcriptase in retrovirus, protein kinase in herpes and adenoviruses ,DNA dependent RNA polymerase in poxvirus.

**7 Carbohydrates:-**

A substantial amount of carbohydrate specified by either host cell ( e.g. arbovirus) or viral genome (e.g. vaccinia virus) is found in viral envelope . For example galactose , mannose , glucose , fucose , glucosamine , galactosamine are found in influenza virus, SV5 and sindbis virus. The carbohydrates are hexoses and hexamines which are present in the form of glycoprotein and / or glycolipids.

**Q5 Give a detailed account of the Structure of the Bacterial Cell.**

**Ans** Upon observation under microscope there reveal several structural components outside and inside the cell wall .

**(1) Capsule:-**

Some of the bacterial cells are surrounded by the extracellular polymeric substances(EPS) which are commonly called capsule glycocalyx. It forms an envelope around the cell wall and can be observed under light microscope after special staining technique. The presence of Capsule may be detected by negative staining also such as India ink method. The capsule is gelatinous polymer made up of either polysaccharide (**Klebsiella pneumoniae**) or polypeptide (**B. anthracis**) or both. The polysaccharides may be of a single type of sugars (homopolysaccharide) or several types of sugars (heteropolysaccharides) .Homopolysaccharide constitutes the capsule of **Acetobacter xylinum** ,and heteropolysaccharide (consisting of D – glucose . D – galactose , D- mannose . D- gluconic acid) is secreted by **Pseudomonas aeruginosa .** The capsule of pneumococci is made up of hexoses , uronic acid and amino sugars and that of streptococci consists of L- amino acids. The bacterial capsule is sticky in nature and secreted form the inner side of the cell which gets firmly attached to the surface of the cell wall. If the substances are unorganized and loosely attached to the cell wall , the capsule is called as slime layer. The fresh water and marine bacteria form trichomes which are enclosed inside the gelatinous matrix called sheath. Sheath is also found in cyanobacteria and other algae.

**Functions of Capsule:-**

(i) The capsule may prevent the attachment of bacteriophages.

(ii) It protects the bacterial cells against desiccation as it is hygroscopic and contains water molecules.

(iii) It may survive in natural environment due to its sticky property. After attachment , they can grow on diverse surfaces e.g. plant root surfaces , human teeth and tissues (dental carries , respiratory tract) , rocks in fast flowing streams.

(iv) They may inhibit the engulfment by WBCs (antiphagocytic feature) and therefore contribute to virulence.

(v) S. mutans uses its capsules as a source of energy. It breaks down the sugars of the capsule.

(vi) Capsule protects the cell from desiccation, the viscosity and inhibits the movement of nutrients from the bacterial cell.

**(2) Flagella:-**

The motile bacterium may possess a flagellum . The flagellum is hair like, helical and surface appendages emerging from the cell wall. It provides various types of motility to the bacterial cell. In addition , the number and position of flagella vary.

The arrangement may be **monotrichous** ( a single polar flagellum e.g. **V .cholerae)** , **lophotrichous (** a cluster of polar flagella e.g. **Spirillum) amphitrichous** ( flagella at both the ends either singly or in clusture) , **cephalotrichous** (two or more flagella at one end of the bacterial cell e.g. **Pseudomonas**) **, peritrichous** (cell surface evenly surrounded by several lateral flagella e.g. **Proteus vulgaris) or atrichous** (cells devoid of flagella e.g **. Lactobacillus**) .

**(i) Structure of Flagella:-**

The structure and function of bacterial flagella have been described by Simon et al. A flagellum consists of three basic parts , the basal body , hook and filament).

**(a) Basal Body:-**

M.L. De Pamphilis and J. Alder isolated the basal body of the flagellum of **E. coli** and **B. subtilis** and studied its fine structure and arrangement of rings. The basal body attaches the flagellum to the cell wall and plasma membrane. It is composed of a small central rod inserted into a series of rings.

In Gram – negative bacteria two pairs of rings , the proximal ring and the distal ring are connected by a central rod. These two pairs of rings i.e. four rings are L – (lipopolysaccharide) ring . P – (Peptidoglycan ) ring, S – (super membrane ) ring, and M- membrane ring .

The outer pair of rings . L – ring and P – ring are attached to respective polysaccharide and Peptidoglycan layer of cell wall and the inner pair of rings i.e. S- ring and M – ring are attached with cell membrane.

**(b) Hook:-**

The hook is present outside the cell wall and connects filament to the basal body. It consists of different proteins. The hook in Gram- positive bacteria is slightly longer than the Gram – negative bacteria.

**( c) Filament or shaft:-**

The outermost long region of the flagellum is called filament or shaft. It has a constant diameter and is made up of globose proteins, the flagellin , the flagellins are arranged in several chains that intertwine and form a helix around a hollow core. The proteins of flagella act to identify certain pathogenic bacteria unlike eukaryotes , the filaments are not covered by a membrane or sheath.

**(3) Pili and Fimbriae:-**

**Pili and Fimbriae** are hair like appendages found on the surface of the cell wall in Gram –negative bacteria.( e.g. Enterobacteriaceae, Pseudomondaceae) . The term Fimbriae is used for all hair like structure covering the surface of the cell. Pili are genetically governed by plasmids , the number of which varies from 3 to 5. The number of Fimbriae is around 1,000. Pili differ from flagella in being shorter and thinner, straight and less rigid. But they are in large number.

**Classes of Pili:**

According to the function pili are of two types:

**(a)** Common pili which act to adhere the cell to surfaces and (b) sex pili which join the other bacterial cell for the transfer of genome. Ottow has classified the pili into the following six groups:

**Group 1:**Fimbriae of this group act for adherence to a particular surface including the surface of the other cells too. These are about 300 per cell arranged peritrichously . Pili of **Neisseria gonorrhoae ,** the causal agent of gonorrhea , help the bacterium to colonize the mucous membranes.

**Group2:** The sex pili of this group have a uniform diameter of about 9mm and length of about 1- 20µm. There are about 10 pili per cell. They are filamentous and determined by sex factor. The plasmid carries genes that code for the synthesis of sex pili. They make contact between the two cells.

**Group3:**Fimbriae of third group is peculiar that are found in **Agrobacterium.** They are thick and like the hollow tubes.

**Group4:** This group consists of pili which are flexible, rod – shaped and polar. These are found in the species of **Pseudomonas** and **Vibrio.**

**Group 5:** Fimbriae of group 5 are polarly arranged and are contractile in nature. They are found in **Agrobacterium spp; Pseudomonas rhodes.** They contract and pull two bacterial cells into close contact and therefore, promote the conjugation process.

**Group6: Group 6**is the characteristic bundles of Fimbriae found in Gram – positive **Corynebacterium renale.**

**(ii) Structure of Pili:**

Both fimbriae and pili are like flagella as both are the appendages on the bacterial cell wall. They originate from cytoplasm that protrudes outside after penetrating the Peptidoglycan layer of the cell wall. Fimbriae are made up of 100% protein called fimbrilin or pilin which consists of about 163 amino acids. Fimbrilin has a molecular weight of about 16,000 daltons. The sex pili are the cylinder of repeating protein units. Its filamentous structure is governed by the sex factor (plasmid) of the bacterium for example Ffactor , Col 1 factor and R factor. There are two types of pili in E.coli foe example F – pili (determined by F factor) and I – pili (determined by Col I factor) .

**Functions of Pili:-**

**(a)** Bacteria containing fimbriae are called fimbriae bacteria. Fimbriae have the adhesive properties which attach the organism to the natural substrate or to the other organism.

(b) Fimbriae are equipped with antigenic properties as they act as thermolabile nonspecific agglutinogen.

(c) Fimbriae affect the metabolic activity. The $Fim^+$ cells (cells containing fimbriae) possess higher rate of metabolic activity than the $Fim^-$ cells (cells devoid of fimbriae). Moreover , they function as aggregation organelles.

(d) The sex pili make contact between two cells. Since they possess hollow core, they act as conjugation tube . The tip of pileus recognizes the female ($F^-$ cell) through which the genetic material of the donor ($F^+$ )cell passes to the recipient (female )cell. Only F-pili (not I- pili) contain axial hole.

**(4) The Cell Wall( Outer Membrane):-**

The cell wall of bacteria is a semirigid and complex structure present beneath capsule and external to the plasma membrane. It is responsible for characteristic shape of the cell. The cell wall protects the plasma membrane and the other cytoplasmic inclusions from adverse environment. It also protects the bacterial cell from bursting when the osmotic pressure of cytoplasm is higher than that of the outside of the cell wall. It provides support for attachment to the flagella.

**Chemical Composition and Wall Characteristics:-**

The cell wall f bacteria is made up of network of peptidoglycan (murein , murus means wall) It is present almost on all bacterial cell wall except **Halobacterium** and **Halococcus.** Because these bacteria live in marine water which contains high salt concentration. Peptidoglycan determines the shape of the cell. It is insoluble and porous polymer that provides rigidity. It is mucopolysaccharide . It accounts for 40 – 80 % of total dry weight of the cell . Its thickness is about 30 – 80 nm.

**(i) Gram – positive Bacteria –**

In most of the Gram – positive bacteria, the cell wall contains several layers of peptidoglycan which is inter – connected by side chains and cross bridges. Peptidoglycan accounts for 40 – 90 % of the total dry weight of cell wall. The thickness of peptidoglycan provides rigidity to the cell wall. The layers of peptidoglycan are thicker in Gram – positive bacteria than that in Gram – negative bacteria. In most of Gram – positive bacteria peptidoglycan is associated with acidic polymers containing phosphorus called **teichoic acid** or acidic polysaccharides such as **teichuronic acids**. Teichoic acids are hydrophilic , flexible and linear molecules. The presence of teichoic acids makes easy to diagnose the bacteria serologically.

Teichoic acids consist of an alcohol ( e.g. glycerol or ribitol) and phosphate. Therefore, it is the polymer of glycerol phosphate or ribitol phosphate. Teichoic acids are mainly of three types (i) ribitol teichoic acids ( found in S. aureus and B. subtilis) , (ii) glycerol teichoic acid ( e.g. B. subtilis) and (iii) glucosylglycerol phosphate teichoic acid ( B. licheniformis ). Out of these only one type is found in a particular bacterium. The acids are linked to layers of peptidoglycan of plasma membrane. The phosphate groups provide negative charge which in turn controls the movement of cations i.e. positive ions across the cells.

**(ii) Gram negative bacteria:-**

The Gram – negative bacteria contain peptidoglycan but in very low amount. They totally lack teichoic acids. Peptidoglycan is situated in periplasmic space and covalently linked to lipoproteins in the outer membrane. The periplasmic space is a space between the outer membrane and plasma membrane which appears like gel and contains high amount of enzymes and transport proteins. Due to the presence of low amount of peptidoglycan, the cell wall of Gram – negative negative bacteria is a bilayered structure consisting of mainly lipoproteins , lipopolysaccharides (LPS) and phospholipids.

**Functions of Cell Wall :**

(a) Peptidoglycan provides structural integrity of cell by forming a rigid layer in outer membrane. The matrix proteins to some extent also contribute to structure with peptidoglycan.

( b) The cell envelope acts as barrier for diffusion to certain molecules across the envelope.

( c) The matrix proteins act as receptor sites for bacteriophages and bacteriocins.

( d) The O – antigen side chain of polysaccharide of LPS determines the antigen specificity of Gram – negative bacteria.

**(5) Plasma Membrane ( Cell or Cytoplasmic Membrane):-**

The plasma membrane also called as cell membrane or cytoplasmic membrane is a structure internal to the cell wall. The term cell membrane was coined by **C . Nugeli** and **C**. C**ramer.** However no cell could be alivewithout a plasma membrane. It is situated just beneath the cell wall and is 7.5nm thick. It consists of proteins (20 -70%) , lipids (28 – 80 %) , oligosaccharides ( 1 – 5%) and water (20%) . The plasma membrane consists of a continuous bilayer of phospholipid molecules in which globular proteins are embedded.

**Functions of Plasma Membrane:-**

The cytoplasmic membrane is the site of many metabolic activities as given below:-

( a) The organic and inorganic nutrients are transported by permeases through plasma membrane.

( b) It consists of enzymes of biosynthetic pathways that synthesize different components of the cell wall such as peptidoglycan, teichoic acids , polysaccharides , lipopolysaccharides and phospholipids.

( c) It possesses the attachment sites for the bacterial chromosome and plasmid DNA.

( d) The inner membrane invaginates to form mesosomes , a site for respiratory activity. The plasma membrane contains about 200 respiratory proteins that have been found to be anchored for the transport of $H^+$ ions.

(e) It provides permeability barrier and thus prevents the escape of cellular materials outside the cell and facilitate the selective entry of organic and inorganic substances inside. Hence , the plasma membranes show selective permeability.

**(6) Mesosomes:-**

Mesosomes are the invaginated structures formed by the localized infoldings of the plasma membrane. The invaginated structures comprise of vesicles , tubules of lamellar whorls. Generally Mesosomes are found in association with nuclear area or near the site of cell division. They are absent in Eukaryotes. The lamellae are formed by flat vesicles when arranged parallel. Some of the lamellae are connected to the cell membrane. The lamellar whorl can be observed in Nitrobacter , Nitromonas.

The vesicles are formed by invagination and tubular accretion of the plasma membrane. The structure of vesicle becomes interrupted due to constriction at equal distance. The constriction does not cause the complete separation of the tubules. Closely packed spherical vesicles are seen in **Chromatium** and Rhodospirillum rubrum.
The exact structure and function of Mesosomes are not known. Mesosomes are supposed to take part in respiration but they are not analogous to mitochondria because they lack outer membrane. In the vesicle of Mesosomes the respiratory enzymes and the components of electron transport such as ATPase , dehydrogenase , cytochrome are either absent or present in low amount. This emphasizes their inability to carry out transport processes in which the membrane is energized. In addition, Mesosomes are supposed as a site for the synthesis of some of the wall membranes.
Mesosomes might play a role in reproduction also. During binary fission a cross wall is formed resulting in formation of two cells. Mesosomes begin the formation of septum and attach bacterial DNA to the cell membrane. It separates the bacterial DNA into each daughter cell. In addition, the infoldings of Mesosomes increase the surface area of plasma membrane that in turn increase the absorption of nutrients.

**(7) Cytoplasm:-**
Cytoplasm of prokaryotes refers to the internal matrix of the cell inside the plasma membrane. Cytoplasm consists of water (80%) , proteins , carbohydrates , lipids , inorganic ions and certain low molecular compounds. Cytoplasm is thick and semitransparent. The DNA molecules , ribosomes and the other inclusions are the structure of cytoplasm. In certain cyanobacteria gas vacuoles are found .

**(i) Ribosomes:-**
All living cells contain ribosomes which act as site of protein synthesis. High number of ribosomes represents high rate of protein synthesis and vice versa. Cytoplasm of a prokaryotic cell contains about 10,000 ribosomes which account upto 30% of total dry weight of the cell. Presence of ribosomes in high number gives the cytoplasm a granular appearance. Prokaryotic ribosomes are smaller and less dense than eukaryotic ribosomes. Bacterial ribosomes are of 70S type .The sedimentation constant of the larger subunit is 50S and that of the smaller subunit is 30S.
In a young bacterium ribosomes may occur in groups of 4-6 or more. They are held together by a special RNA molecule , known as messenger RNA. These groups of ribosomes are known as **polyribosomes.**

( ii) **Nucleoids ( the bacterial chromosome):-**

The characteristic feature of the bacterial nucleus is the absence o nuclear membrane. Nucleolus , chromonemata and nuclear sap Such a nucleus is called **nucleoid** or **genophore.** Under electron microscope the nucleoid appears to be fibrillar and composed of a double or single stranded DNA. The DNA molecule is approximately 1000µm long, usually forming ring like structure or sometimes remains diffused throughout the cytoplasm of the cell. The nucleoid of Escherichia coli has a central core of RNA , surrounded by 12 – 82 supercoilings of DNA. A few protein molecules are also associated with DNA.

The bacterial DNA is devoid of histones, hence cannot be compared with the chromosomes of eukaryotic cells. However , its double stranded DNA is usually referred to as **bacterial chromosome.**

**Plasmids:-**

Bacterial cells also contain some extrachromosomal hereditary determinants which are either independent of bacterial chromosomes or are integrated with them. Lederberg coined the term plasmid for such extrachromosomal hereditary determinants. Hence the plasmids may be defined as a small circular, self – replicating and double stranded DNA molecule present in the bacterial cell , in addition to the bacterial chromosome. It replicates independently during cell division and inherited by both the daughter cells. Each plasmid carries non – essential genes and has no role in viability and growth of bacteria. Hence they are also said to be **dispensable autonomous elements.** The following nine types of plasmids are known:-

(i) F – factor ( for fertility) plasmids ,
(ii) R-factor ( for resistance) plasmids ,
(iii) col factor ( for colicinogeny ) plasmids of the Gram – negative bacteria
(iv) plasmids conferring pathogenecity to mammals
(v) degradative plasmids of Pseudomonas .
(vi) mercury – resistance plasmids ,
(vii) tumor inducing plasmids of Agrobacterium tumefaciens ,
(viii) penicillinase plasmids of Staphylococcus aureus and
(ix) cryptic plasmids.

**(8) Cytoplasmic Inclusions :-**

The cytoplasm of prokaryotic and eukaryotic cells contain several reserve deposits which are called as inclusions.

**Shiveley** has given an excellent account of inclusion bodies of prokaryotes. The inclusion bodies are of two types ( a) free inclusion bodies ( e.g. polyphosphate granules and cyanophycean granules ) and ( b) single layered non – unit membrane enclosed inclusion bodies ( such as poly β-hydroxybutyrate granules , sulphur granules carboxysomes and gas vacuoles. The membrane of inclusion bodies is made up of proteins or lipids. Some of the inclusions are discussed here:-

**( a) Volutin Granules:-**

The Volutin granules are also known as polyphosphate granules or metachromatic granules because after staining the bacteria with blue dye ( e.g. methylene blue) these granules take stain and appear reddish purple in colour. These granules are found in algae, fungi , protozoa, and bacteria. These are present in high amount in **Corynebacterium diphtheria ,** hence it can easily be diagnosed. The Volutin granules are composed of polyphosphates i.e. inorganic phosphates which are used in the synthesis of ATP.

**(b) Carboxysomes ( polyhedral bodies):**

Carboxysomes are found in photosynthetic bacteria , nitrifying bacteria , cyanobacteria and thermobacilli. These are polyhedral or hexagonal inclusions containing ribulose–1,5–biphosphate carboxylase. This enzyme is required in carbon dioxide fixation during photosynthesis.

**( c) Sulphur granules:-**

Sulphur granules are also temporarily stored by some bacteria which are also called a second type of inorganic inclusion body. It is exemplified by photosynthetic purple sulphur bacteria ( e.g. Thiobacillus, Thiospirillum , Thiocapsa) which are found in anaerobic , sulphide – rich zones of lake. They oxidize $H_2O$ to S and internally deposit as sulphur granules within invaginated structures of plasma membrane.

**(d) Lipid Inclusions:-**

**Lipids** are found in high amount in several species of Bacillus, **Azotobacter**, **Mycobacterium** , **Spirillum** etc. These are present as storage material and is polymer of poly β- hydroxybutyric acid . It is formed by the condensation of acetyl CoA. In Bacillus megaterium poly β- hydroxybutyrate (PHB) accounts for 60% of total dry weight when the bacterium has grown on acetate or butyrate (PHB). The monomers of poly β-hydroxybutyrate are linked by ester linkage forming the long poly β- hydroxybutyrate polymer. The collective term poly β- hydroxybutyrate represents all classes of carbon storage reservoir polymer acting as a source of energy and biosynthesis. These are found naturally both in Archaea but not in Eukarya.

**(e)Gas vesicles:-**

There are many prokaryotic microorganisms found in floating forms in lakes and sea that possess gas vesicles. Gas vesicles are gas – filled structures which contain the same gas in which the organisms are suspended. Gas vesicles provide buoyancy and keep the cells in floating form. The most important 'floating and sinking' phenomenon is found in those cyanobacteria which cause water blooms in lakes such as **Microcystis aquaticus and Anabaena flos- aquae.** Besides

, gas vacuoles are also found in certain purple and green phototrophic bacteria and some Archaebacteria such as halobacteria e.g. Thiopedia and Amoebobacter.

Gas vacuoles look like spindles of varying dimension ( 300-700 ×60 – 110 nm) and numbers ( a few to hundreds per cell) . They contain a rigid membrane and internally a hollow structure. The membrane consists of only proteins called GvpA and GvpC.

**Q6 Give a detailed account of reproduction in Bacteria.**

**Ans** There are three mechanisms by which these DNA fragments can pass from a donor to a recipient cell (i) transformation (ii) transduction (iii) conjugation

**(I) Transformation:**

Transformation was discovered by an English bacteriologist, Frederick Griffith in 1928 who made a series of experiments with laboratory mice and two types of pneumonia - causing bacterium , **Diplococcus pneumoniae.** This bacterium has two types of strains. One type has smooth (S) , capsulated cells, whereas another type has rough (R) noncapsulated cells. The disease is caused by smooth type of cells only i.e. smooth – type cells are pathogenic ( virulent) whereas rough type cells harmless or nonpathogenic ( avirulent) .

When live , harmless ( rough type) cells were injected in the body of mice , the animal remained healthy. The injection of dead , pathogenic ( smooth type) cells into the body of mice also did not cause any disease. In a classic experiment , Griffith mixed live , harmless ( rough type ) cells with the dead remains of pathogenic ( smooth type ) cells and then injected the mixture into the laboratory mice. The live cocci taken in the mixture were uncapsulated and formed rough colonies (R) on agar. The dead cocci taken in the mixture originally had a capsule and were taken from smooth ( S) colonies on agar. To Griffith's surprise , the mice developed pneumonia and died. On autopsy ( examination of tissue of dead animal) , he isolated live, capsulated cells that formed smooth colonies on agar. Apparently , the live , harmless rough cocci had been transformed in the mice into live , pathogenic , smooth cocci. A rough to smooth conversion (R S ) had been accomplished. Five years later, James L. Alloway of Rockefeller Institute confirmed Griffith's work using fragments from the dead smooth – type cells to transform the rough – type cells. In 1944 , Oswald T. Avery `Colin M. MacLeod and Maclyn N. McCarty , also of Rockefeller Institute found that deoxyribose- nucleic acid (DNA ) isolated from the fragments could induce the transformation. At that time, DNA was an obscure chemical with little significance. The work of Avery , MacLeod and McCarty helped bring it to the force. Their experiments were the first proof that in living organisms genetic matter is DNA. Though it takes place in less than 1% of a population , transformation is an important method of recombination in Bacteria. A number of donor cells break apart and an explosive release and fragmentation of DNA follows. A segment of double stranded DNA containing about 10 – 20 genes then passes through the cell wall and membrane of a recipient cell . Only a few **competent** recipient cells can take up the DNA. After entry into cell, an enzyme dissolves one strand of DNA leaving the second strand to be incorporated. This strand then displaces a segment from a strand of the recipient's DNA. The displaced DNA is dissolved by another enzyme in the cell. The cell is now transformed . It will display its own traits as well as those coded by the new DNA.

Transformation may also take place by the incorporation of plasmids to competent cells. In this case, no DNA is displaced. Rather , the plasmid adds genes to those already in the cell and multiplies alongwith the cell.

Since the 1940's . transformation has also been demonstrated in species of **Neisseria**, **Bacillus**, **Haemophilus** , **Azotobacter** and **Streptococcus**. The process involves the transfer of DNA from the fragments of donor cells into the cytoplasm of a live recipient cell. Sections of single – stranded or double stranded DNA may be taken up but only a single strand will align with the bacterial chromosome and becomes incorporated into it.

Transformations in bacteria have been observed in the ability to form a capsule, a drug resistance and pathogenicity, and in nutritional patterns. Transformations are not common , however because the large fragments of DNA molecule can not pass through the recipient's cell wall or membrane. In nature , transformation may increase the pathogenicity of an organism.

In cells of some genera of bacteria , DNA binds to the cell surface before uptake. However, this is restricted only to some genera. This problem has been overcome in both , pro – and eukaryotes by the removal of the cell wall to form protoplasts. Addition of a compound – **fusinogen** allows the protoplasts to fuse and mixing of DNA of two or more cells for recombination. This technique is known as **protoplast fusion.** When DNA is included in the incubation mixture transformation occurs simultaneously with fusion and thus small fragments of DNA e.g. plasmids , can be introduced into the cells. Protoplast fusion can also be managed between members of different species by mixing their protoplasts in the presence of a fusinogen. In this way , genetic exchange can be achieved between organisms for which no other gene transfer system is known to exist.

## (II) Conjugation:

(II) Conjugation:

It involves a transfer of genetic material from one living cell to another during a period of contact. In conjugation some cells are donor of DNA , while other are recipients. This process was first postulated by Joshua Lederberg and Edward Tatum in a series of experiments in 1946. Two strains of **Escherichia coli** were used . One was unable to synthesize an essential compound A whereas the other could not synthesize an essential compound B. Neither strain was able to grow in a culture medium lacking both , compound A and compound B because each strain lacked an important enzyme system.

Lederberg and Tatum mixed the cells of the two strains , and after a short incubation time , placed samples on the medium lacking both A and B . Bacterial growth appeared on this medium. When a few colonies appeared . it was first thought that transformation had occurred. However , it was shown experimentally that a physical cell contact was necessary for the recombination to take place. Apparently , the genes for synthesis of compounds A and B passed between the cells and yielded a recombined chromosome that could produce both the missing compounds.

Later experiments by Francois Jacob and Elie L. Wollman established that bacteria were of two mating types . Certain male types or **$F^+$** or **donor cells** were those that donated some of their DNA, whereas female type or **$F^-$** or **recipient cells** were the recipient of the genes. It was noted that recipient cells would rapidly become donor cells when certain small amounts of DNA were passed to a recipient cell. This eventually led William Hayes to discover genetic factors, called **fertility factors** or **F factors** , in the cytoplasm of the donor cell (male) apart from the chromosome. These are also called **sex – factors** or **F- plasmids. F – factors** are double stranded loops of DNA ,apart from the chromosome. The factors contain about 20 genes , most of which are associated with conjugation. One function of these genes is to form a **conjugation bridge** or **sex pilus** , between donor and recipient cells. The F – factor then prepares for replication by the rolling circle mechanism. There is no complete process of replication but as in replication , the two strands begin to separate from each other and a single strand of the factor passes through the sex pilus to the recipient. When it arrives , enzymes synthesize complementary strand and a double helix forms again. The double helix bends into a loop and the conversion from F to $F^+$ cell completed. Meanwhile back in the donor cell , a new strand of DNA forms to complement the leftover strand of the factor. The word **episome** is commonly applied to plasmids that function in conjugation processes.

**High frequency of Recombination:**

There exists in bacteria a type of conjugation that accounts for the passage of chromosomal material. Strains of bacteria that display this ability are called **high frequency of recombination ,** or **Hfr strains .** Such strains were discovered in the 1950s by William Hayes in E.coli. Such strains developed when a male($F^+$) mutated to a **super – male** which showed a high frequency of recombination with a female ($F^-$) , hence the mutant called Hfr.

In Hfr strains, the F- factor attaches to the chromosome. This integration is a rare event and requires that an insertion sequence be present on the chromosome to recognize the F-factor . At the point of attachment , the chromosome opens and a copy of one strand is made by the rolling circle mechanism. A portion of single stranded DNA then passes via the sex pilus into recipient cell . It joins the chromosome . The first genes to enter the recipient are F- factor genes , but these are not the ones that control the donor state. Instead , the last segment to enter the recipient are the F- factor genes for the donor state. These rarely enter the recipient , however , because conjugation is often interrupted by such things as broken pili. Thus the $F^-$ cell usually remains a recipient , but with some new genes acquired from the donor. In certain cases the $F^-$ factor is indeed transferred to the recipient. When this happens the factor usually detaches from the recipient's chromosome and enzymes synthesize a strand of complementary DNA . The factor now forms a loop to assume an existence as a plasmid and the recipient becomes a donor.

**Sexduction:**

On occasion , the F- factor breaks free from the chromosome of an Hfr cell and resumes an independent status. The Hfr cell then reverts to an $\mathbf{F^+}$ cell. Sometimes when the F- factor leaves the chromosome , it takes along a segment of chromosomal DNA. The factor with its extra DNA is now called an F- factor ( pronounced F-prime). When the factor is transferred during a

subsequent conjugation , the recipient acquires chromosomal genes from the donor. This process is known as sexduction. It results in a recipient with its own genes for a particular process as well as additional genes from the donor for that same process.
In the genetic sense, the recipient is a partially diploid organism since there are two genes for a given function. Conjugation has been demonstrated among various genera of bacteria . For example , conjugation is known to occur between Gram – negative Escherichia and Shigella , Salmonella and `Serratia and Escherichia and Salmonella. This has great significance in transfer of antibiotic resistance genes carried on plasmids. When the plasmids are F- factors , the transfer occurs readily. Moreover , when the genes are attached to transposons , the transposons may 'jump' from ordinary plasmids to F-factors, after which transfer may occur. Conjugation may also occur in Gram – positive bacteria as Streptococcus mutants ( a common case of dental cavities).

**Transduction**
Transduction is a special method of genetic recombination in which genetic material is transferred from the donor to the recipient cell by means of a temperate bacteriophage. It was discovered by Zinder and Lederberg in **Salmonella typhimurium**. In transduction , a small piece of bacterial chromosome ( carrying specific character x) is incorporated into an attacking phage particle and when this particle infects a new host cell , it injects the genetic material ( with new piece of chromosome) into it. Transduction may be of two types: - Specialized transduction and Generalized transduction.

**( a) Specialized transduction:**

In this type of transduction transfer of only specific genes of a bacterial chromosome takes place. The main steps of specialized transduction are given below:

(1) The bacteriophage gets attached to the bacterial cell on the receptor site and the nucleic acid of phage particle is transferred to the cytoplasm of the bacterial cell.

(2) The nucleic acid of the phage particle is coded for the synthesis of certain specific proteins in the bacterial cell. These proteins are known as **repressor proteins** and their function is to check the synthesis of phage particles in the bacterial cell. The phage DNA occurs in the bacterial cell in the form of small fragments , known as **prophage.** These fragments are either free in the cytoplasm or are attached to the chromosome. A bacterial cell with prophage

is **lysogenic** and it may remain lysogenic for several generations. During this period the phage DNA keeps on dividing along with bacterial chromosome. A stage comes when synthesis of the repressor proteins stops in the bacterial cell and synthesis of phage components starts.

(3) Under such conditions , the phage DNA which was so far attached to the bacterial chromosome separates and starts synthesizing phage proteins.

( 4) When phage DNA breaks off the bacterial chromosome , few genes of the bacterium remain attached to it. These genes keep on replicating along with the phage DNA and become a part and parcel of the phage particle. Such phage particles when infect any other bacterial cell, then the bacterial genes present in phage particles are incorporated in the chromosome of the new bacterial cell. (i.e. recombinant cell) . Thus the recombinant cell, besides its own chromosome , also contains few genes of the parent bacterial cell.

**(b) Generalized transduction:**
It involves only those prophage particles which are present in the cytoplasm of the infected cell. ( and not in its chromosome) . The main steps of the generalized transduction are as follows:

(1) The phage DNA present in the lysogenic bacterial cell , starts synthesizing new phage components. In this process, the chromosomes of some bacterial cells get fragmented. Eventually these segments are incorporated in some new phage particles . Thus some of the phage particles present in the lysogenic cell have segments of bacterial chromosome incorporated in them , while others have only phage DNA.

(2) If a phage particle with segment of bacterial chromosome in its DNA attacks a bacterium of any other strain , the genes of the parent bacterium are transferred to the new cell. Such phage particles ( with genes of bacterial cell) are thus capable of transduction. On the contrary, the particles with only phage DNA are incapable of transduction.



**Q7 Describe the structure of TMV ( Tobacco Mosaic Virus (TMV) and symptoms developed on tobacco plant**.

**Ans** TMV is the most serious pathogen causing mosaic on tobacco leaves. It is transmitted by artificial inoculation but not by insect vectors.TMV is the most resistant virus known so far of which the thermal death point is 90 ˚C for

10 minutes. This is the first virus that was crystallized in 1935 by W.M. Stanley in the U.SA.

**(i) Virus Structure :-**

**Franklin et al (1957)** have described the structure of TMV . It is rod shaped helical virus measuring about 280 × 150 µm with a molecular weight of 39 × $10^6$ daltons. The virion is made up of 2, 130 protein subunits of identical size. The protein subunits are arranged around a central hole of 4nm (40Å) . Each protein subunit is made up of a single polypeptide chain which possesses 158 amino acids , the molecular weight of which is 17,500 daltons. Inside the protein capsid there is a single stranded RNA molecule which is also spirally coiled to form helix. Virus RNA consists of 6, 500 nucleotides. In one turn , the RNA contains 49 nucleotides. Total number of protein subunits counting in three turns is 49 i.e. **49/ 3** subunits per turn. Therefore, a single protein subunit is linked with 3 nucleotides of RNA.

(ii) **Protein Synthesis:**

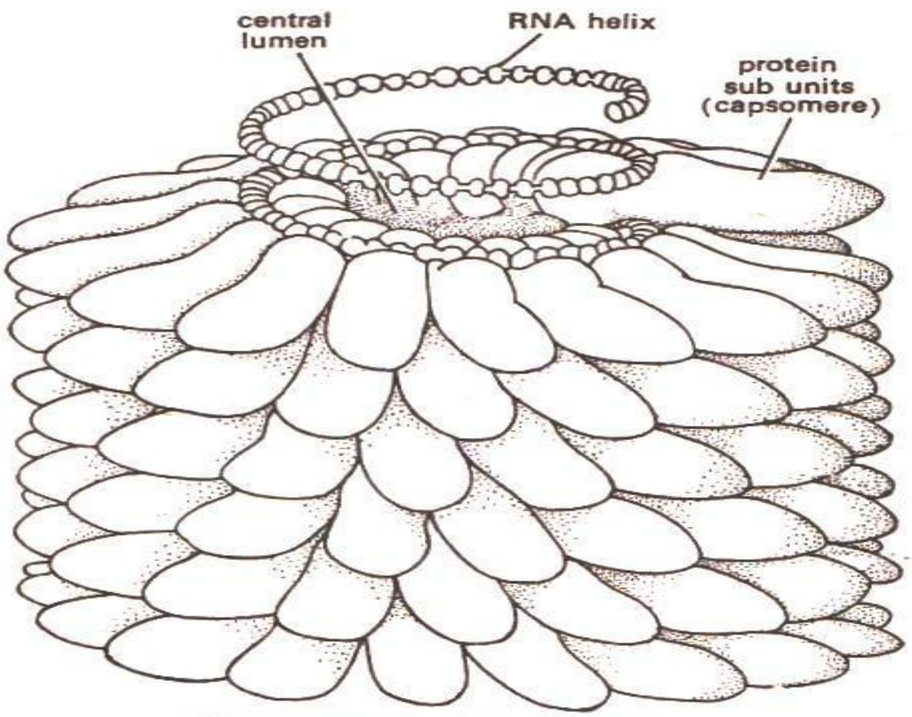
Takeba demonstrated the direct entry of TMV into the isolated protoplast from mesophyll cells of tobacco. After making entry , RNA rapidly starts uncoating by removing the subunits from the capsid by using host enzymes. The parental RNA is localized in nucleus but not in cytoplasm. It performs two important functions. ( i) it acts as mRNA and directs the synthesis of proteins. and (ii) functions as template for the synthesis of complementary strand.

The virus RNA utilizes the amino acids , ribosomes and tRNA of the host and synthesizes the complementary strand and proteins i.e. coat proteins of 17,500 daltons and two other polypeptides ( of molecular weight 160,000 and 140,000 daltons). The ratio of nucleic acid and protein differs with each virus. Nucleic acid is about 5- 40% of the virus and protein 60 -70 %. Each protein subunit of TMV consists of 158 amino acid making a total number to about 17, 531.

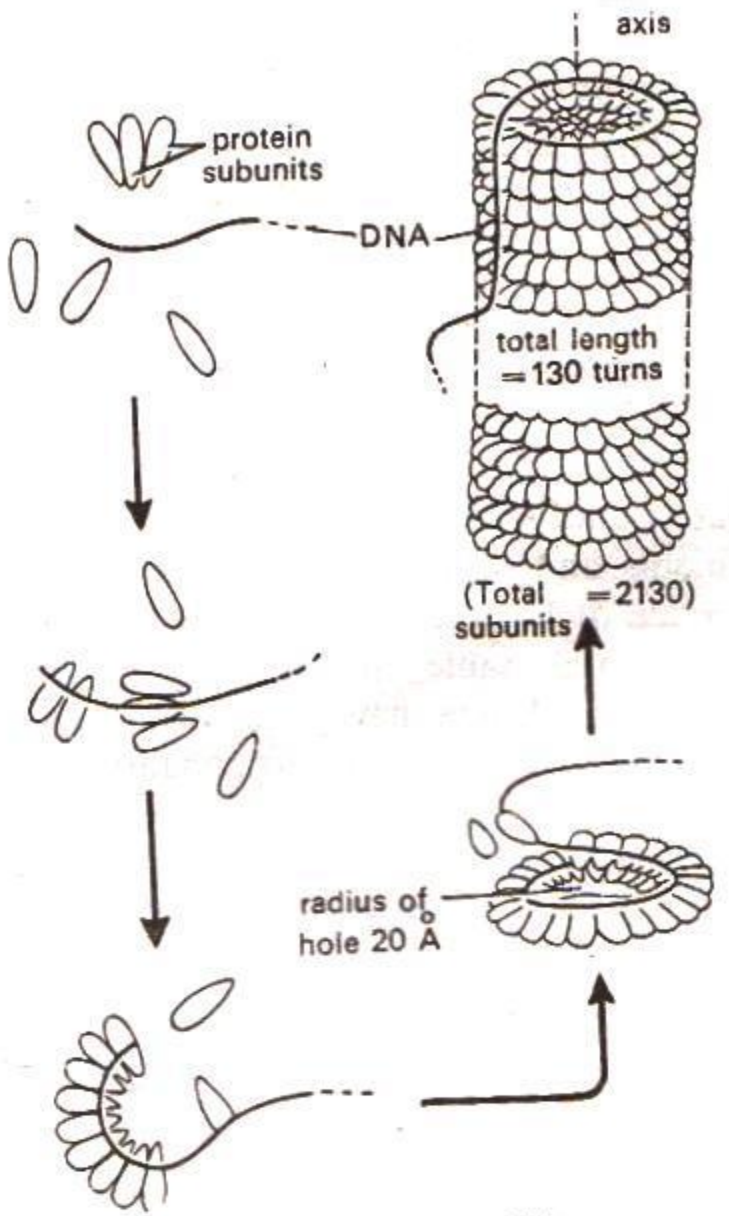
(iii) **Transmission:** TMV is transmitted through the cell sap of host and enters a new host through wound infection. Wound is caused in plant due to various cultural operations such as clipping or topping the shoot. It is not seed transmitted but acts as seed contaminant. It is also transmitted by wind and water.

(iv) **Symptoms:-**

**TMV** damages the solanaceous plants. However, it can infect the other plants too. After infection , it develops symptoms of lightening of leaf colour along the veins in early stages. Thereafter, it turns into light and dark green mosaic symptoms. Along the veins green colour turns into dark green and the internal region turns into chlorotic. Some times dark green blisters appear in the leaf blade. If the plants are infected early in season they become stunted. However, symptoms vary with varieties of tobacco. The virus reduces the yield as well as quality of the products i.e. the nicotine content is decreased by 20 – 30 %.




Tobacco mosaic virus : Structure.




Tobacco mosaic virus (TMV)

Tobacco mosaic virus : Structure and its synthesis from RNA and protein subunits.

**Q8 Write contributions of the following to microbiology?**

**Ans** Antony Van Leeuwenhoek (ii) Robert Koch (iii) Louis Pasteur

**(I) Antony van Leeuwenhoek:**

It was only after the invention of the microscope that microorganisms could actually be visualized. The credit of building a microscope for the first time went to the Dutch lens – maker of Delft , Holland named **Antony van Leeuwenhoek** . With his crude lens system , Leeuwenhoek could see clearly the objects magnified about 200 times. He observed hair fibers , plant structures , crystals , an insect's eye and a variety of fluids , plant structures, crystals , an insect's eye and a variety of fluids including blood and even scrapings from his own teeth. **Leeuwenhoek** made very basic types of **single – lens microscope**s , which were nearly 250 in number. Under his microscope , Leeuwenhoek studied life – forms which he termed **'animalcules'**. He found them first in rain water , then in pond water , later in material from his own teeth. They astonished him at first, then delighted him , and finally perplexed him as he sought to explain where they came from and what use they had. Amongst animalcules he accurately described the three major types of bacteria namely, **rods, cocci** and **spirochaetes.**

**Leeuwenhoek** presented his discoveries in the series of articles from 1676 to 1683 at the Royal Society of London. Besides , bacteria he also described free – living and parasitic protozoans, fibrillar fungi and spherical bodies which we now call as yeasts. It was Leeuwenhoek himself who for the first time discovered **spermatozoa.** Under this single – lens simple microscope , Leeuwenhoek described the shape, size and motility of the bacterial cells. However, this extremely important and significant work and discovery essentially remained a hobby with Leeuwenhoek and he did not leave behind any serious student to pursue his work.

**(ii)Robert Koch:-**

At the time when Pasteur was involved in his researches , another great scientist **Robert Koch** ( 1843 – 1918) was also making history with his work of wide ranging importance on micro –organisms . The discoveries of Koch are considered by many to be of the same importance as those of Pasteur. Besides his other important researches , Koch did painstaking investigations in the isolation and identification of various bacterial species. It is for this reason that Koch laid the foundations of such important and modern sciences like **medical microbiology** , **bacteriology** and **virology.**

Koch was a medical doctor in a small town in **Germany**. There his attention was drawn to the dreaded and sometimes fatal disease **anthrax.** The disease starts like common cold, then the skin becomes irritated and extremely itchy and very soon the skin erupts into boils. The pathogenic bacteria enter the circulatory system and cause fever , shock and many a times death. During the discovery of the causative pathogen of anthrax , **Koch** utilized extremely common type of equipment and techniques. The equipment , culture media and the techniques developed by **Koch** are still used more or less unaltered even today in many modern microbiology laboratories.

On the basis of discovery of causative bacteria of anthrax by Koch for prevention of the disease , Pasteur prepared a vaccine which was also successfully applied. Besides isolation and identification of the bacteria causing anthrax , Koch also discovered and described the causative pathogenic bacteria of such important diseases like **cholera (Vibrio cholerae )** and **tuberculosis ( Mycobacterium tuberculosis )** . On the basis of these researches the concept emerged that a **specific microbe is the cause of a particular disease.**

The methods of study of bacteria are considered as a gift of Koch and at the present time these are referred to as **Koch's postulates.** These postulates can be briefly stated as under:

(i) A **specific microbe** is always associated with a particular disease.

**(ii)** A **pure culture** of the microbe can be prepared by growing the bacteria in the laboratory.

(iii) If the microbes taken from the pure culture are **inoculated into** a healthy individual, then as a result the same particular disease appears in the individual.

(iv) If the microbes from the patient are removed and grown in the laboratory , then once again their pure culture can be prepared.

The next twenty years after the researches of Koch are considered as the **golden age** of bacteriology because during this period ending by the year 1900 almost all disease – causing pathogenic bacteria were isolated and identified.

**(iii) Louis Pasteur:**

**Louis Pasteur** was the greatest scientist of his time . He not only gave some of the fundamental concepts of life sciences , but also provided experimental proof for them.

After filtering microbes from air, **Pasteur** drew the conclusion that the source of **contamination** are microbes. He developed an **aseptic technique** which utilized heat for transfer and working with microorganisms. In 1859, to put an end to the public debate which was ranging between **Punchet** and himself , he performed the famous '**goose-neck flask experiment'** . Pasteur prepared meat – broth by boiling it in flasks having narrow , long and curved necks. In these flasks air was able to enter , but the contained microbes settled in the goose – neck of the flask. Thus only uncontaminated air was circulated in the flask. In such condition , in the meat – broth no organisms originated . However , if the goose – neck of the flask was broken then contaminated air containing bacteria , entered the flask and in such meat – broth microbes appeared. Pasteur with this experiment conclusively showed that organisms or living beings do not have the property of spontaneous generation.

**Germ Theory of Fermentation:**

Intensive studies on microorganisms by **Pasteur** between the years 1860 to about 1880 resulted in many significant concepts. After studying diseases in **Wines Pasteur** demonstrated that in the formation of wine , the alcoholic fermentation of grapes , other fruits and grains is done by special micro – organisms ( germs) termed as **'ferments.'** He also discovered that in maturing – vate containing good quality wine special type of ferments were present while in vats containing batches of poor quality wine some other type of ferments were there. He also discovered that for growth some organisms require **anaerobic** environment. On the basis of his researches , in 1864 **Pasteur** suggested that to remove undesirable types of ferments , fresh fruit juices should be heated at 63ºC for about half-an –hour and then from vats containing good quality wine microbial cultures should be taken and introduced into the heat-treated fruit juices for fermentation which would result in production of good quality wine. This technique was further developed and given the name **pasteurization.** Pasteurization has revolutionized food and beverages industry and as a direct consequence safe , hygienic , **disease – free** food has become available for mankind.

Besides effectively proving the germ theory of fermentation , Pasteur also observed that **germs** or micro – organisms are universally present in the atmosphere and to keep substances uncontaminated from these air – borne germs, the opening of vessels containing these substances , should be stoppered with cotton wool wads. The cotton wool stoppers allow the passage of air into the vessels but filter out the germs or microbes.

As a result of tremendous success achieved by **Pasteur** in solving the problems of the wine – industry , the French government requested Pasteur to save the **silkworm – industry** and thereby saving silk production of France that was being progressively destroyed by a disease called **pebrine.** After several years of research , Pasteur isolated and identified the causative microbe and suggested that silkworm farmers should use only healthy uninfected germ – free insects for reproduction. The utilization of this suggestion practically eliminated the disease and saved the silk – worm production and silk – industry of France. The researchers of Pasteur on micro-organisms were extended to the examination of diseases of domestic animals and humankind.

Pasteur also studied disease **anthrax** in cattle. He demonstrated that if healthy cattle are injected with live anthrax bacteria , then they become immune to the disease. After his success in the work on anthrax , Pasteur started to work on the much feared and fatal disease **rabies** which is transmitted by the bite of a diseased rabid dog ( or another mammal) to humans. Pasteur came to the same conclusion that treatment of rabies can also be done in the similar manner as that used for anthrax. In 1885, for the first time , **Pasteur's** theory was put to test . An extremely frightened and weeping mother came to Pasteur for providing aid to her 5 year old son **Joseph Meister** who had been severely wounded and bitten by a rabid dog. Pasteur inoculated the child with his antirabies vaccine and miraculously saved his life.

Thus Pasteur is described as the greatest scientist of the modern era. He not only laid the foundation of **preventive medicine** but gave rise to the new science of **immunology**. Besides his many great discoveries in microbiology his applications have revolutionized agrobased industries.

**Q10 Describe the morphology and multiplication / replication of Bacteriophage?**

**Ans**

1. **Morphology:**
Bacteriophages are very small particles and they cannot be separated even by bacterial filters. In their appearance , the phage resembles a tadpole or spermatozoid. It is differentiated into a head and a tail. In most phages (**T, $T_2$ , $T_6$** ) the head is prismoid but in **$T_3$** and **$T_7$ phases** it is hexagonal. There are some phages ( e.g. **fl** , **fd** , **$M_{13}$** ) which are filamentous and do not show differentiation into head and tail. The size of the head of $T_2$ phages is approximately **950λ × 650 λ.** The extended part between the head and the tail is called **collar.** The tail is almost equal to the length of the head (950 λ) and has a diameter of **80λ.** At the proximal end of the tail a hexagonal **tail plate** or **end plate** is present. The end plate is approximately 200Å thick. It has six **tail pins** or **fibres** on its under surface , each about **1500λ** long . The tail pins have two main functions : (1) They help in the adsorption of phage particles on the surface of the bacterium. and (ii) the enzymes secreted bt these pins are helpful in the lysis of bacterial cell wall .

**Replication of Bacteriophage:**

The process of replication of bacteriophage involves the following four steps:

**(1) Infection**

**(2) Synthesis of phage components in the host cells.**

**(3) Assembly of new phage particle.**
**(4) Liberation of phage particles from the host cells.**

**(1) Infection:**

The two important events of this step are adsorption of the phage on the host bacterium by means of its tail fibres and transfer of phage nucleic acid into the host cell. Adsorption of phage on the host bacterium depends on the mutual affinity of the phage and bacterium, Only a specific phage can infect a particular bacterium, Some of the coliphages have so much specificity that they are adsorbed only at a specific on the host surface. These sites are known as **receptor sites**. In addition , factors such as composition and viscosity of the medium and temperature also affect adsorption.

Adsorption of phage on the surface of the host is facilitated by interaction of amino groups of proteins at the margins of the phage tail , and negatively charged carboxyl groups on the surface of the host. Thus the host specificity of the phage particle is due to its protein and not the nucleic acid. As such the host range of free viral nucleic acid is much wider than that of the intact virion. After adsorption, the phage particle secretes a special enzyme of **lysozyme** type which hydrolyses **muramic acid-peptide complex** of the bacterial cell wall. Consequently , a minute pore is formed through which the nucleic acid of the phage enters into the host cell. The infection is accomplished through the following steps:

(1) Immediately after landing on the host surface the tail fibres bent, bringing the end plate of the phage in contact with the bacterial cell wall.
(2) The tail sheath then contracts , pushing the central tubular part of the tail into the host cell wall just like an injection needle.
(3) The nucleic acid of the phage flows into the host cell through the hollow centre of the tubular needle.

The protein shell of phage remains attached to the host cell after the transfer of nucleic acid, Such empty protein shells are called **ghosts.** A host cell once infected by a phage particle becomes immune against the infection of the phage of the same type. A phage particle loses its ability of infection after its nucleic acid has been released into the host cell.

**(2) Synthesis of phage components in the host cell:**

The phage nucleic acid , once inside the bacterial cell, takes over the protein synthesis machinery of the cell. It suppresses the synthesis of bacterial protein and directs the metabolism of the cell to synthesize the proteins of the phage particle. This is accomplished by the synthesis of **viral specific m-RNA** ( using the host RNA polymerase).

The replication of phage DNA follows the semi – conservative mechanism. Most of the phage DNA serves as a template for the synthesis of viral specific m-RNA. The latter directs the host cell to synthesize proteins which are used as sub-units ( capsomeres) of the protein coat of the phage particle. These proteins are called **late proteins.** Towards the end of the replication of phage nucleic acid , a late protein , called **phage lysozyme** , is synthesized.

**(3) Assembly of new phage particles:**

Assembly of nucleic acids and proteins ( late proteins) into new phage particles is called **maturation.** This process is controlled by a viral genome. The first step in maturation is the condensation of nucleic acid molecule in crystalline form. The protein sub- units then aggregate around DNA to form the head of the phage. Meanwhile, assembly of the tail starts. It is initiated with the attachment of core tube with the tail plate. The sheath around the core tube is formed afterwards. At this stage the tail gets attached to the base of the head. The tail fibres are attached to the end plate in the last.

**(4) Liberation of phage particles from the host cells:**

The entire cycle of phage development is completed in 30-90 minutes. In an infected bacterium 7-8 phage particles are formed per minute and a total of 200 phages are formed in a bacterium. Lysis of the host cell wall is essential for the liberation of phage particles. It is facilitated by the enzyme lysozyme secreted by the phage DNA in the host cell. The host cell ruptures as a result of lysis and the phage particles are liberated.

# Unit II

# Fungus and Plant Diseases

**Q1 Give an account of the asexual and sexual reproduction in fungus.**

**Ans** Asexual reproduction in fungi usually occurs under conditions that favor growth and several generations may be produced in one season. It takes place by the production of enormous number of spores , uni or multicellular , microscopic propagules containing one or more nuclei , which are liberated from the parent thallus passively or by active discharge. Most are dispersed long distance by wind , or by water , insects and other animals. Asexual spores are of two main types : **sporangiospores** and **conidia.** The former are formed within the sporangia and the latter are formed from or within a conidiogenous cell borne on a specialized hypha , the **conidiophore**. Sporangia are characteristic of the lower fungi . In aquatic fungi and their relatives , the protoplasm of the sporangia differentiates at maturity to form zoospores, which are naked , motile spores usually containing one nucleus and possessing one or two flagella by which they are propelled. In the family **Peronosporaceae**, the sporangia are caducous and wind borne. In most genera germination under moist conditions occurs by zoospores , but in drier conditions a sporangium puts out a germ tube and functions as a spore. Nonmotile spores **(aplanospores)** are characteristic of Zygomycetes. Asexual reproduction by conidia takes place in **Ascomycetes**, in a few **Basidiomycetes** and exclusively in fungi **Imperfecti.**

**(1) Zoospores:**

Motile cells of fungi are either zoospores ( **Gr. Zoon = animal + spora = seed , spore** ) or gametes of uniflagellate or biflagellate lower fungi. The former are the asexual reproductive structures. There are three types of zoospores in fungi:

**(a) Posteriorly uniflagellate zoospores with flagella of the whiplash type; Characteristic of the Chytridiomycetes . e.g. Blastocladiella emersonii** and **Allomyces macrogynus.**

The uninucleate zoospore of **B. emersonii** is tadpole like with a pear shaped head of about 7-9 µm and a single trailing ( posterior ) flagellum nucleus. The nuclear sap is rich in ribonucleic acid (RNA) and protein and is packed with ribosomes. Each zoospore contains a single mitochondrion around the **kinetosome** ( resulting from the fusion of several mitochondria during the development of zoospore) which is situated near the base of the zoospore. The origin of the flagellum is from a basal body of kinetosome ( or blepharoplast) . The kinetosome is cylindrical in shape and made up of nine fibrils each consisting three microtubules. These are arranged in such a manner that they give the appearance of a cart wheel. The main shaft of the flagellum or axoneme continues as a ring consisting of nine double microtubules surrounding a central pair of microtubules.

**(b) Anteriorly uniflagellate zoospores with flagella of the tinsel type ,characteristic of the Hyphochytridiomycetes . e.g Rhizidiomyces apophysatus.**

**( c) Biflagellate zoospores with anteriorly or laterally attached flagella , one of which is of the whiplash type ( backwardly directed) and the other of the tinsel type ( forwardly directed) and is characteristic of the Oomycetes. In the Plasmodiophoromycetes the long flagellum is of the whiplash type and is forwardly directed and the short, blunt one , backwardly directed.**

**2. Sporangiospores:**

In the class **Zygomycetes** . eg. Mucor , the asexual , nonmotile sporangiospores **( aplanospores)** are contained in globose sporangia surrounding a core or columella or cylindrical sac termed as merosporangia. The contents of the terminal sporangia are differentiated into walled spores containing several nuclei , and these are released by the breakdown of the sporangium wall or by discharge of the whole sporangium, These spores are either dispersed by wind, rain, insects or other animals.

Initially sporangiospore delimitation is endogenous since it begins within the cytoplasm by the association of the membranes from the endoplasmic reticulum , nuclear envelope and subsequently morphologically distinct cleavage vesicles are formed as in **Gilbertella persicaria .**

**3.Conidiospores (Conidia):**

**Conidiospores ,** commonly known as conidia are asexual reproductive structures and are produced mainly in **Deuteromycetes** and also in **Ascomycetes** and a few **Basidiomycetes.** Sexually produced spores are not known in Deuteromycetes. According to the definition from the Kananaskis conference , the conidium is a specialized , non – motile , asexual propagule usually caducous , not developing by cytoplasmic cleavage or free cell formation. Conidia may arise directly from the somatic hyphae or from specialized conidiogenous cells that are often borne on special hyphal branches known as **conidiophores.**

Conidiophores may either arise singly from the somatic hyphae or may be originated in various ways to form specialized structures such as **synnemata ( sing.synnema )** which is a compact aggregation of erect hyphae and conidiogenous cells bearing conidia ; **sporodochia ( sing. Sporodochium)** which is a cushion like mass of conidiogenous cells ; **pycnidia ( sing. pycnidium)** which is a hollow fructfication containing a hymenium of conidiogenous cells , which bear conidia ; or **acervuli** ( **sing. acervulus** ) which is a fructification consisting of a mat of hyphae that gives rise to short conidiogenous cells which are closely packed together forming a bed – like mass.

Conidia may be spherical , ovoid elongated , cylindrical , thread like , spirally curved or star shaped. They may be unicellular or multicellular , with either transverse septa or both transverse and longitudinal septa ( muriform) . They may be produced either singly , in groups , or in chains ( catenulate) which may be either **acropetal** or **basipetal .**

**Sexual reproduction**:

With the exception of the class **Deuteromycetes** , sexual reproduction occurs in all the groups of fungi . The process of sexual reproduction is completed in the following three distinct phases:

**(a) Plasmogamy:**

In the first step , fusion of the protoplasts of the two compatible gametes or sex cells takes place , and the two compatible nuclei come close to each other.

**(b) Karyogamy:**

In the second step , fusion of the two nuclei from the two fusing gametes takes place and a diploid zygote nucleus is formed. In Phycomycetes karyogamy occurs just after plasmogamy. But in Ascomycetes and Basidiomycetes karyogamy is much delayed. In the latter groups , the nuclei of the opposite strains get themselves arranged in pairs ( dikaryon). This phase in the life cycle is known as **dikaryophase** and the process by which this stage is accomplished is called **dikaryotization.** The two nuclei of a dikaryon fuse to form a diploid nucleus.

**(c ) Meiosis:**

After karyogamy , reduction division takes place in the diploid nucleus and haploid stage is reestablished.

The compatible nuclei are brought together by the following sexual processes:

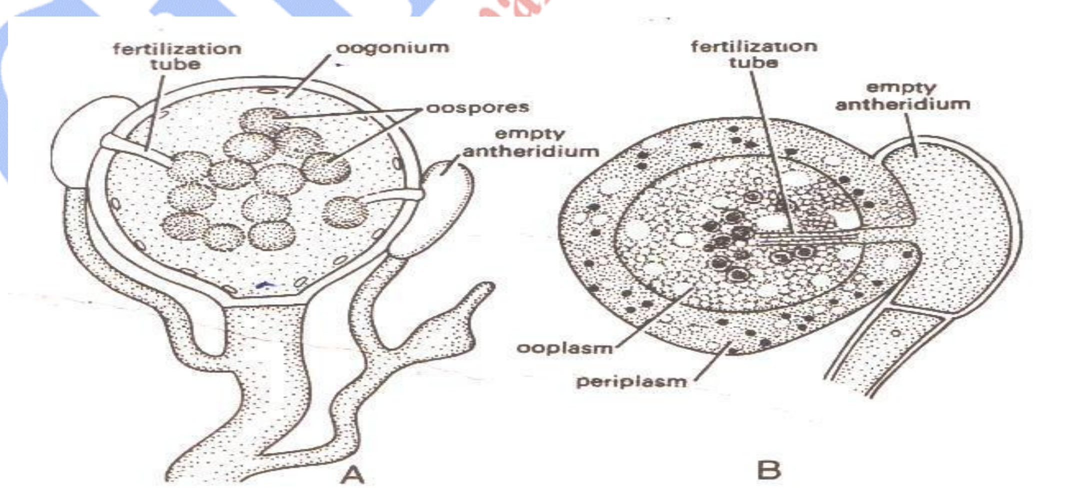
**( a) Planogametic copulation:**
This involves fusion of two naked motile gametes **( planogametes) .** The planogamete copulation is of three types , depending on the nature and structure of the fusing gametes:

**(i) Isogamy:**
The fusing gametes are morphologically similar but physiologically different and are formed on different hyphae. ( e.g. **Synchytrium; Catenaria ) .**

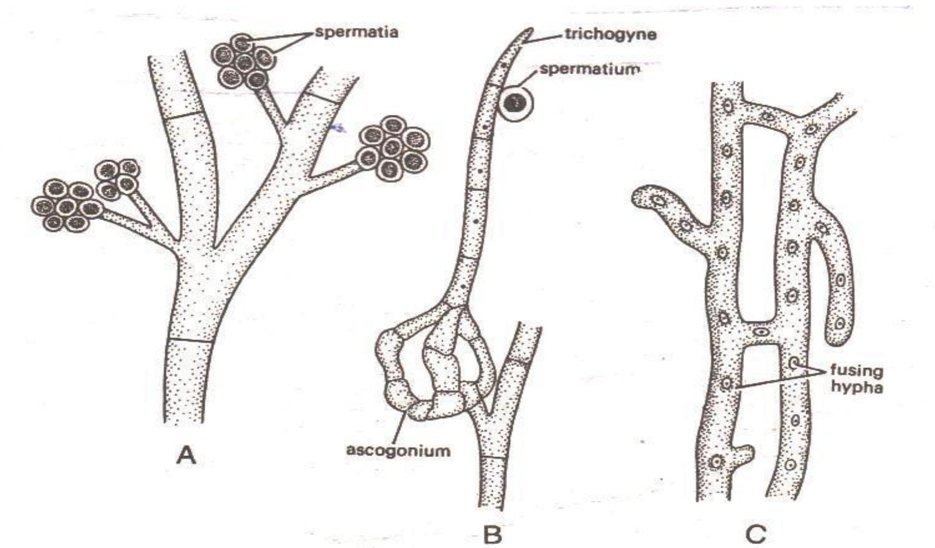
**(ii) Anisogamy:**
The fusing gametes are both morphologically and physiologically different ; the male gamete is smaller and more active than the female gamete. ( e.g. **Allomyces) .**

**(iii) Oogamy:**
The female gamete **( egg)** is non – motile and the male gamete **( antherozoid )** is motile ; they are formed in specialized gametangia , known as **oogonium** and **antheridium** respectively.

**(b) Gametangial contact:**
Here gametes are never released from gametangia , instead the male and female gametangia come in close contact with the help of a fertilization tube. Then one or more male nuclei migrate to the female gametangium . The gametangia never fuse or lose their identity during the sexual act. The male and female gametangia are known as antheridium and oogonium ( ascogonium in Ascomycetes) respectively.




A-B. Gametangial contact.




A-C. Sexual reproduction : A-B. Spermatization; C. Somatogamy.

**Q2 Write short notes on :**
**( a ) Bacterial blight of paddy**
**(b) Late blight of Potato**
**( c) Green ear disease of Bajra**
**(a) Bacterial Blight of paddy:**

**Ans** Bacterial blight is a very common and widespread disease of paddy in Asia, especially in Sri Lanka , China , India , Japan , Indonesia , Taiwan , Philippines and Thailand. The disease causes heavy loss to rice crop.

**1. Symptoms:**

It is a foliar disease which appears in early or late August and causes maximum damage during the heading stage. The disease occurs in all stages of plant growth , from seedling to grain formation . It first appears as water – soaked , translucent spots on the leaf blade and leaf sheath. The spots gradually increase to form elongated yellow to straw coloured streaks which may coalesce to form white blotches. The streaks usually develop from the tip towards the base. Sooner or later the tips dry and become twisted and at times the leaf tissues may die. In dry weather , turbid drops of bacterial mass ooze out, which on drying appears as yellowish beads on the leaf surface.

In severely infected fields , infection may reach the grains . The glumes become discoloured and water soaked spots develop on them. Finally , the whole plant may wilt and appear completely desiccated ( **kresek symptoms )** . The leaves of infected tillers suddenly become dry and roll along the midrib.

**2. Causal organism:**

The pathogen responsible for bacterial blight of paddy is **Xanthomonas oryzae .** It is an aerobic, rod – shaped , non – capsulated , non –spore forming , Gram – negative bacterium, 0.5 -0.8 × 1-2µm in size. It is motile with a single polar flagellum . The bacterium produces waxy yellow coloured colonies on agar medium and is incapable to reduce nitrates.

**3. Disease cycle:**

Seeds and disease stubbles are mainly the primary sources of infection. It is principally a vascular disease. In India , the pathogen also occurs on some grasses which are its collateral hosts.

Cloudy weather, high humidity, double cropping and poorly drained conditions are most conducive for disease development. High doses of nitrate, silicate and magnesium in the soil increase disease severity. Relatively high temperatures ( above 25ºC ) during the growth of the crop increase the incidence of disease but severe heat and drought suppress the disease. The rice plant is susceptible to infection at all stages of its growth , but susceptibility to vascular infection decreases with the age.

**4. Disease Control:**

The following measures can be adopted to control the disease incidence:

**(1)** Seeds are treated with 0.025% water solution of agrimycin plus 0.05% wettable ceresan for 12 hours. Then seeds are transferred to hot water at 52- 54ºC for 3 minutes.

**(2)** Initial infection can be checked by dipping seeds for 8 hours in 0.1% ceresan wet plus streptomycin ( 0.3gm in 2.5 gallons of water).

**(3)** Spraying agrimycin plus copper oxy – chloride for five times at 12 day intervals prevent secondary spread.

**(4)** Chlorination of irrigation water also helps in reducing infection.

**(5)** Burning of infected straw and stubble to destroy the bacteria present is also a good measure.

**(6)** By sowing of nursery beds in disease – free , isolated areas to prevent the inflow of primary inoculum into fields. Pruning of top portions of the host should be avoided.

**(7)** By cultivating resistant varieties such as Sathi, N – 22 , IR – 20 , IR-22, W 529 , W 348 and Ratna.

**(b) Late blight of potato:**

The late blight of potato is one of the destructive disease of potato. The famous Irish famine of 1845 – 46 was largely due to the failure of potato crop, due to late blight infection. In India , the disease was first introduced into the Nilgiri hills between 1870 and 1880 and very soon it spreads to Darjeeling in the Himalayan ranges.

**1. Disease symptoms:**

The symptoms of the disease can be seen on any part of the plant viz. leaves, petioles , stems and tubers. On the leaves , the symptoms appear in the form of dark brown , oval or irregular water soaked areas. In the early stages , the symptoms develop at the tips or the margins of the old leaves. The infection spreads vigorously when temperature is low and atmosphere is humid , and soon appears in the form of blight. In case of severe infection, practically all the parts of the host become brown and then degenerate , After the tops have been blighted , the infection reaches to the underground tubers. In the infected tubers, the skin becomes slightly sunken and dark in colour. If conditions are humid , the cells of the tuber become soft and dark brown. This symptom is known as **wet rot.**

**2. Causal organism:**

The disease is caused by Phytophthora infestans . The mycelium is endophytic consisting of hyaline , profusely branched coenocytic hyphae. The hyphae develop intercellularly and form haustoria. Ovoid or lemon shaped sporangia are produced on sporangiophores. The sporangia are at first terminal but become lateral due to sympodial branching of the sporangiophore.

The sporangium may germinate directly , forming a germ tube at the apex or its protoplasmic contents divide to form a number of biflagellate zoospores which emerge through the papilla. The method of germination is governed by temperature; low temperature favours zoospore formation whereas higher temperature , the germ tube development. Sexual reproduction is oogamous type. The antheridium is somewhat elongated and **amphigynous** whereas the oogonium is pear `shaped to almost spherical , smooth and reddish – brown in colour. The fusion of egg and male nucleus results in the formation of a diploid oospore.

**3. Disease Cycle:**

The infected tubers are the main source of infection. The dormant mycelium in the tubers becomes active and grows upward in the stem and sporulates on small shoots. Epiphytotics of the disease is likely to occur when unusually cool weather combined with abundant moisture prevails at the time the sporangia are being produced. The optimum temperature for sporulation is 21ºC . The sporangia germinates best by zoospores at 12ºC and by germ tube , 21ºC . 100 per cent relative humidity causes abundant production of sporangia. Sporangia are easily detached and disseminated by rain or air. On reaching a suitable host , the sporangia germinate either by germ tubes or by zoospores depending upon the environmental conditions. The spores from the blighted leaves are washed down into the soil where they penetrate to different depths reaching the healthy tubers. Contact of healthy tubers with diseased leaves at the harvesting time is another source of tuber infection.

**4. Disease control:**

The late blight can be effectively controlled by the following methods:

(1) Healthy seed tuber selection.

(2) Field sanitation.

(3) Delayed harvesting and sorting potatoes from a blighted field.

(4) Tuber treatment before storage.

(5) Storage in a cool , dry and well aerated store house.

(6) Use of disease resistant varieties like Kufri red , Kufri neela, Kufri kundan.

(7) Foliar spray of fungicides like Bordeaux mixture , Dithane Z – 78 , Fytolan, Blitox etc.

**( c) Green ear disease or downy mildew of Bajra:**

This is a very common disease of bajra **(Pennisetum typhoides )** occurring in almost all regions where the crop is grown . In India , the disease was first reported by Butler in 1907 in sporadic form.

**1. Disease symptoms:**

There are two stages of the disease , **downy mildew stage –** dominant on the leaves , and **green ear stage –** occurs on the ears (inflorescences ) . The sporangia provide a powdery appearance to the lower surface of the infected leaves. The formation of sporangia is favoured by low temperature and humid atmosphere. The infected leaves become twisted and chlorotic and sometimes they split longitudinally.

The ear is wholly or partly transformed into loosely arranged, twisted , leaf – like green structures . The glumes become enlarged and green and the bristles of spikelets appear contorted due to hypertrophy. The stamens become leafy or are suppressed to rudimentary peglike stumps. Carpels rarely develop in severely affected plants and they are usually replaced by small, leafy shoots or horny outgrowths.

**2. Causal organism:**

The pathogen responsible for this disease is an obligate parasitic fungus , **Sclerospora graminicola .** It has intercellular , branched , aseptate and coenocytic mycelium . It absorbs food from the host tissues with the help of bulbous haustoria. The mycelium remains confined to the mesophyll tissue , where it causes hyperplasia.

**3. Disease Cycle:**

Several erect hyphae , known as sporangiophores , arise from the intercellular mycelium. The sporangiophores develop in the sub – stomatal chambers and emerge through stomata singly or in tufts. The basal part of the sporangiophore is stout and it is aseptate and unbranched. The terminal part is thicker and dichotomously branched. The swollen tips of the branches form sporangia.

The sporangia are hyaline, elliptical , papillate and smooth walled . They are usually formed in the night and detach from the sporangiophore early in the morning. They soon germinate to produce 3- 12 reniform biflagellate zoospores. The zoospore remains active for sometime and then it secretes a wall and becomes dormant. During favourable conditions, the zoospore germinates by producing a germ tube. The germ tube enters through the stoma and forms a new mycelium on reaching the intercellular spaces of the host tissue.

**Q3 Write short notes on :**

**Ans Loose Smut of Wheat:**

Loose smut , a very serious disease of wheat , is world wide in occurrence and is a serious problem in the humid and semi – humid wheat growing regions. In India , the disease occurs in all wheat growing areas , but its incidence is higher in the cooler and moist northern parts than in the south.

**1.Symptoms:**

It is a very destructive disease of wheat crop , almost every ear of the affected plants is converted into a black mass of spores and no grains are formed. There are no signs of the disease until the ear formation. The infected plants grow faster than the healthy plants and produce flowers earlier. They do not form healthy grains and instead a black powdery mass ( chlamydospores) is filled inside the grain wall . In early stages the chlamydospores remain enveloped by a thin silvery membrane but at the time of flowering the membrane bursts open and the spores are gradually blown away by the wind. In severe infection ,only the central axis of the spikelet is left behind on the plant.

**2 Causal organism:**

The fungus responsible for the disease is **Ustilago nuda var. tritici.** The mycelium of this fungus consists of multicellular branched hyphae which are hyaline but turn brown at maturity. The primary mycelium is septate and uninucleate , whereas the secondary mycelium is branched, septate and binucleate. In the vegetative phase the secondary mycelium is profusely branched and spreads in intercellular spaces of the host tissues. The pathogen reproduces by the formation of chlamydospores and basidiospores.

The hyphal cells are transformed into olivaceous brown , spherical and echinulate chlamydospores which germinate readily and produce basidia and basidiospores. The haploid basidiospores produce uninucleate , primary mycelium on germination.

**3.Disease Cycle:**

Chlamydospores are carried to healthy plants by wind. They readily germinate and produce a new mycelium. A healthy host plant can be infected in several ways at various stages of its growth:

(1) The host can be infected at the seedling stage from contaminated grains or contaminated soil present in close proximity of the germinating seeds.

(2) The infection may also occur at blossom time; the spores infect immature ovaries of healthy spikelets , producing an internal mycelium.

The mycelium remains dormant in the grain but after seed germination it becomes active and eventually infects the embryonic spikelets on reaching the inflorescence region, Finally, the mycelium forms dense masses of hyphae in the immature ovaries. These hyphae repeatedly divide to form smut spores. A group of such spores is known as **smut ball** or **sorus . The sporogenous hyphae** grow in between the anticlinal walls of the epidermis of the infected tissue. The epidermis of the infected parts of the host is thus destroyed and the spores are disseminated by air currents.
The maximum development of disease takes place at 23˚C. The disease is less frequent in the areas where humidity is low at the time of flowering.

**4. Disease control:**

The disease is internally seed borne and as such spray of fungicides is not effective in controlling the disease.

**(a) Hot water treatment:**

The seeds are first soaked in water for five hours at 20˚C , the water is drained off and then they are treated with hot water at 49˚C for about a minute and finally with hot water at 52˚C for 11 minutes. Immediately after the hot water treatment , the seeds are cooled off by dipping in cold water and dried. The dormant mycelium inside the seed dies off by this treatment.

**(b) Solar energy treatment:**

In this method , the seeds are first soaked in water for four hours and then dried in sun for four hours. This duration of sunlight is sufficient for inactivation of the mycelium.

**( c) Use of systemic fungicides:**

Several fungicides like carboxin, vitavax and benlate are used for seed treatment to reduce the pathogen infectivity. A combination of vitavax with thiram or maneb is very effective for disease control.

**(d ) Use of resistant varieties:**

The most successful method is the use of resistant varieties, NP – 710 , 718 , 761 ; Bansi 224 and P 9 D are some important varieties of wheat which are resistant to smut disease.

**(e) Crop rotation:**

Crop rotation at suitable intervals is also effective in disease control.

**Q4 Describe the classification of fungus , as given by Ainsworth.**

**Ans Classification Proposed by Ainsworth:**

A more natural system of classification of fungi was proposed by G.C. Ainsworth . He included all fungi in the kingdom **Mycota.** An outline of his classification is as follows:

**Kingdom Mycota**: ( fungal kingdom)

**Division I. Myxomycota ( slime molds)**

**Class 1 Acrasiomycetes** ( cellular slime molds) – assimilative phase free – living amoebae that aggregate to form a pseudoplasmodium before reproduction.

**2. Hydromyxomycetes- plasmodium** forms a slimy net work ; mostly parasitic on marine plants.

**3.Myxomycetes:-** a true **plasmodium ;** free living , saprophytic.

**4 Plasmodiophoromycetes: - Plasmodium** parasitic within the cells of the host plants.

**Division II Eumycota ( true fungi) : -**

**Sub – division I . Mastigomycotina**

**Class 1Chytridiomycetes –** often unicellular , zoospores with single, posterior whiplash flagellum.

**2 Hypochytridiomycetes: -** often unicellular , zoospores with single , anterior , tinsel flagellum.

**3. Oomycetes:-** usually mycelial ; zoospores biflagellate with posterior flagellum whiplash and anterior flagellum tinsel type.

**Sub – divisions 2 . Zygomycotina:**

**Class 1Zygomycetes –** mycelium immersed in host tissue , usually saprophytic, parasitic or predacious.

**2.Trichomycetes: -** mycelium not immersed in host tissue; often parasitic on arthropods.

**Sub – division 3. Ascomycotina**

**Class 1. Hemiascomycetes : -** asci naked ; no ascocarps and ascogenous hyphae.

**2. Loculoascomycetes: - asci** bitunicate ; **ascocarp** an ascostroma.

**3. Plectomycetes: - asci unitunicate , evanescent ;** fruiting body cleistothecium type.

**4. Laboulbeniomycetes: -** fruiting body perithecium type , asci unitunicate , inoperculate ; exoparasites of arthropods.

**5.Pyrenomycetes: -** fruiting body perithecium type, asci unitunicate , inoperculate with apical pore or slit.

**Sub – division 4 Basidiomycotina**

**Class 1. Teliomycetes: - basidiocarp** lacking ; teliospores grouped in sori or scattered within the host tissue.

**2. Hymenomycetes: - basidiocarp** present; basidia arranged in hymenium ; completely or partly exposed at maturity.

**3. Gasteromycetes: -** basidiocarp present; basidia arranged in hymenium , enclosed within the basidiocarp , basidia aseptate.

**Sub – division 5. Deuteromycotina ( Fungi Imperfecti) :**

**Class 1.Blastomycetes :-** true mycelium lacking ; budding cells with or without promycelium.

**2 Hyphomycetes:-** mycelial, sterile or asexual spores producing directly on hyphae or conidiophores.

**3.Coelomycetes:-**mycelial ; asexual spores on pycnidium or acervuli.

# Unit III

# Life cycle of different fungi

**Q1 Describe Asexual and Sexual Reproduction in Aspergillus.**

**Ans**

(I) **Asexual Reproduction:-**

It takes place by conidia produced on the conidiophores. Some cells of the somatic hyphae grow more rapidly and develop a rigid wall. These cells are known as **foot cells.** An erect branch known as **conidiophores ,** arises from each foot cell. The conidiophores is usually unbranched and aseptate . The tip of the conidiophores swells considerably , accumulates cytoplasm and forms a vesicle. Several finger like projections develop on the surface of the vesicle and they are known as **phialides** or **sterigmata** and the subsequent layers as **secondary and tertiary sterigmata.**

**Formation of conidia:**

Conidia develop in long basipetal chains on the sterigmata. There are 10 -12 conidia in each chain. During the formation of a conidium , the nucleus of the sterigmata divides into two. Synchronously a globular protuberance develops at the tip of the sterigmata and it expands to form a conidium. One of the two daughter nuclei present in the sterigmata pass into the conidium. As the conidium expands , the wall of the sterigmata ruptures near its tip. The remnants of the broken wall persist as a cap around the first formed conidium. A long chain of conidia is formed in this fashion. In early stages the cytoplasm of the two successive conidia remains continuous due to the presence of a cylindrical isthmus. But later , due to the formation of an inner conidial wall layer, the cytoplasm of the two successive conidia become separated.

The conidium is a small , globose , echinulate and uninucleate structure. It contains various pigments, such as yellow , green , brown or black , in different species. Conidia are dispersed by wind. They germinate on suitable substratum, each producing a new mycelium.

**(II) Sexual Reproduction:**

Most species of Aspergillus are homothallic but a few ( **A. fischeri** , and A. heterothallicus ) are heterothallic. The sexual reproduction may be isogamous ( e.g. A. nidulans ) or anisogamous ( e.g. A. repens). The male and female sex organs are known as **antheridia** and **ascogonia ( archicarp)** respectively.

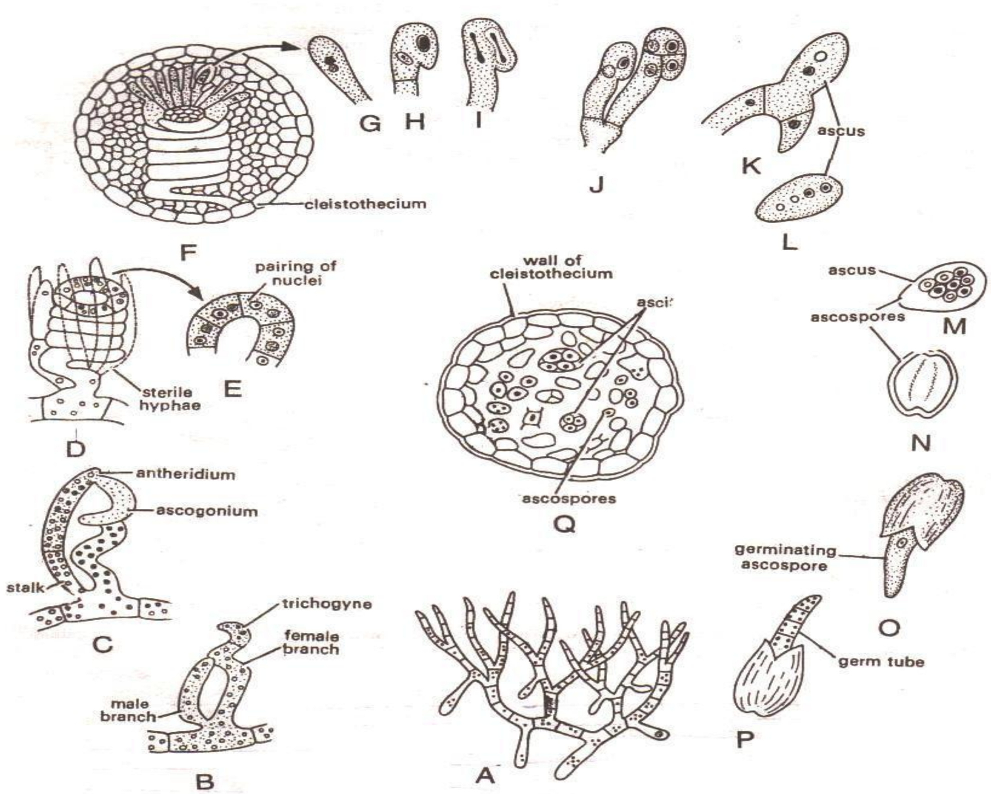
**1. Development of the ascogonium:**

The hyphal branch which forms ascogonium soon becomes septate and loosely coiled. As ascogonium develops the coil becomes dense and looks as a spring – like structure. It is now known as **archicarp.** It is differentiated into the following three regions :

(1) The terminal unicellular and multinucleate part is known as **trichogyne.** It acts as the receptive region.

(2) The middle part is also unicellular and uninucleate. It functions as female gametangium and is known as **ascogonium.**

(3) The basal part is multicellular and multinucleate. It forms the stalk of the ascogonium.




A-Q. *Aspergillus* : Stages of sexual reproduction.

**2. Development of the antheridium:**

The antheridium develops close to the ascogonium on the same or nearby hypha. It begins to initiate just before or during the septation of the ascogonial hypha. The antheridial branch also known as **pollinodium** becomes 2- celled by the formation of a septum. The upper cell forms the **antheridium proper** and the lower one, the **stalk.** Both the antheridium and stalk are multinucleate and remain unicellular even at maturity.

There is a gradual elimination of antheridia in the various species of Aspergillus. The following stages of progressive degeneration can be seen:

(i) In species like **A. herbariorum** antheridia are well developed and functional.

(ii) In **A. repens** and some other related species though antheridia are well developed , their cytoplasmic contents are not transferred to the ascogonium.

(iii) In many species of Aspergillus though antheridia are formed , the male nuclei soon degenerate and there are no functional nuclei in mature antheridia.

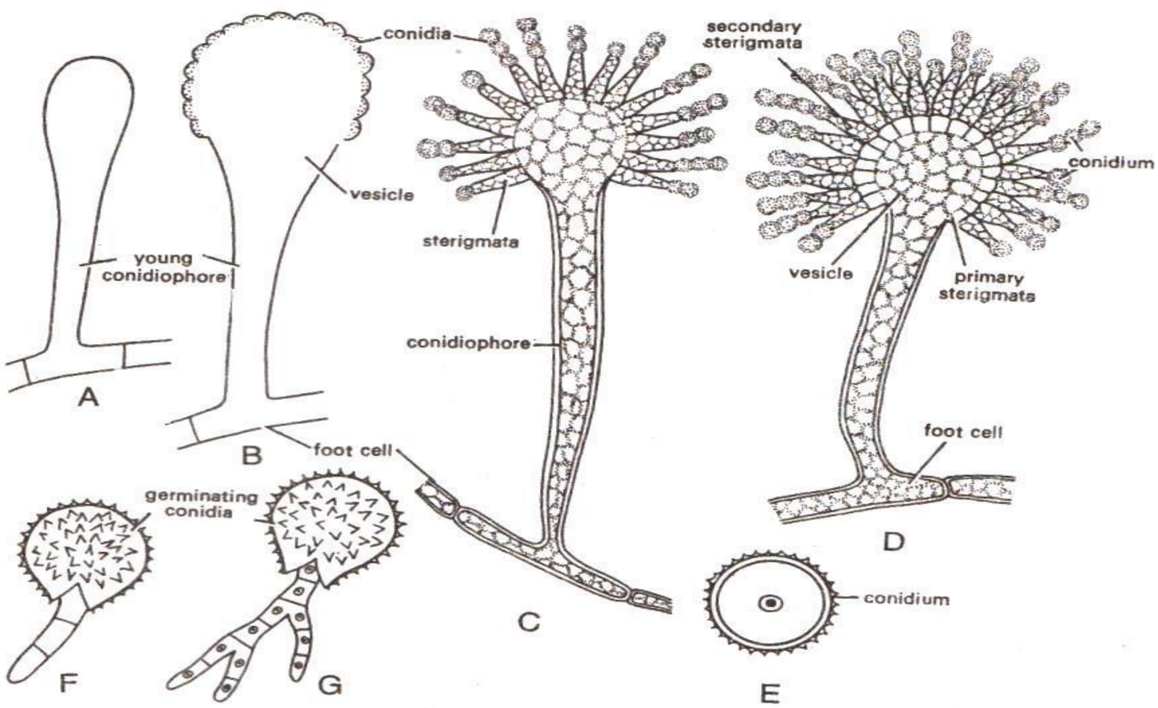
(iv) In A. flavus , A. fischeri and fumigates antheridia do not develop at all.

**(4) Fertilization:** Before fertilization , the stalk of the antheridium elongates and coils and grows upwards in close contact with the ascogonium until the antheridium touches the trichogyne. This is known as **gametangial contact.** The intervening walls at the point of contact of the antheridium with the trichogyne dissolve and the contents of the antheridium are transferred into the ascogonium through the trichogyne. The contents of the antheridium and the ascogonium readily mix but the fusion of male and female nuclei do not take place at once. The male and female nuclei arrange themselves in pairs within the ascogonium and this is known as **dikaryon.**

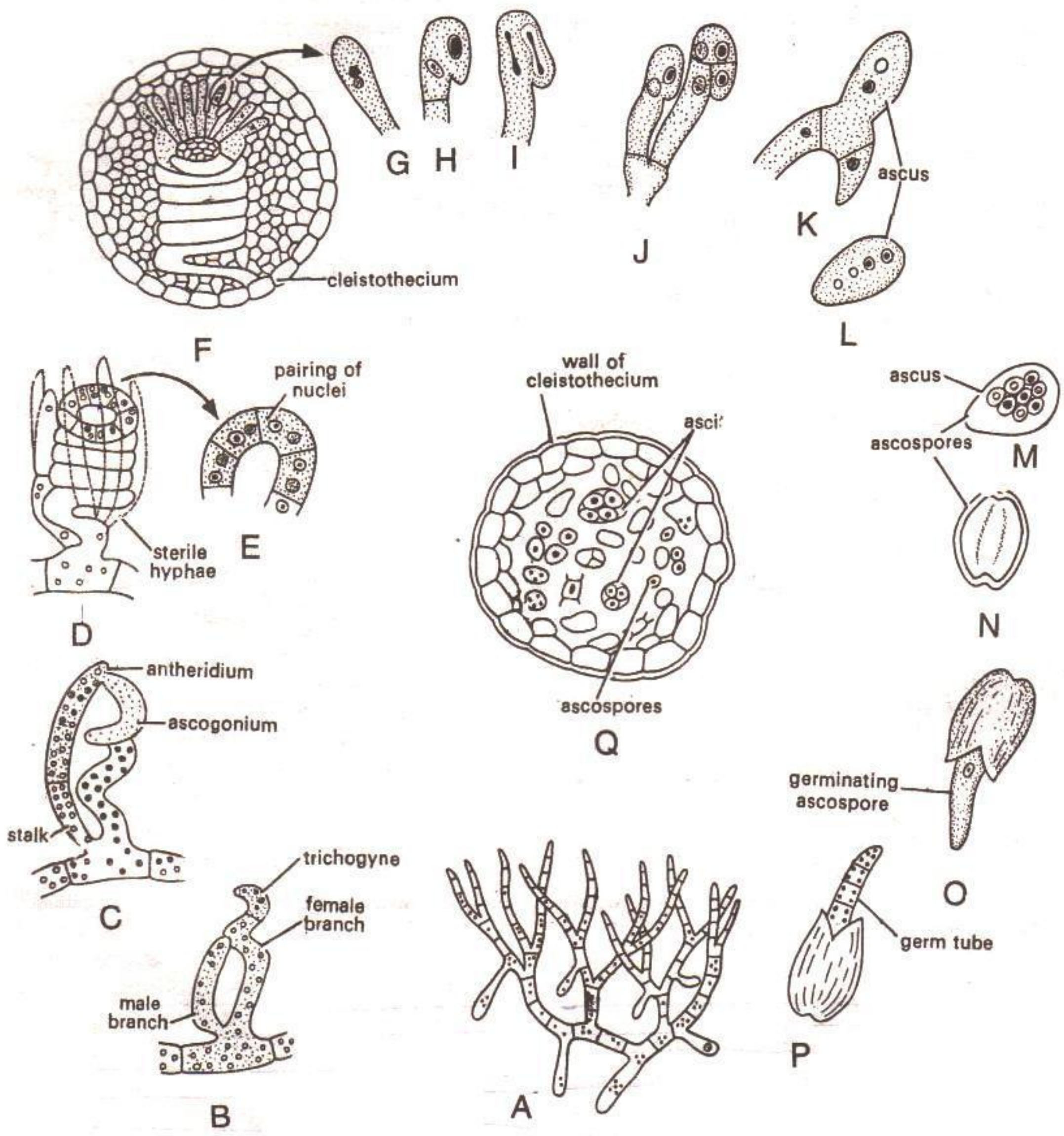
**Development of the Ascus:**

After fertilization a dikaryon is formed in the ascogonium. This is followed by the septation in the ascogonium. Each cell formed contains a dikaryon and develops into a multicellular **ascogenous hypha.** In turn each cell of the ascogenous hypha also has a dikaryon. The terminal cell of the ascogenous hypha curves to form a hook – like structure , known as **crozier.** The two nuclei of the dikaryon present in this cell divide by a conjugate division and thus four daughter nuclei are formed. Now septa are formed in the crozier in such a way that the penultimate cell has two daughter nuclei , and the terminal and basal cells have one daughter nucleus each. The two nuclei present in the penultimate cell fuse to form a diploid nucleus. This cell now functions as the **ascus mother cell** and elongates to form an **ascus.** The diploid nucleus of the ascus first undergoes a meiotic division , followed by mitotic division. Eight haploid nuclei are thus formed in an ascus and each of these ultimately transforms into an ascospore. In this way eight globose or pyriform **ascospores** are formed in each ascus. The wall of the ascospore is differentiated into an outer thick and sculpturous **epispore** and an inner thin **endospore.**

**Development of Ascocarp:**
Simultaneously . with the development of the ascogenous hyphae , many sterile hyphal branches also develop from the cells lying below the ascogonium. These branches forma pseudo parenchymatous structure , which is two layered structure. The peridium which is two layered structure , encloses ascogenous hyphae. The inner layer of the peridium is consumed by the developing asci and ascospores , whereas its outer layer forms a protective covering. The entire structure which appears like a hollow ball of the size of a pinhead is known as the **fruiting body** or **ascocarp.** The ascocarp is a completely closed **cleistothecium.**
**Ascospores** are released by the breakdown of the cleistothecial wall ( peridium) . They are disseminated by wind. They germinate when fall on a suitable substratum and produce new mycelia.




A-G. *Aspergillus* : Asexual reproduction; A-B. Development of conidiophore, C-E. Formation of conidium, F-G. Germination of conidium.




A-Q. *Aspergillus* : Stages of sexual reproduction.



**Q2 Describe the modes of Reproduction in Albugo?**

**Ans** Albugo reproduces both by asexual and sexual means.

**(I)Asexual Reproduction:**

Asexual reproduction takes place by multinucleate structures , known as , conidia , sporangia or zoosporangia. These structures develop in long basipetal chains on short, erect , club shaped structures , called conidiophores or sporangiophores.

(1) **Formation of conidiophores or sporangiophore:**

After establishing in the host tissue, the intercellular mycelium collects beneath the host epidermis. The tips of these hyphae develop into short , erect , thick walled and club shaped structures called **conidiophores** or **sporangiophores** . They develop into as a palisade like layer beneath the host epidermis and is perpendicular to the host surface.

(2) **Formation of conidia or sporangia or zoosporangia :**

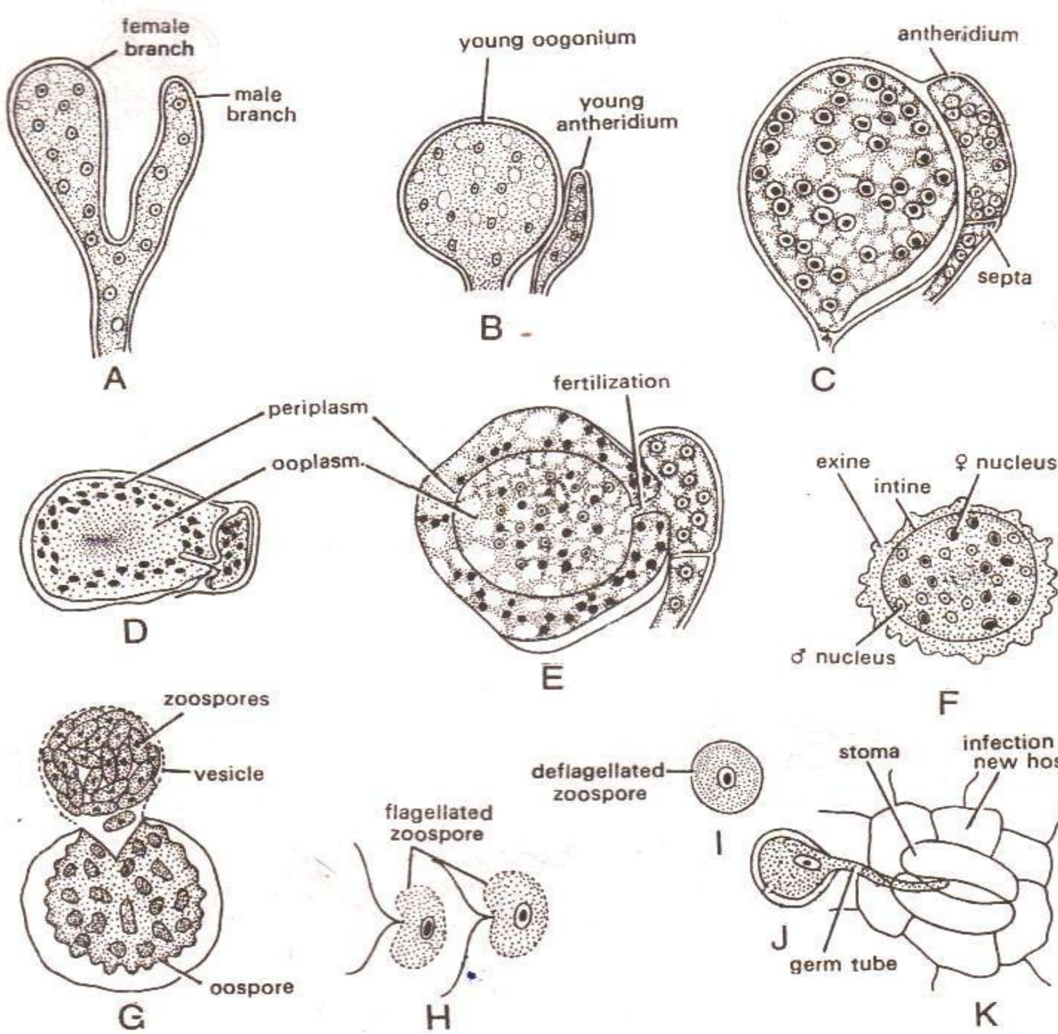
**Conidia** or sporangia develop in long basipetal chains at the distal end of the conidiophores or sporangiophore. During the formation of a conidium , a deep constriction appears below the swollen distal end of the conidiophores , which gradually increases from the periphery to the centre. Ultimately , the constriction develops in the form of a transverse wall and a small bud –like structure develops into a spherical multinucleate ( usually 5 – 8 nuclei) conidium or sporangium. This process is repeated several times and each time a new conidium is formed on the conidiophore. Conidia develop in basipetal succession i.e. the youngest conidium is at the base and the oldest at the top of the chain. An intercalary mucilaginous disc, known as **disjunctor ,** develops between the two successive conidia.

Due to pressure exerted by the developing conidial chains, host epidermis is raised and finally ruptured. Conidia are visible on the host surface as white powdery mass. Hence , the disease caused by the fungus is known as **white rust.**

**Conidia** are smooth , hyaline , multinucleate and spherical or shortly ellipsoid – cylindrical structures , measuring 13 – 18µm in diameter.

(3) **Germination of conidia:**

Conidia are blown away by the wind or washed away by rain splash. They germinate after 2- 3 hours of their dispersal on suitable substratum under moist conditions and low temperature. ( around 10˚C) . The multinucleate protoplast of the conidium divides into a number of uninucleate segments. Each segment metamorphoses into a reniform biflagellate zoospore. Usually 8 zoospores are formed per sporangium ( conidium). After liberation from the sporangium , zoospores remain active for sometime and then they withdraw their flagella and encyst. The encysted zoospore forms a germ tube which enters through the stoma or penetrates the host epidermis and develops into a fresh mycelium.




A-K. *Albugo* : Sexual reproduction; A-C. Development of antheridium and oogonium, D-E. Fertilization, F. Oospore, G. Germination of oospore, H. Zoospores, I-K. Germination of zoospore.

**(II) Sexual Reproduction:**

Sexual reproduction is oogamous. The male and female sex organs are known as antheridium and oogonium respectively. In A. candida , the sex organs are generally formed towards the end of the growing season of the host. They develop in intercellular spaces , quite deep into the host tissues. Their presence is externally indicated by hypertrophy and deformation of the organ.

**(1) Oogonium:**

During oogonial development , the apex of the hyphal branch swells considerably and becomes globular by accumulating cytoplasm and nuclei. The swollen apex , with 6 – 12 nuclei , is separated from the main hypha by the formation of a transverse septum. The nuclei in the young oogonium undergo many mitotic divisions forming about 100 - 300 nuclei. The cytoplasm of the young oogonium is uniformly vacuolated and the nuclei are evenly distributed throughout.

But as the oogonium matures , the protoplast is differentiated into an outer more vacuolated periplasm and a central densely cytoplasmic ooplasm. The periplasm and ooplasm are separated by a plasma membrane . The ooplasm represents the egg . There are many nuclei in the egg when it is first delimited from the periplasm , but later all nuclei except one disintegrate. Thus the mature female gamete or egg has a single nucleus.

**2 Antheridium:**

Antheridia are elongated , club shaped and multinucleate structures. They develop on male hyphae which are placed very close to the oogonium. The tip of the male hypha accumulates cytoplasm and nuclei and the swollen antheridial tip is soon cut off by a transverse septum. There are 6- 12 nuclei in a young antheridium but the mature antheridium has only a single functional nucleus as the other nuclei degenerate.

**3 Fertilization:**

**Plasmogamy** takes place by gametangial contact. The antheridium forms a slender fertilization tube that penetrates the oogonial wall and the periplasm and reaches the ooplasm. Prior to fertilization , the granular cytoplasm of the oogonium forms a mass of protoplast , known as **coenocentrum.** The fertilization tube bursts near the coenocentrum , releasing the male nucleus which fuses with the egg nucleus. The coenocentrum disappears after fertilization.

**Q3 Describe the life cycle of Claviceps in detail?**

**Ans**

Claviceps reproduces by asexual and sexual means.
(I) Asexual Reproduction:-

It takes place by conidia, which develop on conidiophores. After about a week of infection . some hyphae grow towards the ovary wall . They appear to form a palisade like tissue in a transection of the ovary. The exposed apices of these hyphae act as conidiophores and as such numerous conidia develop in acropetal succession from the tip of a conidiophopre. The conidia are small , oval , uninucleate and hyaline structures. The conidial stage of the fungus is also known as **sphacelial stage. ,** as conidia of Claviceps were earlier described under **Sphacelia segetum**. The ovary is enlarged and becomes spongy and the infected flower secretes a sticky sugary substance , known as **honey dew. The conidia** stucked in honey dew are transferred to healthy flowers through insects. They germinate there and produce new mycelia.

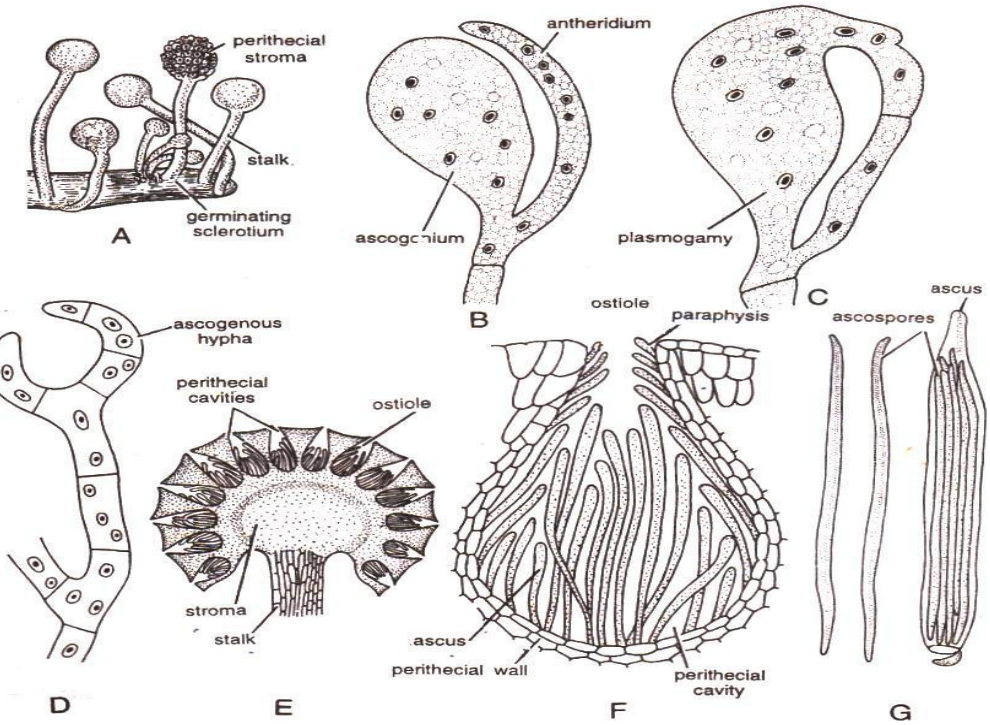
**1.Formation of sclerotium:-**

In the last stages of conidial formation, the mycelium present in the ovary ( known as sphacelial mycelium ) matures. The whole mycelium eventually becomes very hard and changes into a purplish or black pseudoparenchymatous body, called **sclerotium** or **ergot grain.** As the sclerotium matures, the ovary is completely destroyed and the sclerotium is held in between the glumes.

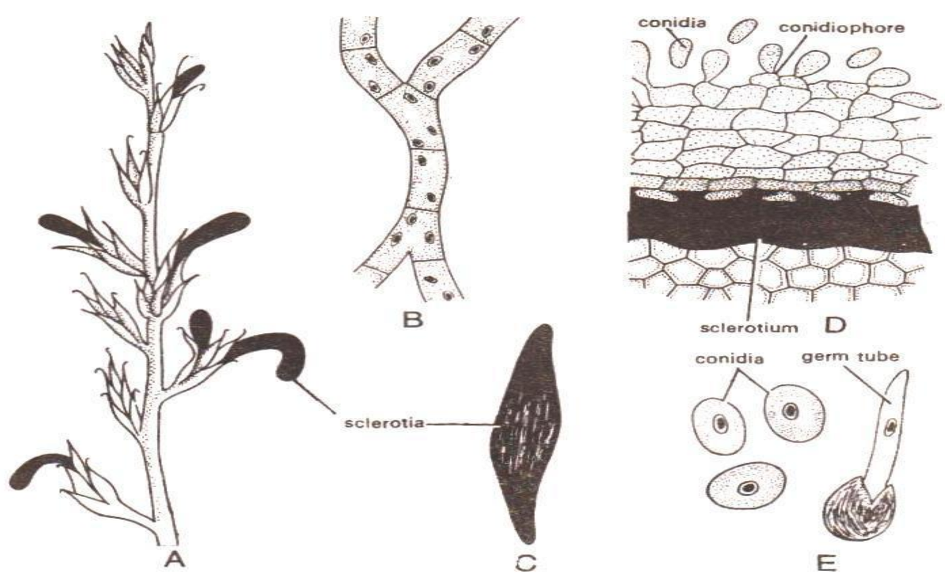
The mature sclerotium is protected by a violet or black covering. Sclerotia fall on the soil and remain viable for a long period due to the presence of a resistant covering.

**2 Germination of Sclerotium:-**

Dispersal of sclerotia takes place during winter season ,but they remain dormant until next spring. In spring when conditions are favourable , they germinate to produce a number of small pink or dark purple , drum – stick like structures , called **perithecial stromata. These stromata** are 1- 2 cm in length **, positively phototrophic** and are differentiated into **stalk** and **capitates head.** There are many minute cavities in the stromatal head. They are known as **perithecial cavities.** They are surrounded by pseudoparenchymatous tissue.




**A-G.** *Claviceps* : Sexual reproduction: **A.** Germinating sclerotium, **B.** Antheridium and ascogonium, **C.** Plasmogamy, **D.** Ascogenous hypha, **E.** Stroma in longitudinal section, **F.** Fruiting body (perithecium) in longitudinal section, **G.** Ascus and ascospores.




**A-E.** *Claviceps* : **A.** Infected inflorescence of *Secale cereale*, **B.** Hyphae, **C.** Sclerotium, **D.** Formation of conidia, **E.** Conidia and their germination.

**(II) Sexual Reproduction:-**

Both male (antheridium ) and female ( ascogonium) sex organs are present in the perithecial cavity. The sex organs develop from the terminal cells of the hyphae present at the base of the cavity. Both antheridium and ascogonium are multinucleate at maturity. The ascogonium is usually stouter and broader than the slender and elongated antheridium.

As the ascogonium matures ,a small papilla – like outgrowth appears on its lateral side. This outgrowth comes in contact of the neighbouring antheridium. The walls of the ascogonium and antheridium dissolve at the point of their contact and plasmogamy takes place. In the process , male nuclei from the antheridium migrate into the ascogonium.

1 **Development of the ascocarp:-**

Following plasmogamy , numerous ascogenous hyphae are produced from the base of the ascogonium. The penultimate dikaryotic cell of an ascogenous hypha functions as ascus mother cell. The two nuclei of this cell fuse to form a diploid nucleus. It becomes narrow and tubular by elongation and forms an ascus. The diploid nucleus of the ascus divides first meiotically and then mitotically to form eight haploid nuclei. Each nucleus transforms into an ascospore by accumulating some cytoplasm and secreting a wall around itself. The ascospores are elongated , hyaline and thread like structures. All the eight ascospores lie parallel to one another in an ascus. The perithecial walls grow around the developing asci within the stromatal heads. The whole structure thus formed is called fruiting body or ascocarp.

**2 Fruiting body or ascocarp:**

The fruiting body or the ascocarp of Claviceps is the perithecium which is a flask – shaped structure embedded in the apical part of stroma. The wall of the perithecium is 1- 2 layered and the perithecium opens at the surface of the stroma by a narrow opening , known as ostiole. A perithecium contains many asci which arise in tufts from its base. Many paraphyses arise from the sides of the inner wall of the perithecium. They surround the asci but are not present in between the asci.

**3 Dispersal of ascospores:**

Ascospores are discharged forcibly due to hygroscopic pressure and are ejected one by one from the ascus. Soon after their , release , they are disseminated by wind . They are carried to the flowers of healthy host plants , where they germinate and infect the ovaries.

**Q4 Describe in detail the asexual and sexual reproduction in Rhizopus?**

**Ans** Rhizopus reproduces by both vegetative, asexual and sexual methods.

**(I) Vegetative Reproduction:-**

Vegetative reproduction takes place by fragmentation. The vegetative hyphae ( stolons) may break up into smaller fragments. Each fragment is capable of developing into new mycelium.

**(II) Asexual Reproduction:-**

Asexual reproduction takes place by the formation of **aplanospores** ( sporangiospores) or by **chlamydospores.**

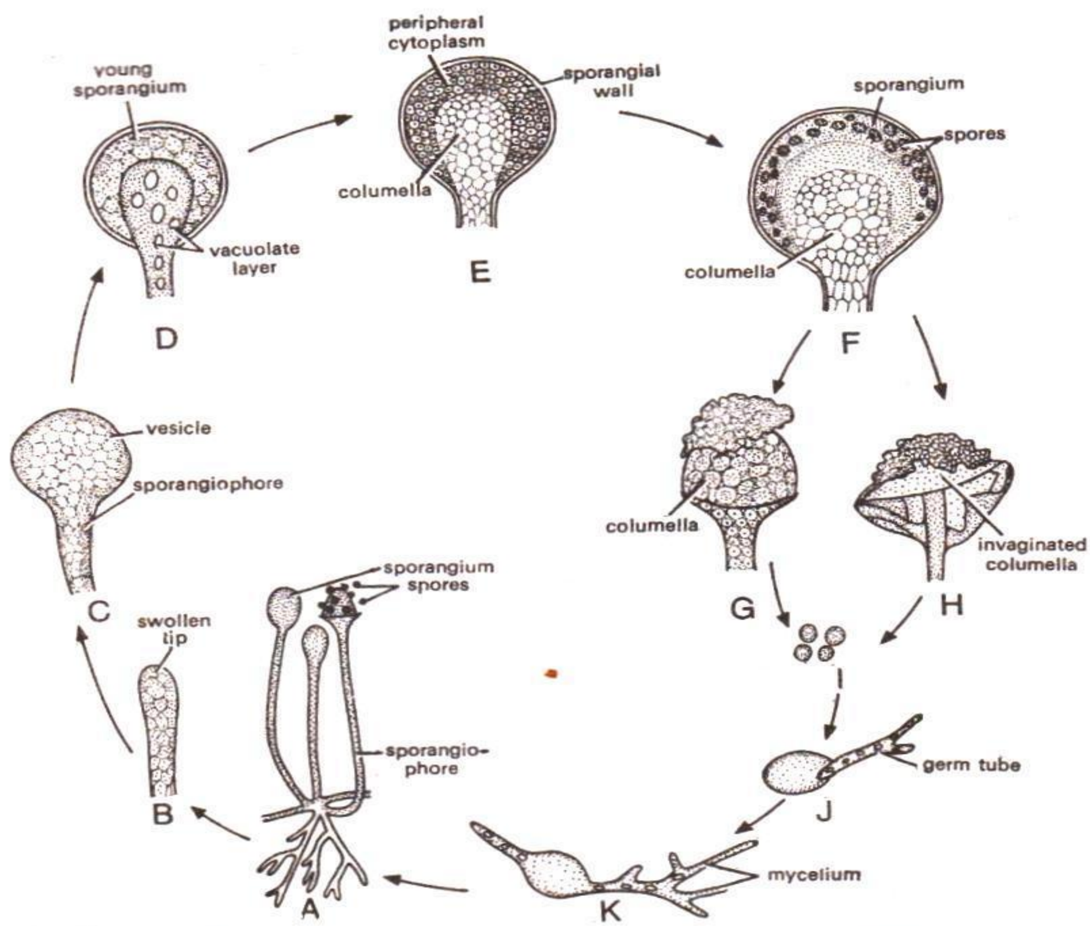
**(I) Asexual Reproduction:-**

During favourable conditions, it is the most common method of asexual reproduction. The multinucleate non – motile spores , known as **aplanospores** or **sporangiospores** are formed inside the round black **sporangia** , which occur singly at the tips of sporangiophores. Sporangiophores develop in tufts from the stolon opposite the rhizoids. At the time of sporangium formation , the tip of the sporangiophores swells into a knob – like vesicle. The cytoplasm , alongwith many nuclei , flows from the sporangiophores into the swollen vesicle. Ultimately , the swollen tip develops into a large globose structure , the young sporangium. The contents of the young sporangium soon differentiate into a peripheral dense multinucleate region and a central region with small flattened vacuoles and fewer nuclei. Thereafter, a cleft is formed between the two regions by the coalescence of vacuoles. Finally , a dome shaped septum is laid down , separating the two regions completely. The central vacuolated region is sterile and is known as **columella** . The outer fertile sporangiferous region forms spores. The columella remains in continuity with the protoplast of the sporangiophore. Cleavage in the peripheral sporangiferous zone results in the formation of several multinucleate segments. Each segment ultimately transforms into a globose, multinucleate , non – motile aplanospores.

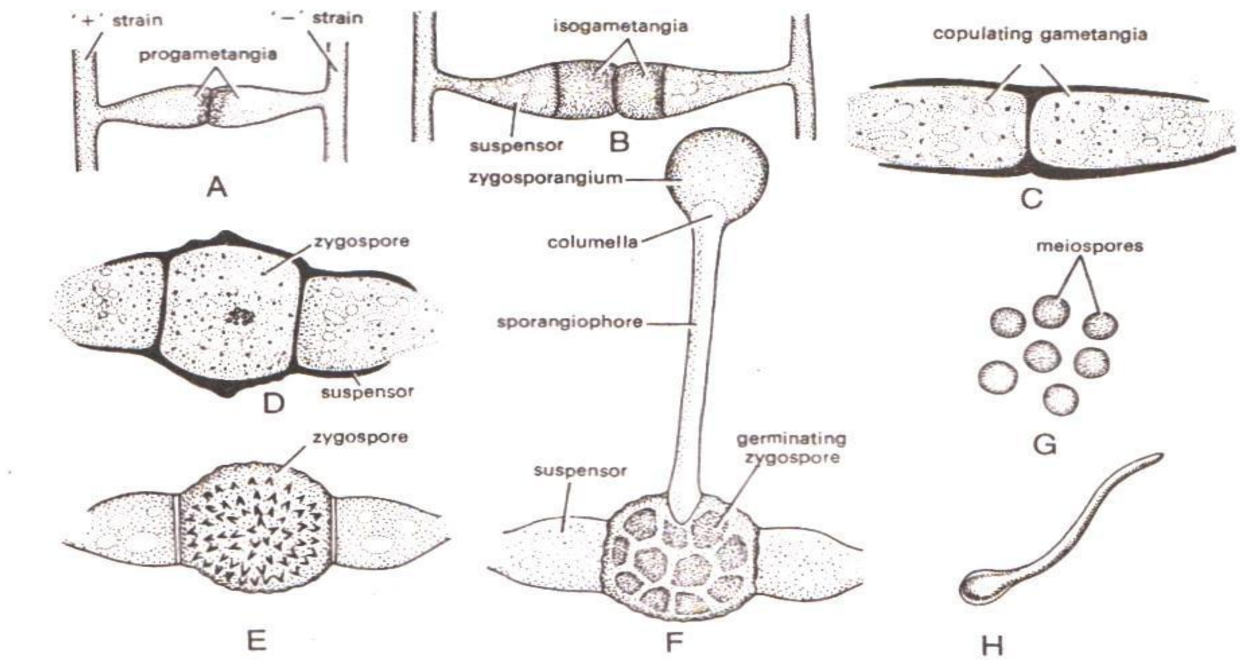
At maturity, the sporangium wall dries and the columella collapses like an inverted cup like dish. Ultimately , the sporangial wall breaks , liberating spores to the atmosphere. The remnants of the sporangium wall can be seen as a frill at the base of the columella. When the spore falls on a suitable substratum, it germinates by producing a germ tube. The germ tube ultimately develops into a fluffy and profusely branched mycelium.

**(2) Chlamydospore formation:-**

During unfavourable conditions, asexual reproduction takes place by means of chlamydospores. At the time of chlamydospore formation , the mature mycelium becomes septate and the protoplast of each cell forms a rounded and thick walled structure, known as **chlamydospore.** The chlamydospores are perennating bodies and they can pass unfavourable conditions. They germinate and form new mycelia.




A-K. *Rhizopus* : Asexual reproduction; A-F. Development of sporangium. G-H. Dehiscence of sporangium. I. Aplanospores. J-K. Germination of spores.




A-H. *Rhizopus* : Sexual reproduction; **A-B.** Formation of gametangia, **C-E.** Gametangial copulation and formation of zygospore, **F.** Germination of zygospore, **G.** Meiospores, **H.** Germinating meiospore.

**(III) Sexual Reproduction:**

Sexual reproduction takes place by the copulation of two morphologically similar multinucleate gametangia. Most of the species of Rhizopus are heterothallic , but a few ( e.g. R. sexualis ) are homothallic.

During sexual reproduction , gametangia are produced as terminal swellings on the tips of two compatible hyphae or hyphal branches. These special hyphae are known as **progametangia.** The progametangia of opposite strains , adhere by their tips and enlarge by accumulating cytoplasm. A septum is then formed a little below the tip of the progametangium , separating the terminal **gametangium** from a proximal suspensor cell. The gametangium has densely granular multinucleate protoplast, whereas the suspensor has a highly vacuolated protopast. The walls of the two gametangia at the point of their contact dissolve and the protoplasts of both gametangia unite to form a **zygospore.** The nuclei of opposite strains pair and fuse to form diploid nuclei in the combined protoplast. The nuclei, which fail to fuse in pairs , ultimately degenerate. Soon , the young zygospore enlarges and secretes several layered thick wall around it.

The zygospore germinates after a long period of rest. During germination, the zygospore cracks open and a **germ sporangiophore** emerges which develops a **germ sporangium** at its tip. Reduction division occurs during the formation of germ sporangium and the sporangium contains numerous haploid spores. Each spore , after liberation , germinates to form a new mycelium. Occasionally , copulation does not take place between gametangia and these gametangia are surrounded by a many layered wall and then develop in **azygospores.**

**Q5** Describe the life history of Peziza , mentioning the features of special interest.

Ans

**Peziza** mostly reproduces sexually but asexual reproduction also takes place in a few species.

**(I) Asexual Reproduction:-**

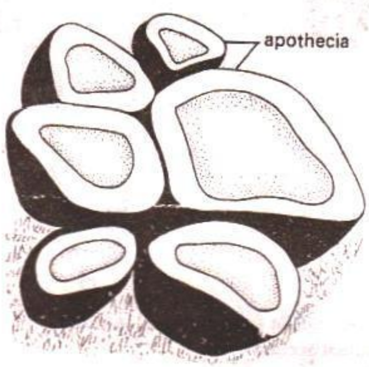
Asexual reproduction is absent in most of the species of Peziza. But a few species ( e.g. P. repanda , P. vesiculosa) produce conidia and chlamydospores. The conidial stage of P. pustulata belongs to the form genus Oedocaphilum.

At the time of formation of conidia, some hyphae grow upwards and act as conidiophores . The conidiophores are long, cylindrical , erect and septate. The tip of the conidiophore swells to form a vesicle. They are hyaline or light coloured , elliptical and thin walled structures. They germinate on a suitable substratum and produce new mycelia.

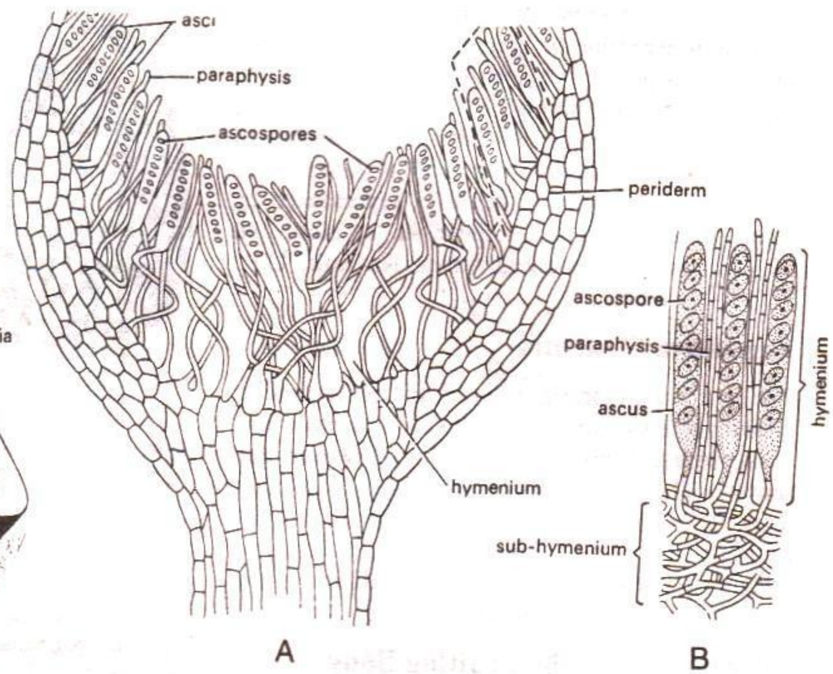
Chlamydospores are thick walled resting cells which are formed in intercalary positions on the hyphae , either singly or in chains. In favourable conditions, they germinate and form germ tubes which eventually grow into new mycelia.

**(II) Sexual Reproduction:-**

Definite sex organs i.e. antheridium and ascogonium are not formed in Peziza. Sexual reproduction takes place by somatogamous copulation. The hyphae grow in all directions and form a pseudoparenchymatous mass . Some hyphal branches in this parenchymatous mass have dense protoplasmic contents and their cells are uni – or multi nucleate. Usually, two adjacent cells of these hyphae fuse to form a dikaryotic cell , but sometimes two nuclei of the same cell form a dikaryon. The later process is known as **autogamous pairing.** The dikaryotic cells give rise to ascogenous hyphae. The terminal cell of the ascogenous hypha usually functions as the ascus mother cell. But in **Peziza vesiculosa** the dikaryotic cell directly acts as ascus mother cell and it elongates and forms a cylindrical or club shaped ascus. The diploid nucleus undergoes a reduction division , followed by a mitotic division , resulting in eight haploid nuclei. Each of these nuclei secretes a wall and organizes into an **ascospore.** In this way , eight **ascospores** are formed in an ascus. The uninucleate ascospores are hyaline, oval or elliptical and have smooth or coarsely reticulate wall. The ascospores are placed obliquely in a row in the ascus.




*Peziza* : Apothecia.




**A-B.** *Peziza* : **A.** Longitudinal section of apothecium, **B.** A part of the longitudinal section in magnified view.

**Apothecium**:
The mature Apothecium is a cup shaped , sessile or subsessile structure, 1- 10 cm in diameter. They may be whitish yellow ( P. coccinea ) , orange (P. aurantia) or bright red or grey in colour. (P. vesiculosus). The asci are arranged in parallel rows within the Apothecium.
**Ascospores** are released from the Apothecium generally in moist environmental conditions. On germination , the ascospore gives rise to a germ tube which develops into a new mycelium.

**Q6 What are various types of life cycle found in Saccharomyces? Describe them briefly with the help of suitable diagrams.**

**Ans Reproduction ;**

**Yeast** reproduces both by **vegetative and sexual means.**

**(I) Vegetative reproduction:**

Vegetative reproduction take place by the following methods:

**1. By budding.**

The protoplast of the yeast cell bulges out in the form of a bud. The nucleus divides into two daughter nuclei and of these one migrates into the enlarging bud. The bud grows and is eventually separated from the mother cell . AS the bud separates a scar with a convex surface is left on the parent cell. This scar is called **bud scar**. A concave scar is also retained by the newly formed daughter cell. It is called birth scar.

**2. By fission:**

**Fission** is simple splitting of a cell into two daughter cells by the constriction and formation of a transverse wall. The parent cell elongates and its nucleus divides by intranuclear mitosis. Then a constriction appears somewhere near the middle of the mother cell followed by a transverse septum and as such two uninucleate daughter cells are formed.

**3 By Endospore formation:**

During unfavourable conditions , thick walled **endospores** are formed. The protoplast usually divides into four parts : each part is surrounded by a thick wall. These structures are known as **endospores.** The endospore may survive adverse conditions and on the return of favourable conditions it germinates by budding and produces a chain of cells.

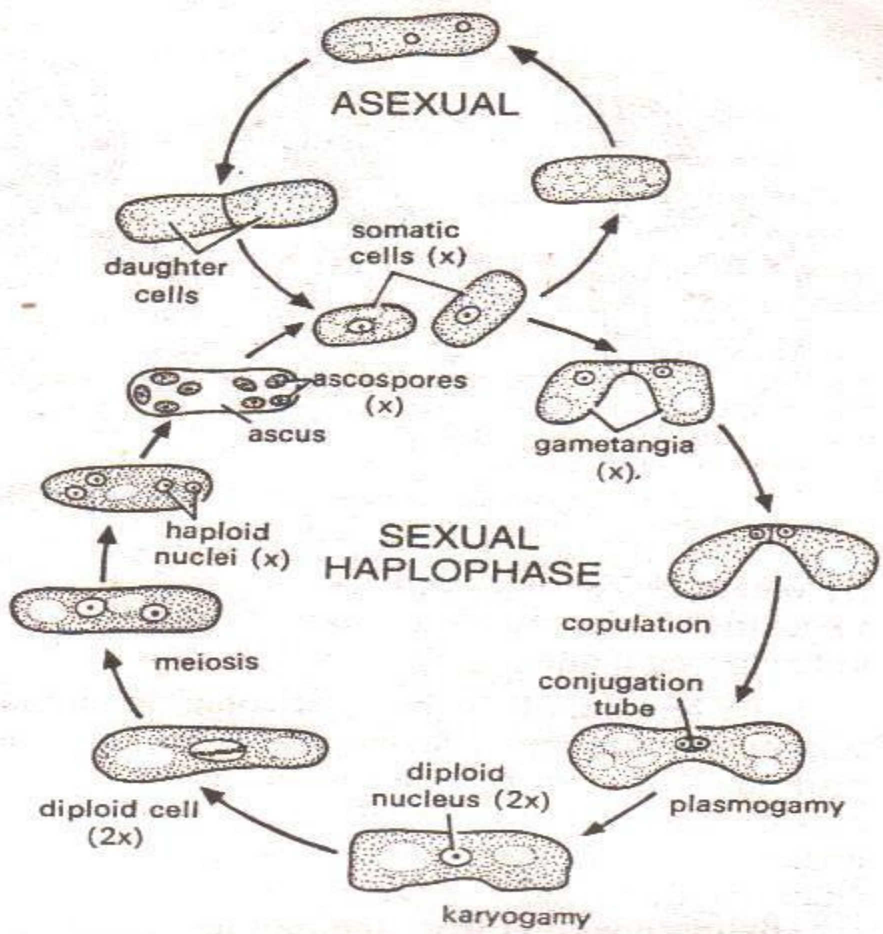
**(II) Sexual Reproduction:**

Sexual reproduction usually takes place during unfavourable conditions when the food supply is exhausted. Sex organs are entirely absent and as such the sexual reproduction is a simple process. In this process either two somatic cells or two ascospores are involved which assume the function of copulating gametangial. The zygote formed by their fusion eventually develops into an ascus which contains 4 or 8 ascospores depending upon the number of nuclear divisions.

Three types of life cycle patterns have been recognized in yeasts:

**1 Haplobiontic type:**

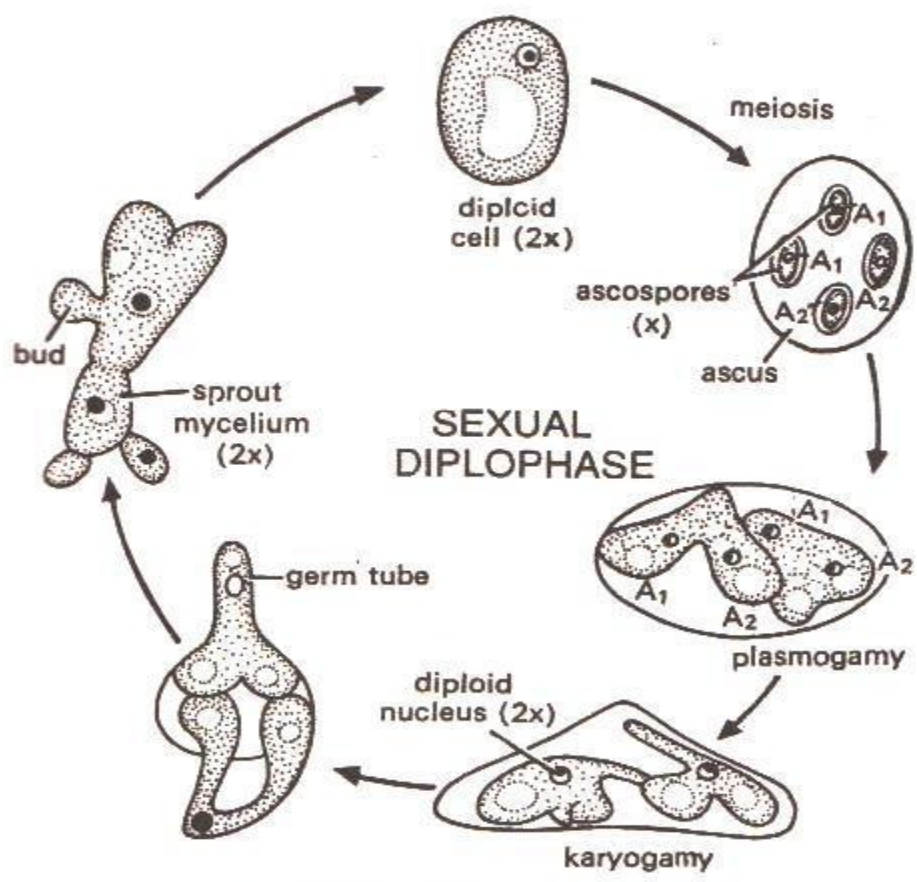
This type of life cycle is found in **S. octosporus.** Here the haplophase is elaborate and the diplophase is very short , confined to the zygote cell only. The somatic cells are haploid and function as a potential gametangia. At the time of sexual reproduction two somatic cells meet in pairs , each sending a small protuberance towards the other. Both the protuberances come in contact and the wall at the point of contact dissolves to form a common passage , called **conjugation tube.** Thereafter , the nuclei of both the gametangia move onto the conjugation tube ; they fuse there and form a diploid zygotic nucleus. The zygote functions as an **ascus.** It undergoes meiosis immediately after karyogamy and thus eight haploid nuclei are formed. These nuclei organize themselves into ascospores. The ascospores are liberated by breaking of the ascus wall. The ascospores behaves like a somatic cell.




*Saccharomyces octosporus* : Life-cycle.

**2.Diplobiontic type:**

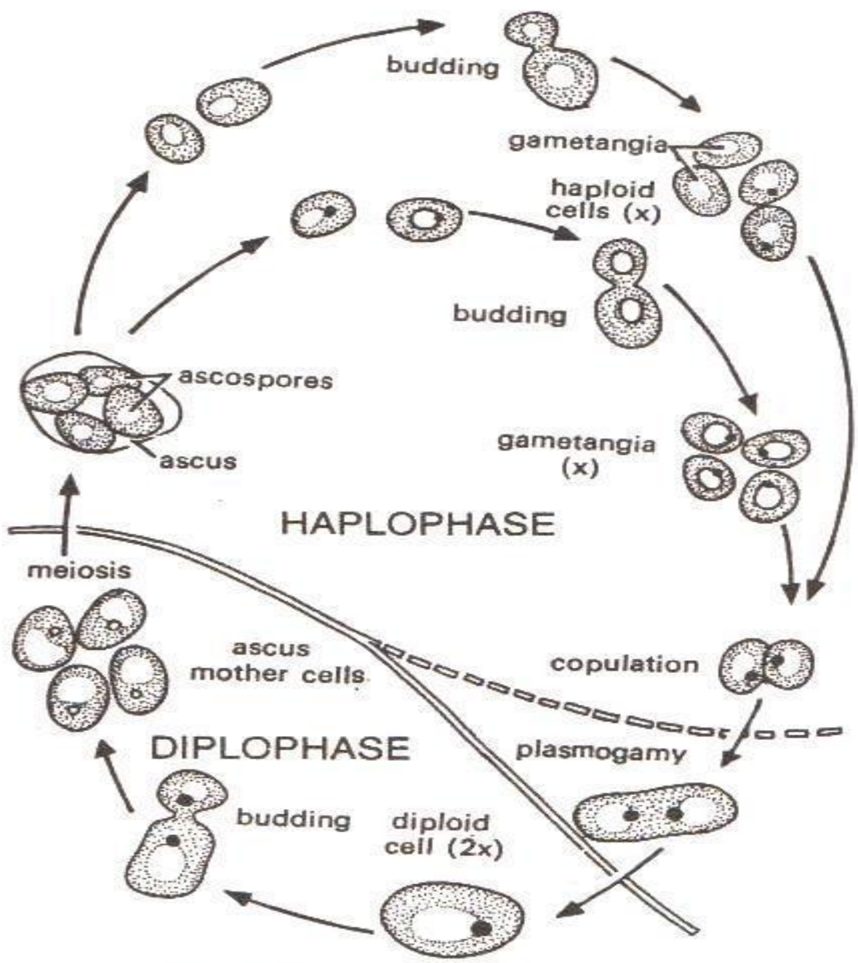
This type of life cycle is represented by **S.ludwigii.** In this type, the diploid somatic stage is long and the haplophase represented by ascospores , is very short. Only four ascospores are formed in an ascus and they are not liberated from the ascus. The ascospores behave as gametangia and they copulate in pairs and each pair by fusion produces a diploid zygote cell within the ascus wall. The zygotic diploid cell produces a germ tube that pushes through the ascus wall. The germ tube becomes multicellular and functions a s a diploid sprout mycelium . The new diploid yeast cells are budded from it. The diploid buds are detached from the parent sprout mycelium and function as diploid sprout cells. Under favourable conditions , these cells function as asci ; each producing four ascospores as the result of a reduction division.




*Saccharomyces ludwigii* : Life-cycle.

**3 Haplo – diplobiontic type:**

This type of life cycle occurs in **S. cerevisiae** . Both , the haploid and diploid phases are of pretty long duration representing somewhat an alternation of generations. Out of the four ascospores formed in an ascus , two are of one mating type and two of the other mating type. Normally the haploid cells of different mating types multiply by budding. But under certain environmental conditions , two somatic cells of opposite mating types behave as gametangia. The zygote formed by the fusion of two gametangia propagates by budding , producing a large number of diploid cells. When there is scarcity of food, the diploid cells function as ascus. Four haploid ascospores are formed in each ascus by a reduction division. On liberation , the ascospore forms many haploid somatic cells by vigorous budding.




*Saccharomyces: cerevisiae :* Life-cycle.

## Unit IV

# Life History and Disease cycle of Fungi

**Q1 Describe the life – cycle of Puccinia in detail?**

**Ans** Life Cycle:

Puccinia graminis is a macrocyclic heteroecious rust. There are five types of spores viz. uredospores, teleutospores basidiospores, pycnidiospores and aeciospores in its life cycle. These spores develop in two different hosts in a definite sequence. The sequence of various stages occurring in the primary and alternate hosts are as follows:

**Uredospore stage**

**Teleutospore stage** — **on primary host (Triticum aestivum)**

**Basidiospore stage**

**Pycnidiospore stage**

**Aeciospore stage** — **on alternate host (Berberis vulgaris) .**

**A. Stages of Puccinia graminis on Wheat Plant:**

**(I) Uredospore stage:-**

The dikaryotic mycelium is produced by the germination of aeciospores on wheat plants. It enters through stomata and develops in the intercellular spaces in the tissues of the leaf, stem and glumes of the host. The dikaryotic mycelium , present in the sub – epidermal region, develops many erect hyphae which grow at right angles to the epidermis. A binucleate uredospore develops at the tip of each erect hypha. These spores develop in groups and these groups are known as **uredosori.** With the formation of uredospores , disease symptoms appear in the form of reddish – brown pustules or streaks on the stem, leaf and leaf base . These symptoms usually appear in late spring . The host epidermis bursts due to the pressure of developing uredosori and thus uredospores are liberated.

The mature uredospore is a stalked , unicellular , oval and binucleate structure. The spore wall is thick and is differentiated into three layers ; the outer layer is relatively thick and spiny, whereas the inner layer has four equatorial thin areas , called **germ pores.**

**The binucleate uredospore** function as a conidium and it has the capacity to germinate immediately after its formation. Uredospores can reinfect wheat plants and they are effective in the spread of the disease.

**Germination of uredospores:**

Under favourable conditions , uredospores germinate as soon as they come in contact with fresh wheat leaves. Each produces one or more germ tubes through germ pores. The germ tube grows over the surface of the host epidermis and on reaching a stoma the tip of the germ tube develops into a vesicle , called appressorium. Hyphal branches develop from the appressorium in the intercellular spaces. This dikaryotic mycelium forms a new mycelium of uredospores which infect healthy plants. This results into a heavy build up of infection on wheat crop.

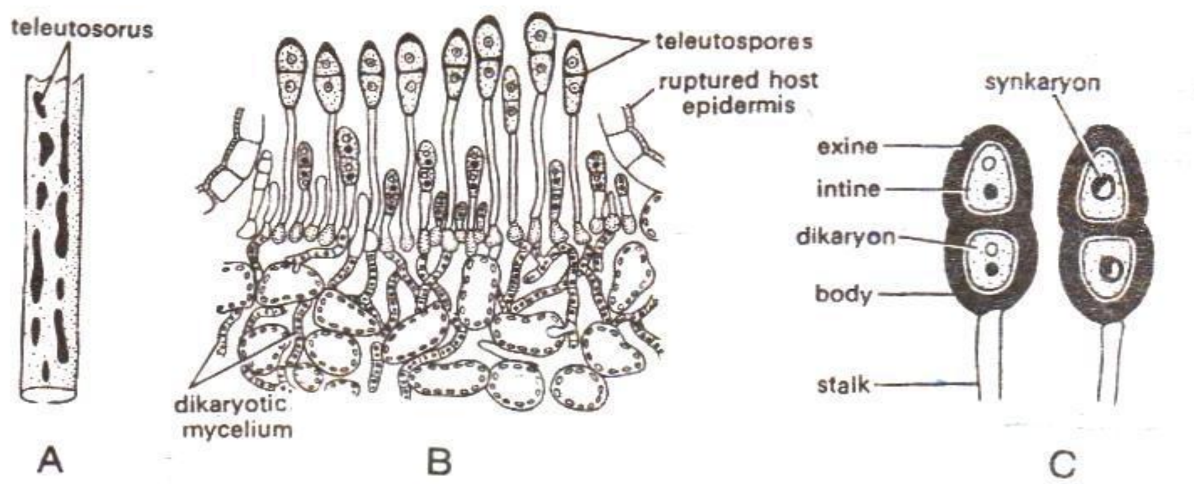
**(II) Teleutospore stage:**

At the close of the wheat season , the uredosori also start producing teleutospores in addition to uredospores, The uredosori are ultimately converted into teleutosori and produce teleutospores exclusively. Teleutosori are also produced independently from the mycelium formed by the late infection of uredospores. The teleutosori appear as black raised streaks along leaf sheaths and stems of infected plants. The groups of binucleate cells which give rise to teleutospores are known as **telia.**

The **teleutospore** is stalked , bi –celled , spindle shaped structure . constricted slightly at the septum. The wall of the teleutospore is thick and smooth and the tip is usually pointed or round. Each cell of the teleutospore is binucleate and is provided with a germ pore. The germ pore is at the apex in the upper cell, whereas it is just below the septum in the lower cell. Teleutospores also exert pressure on the overlying epidermis. The epidermis is thus ruptured and the spores are exposed. The teleutospores act as resting spores and may survive most unfavourable conditions. They are incapable of reinfecting wheat plants . They do not germinate until the next spring. Under favourable conditions of high atmospheric humidity and low temperature , they germinate in soil as no host is required for their germination.

**(III) Basidiospore stage:**

On return of favourable conditions in spring ,the teleutospore germinates. It produces one germ tube from each cell. The germ tube has limited growth and is known as **promycelium** or **epibasidium.** The diploid nucleus moves into the promycelium and divides meiotically to form four haploid nuclei, two of (+) and two of (-) strain. The promycelium divides into four cells by the formation of transverse septa. Each cell produces a single basidiospore which is borne asymmetrically on a fine sterigma. The four basidiospores are thus formed on each promycelium , two of (+) and two of (-) strain.




A-C. *Puccinia graminis* : Teleutospore stage; A. Teleutosori on wheat leaf, B. Vertical section of wheat leaf passing through a teleutosorus, C. Teleutospore.

Basidiospores are small, unicellular and thin walled structures, each with a haploid nucleus . They are discharged by an explosive mechanism and are disseminated by the wind. They can germinate only on the leaves of alternate host, barberry bushes. Basidiospores can survive only for few days and they perish in the absence of alternate host.

**B. Stages of Puccinia graminis on Berberis Plant:**

The haplophase of P. graminis occurs on Berberis plant. This phase begins with the formation of basidiospores.

**(I) Pycnidiospore or spermogonium stage:**

Under favourable conditions basidiospores germinate on the leaves of Berberis. Each produces a germ tube which penetrates through the leaf epidermis and grows into the intercellular spaces of the host tissue. The monokaryotic mycelium thus formed may be of (+) or (-) strain, depending on the strain of the basidiospore. Usually several basidiospores of different strains infect the same leaf and produce mycelia of both (+) and (-) strains. After a few days of infection the mycelia become aggregated into pseudoparenchymatous masses beneath the leaf epidermis and form spermogonia on pycnidia. The spermogonia are yellowish flask shaped structures, developed on the upper surface of the leaf. They may be of (+) or (-) strain , depending on the strain of the mycelium. The spermogonium opens on the upper surface of the leaf by a minute pore called **ostiole.** The **ostiole** is guarded by a tuft of unbranched , tapering , orange – coloured sterile hairs, known as **periphyses.** Amongst the periphyses thin – walled branched **flexuous hyphae** (receptive hyphae) are also present and these hyphae project much beyond the periphyses. The wall of the spermogonium is lined internally with a palisade – like layer of numerous , uninucleate tapering cells , known as **spermatiophores (pycniophores).**

Each spermatiophores abstricts many small , uninucleate spermatia ( pycniospores) . Spermatia ooze out through the ostiole and are held by the periphyses in sticky drop of liquid. The spermatia are small, oval to spherical and smooth spores. They may be of (+) or (-) strain.

When spores are released , the spermogonium secretes nectar drops which attract insects. The spores of one strain are transferred to the flexuous hyphae of the opposite strain by insects. This process is known as **spermatization.**

During the course of spermogonial formation , some hyphae of each mating type form **protoaecidia** on reaching the lower surface of the leaf. The protoaecidia appear as globose mass of hyphae. They do not grow further if there is no spermatization , but if there is spermatization, the protoaecidium develops into an aecidium.

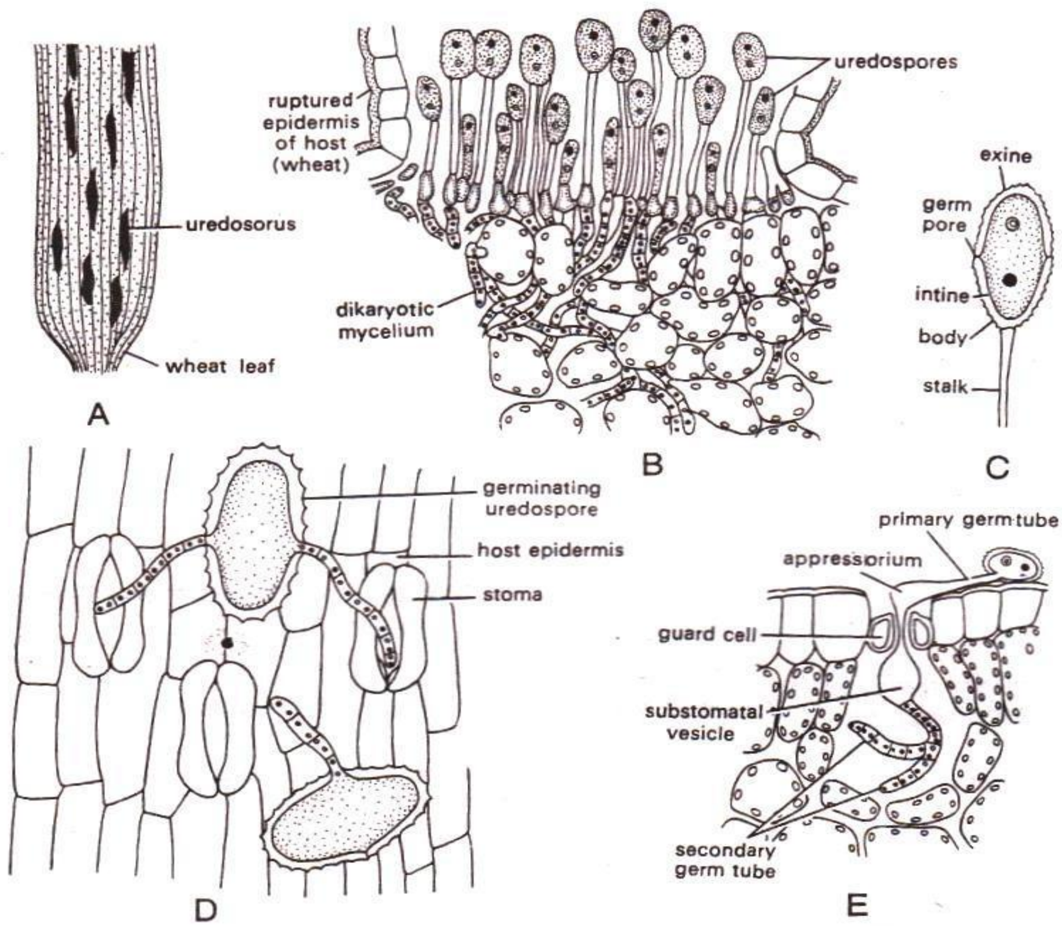
**(II) Aeciospore stage:**

**Aecidia** are cup shaped structures formed on the lower surface of the barberry leaf. They develop from the same mycelium which form pycnidia on the upper surface. The mycelium becomes dikaryotic due to spermatization and this dikaryotic mycelium forms the roof of the protoaecidium. The cells of the protoaecidium are known as aecidiophores. Each aecidiophore cuts off numerous binucleate cells which are arranged in a chain. These chains are made up of long and short cells arranged alternately. The long cells mature into aeciospores , whereas short cells , known as **disjunctor**
, remain sterile and soon disintegrate. Simultaneously with the formation of aeciospores , the peripheral cells of aecidium divide to form a thick protective covering , known as peridium.

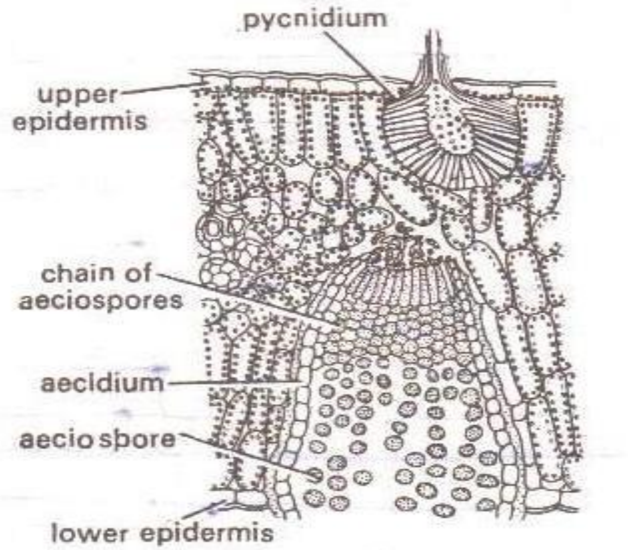
The development of aeciospore chains inside the aecidium exerts a pressure on the peridium, As a result it bursts towards the epidermis. At about the same time , disjunctor cells present in between aeciospores disintegrate and thus aeciospores are released.

Aeciospores are unicellular , binucleate , thin walled and orange coloured structures. In young stages , aeciospores are polyhedral but at maturity they

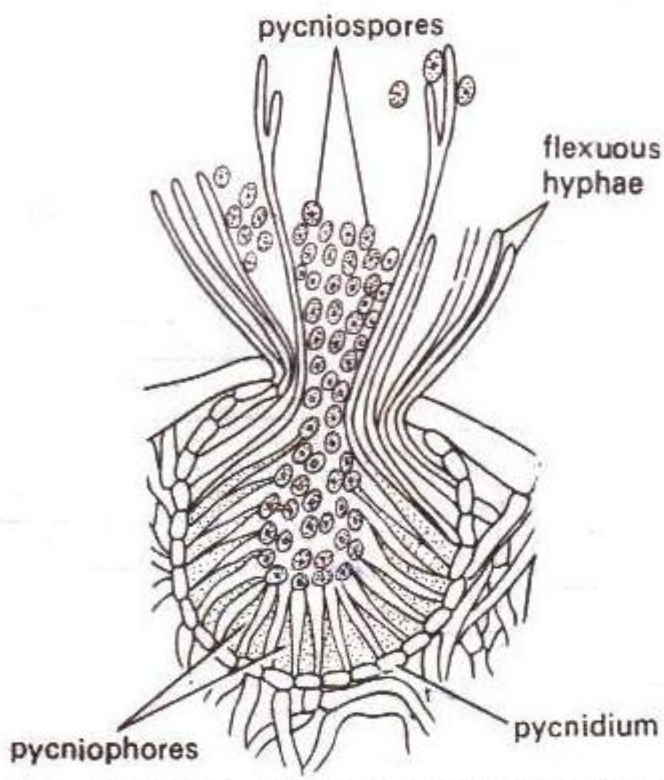
become globose by absorbing water. The aeciospores are incapable of infecting barberry plants , but they can infect wheat plants.
They are dispersed by wind . They germinate on the surface of the primary host by producing germ tubes. The germ tube penetrates stoma and grow in the intercellular spaces of the host tissue and forms dikaryotic mycelium. The dikaryotic mycelium starts producing uredospores within 10 – 12 days.




**A-E.** *Puccinia graminis* : uredospore stage; **A.** Uredosori on wheat leaf, **B.** Vertical section of wheat leaf passing through a uredosorus, **C.** A uredospore, **D, E.** Germination of uredospores.




Puccinia graminis : Vertical Section of leaf showing a young pycnidium and a mature aecidium




Puccinia graminis : Spermogonium Longitudinal Section

# Unit V

**Q1 Describe in detail the life history of a smut fungus?**

**Ans** The genus Ustilago includes more than 300 species, commonly known as **smut fungi.** The reproduction takes place by the formation of **chlamydospores** and **basidiospores.**

**1 Formation of Chlamydospores:**

**Chlamydospores** are formed on dikaryotic mycelium. During the blossom period of the host , the mycelium becomes more active and infects the embryonic spikelets on reaching the inflorescence region. The mycelium then aggregates in the young ovaries and forms dense masses of hyphae. These hyphae, known as sporogenous hyphae , divide into dikaryotic cells. Each dikaryotic cell forms a binucleate chlamydospores. These binucleate chlamydospores are also known as **teleutospores, brand spores** or **smut spores** and the spore mass , **smut ball** or **sorus.**

All species of Ustilago show the same mode of Chlamydospore formation but in loose smuts the sporogenous hyphae grow in between the anticlinal walls of the epidermis of the infected organ and as such the epidermis is destroyed.

**Structure of Chlamydospores:**

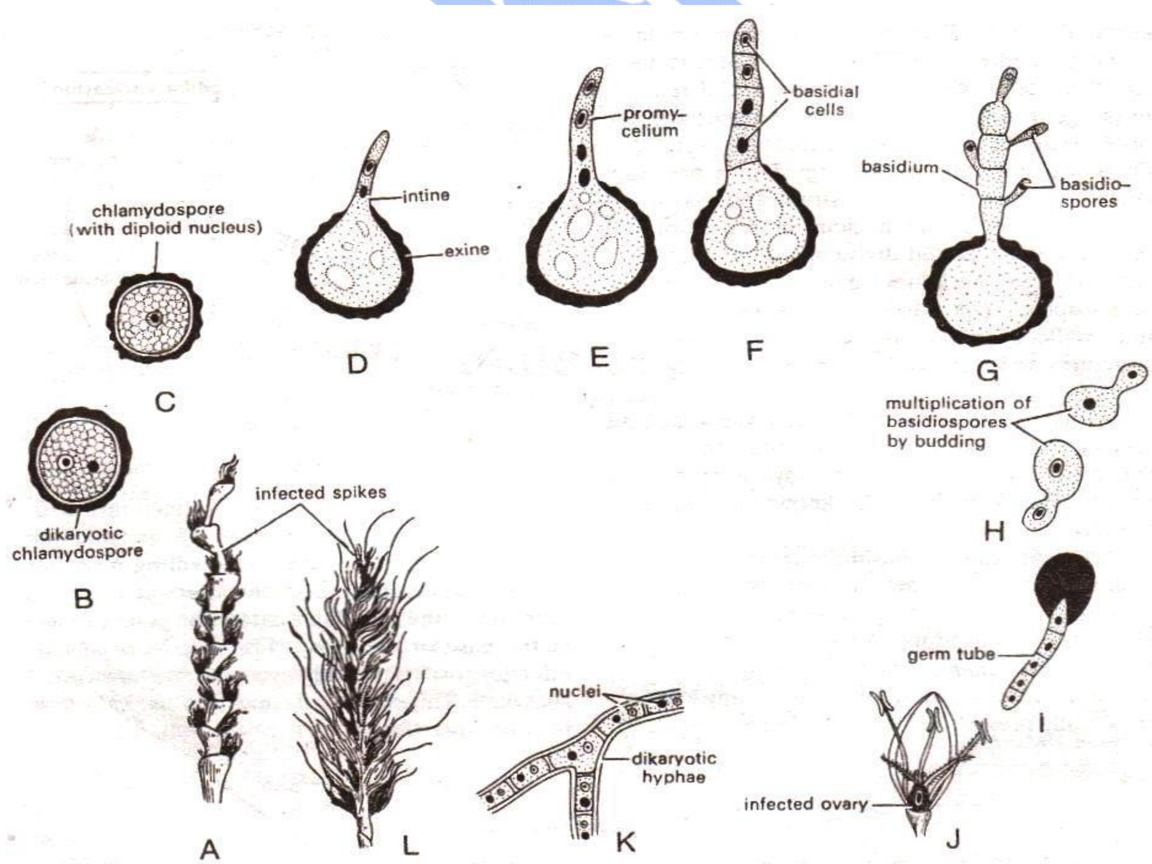
The chlamydospores are globose or elliptical , light brown. The spore wall is differentiated into an outer thick **exine** and an inner thin **intine. The exine** may be smooth (U. hordei ) or ornamented (U. maydis). The chlamydospores are binucleate as they are formed on dikaryotic secondary mycelium. The chlamydospores are binucleate as they are formed on dikaryotic secondary mycelium.

**3 Germination of Chlamydospores and development of basidium.:**

The chlamydospores are readily disseminated by wind. They remain viable up to 5 or 6 months. The mature spores of U. nuda var. tritici germinate soon after dissemination and infect the healthy plants. But in most of the species of

Ustilago, the chlamydospores undergo a period of rest and they germinate in the next season if conditions are favourable.

Before germination , the two nuclei of the binucleate chlamydospore fuse to form a diploid nucleus. During germination , the spore swells by absorbing water , the exine bursts and the intine comes out in the form of a germ tube. , known as **promycelium** or **basidium.** At this stage , the diploid nucleus of the chlamydospore undergoes a reduction division and forms four haploid nuclei, two of + strain and two of – strain. After reduction division , the basidium becomes 4 – celled by the formation of septa. Each cell of the basidium has a single haploid nucleus. The latter divides to form two daughter nuclei, one of these nuclei remains in the germ cell ( i.e. in the basidial cell) and the other passes into the basidiospores through sterigmata. Of the four basidiospores formed in a basidium , two are of '+'strain and two of - strain. The remaining nucleus in the germ cell may undergo repeated divisions and as such each cell of the basidium may form numerous basidiospores. ( sporidia) . The basidiospores are thin walled , uninucleate and globose or oval structures and may also multiply by budding.




A-L. *Ustilago nuda* var. *tritici* : life-cycle.

**Germination of basidiospores:**

The haploid basidiospores germinate to form monokaryotic mycelium . This mycelium may be of (+) or (-) strain, depending on the strain of the spore. Species of Ustilago show different modes of infection . In covered smuts , the chlamydospores are usually present inside the grain and when such seeds are sown, the mycelium is formed inside the host tissue by the germination of spores. Such mode of infection is known as **seedling infection.** In loose smuts , the infection occurs at the flowering time, when the mycelium enters the young tissues at the base of the ovary. Secondary infection occurs by chlamydospores, blown away by the wind. This mode of infection is known as **blossom infection.**

**Q2 Describe the morphology and reproduction in Alternaria. Name some important diseases caused by it.**

**Ans** The form – species of Alternaria are saprophytes or parasites and are distributed throughout the world. The saprophytic species grow on the dead organic material and help in its disintegration., whereas the parasitic species cause several diseases in plants.

**Vegetative structure:**

The profusely branched and septate mycelium is light brown in colour. The cells are multinucleate `In the early stage of infection , the hyphae of the parasitic species are intercellular but later on they become intracellular.

**Reproduction:**

Sexual stages are not known in Alternaria and the asexual reproduction takes place by exogenously formed conidia. The conidia are produced singly or in chains at the tips of the branched or unbranched conidiophores. The conidiophores are undifferentiated and emerge through the stomata of the infected leaf.

The dark coloured conidia are multicellular and **obclavate , obovoid** or **muriform** in shape . They are both transversely and longitudinally septate. There are about 5- 10 septa in each conidium, and the number of septa is dependent on environmental conditions. The conidium measure 30 m- 130μm in length and 12 -30μm in breadth. It is surrounded by a two layered wall , where the outer layer is pigmented.

**Germination of conidia:**

The conidia are readily disseminated by wind. On being detached from the conidiophore, they germinate on a suitable substratum . Humid conditions favour their germination. The conidium produces 5- 10 germ tubes . usually one from each segment. The germ tubes enter through the stomata of the host leaf and soon develop into new mycelia within the intercellular spaces.

**Symptoms:**

The disease symptoms appear when the plants are 3- 4 weeks old. The early symptoms are in the form of small , yellowish brown spots on the leaves which enlarge to from concentric rings. These are known as target board symptoms. The photosynthetic area and eventually the leaf dries and falls off. In severe infection , entire lamina , petiole and stem is badly damaged. Alternaria solani even infects the tubers and the potato pulp turns brown and becomes corky in texture.

Some important pathogenic species of Alternaria are as follows:

(1) A. solani causes early blight of potato and of other solanaceous plants.
(2) A .cucumarina infects the members of the family Cucurbitaceae like water melon , cucumber and gourd.
(3) A. tenuis causes black point disease in wheat.

**Q3 Discuss the asexual and sexual reproduction of Agaricus in detail**

**Ans** Agaricus reproduces by **vegetative, asexual** and **sexual** means.

**(I) Vegetative reproduction:**
The edible mushrooms are propagated by vegetative means. Small pieces of dikaryotic mycelium are used as inoculum. The pieces are grown in soil rich in organic manure to obtain basidiocarps.

**(II) Asexual reproduction:**
It is not a common method of propagation in **Agaricus.** It takes place by chlamydospores formation. The chlamydospores develop in terminal or intercalary positions on the secondary mycelium. They germinate to produce dikaryotic mycelium.
In some species oidia are also formed , but these are involved mainly in dikaryotisation rather than developing directly into new mycelia.

**(III) Sexual reproduction:**

Most species of Agaricus are **heterothallic** ( **A. bisporus** is homothallic) , but they do not have sex organs in traditional sense. Primary mycelia formed by the germination of basidiospores of two different strains act as male and female **sex organs.**

There is somatogamy between the somatic hyphae of opposite strains and this results in diploidization and formation of the secondary mycelium. The secondary mycelium later develops fruiting bodies , known as basidiocarps. Somatogamy between two primary hypha of opposite strains takes place through the following steps:

**( a) Plasmogamy:**

In this step . two primary monokaryotic hyphae of opposite strains come in contact with each other. At the point of their contact , the cell walls are dissolved and a dikaryon is formed. A dikaryotic mycelium develops by successive divisions of the dikaryotic cell. At the time of the division of dikaryotic cell, both nuclei of the dikaryon divide synchronously and form four haploid daughter nuclei , two of (-) and two of (+) strain. Out of these , two nuclei (one of (+) and one of (-) strain ) are transferred to the daughter cell by the formation of clamp connection.

The dikaryotic mycelium is perennial and subterranean . It produces basidiocarps under favourable conditions .

**(b) Karyogamy:**

In this step , both nuclei of a dikaryon fuse to form a diploid nucleus. Karyogamy takes place in young basidium.

**( c) Meiosis:**

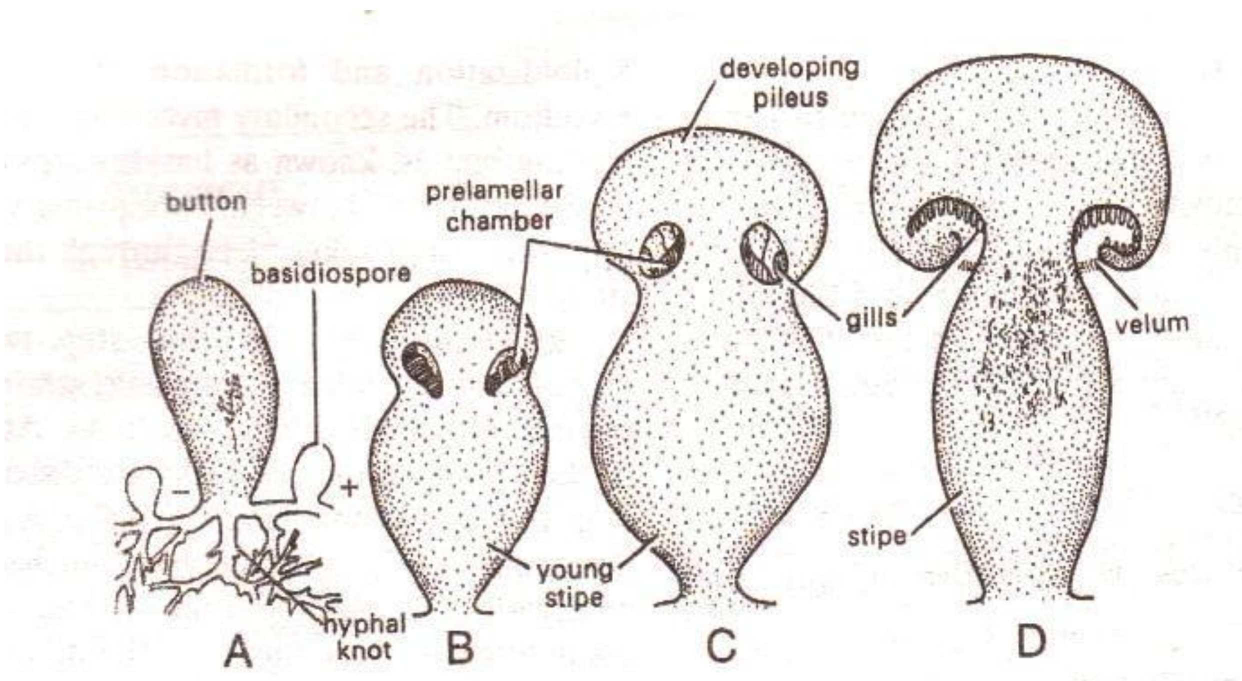
Soon after karyogamy , meiosis takes place in the basidium. The basidiospores thus formed in the basidium , are haploid .

**1. Development of basidiocarp:**

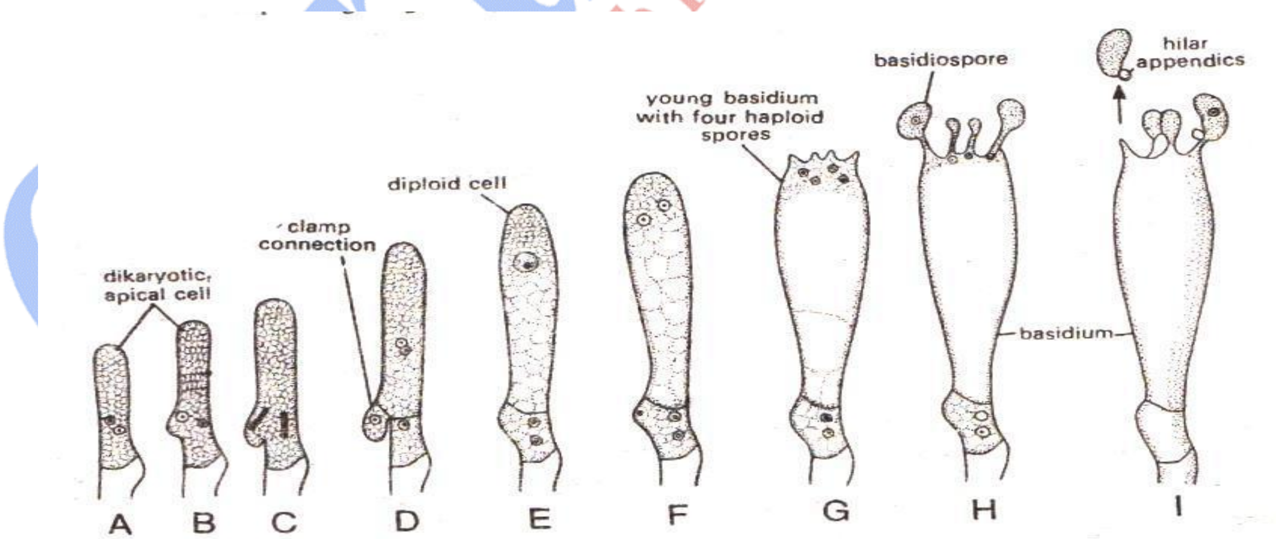
The subterranean secondary mycelium takes nutrients from the soil and then forms the fruiting body or basidiocarp. Basidiocarps develop as small white knot like structures at the tips of the underground hyphae. These hyphal knots enlarge gradually and give rise to **button stage.** At this stage , the developing basidiocarp is differentiated into a basal bulbous part and an apical hemispherical region . The basal bulbous part forms the **stipe,** and the apical hemispherical part, **pileus** . Some hyphae at the junction of the stipe and pileus are drawn apart and form a ring like chamber , called **pre-lamellar chamber.** The inner surface of the roof of the pre – lamellar chamber becomes deeply concave and it is lined with alternating radial bands of slow and rapidly dividing cells. The latter form gill primordia, which develop into

gill lamellae that hang downward into the prelamellar chamber. As pileus expands , there is an increase in radial interspaces between the gills. A membrane ,called **velum** or **inner veil** connects the margin of the pileus with the stipe.
Due to the elongation of stalk, the buttons are raised on the soil surface. The upper hemispherical region of the button grows more rapidly than the stalk. This causes rupture of the velum and the upper hemispherical region finally expands out as an open umbrella – like structure with numerous gills attached to its lower surface. The gills are exposed by the rupture of the velum. At this stage , remnants of the velum are still attached to the stipe in the form of a ring , called **annulus.**
In dry season , when soil is hard , buttons do not grow and remain underground. In rainy season, when soil is moist , they grow rapidly and come out of the soil surface. Hence, many basidiocarps can be seen in rainy season on the soil surface.

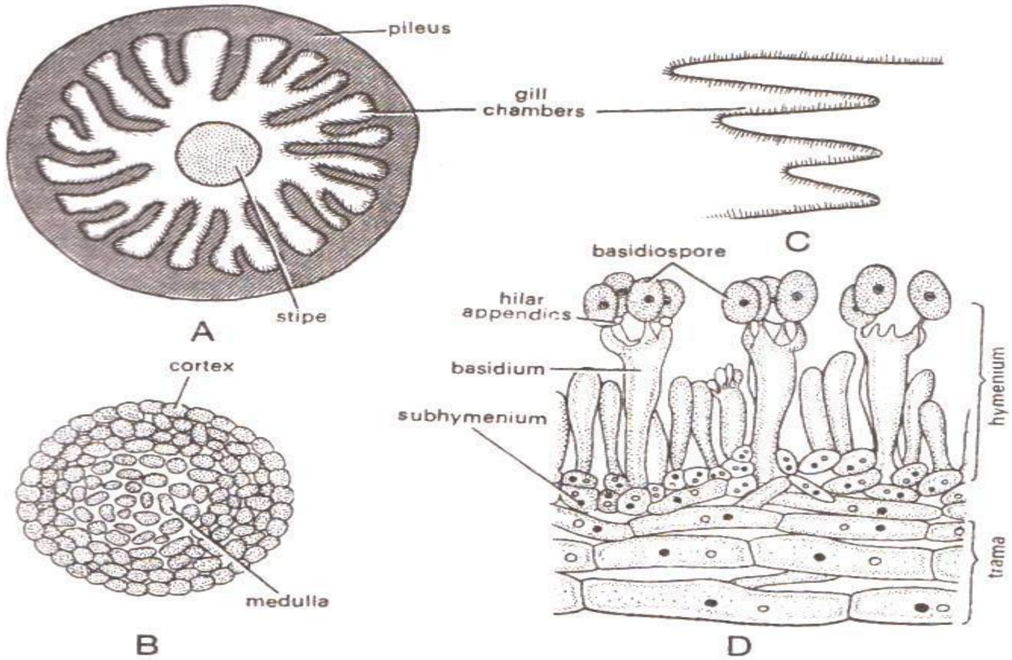
**2 . Structure of mature basidiocarp:**
The mature basidiocarp is an umbrella – shaped structure with a long massive **stipe** and a broad **pileus.** The stipe is a thick , fleshy and cylindrical structure , light pink or white in colour . An umbrella like pileus , 5-12 cm in diameter , is present at the distal end of the stipe. The upper convex surface of the pileus is white, light brown or yellow in colour. About 300- 600 radially arranged gills hang down from the inner surface of the pileus. All gills are not of the same length ; they may be of full, half or quarter length. The surface of the gill is enveloped by a fertile layer , the **hymenium.** The gills are of light pink colour when young , but they turn brown or purplish black at maturity.




A-D. *Agaricus* : Development of basidiocarp.




A-I. *Agaricus* : Development of basidium and basidiospores.




A-D. *Agaricus* : Internal structure of basidiocarp; A. Transverse section of pileus, B. Transverse section of stipe, C. Transverse section of pileus through gill region, D. A part of gill region magnified.

**3 Internal structure of basidiocarp:**

The basidiocarp is made up of pseudoparenchymatous mass of hyphae.

**(a) Internal structure of stipe:**

The stipe is composed of numerous longitudinally intertwined hyphae. The hyphae are compactly arranged and form a pseudoparenchymatous tissue in the peripheral region , whereas they are loosely arranged with large intercellular spaces, in the central region. The peripheral region of the stipe is known as **cortex** and the central region is **medulla.**

**(b) Internal structure of Pileus:**

The internal structure of the pileus is similar to that of the stipe. The pileus is also differentiated into an outer cortex and a central medulla. The hyphae of the stipe region extend in the distal end to form pileus.

**( c) Internal structure of the gills:**

The internal structure of the gills is complex and the following three regions are discernible:

(i) **Trama:**
This is the central sterile region of the gill. It consists of many loosely arranged interwoven hyphae.

**(ii)Sub –hymenium: ( Hypothecium) .**
This region is situated on both sides of the trama. It is formed by the lateral branches of the hyphae of trama region. The cells of these hyphal branches are isodiametric and 2-3 nucleate. This is also a sterile zone like trama.

**(iii) Hymenium:**
This is the outermost layer of the gill. It is fertile and composed of the subhymenium region. In this region , the cells are arranged in palisade- like layer . These aseptate fertile cells are known as **basidia. Club –shaped** sterile paraphysis occur in between the fertile cells.

The young basidium is a dikaryon and as the basidium matures the two nuclei fuse to form a diploid nucleus. This diplophase is ephemeral and after karyogamy the diploid nucleus divides meiotically to form four haploid nuclei. Of these four nuclei , two are of **(+)** strain and two of **(-)** strain. At the distal end of the basidium , four peg like outgrowths are formed. These outgrowths are known as **sterigmata.** The sterigmata swell at their tips and each forms a single basidiospore. Thus, four monokaryotic haploid basidiospores are formed in a basidium. The young basidiospore is unpigmented but it develops brown or black pigments at maturity.

**(4) Dispersal and germination of basidiospores:**
As the basidiospore matures , a drop of liquid appears at the **hilar appendics** which remains surrounded by a limiting membrane . The basidiospore lies just above this drop. The drop increases in size gradually and attains size of about one -fifth of the spore. Then the basidiospore is suddenly shot away from the sterigma. The four basidiospores of a basidium are dispersed in rapid succession.
When the basidiospore falls on a suitable substratum , it germinates by producing a germ tube that grows into a primary monokaryotic mycelium. Depending on the strain of the basidiospore , the mycelium may be of **(+)** or **(-)** strain.

# Multiple Choice Question

## Bacteria

1 Surface appendages used by Bacteria to attack to one another and to host organism are called:

(a) Pili (b) Spirilla
( c) mesosomes (d) thylakoids

2 Compared to Gram '-ve' bacteria , Gram '+ve' bacteria

(a) Have less Peptidoglycan
(b) retain the crystal violet dye
( c) have more complex cell walls
(d) are more resistant to antibiotics

3 A free living Bacterium capable of fixing nitrogen is:
(a) Rhizobium (b) Azotobacter
( c) Pseudomonas (d) Streptococcus

4 When bacteria are rod shaped , they are called
(a) Cocci (b) bacilli
( c) spirila (d) Vibrio

5 9 + 1 fibrillar arrangement is present in:
( a) eukaryotic flagella ( b) bacterial fimbriae
( c) bacterial flagella (d) $T_4$ bacteriophage

6 Bacterium that must have organic molecules both for energy and as a source of carbon is called :
(a) Chemoheterotrophs (b) chemoautotrophs
( c) photoheterotrophs (d) photoautotrophs

7 Bacteria lack :
( a) Cytoplasm (b) DNA
( c) cell membrane (d) endoplasmic reticulum

8 Genetic element in bacteria that can replicate in the cytoplasm or can integrate into the bacterial chromosome and replicate with the host chromosome is:
(a) Retrovirus ( b) plasmid
(c ) episome (d) plastome

9 Bacterium that causes **'botulism'** belongs to the genus:
( a) Clostridium (b) Pseudomonas
( c) Bacillus (d) Staphylococcus

10 When DNA is exchanged , via cytoplasmic bridges , between two bacteria , the process is called:
( a) general transduction (b) conjugation
(c) transformation (d) restricted transduction

11 Bacteria were first discovered by:
( a) Robert Koch (b) A.V. Leeuwenhoek
( c) N.D. Zinder (d) Robert Hooke

12 Bacteria that have a tuft of flagella at one end are called:
( a) monotrichous (b) lophotrichous
( c) amphitrichous ( d) peritrichous

13 Bacteria which in association with legume roots , fix atmospheric nitrogen are called:
( a) Azotobacter (b) Rhizobium
( c) Pseudomonas (d) E.coli

14 Bacteria those get their energy by fermentation and oxygen is lethal for them are called:
( a) obligate aerobes (b) facultative aerobes
( c) obligate anaerob ( d) facultative anaerobes

15 Small, circular , self – replicating DNA found in E.coli:
( a) Chromosomes (b) Plastids
(c) plasmids (d) Ribosomes

16 Which of the following is not a prokaryote?
( a) Bacterium b) Amoeba
( c) Blue green algae (d) Archaebacteria

17 Scientist who for the first time demonstrated the principle of immunization?
( a) Louis Pasteur ( b) Edward Jenner
( c) John Tyndall ( d) Robert Koch

18 Name of the scientist who observed micro – organisms for the first time :
( a) Griffith ( b) A.V. Leeuwenhoek
( c) Lazaro Spallanzani ( d) Robert Hooke

19 $N_2$ fixing bacteria in soil were discovered by:
( a) John Needham ( b) S.N. Winogradsky
( c) Waddington (d) Walter Reed

20 Which of the following bacteria oxidizes ferrous compounds into ferric ones?
( a) Rhizobium (b) Lactobacillus
( c) Pseuformonas (d ) Leptothrix ochracae

21 Which of the following bacteria oxidizes molecular hydrogen into water in soil?
( a) Penicillium notatum ( b) Bacillus pentotrophus
( c) Rhizobium noduliformes (d ) none of these

22 Growth in bacteria reflects:
( a) Growth in number ( b) Growth in weight
( c) Growth in volume ( d) Changes in shape and size

23 Spherical bacteria arranged in a grape bunch manner :
( a) Spirillum (b) Coci
( b) Bacilli ( d) Staphylococci

24 In some bacteria , capsule surrounding the cell wall is made up of :
( a) Cellulose ( b) Polysaccharides
( c) Polypeptide (d) Teichoic acids

25 Which of the following processes does not result in recombination?
( a) Conjugation ( b) Transformation
( c) Transduction ( d) Translation

26 Bacteria that require elevated temperature ( above 55ºC) for growth are called:
( a) psychrophiles (b) thermophiles
( c) halophiles ( d) mesophiles

27 Thermopiles grow in conditions of high :
( a) Temperature (b) Salt
( c) $CO_2$ (d) Food

Answers: Q1( a) Q2( b) Q3 (b) 4 (b) Q5 (b) Q6 (a) Q7 ( d) Q 8 ( b) Q9 (a) Q10 ( b) Q 11 ( b) Q 12 (b) Q13 ( b) Q 14 ( c) Q15 (c) Q16 (b) Q17 (a) Q18(b) Q19 (a) Q20 ( d) Q21 ( b) Q22 ( a) Q23( c) Q24 (b) 25 (d) Q 26 (b) Q27 (a)

## Puccinia

1. In Puccinia which of the following is lacking :
(a) Dolipore (b) epibasidium
( c) Pycnidiospore ( d) dikaryophase

2 Brown rust of wheat is caused by :
( a) P. recondita (b) P. graminis
( c) P. striiformis (d) P. hordei

3 The alternate host of Puccinia graminis is :
( a) Berberis vulgaris (b) Maize
( c) wheat (d) Thalictrum

4 Yellow rust of wheat is caused by :
(a) Puccinia striiformis (b)Puccinia recondita
( c) Puccinia coronata (d) P . graminis

5 The primary host of Puccinia graminis is
( a) wheat (b) Berberis vulgaris
( c) Maize (d) a & b both

6 Name an autoecious& heteroecious rust fungus.

( a) Puccinia (b) Albugo
( c) Alternaria (d) Ustilago

7 Black rust of wheat is caused by :
( a) Puccinia graminis (b) Puccinia hordei
( c) Puccinia striiformis (d) P. recondita

8 During which process does the dikaryotisation of the hyphae in Puccinia takes place ?
( a) spermatization ( b) Somatogamy
( c) Oogamy (d) Plasmogamy

9 Name the most popular group of diseases caused by Uredinales of Basidiomycetes?
( a) rust (b) smut
( c) red rot of sugarcane (d) Ergot of rye

Answers : Q1 ( a) Q2 ( a) Q3 ( a) Q4( a) Q5( a) Q6 ( a) Q7 ( a) Q8 ( a) Q9 (a)

## Peziza

1 Hymenium in Peziza is composed of:
(a) Only ascus (b) only paraphyses
(c ) ascus and paraphyses (d) sterile hyphae.

2 Peziza is commonly called as :
( a) cup fungi (b) sponge mushroom
( c) smut fungi (d ) kukarmutta

3 The fruiting body of Peziza is called as :
( a) Hypothecium (b)Perithecium
( c) epigeal hypothecium (d) epigeal apothecium

4 In Peziza each ascus is:
( a) oval & coperculate (b) cylindrical & coperculate
( c) cylindrical (d) club – shaped

5 In Peziza Sexual reproduction occurs by:
( a) somatogamous copulation

(b) gametangial contact
( c) Planogametic copulation
(d) Gametangial copulation

6 The region found located below the Hymenium in the Apothecium in Peziza is called:
( a) Hypothecium (b) Excipulum
( c) Operculum (d) none of the above

7 Peziza is a ;
( a) saprophytic & coprophilous fungus
(b) parasitic fungus
( c) symbiont
(d) obligate parasitic fungus

8 The mycelium of Peziza is:
( a) branched , septate , uninucleate
(b) branched , coenocytic, multinucleate
( c) branched , septate , multinucleate
( d) none of these

Answers Q1 ( c) Q2 (a) Q3 (d) Q4 (b) Q5 (a) Q6 (a) Q7 (a) Q8 (a)



1 Rhizopus is
(a ) a saprophytic fungus (b) parasitic fungus
( c) heterotrophic fungus (d) autotrophic fungus

2 Bread mould is common name of :
( a) Albugo ( b) Rhizopus
( c) Claviceps (d) Yeast

3 The mycelium of Rhizopus is :
( a) unicellular (b) multicellular
( c) aseptate coenocytic (d) septate

4 Columella is found in:
(a) In the sporangium of Rhizopus

(b) In the sporangium of Albugo
( c ) In the sporangium of yeast
(d) In the sporangium of Penicillium

5 In Rhizopus sexual reproduction is :
( a) Isogamous (b) anisogamous
( c) heterogamous (d) oogamous

6 The reserve food material found in sporangiospore of Rhizopus is:
( a) Starch (b) Sugar
(c ) Glycogen and oil (d) Protein

7 The Limiting hyphal wall of the mycelium and sporangium in Rhizopus is made up of:
( a) Cellulose ( b) Pectin
(c ) Cellulose and Pectin (d) Chitin

8 Name the disease caused by Rhizopus stolonifer on Sweet potato?
( a) Soft rot disease (b) Blight of paddy
( c) Citrus canker (d) None of these

9 During scarcity of water and in dry conditions , Rhizopus reproduces asexually by the formation of :
( a) conidia (b) Sporangiospores
( c) aplanospores ( d) Chlamydospores

Answers Q1 (a) Q2 (b) Q3 (c) Q4 (a) Q5 (a) Q6 (c ) Q7 (d) Q8 (a) Q9 (d)

# Albugo

1 In Albugo coenocentrum is found in :
( a) Antheridium (b) Oogonium
( c) Sporangium ( d) oospore

2 White rust of Crucifers is caused by :
( a)Cystopus (b) Puccinia
( c) Ustilago (d) Pythium

3 In Albugo conidia are :
( a) oval or spherical (b) elongated
( c) flattened (d) spiral

4 In Albugo , the protoplast of the Oogonium is differentiated into :
( a) periplasm & ooplasm ( b) egg & periplasm
( c) ooplasm and oospore (d) only periplasm

5 In Albugo , asexual reproduction occurs by :
( a) conidia or zoospores (b) aplanospores
( c) sporangiospores (d) Hypnospores

6 The order to which Albugo belongs is:
( a) Peronosporales (b) Saprolegniales
( c) Mucorales ( d) Sphaeriales

7 Number of nuclei found in the dormant oospore in Albugo are:
( a) 7 haploid nuclei ( b) 8 nuclei
( c) 32 haploid nuclei (d) 30 nuclei

## Ustilago

1 Name any smut fungus:
( a) Puccinia ( b) Ustilago
( c) Agaricus ( d) Morchella

2 In Ustilago chlamydospores are formed on which mycelium?
( a) primary mycelium (b) secondary mycelium
( c) tertiary mycelium ( d) all of these

3 In Ustilago which of the following spores are found?
( a) Uredospores and basidiospores ( b) aeciospores&teleutospores
( c) chlamydospores & basidiospores ( d) teleutospores& basidiospores

4 Loose smut of Barley is caused by:
( a) Ustilago nuda var. hordei (b) Ustilago nuda var. maydis
( c) Ustilago nuda var. tritici (d) Ustilago avenae

5 Causal organism of Loose Smut of wheat is:

( a) Ustilago nuda var.tritici
(b) Ustilago kolleri
( c) Ustilago nuda var. maydis
( d) none of these

6 Covered smut of Sugarcane is cause by :
(a ) Ustilago scitamineae
( b) Ustilago hordei
( c) Ustilago kolleri
(d) Ustilago avenae

7 Blossom infection is found in which fungus:
( a) Ustilago
(b) Puccinia
( c) Alternaria
(d) Claviceps

8 The teleutospores of Ustilago are also called as :
( a) Smut spores
(b) brand spores
( c) Chlamydospores
( d) all the above

9 Name the method by which dikaryotisation of mycelium takes place in Ustilago.
(a) By union of infection threads
(b) By fusion between primary hyphae
( c) By conjugation between the basidiospores
( d) all the above

## Plant Diseases

1 Early blight of potato is caused by:
(a) Alternaria solani
(b) Phytophthora infestans
( c) Synchytrium endobioticum
(d) Erwinia carotovora

2 The Irish potato famine occurred in North Europe during 1845 , was caused by:
(a) Alternaria solani
(b) Phytophthora infestans
( c) Synchytrium endobioticum
(d) Solanum virus -14.

3 A plant disease in which the pathogen is seen as a cottony growth on the surface of the host is called:
( a) downy mildew
(b) powdery mildew
(c ) smut
(d) rust

4 Tikka disease is caused by :
( a) Fusarium (b) Cercospora
( c) Colletotrichum (d) Puccinia

5 The whip disease of sugarcane is caused by:
(a) Ustilago scitaminae (b) Ustilago avenae
(c) Puccinia striiformis (d) Agaricus campestris

# Key terms

**Acervulus:** A mat of hyphae giving rise to short conidiophores closely packed together forming a bed –like mass.

**Agglutination:** Clumping of cells.

**Anaerobe:** An organism that grows in the absence of molecular oxygen.

**Antibiosis:** Antagonistic association between two organisms in which one is adversely affected.

**Ascostroma:** A stromatic ascocarp bearing asci directly in locules within the stroma.

**Ascus**: A sac like structure , characteristic of the Ascomycetes , in which ascospores are produced.

**Autoclave;** An apparatus using steam under pressure for sterilization.

**Bacteriophage**: A virus that infects bacteria and cause lysis of bacterial cells.

**Botulism**: Food poisoning due to the toxin of Clostridium botulinum.

**Capsid**: The protein coat of a virus.

**Clamp connection**: A bridge -like hyphal connection characteristic of the secondary mycelium of many Basidiomycetes.

**Clone:** A population of cells descended from a single cell.

**Coliphage:** A virus that infects Escherichia coli.

**Conjugate nuclear division:** The simultaneous division of the two nuclei in a dikaryon , giving rise to four daughter nuclei.

**Coprophilous:** Growing on dung.

**Diplanetic:** Refers to a species which produces two types of zoospores and in which two swarming periods occur.

**Dolipore septum**: A septum which flares out in the middle portion of a hypha, forming a barrel – shaped structure with open ends.

**Endobiotic**: An organism which lives within its substratum , usually the cells of its host.

**Epibiotic**: An organism whose reproductive organs are on the surface of the substratum , but part or all of whose soma is within the substratum.

**Epidemiology:** The study of the factors that influence the occurrence and distribution of disease in group of individuals.

**Etiology:** The study of the cause of a disease.

**Eucarpic:** Forming reproductive structures on certain portions of the thallus , the thallus itself continuing to perform its somatic functions.

**Gametangial contact**: A method of sexual reproduction in which two gametangia come in contact but do not fuse. The male nucleus migrates through a fertilization tube into the female gametangium.

**Gametangial copulation;** A method of sexual reproduction in which two gametangia or their protoplasts fuse and give rise to a zygote which develops into a resting spore.

**Gram stain**: A differential stain by which bacteria are classed as gram – positive or gram – negative depending upon whether they retain or lose the primary stain ( crystal violet) when subjected to treatment with a decolorizing agent.

**Heterokaryosis:** A condition in which genetically different nuclei are associated in the same protoplast.

**Holocarpic:** Refers to an organism whose thallus in entirely converted into one or more reproductive structures.

**Homokaryotic:** An individual whose nuclei are genetically alike

**Host:** A living organism harboring a parasite.

**Hypertrophy:** Excessive enlargement of cells

**Koch's postulates:** Guidelines to prove that a disease is caused by a specific micro – organism.

**Macrocyclic:** Long –cycled ; applied to those species of rusts which produce one or more types of binucleate spores in addition to teleutospores.

**Microcyclic :** Short – cycled, applied to those species of rusts which produce no binucleate spores other than teleutospores.

**Monoplanetic:** Refers to a species which produces only one type of zoospore and in which there is but one swarming period.

**Parasexuality:** A process in which Plasmogamy , Karyogamy and hybridization take place in sequence , but not at specified points in the life cycle of an individual.

**Parasite:** An organism that derives its nourishment from a living organism. ( host)

**Pathogen:** An organism capable of producing disease.

**Planogametic copulation:** Fusion of naked gametes , one or both of which are motile.

**Rhizosphere:** The soil region subject to the influence of plant roots and characterized by a zone of increased microbiological activity.

**Saprophyte:** An organism living on dead organic matter.

**Self –compatible:** Self – sterile , refers to a thallus which reproduces sexually by itself.

**Spermatization:** Plasmogamy by the union of a spermatium with a receptive structure.

**Sterilization:** The process of making sterile , the killing of all forms of life.

**Syndrome:** A group of signs and symptoms that characterizes a disease.

**Transduction:** Transfer of genetic material from one bacterium to another through the agency of a virus.

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