CPA COLLEGE OF GLOBAL STUDIES, PUTHANATHANI

2nd SEMESTER BOTANY
CORE COURSE- BOTANY

MICROBIOLOGY, MYCOLOGY, LICHENOLOGY & PLANT PATHOLOGY

Prepared by

Abdul Faisal P & Priyanka T

Assistant professor

Department of Botany

CPA COLLEGE OF GLOBAL STUDIES, PUTHANATHANI

Syllabus

MICROBIOLOGY
1. Introduction to Microbiology
2. Bacteria –Classification based on morphology and staining, ultra structure of bacteria; Bacterial growth, Nutrition, Reproduction.
3. Viruses – Classification, architecture and multiplication; Bacteriophages, TMV, Retroviruses- HIV, Viriods, Prions.
4. Microbial ecology – Rhizosphere and Phyllosphere.
5. Industrial microbiology –alcohol, acids, milk products single cell proteins
6. Economic importance of bacteria, Vaccines: importance, mechanism.

MYCOLOGY
1. General characters and phylogeny of the kingdom Fungi, the concept of anamorph and teleomorph.
2. General characters, distribution, and biology of the following groups of fungi
a) Mastigomycotina. Type: *Pythium*
b) Zygomycotina. Type: *Rhizopus*
c) Ascomycotina. Type:, *Xylaria, Aspergillus*
d) Basidiomycotina. Types: *Agaricus, Puccinia*
3. Economic importance of fungi: medicinal, industrial, agricultural. Fungi as model organisms for research.
4. Ecological importance of fungi: different modes of nutrition (pathogenic/parasitic, saprobic, symbiotic)

LICHENOLOGY
1. Introduction: Type of Interaction between the components symbiosis – mutualism.
2. Classification, growth forms, structure, reproduction, economic importance. Type: *Usnea*
3. Toxicology, Lichens as food, Bioremediation, Ecological indicators, Pollution indicators, Lichen in Soil formation and pioneers of Xerosere.

PLANT PATHOLOGY
1. Introduction – Concepts of plant disease, pathogen, causative agents, symptoms
2. Symptoms of diseases: spots, blights, wilts, rots, galls, canker, gummosis, necrosis, chlorosis, smut, rust, damping off.
3. Control measures: Chemical, biological and genetic methods, quarantine measures.
4. Brief study of Plant diseases in South India (Name of disease, pathogen, symptom and control measures need to be studied)
1. Citrus Canker
2. Mahali disease of arecanut
3. Blast of paddy
4. Quick wilt of pepper
5. Mosaic disease of tapioca
6. Bunchy top of banana
7. Grey leaf spot of coconut

MICROBIOLOGY

Definition: Microbiology

Microbiology defined as the study of organisms too small to be seen with the naked eye. These organisms include viruses, bacteria, algae, fungi, and protozoa. Microbiologists are concerned with characteristics and functions such as morphology, cytology, physiology, ecology, taxonomy, genetics, and molecular biology.

- Study of microbes
- Microscopic - cannot be viewed by naked eyes
- Single cell to sub-cellular
- Beneficial or harmful
- Bacteria, virus, bacteriophages, actinomycetes, viroids, prions, mycoplasmas

Koch's Postulates

1. The bacterium should be constantly associated with lesions of Disease.
2. It should be possible to isolate the bacterium in pure culture from the lesions.
3. Inoculation of such pure culture into laboratory animal should reproduce the lesions of the disease.
4. It is possible to reisolate the bacterium in pure culture from the lesions produced in the experimental animal.

Additional criterion specific antibodies in the serum of patients suffering with disease

Branches of microbiology

- Bacteriologists - study bacteria, there are medical, agricultural, biotechnological specializations.
- Mycologists - study fungi, there are medical, agricultural, biotechnological specializations.
- Protozoologists, study small "animal - like" single celled organisms such as amoeba, and various disease causing parasites.
- Phycologists study algae.
- Study of lichens can also be regarded as a sub discipline of microbiology.
- Parasitologists- a term generally used to describe those who study small animals as agents of disease (like some microscopic worms for instance) but also used to describe those who study protozoan pathogens.
- Immunology is often taught and researched in microbiology faculties.

- Plant pathology (also phytopathology) is the scientific study of diseases in plants caused by pathogens (infectious organisms) and environmental conditions (physiological factors)

- Prokaryotic Cell Structure

  Prokaryotic cells are about 10 times smaller than eukaryotic cells. A typical *Escherichia coli* cell is about 1 µm wide and 2 to 3 µm long. Structurally, prokaryotes are very simple cells when compared with eukaryotic cells, and yet they are able to perform the necessary processes of life. Reproduction of prokaryotic cells is by *binary fission*, the simple division of one cell into two cells, after DNA replication and the formation of a separating membrane and cell wall.

Bacteria

- Bacteria are microscopic, single-celled organisms that thrive in diverse environments.

- These organisms can live in soil, the ocean and inside the human gut.

- Bacteria represent a large and diverse group of microorganisms that can exist as single cells or as cell clusters.

- Some bacteria are harmful, but most serve a useful purpose.

- They support many forms of life, both plant and animal, and they are used in industrial and medicinal processes.

- Bacteria are thought to have been the first organisms to appear on earth, about 4 billion years ago.

- A gram of soil typically contains about 40 million bacterial cells.

Cell wall

• Fairly rigid and chemically complexed outermost component, common to all bacteria except *Mycoplasma species.*

• Situated between Capsule and cytoplasmic membrane Multilayered

• Contains diaminopimelic acid (DAP), Muramic acid and teichoic acid joined to-gather called Peptidoglycan or murein or mucopeptide.

Composed of: 1. Peptidoglycan 2. Outer membrane 3. Surface fibers.

Peptidoglycan

• Peptidoglycan(murein) is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the plasma membrane of most bacteria, forming the cell wall.

• Consists of three parts:

1. A backbone, composed of alternating N-acetyl glucosamine and N-acetyl muramic acid
2. A set of tetrapeptide side chain attached to Nacetylmuramic acid
3. A set of pentapeptide cross-bridges

- Backbone is same for all bacterial species but tetrapeptide side chains and pentapeptide crossbridges very from species to species.
- Amino-sugars are β-1,4 N-Acetylglucosamine(NAG) and N-Acetylmuramic acid (NAM)
- Alternating sugars are connected by a β-1,4- glycosidic bond
- The enzyme lysozyme is capable of hydrolysis of this linkage.(inhibition)-β lactum antibiotics act on peptidoglycan
- Gram positive bacterial cell without cell wall called protoplast achived by lysozyme
- Gram negative treated with EDTA and cell wall is removed called spheroplast

Function of cell wall

1. It is involved in growth and cell division of bacteria
2. It gives shape to the cell
3. It gives protection to the internal structure and act as a supporting layer
4. It provides attachment to complement
5. It shows resistance to the harmful effects of environment

Cytoplasm :

- Matrix is largely formed with 70% water.
- Lack Endoplasmic reticulum, mitochondria.
- Consists : 1. Ribosome
  2. Mesosome
  3. Intracytoplasmic inclusion bodies
  4. Nucleus
  5. Spores

Ribosomes

They are the centers of protein synthesis. They are slightly smaller than the ribosomes of eukaryotic cells

Mesosomes

They are vesicular, convoluted tubules formed by invagination of plasma membrane into the cytoplasm. They are principal sites of respiratory enzymes and help with cell reproduction

Cytoplasmic Inclusions

The Inclusion bodies are aggregates of polymers produced when there is excess of nutrients in the environment and they are the storage reserve for granules,

Cytoplasmic membrane:

Cytoplasmic membrane is present immediately beneath the cell wall, found in both Gram positive & negative bacteria and it is a thin layer lining the inner surface of cell wall and separating it from cytoplasm. It acts as a semi permeable membrane controlling the flow of metabolites to and from the protoplasm phosphates and other substances. Volutin granules are polymetaphosphates which are reserves of energy and phosphate for cell metabolism and they are also known as metachromatic granules

- Thin (5-10nm) semipermiable membrane.
- Composed of a phospholipids bilayer and 200 different kinds of protein.

FUNCTIONS

1. Acts as osmotic barrier and regulate the transportation of metabolites to and from protoplasm.
2. Electron transport and oxidative phosphorylation.
3. Excretion of hydrolytic exoenzyme and pathogenicity protein.
4. Biosynthetic function.
5. Chemotactic systems..

Nucleus

The Nucleus is not distinct and has no nuclear membrane or nucleolus and the genetic material consist of DNA. The cytoplasmic carriers of genetic information are termed plasmids or episomes.

Capsule

Capsule is the outer most layer of the bacteria (extra cellular). It is a condensed well defined layer closely surrounding the cell. They are usually polysaccharide and if polysaccharide envelops the whole bacterium it is capsule and their production depends on growth conditions. They are secreted by the cell into the external environment and are highly impermeable. When it forms a loose mesh work of fibrils extending outward from the cell they are described as glycocalyx and when masses of polymer that formed appear to be totally detached from the cell and if the cells are seen entrapped in it are described as slime layer. The Capsule protects against complement and is antiphagocytic. The Slime layer & glycocalyx helps in adherence of bacteria either to themselves forming colonial masses or to surfaces in their environment and they resists phagocytosis and desiccation of bacteria.

Flagella

Flagella are long hair like helical filaments extending from cytoplasmic membrane to exterior of the cell. Flagellin is highly antigenic and functions in cell motility. The location of the flagella depends on bacterial species as polar situated at one or both ends which swims in back and forth fashion and lateral at along the sides. The parts of flagella are the filament, hook and the basal body. Filament is external to cell wall and is connected to the hook at cell surface, the hook & basal body are embedded in the cell envelope. Hook & filament is composed of protein subunits called as flagellin.

Flagellin is synthesized within the cell and passes through the hollow centre of flagella. The arrangement of flagella may be described as

(i) Monotrichous – single flagella on one side

(ii) Lophotrichous – tuft of flagella on one side

(iii) Amphitrichous – single or tuft on both sides

(iv) Peritrichous – surrounded by lateral flagella

Pilli and fimbriae

• Fimbriae and Pili are filamentous structures composed of protein that extend from the surface of a cell and can have many functions.

• Fimbriae are found in gram negative as well as gram positive bacteria but are shorter in length as compared to pili. Pili are longer than fimbriae and there are only a few per cell.

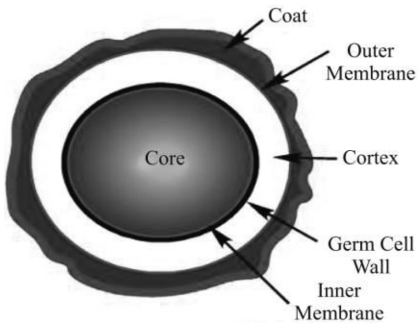
Functions :

1. Adherence of symbiotic and pathogenic bacteria to host cells.
2. Transfer of bacterial DNA takes place through sex pili during the process of conjugation.
3. Antigenic variation of pili of *Neisseria gonorrhoeae makes it to survive even after the* presence of antibody against the original type of pili.
4. Inhibit phagocytic ability of leukocyte.
5. Helps in identification by haemagglitination.

Hair-like proteinaceous structures that extend from the cell membrane to external environment are pili which are otherwise known as fimbriae. They are thinner, shorter and more numerous than flagella and they do not function in motility. The fimbriae is composed of a subunit called pilin. There are two types pili namely Non-sex pili (Common pili) eg. fimbriae or type IV and the sex pili. The fimbriae are antigenic and mediate their adhesion which inhibits phagocytosis. The sex pili help in conjugation.

Spore

Some bacteria have the ability to form highly resistant resting stage called spores, which helps them to overcome adverse environmental conditions that are unfavorable for vegetative growth of cell. They are not a reproductive form and not a storage granule. These spores are resistant to bactericidal agents and adverse physical conditions. Each spore can give rise to only one endospore which plays a role in heat resistance. Spores consists of three layers namely core, cortex and spore coat.



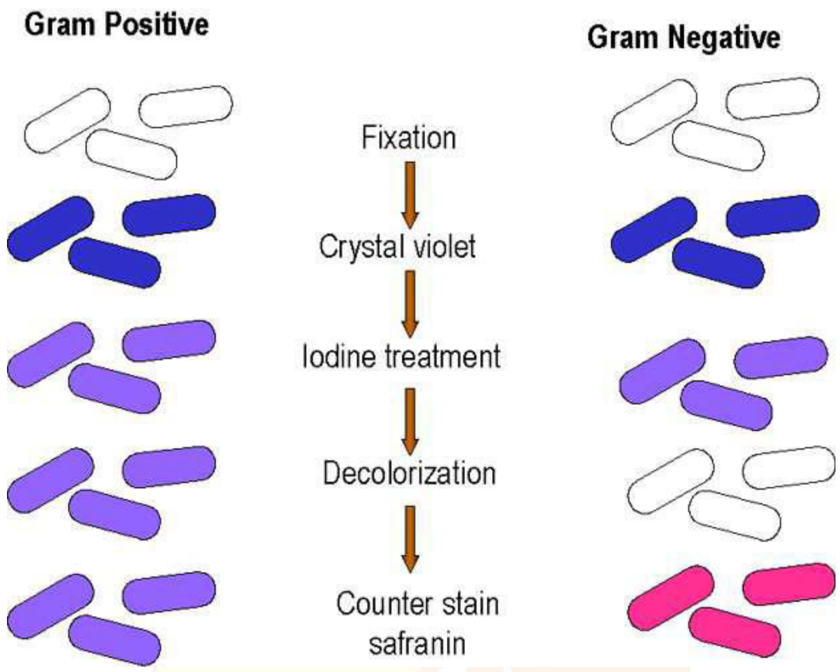
Classification of Bacteria

On the basis of Staining:

1. Gram staining

a) Gram positive

b) Gram negative



Based on the basis of Shape:

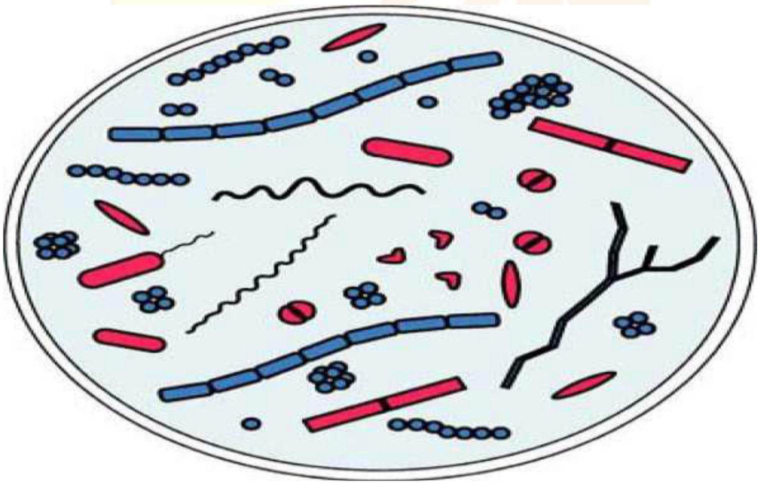
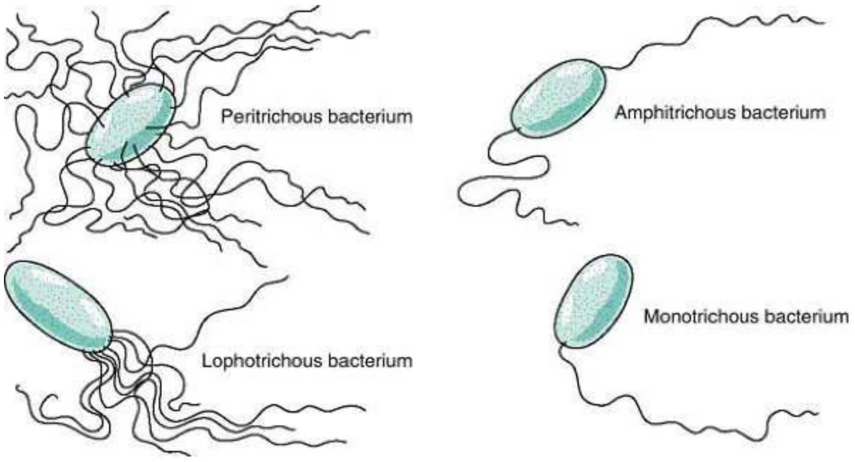
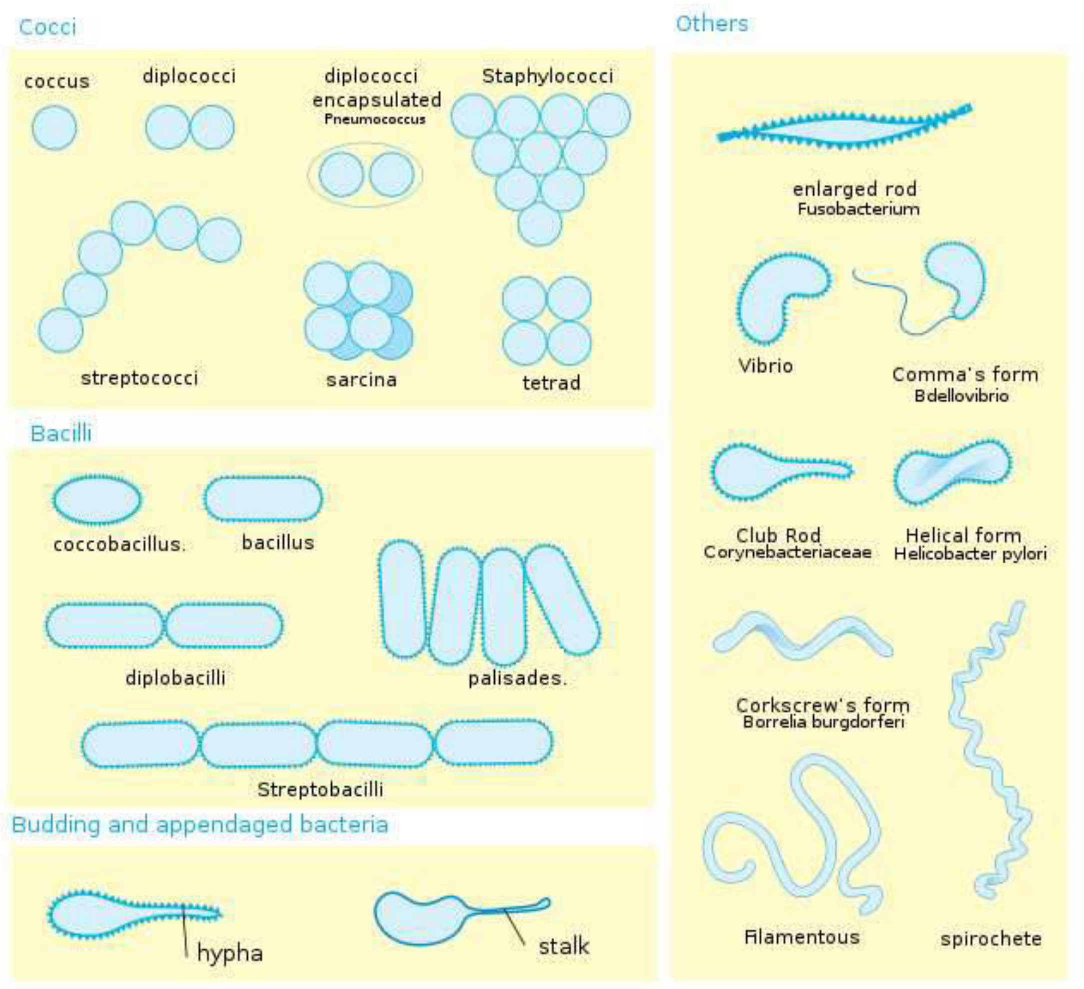


Figure 3-1. Various forms of bacteria, including single cocci, diplococci, tetrads, octads, streptococci, staphylococci, single bacilli, diplobacilli, streptobacilli, branching bacilli, loosely coiled spirochetes, and tightly coiled spirochetes.

Based on Flagella



Based on morphological arrangement



Flagellar arrangement: The four basic types of flagellar arrangement on bacteria: peritrichous, flagella all over the surface; lophotrichous, a tuft of flagella at one end; amphitrichous, one or more flagella at each end; monotrichous, one flagellum

On the basis of Growth and nutrition:

A. Oxygen requirements :

1. Aerobic:

a) Obligate aerobe: *P. aeruginous.*

b) Facultative aerobe: *E.coli.*

2. Anaerobic:

a) Obligate anaerobe: *Clostridium tetani ,Bacteroids.*

b) Aero tolerant anaerobe: indifferent to O2.

B. Carbon dioxide requirement :

1. Capnophilic bacteria: Which require higher amount of CO_2 for their growth (5-10% CO_2 and 15% O_2). Ex – *Haemophilus influenzae, Brucella abortius.*

C. Temperature:

1. Psychrophiles : microbes that grow within 0-20°C. Ex: Arthrobacter sp., Psychrobacter sp. and members of the genera Halomonas, Pseudomonas, Hyphomonas, and Sphingomonas.

2. Mesophiles : microbes that grow within 25-40°C. Ex: *Listeria monocytogenes*, *Staphylococcus aureus* and *Escherichia coli*.

3. Thermophiles : microbes that grow within 55-80°C. Ex- *Bacillus stearothermophilus, Alicyclobacillus Acidocaldarius*

D. pH :

1. Acidophile : which grow at acidic pH (below4.0). Ex- Lactobacilli.

2. Alkaliphile : which grow at alkaline pH (8.2-8.9). Ex.- *V. cholerae.*

3. Neutrophile : which grow at neutral pH (7.2-7.6). Most pathogenic bacterias are neutrophiles.

E. Light :

1. Phototrophs : bacteria deriving energy from sunlight. Ex: **Phototrophic** organisms such as algae (e.g., kelp), other protists (such as euglena), phytoplankton, and **bacteria** (such as cyanobacteria).

2. Chemotrophs : bacteria deriving energy from chemical sources.

F. Osmotic pressure:

1. Halophiles : which can survive at high salt concentration.

2. Osmophiles : which can survive at high sugar concentration.

G. Carbon source :

1. Autotrophs : which reduce inorganic carbon into organic compounds, such as through photosynthesis

2. Heterotrophs : bacteria that grow by using the carbon that has been reduced by the autotrophs.

H. Method of obtaining nutrition :

1. Heterotropic bacteria- Obtain their food from other living organisms, as they cannot synthesize it on their own.

2. Symbiotic Bacteria - Obtain nutrition from host organism by offering something in return. Establish a mutual give-and-take relationship with host.

3. Pathogenic Bacteria - Obtain food from host but are harmful to the host, generally causing diseases.

4. Saprophytic Bacteria - Obtain Nutrition from dead and decaying matter.

GROWTH AND MULTIPLICATION OF BACTERIA

Bacteria divide by binary fission and cell divides to form two daughter cells. Nuclear division precedes cell division and therefore, in a growing population, many cells having two nuclear bodies can be seen. Bacterial growth may be considered as two levels, increase in the size of individual cells and increase in number of cells. Growth in numbers can be studied by bacterial counts that of total and viable counts. The total count gives the number of cells either living or not and the viable count measures the number of living cells that are capable of multiplication.

Bacterial Growth Curve

(i) Lag phase

Immediately following innoculation there is no appreciable increase in number, though there may be an increase in the size of the cells. This initial period is the time required for adaptation to the new environment and this lag phase varies with species, nature of culture medium and temperature.

(ii) Log or exponential phase

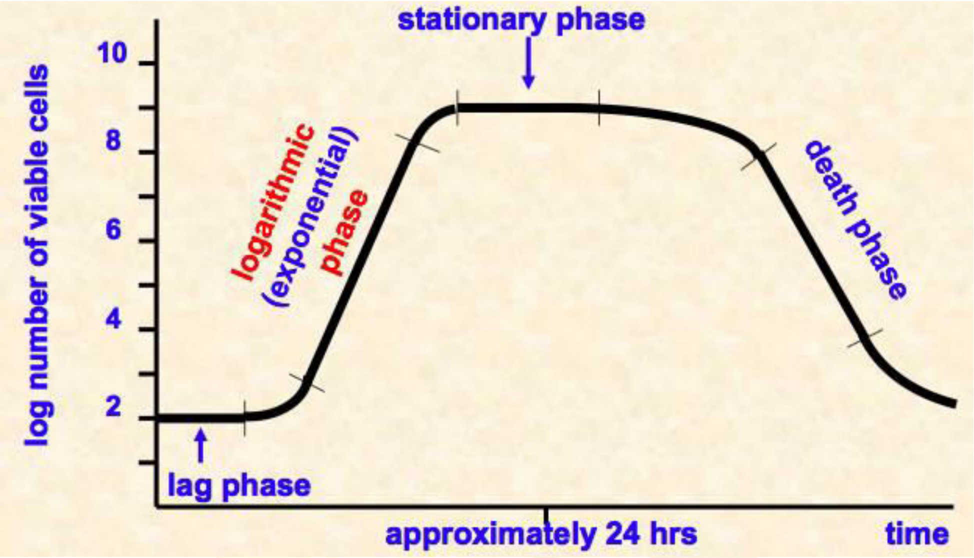
Following the lag phase, the cell starts dividing and their numbers increase exponentially with time.

(iii) Stationary phase

After a period of exponential growth, cell division stops due to depletion of nutrient and accumulation of toxic products. The viable count remains stationary as equilibrium exists between the dying cells and the newly formed cells.

(iv) Phase of decline

This is the phase when the population decreased due to cell death.



GENE TRANSFER

A change in the genome of a bacterial cell may be caused either by a mutation in the DNA of the cell or result from the acquisition of additional DNA from an external source. DNA may be transferred between bacteria by 3 mechanisms:

- transformation
- conjugation
- transduction

➢ Transformation

Bacteria in some genera have been shown to be capable pf taking up DNA either extracted artificially or released by lysis from cells of another strain. Once a piece of DNA has entered the cell by transformation, it has to become incorpored into the existing chromosome of the cell by a process of recombination in order to survive.

➢ Conjugation

Conjugation is a process in which one cell, the donor or male cell, makes contact with another, the recipient or female cell, and DNA is transferred directly from the donor into the recipient. Certain types of plasmids carry the genetic information necessary for conjugation to occur. Only cells that contain such a plasmid can act as donors; those lacking a corresponding plasmid act as recipients.

Plasmids capable of mediating conjugation carry genes coding for a pilus, on the surface of the donor cell. The tip of the pilus attaches to the surface of a recipient cell and holds the two cells together so that DNA can then pass into the recipient cell. The DNA is replicated during transfer so that each cell receives a copy. As donor ability is dependent upon having a copy of the plasmid, the recipient strain becomes converted into a donor, able to conjugate with further recipients and convert them in turn. In this way a plasmid may spread rapidly through a whole population of recipient cells, this process is sometimes described as infectious spread of a plasmid.

- Transduction
  The third known mechanism of gene transfer in bacteria involves the transfer of DNA between cells by bacteriophages

Viruses

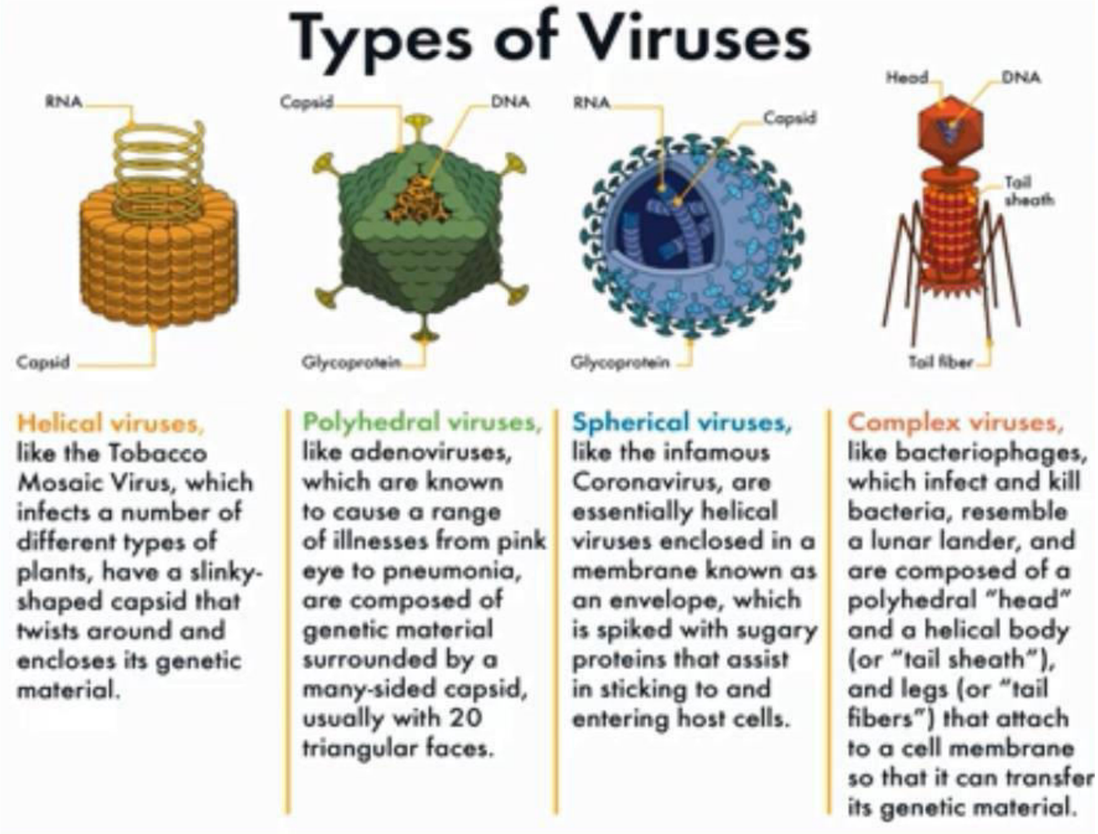
- A viral particle consists of a nucleic acid molecule, either DNA or RNA, enclosed in a protein coat, or capsid
- Viruses lack many of the attributes of cells, including the ability to replicate. Only when it infects a cell does a virus acquire the key attribute of a living system: reproduction
- Viruses are known to infect all cells, including microbial cells. Host-virus interactions tend to be highly specific
- A virus is not a cell!
- Viruses are replicated only when they are in a **living host cell**
- It Consist of DNA *or* RNA core
- Core is surrounded by a protein coat
- Coat may be enclosed in a lipid envelope
- Viruses dependent on Host cells for necessary functions and Multiplication
- Intracellular parasites- Contain either **DNA or RNA never** both.

Discovery of Virus

• Iwanovski – a Russian chemist, 1892– Tobacco Mosaic Disease

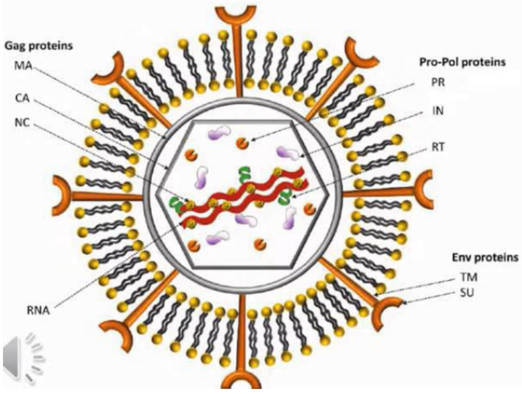
• Beijerinck confirmed

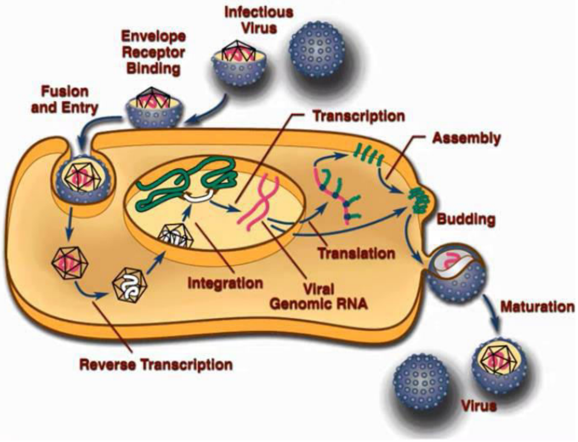
• Walter Reed, USA– Yellow fever virus



RETROVIRUSES

A **retrovirus** is a virus that uses RNA as its genetic material. When a **retrovirus** infects a cell, it makes a DNA copy of its genome that is inserted into the DNA of the host cell. There are a variety of different **retroviruses** that cause human diseases such as some forms of cancer and AIDS.

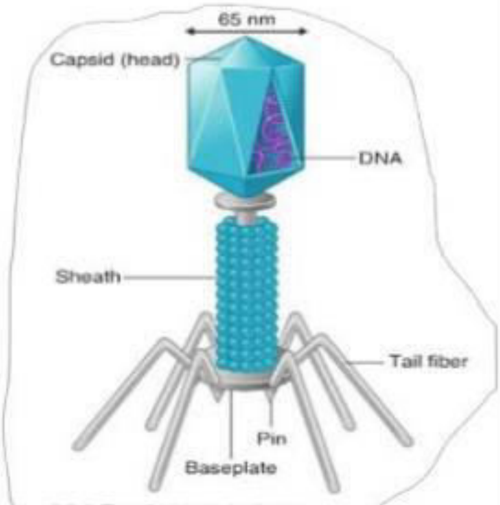




BACTERIOPHAGE

- Discovered by *Twort* in 1915 and described by *de Herelle* in 1917.
- They are viruses which parasites bacteria.
- The nucleic acid may be either DNA or RNA and may be double-stranded or single-stranded.
- ssDNA phages G viruses
- dsDNA phage T even and T odd phages
- ssRNA phage M_{12} phages
- dsRNA phage Φ6 on *Pseudomonas*

- Capsid (head): polyhedral and the tail sheath is helical.
- **Head** - the nucleic acid.
- **Tail** : hollow tube through which the nucleic acid passes during infection
- T4 -largest phage.
- T4 tail - surrounded by a contractile sheath, which contracts during infection of the bacterium.
- End of the tail: **base plate** and one or more **tail fibers** attached to it.
- The base plate and tail fibers - **involved in the binding of the phage to the bacterial cell**.
- Not all phages have base plates and tail fibers.

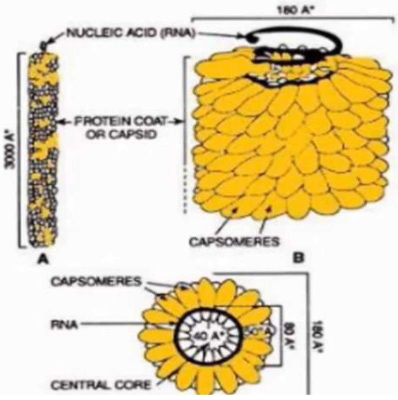


(a) A T-even bacteriophage

TOBACCO MOSAIC VIRUS

- *Tobacco mosaic virus* is a positive-sense single-stranded RNA virus species in the genus *Tobamovirus* that infects plants especially **Tobacco** and other members of the family *Solanaceae*.
- The infection causes characteristic patterns, such as "mosaic"-like mottling and discoloration on the leaves.
- Its capsid is made from 2130 molecules of coat protein and one molecule of genomic single strand RNA, 6400 bases long.
- The protein monomer consists of 158 amino acids
- Virions are ~300 nm in length and ~18 nm in diameter.
- The TMV genome consists of a 6.3–6.5 kbp single-stranded RNA.

- ***TMV*** is a thermostable virus. On a dried leaf, it can withstand up to 50 °C.
- After its multiplication, it enters the neighbouring cells through plasmodesmata.
- For its smooth entry, ***TMV*** produces a 30 kDa movement protein called P30 which enlarges the plasmodesmata.



Prion

- A kind of infectious protein that can resist the digestion of proteinase
- The cellular form of the prion protein (PrPc) is encoded by the host's chromosomal DNA
- An abnormal isoform of this protein (PrPres) is the only known component of the prion and is associated with transmissibility.
- Kuru, Creutzfeldt-Jakob disease (CJD), Gerstmann- Sträussler-Scheinker disease, fatal familial insomnia, and Bovine spongiform encephalopathy (BSE)

Viroid

- Small, single-stranded, covalently closed circular RNA molecules existing as highly base-paired rod-like structures; they do not possess capsids
- They range in size from 246 to 375 nucleotides in length. The extracellular form of the viroid is naked RNA—there is no capsid of any kind
- The RNA molecule contains no protein-encoding genes, and the viroid is therefore totally dependent on host functions for its replication
- The RNAs of viroids have been shown to contain inverted repeated base sequences at their 3' and 5' ends, a characteristic of transposable elements and retroviruses. Thus, it is likely that they have evolved from transposable elements or retroviruses by the deletion of internal sequences

Microbes Benefit Humans

1. Bacteria are primary decomposers – recycle nutrients back into the environment (sewage treatment plants)
2. Microbes produce various food products

– cheese, pickles, sauerkraut, green olives

– yogurt, soy sauce, vinegar, bread

– Beer, Wine, Alcohol

Microbes are also capable of causing many diseases

- Pneumonia
- Botulism
- Cholera
- Diarrhea
- Whooping Cough
- Typhoid Fever
- AIDS
- Tuberculosis
- Measles
- Tetanus
- Black Plague
- Meningitis

ACTINOMYCETES

- **Actinomycetes** are gram-positive mycelial bacteria, known to produce a wide variety of industrially and medically relevant compounds (antibiotics, chemotherapeutics, fungicides, herbicides and immunosuppressants).
- Actinomycetales have 2 main forms of reproduction; spore formation and hyphae fragmentation.
- Actinomycetales can be found mostly in soil and decaying organic matter, as well as in living organisms such as humans and animals.
- They form symbiotic nitrogen fixing associations with over 200 species of plants, and can also serve as growth promoting or biocontrol agents, or cause disease in some species of plants.
- It act as **connecting link between** bacteria and **fungi.**

MYCOPLASMAS

- Is a genus of bacteria that lack a cell wall around their cell membranes.
- naturally resistant to antibiotics that target cell wall synthesis.
- Several species are pathogenic in humans, including ***M. Pneumoniae.***
- Cell wall is absent and plasma membrane forms the outer boundary of the cell.
- Due to the absence of cell wall these organisms can change their shape and are pleomorphic.
- Lack of nucleus and other membrane-bound organelles.
- Genetic material is a single DNA duplex and is naked.
- Ribosomes are 70S type.
- Possess a replicating disc at one end which assist replication process and also the separation of the genetic materials.
- Heterotrophic nutrition. Some live as saprophytes but the majority are parasites of plants and animals.
- The parasitic nature is due to the inability of mycoplasmal bacteria to synthesise the required growth factor.

Rhizosphere and Phyllosphere

	Rhizosphere	and Phyllosphere
DEFINITION	Rhizosphere is the region of soil that surrounds plant roots, which is under the influence of root exudates and root microbiome	Phyllosphere is the total surfaces of a plant inhabited by microorganisms
REGION	Soil region in the vicinity of plant roots	Mainly leaf surfaces
MICROORGANISMS	Both aerobic and anaerobic	Aerobic
EXUDATES	Root exudates such as carbohydrates, amino acids, vitamins etc.	Mainly plant leaf exudates such as amino acids, glucose, fructose and sucrose
LOCATION	Lies below the soil surface	Lies above the soil surface
SUBDIVISION	Exorhizosphere and endorhizosphere	Caulosphere, phylloplane, anthosphere, and carposphere
BIOGEOCHEMICAL TRANSFORMATION	Has a role in biogeochemical transformation	No role in biogeochemical transformation

MYCOLOGY

- Branch of science that deals with the study of fungi is called Mycology *(mykos* = mushroom, *logos*= discourse)
    - Fungi are a group of microscopic as well as macroscopic, spore bearing, chlorophyll lacking, filamentous and heterotrophic thallophytes which reproduce asexually and sexually.
- They are the major group of decomposers in the biosphere.

General character

- Large group with more than 1,00000 species distributed in throughout of the world.
- They donot require light for active growth and metabolism. And they can occur in light as well as in dark, but the presence of external source of organic food is required for normal growth.
- Most usual habitat of fungi is wet soil rich in humus. The forms growing in such habitat are considerd advanced (eg. *Agaricus, Peziza*). Few are aquatic eg, *Saprolegnia.* It is considered as primitive.
- Most fungi grow and contaminate food stuffs such as bread, jams, pickels, fruits and vegetables.
- Some are grow as parasites on plants as well as animals and cause serious diseases.

Habit

- Fungal members lack chlorophyll and exhibit hetertrophic mode of nutrition.
- Live on either decaying organic matter or on living organisms. Some forms live in symbiotic association with other plants or as mycorrhiza.
- According the mode of nutrition fungi classified into

1. **Saprophytes**
   Fungi obtain their food from dead decaying organic matter
   a. Obligate saprophytes: which get their food from dead decaying organic matter and cannot grow on living host. Eg, *Peziza, Agaricus*
   b. Facultative saprophytes: can grow dead decaying matter, under certain condition they become parasites.eg, *Pythium*
2. **Parasites**
   Fungi obtain their food from a living host plant or animal.
   a. Obligate parasite
      True parasites and restricted to living host tissues. They fail to grow on artifitial media. Obligate parasite categorized into

1. Biotrophs: parasite which obtain their food from the living tissues on which they complete their life cycle. Eg, *Albugo, Puccinia, Erysiphe*.
2. Hemibiotrophs: they attack living tissues in the same way as biotrophs but continue to developand sporulate after the tissue is dead. Eg, leaf spot fungi.
3. Perthotrophs :they kill the host tissue in advance and get their nourishment saprophyticacally. Eg, *Sclerotium roffsii*

b. Facultative parasite
Live as parasite and pass most of the life cucle in association with the living host. They can also grow as saprophytes. Eg, *Phytophthora infestans*
Parasites may be ectoparasites (on external surface), endoparasite (insde the host organism).

- Some fungi grow in symbiotic association with other organisms. As lichen, symbiotic association with algae. And fungi live in symbiotic association with the roots of higher plants as mycorrhiza.

Nutrition

- Fungal nutrition is heterotrophic and absorptive.
- It is three kinds
  1. **Saprotropism**- absorbs dead and decaying organic matter in a fluid state. Some of them have root-like structure called rhizomorphs. They usually grow on rotten leaves, fruits, vegetables , moist wood and leather, moist bread, cheese etc. eg, *Mucor, Rhizopus, Agaricus,Aspergillus*
  2. **Parasitism-** obtains nutrients from their hosts. Include ectoparasite and endoparasites. Fungi may have appressoria for attachment, and haustoria for absorption.
  3. **Symbiosis** –fungi live in mutually beneficial or mutually supporting association with other organisms as mycorrhizae and lichens.

Parasitic Fungi (mildew on cucumber) | Saprophytic Fungi | Symbiotic Fungi (Lichen)

- Fungi grow best in slightly acidic medium around pH-6.

Vegetative structure

- Fungi are typically thalloid. Thallus may be unicellular or multicellular.
- In most cases, thallus consists of long, tubular, branched filaments called hyphae. The mass of hyphae is called mycelium. In some unicellular forms the mycelium is completely absent.
- Hyphae are long, tubular. Cell is made up of definite cell walls. It is composed of fungal cellulose, pectose, callose and chitin.
- Cell wall encloses protoplast, differentiated into plasma membrane, cytoplasm, nucleus and vacuoles.
- Reserve food material is glycogen or oil droplets.
- Some lower fungi, the cytoplasm is continuous in the entire mycelium and the cross walls(septa) are not formed. Such a condition of mycelium is called aseptate.
- The mycelium is aseptate and multinucleate is called acellular coenocytic. If the mycelium is divided by a cross wall, the condition is called called septate and multicellular.
- Each septum of euascomycetes and the order- Uredinales possess single simple pore situated centrally. Such a septum allows the cytoplasm and nuclei to pass from one cell into the other. The septum of higher fungi is more complex, called

dolipore septum. Dolipore is abarrel shaped pore with open ends. The edges of septa around the the pore are swollen. The openings of pore on both the sides are guarded by cap-like thickening called parenthosome.

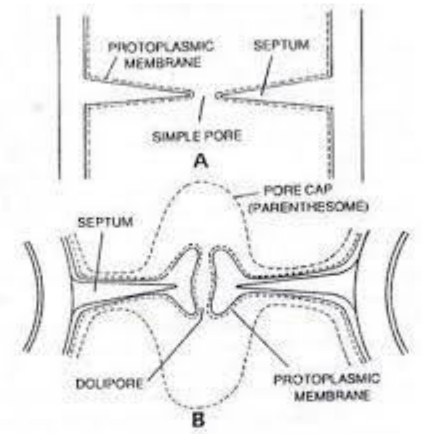


Fig. 8.3. Septal pores in fungi. A, simple pore; B dolipore in many Basidiomycetes.

- Each cell of a multicellular mycelium may be uninucleate, binucleate or multinucleate. Both the nuclei of a dikaryotic cell may be homokaryotic or heterokaryotic.
- Some fungi possess motile bodies with flagella.
- The motile bodies are either uniflegellate or biflagellate with tinsel and whiplash type flagella.
- In some fungi fungal mycelium get modified as different forms. It becomes organized thalloid body. It consists of loosely or compactly woven tissue –like structure called plectenchyma. There are two types of plectenchyma.
    1. Prosenchyma- loosely woven hypha, lie almost parallel to each other and the cells and hyphae clearly distinguishable.
    2. Pseudoparenchyma-compact mass of parenchyma tissues where the hyphae are very closely packed and interwoven. In cross section, these hyphae appear as isodiametric cells.
- Mycelium may modified into
    1. Rhizomorph- several hyphae become interwoven with each other and form cord-like, string-like or root like elongated mycelial strands called rhizomorph.
    2. Sclerotia-compact mass of interwoven hyphae forming psuedoparenchyma. The outer hyphae become hard and form protective covering or rind. These bodies remain dormant under unfavouable conditions and germinate at the onset of favourable conditions.
    3. Stroma-thick mycelial mat on or, in which a large number of fruiting bodies.

REPRODUCTION

- Fungi generally reproduce by asexual and sexual methods.
- The type of reproduction called vegetative is included under the category of asexual reproduction.
- In fungi, the, reproduction typically occur by production of spores (asexual and sexual) but other kinds of reproductive bodies may also be formed in some cases.
- If the plant body (thallus) is unicellular, the complete vegetative cell may be transformed into reproductive body (holocarpic). If a portion of vegetative thallus is transformed into reproductive structure, the condition is called eucarpic.

[A] ASEXUAL REPRODUCTION

- The kind of reproduction which does not involve meiosis and fusion of nuclei is called asexual reproduction. It occurs by the following methods—
    (1) Fragmentation : The fungal mycelium gets broken into smaller fragments accidently or through external force. Each fragment(piece) develops into a new individual. This type of reproduction is very common in fungi.

(2) Budding : The parent cell produces one or more bud-like protuberances which detach from parent cell and grow into new individual. Such type of reproduction is very common in budding yeast(*Saccharomyces*) where chain of buds may produce pseudomycelium.

(3) Fisson: The parent cell splits into two equal halves by a constriction and formation of cell wall and each half develops into a new individual. Fission is very common in bacteria and also occurs in yeasts.

(4) Oidia: The hypha breaks up into its component cells or small pieces which behave like spores. These are called oidia. The oidia aregenerally thin walled and do not store reserve food material. They germinate immediately after liberation and cannot survivor under unfavourable conditions.

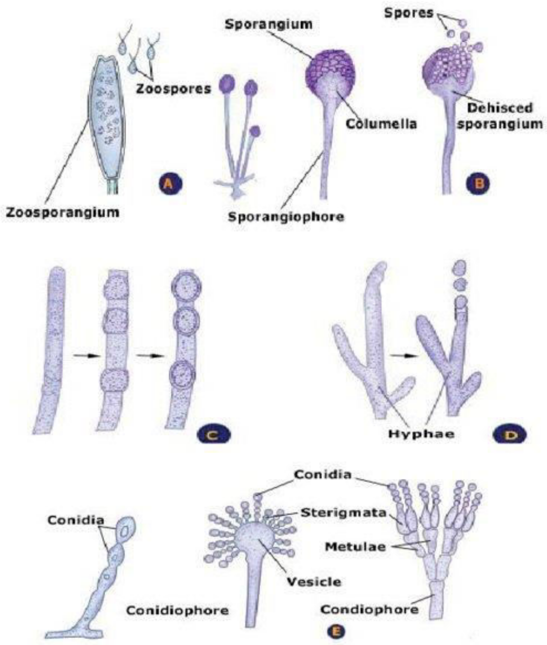
(5) Chlamydospores : These are thick walled resting cells produced in the same manner as oidia. They store reserve food material and capable of withstanding long unfavourable conditions.

(6) Spores: Fungi reproduce most commonly by production of spores. These are minute propogating units which serve in the production of new individuals. They vary in shapes, size and colour in different individuals and sometimes serve as basis in the classification of certain groups of fungi.

The asexual spores are of two types (1) Sporangiospores and (2) Conidia.

i. Sporangiospores : These spores are produced inside the sac-like structures, called sporangia. Sometimes these spores are also termed as endospores. If the sporangiospores are non-motile, they are called aplanospores(e.g., *Mucor, Rhizopus*). If the sporangiospores are motile. They are called zoospores may be uniflagellate or biflagellate.

ii. Conidia: These are non-motile spores produced singly or in chains by constrictions at the tip or lateral side of special hyphal branches, called conidiophores. They are produced exogeously (not enclosed within sporangia). The conidia germinate directly by giving out germ tubes. Sometimes the conidia behave like sporangia and called conidiosporangia.



A. Zoospores; B. Sporangiospores; C. Chalmydospores; D. Oidia; E. Conidia

[B] SEXUAL REPRODUCTION

- Sexual reproduction occurs in almost all the groups of fungi except in fungi imperfecti (Deuteromycotina).
- It involves union of two compatible nuclei of opposite sex at a definite stage in the life-history of fungus. The sexual reproduction in fungi completes in three phases---

  (1).Plasmogamy

  Fusion of two protoplast which brings the two compactible nuclei close together in a single cell. The resulting cell becomes dikaaryon. The phenomenon is termed as dikaryotization.

  (2) Karyogamy

  Fusion of two compactible nuclei brought together as a result of plasmogamy. The resulting diploid nucleus called synkaryon.

  (3) Meiosis.

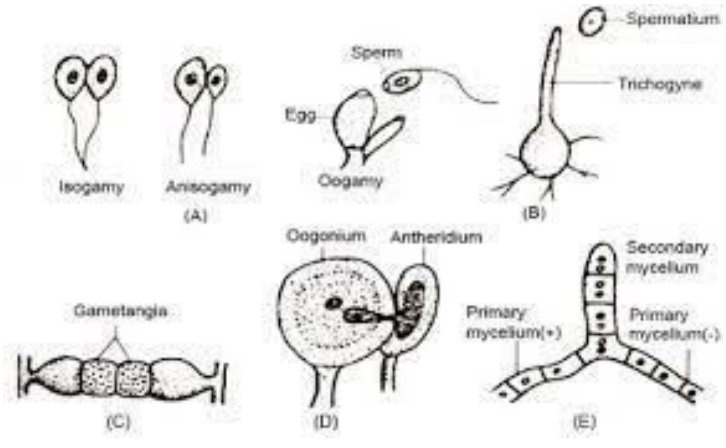
  Diploid nucleus divides by meiosis resulting in the formation of haploid nuclei. Usually meiosis occurs immediately after fusion of two nuclei.
- There are various modes of sexual reproduction in fungi,
  1. Planogametic copulation- motile gametes called planogametes. Here both fusing gametes are motile. Planogametic copulation may further be grouped under 3 categories.

     a. isoplanogametic copulation –gametes are morphologically similar and flagellated.

     b. anisoplanogametic copulation- gametes flagellated and morphologically similar but differs in size.

     c. ooplanogametic copulation-male gametes are flagellated sperm and female gametes are non-flegellated ovum or egg.
  2. Gamatangial contact- kind of oogamous reproduction. Male gametangia or antheridia and female oogonia or ascogonia. Gametes are non-motile aplanogametes which are never released from gamentnagia. The male and female gametangia come in contact with each other. The male gametangium sends a tubular outgrowth, called fertilization tube, that pierces through the wall of female gametangium. Male nucleus or gamete enters into female gametangium through this tube.

     In this method the two gametangia do not fuse with each other.
  3. Gamatangial copulation-two gametangia fuse with each other and lose their identity in the sexual act.
  4. Spermatization-some fungi produce numerous, minute, uninucleate spore like male bodies called spermatia in a specialised structure called spermagonia. These are transferred through various agencies to receptive hyphae or somatic hyphae treated as female gametangia.
  5. Somatogamy- in this mode of reproduction no sex organs are formed. Here the fusion occurs between two vegetative cells resulting dikaryotization.



A-planogametic copulation, B-Gamatangial contact, C.Gamatangial copulation,D.Spermatization, E.Somatogamy

1. MASTIGOMYCOTINA

- Mastigomycotia represent the lowest group of true fungi. Includes 200 genera and 900 species.
- Ainsworth (1966,71), included all oospore producing fungi under the subdivision Mastigomycotina. He divided it into
  1. *Chytridiomycetes*
  2. *Hypochytridiomycetes*
  3. *Oomycetes*
- General characters of sub-division mastigomycotina
  - ✓ Thallus is simple, unicellular or multicellular, aseptate and coenocytic filamentous hyphae. Septa appear in old hyphae or during the formation of sex organs.
  - ✓ Lower forms are holocarpic and higher forms are eucarpic.
  - ✓ Reproduction occurs asexually and sexually.
  - ✓ Production of fllegellated zoospores or planogametes is the characteristic feature of mastigomycotina. The zoospores may be uniflegellate or biflagellate. The biflagellate zoospore usually possesses one tinsel-shaped and one-whiplash-type of flagella.
  - ✓ Asexually reproduce by means of spores produced in sporangia. The protoplasm of sac-like sporangium is cleaved into a large number of protoplasts. Each piece may develop flagella and becomes zoospore or may develop wall and becomes aplanospore.
  - ✓ Terrestrial species produce aplanospore ans aquatic species produce zoospores.
  - ✓ Higher forms reproduce asexually by the formation of conidia or conidiospores.
  - ✓ Sexual reproduction is isogamous or oogamous. Male sex-organ is antheridia and female oogonia.
  - ✓ Sexual reproduction occurs by plasmogamy immediately followed by karyogamy and meiosis. Sexual reproduction leads to the formation of resting oospores

PYTHIUM

- Genus includes about 92 species.
- Majority species are saprophytes or in mycorrhizal association. A few species are aquatic saprophytes. Others are weak parasites of aquatic plants and animals (facultative parasites).
- Some species of *Pythium* cause **damping off, foot rot, fruit rot, rhizome rot** and **root rot** in seedlings of cucurbits,papaya and ginger.
- *Pythium debaryanum*, which cause damping off disease of tobacco, tomato, mustard and chillies.

  Symptoms : damping off may be pre-emergence or post-emergence. In pre-emergence damping of, the radicle and plummule of germinated seeds get rot and killed before actually the seedling emerges above ground.

  In post emergence damping off is by infecting the basal part of stem or hypocotyl of the seedling, near the ground level.the infected portions becomes soft and water soaked. Due to killing and softening of basal part of stem or hypocotyl, the young seedling fails to stand erect. It collapse at ground level and falls down. Finally the fallen seedlings loses its colour and rot away.

  The fungus continues to grow saprophytically upon the dead seedling.

Vegetative structure

- Long, filamentous, branched, aseptate and multinucleate hyphae (acellular aoenocytic condition)
- Septa appears during differentiation of sex organs or in older hyphae.

- In parasitic forms, mycelliu is both intercellular as well as intracellular, but no haustoria are produced.
- Hyphal cell wall is madeup of cellulose impregnated with chitin.
- Hyphae contains granula cytoplasm with many oil globules and glycogen.

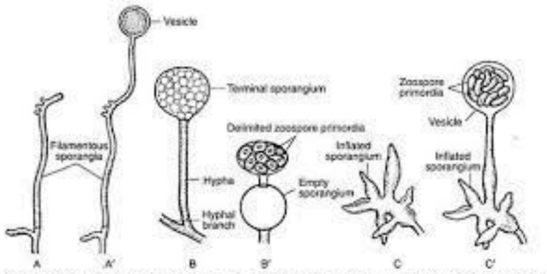


Fig. 4.20 : Different types of sporangia of *Pythium* and their germination : A-A'. Filamentous sporangia, B-B'. Globose sporangia, C-C'. Lobulated sporangia

Reproduction

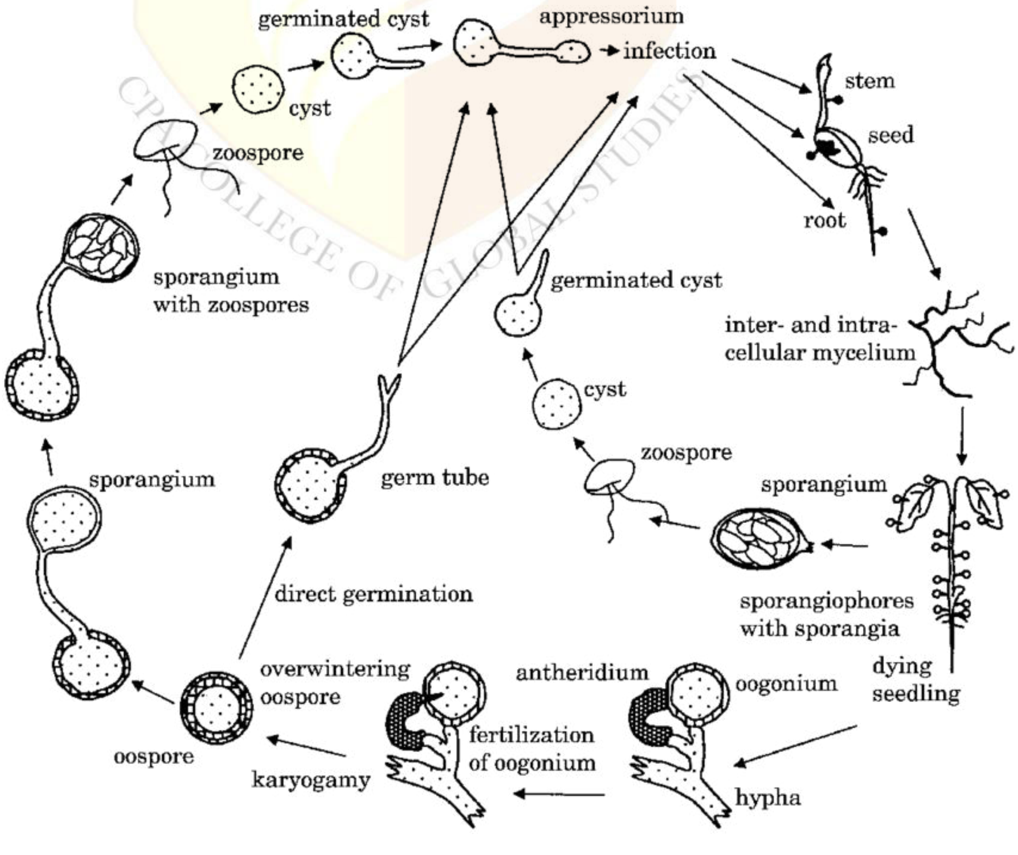
- Reproduce sexually as well as asexually.
  1. Asexual reproduction
     - ✓ By means of biflagellate zoospores, produced from zoosporangia.
     - ✓ Sporangia are arisen from aerial hyphae called sporangiophore.
     - ✓ Sporangia may be terminal or intercalary in position on sporangiophore.
     - ✓ Sporangiophore may be filamentary, branched or globular in form and contain a multinucleate mass of protoplasm.
     - ✓ On the formation of sporangium, a portion of the hyphae swells up and enlarges to form a bubble-like vesicle with a long stalk. Then multinucleate protoplasm flows into it. Soon a transverse septum develops, separating the vesicle from the rest of the hyphae. Finally the vesicle matures to a sporangium.
     - ✓ Mature sporangia behave as conidia under dry condition or as zoosporangia under moist conditions.
     - ✓ Under dry conditions, conidia detach from their parent hyphae and get distributed by wind. Then each conidia germinate directly by giving out a germ tube which elongate and becomes new mycelium.
     - ✓ In moist condition the content of each zoosporangium differentiate into a large number of naked, reniform, uninucleate and biflagellate zoospores.
     - ✓ The crowded zoospore start rocking movement and bounce on the sporangial wall, the zoosporangium bursts like a soap bubble and release zoospores into the moist soil.
     - ✓ Zoospores can swin in the film of soil water. Then they come to rest, withdraw their flagella,become rounded, secrete a protective wall around each of them, and get encysted.Each cyst germinate and giving out a germ tube which elongates and become a new mycelium.
  2. Sexual reproduction
     - ✓ Oogamous and involves gametangial contact.
     - ✓ It takes place by the development of antheridia (male sex organ) and oogonia (female sex organ) which are easily developed in cultures and also after death of the host when the fungus lives saprophytically.
     - ✓ Most of the species like *P. debaryanum* is homothallic, but some like *P. heterothalicum, P. sylvaticum, P. splendens, P. intermedium and P.* catenulatum are heterothallic.

     Oogonium
     - ✓ Oogonium develops as terminal or intercalary swelling of the hypha, which gradually becomes spherical in shape and cuts off by transverse septa from rest of the mycelium. The antheridium develops as terminal club-shaped swelling of hyphal tip, and may originate either from branches of oogonial stalk (monoclinous- antheridium and oogonium in same hyphae) or from neighbouring hyphae (declinous- antheridium and oogonium on separate hyphae).

- ✓ The young oogonium is multinucleate and globose. Eventually, its protoplast is differentiated into central oosphere surrounded by periplasm. Both the regions are multinucleate. The number of nuclei in the oogonium gradu-ally reduces with age.
- ✓ The surviving nuclei undergo meiosis and form 32 nuclei. All nuclei except one in the oosphere degene-rate, the remaining nucleus functions as an egg. The young antheridium is also multi-nucleate and with maturity all except one degenerate. The surviving one undergoes meio-sis to form 4 haploid nuclei.

Antheridium

- ✓ The antheridium is very much smaller in size than the oogonium and a number of antheridia comes in contact with the oogonial wall.
- ✓ During the formation of antheridium, the hyphal end becomes club-shaped and multinucleate mass of cytoplasm flows into it. Soon this portion is separated from the parent hyphae by the formation of the septum.
- ✓ Before fertilisation, a fertilisation tube develops by the antheridium at the contact wall of oogonium through which one of the male nuclei passes and fertilises the egg. The fertilised oosphere develops into a thick walled, smooth oospore or zygote. The oospore germinates after a period of rest.
- ✓ The pattern of oospore germination depends on the variation of environmental temperature. At high temperature (28°C), the oospore germinates by germ tube, while at low temperature between 10-1 7°C, the germ tube elongates at a length of 5-20 μm, then swells up at the tip and forms a vesicle in which zoospores develop.
- ✓ The zoospores come out of the vesicle, after bursting the vesicle wall. After swimming for some time, the zoospores become encysted and take rest. After rest, it germi-nates by germ tube, which develops like the mother mycelium.



Life cycle of *Pythium*

2.ZYGOMYCOTINA

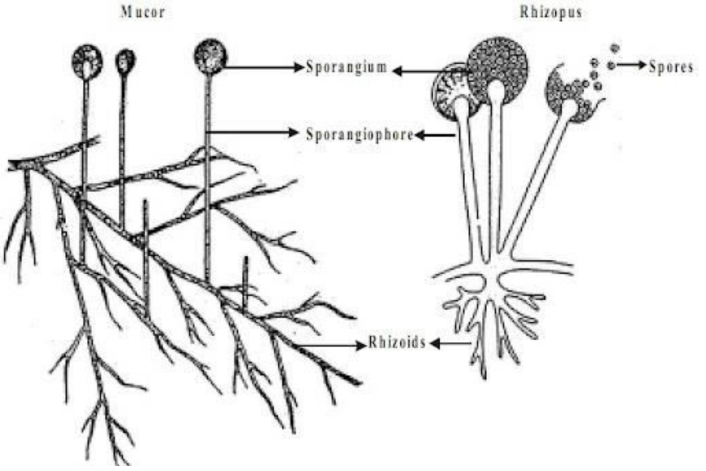
- Group of coenocytic fungi.
- Most of the members are terrestrial saprotrphs and few are parasites of plants, animals and protozoans.
- Terrestrial species include soil saprobes (feed on dead and decaying matter) and coprophilous forms (grow on animal faeces).
- Parasitic species are facultative and obligatory parasites.
- Some parasitic zygomycotines attack human body and cause mucomycosis.
- Some are used for the industrial production of organic acids. Some others are used for production of cortisone. *Rhizopus oryzae* is employed in fermentation for the production of rice wine and other alcoholic beverages.
- Some species of zygomycetes are called sugar fungi- they lack enzyme to degrade complex carbohydrate and can survive only when simple sugars are present in the substrate.
- Alexopaulose et al. (1966) classified zygomycotina into 2 classes.

Diagnostic characters of zygomycotina

- ✓ Mycelium usually coenocytic.
- ✓ Centrioles absent.
- ✓ Usually not adaped to the aquatic habitat.
- ✓ Lack flagellated cells in the life cycle.
- ✓ Asexual reproduction by means of sporangiospores.
  Sporangiospres- non-motile spores produced endogenously in a sac like structure, sporangium.
- ✓ Sexual reproduction by means of zygospore formation.inside the zygosporangium.

General characcters

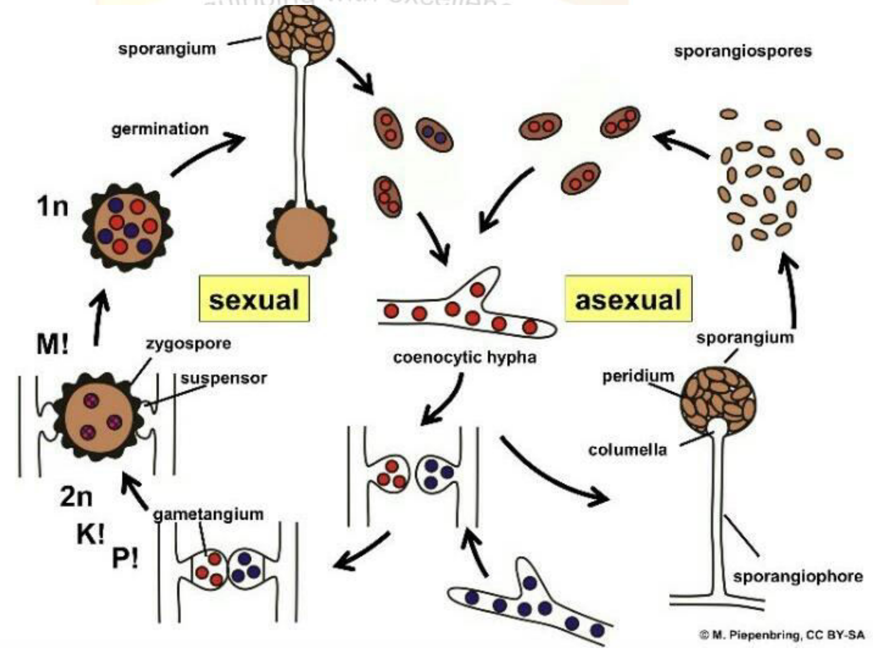
- ✓ Coenocytic hyphae.
- ✓ Anastomoses between the highly branched somatic hyphae are rare in Mucorales and as a result, these fungi do not form the interconnected network typical of most fungi.
- ✓ Hyphal septa usually are produced only to delimit sporangia or gametangia or old or injured hyphae.
- ✓ Some species produce rhizoids with which the fungus adheres to the substrate.
- ✓ The intervening hyphae connecting two groups of rhizoids called stolon.



Reproduction

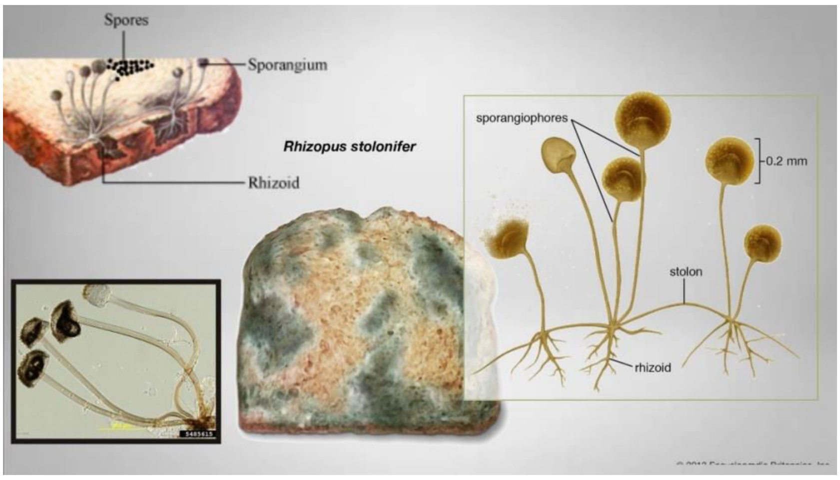
1. Asexual –
   - ➢ by means of production of sporangiospores from sporangium.
   - ➢ But some produce only a few or even a single one spores such sporangia known to besporangiola.
   - ➢ Some species reproduce asexually by formation of arthrospores, chlamydospores, and yeast cells.
2. Sexual reproduction-

- It involves complete gametangial fusion and the formation of a zygospors.
- Both homothallic and heterothallic mycelia exhibit sexual reproduction.
- Zygospore formation is preceded by the fusion of two multinucleate gametangia that are similar in structure but may vary in size. Zygotropism is the directed growth of compactible zygospores towards each other.
- Gametangia may arise from regular somatic hyphae or from specialized hyphal branches called zygophores. Zygophores formed near the tip of actively growing hypae and are rich in beta carotene.
- Zygophore formation is chemically induced. Zygophore of opposite mating types grow towards each other.
- When compactible zygophore contact one other, their tips swells to form progametangia.
- Progametangia fuse apically to form fusion septum. Septa then form to wall off a gametangium at the tip of each progametangium, the remainder of which becomes the suspensor.
- The fusion septum dissolves and the protoplasm of the two gametangia fuse to form a zygosporangium with a thick wall.
- Zygosporangium contain zygospores. Zygospores ggerminate by producing a germ hypae or germ sporangium. Meiosis occurs within the zygospore or upon germination.

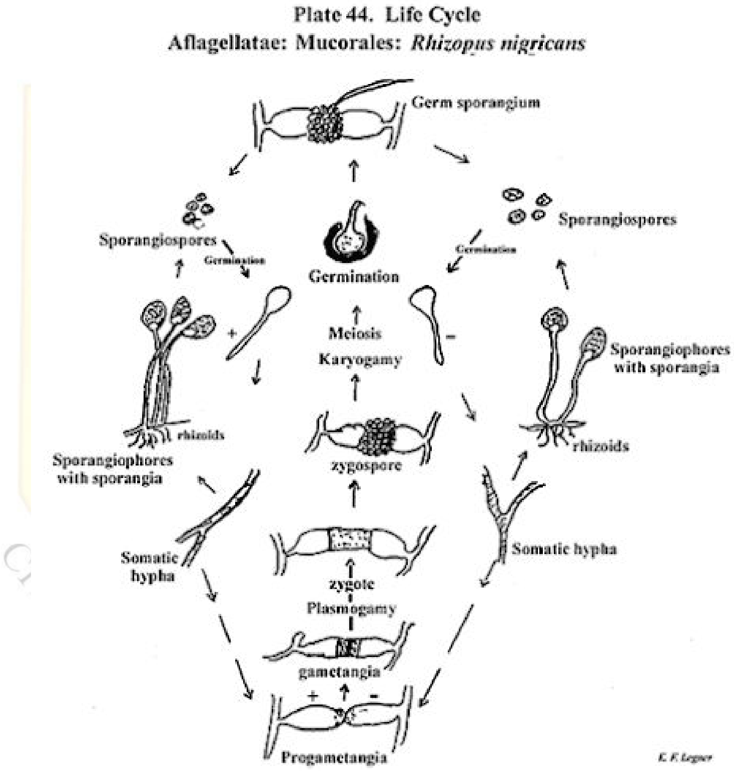


RHIZOPUS

- Also known as black bread mold.
- Majority of the species are common saprophytic fungi and feed on a variety of dead organic matter. Some species are parasitic or pathogenic.
- *Rhizopus stolonifer* is the common bread mold.
- Some species are useful for the production of lactic acid, fumaric acid, biotin and cortisone
- Branching mycelia composed of three types of hyphae; stolons, rhizoids and unbranching sporangiophores.
- Their hyphae lacks cross wall between cells. (coenoocytic).



- The black sporangia at the tip of the sporangiophores are rounded and produce numerous multinucleate spores for asexual reproduction.
- Sexual reproduction, a dark zygospore is produced at the point where two compactible mycelia fuse. Upon germination, a zygospore produces colonies that are genetically different from either parent.



3. ASCOMYCOTINA

- Ascomycotina- term derived from greek words ***askos*=bladder** and ***mykos*=fungi.**
- Also known to be **sac fungi**(presence of sac like sporangia called **asci**)
- Yeast, powdery mildews, cup fungi, edible morels and pink moulds are the common example.
- Ainsworth (1966,71) divided this sub division into 6 classes on the basis of ascocarp and presence and absence of ascogenous hyphae.
- Diagnostic features of Ascomycotina
  - ✓ Thallus is well developed, branched, septate mycelium (except in Yeast).
  - ✓ Complete absence of motile phase.
  - ✓ Asexual reproduction generally occurs by non-motile conidia or conidiospores.
  - ✓ Production of sac-like structure called ascus with definite numbers of ascospores.

- ✓ Plasmogamy is not immediately followed by karyogamy.
- ✓ Production of definite fruiting bodies, ascocarps, in most of the species.

- General characters of ascomycotina
  - ✓ Sac-fungi includes about 2500-3500 species.
  - ✓ Most of the species are terrestrial and occur as saprophyte or as parasite.
  - ✓ Most of the species are Coprophilous (dung loving).
  - ✓ Mycelium is well developed and branched. Hyphae are septate and multicellular.
  - ✓ Septa are characterized by the presence of a minute central pore through which protoplasmic strands and nuclei can pass from one cell to another.
  - ✓ Each cell is uninucleate or multinucleate.
  - ✓ Nuclei may be homokaryotic or heterokaryotic. Cell wall made up of chitin.
  - ✓ In parasitic species, mycelium grows intercellularly but produces intercellular haustoria. The mycelium in fruiting bodies is well organized to form prosenchyma or pseudoparenchyma. In some species the hyphal mass aggregate to form sclerotia or stromata.
  - ✓ Asexually reproduce by means of
    1. Fragmentation
    2. Fission
    3. Budding
    4. Oidia formation
    5. Chlamydspores formation
    6. Conidia formation – common method asexual reproduction. Conidia are disseminated by air or any other means and germinate by giving out or more germ tubes.

  Here the conidiophores may arise singly scattered over the general surface of mycelium or in special fruiting bodies. There are 4 main types of fruiting bodies which encloses conidiophores and conidia.

a) Synnema- conidiophores arise in very close packets in such a way that their greater part is fused in length.
b) Acervulus-conidiophores remain clusterd in a saucer or barrel shaped stromatic masss or frutification. Usually found in parasitic fungi.
c) sporodochium –hemisperical or barrel shaped fruiting bodies with the lower portion of cushioned stroma-like mass of hyphae.
d) Pycnidium- flask shaped body with an opening called ostiole. The conidiophores are arises from the inner line of pycnidium. The conidia are called pycnidiospores.

✓ Sexual reproduction through
1. Gametic copulation
2. Gametangial contact
3. Spermatization
4. Somatogamy
5. Following the plasmogamy further development in ascomycotina is almost uniform. It leads to the development of ascus and ascospores.

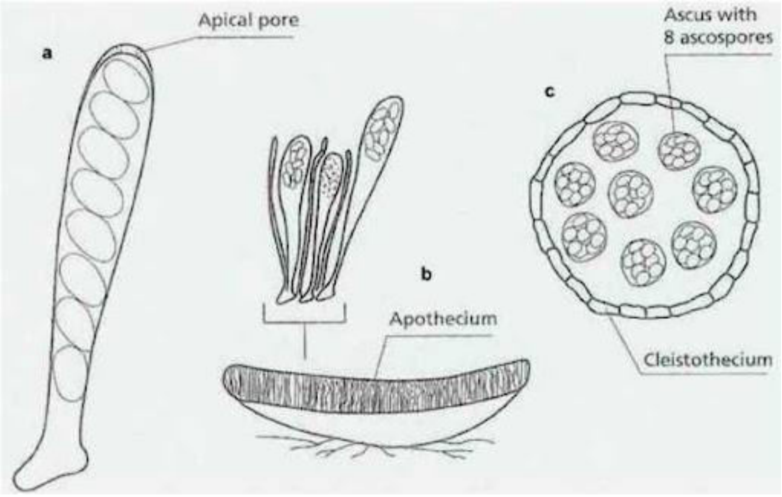
Development of ascus

- Sex organs are antheridia and ascogonia.
- The plasmogay and pairing of nuclei is followed by conjugate nuclear division resulting a large number of nuclear pairs.

- Ascogonium gives rise a number of branched or unbranched hyphal out growths, known as ascogenous hyphae. And the nuclear pairs migrate to the tip of ascogenous hyphae. It continue to divide and become a multicellular septate ascogenous hyphae.
- The terminal cells of ascogenous hyphae always possess two nuclei of opposite strains. It bends and forms a hook like crozier. Two nuclei of crozier divide mitotically and one goes to apical portion of crozier, and two remain in the middle and one goes to basal part. Now the septa are laid down forming uninucleate terminal cell(uninucleate), binucleate crook cell (penultimate cell) and uninucleate basal cell.
- The two nuclei of crook cell fuse to form a diploid nucleus. This stage is called karyogamy (fusion of two compactible nuclei). This cell with diploid nucleus and apical position becomes ascus mother cell.
- The ascus mother cell elongates and diploid nucleus divides by meiosis and form 4 haploid daughter nuclei. This divides mitotically and forms 8 daughter nuclei. The cytoplasm collects around each nucleus and thin walled uninuclete ascospores are formed by free-cell formation, the portion of cytoplasm not used up in the ascospores serves nutritive function.
- Usually 8 ascospores are produced endogenously inside the sac-like ascus. Ascospores are liberated and germinate to produce haploid mycelium.

Asci and ascospores

- The asci are usually club-shaped, cylindrical and elongated. They may be ovoid, globose or even rectangular.
- Each ascus is unicellular but septate asci are also found.
- Asci may be stalked or sessile. Usually 8 ascospores are produced by asci.
- Ascospores are arranged in one or two rows inside the club-shaped ascus. Sometimes ascospores irregularly dispersed in in the asci.
- Ascospores are unicellular, thin walled and uninucleate. Sometimes they are septate.
- In most of case asci absorb water, swell and forcibly burst ejecting the ascospores.
- Some times ascus dehisces along a definite line of dehiscence. In some cases, the tip of ascus seperates in a lid-like manner and the ascospores are ejected from the apical pore.

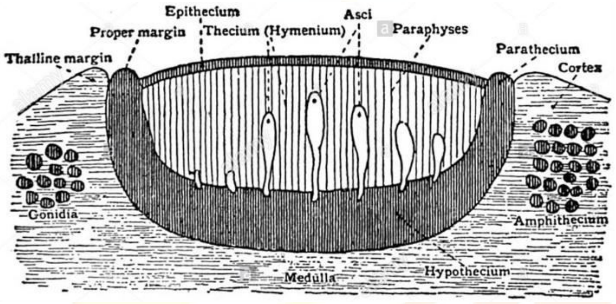


Fruiting bodies or ascocarps

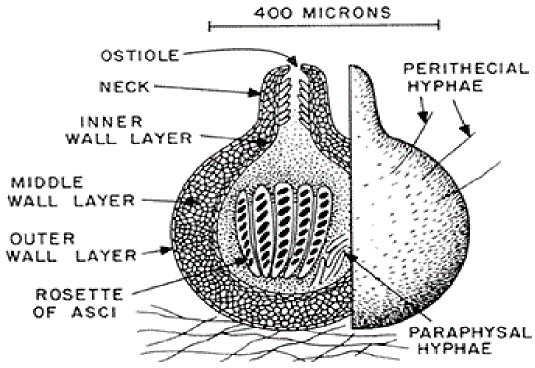
- The asci are produced inside complex fruiting bodies called ascocarps.
- Ascocarps are usually developed as a response of sexual stimulus. It begins to form as soon as plasmogamy has taken place.
- In some cases, the development of ascocarp begins first and the sex organs develop later on.
- Each ascocarp consist of one or many asci enclosed within the sterile somatic hyphae, which interweave to form prosenchymatous or psudoparenchymatous structure.

- According to their shape and structure, the ascocarps are 4 different types.

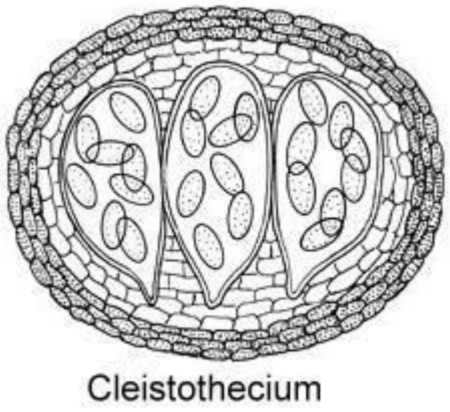
1. Apothecium- These are cup shaped or disc shaped fruiting bodies. The club-shaped asci are intermingled with sterile paraphyses in the upper fertile layer called hymenium.
   The hymenium layer is variously coloured and forms inner lining apothecium. Beneath the hymenium there is a layer of interwoven hyphae, called hypothecium. It is followed by fleshy part of apothecium called excipulum. Eg- *Peziza, Morchella*



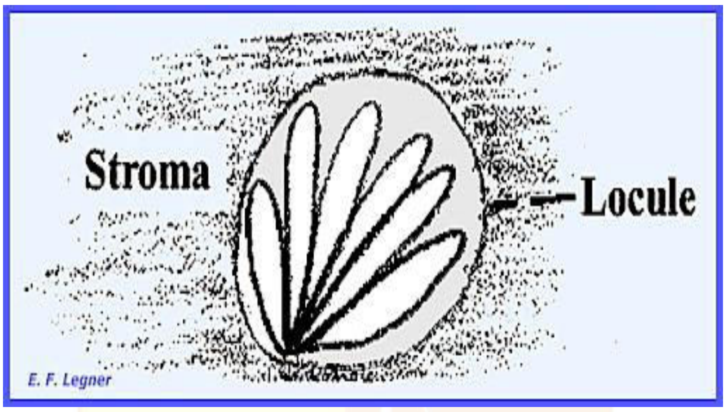
2. Perithecium-rounded or flask shaped fruiting bodies with a definite apical pore or ostiole.
   The fertile layer hymenium consisting of asci and paraphyses is situated usually at the basal portion of perithecium cavity.
   The ostiolar opening is guarded by sterile hyphal branches called periphyses.
   The ascospore liberated through ostiole. Eg-*Claviceps*



3. Clestothecium-small spherical or ovoid indehiscent fruiting body which is completely closed from all the sides. It encloses elliptical or globose asci arranged irregularly within the cavity. The asci and ascospore liberate by the decay or irregular splitting of the wall of cleistothecium (peridium). Eg- *Aspergillus*



4. Ascostroma-it is not a distinct fruiting body. The asci develop directly within the cavity of the stroma, called loculus



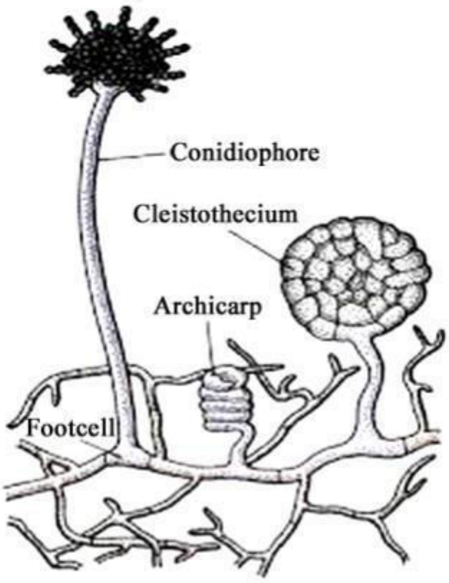
.ASPERGILLUS

- Commonly known as Green orBlack mold.
- Genus includes about 160 species distributed from arctic to tropical regions of the world.
- Saprophytic and grow on decomposing organic substances such as fruits, vegetables, jams , cheese, wood, leather etc. It appears in the form of greenish smokey Patches.
- Aspergillus niger cause rot disease of dates, pomegranate and fig.
- Aspergillus fumigatus, A. niger and A. flavus cause aspergillosis in lungs of human beings.

Aspergillus grows on bread

- Mycelium consists of Slender, tubular, pale coloured, extensively branched,thin walled septate hyphae.
- Cells are thin walled, multinucleate and contain granular protoplasm with oil globules.
- Hyphae may grow over the substratum or penetrate in to the substratum

- Majority of the species of aspergillus are homokaryotic, but sometimes it may heterokaryotic..



Reproduction

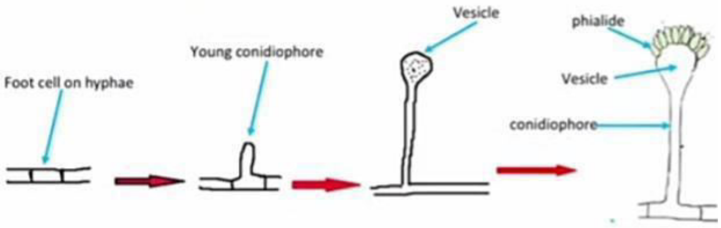
1. Vegetative reproduction

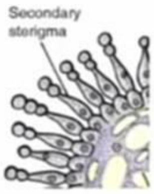
-Fragmentation

-Sclerotia: rusting body of fungi, consisting of amass of threads,Capable of remaining dormant for long periods.

2. Asexual reproduction
   - Through the production of spores known as conidia.
   - Conidia developed from conidiophore.
   - Once the spore on a favorable environment (with moisture, warmth and nutrients) germinating period create numerous hyphae that form the mycelium.

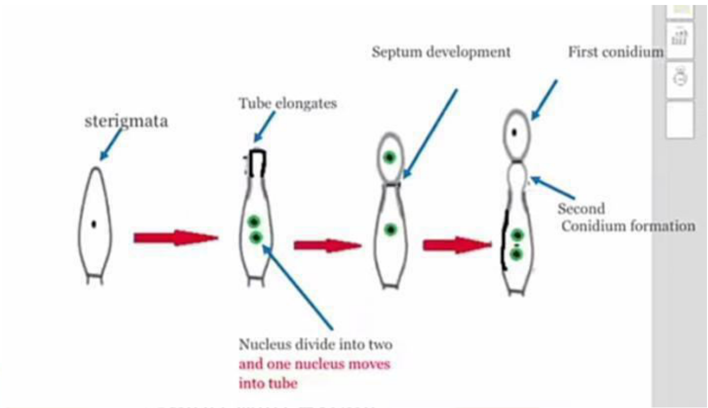
   Development of conidia
   - Conidiophores are developed on some specialized cells called foot cells. Present on the hyphae
   - Foot cell produces a special effect branch us and outgrowth called Conidiophore.
   - Tip of the Conidiophore swells up into on elliptical or globular multinucleated head called vesicle.
   - The vesicle produces numerous tubular uninucleate outgrowths called sterigmata or phialides.





Formation of conidia

- Sterigmata elongate at tip of to Form a tube
- Single nucleus of the phialide divide mitotically into two daughter nuclei
- One of the duaghter tor nucleus moves into the tube
- The tube extends and separated by a saptum to form conidium
- Second conidium is cutoff below the first formed conidium (basipetal succession).i.e., the youngest medium is at its base and the oldest at the tip



- The cytoplasm of both the conidia is confluent through a narrow cellular link called isthamus

- The continuity of the cytoplasm is stopped by the formation of the inner conidial wall. The isthmus becomes empty and now it is called connective

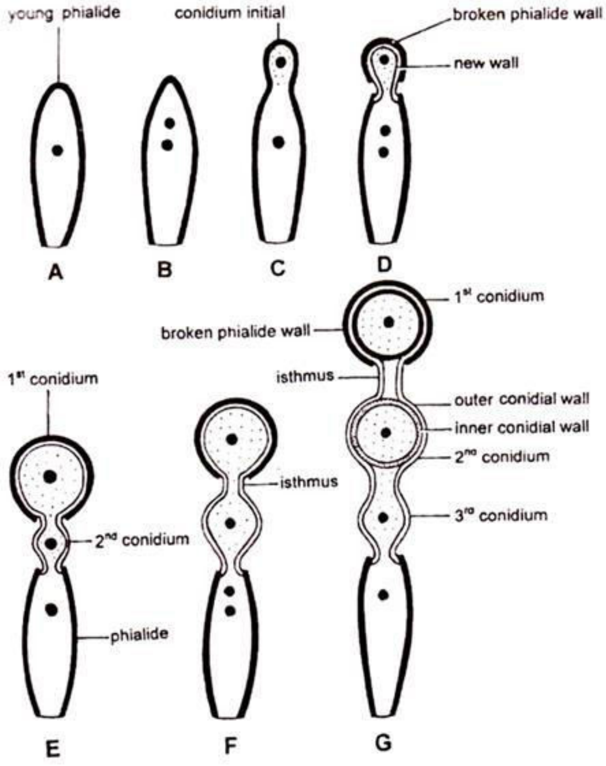


Fig. 11. (A–G). *Aspergillus* : Asexual reproduction. Formation of conidia.

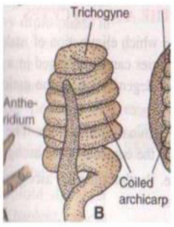
- Conidia are small, globose, unicellular, uninucleate black, brown or yellow green in colour
- They germinate on suitable substratum by giving out a germ tube
- The germ tube becomes septate, branched and forms a mycelium

Sexual reproduction

- sexual reproduction is of rare occurrence
- It takes place by the formation of male and female sex organs.
- Male sex organ is known as antheridium and the male branch is called Pollinodium
- Female sex organ is called ascogonium and female branch is archicarp

ARCHICARP

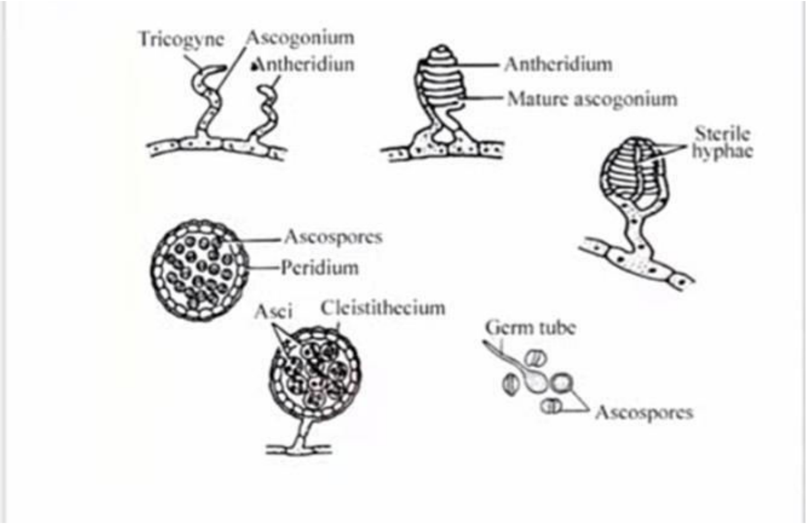
- The basal multicellular, multinucleated stalk.
- Middle unicellular, multinucleate ascogonium.
- Apical unicellular, multinucleate receptive organ called trichogyne.



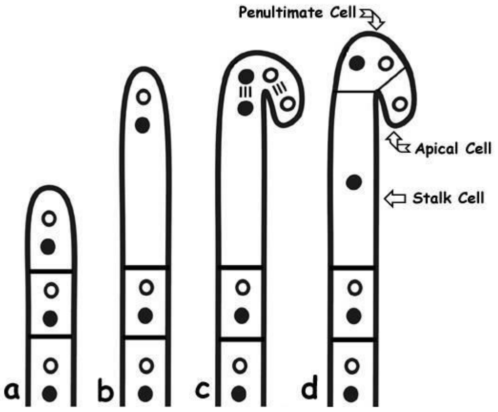
POLLINODIUM

- Upper part, slightly broader, unicellular, multinucleate and behaves as antheridium.
- Lower unicellular and multinucleate part called stalk.

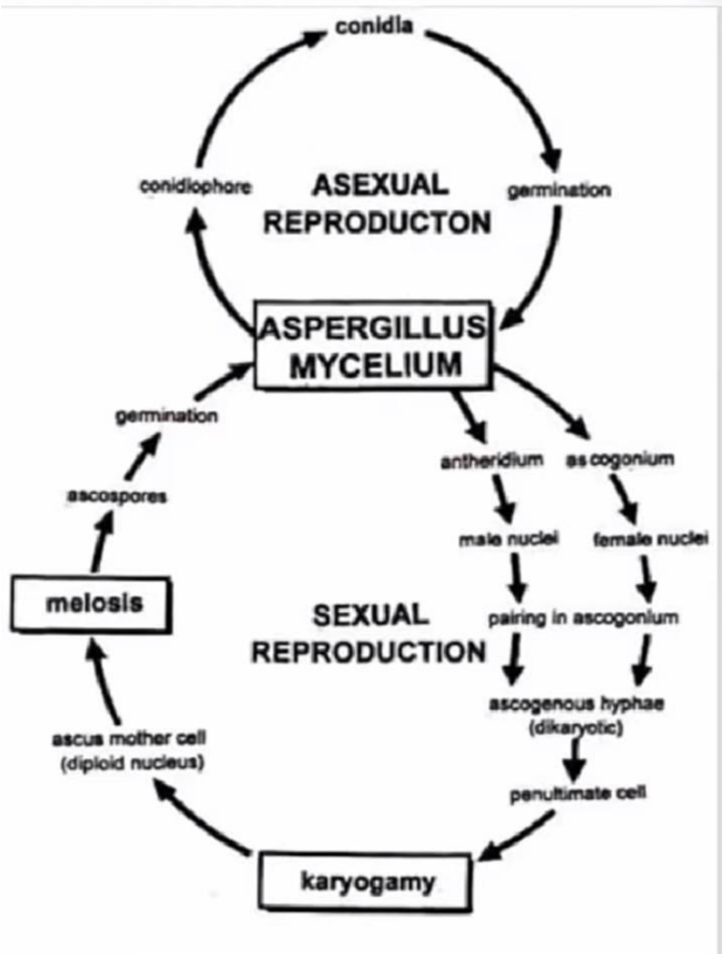
- Fertilization



- After the pairing of the nuclei (FERTILIZATION), the ascogonium becomes septate. Each segment consists of one male and one female nucleus (dikaryon). From these dikaryotic segments arise ascogenous hyphae. Each iscogenous hypibil is multicellular with a pair of nuclei and produces asci by crozier formation.



- As the asci develop from ascogenous hyphae, a large number of sterile hyphae grow and round them and form a protective covering called peridium. The entire structure is known as lesxarp. It is spherical and has no opening, Such an ascocarp is known as cleistothecium
- Ascus produces ascospores.
- After falling on a suitable substratum each ascospore germinates to give rise to a germ tube which develops into a new haploid mycelium.



Life cycle of Aspergillus

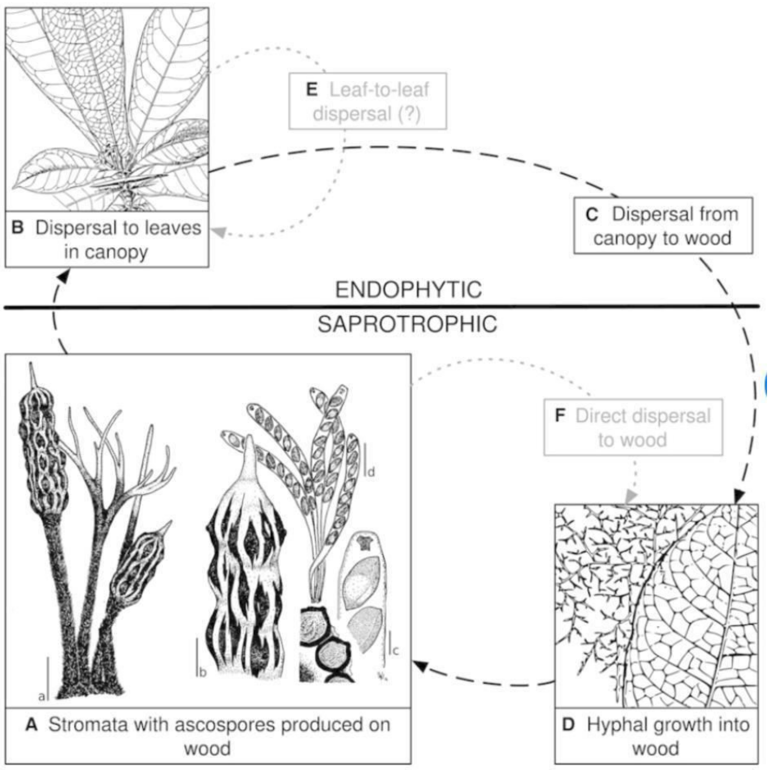
XYLARIA

- Xylaria is a genus of ascomycetous fungi commonly found growing on dead wood.
- The name comes from the Greek, *xylon* meaning wood.
- Two of the common species of the genus are *Xylaria hypoxylon* and *Xylaria polymorpha*.
- It have complicated life cycle.

Reproduction

- Asexual reproduction-
  Asexual reproduction by formation of conidia. Small oval conidia are borne in large numbers on small conidiosphores.
- Sexual reproduction
  - ✓ Stroma is sterile tissue that contains perithcia like ascocarp.
  - ✓ Sex organs are present in a flask – shaped cavity with protruding tips called peritheca they develop from the terminal cells of the hyphae present at the base of the cavity
  - ✓ Asci is cylindrical ,eight-spores and are mixed with paraphyses.
  - ✓ Ascospores are uninucleate, fusiform and non septate often with equatorial germ pore.
  - ✓ Mycelia develop from the ascospores.
  - ✓ Hyphae unite into thick strands. They first differentiate into a black pseudo parenchymatous rind and a light fibrours core.
  - ✓ Then,they gradually develop to cylindrical,cleavage or branched black fructification

- **Life cycle of xylaria**



BASIDIOMYCOTINA

- Also known as **club fungi.**
- Most advanced and largest group of higher fungi.
- It consists of about 500 genus and 25,000 species.
- Members of basidiomycotina commonly known as **rust, smut, mushrooms, puff balls, bracket fungi and shelf fungi**.
- Basidiomycotines are unique in having **club shaped basidia**.
- Ainsworth 1966, divided basidiomycotina into **3 classes**.
  Teliomycetes, Hymenomycetes and Gasteromycetes.
- Diagnostic features of basidiomycotina
  - Mycelium is usually perennial, septate, and multicellular. And the septa are perforated by centrally located dolipore.
  - Moile phase is completely absent in the life cycle.
  - Plasmogamy occurs early in the life history and it is immediately followed by karyogamy and meiosis.
  - The sexual stage spores are basidiospores, which are produced exogenously on specilaised structure called basidia. 4 basidiospores are produced from a single basidium.
- General characters of basidiomycotina
  - Most of the species are terrestrial, saprophytes or parasites.
    - Saprophytes-mushrooms, buff balls, bracket fungi and jelly fungi.
    - Parasites- rust and smuts. Cause serious damage on food crops.
  - Mycelium is well developed and consist filamentous, branched and septate hyphae.
  - In higher form each cell septate with dolipore septa.
  - Cell wall is made up of chitin.
  - The mycelium passes through three distinct stages before the fungus completes its life cycle.
  - The three stages are
    1. Primary mycelium/ monokaryon-
       - Develops from germination of basidiospores.
       - It represent haplophase of the life cycle.

- Initially, its hyphae is non-septate, non-cellularr and multinucleate or coeocytic.
- Later on it become septate and cellular, with uninucleate(monokaryotic) cells.
- In some species primary mycelium is septate and cellular right from the very beginning itself. Primary mycelium has only a very short period of existence.
- It can multiply asexually by conidia or oidia.
- It can never form basidia or basidioospores.
- In rust fungi, primary mycelium produces spermatia and spermatiophores in a flask shaped body called, spermagonium.

2. Secondary mycelium-
   - Hyphae with binucleate cells.
   - It represents the dikaryophase of the life cycle.
   - Secondary mycelium may produce dikaryotic oidia, uredospores, teliospores, basisia and basidiospore.
   - Secondary mycelium usually develops from the primary mycelium by the process called dikaryotization.
   - The dikaryotization occurs through;
     1. Union of primary hyphae of opposite strains.
     2. Somatogamy between two uninucleate cells of the primary hyphae of opposite strains.
     3. Fusion between two germ tubes of two basidiospores of opposite strains
     4. Fusion of two basidiospores.
     5. Fusion between two basidia that are formed by the germination of the spores of opposite strains.

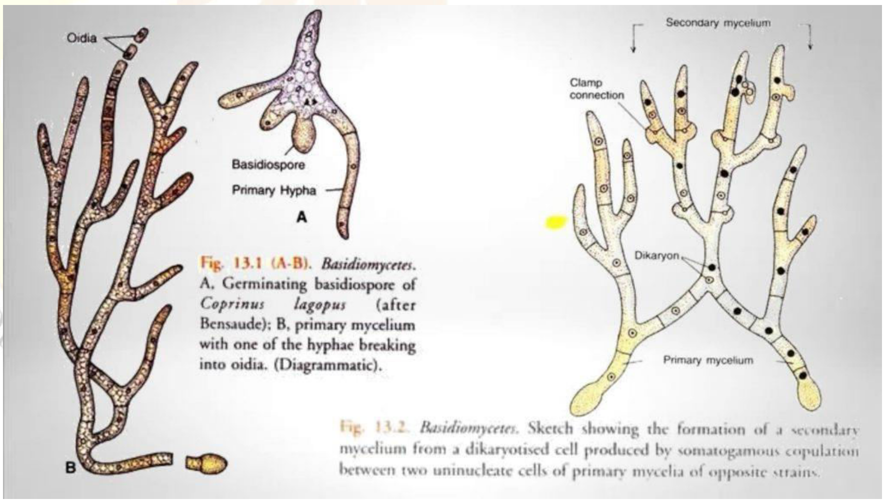


Fig. 13.1 (A-B). *Basidiomycetes*. A. Germinating basidiospore of *Coprinus lagopus* (after Bensaude); B, primary mycelium with one of the hyphae breaking into oidia. (Diagrammatic).

Fig. 13.2. *Basidiomycetes*. Sketch showing the formation of a secondary mycelium from a dikaryotised cell produced by somatogamous copulation between two uninucleate cells of primary mycelia of opposite strains.

3. Tertiary mycelium-
   - Complex tissue, formed by the organized arrangement of secondary mycelium.
   - Cells are dikaryotic.
   - Tertiary mycelium is common in fruiting bodies or sporophores.

Reproduction

- It occurs by vegetative, asexual and sexual methods.
  - Vegetative reproduction by means of fragmentation and budding.
  - Asexual reproduction by the formation of conidia (uredspores of rust considered to be conidia in origin and function), oidia, chlamydospores ansd arthropores.

    Arthrospore-thick walled, unicellular mycelial fragements producd by breaking hyphae. They may be uninucleate or binucleate. Each arthrspores germinates by giving out a germ tube.

sexual reproduction

- Sex organs are altogether absent in basidiomycotina.
- In rust fungi the receptive hyphae(female) and spermatia (male) serve as specialised structure functioning as sex organs.
- In all the cases primary hyphae, oidia or basidiospores function as sex cells.
- Sexual reproduction complete in three phases. These occurs indifferent stages and at different locations.
  1. Plasmogamy- it occurs earlier, during the dikaryotization of primary mycelium to secondary mycelium. Plasmogamy takes place by two methods somatogamy and spermatization.
     In somatogamy no sex organs or sexual process are involved. It may takes place by
     a. Fusion between two vegetative cells of primary mycelia.
     b. Fusion between oidium and cell of primary mycelium.
     c. Fusion between oidial mycelia of opposite strains.
     d. Fusion between oidial mycelium and primary mycelium of opposite strains.

     Spermatization, sexual fusion between a spermatium (male) of one strain and receptive hyphae (female)of the opposite strain.

     During the formation of secondary mycelia, it is formed from dikaryotic cell by the process of cell division and formation of clamp onnection.

     Clamp connection

     'During cell division in a dikaryon, the two nuclei of opposite strains divide by conjugate division. It is followed by the formation of septum between two pairs of nuclei. Each of the two daughter cells possess two nuclei, one of (+) strain and another of (-) strain. This kind of distribution of nuclei, in each cell, is possible only when the nuclei migrate in opposite direction bypassing each other. This by-pass is possible in case of broad hyphae. If the hyphae are thin and the cell lumen is narrow the by-pass of nuclei is not possible. In that case an additional bridge is developed through which one of the daughter nucleuses are transferred from one cell to the other. It is called clamp connection.'

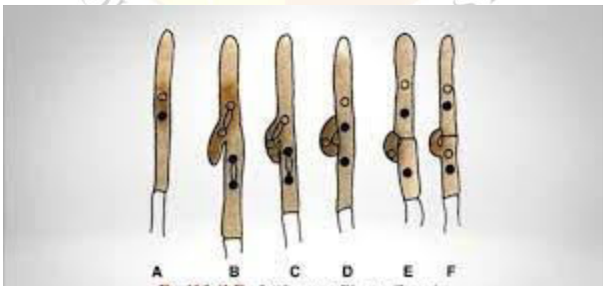
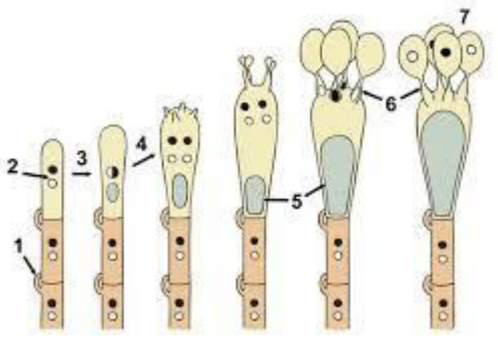


Fig. 13.3 (A-F). Basidiomycetes. Diagram illustrating the formation of clamp connections.

  2. Karyogamy-it is much belated due to the existence of prolonged dikaryophase. It occurs in young basidia, or in teliospores or teleutospores which directly give rise to basidia.
  3. Meiosis – it occurs immediately after karyogamy in basidia. During this time small outgrowths with swollen tips are given out from the basidium. They are called sterigmata. Into each of them a haploid nucleus migrates. Eventually, the sterigmatal swellings develop to basidiospores.

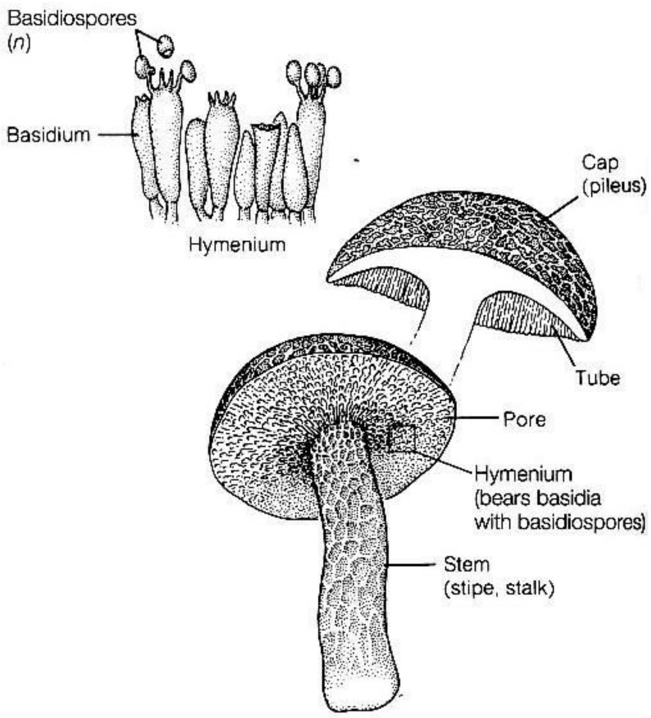


Basidia

- Reproductive structure, which bears basidiospores.
- There are 2 major types of basidia.
  1. Holobasidia
     - Cylindrical, aseptate and rounded at the apices.
     - Each basidium develops from a terminal cell of the dikaryotic hyphae.
     - in the beginning the young basidium is narrow and elongated but later on it becomes rounded.
     - The two nuclei fuse to form single diploid nucleus (karyogamy).
     - Karyogamy immediately followed by meiosis which result the formation 4 daughter nuclei.
     - These 4 daughter nuclei will move towards the apex due to the formation of a large central vacuole.
     - At the same time basidium develops 4 tubular sterigmata at it distal end.
     - Each sterigma swells at its apex forming bud like basidiospore initials.
     - Later the central vacuole enlarges and pushes the nuclei into basidiospore initials.
     - Single nucleus move into each basidiospore, late cut off by cross wall formation.
     - Finally each basidium bears 4 exogenous basidiodpores usually attached to its apex by means of sterigmata.
  2. Phragmobasidia.
     - It is elongated and divided by transverse or vertical septa.
     - It develops from special spores (teleutospore) usually in case of rust and smut.
     - Here the nuclei of dikaryon usually fuse to form a diploid nucleus before the germination of the spore.
     - The spores germinate to give rise a tubular germ tube called probasidium.
     - The diploid nucleus migrates into it and divides by meiosis into 4 daughter nuclei.
     - It is followed by the formation of septa between the nuclei so that the basidium becomes 4 celled.
     - Later sterigma develops in each basidial cells and one or more basidiospores develops at the apex of each sterigma.

Basidiospores

- Samall, haploid, thin walled uninucleate cell preoduced exogenously from basidium.
- Each basidium usually produce 4 basidiospore.
- In smut they are produced in large numbers, called sporidia. They are usually borne obliquely over the tubular outgrowths, called sterigmata.
- Basidiospores vary in shape, size and color in different species.



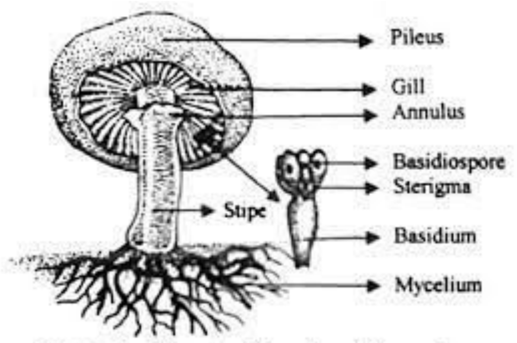
Basidium and basidiospores

AGARICUS

- *Agaricus* is a common saprophytic fungus.
- Mostly growing on humus rich soil of grassy plains, meadows, lawns, damp and shady places.
- About 25 species are discovered from India.
- *A. campestris* commonly called field mushroom, is the most widely used edible species of Kerala. It contains campestrin (antibiotic).
- Mycelium is eucarpic, septate, branched and sub-terranean. It remains underground and grows saprotrophically.
- There are 3 kind of mycelium in *Agaricus.*
    1. Primary mycelium- develops by the germination of uninucleate basidiospores. It is short living. It consists of haploid, filamentar, much branched, septate and loosely tangled hyphae which ramify extensively in the substratum, just below the surface.
    2. Secondary mycelium-primary mycelium undergoes dikaryotization by somatogamy or oidisation and gives secondary mycelium. The dikaryotic cells of secondary mycelium divide repeatedly, resulting in the branching and spreading of the mycelium. The branching hyphae of the secondary mycelium form dense underground tangles called rhizomorphs. Adjescent cells of secondary mycelium are separated from each other by dolipore septum.
    The pieces of secondary mycelium called spawns; they serve as the seeds for the cultivation or propogation of the fungus.
    3. Tertiary mycelium- secondary mycelium forms a compact mass of hyphal strands which constitutes the tertiary mycelium. It is characteristically found in fruiting bodies.
- Secondary mycelium is perennial. It can perennate in the substratum for many years. It may go on growing and spreading from the centre. This centrifugal growth of the secondary myceliumis followed by the degeneration of the older hyphae in the centre.
- During spore formation, umbrella-like aerial fruiting bodies, commonly called fungal flowers, develops from the secondary mycelium. Soon after rains. They emerge on the surface of the soil in circles called fairy rings. They emerge rhizomorphs from every year.

Fruiting body

- The fruiting body of *Agaricus* is called basidiocarps or sporophores.
- They are the aerial frutifications called mushrooms.
- This is the edible part of *Agaricus.*



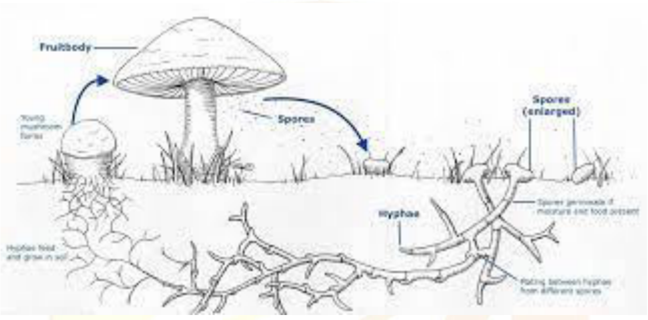
Fruit body of *Agaricus* (Fungus) and other parts

- Initially, a basidiocarp is only a tiny knot of compact hyphae. Then it grows to a spherical body. This stage is button stage.
- A mature basidiocarp has a stout fleshy and basally swollen stalk or stipe and cup-like cap or pileus. Both these are formed of closely packed and compacted hyphae which constitute the tertiary mycelium.
- In the button stage, the margin of the pileus is joined to the stipe by a membrane called veil or velum.
- As the pileus grows further, the velum ruptures and forms a ring around the stipe called annulus.
- Stipe is negatively geotropic. This enables to hold the pileus high above the ground level.
- Anatomically, stipe has 2 parts, namely cortex and medulla. Cortex is the outer zone formed of psuedoparenchymatous tissue. Medulla is central zone, made up of prosenchymatous tissue.
- Initaially pileus is fleshy convex structure. But later on, it becomes almost flat. On its lowerside, there are numerous vertically hanging plate like structure called gills or lamellae present.
- These gills are lined by thousands of elongated and club-shaped basidia. Each basidium bears 4 haploid, uninucleate and non-motile basidiospores on small stalks, called sterigmata. Basidiospores belongs to +ve and –ve strains.
- Structurally the gills has 3 regions,
  1. Hymenium- outer part, with fertile basidia nd sterile paraphyses.
  2. Subhymenium- middle, with small, rounded and dikaryotic sterile cells.
  3. Trama – inner, pseudoparenchymatous tissue, formed of long, slender and loosely interwoven hyphae.

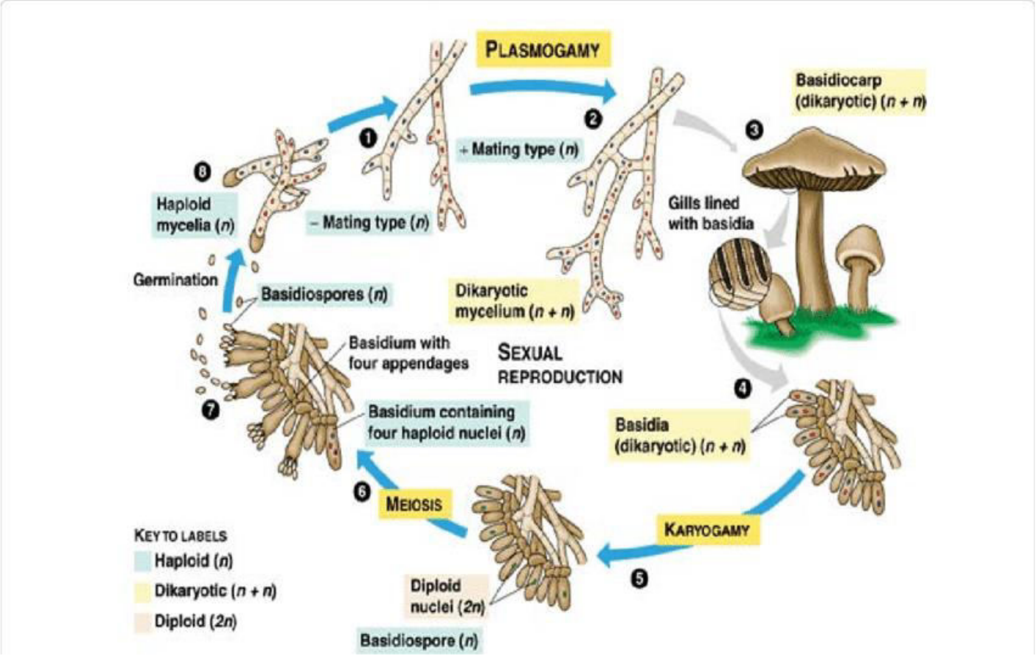
Reproduction

- Reproduce by means
  1. Vegetative- fragmentation(fragments of dikaryotic mycelia can germinate to new one)
  2. Asexual- not common. But in some species chlamydospores and oidia are formed.
  3. Sexual- well differentiated sex organs are absent.
     - ✓ Their function is taken over by heterothallic somatic hyphae.
     - ✓ Sexual reproduction is accomplished by somatogamy, karyogamy, meiosis and production of basidiospores.
     - ✓ Somatogamy results in the dikaryotisation of primary mycelium and the formation of dikaryotic secondary mycelium. The dikaryotic cell of the secondary mycelium undergoes repeated conjugate division, resulting in the growth of the secondary mycelium.
     - ✓ Under favorable condition secondary mycelium forms the fruiting bodies basidiocarps or saprophores.

- ✓ Basidiocarps contain the fertile cells basidia which are concerned with karyogamy, meiosis and spore formation.
- ✓ Initially maturing basidium is dikaryotic with 2 haploid nuclei. During the course of maturation, the two nuclei undergo fusion and forms a diploid synkaryon or fusion nucleus.
- ✓ Synkaryon migrates to the apex of the basidium and undergoes meiosis. This results in four haploid nuclei 2 of which are +ve and others are-ve .
- ✓ The basidium gives out 4 peg like terminal precessess, called sterigmata.
- ✓ Terminally each of them gives out basidiospores.
- ✓ Near the junction between the spore and the sterigma, there develop a small lateral outgrowth called hilum.
- ✓ When basidiospore becomes mature, a mature liquid droplet appers on the hilum. It enlarges in size, exerting pressure on the basidiospores. This pressure causes the explosive ejection of the basidiospore, together with the liquid droplet.
- ✓ The 4 basidiospores of each basidium are usually shed one after another. The spores get dispersed by wind, water and other agencies.
- ✓ On the return of favourable condition, the spores which have landed on suitable substrata germinate and give rise to new primary mycelia to repeat the cycle.



Life cycle of Agaricus



PUCCINIA

- Commonly known as rust, it produces rusty patches on the leaves and stem of the host plant.
- Obligate parasite, capable of thriving only upon living hosts.
- *Puccinia* attacks a variety of host plants like many cereals and millets.
- Species of *Puccinia* are either autoecious(complete its life cycle on a single host) or heteroceious(complete their life cycle two host plants).

- *Puccinia graminis* is a heteroecious fungus. It complete life cycle in two different host like wheat (primary host) and barberry (alternate host).

Puccinia graminis

- Cause black stem rust of wheat in almost all wheat-growing areas of the world, inflicting considerable damage on the wheat plant.
- It also attacks a large number of other hosts, such as oats, barley, rye and many wild grasses.
- The dikaryophase of the life cycle of *Puccinia* completed on the wheat plant and haplophase is completed on the barberry plant.
- Symptoms of the disease appear more severely on stem and leaf sheath in the form of uredosori and teleutosori.
  The uredosori or uredia appear in the form of large, elongated, coalescing pustules or streaks. The reddish brown or rusty-red colored uredospores are exposed by the rupture of host epidermis.
  The teleutosori also look like uredosori, but they are black in colour.
- Severe infection in wheat plants results in poorly filled heads and shriveled grains. The disease cause great economic loss as the plant becomes stunted and the yield is reduced.

Puccinia infected plant leaves

Life history of *Puccinia graminis*

- It requires two hosts to complete its life cycle.
- Primary host is wheat and alternate host is barberry.
- Mycelium is localized to isolated patches in stem and leaves. It grows in the intercellular spaces of host plant.
- Mycelium is well developed, branched, septate and dikaryotic hyphae. Cells are binucleate and heterokaryotic(2nuclei from two strains)
- Mycelium produces intercellular button-shaped haustoria. The haustoria absorb nourishment from the host cells.
- Life history of *Puccinia graminis* can be studied in three stages.
  A. Fungus on wheat
     - ✓ The primary host wheat get infected either by germination of aecidiospores, produced from barberry or germination of uredospores from wheat plant.
     - ✓ These spores germinate to form secondary mycelium.
       1. Uredineal stage
          - ➢ Dikaryotic mycelium produces 2 kinds of spores- uredospores in uredosori and teleutospore in teleutosori.
          - ➢ Uredospores are produced in early summer on stem as well as on leaves in uredosori or uredia.
          - ➢ The dikaryotic mycelium accumulates below the epidermis.
          - ➢ Dense mycelium develops several two-celled branches which press towards the epidermis. This results epidermal bulging.

- Outer cell of each branch enlarges to form large, oval uredospore and the lower cell forms a long stalk. Finally the epidermis ruptures and the uredospores are exposed.
- Uredospores are one celled, oval, binucleate and heteronucleate structure.
- It is brown in colour. It has a thick double layered wall. The outer layer is thick, brown coloured called exospore. Inner layer is thin, hyaline called endospore.
- Each uredospore has 4 germ pores situated at equal distances.
- At maturity the uredospores are liberated by breaking of stalk and disseminated by wind.
- They germinate on suitable host under favorable condition by giving out germ tubes. The germ tubes develops appressorium at the stomatal opening and a narrow branch from it penetrates the stomatal pore.
- It forms a vesicle in substomatal cavity, which develops dikaryotic mycelium.
- These spores repeat the short cycle many times in the same growing season of host and known as repeating spores comparable to conidia.

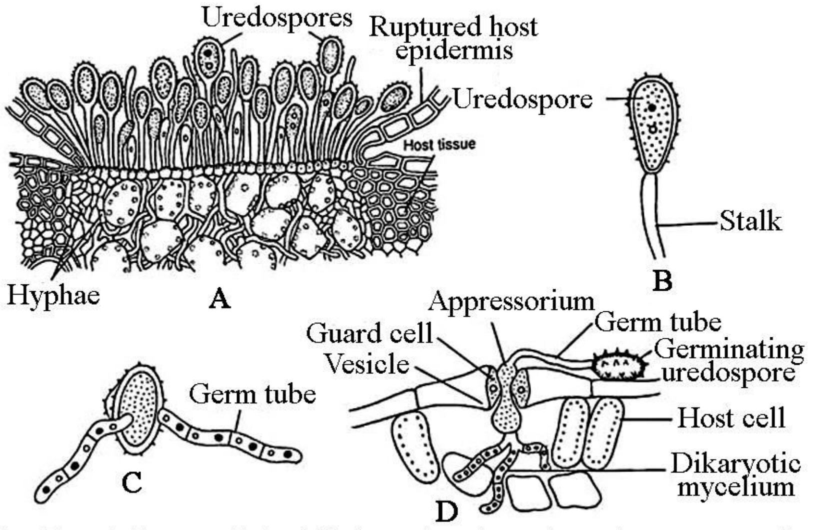


Fig: ***Puccinia graminis.*** **(A)** A section through uredosorous on whea stem showing uredospores, **(B)** Single uredospore, **(C)** Germinating uredospore, **(D)** Infection of wheat leaf by germinating uredospore.

2. Telial stage
   - Late in the summer the fungus produces another type of spores called teleutospores or teliospores either in the same sorus or in separate sorus, called teleutosorus or telium.
   - The telia are black in black in colour and develop characteristic black coloured pustules on stem and leaf blades.
   - Teleutospores develop in the same manner as the uredospores from two branch of dikaryotic mycelium, but the apical cell again divides to form a two celled teleutospore.
   - Each cell of of abicelled spore is dikaryotic. Soon the two nuclei in each cell fuse with each other forming diploid nuclei. The wall become thick and turns black in color.
   - Mature teleutospore is bicelled, spindle shaped with rounded or conical apex. Spore wall is thick and bilayered. Outer thick and smooth exospore, inner thin and membraneous endospore.

- Each cell of teleutospore possesses a germ pore. Germ pore of upper cell is an apical where as that of lower cell is lateral.
- Each cell possesses a diploid nucleus.
- The teleutospores are liberated by breaking of stalk and disseminated by wind.
- After 30 days resting period, they germinate under favourable condition in soil.

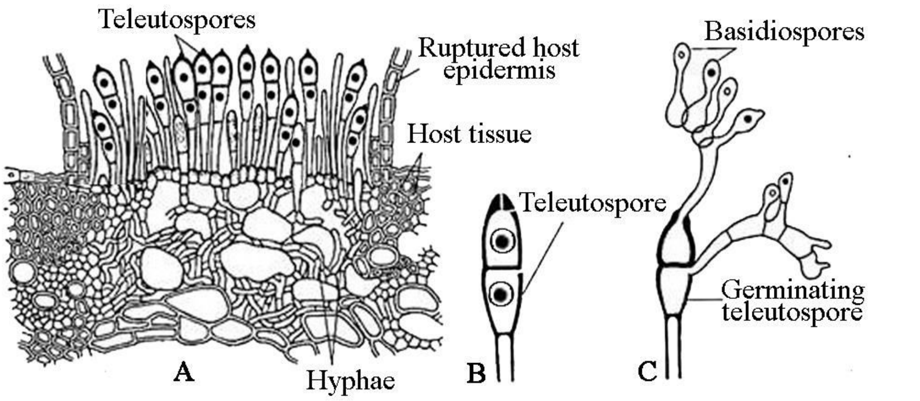
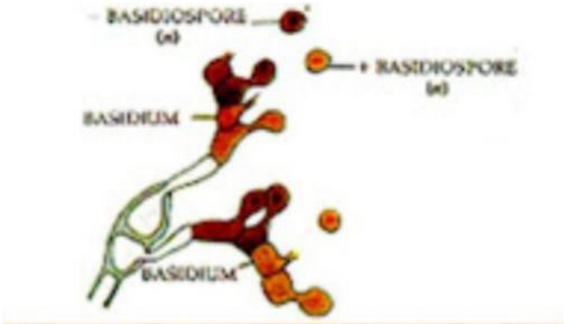


Fig: ***Puccinia graminis.*** **(A)** Section through teleutosorus showing teleutospores, **(B)** Single teleutospores, **(C)** Germinating teleutospore.

B. Fungus on soil/ Basidial stage
  - ✓ The liberated teleutospores fall on ground and perrenete the freezing temperature of winter and adverse wheather conditions.
  - ✓ They germinate after the resting period and under favourable conditios ie at high atmospheric humidity, moisture and low temperature.
  - ✓ On germination each cell of the bicelled teleutospores give rise a short hyphae from the germ pore. It is called promycelium or epibasidium.
  - ✓ The protoplasm, along with the diploid nucleus, migrates into promycelium. The nucleus then divides by meiosis and forms 4 haploid daughter nuclei which get arranged linearly in a club shaped epibasidium.
  - ✓ Thus out of 4 daughter nuclei 2 are of (+) strain and 2 are of (-) strain.
  - ✓ After meiosis the promycelium is divided into 4 cells by the formation of 3 septa.
  - ✓ Each uninucleate cell then forms a small projection- sterigma on lateral side which swells at the tip. Nucleus of the cell migrates into the swelling which differentiates into rounded basidiospores.
  - ✓ Here promycelium finally get differentiated into pragmobasidium.



Basidium with basidiospores

C. Fungus on barberry
  - ✓ Basidiospores fall on barberry leaf and get favorable moisture condition they germinate without resting period.
  - ✓ Each basidiospore germinate by giving out a germ tube.
  - ✓ The germ tube elongates and enters into the barberry leaf directly piercing through cuticle and epidermal cell.

- ✓ It grows vigorously inside the host and develops a monokaryotic primary mycelium.

1. Pycnidial or spermogonial stage
    - ➢ The primary mycelium grows in the intercellular spaces of barberry leaf.
    - ➢ After 4 days of infection, it develops spermagonia on the upper surface.
    - ➢ During the formation of spermagonium, mycelium collects below the epidermis and forms a pseudo-parenchymatous stroma in between the epidermis and palisade cells from which the spermagonium differentiates.
    - ➢ Spermagonia or pycnidia is oval to flask shaped structure situated on the upper surface of barberry leaf.
    - ➢ Spermagonia is visible to the naked eyes as a small yellowish speck on the leaf surface.
    - ➢ It opens on the upper surface by ostiole, which is guarded by periphyses hyphal branches.
    - ➢ The wall of spermagonium gives rise several elongated slender hyphal branches called spermatiophores or pycniophores. These are intermixed with sterile periphyses.
    - ➢ Each spermatiophore cuts off small rounded or oval uninucleate spore like bodies called spermatia. Spermatia produced in basipetal manner.
    - ➢ Towards the maturity, a small droplet of sweetish nectar oozes out of the ostiole , which carries the spermatia along with it.
    - ➢ There are certain long hyphal branches, which protrudes through the ostiole called receptive hyphae.
    - ➢ Spermatia (male sex cell) and receptive hyphae(female sex cells) of two opposite stains will fuse together.
    - ➢ At maturity the transfer of spermatia to the receptive hyphae of opposite strains usually occurs by the agencies of insects (attracted by fragrance).
    - ➢ Insect visit and sip the sweet nectar which oozes out through ostiole. During this process some other spermatia adhere to the body parts of insect. When the same insect visits opposite strain it transfer the spermatia to receptive hyphae. It results cross fertilization, plasmogamy and dikaryotization.

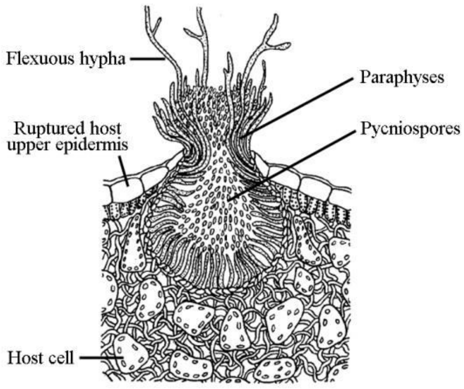
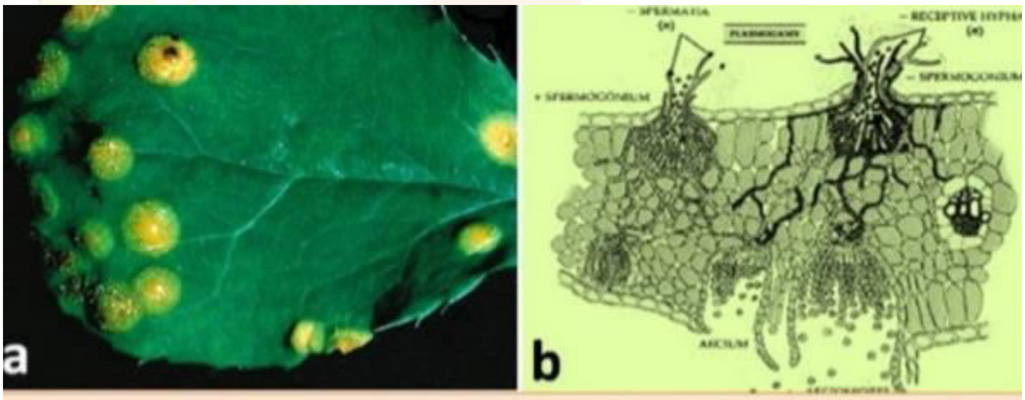


Fig: A section through Pycnium showing pycniospores.

2. Aecidial stage
    - ➢ At the time of spermagonium formation on upper surface, a mat of hyphae also accumulate near the lower epidermis.
    - ➢ The hyphal branches from the base of the spermagonia extend and collect below the lower epidermis. This

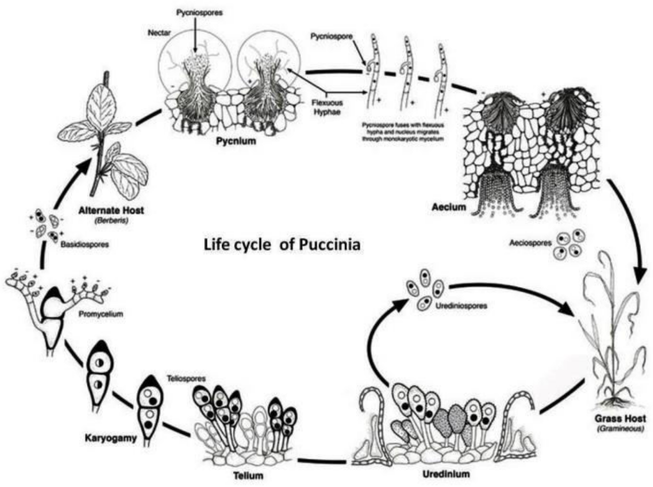
monokaryotic mycelium differentiate into protoaecidium or aecidial primodium.

- Spermatization in spermagonium results fusion of spermatium with receptive hyphae. The common wall between the two dissolves and the spermatium migrates into receptive hyphae. Then it passess from cell to cell through septal pore and finally reaches the basal cells of the protoaecidium.
- The basal cells then become dikaryotic. These dikaryotic basal cells also called aecidiospore mother cell, then start producing aecidiospores.
- At the time the basal cells of protoaecidium elongates and the two nuclei divide by conjugate division. Septum appears and terminal binucleate cell is formed. This terminal cell enlarges in size and divided unequally following another conjugate division resulting in the formation of upper large binucleate aecidiospore and lower small disjunctor.
- Protoaecidium is a globular body due to the pressure of chains of aecidiospores it elongates and finally breaks towards the lower epidermis exposing the spores.
- Aecidial cups are bright yellow or orange colored. The body of cup is made up of thick walled sheath called peridium.
- Mature aecidiospore is rouded, unicellular, binucleate, heterokaryotic, yellowish orange in colour and possess two layered thick wall. Spores with 6 germ pore and dessiminated by wind.
- They do not germinate again on barberry plant, but germinate on wheat.



a) Infected barberry leaf b) leaf with with upper pycnia and lower aecidium

Life cycle of *Puccinia*



ECONOMIC IMPORTANCE OF FUNGI

Role of fungi in medicine

- Antibiotic substances such as Penicillin & some alkaloids extracted from fungi are extremely important in medicine.
- Most important antibiotics are produced by *Actinomycetes*.Theyare used to combat the harmful effects of pathogenic bacteria.
- Some *Actinomycetes* are the source of many antibiotics such as chloromycetine, Aureomycine,terramycin,etc.
- Aureomycine is effective in curing the diseases in animals & plants.

Role of fungi in industry

- Fungi are very important in industries.
- *Saccharomyces cerevisiae* is significant in baking & brewing industries.
- *Penicillium roqueforti&P.camemberti* are important in preparation ofcheese.
- Some fungi such as *Aspergillus niger* are useful in production of citricacid,gluconic acid, Itaconic acid & some vitamins.
- Some are useful for the extraction of pigments that are useful for themanufacture of paints.
- *Thamnidium elegans* is used in USA for improving the taste & tenderness ofbeef.

Role of fungi in agriculture & forestry

- Fungi are important in humus formation,biological pestcontrol,formation of mycorrhizal association with many plants.

a) Humus formation

- Fungi are useful in degrading huge quantities of organicwastes,formed by the death of plants & animals,agricultural &household activities,etc.
- It produces humus & also controls environmental pollution.
- Humus is nutrient rich & is essential for plant growth.
- It increases the soil fertility & promotes various biological activities insoil.

Biological pest control

- Fungihave used to control many pests of plants such asinsects,nematodes & other fungi.

Mycorrhizal association

- Fungi help in maintaining soil balance & also in recovering the loss ofsoil nutrients.
- They are very important in maintaining soil fertility.

Role in food processing

- Fungi are used in processing of certain food products.
- Bread,bun,etc. are prepared from wheat through fermentation byyeasts.
- Many types of Yeasts &*Candida* are used in production of single cellprotein.
- Mixture of yeasts & cereal flour forms a nutritious preparation called Incaparina.

Role of fungi in researchstudies

- Fungus *Neurospora* has been instrumental in genetic & biochemicalstudies.
- *Saccharomyces&Aspergillus* has been significant in experimentalstudies.
- *Aspergillus niger* is used for detecting of copper in soil.

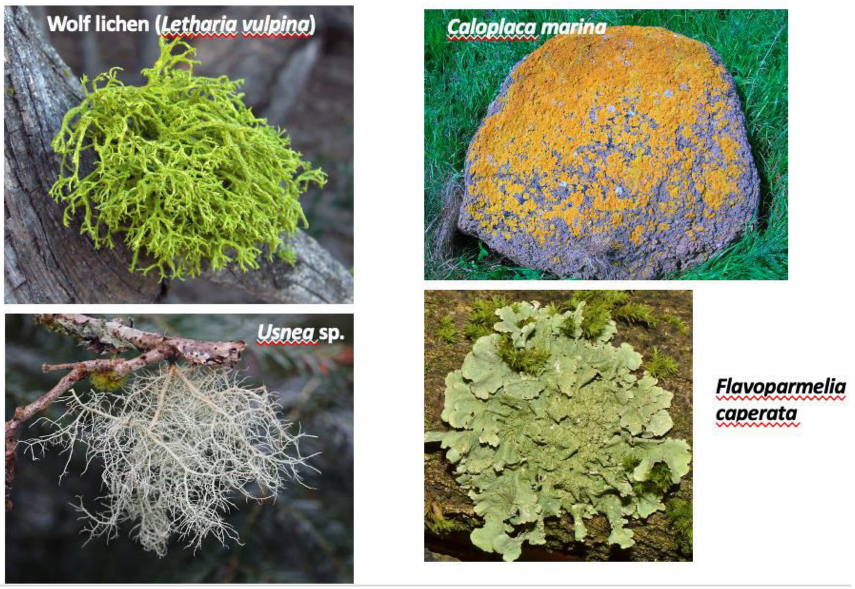
Harmful effects of fungi

- Cause human diseases such as ringworm of skin,moniliasis of nails,etc.
- Cause diseases of crop plants such as rust,smut rot,blast & blight.
- Spoilage of food.
- Rotting of wood.
- Damage commercial articles.
- Production of toxins & hallucinogens which are seriously harmful tohuman beings.(eg:Lysergic Acid Diethylamide-LSD)
- Destruction to paper pulp & affect paper industry.

LICHENOLOGY

LICHENS

- Lichens are slow growing and long living organism, formed by the intimate and permanent association between a fungus and green algae or cyanobacteria.
- The algal (phycobiont) and fungal (mycobiont) components of lichens develop independently at the initial stage. Later on, they come into mutually beneficial symbiotic association, forming lichen.
- Fungal partner absorbs water and also protects the algal partner from unfavourable conditions, such as drought. Algal partner supplies organic food to the fungal partner.
- Lichens are vary in their size and form.
- The lichens distributed in sea shore mountains and deserts, and from the equator to the artic regions.
- Lichens do not grow in areas of heavy air pollution with industrial smoke and soot. So the lichens are often taken as indicators of air purity.
- They can grow on extreme temperature and heat.
- Lichens can grow on a wide variety of substrata, such as exposed rocks, bark of trees, decaying wood and moist soil and some are found even in fresh and salt water.
  Saxicoles- grow on rocks.
  Corticoles- grow on tree bark.
  Terricoles- living in soil.
- The body of lichens is a thallus. Thallus is irregularly shaped and deeply and variably pigmented. The colours are grey, greyish green,bluish green, orange, red or brown. The colouration of the thallus results from the pigmentation of the algal partner.



Classifications of lichens

1. Based on the fungal component
   - ✓ Based on the mycobiont, lichens are classified into 3 grooups.
     a) Ascolochens- fungal partner is a member of ascomycotina and the algal partner is a blue green algae. Ascolichens are further divided into
        1. Gymnocarpae-fruiting body is an apothecium.
        2. Pyrenocarpae- fruiting body is perithecium.
     b) Basidiolichens- fungal partner is the member of basidiomycotina and the algal partner is a blue green algae.

c) Dueteriolichens or lichens imperfecti.-fungal partner is a member of deuteriomycotina. These lichens are sexually sterile and will not produce sexual spores.

2. Based on thallus.
   - ✓ Thallus of lichen is irregular and remarkably complex. Resembles externally either to algae or to non-lichenised fungi.
   - ✓ It varies in form, shape and organization.
   - ✓ Based on external form, nature of thallus and manner of attachement, lichens are classified under four groups-

   1. Crustose lichen –
      - thallus is thin, flat and crust-like, firmly attached to the substratum. The thallus forms a thin cover or crust over the substratum.
      - It is is very difficult to dislodge it from the substratum. Eg. Lacanora

   2. Foliose lichen-
      - thallus is flat, broad, much lobed and leaf-like or scale like which looselely spread over the substratum.
      - They resemble crinckled and twisted leaves.
      - Thallus is attached to the substratum only at certain points with the help of rhizoid like outgrowth called rhizines. In some species, rhizine consist of a single unbranched or branched hyphae. In others it is formed of a bundle of closely applied hyphae.
      - The free end of the rhizines is a flat disc which secretes mucilage and attaches itself firmly to the substratum. Rhizines serves as a organs of anchorage and absorption.
      - In some species, the thallus is attached only by a sigle rhizine growing from the centre of the lower surface of the thallus. Eg. Parmelia

3. Fruticose lichen-
    - thallus is slender, much branched and shrubby. The branches may be cylindrical to ribbon like in form.
    - Thallus attaches itself to the substratum by a single basal disc and grows erect or hangs down from the substratum. This disc is composed of densely packed hyphae. Eg. Usnea

4. Leprose lichen-
    - Odd group of lichen with some fungal hyphae, surrounding one or more algae cells.
    - These lichens have not yet been properly identified and scientifically named because the absence of fruting bodies.

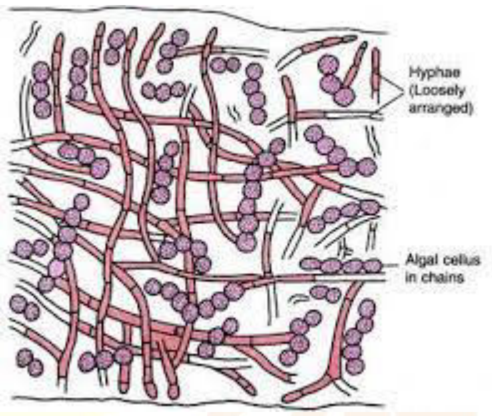
- ✓ Some lichens have a portions of their thallus lifted off from the substrate to form squamulae(small scale). They are called scamulose or scale- covered lichens. They are otherwise similar to crustose lichens in having an upper cortex, but no lower cortex.
- ✓ Gelatinous lichens are the simplest lichen. In these algae are *Chrococcoaceae*and Nostocaceae. The fungal makes its way into the gelatinous membranes of the algal cells and ramifies there. These lichens are

unique in having a homoisomerous thallus i.e.,the thallus in which algae and fungi are equally distributed.

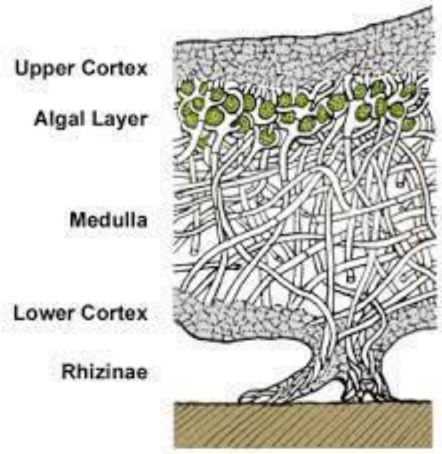
Internal structure of lichens

- ✓ The internal organization is almost same in the different kinds of lichens but with some minor variations.
- ✓ In some cases, the algal and fungal components of the thallus are almost uniformily distributed, without the formation distinct cellular layer. This is called homomerous or homoisomerous conditions.
- ✓ In others, the algal and fungal components are arranged in distinct cellular layers. This is called heteromerous conditions.

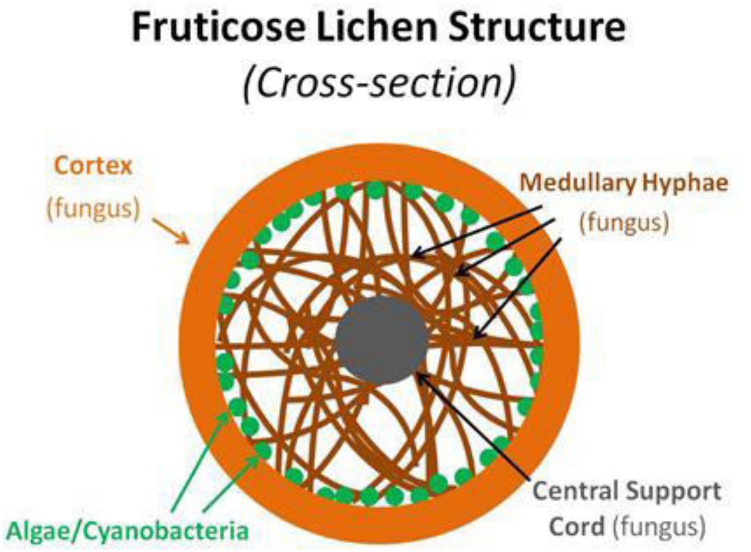
1. Structure of crustose lichen
    - Thallus is homomerous because its algal and fungal components are irregularly distributed in a gelatinous matrix, without differentiation into definite cellular layers.



2. Structure of foliose lichen
    - Thallus is mostly heteromerus, algal and fungal components are organized in definite cellular layers.
    - 4 layers of different tissues are present.
        1. Outer cortex- upper layer, formed of vaertical and closely packed or compactly interwovwn fungal hyphae. Intercellular spaces are either absent or are filled with gelatinous substance. Upper surface of outer cortex may have some fine felt of septate, thick walled and branched or unbranched hairs.
        2. Algal layer- formed of algal cells, intermingled with fungal hyphae. This is the layer photosynthetic in function.
        3. Medulla- formed of thick walled and loosely interwoven fungal hyphae with large intercellular spaces in between them.
        4. Inner cortex –formed of dark coloured, compact and loosely packed fungal hyphae, arranged parallel or perpendicular to the main axis of the thallus. Intercellular spaces between these hyphae are either absent or filled with a gelatinous material. There will be rhizines produced from this layer, for the attachment to the substratum.



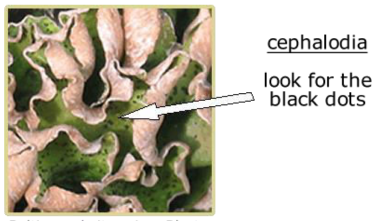
3. Structure of fruticose lichen
    - Radially symmetrical lichen.
    - With three distinct zone.
    - Upper psuedocortex formed of thick walled and compactly arranged fungal hyphae.
    - Middle algal layer is formed of algal cells and fungal hyphae. Single photosynthetic layer.
    - Inner medulla is formed of compact hyphae, which lie parallel to the main axis of the thallus.



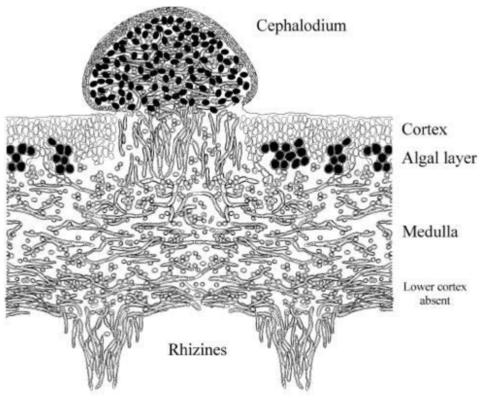
Specialized vegetative structure – for special function

1. Breathing pores- localized depression or cone shaped areas for gas exchange between thallus and the atmospheric air. Seen on upper surface of some foliose lichen. In them the compact cortical hyphae are replaced by loosely interwoven hyphae to facilitate gas exchange.
2. Cyphellae-small, circular pits or depressions in the lower cortex of some foliose lichens. They have definite form, with apical rims. Functioned as a aerating organs and appears as cup-like white spots on the thallus. Here hyphae from the medulla may extend into thse depressions which, in turn provide surfaces for aeration or respiratory gas exchange. Cyphellae open to the medulla to enable gas exchange.

3. Cephalodia-small, hard and dark, gall-like or wart like, internal or external swellings on the upper surface of the thallus. A cephalodium is formed of algal cells, enclosed by fungal hyphae. These algal cells are different from those of other regions. They are probably produced in response to the reaction of the fungus.



Peltigera britannica. Photo by Karen Dillman.

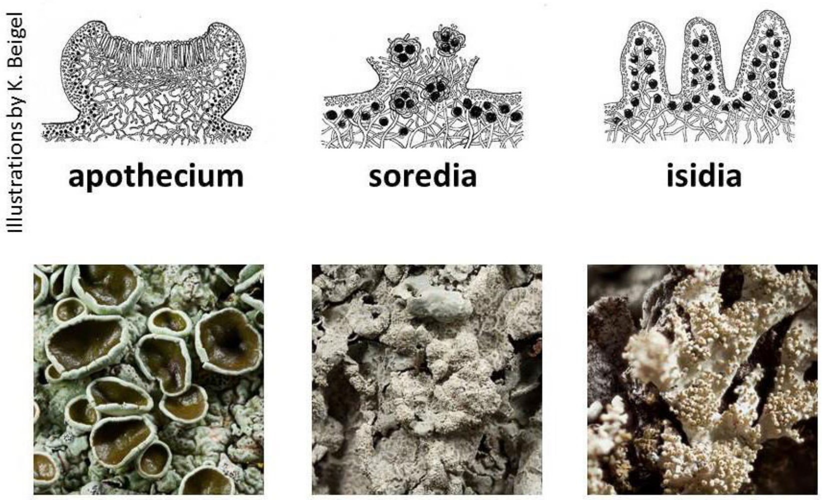


4. Isidia-stalked, branched or unbranched and pappilate outgrowths from the upper surface of the lichen thallus. They consist of algal and fungal components covered by definite cortex. Primary function to increase photosynthetic efficiency by increasing

surface area of the thallus. But some time, they may detach from the thallusand grow to a new thallus. Thus, it serves as a vegetative propogule.

5. Soredia-minute, rounded and bud like outgrowths or bodies on the general surface of the thallus or in pustules like area called soralia. They may appear as a greyish powder on the surface. They are formed in the algal layer in places where the overlying upper cortex is absent.

   Each soredium consist of one or more algal cells, surrounded by fungal hyphae. Soredia detach from the thallus, and get disseminated through wind. Thus soredia serve as a vegetative propogule.



Reproduction

1. Vegetative reproduction-by means of
   - Fragmentation – common method among pendant forms like *Ramalina reticulate* old main thallus accidentally breaks upto small pieces and each pieces grows to a new thallus.
   - Isidia-corticated coralline outgrowth of the thallus. They got separated from the main thallus and grow to a new thallus.
   - Soredia-powdery bodies, produced in soralia. They got separated from the main thallus and under favorable conditions form new thalli.
2. Asexual reproduction- by means of asexual spores like
   - Oidia-small, thin walled bodies, formed from the fungal hyphae of lichens. Released from the parent lichen, come in contact with suitable algal component and forms a new lichen thalli.
   - Conidia- conidia formed from conidiophores of mycelia of fungal component of lichens.

     They get released, come in contact with suitable algal component and forms anew lichen thalli.

     Pyniospores- conidia formed in flask-shaped structure, called pycnidia, which are remains embedded in the thallus. Pycniospores get liberated from the lichen andcome in contact with suitable algal component and forms anew lichen thalli.

3. Sexual reproduction
   - Only fungal partner have potential to reproduce sexually.
   - Sexual reproduction is unknown in deuteriolichens.
   - Sexual reproduction taken place in ascolichens and basidiolichens.

Sexual reproduction in ascolichens

- ✓ Ascolichens rproduce sexually by developing sex organs and fruiting bodies.
- ✓ Male and female sex organs may be seen on same thallus called monoecious, in different thallus known to be dioecious forms.
- ✓ Male sex organ is spermagonia and female sex organ is carpogonia or ascogonia.

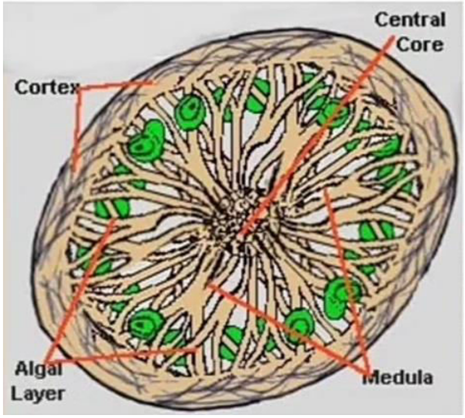
  1. Spermagonia or pycnia
     - Spermagonia are flask shaped or pitcher shaped receptacles, lying embedded on the upper surface of the thallus. Each of them opens out by a amall opening called ostiole.
     - Spermagonial cavity is filled with fertile and sterile hyphae.
     - The fertile hyphae lining the cavity are called spermatiophores. They bud off male reproductive bodies called spermatia or pycniophores.
     - Spermatia are unicellular, uninucleate, non-motile, colourless and walled male gametes, produced in large numbers in each spermogonium.
     - Spermatia are released through a slimy fluid that oozes out through the ostiole and then disseminated by wind.
  2. Carpogonia or ascogonia
     - Carpogonia are multicellular, elongated and basally coiled female sex organs, lying embedded in the upper cortx of the thallus.
     - Their helically coiled basal portion is called oogonium. The extended terminal portion called trichogyne.
     - Oogonium contains the egg nucleus.

- ✓ Fertilization
  - The fertilization mechanism is believed that it occurs when a wind dispersed spermatium happens to get landed on the sticky tip of the trichogyne of the carpogonium.
  - After this , the walls at the point of their contact dissolve and the contents of the spermatium flow to the trichogyne.
  - Plasmogamy results formation of dikaryon.
  - Then male nucleus gradually passes down to the oogonim.
  - Several septate ascogenous hyphae develop from the dikaryon of the ascogonium. The ultimate or penultimate cell of each ascogenous hyphae develops to an ascus through crozier formation, in the same way as in ascomycotina.
  - Karyogamy occurs in ascus mother cell, followed by meiosis and mitosis. This result in the formation of 8 ascospores in each ascus.
  - And sterile hyphae are formed around the ascogonium, ascogonium hyphae and developing asci. As a result, a fruiting body called ascocarp is formed.
- ✓ Fruting body or ascocarp
  - The fruting bodies are perithecium and apothecium.
  - Apothecia are bowl shaped or cup shaped. Perithecia are pitcher shaped.
  - The wall of ascocarp is formed of either fungal hyphae alone, or by algal and fungal layers.
  - Central part is formed asci and sterile tissues called homathecium. It consist of paraphyses- arise from the base of ascocarp and grow vertically upward.
    Periphyses-arise from the side of the ostiolar canal and protrude out of the ostiole.
    Paraphysoids- arise by the starching of the tissue of the ascocarp.
    Periphysoids-arise from the rrof of the ascocarp and grow vertically downward.
  - Internally ascocarp has 3 distinct zones
    Thecium- central zone formed of asci and homathecium.
    Epithecium-terminal zone, formed by tip of the paraphyses projecting beyond the asci.
    Hypothecium- basal zone, formed by loosely packed fungal hyphae.

- At maturity, the asci dehisces and release the ascospores. Under favourable cpndition it germinate to form fungal hyphae. On coming contact with suitable algal component and forms anew lichen thalli.

USNEA

- Fruticose lichen.
- Cylindrical to ribbon-like and much branched thallus.
- It attaches with substratum by rhizines.
- The plant grows erect to pendent with a main branch, bearing many leteral branches.
- The colur of the thallus is grey, green or greenish yellow.
- Several conspicuous bristles or fibrils cover the thallus.
- The thallus lateral branches are terminally bears large, plate like apothecia. Their margin is fringed with bristle outgrowth that may be simple or branched.
- Usnea is heteromerous lichen with peripheral zone, cortex, algal zone (photosynthetic zone) a d medulla.
    - ✓ Peripheral zone- outermost region, generally thick and protective. Very closely interwoven hyphae and spsces filled with a mucilaginous substance.
    - ✓ Cortex-broad zone, loosely packed hyphae with much interbspaces. Cortex divided into outer and inner cortex.
    - ✓ Algal zone- algal cells and a tangled network of loosely interwoven fungal hyphae. Unicellular green algae is protococcus. The algal cells sometimes called gonidia and refered to as gonidial layer.
    - ✓ Medulla- central core zone, hyphae loosely interwoven, giving a psudoparenchymatous appearance.

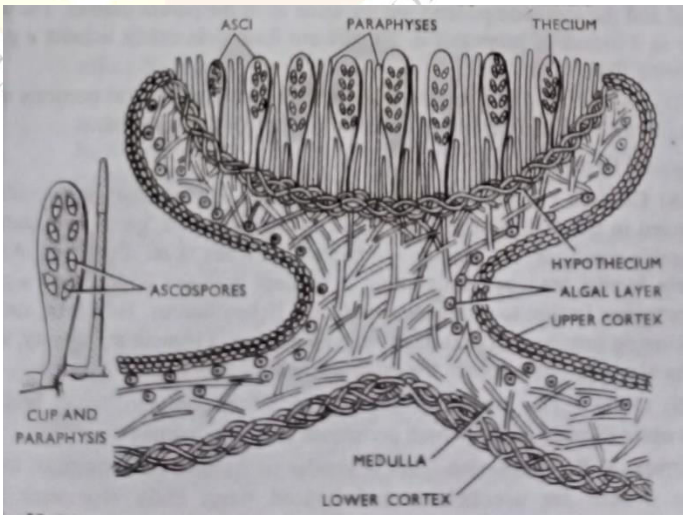


- **Reproduction**
    1. Vegetative – by fragmentation and formation of soredia.
    2. Sexual reproduction- it is performed by fungal partner, male and female sex organ would be spermagonium and ascogonium.
       Fertilization takes as same as the formation of sex organs and fusion of male and female nucleus or gamete in ascolichens.
       Later on apothecium will be formed. Ascospores get liberated from asci.

Structure of the apothecium

- Apothecium is the fruting body.
- It is produced by sexual reproduction. The surrounding vegetative hyphae slso actively take part in the formation of apothecium.
- Apothecium is saucer shaped structure, produced on the long stalk.
- Each apothecium contains large asci intermingled with paraphyses.
- Each ascus with 8 ascospores.
- The asci and peraphysesare closely packed to form a continuous fertile layer called hymenium or hymenial layer. Also known as thecium.
- Beneath the hymenium, is a region consisting of a dense mass of sterile tissue called subhymenium. It consists of closely packed and interwoven hyphae. Below subhymenium, is the hypothecium hat forms the main body of apothecium.
- Hypothecium contains loosely arranged hyphaw internally and compactly arranged peridium externally.
- The outer part of peridium contains several short, stiff, simple or branched bristle like outgrowths.
- When apothecium matures, ascosporesare liberated. Dispersed through wind. They germinate to form new thalli. And coming contact with suitable algal component and forms anew lichen thalli.

External morphology of apothecium



Internal structure of apothecium

Phytopathology

- What is Plant Pathology?

  Phytopathology (Phyton : plant) Greek - Pathos (suffering) + Logos (study) = The study of the suffering plant

- Plant pathology is that branch of agricultural, botanical or biological sciences which deals with the study of:
  - **Cause of the disease**
  - **Resulting losses and**
  - **Control of plant diseases**
- Objectives of Plant pathology

1. Study of origin, causes or reasons. Study of living, non-living and other causes of disease or disorder in plants- **Etiology:**

2. Study of mechanism of disease development i.e. processes of infection and colonization of the host by the pathogen. This phase involves complex host-pathogen interactions- **Pathogenesis**

3. Study the interaction between the causal agent and the diseased plants in relation to environmental conditions. Generally at the population level- **Epidemiology**

4. Development of management systems of the diseases land reduction of losses caused by them- **Control/ Management**.

- **Parasite**

  An organism that lives on or in another organism and obtains food from the second organism

- **Pathogenicity**- is the ability of a pathogen to cause the disease by interfering with one or more of the essential plant cell functions.

What is Pathogen?

- Any entity that can cause disease in a host
- Eg., Fungus, Bacteria, virus, Phytoplasma, Viroids, RLO's, Parasitic Plants, Nematode

PLANT DISEASES

- Plant disease is an impairment of normal state of a plant that interrupts or modifies its vital functions.
- A plant disease can also be defined as any problem with the plant that leads to a reduction in yield or appearance.
- Many plant diseases are caused by pathogens ,disease causing agents are called pathogens.
- A plant may be said to be diseased, when there is a harmful deviation from normal functioning of physiological processes.

CLASSIFICATION OF PLANT DISEASES BASED ON CAUSAL AGENTS

NON INFECTIOUS PLANT DISEASES

- They are not associated with any animate or viral pathogen , so they cannot be transmitted from an infected plant to a healthy one.
- These are due to disturbances in the plant body caused by lack of certain inherent qualities, by improper environmental conditions of soil and air & by mechanical influences. Examples: 1)Low/high temperature,2) unfavourable oxygen levels , 3) unfavourable water levels, 4) hail , 5)wind, 6)air pollution toxicity etc.

INFECTIOUS PLANT DISEASES

- These are the diseases caused by pathogenic organisms or viruses under a set of environmental conditions.
- Fungi, bacteria , viruses , nematodes & even some plants can be pathogens. They obtain nutrients, water & everything they need to reproduce from their host.
- Fungal & viral pathogens cause many plant diseases; bacterial & nematode pathogens cause a few.
- Some pathogens can infect several kinds of plants; others require a specific type of host.
- Pathogens such as fungi & bacteria differ in their ability to survive, spread & reproduce. Based on plant part affected
- **Localized**: if they affect only specific organs or parts of the plants.
- **Systemic**, if entire plant is affected. Or They can be classified as root diseases, stem diseases, foliage/foliar diseases, etc.

Based on perpetuation and spread

• **Soil borne -***when the pathogen perpetuates through the agency of soil.*

• **Seed borne -**when the pathogen perpetuates through seed (or any propagation material).

• **Air borne -**when they are disseminated by wind e.g. rusts and powdery mildews.

Classification of Animate Diseases : in Relation to Their Occurrence

• **Endemic diseases -**which are more or less constantly present from year to year in an moderate to severe form in a particular geographical region, i.e. country, district or location.

• **Epidemic or epiphytotic diseases -**which occur widely but periodically particularly in a severe form. They might be occurring in the locality every year but assume severe form only on occasions due to the favourable environmental conditions occurring in some years.

- **Sporadic diseases** occur at irregular intervals and locations and in relatively few instances.
- **Pandemic diseases:** A disease may be endemic in one region and epidemic in another. When epiphytotics become prevalent throughout a country, continent or the world, the disease may be termed as pandemic.

CONDITIONS NECESSARY FOR PATHOGENIC DISEASES

- In order for a pathogenic plant disease to occur, three conditions must be met:
  1. The host plant must be susceptible.
  2. An active, living pathogen must be present.
  3. The environment must be suitable or favourable for disease development.
- All three factors must occur simultaneously. If one factor is absent or unfavourable , disease does not occur.

DISEASE CYCLE

- The sequence of events from a pathogen's survival to plant disease development and back to pathogen cycle is called the disease cycle, or the pathogen's life history.
- By understanding the disease cycle – chain of events that contribute to a disease – we can find the weakest links and take measures to break the cycle.
- Most pathogens must survive a period of adverse conditions , usually winter , when they do not actively cause disease.
- The host plant is infected or continues to be infected by pathogen's overwintered disease-transmitting substance , inoculum , in the spring.

Stages in Disease Development

1) **Inoculation :** The arrival of pathogen on the host
2) **Penetration** : The initial invasion of a host by a pathogen:
    1. Direct penetration
    2. Penetration through Natural Openings
    3. Penetration through Wounds

3) **Infection:** Establishment of pathogen with vulnerable cells or tissues of the host and obtain the nutrients from them. **Successful infection will produce symptoms**

4) **Growth and Reproduction:** The pathogen will grow and multiply within the infected host.

Fungi – spores

Viruses – replicated by the cell

Nematodes – reproduce by means of eggs

5) Dissemination of Pathogen

Pathogens are disseminated by several ways:

By air

While airborne – spores touch wet surfaces – get trapped – air movement stops / rains – washed out

From the air – brought down by rain drops

Winds also helps spreading by blowing away rain splash droplets containing pathogens

SYMPTOMS, SIGNS AND SYNDROM:-

SYMPTOM – are the expression of the disease caused by the manifestation of the physiological reaction of the plant due to harmful activity of the pathogen

SIGN- variety of structure produce by pathogen like mycelium , conidia , spores, fruting bodies

SYNDROM

Defined as sequential appearance of disease symptoms on a plant during the development of the disease or sum total of symptoms exhibited by a disease

Fleck or necrotic spot

Types of symptoms

- Morphological symptoms: Symptoms which are clearly evident on the body of host.Ex.

  -- Necrosis

  – Hypoplasia

  – Hyperplasia & Hypertrophy
- Cytological Symptoms: (can be detected microscopic studies of the disease sample/ tissue) also called Pathological anatomy or Morbid anatomy e.g. Cuticle thickness, cell wall degeneration etc. Tylose form

SYMPTOMS OF FUNGAL DISEASES

Mildews : White , grey ,brownish ,or purplish patches of varying sizes on leaves , herbaceous stems or fruits.

Rusts: relatively small pustules of spores , usually breaking through the host epidermis.

Smuts: In plant diseases known as smuts , the affected parts of the plant show a purplish black or black dusty mass.

White blisters: White blister-like pustules which break open & expose powdery mass of spores.

Scab : Scab refers to a roughened or crest-like lesion or to a freckled appearance of a diseased organ.

Sclerotia : Sclerotium is a compact, often hard mass of dormant fungal mycelium. Sclerotia are most often black. They may be sometimes buff or dark brown or purplish in colour.

Blotch : It is a superficial growth giving the fruits a blotched appearance as in sooty blotch & fly-speck disease of apple fruits.

Fruiting bodies: They are large, fleshy or woody, spore bearing structures, developed by wood rotting fungi.

Tar spots: These are somewhat raised, black-coated fungal bodies with the appearance of a flattened drop of tar on the leaf.

SYMPTOMS OF BACTERIAL DISEASES

Exudations: In several bacterial diseases, such as bacterial blight of paddy & fire blight of pome fruits, masses of bacteria ooze out from the affected organ & appear on the surface as drops or smears.

SYMPTOMS DUE TO SOME EFFECT ON THE HOST PLANT

- Diseases cause marked changes in the form, size , color , texture , attitude or habit of the plant or some of its organs.
- Two or more of these changes may occur in the same host organ as effects of the same disease.
- These changes result from the presence & activity of some pathogenic organisms & also from the reaction of the host tissues against them.
- The pathogen may be found within the affected tissues or upon the surface.
- **Colour Changes** : Discoloration of the plant , or change of colour from normal colour.

Example :

1) Chlorosis : Green → Yellow
2) Albinism : Green → Colourless
3) Chromosis : Green → Red , purple or orange

- **Overgrowth**: Abnormal increase in the size of one or more organs of the plant or certain portions of it. This is usually the result of stimulation of the host tissues for excessive growth. It may be due Hyperplasia or Hypertrophy.
- Hyperplasia: Abnormal increase in the size of a plant organ due to increase in the number of cells.
- Hypertrophy: Increased size of the organ due to increased size of cells.
- Atrophy or hypoplasia: Here inhibition of growth occurs , resulting in stunting or dwarfing.
- Dwarfing results from atrophy or hypoplasia. Atrophy is degeneration of cells and organs, where as hypoplasia is the abnormal decrease in the size of cells & organs.
- **Necrosis**: It is the death of tissues & organs due to parasitic activity. Necrotic symptoms are highly variable.
- **Wilts**: It is the drying or wilting of the entire plant.

- The leaves & other green or succulent parts lose their turgidity, becomes flaccid &droop. This effect is usually seen first in some of the leaves.

- **Die-back** : It is the dying of plant organs, especially stem or branches , backwards from the tip.

PLANT DISEASE CONTROL

EXCLUSION

- This method includes quarantines, inspections & certification.
- These techniques prevent movement of diseased plant material into a particular country , state , or geographical area where the disease doesn't exist. E.g.: Agricultural Inspection Station in California.
- Quarantines are regulations forbidding sale or shipment of plants or plant parts.

AVOIDANCE

- If a disease doesn't occur in your area , you may be able to avoid its development on your plants.
- Planting certified, virus-free stock is a good way to avoid viral diseases.
- Root rots can be avoided by not planting in heavy poorly drained soils.
- Delaying planting until soils are dry & warm can avoid damping-off of vegetable seeds.
- Avoid wounding plants when pruning or using equipment , as wounds can be the entry points for pathogens or can weaken the plant so that it cannot defend itself.
- Use good horticultural practices, such as proper fertility , pruning , watering to ward off infections.

ERADICATION

- Rotation , sanitation , elimination of alternate hosts , chemical application & heat treatment are eradication methods , when a plant is infected or an area is infested with a pathogen.
- Crop Rotation: It is common in both commercial & home gardens , involving planting of different crops in a given location each year. It can reduce soil populations of fungi & nematodes.
- To practice rotation you need to know the pathogen & which plants are its hosts.
- Rotation works only if you plant non-hosts.

SANITATION: Removing plant debris , is important where pathogens may overwinter.

- Rake leaves , remove rotted fruit , pick up old vines & prune out dead wood or canes.
- Dispose of the debris by burning burying or hot composting.

ELIMINATION OF ALTERNATE HOSTS: Certain pathogens complete their life cycle on two or more hosts (E.g.: Rusts) only one of which may be a crop plant. Eliminating alternate hosts may reduce pressure from these diseases , Since such pathogens cannot complete their life cycle without the alternate host.

LEAF MOSAIC OF TAPIOCA Also known as cassava mosaic disease, a viral disease , wide-spread in Kerala , India , Africa & other Tropical countries.Caused by Tapioca/Cassava mosaic virus, transmitted by White fly (*Bemisia tabaci*)

- Leaves of plants affected by CMV are often withered & small & have patches that are light green or yellow.
- When Cassava has CMV badly , so it doesn't photosynthesize well so the carbohydrate yield from the roots is greatly reduced.
- Initially the affected leaves show mosaic mottling.
- At a later stage , it causes distortion & malformation of leaf blade & also stunted growth of the plant.

Control Measures

- Spraying insecticides.
- Burning of infected parts.
- Altered cultural practices, such as changing the planting season.
- Selection of disease resistant varieties.

CITRUS CANKER

- Caused by pathotypes or variants of *Xanthomonas axonopodis* pv. citri, a quarantine pest. Probably originated in India or Southeast Asia & is now present in 30 countries. In tropical & sub-tropical countries where there is plenty of rainfall with warm temperature.
- It is mainly a leaf spotting & rind-blemishing disease, but under favorable conditions defoliation, fruit die-back & fruit drop occur.
- Infection occurs primarily through stomata, other natural openings & wounds.
- A combination of rain & wind increases the potential for the disease to spread.


Control Measures

- Use of disease free nursery stock for planting.
- Spraying 1 % Bordeaux mixture before planting.
- In addition, Pruning of affected twigs in old orchards.
- Dropped off canker-affected leaves or twigs should be collected & burnt.
- Use of fertilizers & proper irrigation.
- Minimize the attack of leaf miners.
- Plant disease resistant variety.

BLAST DISEASE OF PADDY

- Caused by the fungus, *Pyricularia grisea* Sacc.
- The teleomorph , Magnaporthe grisea, has not been found in nature but is known to occur in laboratory culture.
- Leaf lesions begin as small whitish, greyish or bluish spots. They enlarge quickly under moist, warm conditions to oval spots.
- In case of severe or multiple infections, lesions may coalesce covering most of the leaf blades.
- COLLAR ROT: It occurs due to infection at the junction between the leaf blade & sheath resulting in a brown to dark brown lesion.
- NECK ROT: Neck rot or rotten neck blast phase is caused by infection of the neck node
    - The infected tissue often turns dark brown to black & shrivels causing the stem to break.
    - Panicles turn straw coloured & are either completely or partially blanked. Often they break & their heads falls off to the ground.
- NODE BLAST : Lesions on the stem nodes causes the tissue to turn blackish & shrivel as the plant approaches maturity.
    - The infected area becomes dark purple or blue grey due to conidia production.
    - Culms & leaves become straw coloured & then die above the infected node.
- Control Measures
    - Requires an integrated approach including resistant cultivars , cultural practices & fungicides.
    - Destruction of infested residues
    - Uses of non-infested seed, flood avoidance & avoidance of N fertilizers have limited the spread of the disease.
    - Quadries is used as a protectant against the neck rot phase.

Bunchy top of Bannana

- Bunchy top virus or Banana virus – 1 or Musa virus-1
- First reported from Fiji in 1889 in Cavendish varieties
- Around 1940, introduced into **India from Srilanka through cyclone.**

➢ Banana bunchy top virus is a **ss DNA virus with single isometric particles.**

Occurrence

• World : Asia, Africa, Australia and South Pacific areas.

• India: Tamil Nadu, Kerala, Karnataka and Andhra pradesh.

• Inventor: Fiji (1889).

• Hosts: Banana.

• **Economic Importance**

• Banana bunchy top disease is the most serious virus disease of banana worldwide.

• Diseased plants rarely produce fruit and when they do, the fruit is stunted and twisted.

- It is edible.
- The banana bunchy top disease has had a huge impact on the banana industry in Hawaii and Australia and among other areas of the world.
- The disease was first seen on the Hawaiian island of Oahu in 1989 and by 2002, only 13 years later, it was a major disease on four of the Hawaiian islands (Hawaii, Oahu, Kauai and Maui).

• The movement of BBTV was mostly facilitated by human movement of diseased plant material and banana aphids from island to island. In the 1920s it almost completely destroyed the banana growing industry in Australia.

Symptoms

• Prominent dark green streaks on the petioles and midrib along the leaf veins.

• Green streaks range from a series of dark green dots to a continuous dark green line (**Morse code).**

• Marginal chlorosis and curling of leaves.

• Petioles fail to elongate.

• Leaves are reduced in size, chlorotic, stand upright and become brittle and are crowded at the top (Bunchy top) and shoe dark green streaks with **'J hook' shape** near the midrib.

TRANSMISSION OF BBTV

• BBTV can spread from one plantation to the next by means of infected planting material and between plants with the Banana aphid, *Pentalonia nigronervosa* (Hemiptera: Aphididae).

• The immature aphid stages are small, reddish-brown to almost black, oval shaped, and wingless.

Vector

Banana aphid (*Pentalonia nigronervosa*)

Identification of pathogen:

• The virus is an isometric particle measure 20nm in diameter.

• It is ssDNA virus belonging to *Nanoviridae* family and *Babuvirus* genus.

• The virus has multi component genome

• There are six circular single stranded genomes known to be established.

• The virus concentration is more present in phloem.

• It is transmitted by infected suckers and banana aphid

Management

Cultural method:

• Adaptation of strict quarantine measures.

• Use virus free planting materials.

• Remove and rouging of infected banana plants.

• Chop, dry and bury the infected plants.

• Maintain clean, weed free field for early detection of infested suckers.

• Avoid banana cultivation in sugarcane and cucurbitaceous areas as sugarcane mosaic virus or cucurbit mosaic virus can easily spread to banana.

Chemical method

• Vector control with systemic insecticides, *viz.,* Phosphomidon @ 1ml/ l or Methyl demeton @ 2 ml/ l**.**

• Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Thiacloprid @ 2ml/l.

• Eradication of all infected suckers by spraying with kerosene or by injecting herbicide, 2, 4-D.

Quick wilt of pepper

Significance:

• Quick wilt is one of the most destructive diseases of pepper prevalent in Kerala.

• The infection initiates with the onset of south-west monsoon.

SYMPTOMS

Collar:

• Formation of water soaked lesions, changing to wet slimy dark patches on the collar region and rotting.

• Foot rot, the fatal symptom, is seen at the collar region resulting in quick wilt.

Roots:

• Root infection also initiates as water soaked dark patches on feeder, tertiary, secondary and primary roots resulting in root decaying and shredding of roots.

Stem:

• The infection on runner shoots and cuttings cause rotting of sprouts resulting in shoot rot.

• breaking of stem at the nodal regions branches turn dark brown due to rotting

Leaves:

• Uniformly dark on young leaves or shows concentric zonation with grayish centre on mature leaves.

• Water soaked lesions and rapidly expands into large dark brown spots.

Spikes and Berries:

• Withering and shriveling of berries and heavy spike shedding without any discoloration.

Pathogen:

• Causal organism: *Phytophthora capsici* Leonian

• It is a heterothallic oomycete

• *Phytophthora capsici* produces both a male and a female type gametangia called an antheridium (male) and an oogonium (female).

• The oospores, zoospore and chlamydospores surviving in soil germinate with the receipt of monsoon showers and initiate infection in roots and at collar region.

Mode of spread:

• Primary spread: oospores

• Secondary spread: zoospores

• Secondary inoculum, Zoospore leads to sudden outbreak.

• Spread is through soil, water, root contacts, movement of people, slugs, snails, use of contaminated implements etc.

• Intercultural operations especially soil digging around the vine, nematode infestation, root mealy bug attack etc. predispose the infection.

Management:

• Phytosanitation.

• Drench such spots with 0.2% COC (2g/L) or 1% Bordeaux mixture to eradicate the inoculum from the soil.

• Plant disease free rooted cuttings.

• Allow penetration of sunlight.

• Proper pruning.

• Use biocontrol agents such as *Trichoderma viride, Pseudomonas fluorescens* and VAM inoculated cuttings.

- During the initial phase of infection, drench the vines with 0.2 % Potassium/Sodium Phosphonate.

• Spray with 0.1 to 0.15% Potassium/ Sodium Phosphonate which is compatible with biocontrol agents.

• Do not use copper fungicides if the garden is protected with biocontrol agents.

• Spray Ridomil MZ (Metalaxyl + Mancozeb) @ 2g / L.

Bordeaux mixture

Bordeaux mixture is one ofthe important non-systemic copper fungicides used for the management of many crop diseases. The Bordeaux mixture is a combination of copper sulphate, lime and water. 1% Bordeaux mixture preparation: available in the market as two different forms *i. e.* To prepare 1 % Bordeaux mixture, three calcium hydroxide (also called as 'hydrated lime' mam constituents are required *i.e.* copper or 'slaked lime') and calcium oxide (also called as sulphate, lime and water. Purity ofthe ingredients 'quick lime' or 'burnt lime').

- Ingredients o fBordeaux mixture i.e. copper sulphate and lime (quick lime or hydrated lime)
- Dissolve 1 kg copper sulphate crystals in 10 litres ofwater in a plastic container.
- Dissolve required quantity* ofquick lime or hydrated lime in 10 litr S ofhot water in another plastic container.

- *Note: Ifquick limeisused,-750g-850gisneededand if hydrated limeis used,-375g450gislleededto neutralize thecoppersulpbate solution.
- Pour both the copper sulphate and hydrated lime solutions simultaneously to 80 litres ofwater with constant stirring and check for the pH until it becomes neutral.
- The mixture should be tested for its neutrality of the pH (pH of7.0); because the free radicals ofthe copper are toxic to the plants.
- To test the neutrality of the pH, either pH paper or a well-polished knife or a sickle can be used for checking.
- Dip pH paper in the solution and if it turns blue it indicates that the mixture is neutral.
- Dip a well-polished knife or sickle into the mixture. If the blade shows a reddish colour, add lime to the mixture till the blade does not show staining on dipping the knife
- As per the weather conditions (rainy/wet), required quantity of the wetting agents 0 can be added before spraying.
- Mist nozzle should be used for effective spraying.

REFERENCES

1. Sharma P.D. (2004). Microbiology and Plant Pathology Rastogi Publication
2. Dubey R.C. & D.K. Maheswari (2000) A Textbook of Microbiology, Chand & Co, New Delhi.
3. Prescott, L.M., Harley J.P., Klein D. A. (2005) Microbiology, McGraw Hill, India. 6thedition
4. P.C. Vasishta-Mycology
5. Microbiology, Mycology, Lichenology and plant pathology- Manjusha Publications
6. Sharma P.D. (2004) Plant Pathology Rastogi Publishers
7. Pandey, B.P. (1999) Plant Pathology. Pathogen and Plant diseases. Chand & Co., New Delhi